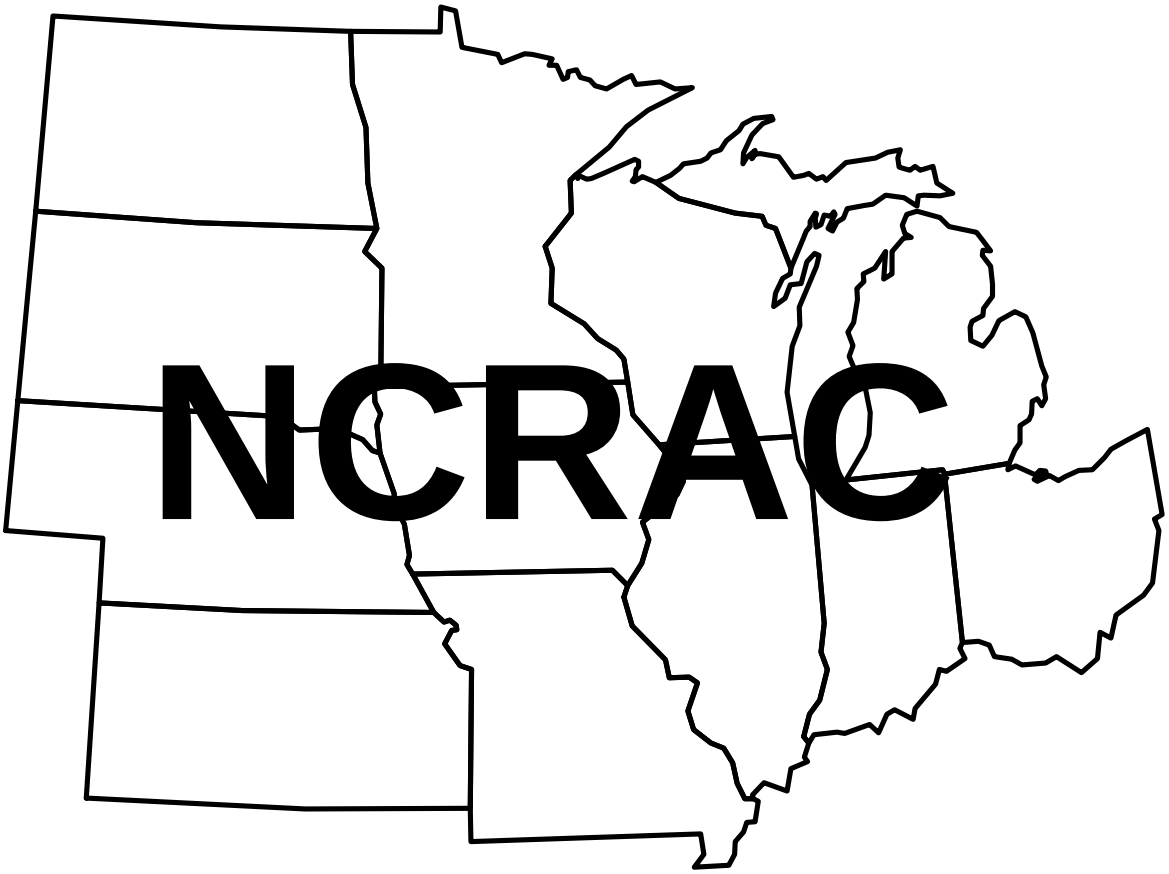
NORTH CENTRAL
REGIONAL AQUACULTURE CENTER



ANNUAL PROGRESS REPORT 1998-99

FEBRUARY 2000

ANNUAL PROGRESS REPORT

For the Period
September 1, 1998 to August 31, 1999

February 2000

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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 1997 reached 768 million pounds and generated approximately $934 million for producers. Yet, anticipated growth in the industry, both in magnitude and in species diversity, continues to fall short of expectations.

Much of what is known about aquaculture science is a result of institutional attention given to our traditional capture of wild fisheries with the goal of releasing cultured fishes into public waters for enhancement of declining public stocks. Despite extensive efforts to manage wild populations for a sustained yield, as a nation we consume substantially greater amounts than we produce. Much of the United States' demand for seafood has been met by imports. The value of imported fisheries products more than doubled during the 1980s and has continued to increase in the 1990s. In fact, the $15.6 billion value for 1998 was a record. In 1998, the trade deficit was $6.9 billion for all fisheries products, $5.9 billion of which was for edible fish and shellfish.

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

Congress recognized the opportunity for making significant progress in aquaculture development in 1980 by passage of the National Aquaculture Act (P.L. 96-362). Congress amended the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (P.L. 95-113) in Title XIV of the Agriculture and Food Act of 1981 (P.L. 97-98) by granting authority to establish aquaculture research, development, and demonstration centers in the United States in association with colleges and universities, State Departments of Agriculture, Federal facilities, and non-profit private research institutions. Five such centers have been established: one in each of the northeastern, north central, southern, western, and tropical/subtropical Pacific regions of the country. The 1996 Federal Agriculture Improvement and Reform Act (FAIR) (P.L. 104-127) otherwise known as the Farm Bill, has reauthorized the Regional Aquaculture Center program at $7.5 million per annum. As used here, a center refers to an administrative center. Centers do not provide monies for brick-and-mortar development. Centers encourage cooperative and collaborative aquaculture research and extension educational programs that have regional or national application. Center programs complement and strengthen other existing research and extension educational programs provided by the U.S. Department of Agriculture (USDA) and other public institutions. As a matter of policy, centers implement their programs by using institutional mechanisms and linkages that are in place in the public and private sector.

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

The North Central Regional Aquaculture Center (NCRAC) was established in February 1988. It serves as a focal point to assess needs, establish priorities, and implement

research and extension educational programs in the twelve state agricultural heartland of the United States which includes Illinois, Indiana, Iowa, Kansas, Michigan, Missouri, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. NCRAC also provides coordination of interregional and national programs through the National Coordinating Council for Aquaculture (NCC). The council is composed of the RAC directors and USDA aquaculture personnel.

ORGANIZATIONAL STRUCTURE

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

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

- Serving as executive secretary to the Board of Directors, responsible for preparing agenda and minutes of Board meetings;
- Serving as an ex-officio (non-voting) member of the Technical Committee and Industry Advisory Council;
- Coordinating the development of research and extension plans, budgets, and proposals;
- Coordinating and facilitating interactions among the Administrative Center, Board of Directors, Industry Advisory Council, and Technical Committee;
- Monitoring research and extension activities;
- Arranging for review of proposals for technical and scientific merit, feasibility, and applicability to priority problems and preparing summary budgets and reports as required;
- Recruiting other Administrative Center staff as authorized by the Board of Directors;
- Maintaining liaison with other RACs; and
- Serving on the NCC.

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

- Coordinating, facilitating, and executing regional aquaculture extension program activities;
- Serving as head of Publications for NCRAC, including editor of the fact sheet, technical bulletin, culture manual, and video series as well as of the NCRAC Newsletter;
- Serving as the NCRAC liaison with national aquaculture extension programs, including in particular, extension programs of the other four USDA Regional Aquaculture Centers; and
- Serving as a member of NCRAC's Extension Executive Committee.

The Board of Directors (BOD) is the primary policy-making body of the NCRAC. The BOD has established an Industry Advisory Council (IAC) and Technical Committee (TC). Membership of the BOD consists of four persons from the IAC, a representative from the region's State Agricultural Experiment Stations and Cooperative Extension Services, a member from a non-land grant university, representatives from the two universities responsible for the center: Michigan State and Iowa State, and chairs of the two subcommittees of the Center’s Technical Committee. The IAC is composed of representatives from each state’s aquaculture

association and six at-large members appointed by the BOD who represent various sectors of the aquaculture industry and the region as a whole. The TC is composed of a sub-committee for Extension (TC/E) and a sub-committee for Research (TC/R). Directors of the Cooperative Extension Service within the North Central Region appoint representatives to the TC/E. The TC/R has broad regional make-up and is composed of scientists from universities and state agencies with varied aquacultural expertise who are appointed by the BOD. Each sub-committee of the TC has a chairperson who serves as a member of the BOD.

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

ADMINISTRATIVE OPERATIONS

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

The Center functions in the following manner.

- After BOD approval of Administrative Center costs, the Center submits a grant to USDA/CSREES/Grants Management Branch for approval. To date the Center has received 12 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), and FY99 (#99-38500-7376) with monies totaling $8,702,981. Currently, five grants are active (FY95-99); the first seven grants (FY88-94) have terminated.
- The Center annually coordinates a program planning meeting which 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.
- The BOD, using 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 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, 1999, the Center has funded or is funding 49 projects through 295 subcontracts from the first eleven grants

received. Funding for these Center supported projects is summarized in Table 1 below (pages 5-6).

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 Appendix A 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; in conjunction with the Aquaculture Network Information Center (AquaNIC) maintaining a NCRAC Web site (ag.ansc.purdue.edu/aquanic/ncrac); and finalizing a Strategic Plan which is contained in Appendix B (also available at the Center's Web site). During this reporting period a significant amount of time and energy was devoted to the development and finalization of the Strategic Plan which will serve as a roadmap for the Center as it moves into the next millennium.

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 six separately funded projects in regard to Extension, Hybrid Striped Bass, and Walleye. Project outlines have been written for each separate project within an area, or the project area itself if only one project. These project outlines have been submitted in POWs or amendments to POWs for the grants as indicated in Table 1. Many times, the projects within a particular area are continuations of previously funded activities while at other times they are addressing new objectives. Presented below are Progress or Termination Reports mostly for projects that were underway or completed during the period September 1, 1998 to August 31, 1999. Projects, or Project components, that terminated prior to September 1, 1998 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 Appendix A.

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	$10,875	92-38500-6916
			$21,700	95-38500-1410
	6	9/1/97-8/31/99	$40,000	97-38500-3957
			$384,423	
Economics and Marketing	1	5/1/89-12/31/91	$127,338	88-38500-3885
			$34,350	89-38500-4319
	2	9/1/91-8/31/92	$53,300	91-38500-5900
	3	9/1/93-8/31/95	$40,000	93-38500-8392
			$254,988	
Yellow Perch	1	5/1/89-8/31/91	$76,957	88-38500-3885
			$85,723	89-38500-4319
	2	6/1/90-8/31/92	$92,108	90-38500-5008
	3	9/1/91-8/31/93	$99,997	91-38500-5900
	4	9/1/93-8/31/95	$150,000	93-38500-8392
	5	9/1/95-8/31/97	$200,000	95-38500-1410
	6	9/1/97-8/31/99	$185,600	97-38500-3957
	7	9/1/98-8/31/00	$187,300	98-38500-5863
			$1,077,685	
Hybrid Striped Bass	1	5/1/89-8/31/91	$68,296	88-38500-3885
			$68,114	89-38500-4319
	2	6/1/90-8/31/92	$101,000	90-38500-5008
	3	9/1/91-8/31/93	$96,550	91-38500-5900
	4	9/1/93-8/31/95	$168,000	93-38500-8392
	5	9/1/95-8/31/97	$150,000	95-38500-1410
	6	6/1/99-5/31/00	$15,000	96-38500-2631
			$666,960	
Walleye	1	5/1/89-8/31/91	$177,517	89-38500-4319
	2	6/1/90-8/31/92	$111,657	90-38500-5008
	3	9/1/91-8/31/92	$109,223	91-38500-5900
	4	9/1/92-8/31/93	$75,000	89-38500-4319
	5	9/1/93-8/31/95	$150,000	93-38500-8392
	6	9/1/95-8/31/97	$117,395	94-38500-0048
			$59,847	95-38500-1410
			$800,639	
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	$200,000	96-38500-2631
			$654,119	

Project Area	Project Number	Proposed Duration Period	Funding Level	Grant Number
Salmonids	1	6/1/90-8/31/92	$9,000	89-38500-4319
			$120,799	90-38500-5008
	2	9/1/92-8/31/94	$149,997	92-38500-6916
	3	9/1/94-8/31/96	$199,290	94-38500-0048
	4	9/1/97-8/31/99	$160,000	97-38500-3957
			$639,086	
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
			$6,7005	
Crayfish	1	9/1/92-8/31/94	$49,677	92-38500-6916
Baitfish	1	9/1/92-8/31/94	$61,973	92-38500-6916
Wastes/Effluents	1	9/1/92-8/31/94	$153,300	92-38500-6916
	2	9/1/96-8/31/98	$100,000	96-38500-2631
			$253,300	
National Aquaculture INAD/NADA Coordinator	1	9/1/93-8/31/94	$2,000	89-38500-4319
		5/15/95-5/14/96	$5,000	94-38500-0048
		5/15/96-5/14/97	$6,669	92-38500-6916
			$3,331	95-38500-1410
		5/15/97-5/14/98	$15,000	96-38500-2631
		5/15/98-5/14/99	$13,241	94-38500-0048
		5/15/99-5/14/00	$10,000	95-38500-1410
			$55,241	
Tilapia	1	9/1/96-8/31/98	$120,000	96-38500-2631
	2	9/1/98-5/14/00	$150,000	98-38500-5863
			$270,000	
Aquaculture Drugs	1	7/1/96-6/30/97	$27,000	95-38500-1410
	2	12/1/96-11/30/97	$5,000	95-38500-1410
			$32,000	
White Papers	1	7/1/98-12/31/98	$5,000	96-38500-2631
	2	9/1/99-12/31/99	$17,500	97-38500-3957
			$22,500	

PROJECT TERMINATION
OR
PROGRESS REPORTS

EXTENSION[1]

Progress Report for the Period
May 1, 1989 to August 31, 1999

NCRAC FUNDING LEVEL: $384,423 (May 1, 1989 to August 31, 1999)

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 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 Lee	Kansas State University	Kansas
Frank R. Lichtkoppler	Ohio State University	Ohio
Jerry Mills	Brown County Extension	South Dakota
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
Brian R. Stange	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
LaDon Swann	Purdue University	Indiana/Illinois
Laura G.Tiu	Ohio State University	Ohio

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

PROJECT OBJECTIVES

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

(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 videotapes

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; 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 funded NCRAC project.
- Assisted in writing and developing the NCRAC Walleye Culture Manual, edited by Bob Summerfelt of Iowa State University.
- Assisted with the planning, promotion, and implementation of the hybrid striped bass, walleye, and yellow perch workshops held throughout the region.
- Provided the NCRAC Economics and Marketing Work Group with information relevant to that group's efforts to develop cost of production budgets and expected revenues for the commercial production of food-sized hybrid striped bass, walleye, and yellow perch in the NCR.
- Participated as Steering Committee members for a regional public forum regarding revision of the National Aquaculture Development Plan and two National Aquaculture Extension Workshops/Conferences.
- Participated as Steering Committee members for the past four North Central Regional Aquaculture Conferences.
- Served as editors for regional aquaculture newsletters as well as in-state aquaculture associations.
- Wrote and edited the upcoming Sunfish Culture Guide.

OBJECTIVE 2

The demand for aquaculture extension education programs cannot be met by the few specialists in the NCR (4.0 full time equivalents). Networking of specialists and Cooperative Extension Service (CES)-designated contacts has maximized efficiency of

education programs and minimized duplication. The NCRAC Extension Project is designed to assess and meet the information needs of the various clientele groups through cooperative and coordinated regional educational programming. In fact, individual state extension contacts often respond to 10-15 calls per month from outside their respective states 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, and detailed responses to both generalized and specialized questions.

Prior to mid-1994 little coordination of international aquaculture information sharing existed. National and international agency produced information could only be obtained by contacting the respective sources of this information. Also, individual Sea Grant and CES personnel relied heavily on information produced by individual states or through regional cooperative projects. As Internet access extended beyond educational institutions and governmental agencies, a clear need developed to utilize the Internet to reach a much broader audience. In the age of an "information overload" the need for a centralized gateway to the ever-increasing number of aquaculture resources in electronic format was apparent.

AquaNIC (http://aquanic.org) is a collaborative effort to provide access to aquaculture information through a central location on the Internet regardless of the physical location of those information resources. AquaNIC was implemented in 1994 and is housed in the Department of Animal Science at Purdue University (Purdue). The Illinois-Indiana Sea Grant College Program, the Cooperative Extension Service at Purdue, and University of Illinois Extension provide leadership for AquaNIC. A national steering committee and other aquaculture stakeholders provide oversight and direction for AquaNIC. Land-grant institutions, Sea Grant Colleges, the World Aquaculture Society, NCRAC, and others with an expertise in aquaculture contribute significantly to AquaNIC.

AquaNIC houses over 8,000 publications, newsletters, photographs, slide sets, videos, and directories with more than two million files downloaded in 1998-99. The home page of AquaNIC averages more than 5,000 visits per month by people from 90 countries and is linked to more than 600 other Web sites.

Through AquaNIC, individuals can access the World Aquaculture Society home page as well as the employment services provided for the Society by the Delaware Sea Grant College. In addition, AquaNIC hosts NCRAC's Web site.

Specific resources of AquaNIC include:

- a tools section providing access to resources for the Web and sites beneficial to the daily lives of users;
- a beginner's section established to quickly locate information of interest to prospective aquaculturists;
- federal publications from, in part, the Joint Subcommittee on Aquaculture, National Oceanic and Atmospheric Administration Library, National Agriculture Library, Sea Grant Depository, Sea Grant, National Marine Fisheries Service, National Fisheries Institute, the Food and Drug Administration, and the five U.S. Department of Agriculture Regional Aquaculture Centers;
- publications from 26 states which are results of university-based research and outreach activities;
- links to newsletters from state, national, and international aquaculture associations;
- a database of over 700 electronic

photographs available to view or download;
- a searchable database of over 600 aquaculture Web sites and 40 list servers;
- a database of the e-mail addresses and areas of interest for the U.S. and internationally; and
- a calendar of events of conferences, public hearings, workshops, and other aquaculture related events.

AquaNIC has been recognized by various groups including, in part by the National Agriculture Communicators in Education, USDA, Mckinley Group's online editorial team, Progressive Farmer On-Line, Dow Jones Business Directory, The Bridge Ocean Science Teacher Center, and Netscape "Open Directory."

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

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. In North Dakota, Klinkebiel was the first aquaculture extension contact; he was followed by Stange in 1996, then Sanders in 1998, and Jarvis in 1999. In 1998 Mills became the first formally appointed NCRAC Extension contact for South Dakota. As of 1999, Kayes is no longer with Nebraska Extension; to date no replacement has been designated.

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 and safe seafood handling including Hazard Analysis Critical Control Points (HACCP). Many of these individuals have, in turn, trained industry representatives in HACCP.

OBJECTIVE 4
A number of workshops, conferences, videos, field-site visits, hands-on training sessions, and other educational programs have been developed and implemented.

There have been workshops on general aquaculture, fish diseases, commercial recirculation systems, aquaculture business planning, crayfish culture, pond management, yellow perch and hybrid striped bass culture, rainbow trout production, in-service training for high school vocational-agricultural teachers, and polyploid induction in sunfish held in the region. In several states, e.g., Iowa, Ohio, and Wisconsin, potential fish farmers have been able to view aquaculture systems being operated by extension and research personnel.

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 and the third conference was held in Indianapolis, Indiana. The fourth conference 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 ten five- to seven-minute videotape segments which addressed production aspects of channel catfish, crayfish, rainbow trout, hybrid striped bass, tilapia, yellow perch, baitfish, and sportfish. The entire teleconference is available as a videotape from NCRAC's Publications Office as well as two other videotapes by the University of Nebraska-Lincoln that are reprises of the broadcast.

In support of extension activities being funded through research projects, i.e., the Hybrid Striped Bass and Sunfish research projects, extension specialists have completed fact sheets/book chapters/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, several 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. The Missouri Aquaculture Initiative continues to provide the framework from which aquaculture information and educational programs are delivered in the state.

Tiu has also worked to revitalize the Ohio Aquaculture Association (OAA). The OAA board of directors of the previously inactive organization has met and a membership drive ensued. An OAA newsletter was published in August 1999.

Many of the NCRAC extension contacts have worked with industry and governmental representatives to produce state aquaculture plans and improve 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 the 1998 Wisconsin Aquaculture Directory.

All fish processors, including those who handle aquaculture products, are now required by law to process their fish following HACCP guidelines. Four three-day HACCP training workshops were conducted by Kinnunen. 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. Fish being processed at facilities running under HACCP now meet standards enforced by the FDA. In 1998-99, Kinnunen conducted two more HACCP courses with attendees including fish processors, aquaculturists, and baitfish producers. Each course was three days and participants were awarded certificates upon successful completion through the National Association of Food and Drug Officials.

Kinnunen also worked with the Great Lakes Fish Health Committee on establishing a risk-based system to guide appropriate health decisions recognizing that zero risk is never attainable.

In 1998-99, Gunderson and Paul Tucker shared the NCRAC extension liaison responsibilities for Minnesota. Gunderson and Tucker participated in an aquaculture workshop on the Red Lakes, Minnesota Indian reservation, presenting information on leech and baitfish culture. Wisconsin aquaculture researchers also presented information at this workshop.

Gunderson and Tucker have worked closely with industry collaborators to develop horneyhead chub culture techniques in Minnesota. Materials developed by NCRAC and other RACs and distributed through NCRAC have been used extensively as teaching tools and for developing spawning and production systems.

Although not funded by NCRAC, Gunderson and Tucker worked with other aquaculture and exotic species specialists from around the region to address an issue important to many fish farmers in the NCR, especially people raising fish for stocking or baitfish. 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. 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 which 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.

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 Appendix A.

Other extension-funded activities include: (1) a 4-H Guide for Aquaculture, (2) "Getting Started in Freshwater Aquaculture" CD-ROM and workbook, and (3) HACCP videos. The first two activities have been undertaken by Swann whereas Kinnunen has been working with Steve Ingham (University of Wisconsin-Madison) on the HACCP videos. NCRAC has only provided a small component of the funding for the first two activities.

A one-year no-cost extension was granted to complete the 4-H Guide because of the difficulty in hiring a part time technical writer for the project. Production of a national 4-H aquaculture curriculum using an experiential learning approach not only provides essential technical information, it allows youth to lead enriching and fulfilling lives through improved self-esteem, critical thinking, and greater appreciation of human diversity and values. An aquaculture curriculum that allows both goals to be achieved without compromising one for the other provides youth with technical training and life skills. The guide has been written and reviewed by the NCRAC Extension Work Group Chair. A second draft has been completed and is in the process of being formatted and final graphics created. The layout should be completed in winter and pilot testing initiated during the summer of 2000. The final version will be completed during the winter of 2000.

The "Getting Started in Freshwater Aquaculture" CD-ROM and workbook is computer-based instruction on the fundamentals of aquaculture. The workbook serves as a guide for use of the CD-ROM which contains technical information, business planning forms, and example examination questions for instructors teaching aquaculture courses.

One HACCP video has been developed that describes the steps involved in smoking fish, with particular emphasis on the Critical Control Points in this process that must be monitored in a HACCP system.

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 a sunfish culture guide, yellow perch culture guide and videos, hybrid striped bass culture guide, a publication on fee-fishing (sunfish), tilapia culture information packet, and a publication on yellow perch culture in flowing water systems. In addition, a draft of the 4-H Guide for Aquaculture will be completed and pilot-tested and the two HACCP videos completed.

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 regionally advertised fish disease workshop will be held November 1999 at the Ohio State University Research and Extension Center at Piketon. The annual meeting of the OAA will be held in conjunction with this meeting and new officers will be elected. Another introductory aquaculture workshop will be held in January 2000.

A second HACCP video on the basics of sanitation in a fish processing plant and the development of a Sanitation Standard Operating Procedure will be developed. This video will be similar to one produced for the American Association of Meat Processors in 1996 which sold over 300 copies nationwide.

Pierce developed a Professional Improvement Experience for Extension Educators entitled: "Aquaculture, Water Quality, Aquatic Plant Identification and Management," which was approved and will be conducted in the early months of 2000 in southeast Missouri.

A Yellow Perch Producer Forum is planned for January 2000 in Hudson, Wisconsin. Both producer and research presentations will be part of the program.

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. Approximately 5,000 individuals have attended workshops or conferences organized and delivered by the NCRAC Extension Work Group. Clientele attending regional workshops learned of aquaculture development strategies in other areas of the country and acquired information which was of direct use to their own enterprises. Education programs also created situations where problems encountered by producers were expressed to extension personnel who later relayed them to researchers at NCRAC work group meetings for possible solutions through the research effort.
- Fact sheets, technical bulletins, and videos have served to inform a variety of clients about numerous aquaculture practices for the NCR. For instance, "Making Plans for Commercial Aquaculture in the North Central Region" is often used to provide clients with initial information about

aquaculture, while species specific publications on walleye, trout, and catfish have been used in numerous regional meetings and have been requested by clients from throughout the United States. Publications on organizational structure for aquaculture businesses, transportation of fish in bags, and others are beneficial to both new and established aquaculturists. In a 1994 survey, NCRAC extension contacts estimated that NCRAC publications were used to address approximately 15,000 client questions annually.

- NCRAC extension outreach activities have helped to foster a better understanding and awareness for the future development of aquaculture in the region.
- AquaNIC has become an entry point for many people searching for aquaculture information on the Web. AquaNIC's home page now averages more than 5,000 visits per month by people from more than 90 countries. The Illinois-Indiana Sea Grant Program has also created Web pages for the Indiana Aquaculture Association, the Illinois Aquaculture Industry Association, NCRAC, and the World Aquaculture Society.
- The 4-H Guide for Aquaculture will offer a tremendous opportunity to teach math, biology, and chemistry using experiential learning. Aquaculture could also be easily adapted to teach life skills, e.g., communications and leadership to youth. Leadership and analytical skills can be strengthened through carefully choosing how content is selected and used. Incorporating aquaculture into 4-H Youth programs is not limited to rural farming communities; the curriculum could also be used in urban and inner city schools.
- Fish processors who have attended NCRAC-sponsored HACCP Training Workshops have learned the principles of HACCP with regards to its importance in insuring the production of a safe fishery product. They also learned how to work with their production employees on developing a HACCP Plan specific to their own processing facility. HACCP Plans have now been implemented by workshop attendees who are now keeping records of their daily processing and Sanitation Standard Operating Procedures. About 140 fish processors and/or aquaculturists attended one of the four HACCP Training Workshops.
- In Ohio, new fish farmers have applied for Aquaculture Permits for 1999 as well as worked on their business plans with hopes of creating successful aquaculture businesses. With the OAA getting organized, producers will have the forum necessary to encourage appropriate legislation necessary for the success of the aquaculture industry.
- In Minnesota, three industry collaborators operated successful horneyhead spawning systems in 1999 and are currently building new enlarged spawning systems for 2000. It is anticipated that these three fish farmers will produce significant quantities of horneyhead chubs next year, which will reach the Minnesota baitfish market in 2001.

PUBLICATIONS, MANUSCRIPTS, WORKSHOPS, AND CONFERENCES

See Appendix A 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	$32,575	$149,325	$5,000	$84,000		$238,325	$270,900
1997-99	$40,000	$110,559				$110,559	$150,559
TOTAL	$384,423	$848,042	$5,000	$334,000	$55,000	$1,242,042	$1,626,465

YELLOW PERCH[2]

Progress Report for the Period
September 1, 1997 to August 31, 1999

NCRAC FUNDING LEVEL: $185,600 (September 1, 1997 to August 31, 1999)

PARTICIPANTS:

Paul B. Brown	Purdue University	Illinois
Konrad Dabrowski	Ohio State University	Ohio
Donald L. Garling	Michigan State University	Michigan
Robert S. Hayward	University of Missouri-Columbia	Missouri
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Extension Liaison:		
Donald L. Garling	Michigan State University	Michigan
Industry Advisory Council Liaison:		
Forrest Williams	Bay Port Aquaculture Systems, Inc., West Olive	Michigan
Non-funded Collaborators:		
Marty Domer	Ohio Valley Fish Hatchery Inc., Mineral City	Ohio
Forrest Williams	Bay Port Aquaculture Systems, Inc., West Olive	Michigan

PROJECT OBJECTIVES

(1) With the goal of larval intensive yellow perch feeding in tanks from the onset of first feeding, continue to develop methods to produce fingerlings.

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

(3) Develop out-of-season spawning methods for yellow perch.

ANTICIPATED BENEFITS

This project will address priority needs identified by the North Central Regional Aquaculture Center (NCRAC) Industry Advisory Council (IAC) for advancing yellow perch aquaculture in the North Central Region (NCR). The proposed research on Objective 1 will improve larval rearing techniques by developing and evaluating different starter diets and environmental conditions. The information generated by these studies will greatly assist perch producers in their efforts to reliably raise the large numbers of perch fingerlings needed by the industry. Research on Objective 2 will

[2]NCRAC has funded seven Yellow Perch projects. Termination reports for the first three projects are contained in the 1989-1996 Compendium Report; a termination report for the fourth and fifth projects is contained in the 1997-98 Annual Progress Report. This progress report is for the sixth Yellow Perch project, which is chaired by Jeffrey A. Malison. It is a 2-year study that began September 1, 1997. Originally Fred Binkowski of the University of Wisconsin-Milwaukee was to have participated in Objective 3 but because the brood stock that were to have been used for the project were destroyed he withdrew from the project and did not expend any funds. A progress report for the seventh Yellow Perch project is contained elsewhere in this Annual Progress Report.

develop and evaluate methods for improving growth of perch as they approach market size. The use of these methods by commercial perch producers will decrease the time needed to raise perch to market size and thereby increase the efficiency of production facilities and reduce production costs. One of the most promising strategies in this regard is the production of mono-sex female stocks of perch. A method for producing 100% female perch has been developed by researchers at the University of Wisconsin-Madison (UW-Madison) and is currently being used by several regional perch producers under an investigational new animal drug (INAD) exemption granted by the Federal Drug Administration (FDA). Research under another NCRAC project entitled "Safety of 17α-Methyltestosterone for Induction of Sex Inversion in Walleye" was aimed at gaining a universal New Animal Drug Application approval for using this method in percids. The proposed research on Objective 3 will develop methods to induce out-of-season spawning in perch. The resultant availability of perch fry at different times during the year will increase the efficiency of existing pond and tank fry culture systems by allowing multiple cropping of these systems. In turn, the availability of fingerlings at multiple times during the year would facilitate a fuller, more efficient use of grow-out facilities and equipment. The availability of fertilized eggs outside the normal spawning season would also greatly facilitate research on the culture of perch fry in tanks. Additional benefits of using the procedures developed in these studies include greater predictability of gamete production and reduced incidence of failed spawning, gamete resorption, and subsequent brood fish losses.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Research at Purdue University (Purdue) was designed to evaluate the available larval diets fed to yellow perch and determine the appropriate size for transferring larvae to formulated diets. In two separate studies, researchers at Purdue offered quadruplicate groups of larval perch several of the available diets and monitored survival and growth. Four of the feeds were offered in both studies. Perch offered rotifers then *Artemia* gained significantly more weight and exhibited significantly higher survival than perch fed any of the dry diets. Among the dry diets, there were no clear distinctions between groups.

Research at Michigan State University (MSU) looked at the effect of a special tank design and three feeds on the survival of larval yellow perch. Yellow perch readily accepted vinegar eels, newly hatched *Artemia* nauplii, and an artificial plankton (Argent) at first feeding. Survival to 30 mm (1.2 in) was approximately 85%. Unfortunately, tank drains clogged near the end of the experimental period and all fish were lost overnight.

Researchers at Ohio State University (OSU) determined the effects of krill hydrolysate as a feed attractant. Growth trials were conducted using commercial trout starter diet alone (control) or the same diet coated with liquid krill hydrolysate. The diet coated with attractant increased growth rate of yellow perch juveniles by 31% compared to the non-coated control diet (average final wet weight, 734 ± 33 and 559 ± 82 mg [0.0259 ± 0.0012 and 0.0197 ± 0.0029 oz], respectively). Moreover, weight gains were not significantly different compared to fish fed exclusively with live brine shrimp nauplii. The effects of krill hydrolysate on dry diet ingestion rates were also determined using radioactive (^{14}C) labeling. A commercial starter diet was coated with 5% hydrolysate or the soluble fraction of krill was added to the experimental tank water. In both cases an increase in ingestion followed (approximately 200%), although ingestion rate

expressed on a per weight basis was not significantly different compared to that of live brine shrimp nauplii.

In previous experiments, OSU researchers observed a correlation between low frequency of swim bladder inflation and skeleton deformities and mortality. Therefore, in a follow up study, the question of conditions resulting in swim bladder inflation in yellow perch larvae as related to dry diet utilization was addressed. Newly hatched fry were collected in a single 100-L (26.4-gal) rearing tank. Water flow into the tank was provided using four surface sprinklers to facilitate swim bladder inflation as observed in other percids. Temperature was kept at 20–23°C (68.0–73.4°F) and indirect dim light of 50–80 lux at the surface was provided. Prior to completion of yolk sac absorption, newly hatched live brine shrimp nauplii were provided by peristaltic pump during light hours (24 h). The density of nauplii was maintained at 4–5 individuals/mL (118–145/oz). The rearing system was cleaned and mortalities were recorded daily. Swim bladder inflation and gut content were recorded after three weeks of culture. Survival was 20% whereas only 5.5% of these survivors had inflated swim bladders. There was no significant difference between fish with non-inflated and inflated swim bladders in total length (10.4 ± 1.2 and 11.1 ± 1.3 mm [0.41 ± 0.0472 and 0.44 ± 0.0512 in], respectively). Histological analysis revealed that 100% of fish with non-inflated swim bladders showed infiltration of macrophages into their lumen. A similar process was earlier described in walleye larvae following the ingestion of bacteria and organic debris and attributed to their poor survival.

At UW-Madison a 2 × 3 factorial experiment comparing the habituation success of two sizes of small (12.5 mm [0.49 in] and 15.5 mm [0.61 in] total length) pond-raised perch fingerlings fed one of three commercial starter diets (Biokyowa A250/B400, Bioproducts Biokrill trainer, and Silver Cup soft-moist) has been completed. Habituation success was generally twice as good in the 15.5 mm (0.61 in) fish when compared to their 12.5 mm (0.49 in) counterparts (43–76% versus 20–37%). Overall habituation success was highest in the fish fed Biokyowa (μ = 76% in 15.5 mm [0.61 in] fish and 37% in 12.5 mm [0.49 in] fish). Groups fed Biokrill trainer showed the strongest initial acceptance, but by the end of the trial virtually all these fish were small and suffered from scoliosis, suggesting a nutritional deficiency in the krill diet. A strategy that employs krill for the first few days (to take advantage of its initial attraction) with a transition to a more nutritionally complete diet may be worth investigating. Tank husbandry of the 12.5 mm (0.49 in) fish was extremely labor intensive.

OBJECTIVE 2

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

Also at the UW-Madison the first replicates of studies comparing the growth of male and female yellow perch in ponds have been completed. Preliminary examination of the data suggests that female yellow perch had greater weight and length gains than males when grown in ponds. However, the growth of both males and females in these studies was poor, possibly due to a disease outbreak among tagged fish or the type of tags used to identify individuals. A second round of studies using a different style

of identification tag has been completed, and the data is currently undergoing analysis.

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

Research done by University of Missouri (UM) scientists sought to determine whether the use of a compensatory growth feeding regime would cause yellow perch to outgrow counterparts fed every day, the latter feeding regime being standard in aquaculture. This idea was based on previous work in age 0 hybrid sunfish in which a novel overcompensation response was found when certain repeating cycles of no-feeding followed by refeeding (hereafter, NFRF cycles) were implemented. The first study was a scoping experiment to determine which, if any, NFRF cycles would produce growth overcompensation in adult yellow perch. Episodes of hyperphagia occurred after each food deprivation period for all treatment groups, demonstrating that yellow perch do possess compensatory growth capacity. However, no growth overcompensation resulted in any of the treatment groups, and control fish consumed more food and showed greater overall weight gain and growth efficiency than did any of the compensatory growth treatment groups. In all treatments female yellow perch showed higher growth rates and growth efficiencies than males.

Results of the first experiment raised the question of whether growth overcompensation might be induced in yellow perch if one of the better performing longer-cycle NFRF regimes was used, but with maintenance-level feeding followed by refeeding (MFRF) substituted for total food deprivation to elicit the compensatory growth response. Comparisons of NFRF versus MFRF regimes have not been made previously in any fishes in relation to compensatory growth responses. Yellow perch fed according to the NFRF schedule did not show growth overcompensation, but did show consumption, specific growth rate, and growth efficiency equivalent to controls. Fish fed according to the NFRF regime consumed 28% less food, had a 59% lower specific growth rate, and showed a 55% lower growth efficiency than controls and counterparts fed on the MFRF schedule. In general, this result suggests that under conditions where growth overcompensation does occur, the MFRF regime may produce even better growth improvements than the NFRF regime. It is quite possible that growth overcompensation in yellow perch was impeded in the present study due to the individual holding of the fish, and this may warrant testing.

Research at MSU was designed to compare gender related growth rates of yellow perch greater than 150 mm (6 in) raised in single gender or mixed gender cohorts. Gender related growth differences are being evaluated using a saturation kinetics model developed by Mercer. Fish were separated by gender and randomly assigned (8/tank) to 110-L (29.1-gal) tanks. Water temperatures were maintained at 21°C (69.8°F) by a recirculation system.

Three replicate tanks per feeding rate treatment were randomly assigned feeding rates of 0.5, 1.0, 2.0, or 3.0% of total wet weight fish per day. Fish were then weighed every two weeks and feed levels were adjusted accordingly. The saturation kinetics model will be used to determine feeding levels required for maintenance and maximum and optimal feed efficiency.

Single gender cohort growth trials have been completed. A preliminary growth model was used to examine the growth rates between males and females, and this model indicated a significant difference in the growth rates, however, complete statistic analysis of the data has not been completed. The maximum growth rate was 0.024 g/day (0.0009 oz/day) for males and 0.035 g/day (0.0012 oz/day) for females. Using this model, the maintenance value was 0.04% total weight per day. According to this model, the feed level to achieve maximal growth is 1% body weight per day for males and slightly higher for females. Crude protein analysis of whole body samples has also been completed. Whole body crude protein levels were inversely related to feeding rate.

OBJECTIVE 3

UW-Madison researchers have induced out-of-season spawning with variable degrees of success in several year classes of yellow perch females. Due to its immediate commercial applicability, emphasis has been placed on inducing spawning in July, which may allow for the double cropping of fingerling ponds. Research efforts under this objective have been hampered by the failure of a water chilling system, and subsequent loss of many of the acclimatized brood stock due to a suspected toxin from the failed chiller. A replacement water chiller has been obtained to supply necessary cold water for the simulation of winter-like conditions during the spring and early summer of 2000. A group of male and female perch are currently undergoing acclimatization for a planned July 2000 spawning.

WORK PLANNED

OBJECTIVE 1

Research at Purdue will include two more diet evaluations for this coming year. Those evaluations will be continuations using rotifers and *Artemia* as a positive control, then comparing several of the available dry diets available for use in the United States.

Larval perch studies at MSU will be repeated to verify high survival and swim bladder inflation. If fertilized eggs are available from researchers conducting out-of-season spawning (Objective 3), trials will be run in January 2000.

OBJECTIVE 2

At UW-Madison, collection and analysis for the second round of studies comparing the growth of males and females in ponds will be completed, and a manuscript reporting the results of the study will be prepared for publication.

At Purdue a study evaluating flavor additives to perch diets will be completed later this year.

UM researchers will continue research to identify compensatory growth feeding schedules that maximize growth and growth efficiency in yellow perch (>150 mm; 6 in).

MSU will complete the statistical and proximate analysis of data collected during the first growth trial. Total proximate analysis will be performed on whole fish tissue. Currently, a

second set of growth trials are under way to compare the growth rates of the males and females raised in a mixed stock. Three tanks of females fed at 3% of total wet weight are being raised as a control. Experiments should be completed by December 1999.

OBJECTIVE 3
UW-Madison studies on out-of-season spawning induction will continue.

IMPACTS
OBJECTIVE 1
Research on Objective 1 is improving larval rearing techniques by developing and evaluating different starter diets and environmental conditions. Methods for successfully rearing yellow perch fingerlings as small as 15.5 mm (0.61 in) using readily available commercial feeds have now been demonstrated. For newly hatched perch larvae, we have shown that live foods including rotifers, *Artemia*, and vinegar eels can be used successfully as a first food source, and dry diets including artificial plankton and diets containing krill hydrolysate show promise for the future. The information generated by these studies will greatly assist perch producers in their efforts to reliably raise the large numbers of perch fingerlings needed by the industry.

OBJECTIVE 2
Research on Objective 2 is developing and evaluating methods for improving perch growth as they approach market size. Studies to date have shown that female perch outgrow males, and accordingly the use of monosex female stocks may be a method for producers to increase growth rates of perch. Previous work has led to the development of methods for producing monosex female stocks of perch, and this technology is currently being used by six regional perch producers under an INAD exemption granted by the FDA. The establishment of optimum feed levels for perch will help producers to minimize feed costs, which are one of the primary costs of aquaculture production. The development of methods to promote perch growth with naturally occurring dietary supplements may further improve the profitability of the culture of food-size yellow perch. Together, the above strategies should provide the means for producers to reduce the cost of raising perch to market size.

OBJECTIVE 3
Research on Objective 3 is developing methods to induce out-of-season spawning in perch. The resultant availability of perch fry at different times during the year will increase the efficiency of existing pond and tank fry culture systems by allowing multiple cropping of these systems. In turn, the availability of fingerlings at multiple times during the year will facilitate a fuller, more efficient use of grow-out facilities and equipment. The availability of fertilized eggs outside the normal spawning season will also greatly facilitate research on the culture of perch fry in tanks.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED
See Appendix A for a cumulative output for all NCRAC-funded Yellow Perch activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1997-98	$95,300	$98,565	$2,000			$100,565	$195,865
1998-99	$90,300	$94,335				$94,335	$184,635
TOTAL	$185,600	$192,900	$2,000			$194,900	$380,500

YELLOW PERCH[3]

Progress Report for the Period
September 1, 1998 to August 31, 1999

NCRAC FUNDING LEVEL: $61,700 (September 1, 1998 to August 31, 1999)

PARTICIPANTS:

Christopher Starr	Bay Port Aquaculture Systems, Inc., West Olive	Michigan
Donald L. Garling	Michigan State University	Michigan
Michael D. Libbin[4]	Paragon Aquaculture, Oshkosh	Wisconsin
Harvey Hoven	University of Wisconsin-Superior Sea Grant Institute	Wisconsin
Extension Liaison:		
Donald L. Garling	Michigan State University	Michigan
Industry Advisory Council Liaison:		
Harry Westers	Aquaculture Bioengineering Corporation, Rives Junction	Michigan

PROJECT OBJECTIVES

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

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

ANTICIPATED BENEFITS

This project will address priority needs identified by the North Central Regional Aquaculture Center (NCRAC) Industry Advisory Council for advancing yellow perch aquaculture in the North Central Region. The research activities will evaluate replicated multiple cohort-continuous loading management strategies compared to more traditional stocking and grow-out procedures. The research project will also address questions concerning the magnitude of differences in growth rates between males and females and if fingerlings with suppressed growth rates resume normal growth rates when conditions are no longer limiting. The information generated will

[3]NCRAC has funded six 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 progress report for the sixth project, chaired by Jeffrey A. Malison, is contained elsewhere in this Annual Progress Report. This progress report is for the seventh Yellow Perch project, which is chaired by Donald L. Garling. It is a 2-year study that began September 1, 1998.

[4]Paragon Aquaculture has withdrawn from the project for year two as noted in the body of the report.

help aquaculturists using recirculating technology weigh the relative theoretical benefits of continuous loading (continuous harvest and utilization of the recirculating system near threshold design limits) against its potential drawbacks (reduced feed efficiency, increasing numbers/biomass of slow growing fish, and declining harvest rates over time). This project will also evaluate different larval yellow perch culturing methods to enhance survival of perch fry.

The calculation of the break-even financial levels using actual costs of production and actual revenues received from product sales would allow current and prospective producers of yellow perch in a recirculating system to compare and forecast their financial results with some confidence. Each current or prospective producer can compare their forecasted or actual production output, market prices received, and total operating costs against the actual financial results reported in this study.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

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

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

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

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

Paragon received a second cohort of fish in February 1999. Fish mortality was significantly higher than normal for the facility and continued throughout the first six months.

The MSU recirculating system was designed and constructed during the fall of 1998 and has been operating for ten months. Yellow perch were obtained from Bay Port in January 1999. The fish experienced high mortality rates within days after stocking into a holding tank supplied with 12.5°C (54.5°F) well water. A second group of perch was obtained from Bay Port in February 1999 which also experienced high rates of mortality after transport and stocking into a holding tank at MSU. The initiation of research trials was postponed until healthy yellow perch could be obtained from Bay Port.

The high level of mortality in yellow perch from the single group of fish from Bay Port observed at MSU and Paragon was observed at other yellow perch culture facilities receiving the same fish. Fish from MSU were sent to the MSU

Animal Health Diagnostic Laboratory for evaluation. Necropsy, histopathology, bacteriology, and parasitology results were inconclusive. Fish from Paragon were evaluated by the Division of Animal Health by the State Aquaculture Veterinarian (Myron J. Kebus, M.S., DVM) and virology samples were submitted to Dr. Scott LaPatra, Clear Springs Foods, Idaho for diagnostics. Dr. Kebus also consulted with Dr. Michael Vander Klok (Michigan Department of Agriculture), Dr. Gerald Johnson (Atlantic Veterinary College Fish Diagnostic Laboratory), Dr. Fred Rommel (Pennsylvania Department of Agriculture Fish Diagnositic Lab), and Dr. Hamish Rogers (University of Pennsylvania Fish Diagnostic Lab). No definitive diagnosis has been reported by any of the laboratories involved in performing diagnostics on the affected yellow perch from any of the locations.

In July 1999 two groups of young of the year (YOY) yellow perch were obtained from Bay Port and brought to the MSU facility. One group of perch was harvested from the pond that had contained the perch that exhibited the high rates of mortality and the second group was harvested from other ponds. Fish were reared in triplicate tanks to determine if these fish also experienced high mortality rates. The YOY yellow perch from both groups obtained from Bay Port had nearly 100% survival. These fish were used to supply the smaller-sized fish for the research. Larger yellow perch were purchased from Willow Creek Aquaculture, Middleton, Wisconsin in September 1999. The mixed versus single-sized cohort research will be started in September 1999.

OBJECTIVE 2

Work was completed to design a method and system to collect financial operating data from active yellow perch producers during September and October 1998. When the study was originally proposed and funded, there were four yellow perch production facilities that agreed to cooperate in the study by providing monthly financial operating data. Three of the original operators have either terminated their operations or not established production levels sufficient to become commercially viable as a business. The fourth cooperator, Paragon, did commence commercial production levels in November 1998, and operating financial data was collected until June 1999. The Paragon operation was terminated when all of the fish in the production facility died from unknown causes. Paragon will not be resuming operations. The financial data supplied by Paragon is incomplete and, therefore, not useful in this study. The financial data provided does not cover a full grow-out cycle and, therefore, a break-even analysis is not possible because there were no revenues produced.

WORK PLANNED

OBJECTIVE 1

The nine-month mixed versus single-sized cohort growth trial conducted at MSU will continue until June 2000. Data will be analyzed and a report prepared with suggestions for future research by the end of the project.

MSU will also conduct a set of larval yellow perch experiments beginning in January 2000, if researchers conducting out-of-season perch spawning can provide fertilized eggs, or during the normal spawning period in April 2000. Eggs will be transported to MSU where they will be incubated and hatched. Experiments will be conducted in an attempt to replicate promising preliminary results observed in 1999. The use of uniquely designed tanks and feeding protocols resulted in larval survival exceeding 85% to approximately 30 mm (1.2 in) in TL.

As already noted, Paragon has withdrawn from the project and will not receive second-year funds.

Bay Port will begin construction of their recirculating aquaculture facility which will be operational by January/February 2000. Bay Port will begin single-size cohort culture experiments and will conduct a portion of the research that was to be done by Paragon on multiple-size cohort culture.

OBJECTIVE 2

As of August 31, 1999, the end of the first year of this grant, no active yellow perch producers have provided monthly financial operating data. Attempts are being made to contact other yellow perch producers in the region by telephone and letters to determine their willingness and ability to provide commercial level production and financial data to be used for this study during Year 2.

IMPACTS

Results from research conducted as part of Objective 1 will provide information on grow-out of food-size yellow perch using single or multiple-size cohorts in recirculating systems. This information will also be valuable to yellow perch culturists using flow-through tank systems.

If additional participants can be identified who are willing to provide monthly financial data, the results of Objective 2 will result in the construction of an annual financial operating statement of total operating revenues and expenses, and calculation of a break-even financial operating level based on the expenses of production and the sales prices of the production for each cooperator.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

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

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1998-99	$61,700	$36,007	$64,575			$100,582	$162,282
TOTAL	$61,700	$36,007	$64,575			$100,582	$162,282

HYBRID STRIPED BASS[5]

Progress Report for the Period
September 1, 1995 to August 31, 1999

NCRAC FUNDING LEVEL: $30,000 (September 1, 1995 to August 31, 1999)

PARTICIPANTS:

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

PROJECT OBJECTIVES

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

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

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

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

ANTICIPATED BENEFITS

The overall goal for the NCRAC-funded collaborative Hybrid Striped Bass projects is to enhance the culture potential of this fish in the NCR. Extension related-activities and outputs will assure that the research information generated gets to the industry in a user-friendly form.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

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

A hybrid striped bass fact sheet developed by Morris and Kohler has been completed

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

(NCRAC Fact Sheet Series #107). This publication will be available January 2000.

Kohler and Morris served as co-chairs for the first NCRAC Hybrid Striped Bass Workshop that was held in November 1995 in Champaign, Illinois. The topics for the workshop included larval culture, cage culture, brood stock management, and an industry perspective. The 35 attendees were from Illinois, Indiana, Iowa, and Missouri. Speakers who have been participants in various NCRAC-funded projects included Chris Kohler, Sue Kohler, and Bob Sheehan of Southern Illinois University-Carbondale, George Brown and Joe Morris of Iowa State University, and LaDon Swann of Purdue University. Proceedings from this workshop are available from the NCRAC Publications Office at Iowa State University.

WORK PLANNED

The culture manual will be produced in two phases. In the first phase, the editors, Kohler and Morris, will review the current status of information using previously produced related materials, e.g., "Culture and Propagation of Striped Bass and its Hybrids" produced by the American Fisheries Society and "Farming a New Fish: Hybrid Striped Bass" available from North Carolina Sea Grant. The second phase will consist of producing materials that fill in the voids using information garnered from NCRAC research activities, e.g., nutritional and gamete storage and transportation. These materials will be developed in 2000 to support a second Hybrid Striped Bass Workshop.

The second workshop will focus on presenting technologies developed through NCRAC-funded projects over the past decade. The general methods used for culturing this important food fish will be fully covered. The workshop will be held in St. Louis, Missouri at a hotel near the airport to facilitate travel within the region. To lessen conflicts with fish farm activities, the workshop will be held in early spring or late fall in the year 2000. Speakers will include selected members of past NCRAC Hybrid Striped Bass Work Groups, as well as one or more guest speakers from the private sector. Workshop registrants will receive information packets covering important details of hybrid striped bass culture. To obtain the greatest number of conference attendees, a workshop brochure will be developed, advertised, and distributed throughout the NCR using existing extension and research networks.

A video will be produced using a combination of computer software, slides, and moving-video footage. A video capture card with editor will be employed to incorporate moving images into a Microsoft® PowerPoint presentation. A digital camera will be used to allow for high-quality slide presentation. The video will cover information contained in the culture manual on the basic aspects of hybrid striped bass production and the advances made by the various NCRAC-funded Hybrid Striped projects.

IMPACTS

The proceedings from the 1995 NCRAC Hybrid Striped Bass Workshop has been used to address industry concerns and questions. The forthcoming culture workshop and video should be useful in building upon previous related outreach materials in bringing forth new information to the public and in particular the aquaculture industry.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

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

SUPPORT

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

SUNFISH[6]

Project Termination Report for the Period
September 1, 1994 to August 31, 1999

NCRAC FUNDING LEVEL: $373,562 (September 1, 1994 to August 31, 1999)

PARTICIPANTS:

Bruce A. Barton	University of South Dakota	South Dakota
Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Paul B. Brown	Purdue University	Indiana
Donald L. Garling	Michigan State University	Michigan
Robert S. Hayward	University of Missouri	Missouri
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Joseph E. Morris	Iowa State University	Iowa
Douglas B. Noltie	University of Missouri	Missouri
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Robert C. Summerfelt	Iowa State University	Iowa
James R. Triplett	Pittsburg State University	Kansas
Industry Advisory Council Liaison:		
Charlie Stevens	Knoxville	Iowa
Extension Liaisons:		
Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborators:		
Denzil Hughes	Farmland Industries, Inc., Kansas City	Kansas
IL Dept. of Conservation	Little Grassy State Fish Hatchery, Carbondale	Illinois
Jim Frey	Jim Frey Fish Hatchery, West Union	Iowa
Ron Johnson	Spruce Creek Fish Farm, Miltona	Minnesota
Myron Kloubec	Kloubec Fish Farms, Amana	Iowa
MO Dept. of Conservation	Columbia	Missouri
Tribal Council	Red Lake Band Chippewa, Red Lake	Minnesota
National Biological Service	Midwest Science Center (formerly USFWS National Fisheries Contaminant Research Laboratory), Columbia	Missouri
U.S. Fish & Wild. Service	Gavins Point Nat'l. Fish Hatchery, Yankton	South Dakota

[6]NCRAC has funded four Sunfish projects. This termination report is for the third and fourth projects. Termination reports for the first two Sunfish projects, or components thereof, are contained in the 1989-1996 Compendium Report. The third and fourth projects continued and built upon the first two projects. The third project was a 2-year study that began September 1, 1994 and was chaired by Donald L. Garling. The fourth project was also a 2-year study that began September 1, 1996 and was chaired by Robert J. Sheehan. Charlie Stevens was appointed to serve as the Center's Industry Advisory Council Liaison for the fourth project.

REASON FOR TERMINATION
The objectives were completed.

PROJECT OBJECTIVES
(1) Produce a production manual, accompanying videos, and other information as necessary to demonstrate the technology for culturing centrarchids.

(2) Determine the major nutritional requirements for centrarchids and compare their growth and performance using available commercial feeds in laboratory and field settings.

(3) Determine the best feeding management strategies for culturing centrarchids in laboratory and field settings.

(4) Compare feeding trials for grow out of locally available 5.1–10.2 cm (2–4 in) black crappie (*Pomoxis nigromaculatus*) and female green sunfish (*Lepomis cyanellus*) with a male bluegill (*L. macrochirus*) hybrids in:

   (a) ponds at dissimilar latitudes in the region, and

   (b) recirculating systems using compensatory feeding strategies.

(5) Establish baseline physiological measures for small 2.5–7.6 cm (1–3 in) black crappie subjected to handling stressors and test the effect of salt and temperature on stress reduction.

PRINCIPAL ACCOMPLISHMENTS
OBJECTIVE 1
Michigan State University (MSU) and Iowa State University (ISU) personnel have completed the 100-page Sunfish Culture Guide; it is now being proofed and should be available for distribution from the NCRAC Publications Office spring 2000. ISU personnel have produced a video addressing various production areas of male bluegill × female green sunfish (BG × GS) hybrids. The 8-minute video entitled "Sunfish (*Lepomis* spp.) Culture" is now available from the NCRAC Publications Office. This video depicts methods for determining the sex of brood stock, species identification, and out-of-season spawning techniques.

OBJECTIVE 2
Researchers at MSU have empirically determined the optimal energy level for growth and protein retention in 125 mm (4.9 in) BG × GS hybrids utilizing a saturation kinetics model for curve fitting. Results demonstrate the semi-purified diet developed for these trials is well accepted by these fish; this results in a slightly lower but comparable growth to that obtained using a commercial control diet.

Studies at Purdue University (Purdue) were designed to quantify the dietary requirement for phosphorus (P) and optimum lipid to carbohydrate ratio. It appears the dietary requirement of BG × GS hybrids for P is $\leq$0.5% of the dry diet. Both pure bluegill and BG × GS hybrids grow best when fed diets containing no less than 10% dietary lipid in the form of fish oil.

Southern Illinois University-Carbondale (SIUC) researchers used practical diets containing crude protein levels of 32, 36, 40, and 44% for culturing BG × GS hybrids in two culture systems: recirculating culture system and culture ponds. Similar results were obtained regardless of culture system in regards to dietary protein levels. Increasing protein levels resulted in increasing growth rates with the

optimum protein level of 40%. Dress-out analysis indicated a similar trend where increasing dietary protein levels resulted in increased percent gutted, headed, and fillet weight. Fillet composition also varied where increasing protein levels resulted in decreasing lipid content.

OBJECTIVE 3

ISU researchers have developed a procedure for tank-rearing larval bluegill and larval BG × GS hybrids in the laboratory. Results indicate that the protocol for tank-rearing larval bluegill and larval BG × GS hybrids should include using brine shrimp nauplii (*Artemia franciscna*) prior to using a commercial diet. It appeared that larval BG × GS hybrids could digest the commercial diet at the onset of exogenous feeding. However, without brine shrimp nauplii much lower survival rates resulted. Survival rates of about 25 and 37% can be expected for bluegill and BG × GS hybrids, respectively, by following this protocol.

The primary goal of the University of Wisconsin-Milwaukee (UW-Milwaukee) researchers was to utilize the early life stage feeding technology developed for yellow perch and apply this approach to centrarchids, specifically, black crappie. Young-of-the-year (YOY) black crappie were trained to accept commercial diets using a combination of adult frozen brine shrimp (*Artemia*); "green water" organisms, which included copepods, ostracods, and smaller cladocerans; and beef liver mixture.

Past efforts of UW-Milwaukee researchers to spawn adults in the laboratory or to collect wild adults have not been successful. The group of YOY black crappies acquired in October 1994 have been retained for use as captive brood stock; they have been maintained on a rearing regime that is intended to promote gonadal development.

Researchers at the University of Missouri (UM) have examined the potential to increase growth rates of BG × GS hybrids during grow out by using feeding schedules that bring out these fishes' compensatory growth response (increased growth following a period of fasting). Mealworms (*Tenebrio molitor*) were used as the food in these initial experiments so that daily consumption by individual fish could be accurately determined. Mean growth rates of BG × GS hybrids in the 2 and 14 day no feeding cycle groups were 2.1 and 1.5 times faster than the controls that were fed ad libitum every day. Growth improvements from compensatory growth appeared to result from increases in both consumption rate and growth efficiency.

UM researchers then evaluated the potential to increase growth rates of hybrid sunfish via compensatory growth under conditions closer to those used in aquaculture (use of commercial trout diet) than were used in their previous work. In contrast to their earlier studies, UM researchers found that while compensatory growth responses were indicated in all treatments by periods of hyperphagia (increased appetite) after no-feed periods, none of the treatment groups outgrew the controls (absolute growth rates ranged from 63–86% of the controls). UM researchers subsequently determined that the commercial diet was the cause for these contrasting findings. Because they were unable to duplicate the superior growth over controls as in earlier work, UM researchers reran the treatments as in a 1997 study done by them to ensure that their previous results were reproducible. Results of their earlier study were duplicated with both compensatory growth treatments outgrowing

controls. UM research also determined that a significant effect of social interaction occurred upon growth variables and size variation in juvenile hybrid sunfish.

OBJECTIVE 4

Purdue researchers investigated three different diets, 32, 36 or 40% crude protein, for pond-reared hybrid sunfish; feed conversion ratios ranged from 1.3–1.5. Hybrid bluegill can be fed diets containing 32% crude protein without sacrificing weight gain or feed conversion. Further, it appears that hybrid bluegill fed dietary crude protein concentrations of 32% reproduce to the same extent as fish fed 36 or 40% crude protein.

Growth of black crappie and BG × GS hybrids were compared using common pond aquaculture techniques at SIUC. Hybrid sunfish were successfully cultured while black crappie were not. Net production for hybrid sunfish was 621.6 and 943.2 kg/ha (554.6 lb/acre and 841.5 lb/acre) in the 8,000 and 14,000 fish/ha (3,238 and 5,666 fish/acre) ponds, respectively. Black crappie net production was -111.0 kg/ha and -193.9 kg/ha (-99.0 lb/acre and -173.0 lb/acre), respectively, in ponds stocked at 8,000 and 14,000 fish/ha (3,238 and 5,666 fish/acre). The crappie did not appear to be using the prepared diet.

In response to their poor performance, black crappie were habituated to prepared diets prior to stocking in 1998 (hybrid sunfish were similarly treated) at SIUC. Hybrid sunfish accepted the production diet virtually immediately, whereas the crappie did not. Freeze-dried mysid shrimp and Biokiowa™ 2000 mini-pellets were then given to the black crappie as starter diets. Freeze-dried mysids were eagerly taken the first time they were offered, and the Biokiowa™ diet was also readily accepted within a few days.

Researchers at ISU conducted two, 12-week feeding trials in 1997-1998 to compare growth and food conversion of fingerling hybrid sunfish derived from tank- and pond-spawning to a compensatory feeding strategy when raised in a recirculating aquaculture system. In both feeding trials, the restricted feeding group was fasted 2 days every week followed by 5 days of full feeding (2–5 day feeding regimen).

Although feed consumption in the restricted feeding group was greater than the daily feeding group for up to 3 days following resumption of daily feeding, overall, feed consumption was less in the restricted feeding group and compensatory growth did not occur. Food conversion in the restricted and daily feeding groups were similar. Most differences in growth between the restricted and daily feeding groups were not statistically significant, but when statistical significance was found in comparing the two groups, fish in the daily feeding regimen had faster growth than fish in the restricted feeding group. The restricted feeding strategy used here (2–5) is only one of many options on restricted feeding. Thus, these findings do not imply that other variations of restricted feeding will not produce more desirable results, or that the 2–5 system used here will not be successful with a different size group of hybrid sunfish, or with other species.

Although the parents of both groups of fingerlings were from the same stock of fish, they represented progeny of different families and of different numbers of parents; fewer brood stock were used to produce the tank-reared fish than the pond-reared fish. The most probable explanation for the results is the genetic differences among individual parental stocks.

Results from Pittsburg State University's (PSU) work indicate that compensatory feeding appeared to have little effect on biofilter performance at the loading densities of black crappie used for their study.

The compensatory feeding trial of 2, 3, and 4 day starvation periods were run for 50 days each and compared against a control group, which were fed daily to satiation on 2.5 mm (0.1 in) Biodiet™ grower. The best growth occurred during the control feeding. The next best was the 3-day; however, differences between the feeding trials were not statistically significant.

Individual trials were run on Biodiet™ at PSU using larger black crappie, 150–200 mm (5.9–7.9 in) size range. Comparisons of daily feeding to 2, 3, and 4 day starvation periods produced no differences in food consumption. Following concern about the commercial feed acceptability, individual trials were repeated using natural foods with 2, 4, and 8 day starvation periods. The best growth occurred in the control group fed daily.

OBJECTIVE 5

Juvenile black crappies were reared extensively at the Gavins Point National Fish Hacthery in Yankton, South Dakota and transported to the University of South Dakota (USD). Results from stress tests performed at USD and analyzed by USD and University of Wisconsin-Madison (UW-Madison) scientists indicate that black crappies are stressed from simple handling with the maximum corticosteroid response occurring at 0.5 h. Limited plasma chloride analysis shows that the crappies experienced an osmoregulatory imbalance from the stress, the effect of which was still apparent after 24 h. The results also indicate that routine handling, at least under these experimental conditions, was insufficient to cause significant mortality. The results show that using chilled water where fish were subjected to a rapid 6–7°C (42.8–44.6°F) temperature drop was more stressful to the fish than leaving them at ambient conditions. However, all fish appeared to recover partially from stress relatively quickly, although not completely by 24 h. Using an isotonic concentration of salt (NaCl), however, appeared to be beneficial to the fish by reducing or eliminating the decline in blood chloride levels caused by the osmoregulatory upset that usually accompanies a response to an acute stressor.

IMPACTS

The development of the Sunfish Culture Guide that incorporates information garnered from NCRAC-funded research will be a valuable resource for current and future sunfish producers.

Developing diets specifically for targeted species results in maximum performance at the lowest possible cost. Purdue research directed at minimizing costs of feeds will help to maximize profit to the producer.

It now appears that the intensive culture technology developed for yellow perch can be applied to black crappie. Also, YOY (30–60 day old) pond-produced black crappie can habituate to prepared diets within 26 days; YOY (100 day old) pond-produced black crappie can habituate to prepared diets within 14 days. The potential for the intensive culture of black crappie looks very promising.

UM's findings suggest that the compensatory growth response differs according to the type of food used; natural versus commercial diets. An exciting potential exists for using compensatory growth feeding schedules with sub-maximal feeds (e.g., mealworms), to achieve BG × GS hybrid growth rates approaching those obtained with commercial feeds.

Pond studies at SIUC showed that hybrid sunfish grow rapidly during the second year of the production cycle, but not fast enough when beginning with small (6 g; 0.2 oz) fingerlings to produce highly desirable, market-size 227–340 g (0.50–0.75 lb) fish by the end of year 2. This suggests a 3-year production cycle may be necessary to achieve 227–340 g (0.50–0.75 lb) fish.

The SIUC pond study also clearly showed that production methods suitable for hybrid sunfish are not suitable for black crappie. The latter showed poor growth and survival, and they appeared to be subsisting on the natural food supply rather than the production diet. However, great success was obtained with crappie with two starter diets, freeze-dried mysids and Biokiowa™. More work is needed to develop methods for weaning crappie from the starter to production diets.

Hybrid sunfish fed diets higher in crude protein yielded higher dress-out weights. Accordingly, a producer concerned about a processed product must consider the synergistic affects of production rates and dress out as a function of dietary protein levels when determining cost effectiveness of practical dietary formulations.

USD and UW-Madison results indicated that black crappies are stressed from simple handling, the effect of which was still apparent after 24 h. Their results also indicated that routine handling, at least under these experimental conditions, was insufficient to cause significant mortality. The use of chilled water to mitigate the stress response in crappies was actually more stressful to the fish than allowing them to recover at ambient temperature. The addition of salt (NaCl) may be useful in mitigating the effect of handling and transport stress in crappies.

RECOMMENDED FOLLOW-UP ACTIVITIES

Additional research on decreasing fish meal and continuing evaluations of optimal dietary crude protein should be pursued as these are the most expensive components in feeding of fish. It appears that the BG × GS hybrid will be more similar to the channel catfish than other species in that it will grow best when fed relatively low concentrations of dietary crude protein. This significantly aids in overall economics of bluegill culture, yet the hybrid remains a relatively slow growing candidate. Other members of this groups of fishes should be considered candidates for culture and those evaluations should be linked with nutritional evaluations.

ISU studies indicate that when carefully studied, family differences in performance characteristics are invariably observed. Thus, effort must be undertaken to avoid a culture program based on a limited gene pool.

Although not directly evaluated, the findings from UM's experiments in the fourth project, in combination with previous work, hinted that time-of-year may be a critical determinant of when compensatory growth feeding can improve growth. The three experiments involving compensatory growth that did not yield growth in excess of controls were begun prior to November, while the two that did began no earlier than December-February. Conceivably, better compensatory growth occurs only during late winter to early spring when control fish growth rates have been low despite summer-like temperature and photoperiods. If so, future efforts should evaluate the use of compensatory growth feeding to improve growth of hybrid sunfish in recirculation tanks (where summer-like conditions can be maintained) during the months of January through April, as a means to

reduce total grow-out times and to improve feed conversion.

PAPERS PRESENTED

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

PUBLICATIONS, MANUSCRIPTS, OR

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1994-96	$173,562	$177,300	$12,012[a]			$189,312	$362,874
1996-98	$200,000	$274,773				$274,773	$474,773
TOTAL	$373,562	$452,073	$12,012			$464,085	$837,647

[a]Farmland Industries, Inc.

SALMONIDS[7]

Progress Report for the Period
September 1, 1997 to August 31, 1999

NCRAC FUNDING LEVEL: $160,000 (September 1, 1997 to August 31, 1999)

PARTICIPANTS:

Paul B. Brown	Purdue University	Indiana
Konrad Dabrowski	Ohio State University	Ohio
Donald L. Garling	Michigan State University	Michigan
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
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:		
Myron Kebus	Wisconsin Aquatic Veterinary Service, Madison	Wisconsin
David Mueller	Rushing Waters Fisheries, Inc., Palmyra	Wisconsin
David A. Smith	Freshwater Farms of Ohio, Inc., Urbana	Ohio
Brad Strahm	Wenger, Inc., Sabetha	Kansas
Kathy Warner	National Center for Agricultural Utilization, ARS, USDA, Peoria	Illinois
Y. Victor Wu	National Center for Agricultural Utilization, ARS, USDA, Peoria	Illinois
M. Randall White	Purdue University	Indiana

PROJECT OBJECTIVES

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

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

(3) Investigate the effects of trace mineral supplementation on the growth and stress response of rainbow trout in high density

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

culture, as evaluated by plasma cortisol levels and fin nipping behavior.

ANTICIPATED BENEFITS

OBJECTIVE 1

The major cost in aquaculture of salmonids is the cost of feed and, more specifically, highly priced fish meal. Therefore, replacement of fish meal protein with proteins of similar biological value is the most desired goal in the culture of carnivorous fishes. Decreasing pollution due to leaching minerals/nutrients (phosphorus and ammonia) should be achieved simultaneously with changes in diet formulations. In addition, feedstuffs of fish origin have been subject to dramatic price fluctuations. Significant new production of fish and shellfish will place strains on the supplies of fish meal and fish oil in the future. Further, fish meal is one of the more difficult feed ingredients to transport to the North Central Region (NCR).

Work proposed and conducted under this objective was designed to develop diets for rainbow trout that are free of fish meal and rely on feed ingredients common in the NCR. This line of research will result in diet formulations that are lower in cost, which will reduce overall production costs, as well as that can be taken to local feed mills which will reduce transportation costs.

North Central Regional Aquaculture Center (NCRAC)-funded research has shown that pretreatment of plant feedstuffs with the enzyme phytase can help improve utilization of phosphorus (P) and nitrogen (N) in limited fish meal and all-plant diets for rainbow trout. In addition, insulin-like growth factor (IGF-1) levels can be used as a rapid indicator of nutritional status in rainbow trout.

OBJECTIVE 2

These studies will provide detailed information on the growth and stress responses of Kamloops and Donaldson strains of rainbow trout and Arctic charr reared under thermal conditions typically found in the NCR. Regional salmonid producers will be able to use this information to determine which of the three species/strains can be best utilized at their operation (i.e., under their specific thermal conditions) to maximize productivity and profitability.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

In the past year, researchers at Purdue University (Purdue) developed a new series of 10 experimental diets and fed those to Shasta strain rainbow trout of 52 g (1.8 oz) initial weight. Weight gain, feed intake, feed conversion ratio, and specific growth rate of fish fed two of the formulations free of fish meal were not significantly different from fish fed a control diet. However, both diets contained fish oil as the lipid source.

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

began to show differences in growth rate from the eighth week followed by significant differences at the 12th and 16th weeks. At the final 16th week weighing, fish fed diets FMA40, FMA60, and FMA100 exhibited significantly lower weight gain, feed efficiency, protein efficiency ratio, and specific growth rate than fish fed FMA20 and the control diet. Hematocrits of fish fed FMA-containing diets were significantly lower than those of fish fed a control diet. FMA inclusion up to 60% in diets did not show differences in apparent protein digestibility compared to the control (85.0 ± 1.9%), whereas the FMA100 group was significantly lower (77.7 ± 4.4%). These results suggest that a FMA could be used up to 20% as a fish meal protein substitution in diets for juvenile rainbow trout without an adverse affect on growth rate and hematological indicators.

In the second experiment at OSU, fish meal protein was replaced partially or entirely with a mixture of animal by-products and/or plant protein mixtures (soybean and cottonseed meals). Fish averaging 0.96 g (0.034 oz) were divided into 18 groups (three replicates per diet). Six diets were formulated as follows: (1) control diet (100% fish meal), (2) APM50 (50% animal by-products + 50% fish meal), (3) APM100 (100% animal by-products), (4) CM-CA (25% California cottonseed meal product + 25% soybean meal + 50% animal by-products), (5) CM-TN (25% Tennessee cottonseed meal product + 25 soybean meal + 50% animal by-products), and (6) CM-AR (25% Arkansas cottonseed meal product + 25% soybean meal + 50% animal by-products). The results of the weight gain and feed efficiency showed that fish meal can be entirely replaced by a mixture of animal by-products and either of two cottonseed meal products (1370 ± 17, 1330 ± 16, and 1350 ± 10% body weight gain for control, CM-TN and CM-AR diets, respectively). Significantly lower hematocrit levels were found in fish fed five test diets compared to those fish fed the control diet. Higher concentrations of total gossypol were found in feces of fish fed CM-TN and CM-AR diets than those fed CM-CA diet. The percentage of dietary gossypol accumulated in the whole body indicated that the majority of this substance is excreted in feces. The gossypol isomer selectively accumulated in liver and bile is the (+) isomer, whereas equal proportions of (+) and (-) isomers were found in diet, whole body, and feces. The findings suggest that a fish meal-free diet could be used without adverse effects for 16 weeks on growth performance and histopathological changes in liver in juvenile rainbow trout.

At Michigan State University (MSU) tanks were stocked with rainbow trout and experimental or reference diets were randomly assigned. Dietary treatments consisted of: (1) negative reference (sub-optimal protein), (2) positive reference (fish meal based), (3) soybean meal substituted-untreated diet, and (4) soybean meal substituted-pretreated with phytase. Experimental diets were formulated with 35% crude protein, a protein to energy ratio of 100, and vitamin and mineral premixes added to meet the requirements of the fish. The animals were given a two-week acclimation period prior to the start of the study to allow them to adjust to their new surroundings and feeding regime. Diets were fed three times a day to three replicates of 16 fish per treatment for a period of 10 weeks. Feed rates were calculated on a percent body weight basis, which was determined during the two-week acclimation period by feeding the fish to satiation. Fish were weighed every two weeks and feed rates were adjusted according to

weight gain. Initial findings showed that phytase pretreatment of soybean meal significantly increased weight gain and protein deposition above the fish meal based diet and significantly improved feed conversion ratios. Results from this study were presented at the World Aquaculture Society meeting in Sydney, Australia in April-May 1999. The data showed that phytase pretreatment of plant products in diets increased growth significantly above fish meal diets. The data also showed that without phytase pretreatment diets could be formulated that were not significantly different from fish meal diets. The IGF-1 isolation procedure was also refined to work on rainbow trout. A study on dietary iron retention in rainbow trout was also completed.

OBJECTIVE 2

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

In March 1998, approximately 120 Arctic charr (average total length 160 mm [6.3 in], weight 31 g [1.1 oz]) and 100 rainbow trout (average total length 150 mm [5.9 in], weight 34 g [1.2 oz]) were obtained from Rushing Waters Fisheries and Trout Haven, Bryant, Wisconsin, respectively. The fish were held in separate 750-L (198-gal) flow-through tanks at a water temperature of 12.5°C (54.5°F). In April 1998, the fish were weighed, measured, and 25 fish were transferred into each of four 120-L (32-gal) flow-through tanks (two tanks of rainbow trout, two of Arctic charr). Over the next two weeks, the water temperature was gradually raised to 15°C (59.0°F) in two tanks (one rainbow trout tank, one charr tank) and lowered to 10°C (50.0°F) in two tanks. After three weeks acclimation, six fish from each tank were quickly removed, anesthetized, and bled via the caudal vasculature. The remaining fish were given an acute stress challenge test by holding them out of the water for 1 min, then randomly placing them into separate tanks. Groups of six fish were then netted, anesthetized, and bled at 1, 3, and 24 h following the stressor.

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

In spring 1999, Freshwater Farms of Ohio, Inc. (Urbana, Ohio) stocked Shasta and Donaldson rainbow trout in an outdoor raceway and have been monitoring the growth, survival, and incidence of disease. UW-Madison researchers will complete this experiment in October 1999 by evaluating the stress responses of these fish to an acute stress challenge test.

OBJECTIVE 3

A questionnaire was designed by MSU researchers to evaluate the extent and impact of trout fin nipping/erosion in the NCR. The questionnaire was reviewed by two MSU social scientists with expertise in survey methods and by three NCRAC extension

contacts. Minor revisions were made prior to pre-testing the questionnaire. The questionnaire was pre-tested in Michigan by sending it to 15 trout producers.

NCRAC extension contacts in eight states were asked to provide the names and addresses of up to 15 trout producers in their state. One state contact and the State Aquaculture Coordinator chose not to cooperate in the survey, three states had too few producers (1 or 2) to participate and one state specialist (Nebraska) chose to survey his producers by phone interview using the questions provided. Responses were received from 34 of 42 producers surveyed in Michigan, Missouri, and Wisconsin which represented an 87% response rate. Fin nipping/erosion was rated as no or a minor problem without significant economic impact by 30 producers (88%) who responded by mail and by those who participated in phone interviews. Two producers each indicated a moderate or severe fin nipping/erosion problem. Since so few producers indicated that fin nipping/erosion was a problem, causes of their problems could not be identified.

WORK PLANNED

OBJECTIVE 1

Purdue researchers will evaluate five to seven lipid sources alone or in combination in their basal fish meal-free diet.

An MSU study is currently in progress and will be completed in six weeks. Tanks were stocked with rainbow trout and experimental or reference diets were randomly assigned. Dietary treatments consisted of: (1) negative reference, (2) positive reference (fish meal based), (3) soybean meal substituted-untreated diet, (4) soybean meal substituted-pretreated with phytase, and (5) commercial diet. Experimental diets were formulated with a 35% crude protein, protein to energy ratio of 100, and vitamin and mineral premixes added to meet the requirements of the fish. A two-week acclimation period was given to the animals prior to the start of the study to allow them to adjust to their new surroundings and feeding regime. Diets are fed three times a day to three replicates of 16 fish per treatment for a period of at least six weeks. Feed rates will be calculated on a percent body weight basis, which was determined during the two-week acclimation period by feeding the fish to satiation. Fish will be weighed every two weeks and feed rates will be adjusted according to weight gain. Waste products will be collected until the termination of the experiment and effluent P and N concentrations will be estimated by using a modified mass balance equation:

$$P_{ho} = P_{fed} - [P_f + (P_{tm} - P_{ti})]$$

P_{ho} = P in effluent of hatchery origin
P_{fed} = P in feed
P_f = P in feces
P_{tm} = P in fish at end of growth period
P_{ti} = P in fish at beginning of the growth period

OBJECTIVE 2

Growth and stress response data from Shasta and Donaldson rainbow trout will be analyzed and summarized, and a final report detailing the two experiments will be prepared.

IMPACTS

OBJECTIVE 1

Grow-out diets that are free of fish meal have been developed and tested in Shasta strain rainbow trout at Purdue. Fish fed two formulations exhibited responses that were not significantly different from fish fed a control diet.

Research at OSU has provided strong evidence

that a diet with 15% cottonseed meal, 15% soybean meal, and 20% animal by-products can be used to produce grow-out diets for rainbow trout without compromising growth rate or health indicators (liver histology). Taking into account current prices for fish meal ($0.62/kg or $560/ton) and cottonseed meal ($0.15/kg or $140/ton), this replacement should make considerable difference in feed costs. It is recommended, however, that cottonseed meals should be used with caution for rainbow trout because of the phytoestrogens and gossypol content.

MSU research has shown that improved utilization of dietary phosphorus and nitrogen will reduce the impact of aquaculture on the water quality of streams receiving water discharge from fish farms. This research will demonstrate that phytase can be used to improve utilization of P and N and that IGF-1 can be used as a rapid indicator of nutritional status in rainbow trout.

OBJECTIVE 2

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

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

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

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1997-98	$80,403	$92,640				$92,640	$173,043
1998-99	$79,597	$89,145				$89,145	$168,742
TOTAL	$160,000	$181,785				$181,785	$341,785

NORTH CENTRAL REGIONAL AQUACULTURE CONFERENCE[8]

Project Termination Report for the Period
December 9, 1998 to August 31, 1999

NCRAC FUNDING LEVEL: $3,000 (December 9, 1998 to August 31, 1999)

PARTICIPANT:
Joseph E. Morris Iowa State University Iowa

REASON FOR TERMINATION
The objective for this project was completed.

PROJECT OBJECTIVE
To provide a forum for exchange of information and technology between private and public sector aquaculturists in the North Central Region (NCR).

PRINCIPAL ACCOMPLISHMENTS
Funds provided for this project were used to help defray travel costs of presenters for the fourth NCR Aquaculture Conference ("Aquaculture at the Crossroads: Linking the Past to the Future") that was held February 24-26, 1999 in Columbia, Missouri. This conference was held in conjunction with the North Central Regional Aquaculture Center (NCRAC) Annual Program Planning Meeting. Over 150 people participated in the conference. Each participant received a 106-page document that was edited by Morris, which contained abstracts, papers, and supporting articles for the presentations that were made during the conference. In addition to NCRAC, other sponsors and contributors included: the University of Missouri; Missouri Aquaculture Association; Missouri Department of Agriculture; Illinois Aquaculture Association; Southern Aquaculture Supply, Inc.; Arkat Feeds, Inc.; Country Fish Farms; Nelson and Sons, Inc.; Flowers Fish Farm; and Crystal Lake Fisheries.

IMPACTS
Persons from both the public and private sectors were provided with the most recent information and technologies pertaining to a variety of aquacultural topics in the NCR.

RECOMMENDED FOLLOW-UP ACTIVITIES
The NCR Aquaculture Conferences allow for the exchange of the latest information and technologies pertaining to aquaculture in the region between the private and public sectors. A conference of this type has proven to be an effective forum for this sort of exchange. They also provide a showcase for NCRAC, because many of the conference speakers present outcomes of their NCRAC-funded projects. In addition, experts outside of the region presented information in the conference that would otherwise have been unavailable to

[8]NCRAC has provided funding for two North Central Regional Aquaculture Conferences. The termination report for the first funded conference is contained in the 1989-1996 Compendium Report.

NCR aquaculturists. This sort of regional conference should continue to be a bi-annual event.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See Appendix A for a cumulative output for all NCRAC-funded North Central Regional Aquaculture Conference activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1998-99	$3,000				$11,425		$14,425
TOTAL	$3,000				$11,425		$14,425

WASTES/EFFLUENTS[9]

Project Component Termination Report for the Period
September 1, 1996 to August 31, 1999

NCRAC FUNDING LEVEL: $10,000 (September 1, 1996 to August 31, 1999)

PARTICIPANT:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Industry Advisory Council Liaison:		
Harry Westers	Aquaculture Bioengineering Corporation, Rives Junction	Michigan
Extension Liaison:		
LaDon Swann	Purdue University	Illinois/Indiana

REASON FOR TERMINATION

The objective for this work on Wastes/Effluents has been completed.

PROJECT OBJECTIVE

(1) Develop a report that:

(a) describes the potential benefits of aquacultural by-products (effluents and solids) in the context of Integrated Resource Management and Sustainable Development,

(b) characterizes the differences between the aquacultural discharges and other agricultural and industrial discharges, and

(c) identifies case studies of previous controversies highlighting real versus perceived impacts of aquaculture.

PRINCIPAL ACCOMPLISHMENTS

Selected references specifically on aquacultural wastes and on related agricultural, municipal, and industrial waste management and recovery techniques were compiled into a 96-page report. The report is divided into a number of sections each containing a list of references and summarizing comments. The sections cover a variety of topics and subject areas including: a general overview; different rearing systems (e.g., ponds, flow through, etc.); sources of aquaculture by-products and waste generation including the role of fish bioenergetics, feed formulation, microbial content, and antibiotics; potential utilization and recovery of solids and nutrients from aquaculture effluents by irrigation, wetlands, vegetative buffers, and hydroponics; waste solids and sludge utilization by land application and composting, including aquaculture examples in comparison to agricultural manure and sewage sludge utilization, along with coverage of water quality,

[9]NCRAC has funded two Wastes/Effluents Projects. The termination report for the first project is contained in the 1989-1996 Compendium Report. This project component termination report is for one of the two objectives of the second project, which is chaired by Fred P. Binkowski. It was originally a 2-year study that began September 1, 1996. A progress report for the other objective of the second project is contained elsewhere in this Annual Progress Report.

soil, health and toxicity issues associated with sludge usage; and a comparison of aquaculture waste production with alternative land use practices. Available regional cases were highlighted as examples of various effluent issues and practices.

IMPACTS

The report summarizes scattered information on aquacultural wastes and effluents which could be used by regional aquaculturists, researchers, and resource agency personnel to locate information on potential recovery and reuse of aquaculture effluents and waste solids when planning waste management strategies or policies.

RECOMMENDED FOLLOW-UP ACTIVITIES

Several topical extension fact sheets or technical bulletins concerned with aquaculture waste management could be developed from sections of this report.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

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

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1996-99	$10,000						$10,000
TOTAL	$10,000						$10,000

WASTES/EFFLUENTS[10]

Progress Report for the Period
September 1, 1996 to August 31, 1999

NCRAC FUNDING LEVEL: $90,000 (September 1, 1996 to June 30, 1999)

PARTICIPANTS:

Ira R. Adelman	University of Minnesota	Minnesota
Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Industry Advisory Council Liaison:		
Harry Westers	Aquaculture Bioengineering Corporation, Rives Junction	Michigan
Extension Liaison:		
LaDon Swann	Purdue University	Illinois/Indiana
Non-Funded Collaborators:		
Antony Grabowski	Milwaukee County House of Correction Fish Hatchery	Wisconsin
John Hyink	Glacial Hills, Inc./Alpine Farms, Sheboygan Falls	Wisconsin
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
John Wolf	Glacial Hills, Inc./Alpine Farms, Sheboygan Falls	Wisconsin

PROJECT OBJECTIVE

(1) Study and evaluate solid waste management by:

(a) describing the relevant physical characteristics of fecal material from fish fed commonly used commercial feeds,

(b) developing diets to maximize integrity of fecal pellets without loss of fish performance and compare the physical characteristics of these pellets to those in subobjective a, and

(c) developing operational and engineering solutions to minimize destruction of larger particles and to remove all particulates.

ANTICIPATED BENEFITS

Characterization of the possible differences in fecal waste properties of important regional alternative species will assist in the engineering

[10]NCRAC has funded two 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 elsewhere in this Annual Progress Report. This progress report is for other objective of the second project, which is chaired by Fred P. Binkowski. It was originally a 2-year study that began September 1, 1996.

design and operation of rearing systems for waste removal.

Faster and more complete separation of structurally intact fish fecal material from the culture water could greatly reduce biological activity associated with fecal breakdown. Removal of organic fecal components could reduce biological and chemical oxygen demands associated with their breakdown as well as reduce the need for water oxygenation/aeration. Controlling levels of fecal material could also deprive potentially pathogenic bacteria of favorable environments that could promote epizootics. Improving fecal structural integrity could also control leaching of nitrogenous waste that increases requirements on biofilters for nitrification activity.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1A

University of Wisconsin-Milwaukee (UW-Milwaukee)

Researchers investigated the physical properties of freshly deposited feces generated through intensive tank culture of yellow perch fed commercial feeds at various phases of the production cycle at commercial rearing densities and grow-out temperature (18–23°C; 64.4–73.4°F). The phases examined to date include: (1) perch approaching market size (approximately 100–150 mm [3.9–5.9 in] total length) and fed Zeigler Bros. trout grower, (2) mature perch at marketable sizes (>150 mm; >5.9 in) fed Zeigler Bros. trout grower, (3) advanced fingerlings (50–100 mm; 2.0–3.9 in) fed Zeigler Bros. salmon starter, and (4) young fingerlings (25–75 mm; 1.0–3.0 in) habituated to feed exclusively on Biodiet #2 starter feed.

Initial attempts at individually isolating or anesthetizing fish to collect freshly egested fecal material were found to be unreliable in obtaining enough material to conduct investigations of specific gravity and fecal friability. Therefore, a low-head, side-stream siphoning device was constructed and installed on circular rearing tanks so that freshly settled fecal materials and uneaten food could be collected from the sump of the rearing tanks. The collecting basin (a 18.9-L [5.0-gal] pail) for the siphoned material was raised so that the water surface in the collection basin was just below that of the rearing tank. For 2.44-m (8.0-ft) diameter tanks, a smooth semi-flexible clear vinyl tube (approximately 28-mm [1.1-in] diameter) and a side-stream flow of around 4–7 L/min (1.1–1.8 gal/min) was used to siphon waste. In this way the water velocity within the siphon was low enough (adjustable in the range of <1–15 cm/sec; <0.4–5.9 in/sec) to collect the fecal material with minimal handling and disturbance. The clear tube allowed visual monitoring of the condition of the waste during collection. To insure freshly deposited material, the rearing tank was cleaned at the start of each collection period. By arranging for the inflow to the tank to rotate the water, solid material would rapidly settle and collect in the sump at the base of the central standpipe of the circular rearing tanks. By attaching the siphon tube to collars mounted on the outer diameter of the standpipe and holding the collecting end at a narrow fixed height above the bottom in the central collecting sump, settled solids could be continuously removed from the rearing tank. For perch larger than approximately 100 mm (3.9 in) in size this collection device could be left unattended even over night without fish entering the waste collection stream. Small fingerlings tended to enter the waste collector even though the opening was positioned very close to the tank bottom and feces from these fish were collected by hand-directing the low-head siphon hose.

In a tank of adult perch at a rearing density of 84 kg/m^3 (5.2 lb/ft^3) fed a ration of 2.4% (approximately 2 kg; 4.4 lb) this low-head siphon device would collect 4–5 kg (8.8–11.0 lb) of sludge that was 8–10% solid on a dry weight basis (320–500 g; 0.7–1.1 lb). This represents a recovery of 17–26% of the food solids entering the tank on a dry weight basis. The literature reports that for salmonids, 25–30% of the dried weight of food is converted to feces on a dry weight basis. Therefore, between 69 to nearly 100% of the excreted solids produced in the rearing tank were removed by this simple device that concentrates the recovered waste in a side-stream of 4–5% of the tank's water inflow. In effect, with only a few pieces of inexpensive hardware, the rearing tank itself acts like a "swirl concentrator." With improvement this device could be incorporated as an inexpensive initial clarifier component, prior to further fine solids removal, in recirculating aquaculture systems (RAS). Fecal waste and uneaten food particles are removed directly from the rearing tank relatively intact before they are further broken up by more turbulent components of RAS.

Overall, freshly deposited feces (*N* = 887) ranged from 0.4–6.2 mm (0.02–0.24 in) in diameter and 0.6–23 mm (0.02–0.91 in) in length. Median fecal pellet diameters were 0.7 mm (0.03 in) (*N* = 344), 1.6 mm (0.06 in) (*N* = 240), 2.6 mm (0.10 in) (*N* = 182), and 3.2 mm (0.13 in) (*N* = 121) for perch in the size categories of 25–75 mm (1.0–3.0 in), 50–100 mm (2.0–3.9 in), 100–150 mm (3.9–5.9 in), and >150 mm (>5.9 in) total length, respectively. The corresponding median lengths of intact fecal particles for these size categories were 4.8 mm (0.19 in), 4.0 mm (0.16), 6.7 mm (0.26 in), and 5.4 mm (0.21 in), respectively. Fingerling perch on the Biodiet feeds tended to have longer feces in relation to their diameter and the feces tended to lack the multifolded rough character of the pellets of larger sized perch fed the Zeigler feeds.

Settling velocities of individual fecal and food particles were determined in a 180 cm (70.9 in) high settling column (10-cm [3.9-in] diameter). As anticipated by Stoke's law, settling velocities increased with increasing particle size and density. Settling velocities for feces increased gradually over a range of 0.4–5.0 cm/sec (0.16–1.97 in/sec) (*N* = 204) with increasing fish size. The settling velocities of the intact food granules and pellets were higher (5.0–16.0 cm/sec; 1.97–6.30 in/sec) than settling velocities of feces of similar diameter, except for the smaller granules of Biodiet #2 starter and feces of the fingerling perch with diameters <1 mm (<0.004 in) and settling velocities from 0.7–3.2 cm/sec (0.28–1.26 in/sec) and 0.4–1.8 cm/sec (0.16–0.71 in/sec), respectively. This difference mainly reflects the higher density of the pelletized food compared to the less dense fecal material after passage through the digestive tract.

Specific gravity measurements of freshly collected fecal solids were made before and after uniformly compressing the water from approximately 50 mL (1.7 oz) of collected sludge by centrifugation for 5 min at 2,500 rpm, pouring off the water, determining the resulting volume and weight of solid material and comparing it to the weight of an equal volume of deionized water and correcting for temperature. The overall mean specific gravity by this method was 1.055 (SD = 0.019; *N* = 36) after centrifugation and 1.029 (SD = 0.013; *N* = 24) without centrifugation. Differences in specific gravity of feces based on the type of food used were not detectable. It

appeared that these mass techniques might create uniform conditions due to consistent packing of the material, while individual fecal particles can vary considerably in compactness and durability. Perhaps measuring settling velocities directly will be more expedient than using a representative value for specific gravity, that may be influenced by collecting and compaction techniques, to infer settling rates using Stoke's law. It may be better to measure the settling velocity and calculate specific gravity using Stoke's law and to use these values to make further estimates of settling velocities.

Initial attempts to examine the friability of feces of larger perch fed Zeigler grower diets using direct observation of small numbers of fecal particles in water in Erlenmeyer flasks were unsuccessful due to the heterogeneous nature of the fecal particles. Some of the larger fecal pellets appeared to consist of fine solid material approximately the size of the finely milled material in the formulated diet, encased in an outer more durable mucus-like shell that either was a solid smooth-surfaced stream of material or became folded on itself and compressed into a larger diameter rough surface pellet. In some fecal pellets the proportion and durability of the outer casing appeared to vary in thickness and a relatively small proportion of fine material was inside this casing. These fecal pellets were extremely compressed and durable and tended to have a grayish to white color compared to the less durable brownish type encasing large amounts of finely milled material. Some fecal pellets tapered along their length from wide easily friable character to the more durable grayish cast. This complicated the visual determination of when the pellet was completely broken down. For this reason it seemed better to use a larger (45–70 mL; 1.5–2.4 oz), more representative sample of fecal material to quantify fecal friability. Samples of intact settled fecal material collected by low-head siphoning and an approximate settled volume of 45–70 mL (1.5–2.4 oz) of material was scooped into a 150 mL (5.1 oz) graduated beaker, the contents of this beaker were poured into a 250 mL (8.5 oz) Erlenmeyer flask capped with parafilm and subjected to mechanical agitation of 0, 5, 15, 30, 60, 120, and 240 sec duration at 300 rpm on an orbital rotary shaker. The contents of the flasks were then poured into Imhoff cones and the settleable solids determined along with the volume of intact particles by visually determining the boundary between the fine broken settled solids (less than the diameter of intact fecal material) and the more rapidly settled mainly intact fecal material. The difference in settled volume of the intact feces versus the fines as a percent of the settled solids in the cone was used to express the degree of breakdown. Four or five repeated samples at each time duration were used to express the breakdown of fecal material over time.

Using this technique it was found that the feces of the larger perch fed Zeigler grower and salmon starter diets rapidly decreases from 60–80% intact material to around only 20% of the durable type of intact fecal material after only 5–60 sec of agitation at 300 rpm, while fecal material of fingerling perch fed Biodiet #2 starter also started out 70–80% intact and tended to remain around >60% intact even after 240 sec at 300 rpm. The fineness of the milling of the various components appeared to influence the durability of the fresh fecal material. The coarser "fines" in the grower diet fed to the larger sized perch appeared to give the fecal material a more friable consistency.

The smaller diameter and proportionately

greater length of the intact fecal particle of fingerling perch fed semi-moist starter diet contributes to a slower rate of settling. This proportionately greater length suggests a greater resistance to mechanical agitation and further breakdown.

Southern Illinois University-Carbondale (SIUC)

Comparisons of fecal characteristics using commercial feeds are awaiting completion of Objective 1b so that experimental diets can be included in the trials.

OBJECTIVE 1B

UW-Milwaukee

In order to examine the influence of variations in composition of commercial diets, the effect of a "high-energy" versus a "grower" type commercial diet formulation on the physical properties of yellow perch wastes was compared.

Wastes from a 2.44-m (8.0-ft) diameter tank with approximately 3,000 perch that were 227 to 286 days post hatch were collected with the low-head siphon device used for Objective 1a. This group of fish was fed a typical "grower" diet (38.2 % protein and 8.2% lipid) for an approximate two-week period during which the size distribution and physical characteristics of freshly collected "intact" perch feces were evaluated with the same techniques used for Objective 1a. During a subsequent two-week period, a "high-energy" diet (42% protein and 15% lipid) was fed to this same group of fish and the fecal characteristics evaluated.

The size distributions of fecal diameters and lengths of feces from fish fed either the “high-energy” diet or the grower diet overlapped considerably. The settling velocities of individual feces produced by fish fed the “high-energy” diet were slightly but consistently lower than those produced by fish fed the "grower" diet. No difference was demonstrated in the specific gravity of the gathered and centrifuged fecal sludge samples, using the techniques employed in this investigation.

During agitation at 300 rpm feces produced from fish fed the "high-energy" diet generated a higher proportion of total suspended solids than did feces from the "grower" diet. Also, at least during the first 10 min of agitation, the "high-energy diet" feces appeared to remain slightly less intact as a percentage of the settleable material in the Imhoff cones.

These differences in fecal characteristics suggest that feces produced by fish fed the "high-energy" diet are more likely to be resuspended by turbulence in the fish rearing tanks and break up to small-sized suspended particles slightly more readily than those produced from the "grower" diet.

Engineering strategies aimed at removal or recovery of biosolids from aquaculture rearing facilities must aim to separate solids before they are further broken up. Given the fragility of these particles, it seems that using the fish rearing tank itself as a settling unit is the most rapid means of accomplishing this with minimal mechanical disturbance.

The settling velocities of fecal material are important for rapid collection and removal. Interestingly, by using highly digestible nutrient dense formulations to reduce waste output by the fish, fecal properties might also be altered in ways that make them more readily broken down and consequently more difficult to settle and remove. Strategies to reduce the output of waste by increasing the digestibility and incorporation of dietary nutrients into fish flesh

may have trade-offs in the characteristics of the fecal material produced. A combined strategy considering feed formulation and resulting fecal properties that influence engineered removal of biosolids may result in more effective waste removal.

SIUC

The growth trial with Nile tilapia indicates dietary fiber level manipulation in the range of 0 to 18%, using semi-purified formulations, does not affect growth rates, regardless of fiber type.

Tilapia, yellow perch, and largemouth bass have been fed fiber-manipulated diets (cellulose or beet pulp) for fecal collection. Yellow perch and hybrid striped bass had a poor acceptance rate for the prescribed formulations (<0.5% body weight/day, <2% body weight/day). A modified semi-purified basal diet with more menhaden fishmeal and without casein was adopted for the more carnivorous species and gave satisfactory results. Trials with the modified diets have been completed for yellow perch and largemouth bass. Hybrid striped bass were tested but intake rates of the prescribed diets were inadequate to promote formation of representative feces and rates needed to run integrity tests.

Fish species, fiber source and fiber level can affect feces in the ability to endure mechanical stress. Nile tilapia feces did not respond favorably to the highest fiber levels (18%), particularly beet pulp. The mucous strands were prone to break and spill their contents when distended with large amounts of fiber. Yellow perch and largemouth bass produce fecal masses that are considerably different from those of tilapia. The yellow perch and largemouth bass produce feces which are generally made of smaller round pellets that are excreted either singly or attached as pellet masses. Individual pellets are very resistant to mechanical stress but the break up of bunches often results in many individual pellets breaking into smaller particles. Largemouth bass fecal integrity appears to be enhanced by the addition of beat pulp (8 and 18%) and decreased by 18% cellulose or no added fiber. Yellow perch fecal integrity appears to be enhanced by modest amounts of beet pulp (8%). Hybrid striped bass trials to date present a picture with a highly variable fecal structure that is difficult to manipulate due to its fragility.

A problem that has been identified deals with quantitative collection of feces. Much of the feces, particularly that promoted by feeds without fiber, disintegrates immediately upon exiting the anus. The resulting feces retained by the collector is often considerably more durable than the feces excreted as a whole.

OBJECTIVES 1A AND 1C

University of Minnesota (UM)

A break in the production cycle at the UM facility occurred while adult tilapia, which became infected with *Aeromonas hydrophila,* were treated, held for a withdrawal period, and marketed. The stress from this disease limited the ability of the fish to tolerate decreased water quality and thus the degree to which the tanks could be loaded. During this time the fish were fed a maintenance ration. This lessened the nutrient input and resulted in better water quality and a lower suspended solids load than would normally be experienced in a production system. The disease problems necessitated a complete shutdown of the production system tanks. The shutdown afforded an opportunity to rework system configurations and make repairs and improvements. In preliminary work with the tilapia production systems before the disease outbreak, total suspended solids levels in the three system types ranged from

approximately 10–45 ppm. These values correspond well to average values reported in the literature.

WORK PLANNED

OBJECTIVES 1A-C

SIUC

A growth trial using hybrid striped bass is underway using a modified basal diet and should be completed by the end of January 2000. Rainbow trout and hybrid striped bass will be tested using the more palatable basal diet. If possible, the use of a more finely ground beet pulp will be tested on Nile tilapia. The comparison of commercial feeds and resulting fecal characteristics will be conducted following completion of all experimental trials using beet pulp.

UM

UM participants will continue to complete Objectives 1a and 1b.

IMPACTS

- Provide a broad base of information with regard to alternative species for rearing system design.
- System design of settling basins and clarifiers will be improved through the use of data gathered during this project.
- Fiber sources of alpha-cellulose and sugar beet pulp, when supplied at levels of 0, 8, or 18% , do not appear to affect growth of Nile tilapia and may thus enable variations in dietary fiber levels to promote waste management without negatively impacting production.
- The use of modest amounts of beet pulp in some carnivorous fish diets may be useful in enhancing fecal integrity, thus promoting solid waste removal from culture waters and waste effluents.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

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

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1996-99	$90,000	$79,968				$79,968	$169,968
TOTAL	$90,000	$79,968				$79,968	$169,968

NATIONAL AQUACULTURE INAD/NADA COORDINATOR[11]

Progress Report for the Period
September 1, 1992 to August 31, 1999

NCRAC FUNDING LEVEL: $55,241 (September 1, 1993 to May 14, 2000)

PARTICIPANTS:

Robert K. Ringer	Michigan State University	Michigan
Rosalie A. Schnick	Michigan State University	Wisconsin

PROJECT OBJECTIVES

(1) Ensure effective communications among groups involved with Investigational New Animal Drug/New Animal Drug Applications (INADs/NADAs), including Canada.

(2) Serve as an information conduit between INAD/NADA applicants and the Food and Drug Administration's Center for Veterinary Medicine (CVM).

(3) Identify and encourage prospective INAD participants to become involved in specific investigational studies and NADA approval-related research.

(4) Seek the support and participation of pharmaceutical sponsors for INAD studies and NADAs and coordinate with INAD/NADA sponsors to achieve CVM approval more quickly.

(5) Guide prospective and current INAD holders on the format for INAD exemption requests and related submissions to CVM.

(6) Identify existing data and remaining data requirements for NADA approvals.

(7) Review, record, and provide information on the status of INADs and NADAs.

(8) Encourage and seek opportunities for consolidating the INAD/NADA applications.

(9) Coordinate educational efforts on aquaculture drugs as appropriate.

(10) Identify potential funding sources for INAD/NADA activities.

ANTICIPATED BENEFITS

Investigation and approval of safe therapeutic and production drugs for use by the aquaculture industry are some of the highest priorities currently facing the industry. At present, only a few approved compounds are available to the industry and further development of the aquaculture industry is severely constrained by a lack of approved drugs essential for treating more than 50 known aquaculture diseases. CVM has afforded the aquaculture industry throughout the U.S. with a "window of

[11]Ted R. Batterson serves as the facilitator for this multi-year project interacting with a steering committee in overseeing the Coordinator's activities.

opportunity" to seek approval of legal drugs to be used in their production practices. The need for additional drugs is great, but securing data necessary to satisfy the requirements of CVM for drug approval is time consuming, costly, and procedures are rigorous. The INAD/NADA process is the one method that allows the industry to provide CVM with data on efficacy and also aids producers in their production practices.

Coordination and educational efforts directed toward potential INAD/NADA applicants will save time and effort for both the industry and CVM. The National Coordinator for Aquaculture New Animal Drug Applications (National NADA Coordinator) serves as a conduit between an INAD/NADA applicant and CVM. The National NADA Coordinator helps to alleviate time demands on CVM staff, thus allowing more time to process a greater number of applications as well as increasing the breadth of research endeavors within the industry. The grouping of INAD applicants should help to alleviate redundancy, amalgamate efforts, and increase the amount of efficacy data, all of which should result in greater progress toward developing available, approved therapeutic and production drugs.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

In September 1992, Ringer, Professor Emeritus of Michigan State University, was hired on a part-time basis as National Coordinator for Aquaculture INAD Applications. He served in that capacity through August 31, 1994.

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

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

On May 15, 1995, Schnick, recently retired Registration Officer from the National Biological Service's Upper Midwest Environmental Sciences Center (UMESC), was hired on a three-quarter time basis as National Coordinator for Aquaculture New Animal Drug Applications (National NADA Coordinator). On May 15, 1996, her position was increased to a full-time basis and the position has remained full time in Year 5 (May 15, 1999 to May 14, 2000).

NEW INAD/NADA SPONSORS

Schnick helped gain a new INAD/NADA sponsor for amoxicillin (INAD #9659) and met with Vetrepharm Limited (United Kingdom) in May 1996 in Fordingham, United Kingdom, to discuss an action plan for the development of the INAD/NADA on their broad spectrum antibacterial product. Schnick also helped obtain and is working with INAD/NADA

sponsors for hydrogen peroxide (external microbicide, INAD #9671), luteinizing-hormone releasing hormone (spawning aid, INAD #9709), common carp pituitary (spawning aid, INAD #9728), Aqui-S™ (anesthetic, INAD #9731), GB Research Inc., another sponsor for amoxicillin (oral antibacterial, INAD #9853), EarthTec™ (external microbicide, INAD #9996), copper sulfate (external microbicide, INAD #10-046), Ovaprim™ (spawning aid, INAD #10-040), fumagillin (myxozoan control, INAD #10-106), gonadotropin releasing hormone analog (spawning aid, INAD #10-087), azamethiphos (sea lice control, INAD #10-137), potassium permanganate (external microbicide, INAD #10-223), 17α-methyltestosterone (gender manipulation agent, INAD #10-296), and Pyceze™ (external microbicide, INAD #10-366). Another sponsor for MS-222 gained an approved NADA. Three sponsors renewed their commitment to their INAD/NADA process for formalin, chloramine-T, and oxytetracycline.

A major breakthrough has occurred in developing a new, oral antibacterial for aquaculture; Schering-Plough Animal Health has agreed to allow the development of florfenicol as a broad spectrum antibacterial for public and private aquaculture and as the model oral drug for crop grouping research. The stakeholders in the federal-state aquaculture drug approval partnership program (International Association of Fisheries and Wildlife Agencies [IAFWA] Project) voted overwhelmingly on a December 31, 1997 ballot to replace sarafloxacin with florfenicol as the oral antibacterial and model drug for the crop grouping research.

PROGRESS ON THERAPEUTIC DRUGS

Amoxicillin

The National NADA Coordinator met on October 19, 1998 with CVM and GB Research Inc. (a sponsor of amoxicillin) for a pre-submission conference regarding the development of data that will lead to an approved NADA for amoxicillin trihydrate. GB Research Inc. presented a plan for funding the necessary research and CVM provided insight on the technical sections needed for completion of a NADA submission.

The U.S. representative for GB Research Inc. sent out the funding plan for gaining approval of amoxicillin to INAD holders through individual mailings, the USDA mailgroup, and the National NADA Coordinator in January 1999.

The National NADA Coordinator requested and was able to establish a Public Master File on amoxicillin at CVM on January 14, 1999.

Chloramine-T

Schnick and representatives of the UMESC, La Crosse, Wisconsin held a special session at the Midcontinent Warmwater Fish Culture Workshop in February 1996 to consider label claims and identify potential pivotal study sites for chloramine-T under the IAFWA Project. A meeting was held with CVM on October 30, 1996 to gain clarification on the design of the protocols for conducting pivotal efficacy studies on aquaculture drugs (especially chloramine-T) that are used in water treatments. That meeting was followed by a meeting on November 7-8, 1996 with INAD holders of chloramine-T to coordinate efforts on draft label claims, design protocols for pivotal clinical field trials, and identify pivotal study sites for chloramine-T. Several large, active compassionate INADs are held by public aquaculture agencies and organizations. Several of these INAD holders (e.g., U.S. Fish and Wildlife Service [USFWS]) are conducting pivotal efficacy studies for several potential label claims of chloramine-T. Akzo Nobel Chemicals, Inc. (Dobbs Ferry, New York) submitted a letter to their existing INAD (INAD #8086) file on July

21, 1997 committing to the development of a NADA on chloramine-T for aquaculture use.

In 1998, Akzo Nobel Chemicals, Inc. indicated that the company would fund genotoxicity studies required by CVM and assessed mammalian and environmental safety requirements delineated by CVM at a meeting on November 3, 1997.

At a January 25, 1999 meeting, CVM requested two genotoxicity studies to fulfill the mammalian safety data requirements for chloramine-T instead of the more expensive studies originally requested on November 1997. These studies will allow CVM to establish a tolerance for all life stages of all fish at both public and private aquaculture facilities.

A regulatory analytical method for para-toluenesulfonamide in fish tissue to support residue depletion studies was submitted on May 15, 1998 to CVM for review. Efficacy and residue chemistry technical sections were submitted on July 30, 1998 by the IAFWA Project for review by CVM.

Akzo Nobel Chemicals, Inc. informed the National NADA Coordinator on March 24, 1999 that the company will not fund any additional studies to support the approval for chloramine-T, including the additional genotoxicity work that is required to establish a tolerance for chloramine-T in fish tissues. The company will continue to act as a sponsor for their product in the U.S. and to provide any existing materials such as protocols, environmental safety data, and product chemistry information. Because of this change, UMESC will return to Akzo the funds they contributed to UMESC so Akzo can spend the funds on the required genotoxicity studies. Formerly, UMESC was recommending that these funds be used to support target animal safety studies in salmonids. Instead, the work on salmonids will be completed by Bozeman Fish Technology Center and UMESC will conduct target animal safety studies on representative cool- and warmwater species with public funds.

The National NADA Coordinator developed a fact sheet on March 29, 1999 entitled "What is needed to gain an approval of chloramine-T for salmonids?" in an attempt to answer questions concerning the drug's status.

The National NADA Coordinator met with representatives of Akzo Nobel Functional Chemicals on June 8, 1999 in La Crosse, Wisconsin to discuss the remaining data requirements for chloramine-T, develop a timetable to complete these requirements, and determine the market potential for all its uses.

Copper Sulfate

Based on residue and environmental data, CVM determined on July 11, 1996 that there are no human food or environmental safety concerns over the use of copper sulfate as a therapeutant, thus making approval relatively easy. Two meetings were held in July and August 1996 with a potential NADA sponsor and CVM to discuss the data requirements for approval and develop an action plan needed to obtain approval of copper sulfate as a therapeutant. Phelps Dodge Refining Corporation (El Paso, Texas) submitted an application for an INAD/NADA (INAD #10-046) on April 3, 1997, a request for two labels on the same package on October 24, 1997, and the product chemistry data on March 12, 1998. The product chemistry technical section was reviewed by CVM on April 15, 1998 and the sponsor responded to the items on July 31, 1998. The sponsor of copper sulfate obtained acceptance of the product chemistry technical section from CVM on May 4, 1999.

Efficacy and target animal safety data and the environmental assessment have been submitted to CVM by the Stuttgart National Aquaculture Research Center (SNARC). All the data needed for an approval of copper sulfate have been submitted as of early 1998 and all the technical section packages are under review by CVM.

The revised Ecological Risk Assessment (ERA) for the use of copper sulfate to control certain waterborne fish diseases was submitted by SNARC to CVM on June 29, 1999. SNARC plans to submit the revised target animal safety studies to CVM by October 31, 1999.

Florfenicol

The National NADA Coordinator presented a seminar on aquaculture and its drug needs to representatives of Schering-Plough Animal Health on August 26, 1997. She encouraged them to consider developing their oral antibacterial, florfenicol, for the U.S. market.

A meeting on August 26, 1998 between CVM and Schering-Plough Animal Health covered the development of florfenicol for aquaculture in light of CVM's new policy on antimicrobial resistance issues. This issue affects all antimicrobial drugs used on animals including any developed for aquaculture uses.

The National NADA Coordinator developed draft letters of request for INADs on florfenicol for UMESC and USFWS on February 26, 1999 and March 19, 1999, respectively.

A coordination meeting was held in La Crosse, Wisconsin on March 17-18, 1999 to discuss plans for implementation of a general USFWS INAD exemption for florfenicol.

USFWS has developed a draft protocol that the sponsor reviewed for a new, limited INAD to be initiated in early 2000. USFWS developed a list of facilities that have a proven track record of doing good efficacy studies that was given to Schering-Plough Animal Health for their review and acceptance. The sponsor expects to tightly oversee the development of florfenicol for aquaculture use in the United States.

A meeting was held on July 20-21, 1999 with Schering-Plough Animal Health, USFWS, UMESC, and the National NADA Coordinator to discuss the details of initiating the efficacy studies through a USFWS-INAD and in conducting the residue chemistry studies.

Schering-Plough Animal Health submitted a data package containing product chemistry, residue chemistry, target animal safety, and efficacy for florfenicol to control furunculosis in salmonids on September 30, 1999.

Formalin

A supplemental NADA for formalin by Western Chemical, Inc. was approved on June 18, 1998 for control of certain fungi on the eggs of all finfish and certain external protozoa and monogenetic trematodes on all finfish. An additional data package was submitted to CVM on April 22, 1998 to expand the NADA for its use to prevent mortalities associated with external fungal infections on all cultured freshwater fish.

At the Work Planning/Coordination Meeting of the IAFWA Project held November 19-20, 1998 in La Crosse, Wisconsin, CVM reviewers indicated that a broad label of all fish to treat external fungal infections was not possible because of the lack of information for cool- and warmwater fish. Drug Approval Oversight Subcommittee (DAOS) members attending the meeting voted to have UMESC proceed immediately to perform pivotal efficacy studies on cool- and warmwater fish to support an amended NADA and to delay

pivotal efficacy studies on potassium permanganate and Aqui-S™.

Fumagillin

The National NADA Coordinator met with the potential sponsor of fumagillin, Sanofi Santé Nutrition Animale (Libourne Cedex, France) on April 19, 1996 in Paris, France to discuss cooperative efforts and the potential for development of a NADA in the United States. Sanofi committed to an INAD/NADA on fumagillin in June 1997. The NADA Coordinator is determining the potential of fumagillin to control or prevent hamburger gill disease in catfish and whirling and proliferative kidney diseases in salmonids. Meetings were held with the sponsor on September 16, 1997 in Edinburgh, Scotland and on February 14, 1998 in Las Vegas, Nevada to discuss the strategy and action plan for the development of a NADA on fumagillin. Meetings were also held with several potential researchers on November 12, 1997 in Stoneville, Mississippi and on December 11, 1997 in Bozeman, Montana to discuss a research action plan for generating efficacy data on fumagillin to control hamburger gill disease and whirling disease, respectively. Efficacy research is ongoing for both diseases.

Hydrogen Peroxide

A meeting was held April 12, 1997 with CVM to discuss the data requirements for hydrogen peroxide as an external microbicide and how to obtain the data so that an approval can be achieved for all the uses for which the drug seems to be efficacious. Efficacy (control or prevention of saprolegniasis on fish eggs) and target animal safety technical sections were submitted to CVM by the IAFWA Project on April 21 and 27, 1998. Data on the efficacy of hydrogen peroxide to control or prevent mortalities associated with saprolegniasis on fish was submitted by the IAFWA Project to CVM on September 18, 1998. A meeting was held with CVM on June 18, 1998 at CVM headquarters to discuss the remaining data requirements for hydrogen peroxide. Discussions centered on the mechanisms for transferring the Canadian dossier to CVM and for setting up a Public Master File of data from UMESC. Enough data may exist for an early approval in the United States. CVM determined that the human food safety data requirements are met.

In 1999 UMESC was in the process of completing experiments in collaboration with state hatcheries to determine the efficacy of hydrogen peroxide to control external parasitic infestations and to control mortalities associated with external flavobacterial infections on representative cultured freshwater fish.

The sponsor has completed the negotiations with Syndel International Inc. to do the marketing of hydrogen peroxide (Perox-Aid™) for fisheries use in Canada.

The sponsor, Eka Chemicals Inc., submitted the product chemistry technical section for hydrogen peroxide on July 12, 1999.
A series of meetings were held in July and August 1999 at UMESC to discuss the development of the remaining data requirements to complete the submission of all the technical sections needed for approval.

Oxytetracycline

A meeting was held on April 11, 1997 with CVM to discuss remaining data requirements to obtain full approval for oxytetracycline (OTC). CVM indicated that additional data would be required to expand the NADA for OTC as an oral antibacterial at temperatures below 9°C (48.2°F) and at doses above the current label and that at least one pivotal efficacy study would be required for these uses to be added to the label.

A call-in of efficacy data was initiated on October 7, 1997 for any and all efficacy data on OTC that can support the extension and expansion of the NADA. Data were received November 18, 1997, organized in December 1997, and evaluated in May 1998. An efficacy technical section was submitted to CVM on January 25, 1999 to support extension of the label claim to include control of *Aeromonas* sp. in esocids and potentially other coolwater fish.

An OTC residue depletion study was recently completed at low temperatures at the Quilcene National Fish Hatchery. The data should allow treatment of yearling salmonids below 9°C (48.2°F). The report was submitted to CVM on January 29, 1999.

A method to analyze for the drug in fish feeds in support of INAD pivotal efficacy testing was accepted by CVM on July 29, 1998.

On March 16, 1999, the National NADA Coordinator sent a letter to Pfizer to request that the company amend its label when CVM has accepted: (1) the residue depletion data for treatments below 9°C (48.2°F) and the efficacy data for the use of OTC to control coldwater disease in salmonids and (2) the efficacy and residue chemistry data for the control of *Aeromonas* sp. in coolwater species. In addition, Pfizer was requested to ask for a reduction of the withdrawal time in all fish from CVM.

Sarafloxacin

Abbott Laboratories (North Chicago, Illinois) was in the process of preparing the last portion of a technical section to complete the data requirements for NADA approval of sarafloxacin when concern for development of disease resistant pathogens in humans with the use of fluoroquinolones in animals was raised as an issue by the Centers for Disease Control and Prevention (CDC). The Catfish Farmers of America (CFA) sent a letter written by the National NADA Coordinator to the U.S. Food and Drug Administration (FDA) commenting on the impending ruling regarding the prohibition of extra-label use of fluoroquinolones. The CFA was concerned that this regulation: (1) establishes that these drugs, when used in the catfish industry, "are capable of increasing the level of drug resistant zoonotic pathogens (pathogens that are infective to humans) in treated animals at the time of slaughter" and (2) will negatively impact or stop the approval of fluoroquinolone, sarafloxacin, and other fluoroquinolones for the catfish industry. The catfish industry and researchers have agreed to consider developing a risk assessment on the use of sarafloxacin in catfish to control enteric septicemia to alleviate concerns of disease resistant pathogens developing in humans from the use of this fluoroquinolone. It is now doubtful that a new NADA will be allowed for aquaculture uses by CVM. Sarafloxacin was replaced by florfenicol in January 1998 by a unanimous vote of the IAFWA Project stakeholders.

Potassium Permanganate

A meeting was held with CVM and the new sponsor of potassium permanganate, Carus Chemical Corporation, on January 28, 1998 at CVM headquarters to discuss the requirements to complete a NADA application and the progress that has been made on the various technical sections.

The sponsor of potassium permanganate submitted to CVM the product chemistry technical section on December 8, 1998 and environmental safety technical section on February 23, 1998. CVM has requested more information on the Environmental Assessor (EA).

A residue chemistry technical section for channel catfish was submitted by SNARC to

CVM for review on June 16, 1998. CVM has indicated that, if residue levels and depletion rates are similar to copper sulfate, the human food safety requirements could be met without additional requirements for mammalian safety studies. A report of an additional residue chemistry study in rainbow trout is in preparation by a private company and will be submitted to CVM.

Pyceze™

The National NADA Coordinator met with the potential sponsor of Pyceze™, Grampian Pharmaceutical Ltd., in Edinburgh, Scotland on September 16, 1997 to discuss its plans for development of Pyceze™ in the United States. Meetings were held with Grampian Pharmaceutical Ltd. in Seattle, Washington and Stoneville, Mississippi in mid-April 1998 to determine the potential for use of Pyceze™ in the salmonid and catfish industries in the United States.

A meeting was held with CVM, Grampian Pharmaceutical Ltd., and the National NADA Coordinator on April 24, 1998 at CVM headquarters to discuss the requirements to complete a NADA application for Pyceze™ and the preliminary evaluation of the existing data.

Grampian Pharmaceutical Ltd. sent a letter of intent to commit to development of Pyceze™ as an external microbicide on freshwater fish along with summary information for approval as a fungicide on fish eggs to CVM on September 3, 1998.

Trichlorfon

The National NADA Coordinator worked with the National Aquaculture Association, private producers, state extension personnel, and Bayer Business Group Crop Protection to develop a plan to gain legal use of trichlorfon in non-food fish culture. Because this Bayer group did not think that it was economically feasible to develop trichlorfon as a drug, the registrant worked with the aquaculture industry on "Special Local Need" (SLN) registrations for use of trichlorfon to control predaceous insects, zooplankton, and adult lernea. Several states have either obtained or submitted requests for SLNs.

Crop Grouping

Ohio State University is completing work on the model waterborne drug, benzocaine. Classical compartmental pharmacokinetic models are being developed in five phylogenetically diverse species. Physiologically based pharmacokinetic (PBPK) models have been developed in channel catfish and rainbow trout. UMESC is using these PBPK models to support their work on florfenicol. Work on florfenicol will continue until the end of the IAFWA Project. When completed, CVM will have a comprehensive data set from which to make a decision on crop grouping.

Florfenicol replaced sarafloxacin as the model oral drug based on a 1998 IAFWA Project stakeholder survey. Models are developed for diverse species using benzocaine and those will be used to support work on florfenicol. Crop grouping should be completed in 2002. Acceptance of the crop grouping concept by CVM will reduce residue chemistry data requirements and costs of approvals for all aquaculture drugs.

PROGRESS ON ANESTHETICS

Aqui-S™

Two meetings in June and August 1996 were held with representatives of Aqui-S™, an anesthetic approved for use on fish in New Zealand, to discuss the potential for development of their product in the United States. Aqui-S™ is approved in New Zealand with a zero withdrawal time and offers a

potential alternative to benzocaine. UMESC decided to evaluate the comparative efficacy and regulatory requirements needed for approval on both benzocaine and Aqui-S™.

UMESC completed an efficacy and safety evaluation of Aqui-S™ in two size ranges of six representative freshwater fish species. The report was sent by the National NADA Coordinator on July 18, 1997 to all IAFWA Project stakeholders/cooperators for their decision on which anesthetic, benzocaine or Aqui-S™, should be the IAFWA Project drug. Twenty-four votes were cast for Aqui-S™ and no votes for benzocaine. Detailed assessments will be made of what data requirements will be addressed by the sponsor and what data requirements will be addressed by the IAFWA Project.

The sponsor of Aqui-S™ submitted an environmental assessment to CVM on November 13, 1998. The sponsor of Aqui-S™ completed a Cooperative Research and Development Agreement with the U.S. Geological Survey on July 7, 1999 to provide funding for a residue chemistry study.

The National NADA Coordinator met with representatives of the company that developed Aqui-S™ in Sydney, Australia during World Aquaculture '99 and in Nelson, New Zealand on May 11, 1999 to discuss the strategies for the development of the drug for the U.S. market and worldwide.

The sponsor has recent information from a National Toxicology Program (NTP) study at the University of Arizona that the major ingredient in Aqui-S™ is not a carcinogen. However, NTP continued to pursue studies on the safety of the main ingredient so that CVM was not able to grant a compassionate INAD until this issue is resolved.

The plan by USFWS to have a compassionate INAD exemption in place on Aqui-S™ by the end of July 1999 has been put on hold until agreement can be obtained from CVM that the mammalian toxicology studies show no potential for being a carcinogen.

MS-222

Western Chemical, Inc. obtained an approved NADA for MS-222 or tricaine methanesulfonate (Tricaine-S) as an anesthetic on November 21, 1997.

PROGRESS ON HORMONES

Common Carp Pituitary

A meeting was held at CVM headquarters on April 11, 1996 with Stoller, users of common carp pituitary (CCP), and researchers to determine a course of action for gaining approval of CCP. As a follow-up to that meeting, CVM coordinated a conference call on May 15, 1996 that covered: (1) the identification of researchers and the design of target animal safety studies; (2) the writing of the environmental assessment through the National Research Support Program Number 7 (NRSP-7), and (3) potential funding sources of the target animal safety studies. A literature review on efficacy and target animal safety of CCP was completed, presented on August 5, 1998 in Bozeman, Montana and submitted to CVM in the summer 1999 by NRSP-7.

The National NADA Coordinator is working with a researcher from Mississippi State University to complete the needed target animal safety studies on CCP.

17β-estradiol (Estrogen)

The National NADA Coordinator began in June 1999 to work with the potential INAD sponsor for the development of estrogen to gender manipulate American eels to all female populations. Draft protocols were reviewed and procedures delineated for gaining an approval.

Human Chorionic Gonadotropin

The National NADA Coordinator contacted all the holders of disclosed INADs on human chorionic gonadotropin (hCG) at the urging of CVM to send all the data to the sponsor, Intervet, Inc., that was incorporated in a February 1996 Intervet submission to CVM. CVM ruled on February 12, 1996 that enrollment in an INAD will not be required to use hCG as a spawning aid. CVM will defer regulatory enforcement if used by or on order of a veterinarian. Any hCG product may be prescribed, but CVM strongly encouraged the use of Intervet's product, Chorulon®. This policy was renewed in 1998 and will continue until hCG gained approval.

Chorulon® (human chorionic gonadotropin, hCG) was approved on September 7, 1999 by CVM as a spawning aid by intramuscular injection for all fish and requires a prescription under the direction of a veterinarian. This approval is significant because it is the first original approval since 1986 when formalin was first approved for fish and because it was approved for all fish.

Ovaprim® and Ovaplant®

The National NADA Coordinator and Dr. David Erdahl (USFWS) met with Syndel International Inc. (Canada) in Seattle, Washington on February 23, 1997 to discuss the development of Ovaprim® in the United States. Another meeting was held with CVM on April 11, 1997 to discuss the strategy for development and the data requirements to gain an approval in food fish. Syndel International Inc. recently obtained INADs for its gonadotropin releasing hormone analog product (#10-087) and Ovaprim® (#10-040). USFWS and other INAD holders are working with Syndel to develop the technical sections of the NADA package.

17α-methyltestosterone

Schnick worked with CVM, Auburn University, Rangen, Inc. and tilapia producers to develop INAD #9647 on 17α-methyltestosterone (MT) for tilapia (obtained January 25, 1996) and then worked to obtain authorization from CVM and permission from Auburn University to allow the use of MT on yellow perch under Auburn's INAD (obtained February 22, 1996). The North Central Regional Aquaculture Center (NCRAC) provided $27,000 to Southern Illinois University-Carbondale and the University of Wisconsin-Madison to conduct a target animal safety study on MT with walleye and provided $5,000 for Auburn University to conduct a literature review of the environmental data on MT and submitted an EA to CVM on November 7 and 26, 1998. CVM responded to the EA on June 9, 1998 and Auburn is preparing a response. The human food safety portion of the NADA submission on MT was submitted by Auburn University to CVM for review, and CVM accepted MT as safe.

The Drug Enforcement Administration (DEA) has removed certain regulatory controls from the use of 17α-methyltestosterone feed for gender manipulation because the DEA perceives that there is no significant potential for abuse.

A meeting was held with CVM, Rangen, Inc., and the National NADA Coordinator on January 29, 1998 at CVM headquarters to discuss the requirements to complete a NADA application for 17α-methyltestosterone and the progress that has been made on the various technical sections.

Rangen, Inc. submitted a letter of intent to CVM on February 27, 1998 to pursue the approval of 17α-methyltestosterone feed for gender manipulation under an INAD (#10-296).

On June 9, 1998, CVM responded to the EA that was submitted by Auburn University on November 7 and 26, 1997. A response including revisions to the calculations and assumptions made in the original submission was prepared and submitted by Auburn to CVM on October 30, 1998.

PROGRESS ON THE IAFWA PROJECT
Several meetings were held at UMESC in May and June 1996 to review the whole IAFWA Project related to the following topics on each of the 10 study plans: (1) remaining data requirements; (2) tasks and jobs; (3) assignments for each job; (4) a time table for completing each assigned task; (5) budget projections by study plan and year; (6) budget shortfalls for the original IAFWA Project; and (7) assessment of the potential products at the end of the IAFWA Project. UMESC has reprogrammed its effort and direction under the IAFWA Project due to changes in requirements and circumstances for benzocaine, chloramine-T, hydrogen peroxide, OTC, and sarafloxacin. Efforts were made to save the entire IAFWA Project during government downsizing and budget reductions.

A DAOS was formed to aid the IAFWA Project to achieve its goal of obtaining drug approvals for U.S. public aquaculture. The first meeting was held May 5, 1997 in Hot Springs, Arkansas.

A meeting was held with representatives of the USFWS, Biological Resources Division (BRD) of the U.S. Geological Survey, CVM, American Fisheries Society, the IAFWA, and the National NADA Coordinator on September 30, 1997 in Arlington, Virginia. The specific objectives of this meeting were to review and discuss: (1) the current status of public sector aquaculture drug and chemical approval activities; (2) the need for collecting pivotal field efficacy data at USFWS facilities; (3) the possibility of including non-FWS entities on its INADs; (4) the steps needed to ensure continued support for public sector drug approval activities beyond June 1999; and (5) other areas of interest that will foster continued and future support for approval of aquaculture drugs and chemicals. A major topic of discussion centered on the lack of federal funding from BRD for the IAFWA Project after September 30, 1998. All groups agreed to search for mechanisms and sources of funds to continue the IAFWA Project for a total of at least eight years (to June 30, 2002). Subsequent meetings were held on March 20-22, 1998 and April 17-19, 1998 that produced the support needed for the three-year extension.

A Work Planning/Coordination Meeting of the IAFWA Project held November 19-20, 1998 in La Crosse, Wisconsin evaluated the progress being made on the technical sections for each work plan and made amendments to the existing work plan where necessary.

DAOS met in Savannah, Georgia on September 11, 1998, in San Francisco, California on March 26-27, 1999, and in Killington, Vermont on September 16-17, 1999 to discuss the progress being made on the IAFWA Project drugs and to support the extension of the IAFWA Project until at least 2002.

A meeting was held at the USFWS in Arlington, Virginia on January 11, 1999 to brief Project stakeholders and participants on the status of the IAFWA Project. Project issues were discussed, clarifications in work plans were presented and definitions of the Project objectives were made.

As a result of the January 11, 1999 meeting, DAOS Chair Mike Gibson asked that brief progress reports be prepared for submission to all state resource agencies requesting participation for an additional three years. In response, the National NADA Coordinator and Dr. William Gingerich prepared documents that were sent to the Chair to brief DAOS members and state partners. Single page tables and two page summaries of all accomplishments and the current status of each project drug were prepared.

MEETINGS AND SPECIAL ACTIVITIES
The National NADA Coordinator organized and coordinated a major INAD/NADA workshop in November 1995 under sponsorship of CVM that led to increased communications between INAD coordinators,

better coordination of the data generation for each drug, and consolidation of several INADs.

CVM held a Joint Canadian-United States Workshop on Jurisdiction of Sea Lice Treatment and Control in September 1996 that will impact aquaculture drug approvals. One of the action items resulting from the workshop is the strategies and mechanics to institute forums for harmonization activities, i.e., the establishment of a joint Canada and United States Aquaculture Working Group. This means that data could be shared and certain requirements for all drugs could be harmonized so that there could be joint submissions leading to approvals being granted simultaneously in both countries.

The National NADA Coordinator met on October 30, 1996 in Rockville, Maryland with Dr. Meg Oeller, CVM Liaison to NRSP-7, and Dr. William Gingerich (UMESC) to discuss coordination of the mutual projects that NRSP-7 and the IAFWA Project have in common. Both projects are working on chloramine-T, copper sulfate, hydrogen peroxide, OTC, potassium permanganate, and sarafloxacin. Schnick also discussed coordination of the other NRSP-7 projects on common carp pituitary, erythromycin, and amoxicillin.

CVM held a meeting on February 13, 1997 with several representatives from the aquaculture community to discuss the effects on aquaculture of two recent laws, the Animal Medicinal Drug Use Clarification Act and the Animal Drug Availability Act. CVM also released a document on April 30, 1997 that further summarizes the two laws and the associated regulations.

The National NADA Coordinator chaired a special session on partnerships for aquaculture drug approvals at World Aquaculture '97 held in Seattle, Washington on February 22, 1997.

The National NADA Coordinator helped to coordinate the International Harmonization Workshop for Aquaculture Drugs/Biologics held in Seattle, Washington on February 24, 1997. The purpose of the workshop was to create an educational forum to exchange information and identify issues between public and private sectors and international organizations with the goal of initiating follow-up strategies to advance harmonization of drug maximum residue levels, aquaculture drug approval standards, and biological licensure. Several committees were set up to advance the harmonization of aquaculture drugs and biologics. The National NADA Coordinator chairs the committee to identify approved drugs worldwide for aquaculture and which drugs are being pursued for approval.

In February 1997, the National NADA Coordinator was elected to a two-year term on the Board of Directors of the U.S. Chapter of the World Aquaculture Society.

To attract more pharmaceutical companies to aquaculture, the National NADA Coordinator is working on gaining information on the market for aquaculture drugs both in the U.S. and worldwide. She gave a seminar to the Pfizer Animal Health Group on May 5, 1997 to encourage the company's interest in developing its products for aquaculture.

The National NADA Coordinator wrote a letter on May 29, 1997 in support of the efforts by the Office of New Animal Drug Evaluation (ONADE) to the Director of that office, Dr. Robert Livingston, because the progress that the aquaculture industry is making toward approvals has been helped by the ONADE.

The National NADA Coordinator wrote a letter on June 4, 1997 to Dr. Gary Edwards, Assistant Director-Fisheries, USFWS, in support of having the Bozeman National INAD Office expanded in its scope to include other entities under their INAD exemptions. Currently, USFWS is pursuing the mechanism that would allow other public agencies and private producers to be cooperators under USFWS INADs.

NATIONAL AQUACULTURE INAD/NADA COORDINATOR

The National NADA Coordinator wrote a draft letter on July 30, 1997 about regulatory options that would encourage animal drug approvals for minor species and for minor use. The options included: (1) criteria for the determination of a minor species or a minor use, (2) creating additional statutory authority, (3) administrative and regulatory changes, (4) creating incentives, and (5) extending existing authority.

The National NADA Coordinator organized and chaired a follow-up workshop and round table to the International Harmonization Workshop for Aquaculture Drugs and Biologics that was held in Edinburgh, Scotland on September 17, 1997 to identify approved drugs worldwide for aquaculture, identify those drugs that are being pursued for approval, and determine where cooperative efforts can begin.

On January 13, 1998, Schnick commented on a discussion draft "Proposals to increase the availability of approved animal drugs for minor species and minor use" (MUMS document).

The Agriculture Research Service held a Program Planning Session at SNARC on February 2-3, 1998 to identify the principal target species and research priorities for a comprehensive research program for the next five years.

Schnick organized and chaired a producers session on compassionate INADs and was on the program committee for the International Harmonization Meeting for Aquaculture Drugs and Biologics at Aquaculture '98, Las Vegas, Nevada, February 15-19, 1998. Schnick also gave a presentation at a special session on aquaculture drug approvals at the same conference.

The National NADA Coordinator volunteered to be on two National Aquaculture Association committees—pursuing the Minor Use/Minor Species provisions and developing a white paper on antimicrobial resistance. She is working with the MUMS Coalition to develop legislation that will go to Congress in 2000.

Comments were submitted to the U.S. FDA on August 21, 1998 regarding the FDA Modernization Act of 1997. The FDA was urged to increase the number of aquaculture reviewers and submit to Congress the MUMS document which was released to Congress and the public on October 29, 1998.

The National NADA Coordinator reviewed the MUMS document and presented analysis of the proposal to the Animal Health Institute on November 9, 1998. To fully implement the MUMS document, the following will be required: (1) six amendments to the Food, Drug and Cosmetic Act, (2) one amendment to the Internal Revenue code, (3) increased or new congressional appropriations for budgets of minor use programs (including UMESC, SNARC, and Bozeman National INAD Office) and CVM, and (4) numerous changes to federal regulations, policies, and administration of FDA, CVM, and USDA.

The National NADA Coordinator participated in a November 1998 workshop to develop internationally harmonized sensitivity tests. These tests will allow the aquaculture community to defend its attempts to gain approval and use of oral antimicrobials in the aquatic environment, an area under attack by the CDC mainly because of antimicrobial resistance issues. CDC has stated that the environmental application of antibiotics in aquaculture should be banned.

The USFWS Bozeman National INAD Office expanded its scope in January 1999 to include other entities (other public agencies and private producers) under their INAD exemptions.

The National NADA Coordinator organized and chaired a producers session on compassionate INADs at Aquaculture America '99, Tampa, Florida, January 27-30, 1999.

The National NADA Coordinator prepared a draft letter for the National Aquaculture Association for additional CVM funding and reviewers for aquaculture drugs on February

16, 1999 to alleviate the backlog in aquaculture drug reviews.

A Web site was established for the National NADA Coordinator on April 12, 1999 at http://ag.ansc.purdue.edu/aquanic/jsa/Aquadrugs/index.htm.

The National NADA Coordinator organized, chaired, and gave the keynote address at a session on worldwide cooperation toward aquaculture drug approvals at the 30th Annual Meeting of the World Aquaculture Society, April 26-May 2, 1999 in Sydney, Australia.

The National NADA Coordinator attended a meeting at the American Farm Bureau Association on June 29, 1999 to bring together stakeholders interested in forming a coalition to institute various provisions in the MUMS document. The intent was to reach an agreement on the priority provisions, develop specific strategies for implementing priority items, identify collective and individual actions, and develop an appropriate communication network.

In its meeting on September 8, 1999, the MUMS Coalition asked CVM a series of questions and supplied a list of provisions it supports in general. CVM was very supportive of all the provisions and answered all the questions raised by the MUMS Coalition.

The National NADA Coordinator organized, chaired, and gave the keynote address at a session on international harmonization of antibacterial approvals and sensitivity testing at the EAFP 9th International Conference, September 19-24, 1999 in Rhodes, Greece.

WORK PLANNED

The National NADA Coordinator developed an action plan that centers on coordinating all drugs of high priority for aquaculture toward NADAs through the INAD process. In particular, Schnick plans to: (1) develop a major initiative on amoxicillin to obtain approval for its use as a broad spectrum antibacterial in all fishes; (2) develop a major initiative on florfenicol to obtain approval for its use as a broad spectrum antibacterial in all fishes; (3) determine the potential of fumagillin to control or prevent whirling disease in salmonids and hamburger gill disease in catfish and pursue an INAD/NADA if feasible; (4) help develop the anesthetic, Aqui-S™; (5) try to help the industry overcome negative attitudes about the perceived potential for antimicrobials to develop resistance in humans from use in aquaculture by participating in a white paper on the subject; (6) help to develop the MUMS document for legislative action; (7) identify potential funding sources for INAD/NADA activities; and (8) continue to coordinate efforts to obtain approvals for all 19 high priority aquaculture drugs and additional new drugs as they are identified.

IMPACTS

Establishment of the National NADA Coordinator position in May 1995 has resulted in coordination, consolidation, and increased involvement in the INAD/NADA process on 18 of the 19 high priority aquaculture drugs and activities on 14 new drugs of interest to aquaculture. Twenty established or new INAD/NADA sponsors have initiated new INADs and progress has been made toward unified efforts on existing and new INADs/NADAs or have renewed their commitment to the INAD/NADA process on their drug products.

This enhanced coordination will help gain extensions and expansions of approved NADAs and gain approvals for new NADAs. In fact, an original NADA has been approved by CVM for Chorulon® as a spawning aid for all fish, a supplemental NADA has been approved for formalin as a fungicide on all fish eggs and external parasiticide on all fish, and a new NADA has been granted to Western Chemical Inc. for its MS-222 product (an anesthetic).

The approval of the candidate drugs will aid the aquaculture industry to reduce mortalities

associated with infectious and handling diseases and to increase their efficiency by using spawning aids and gender manipulation aids. The domestic aquaculture industry will be better able to deliver more and healthier aquatic species for consumption and recreational purposes and to compete with foreign producers who can use many drugs without regulation.

Efforts to develop the MUMS document into legislation will encourage more sponsors to support aquaculture drug approvals

PUBLICATIONS, MANUSCRIPTS, PAPERS PRESENTED, AND REPORTS

See Appendix A.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1992-93				$17,000[a]		$17,000	$17,000
1993-94	$2,000			$12,180[b]	$4,000[c]	$16,180	$18,180
1995-96	$5,000		$22,750[d]	$63,359	$11,000[f]	$97,109	$102,109
1996-97	$10,000		$29,000[g]	$46,920[h]	$26,000[i]	$101,920	$111,920
1997-98	$15,000		$42,000[j]	$54,419	$11,000[l]	$107,419	$122,419
1998-99	$13,241		$37,500[m]	$54,418[n]	$22,000[o]	$113,918	$127,159
1999-00	$10,000		$34,000[p]	$55,834[q]	$30,000[r]	$119,834	$129,834
TOTAL	$55,241		$121,250	$248,396	$104,000	$573,380	$628,621

[a]USDA funding through a Cooperative Agreement with NCRAC
[b]USDA funding through a Cooperative Agreement with NCRAC ($8,500) and FDA=s Office of Seafood Safety ($3,680)
[c]Northeastern Regional Aquaculture Center ($2,000) and Southern Regional Aquaculture Center ($2,000)
[d]American Pet Products Manufacturers Association ($7,500), American Veterinary Medical Association ($10,000), Catfish Farmers of America ($2,000), Florida Tropical Fish Farm Association, Inc. ($500), Natchez Animal Supply ($1,000), National Aquaculture Council ($1,000), Striped Bass and Hybrid Producers Association ($500), and American Tilapia Association ($250)
[e]USDA funding through a Cooperative Agreement with NCRAC ($20,000), CVM ($20,359), and USDI/NBS International Association of Fish and Wildlife Agencies Project ($23,000)
[f] Center for Tropical and Subtropical Regional Aquaculture ($5,000), Fish Health Section of the American Fisheries Society ($1,000), and Northeastern Regional Aquaculture Center ($5,000)
[g]American Pet Products Manufacturers Association ($1,000), American Veterinary Medical Association ($10,000), Catfish Farmers of America ($10,000), Florida Tropical Fish Farms Association, Inc. ($1,500), Striped Bass & Hybrid Producers Association ($1,500), Simaron Fresh Water Fish, Inc. ($2,500), and Abbott Laboratories ($2,500)
[h]CVM ($18,400) and USDI/NBS International Association of Fish and Wildlife Agencies Project ($28,520)
[i]Center for Tropical and Subtropical Aquaculture ($10,000), Fish Health Section of the American Fisheries Society ($1,000), Northeastern Regional Aquaculture Center ($10,000), and Western Regional Aquaculture Center ($5,000)
[j]American Pet Products Manufacturers Association ($1,000), American Veterinary Medical Association ($10,000), AquaCenter, Inc. ($2,500), Aqui-S New Zealand Ltd. ($2,500), Catfish Farmers of America ($10,000), Earth Science Laboratories, Inc. ($2,500), Florida Tropical Fish Farms Association, Inc. ($1,500), Gurvey & Berry, Inc. ($5,000), National Aquaculture Association ($2,000), Simaron Fresh Water Fish, Inc. ($2,500), Striped Bass & Hybrid Producers Association ($1,500), and Western Chemical, Inc. ($1,000)
[k]CVM ($18,519) and USDI/BRD International Association of Fish and Wildlife Agencies Project ($35,900)
[l] Center for Tropical and Subtropical Regional Aquaculture ($10,000) and Fish Health Section of the American Fisheries Society ($1,000)
[m]American Veterinary Medical Association ($10,000), Aqui-S New Zealand Ltd. ($1,500), Carus Chemical Corporation ($1,000), Catfish Farmers of America ($10,000), Kent Seafarms Corporation ($1,000), National Aquaculture Association ($2,000), Phelps Dodge Refining Corporation ($5,000), Sanofi Santé Nutrition Animale ($2,500), Simaron Fresh Water Fish, Inc. ($2,500), and Striped Bass & Hybrid Producers Association ($2,000)
[n]CVM ($18,519) and USDI/BRD International Association of Fish and Wildlife Agencies Project ($35,899)
[o] Center for Tropical and Subtropical Regional Aquaculture ($10,000), Fish Health Section of the American Fisheries Society ($1,000), Fish Culture Section of the American Fisheries Society ($1,000), and Western Regional Aquaculture Center ($10,000)
[p] American Pet Products Manufacturers Association ($1,000), Aqui-S New Zealand Ltd. ($1,500), Catfish Farmers of America ($10,000), Florida Tropical Fish Farms Association, Inc. ($2,000), Kent Seafarms Corporation ($1,000), National Aquaculture Association ($2,000), Phelps Dodge Refining Corporation ($5,000), Sanofi Santé Nutrition Animale ($2,500), Simaron Fresh Water Fish, Inc. ($2,500), Stoller Fisheries ($1,000), Striped Bass & Hybrid Producers Association ($2,000), U.S. Trout Farmers Association ($1,000), and Vericore Limited ($2,500)
[q] CVM ($18,519) and USDI/BRD International Association of Fish and Wildlife Agencies Project ($37,315)
[r] Center for Tropical and Subtropical Regional Aquaculture ($10,000), Northeastern Regional Aquaculture Center ($10,000), and Western Regional Aquaculture Center ($10,000)

TILAPIA[12]

Project Termination Report for the Period
September 1, 1996 to August 31, 1999

NCRAC FUNDING LEVEL: $120,000 (September 1, 1996 to August 31, 1999)

PARTICIPANTS:

Paul B. Brown	Purdue University	Indiana
Konrad Dabrowski	Ohio State University	Ohio
Paul A. Fuerst	Ohio State University	Ohio
Donald L. Garling	Michigan State University	Michigan
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Kerry W. Tudor	Illinois State University	Illinois
Industry Advisory Council Liaison:		
Curtis D. Stutzman	Kalona	Iowa
Extension Liaison:		
Donald L. Garling	Michigan State University	Michigan
Non-Funded Collaborator:		
Dr. Victor Wu	National Center for Agricultural Utilization, ARS, USDA, Peoria	Illinois

REASONS FOR TERMINATION

The objectives for this project were completed or carried over into the second Tilapia project and funds were expended.

PROJECT OBJECTIVES

(1a) Develop and/or identify cost-effective feeds for tilapia culture in recirculating systems that minimize waste generation.

(1b) Compare and evaluate economically important traits of current commercial tilapia strains in the North Central Region (NCR) with other strains cultured in recirculating systems.

PRINCIPAL ACCOMPLISHMENTS

Nile tilapia (*Oreochromis niloticus*) from the same genetic stock were used for all nutritional experiments conducted at sites participating in research on Objective 1a. This stock was also included in genetic research by Ohio State University (OSU) on Objective 1b.

This project has provided seed monies that have been supplemented by industry and the institutions involved. The ratio of other support to North Central Regional Aquaculture Center (NCRAC) funds was 2.3:1.

OBJECTIVE 1A

Research at Purdue University (Purdue) was designed to provide formulation guidelines for practical grow-out diets that are free of fish meal. In the initial phase of this project, 28% crude protein was identified as the minimum amount that resulted in maximum weight gain. In the second phase of the project, the optimum energy to protein ratio was explored using the minimum crude protein concentration. The optimum energy and lipid concentrations of

[12]NCRAC has funded two Tilapia projects. A progress report for the second project is contained elsewhere in this Annual Progress Report. This termination report is for the first Tilapia project, which was chaired by Donald L. Garling. It was originally a 2-year study that began September 1, 1996.

grow-out tilapia 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. This work has been continued in the second Tilipia project to determine methionine and choline requirements which are deficient in all plant diets.

Investigators at Illinois State University (ISU) compared 28% crude protein and 34% crude protein diets that were free of fish meal with a 36% crude protein experimental diet that contained 6% fish meal by weight and a 36% crude protein commercial diet (Purina 5144). The diets were tested over 8-week intervals in the recirculating grow-out facility at ISU. Results indicated that fish fed the commercial diet realized superior growth and greater efficiency of protein utilization compared to fish fed the three experimental diets. Although the 28% crude protein and 34% crude protein diets were based upon diets formulated and tested at Purdue, the results of the ISU experiment do not negate results obtained at Purdue. Because two different feed processors prepared the ISU and Purdue diets, modifications in ingredients were required. In addition, sources of error were found to be more difficult to control in the ISU grow-out facility.

In Year 1 of the project, researchers at OSU replaced dietary fish meal protein with an animal by-product mixture. There were no significant differences in growth among fish fed on fish meal-free or animal by-product based diets. In Year 2, OSU researchers completed a feeding experiment with five feed formulations where fish meal protein was gradually replaced (25, 50, 75 and 100%) with cottonseed meal protein, so that one diet was all-plant protein. Essential amino acids, lysine, and methionine were supplemented in the test diets to account for an indispensable amino acid requirement. A 16 week feeding study was conducted with tilapia having an initial weight of 10.2–13.4 g (0.36–0.47 oz). Anticipated effects of diet formulations with cottonseed meal include gossypol toxicity, phytoestrogen effects, and decreased availability of essential amino acids. There were significant differences in growth among fish fed diets with 75 and 100% cottonseed meal and the rest of the dietary treatments. Growth depression amounted to 33.3 and 54.1%, respectively. Tilapia fed diets containing 75% or higher of cottonseed meal had significantly depressed hemoglobin and hematocrit values in comparison to fish fed a diet based on fish meal. For example, hematocrit values were depressed to 7–9% in comparison to 31–35% in fish fed diets with no or 25% cottonseed meal protein. This was the first observation of pathologies related to cottonseed meal inclusion in diets of tilapia, which was considered to be one of the most resistant species to gossypol toxicity.

Researchers at Michigan State University (MSU) evaluated the effect of phytic acid, contained in many oil seed meals, on protein digestion and availability and the use of the enzyme phytase to ameliorate these effects. In Year 1, they completed experiments that indicated feeding tilapia maintained on a photoperiod of 14-h light/10-h dark to satiation three times per day improved growth and feed utilization compared to fish fed one, two, or five times per day. Two studies to determine the rate of feed and fecal movement through the intestine to determine an appropriate procedure for digestibility trials and phytate binding studies were also completed. In Year 2, MSU researchers fed juvenile tilapia a herring meal control diet or experimental diets which incorporated either untreated or phytase-treated soybean meal substituted at 0, 25, 50, 75, or 100% of the total protein. The dry, untreated soybean meal diets contained 0, 0.20, 0.39, 0.58, and 0.77% phytic acid, respectively. Phytic acid was below detectable limits in all the phytase-treated diets. During an eight week growth trial, fish were evaluated for weight gain, whole body crude protein, feed conversion ratio, protein efficiency ratio, and apparent net protein utilization. An inverse relationship was observed between percent substitution of soybean meal and growth,

protein efficiency ratio, and apparent net protein utilization. Differences were not significant from the control for either treatment until soybean meal comprised 100% of the dietary protein. Significant differences detected between the treated and untreated groups were at 50% replacement for growth and feed conversion ratio; 50 and 100% replacement for protein efficiency ratio; and 50, 75, and 100% replacement for apparent net protein utilization ($P < 0.05$). In all instances the fish fed the untreated diets performed better than the fish fed the phytase-treated diets.

In a final series of experiments, juvenile tilapia were fed diets incorporating graded levels of phytic acid into a herring meal based diet. Phytic acid incorporation was calculated to correspond to phytic acid levels in soybean meal in diets incorporating 0, 25, 50, 75, 100, and 200% of the protein, on a dry matter basis into a 33% crude protein diet. Percent weight gain among the treatments was 430–560%. Fish fed diets containing phytic acid at 1.5% of the dry diet, or twice as much phytic acid as determined in soybean meal, showed the lowest increase in weight gain. No relationship to the amount of phytic acid incorporation could be determined.

Researchers at Southern Illinois University-Carbondale (SIUC) evaluated *Yucca shidigera* extract (Micro-Aide, Distributors Processing Inc., Porterville, California) as a feed additive to reduce fecal ammonia. They fed juvenile tilapia (22.8 ± 1.8 g; 0.80 ± 0.06 oz) diets containing the extract to determine its effects on growth. The extract was added to a commercially available feed (Rangen Production™ 32% crude protein, floating 3/16 in pellet) to yield treatments of 0, 0.5, 1.0, 1.5, and 2.0 g of extract per kg (0.000, 0.008, 0.016, 0.024, and 0.032 oz per lb) of diet. Four replicates of each treatment were randomly assigned to separate circular tanks (300 L; 79.3 gal) stocked with five fish each. Culture conditions were maintained with a single recirculating system with water temperatures between 28–30°C (82.4–86.0°F) and a photoperiod of 14-h light/10-h dark cycle. Total ammonia and nitrite concentrations were monitored weekly. All fish were fed at a rate of 4% body weight divided over two feedings (dry feed per wet body weight) corrected for changes in fish weight every two weeks. After a two week acclimation period, experimental diets were fed for 12 weeks. At the completion of the feeding trial, all fish were sacrificed and analyzed for proximate composition of the whole body. Growth in terms of percent weight increase was significantly different only between treatments containing 0.0 and 1.5 g extract per kg of diet (0.000 and 0.027 oz per lb), with values of 361 and 258%, respectively. All other extract levels produced growth responses that were intermediate between those extremes and were not statistically different. This work is being continued in the second Tilapia project.

OBJECTIVE 1B

Previously, OSU researchers developed a series of short tandem repeat (microsatellite) loci, which were isolated from the haplochromine cichlid species *Astatoreochromis alluaudi*. From these a subset of eight microsatellite markers was identified which have been used to characterize strains of tilapia and which are able to amplify genetic material from a series of seven tilapia species (*O. niloticus*, *O. variabilis*, *O. esculentus* and *O. leucostictus*, as well as hybrid strains of *Oreochromis*, and *Tilapia rendelli* and *T. zilli*, and *Seratherodon galileus*) to verify their utility and genetic variability. In addition to the microsatellite markers, OSU researchers have used a set of markers isolated by Thomas Kocher of the University of New Hampshire to determine genetic variation in populations of tilapia, especially *O. niloticus*. The populations examined included an aquacultural stock maintained at OSU's Piketon Aquaculture facilities, a stock of *O. niloticus* recently isolated from the wild, and a set of natural populations of *O. niloticus* from East Africa in the Lake Victoria basin and other lakes of Uganda. A set of studies have been completed on the use of randomly amplified polymorphic DNA (RAPD) applied to *O. niloticus*

populations. These results were compared to the aquaculture strains. They show that the RAPD technology is a quick, relatively inexpensive approach to assessing genetic variation and interstrain divergence. OSU researchers have also become involved in a review of worldwide genetic resources of tilapia which will be published in an important compilation of information on the biology of tilapia as used in aquaculture. Finally, they have used their microsatellite markers to experimentally assess the impact of breeding structure on loss of genetic variability of small populations. Such populations are equivalent to many which would be found in aquacultural situations. Their results show that genetic variation is being lost at a much faster rate than usually assumed. This is likely to have important implications on efforts to maintain genetic variation in stock strains of tilapia. The comparison of genetic variation in natural and aquaculture strains will allow a better assessment of the variability between strains which OSU is studying in ongoing growth and sex-reversal experiments being carried on in Dabrowski's laboratory.

SIUC researchers identified six strains or hybrids of Nile tilapia through the Aquaculture® Magazine Buyer's Guide and Industry Directory. No local sources of red tilapia were available at the appropriate size, one white strain came from Colorado and one was bred in-house, and the two Nile strains came from different sources in Indiana. An initial grow-out period was necessary to obtain the mean tank starting weight of at least 50 g (1.8 oz) per fish. Grow-out experiments were conducted for 24 weeks, with bi-weekly sampling to determine weight gain and to recalculate feeding rates. Upon termination of the study, each fish was weighed and measured individually. Ten fish from each strain, except Arizona Red, were filleted to calculate the dress-out percentage and for proximate analysis. The viscera were also weighed to calculate the visceral somatic index. Individuals from the Arizona Red tilapia stocks did not reach 200 g (7.1 oz) and were not included in the dress out and proximate analysis.

The top two performers were the Aquamanna Niles and the Rocky Mountain Whites, achieving final mean fish weights of 512.1 ± 33.6 and 415.9 ± 45 g (18.1 ± 1.2 and 14.7 ± 1.6 oz), respectively. The Arizona Red strain did not reach market weight by the end of the six-month study (122.4 ± 12.3 g; 4.3 ± 0.4 oz). Both of the best performing strains exhibited an 87% increase in weight, but the initial average weight of the Aquamanna strain was 13.1 g (0.5 oz) higher than the Rocky Mountain Whites.

Feed conversion ratios were very poor due to failures of the heater in the recirculating system, and subsequent disease loss in some strains. Temperatures were at times below 25°C (77.0°F), but never below 21°C (69.8°F). However, all fish were subjected to the same temperature regime. The possibility exists that the best performing species strains and hybrids were the most cold tolerant. The Rocky Mountain Whites had the lowest feed conversion ratio at 3.2, and the Arizona Reds had highest at 6.0. The other four strains were not significantly different ranging from 4.1 to 5.0. The visceral somatic index did not differ significantly ($P = 0.05$) among the six strains, ranging from 5–19%. Surprisingly, the dress-out percentages did not differ significantly between the species strains or hybrids, with the exception of the Arizona Red strain which did not reach market size. Dress outs ranged from 25.23 ± 2.71 to 31.42 ± 2.19% of total fish weight. Based upon all data, the Aquamanna Nile strain appeared to be the top performer among the six species/strains/hybrids tested in the SIUC system, even though the Rocky Mountain Whites had a slightly higher increase in mean tank weight and a much better feed conversion ratio. The Aquamanna Nile strain was the only strain to reach a potential market weight during the six month study, but the Rocky Mountain Whites may have reached market weight had the heating system not failed.

IMPACTS

Quantifying critical nutritional requirements for targeted species reduces feed costs and allows

variation in use of feed ingredients. The research completed at Purdue, ISU, MSU, OSU, and SIUC is defining a tilapia diet and feeding strategies that will improved production in recirculating aquaculture systems.

Gross formulation guidelines for grow-out tilapia diets that are free of fish meal have been developed by Purdue and field tested by ISU. The basic formulation will be expanded to incorporate other ingredients that are readily available in the NCR in the second Tilapia project. 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.

Research at OSU has provided strong evidence that a diet with 50% fish meal protein replaced with cottonseed meal can be used to produce marketable-size tilapia without compromising growth rate. Taking into account August 1998 prices for menhaden fish meal ($0.62/kg; $560/ton) and cottonseed meal ($0.15/kg; $140/ton), this replacement should make considerable difference in feed costs. However, the decreased hematological parameters would most severely affect fish performance in conditions of low oxygen concentrations. Therefore, it is recommended that there should be no more than 50% protein replacement for tilapia production in recirculating systems. Further studies need to be conducted on possible impact of gossypol on marketability of fish fillet.

MSU research has lead to the development of more efficient feeding strategies and improved methods to determine digestibility for tilapia. Their research has indicated that soybean meal could be incorporated into juvenile tilapia diets at levels up to 50% of the protein in a 32% crude protein diet. Unlike mammals, poultry, and rainbow trout, their results suggests that treating soybean meal with phytase does not increase dietary nitrogen retention. This may reflect higher levels of proteolytic activity compared to carnivorous fish and terrestrial vertebrates.

Incorporation of *Yucca shidigera* extract into a practical diet for tilapia does not appear to adversely affect growth response when incorporated at less than 2 g of extract per kg (0.032 oz per lb) of diet. Work in progress as part of the second tilapia project will determine the efficacy of the extract in enhancing protein utilization and/or manageability of nitrogenous wastes.

The development of genetic markers and assessment of genetic differences between strains will help aquaculturists better evaluate the importance of interstrain differences. In addition, development of new markers will have a significant contribution to the effort to develop a genome map for tilapia which can be used to direct future selective breeding for improved aquacultural production.

RECOMMENDED FOLLOW-UP ACTIVITIES

Producers throughout the NCR are raising tilapia. However, the combination of species and culture system are not operating at peak efficiency. Diets fed to tilapia are most often modified catfish diets. Those same diets are thought to cause increased muscle lipid concentrations in catfish. If the same problem exists in tilapia during the grow-out phase of production, then the same problems will occur as in catfish. Fish containing relatively high concentrations of lipid in the muscle are subject to more rapid uptake of off-flavor compounds from the water. Further, shelf life of the product can be impaired because of the higher degree of lipid oxidation that can occur. Higher lipid concentrations in fillets is often the result of imbalanced energy to protein ratio. Thus, the benefits of this line of research are continued improvement of diets fed to tilapia in recirculating systems, continued development of all-plant diets, enzymatic feedstuff enhancement, and use of animal agriculture co-products that can be easily manufactured in this region, and continued improvement in product quality for the consumer. While studies conducted as part of this project and the second Wastes/Effluents project have provided important information regarding tilapia

production, they have also served to emphasize several areas in which improvements are needed.

Results of the diet studies conducted as part of this project and the second Wastes/Effluents project are being used to continue to improve feed formulations specifically for tilapia reared in recirculating systems as part of the second Tilapia project. Feeds developed through this project are being evaluated against standard commercial feeds in different commercial scale recirculating aquaculture systems based on growth, performance (survival, health, feed conversion), water quality, and economic impacts. Development of all-plant diets and continued research on alternative ingredients and waste management issues should reduce costs for tilapia producers in the NCR.

The ability to evaluate genetic differences within and between strains, and to determine the degree of hybrid mixture within some strains will assist the design of future work to select strains which are better adapted to culture conditions which will be utilized in the northern U.S., and to assist in the evaluation of genetic schemes such as the production of YY male lines, which can be used to improve aquacultural production. Gene markers for hypervariable neutral polymorphisms have been shown to be able to discriminate among populations and species with better resolution than morphometric traits. These gene markers also have the potential for application in aquaculture, including identification of individuals, families and species, and labeling of brood stocks. They can also be of importance in the identification of hybridization between stocks and species and in the monitoring of inbreeding rates in managed stocks for proper fisheries management.

OSU researchers have used their microsatellite markers to experimentally assess the impact of breeding structure on loss of genetic variability of small populations. Such populations are equivalent to many which would be found in aquacultural situations. Their results have shown that genetic variation is being lost at a much faster rate than usually assumed. This is likely to have important implications on efforts to maintain genetic variation in stock strains of tilapia. The comparison of genetic variation in natural and aquaculture strains will allow a better assessment of the variability between strains. Genetic guidelines for tilapia fingerling producers should be developed to maintain genetic diversity. Further studies are needed to compare growth and performance of strains and hybrids relative to their level of genetic variation under recirculating aquaculture conditions typically encountered in the NCR.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See Appendix A 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	
1996-97	$86,500	$104,635	$56,566			$161,201	$247,701
1997-98	$33,500	$51,795	$46,000			$97,795	$131,295
1998-99		$7,250	$11,000			$18,250	$18,250
TOTAL	$120,000	$163,680	$113,566			$277,246	$397,246

TILAPIA[13]

Progress Report for the Period
September 1, 1998 to August 31, 1999

NCRAC FUNDING LEVEL: $74,773 (September 1, 1998 to August 31, 1999)

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	Kloubec Fish Farms, Amana	Iowa
Forest Sawlaw	ADM (Archer, Daniels, Midland), Decatur	Illinois
Chris Shimp	Grayson Hills Farms, Harrisburg	Illinois
Dan Selock	Aquaculture Consultants for the Heartland, Carbondale	Illinois

PROJECT OBJECTIVES:

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

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

ANTICIPATED BENEFITS

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

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

competitive advantage they have by producing fish close to major markets.

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

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

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

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

During the first year of this project, Southern Illinois University-Carbondale (SIUC) researchers worked with Grayson Hills Farms in Harrisburg, Illinois to modify their greenhouses to accommodate tilapia production. Eight 18,927-L (5,000-gal) concrete tanks were constructed. Four of these tanks were equipped with bead biofilters and pumps and stocked with 3,000 tilapia (*O. niloticus*) fingerlings. Water from the tanks is distributed through tomato plant roots grown directly above the fish tanks hydroponically. The bead biofilters serve to collect solid wastes while providing media for bacterial nitrification. The tomato plants serve to remove dissolved nutrients from the system. Inorganic fertilization use for the tomato production has been reduced by half as a consequence. The first crop of fish will be ready for harvest in November 1999.

Several laboratory studies were conducted at SIUC to test the feasibility of using beet pulp in tilapia diets (conducted in conjunction with the second NCRAC Wastes/Effluents project). The nature of tilapia feces, which strings out in gelatinous strands, proved not to be conducive to this strategy. Instead of the additional fiber weighing down the feces and making settlement easier, the excess fiber tended to make the fecal strands more fragile, resulting in them breaking apart. Accordingly, the use of beet pulp in tilapia feeds will only be examined further if grinding the pulp into smaller particles provides the intended effect (studies which are underway).

Michigan State University (MSU) has begun drafting an extension publication on feeding methods for tilapia to enhance production in recirculating aquaculture systems.

During the first year of the project SIUC determined the capital costs for construction of the concrete raceways and associated equipment at Grayson Hills Farms. Site

preparation and excavation costs for eight raceways included $2,400 for labor and $3,300 for equipment rental. Each raceway required $550 in concrete, $200 for sealer and $450 in labor. Each raceway was equipped with heating coils at a price of $150, a 1/2 hp high volume low head submersible pump ($800 each), and a BBF-4™ bead biofilter ($1,250 each). One 1.0 hp regenerative blower ($400) was purchased to service four raceways. Accordingly, capital expenditures were $4,162 per completed raceway.

WORK PLANNED

Research planned by Purdue scientists to evaluate several new diet formulations at commercial production sites in Iowa and Illinois were delayed by unexpected changes in management at both facilities. Those studies will be undertaken during 1999-2000.

Researchers at SIUC have been evaluating *Yucca shidigera* extract (Micro-Aide™, Distributors Processing, Inc., Porterville, California) in tilapia feeds as part of the second NCRAC Wastes/Effluents project. This extract has shown promise in the control of ammonia with various terrestrial livestock animals, as well as in dogs and cats. Should laboratory studies indicate promise for the use of this extract in tilapia feeds, a replicated commercial-scale study will be initiated with appropriate controls. A research-scale study will also be conducted for comparative purposes. Alternately, studies will be conducted comparing feed specifically formulated for tilapia with one formulated for channel catfish. Studies will commence in fall 1999.

MSU will complete the tilapia feeding methods extension publication during the second year of the project.

SIUC will determine the fixed and variable costs in conjunction with the tilapia feeding trials in Year 2. Actual figures for capital, fixed, and variable costs will be used to calculate the "break-even analysis." Sensitivity analysis will also be conducted on production costs.

IMPACTS

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

A commercial-scale recirculating aquaculture system incorporating hydroponic tomato production has been established at Grayson Hills Farm. Commercial-scale feeding studies will provide "real world" data on tilapia growth and nutrition, water quality, and cost of production. The project will also compare commercial-scale studies to a laboratory-scale study to allow for an assessment of "scale" with respect to data interpretation.

This project will provide information on economic conditions and constraints affecting profitability of a commercial tilapia aquaculture system. It ultimately will provide information on production costs and potential revenues as well as costs per unit of production to cover expenses. The information on factors affecting profitability and measures to be taken to reduce costs and/or increase revenues will enable producers to make informed decisions on the potential of indoor recirculating aquaculture systems for tilapia. The project has the added impact of providing data regarding integration of aquaculture with hydroponics, commonly referred to as aquaponics.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See Appendix A 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
TOTAL	$74,773	$82,052				$82,052	$156,825

WHITE PAPERS[14]

Progress Report for the Period
September 1, 1998 to December 31, 1999

NCRAC FUNDING LEVEL: $22,500 (July 1, 1998 to December 31, 1999)

PARTICIPANTS:

Jeffrey L. Gunderson	University of Minnesota-Duluth	Minnesota
Roy C. Heidinger	Southern Illinois University-Carbondale	Illinois
Ronald E. Kinnunen	Michigan State University	Michigan
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Joseph E. Morris	Iowa State University	Iowa
Robert C. Summerfelt	Iowa State University	Iowa
Harry Westers	Aquaculture Bioengineering Corporation, Rives Junction	Michigan

PROJECT OBJECTIVE

Develop white papers on a limited number of species and systems.

ANTICIPATED BENEFITS

The North Central Regional Aquaculture Center (NCRAC) Board of Directors approved the final draft of a Strategic Plan for the Center on June 16, 1999 (see Appendix B). The first goal of the NCRAC Strategic Plan is to research, develop, and extend profitable aquaculture technology, marketing, and economics for a limited number of species and systems. The first objective for achieving that goal is to develop a long-term needs assessment which establishes industry priorities in the North Central Region (NCR). One of the major steps for obtaining that objective is the development of white papers on a limited number of species and systems. These white papers will synthesize the literature for the purposes of identifying the most critical gaps of knowledge required for the economical and sustainable production in the NCR. NCRAC's Board decided that white papers on baitfish, effluents, hybrid striped bass, largemouth bass, salmonids, sunfish, tilapia, walleye, and yellow perch should be developed which, in turn, will be used by each state in the NCR to develop their industry priorities. The white papers are not to be an exhaustive literature review, but rather working documents that clearly define the current state of technology for the respective species and/or systems, the critical factors limiting economical and sustainable commercial production, and recommendations as to the research/extension agenda that should be considered. Industry participation and peer review are critical components of the white paper process.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Kohler and Malison have completed white papers on tilapia and yellow perch, respectively, which were posted on NCRAC's

[14]NCRAC has funded the development of nine white papers.

Web site (http://ag.ansc.purdue.edu/aquanic/ncrac/wpapers/wpapers.htm) in February 1999. They have served as models for the seven new white papers that the Board requested in June 1999.

WORK PLANNED

White papers on baitfish (Gunderson), effluents (Westers), hybrid striped bass (Kohler), largemouth bass (Heidinger), salmonids (Kinnunen), sunfish (Morris), and walleye (Summerfelt) will be completed by early 2000.

IMPACTS

The nine white papers will be used by each state in the NCR to develop their aquaculture industry priories. These will be instrumental in guiding NCRAC resource allocations in the next three to five years so that the limited resources have the greatest impact on the industry in the NCR.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See Appendix A for a cumulative output for all NCRAC-funded White Paper activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1998-99	$22,500						$22,500
TOTAL	$22,500						$22,500

APPENDIX A

EXTENSION

NCRAC Extension Fact Sheet Series

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

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

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

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

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

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

Morris, J.E., C.C. Kohler, and C.C. Mischke. 1999. Pond culture of hybrid striped bass in the North Central Region. NCRAC Fact Sheet Series #107, NCRAC Publications Office, Iowa State University, Ames.

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

Riepe, J.R. 1999. Marketing seafood to restaurants in the North Central Region. NCRAC Fact Sheet Series #110, NCRAC Publications Office, Iowa State University, Ames.

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.

Riepe, J.R. 1999. Supermarkets and seafood in the North Central Region. NCRAC Fact Sheet Series #112, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E. In review. Plankton management for fish culture ponds. NCRAC Fact Sheet Series #114, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Technical Bulletin Series

Thomas, S.K., R.M. Sullivan, R.L Vertrees, and D.W. Floyd. 1992. Aquaculture law in the north central states: a digest of state statutes pertaining to the production and marketing of aquacultural products. NCRAC Technical Bulletin Series #101, NCRAC Publications Office, Iowa State University, Ames.

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

Kinnunen, R.E. 1992. North Central 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.

Swann, L., J. Morris, and D. Selock. 1995. Cage culture of fish in the North Central Region. NCRAC Technical Bulletin Series #110, NCRAC Publications Office, Iowa State University, Ames.

Riepe, J.R. 1997. Enterprise budgets for yellow perch production in cages and ponds in the North Central Region, 1994/95. NCRAC Technical Bulletin Series #111, NCRAC Publications Office, Iowa State University, Ames.

Brown, P., and J. Gunderson, editors. 1997. Culture potential of selected crayfishes in the North Central Region. NCRAC Technical Bulletin Series #112, NCRAC Publications Office, Iowa State University, Ames.

Riepe, J.R. 1998. Walleye markets in the North Central Region: results of a 1996/97 survey. NCRAC Technical Bulletin Series #113, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E., and C.C. Mischke. In press. Plankton management for fish culture ponds. NCRAC Technical Bulletin Series #114 NCRAC Publications Office, Iowa State University, Ames.

NCRAC Video Series

Swann, L. 1992. Something fishy: hybrid striped bass in cages. VHS format, 12 min. NCRAC Video Series #101, NCRAC Publications Office, Iowa State University, Ames.

Pierce, R., R. Henderson, and K. Neils. Aquacultural marketing: a practical guide for fish producers. 1995. VHS format, 19 min. NCRAC Video Series #102, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., editor. 1993. Investing in freshwater aquaculture. VHS format, 120 min. NCRAC Video Series #103, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E., and C.C. Mischke. 1998. Sunfish culture. NCRAC Video Series #104, NCRAC Publications Office, Iowa State University, Ames.

Kayes, T.B. In production. Spawning and propagating yellow perch. VHS format, 45 min. NCRAC Video Series, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Culture Series

Summerfelt, R., editor. 1996. Walleye culture manual. NCRAC Culture Series #101, NCRAC Publications Office, Iowa State University, Ames.

Mischke, C.C., and J.E. Morris, editors. In press. Sunfish culture guide. NCRAC Culture Series #102, NCRAC Publications Office, Iowa State University, Ames.

Other Videos

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

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

CD-ROMs

Swann, L. 1998. Getting started in freshwater aquaculture. NCRAC CD-ROM Series #101, NCRAC Publications Office, Iowa State University, Ames.

Situation and Outlook Report

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

Workshops and Conferences

Salmonid Culture, East Lansing, Michigan, March 23-24, 1990. (Donald L. Garling)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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APPENDIX B

A STRATEGIC PLAN FOR THE NORTH CENTRAL REGIONAL AQUACULTURE CENTER (NCRAC)

June 1999

NCRAC is one of five Regional Aquaculture Centers administered by the U.S. Department of Agriculture's Cooperative State Research, Education, and Extension Service. These centers work together within the broader, integrated aquaculture program of USDA to promote a well developed and sustainable aquaculture industry in the United States.

NCRAC is an administrative unit that serves 12 states in the heartland of America: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. The region's geography spans approximately 920 miles south to north and over 1,200 miles east to west. Within this region, aquaculture is characterized by great diversity with more than 1,000 producers, but only a few per state who account for the majority of the production of food fish, baitfish, and fish for stocking into recreational and ornamental water bodies.

These producers are highly diverse, ranging from the well established with a significant capital investment who are interested in ways of reducing production costs while increasing output to those who could be classified as newcomers, who need training, capital, and an awareness of the potentially high risk, high investment, and low returns that most producers encounter.

NCRAC is jointly administered by Michigan State University (MSU) and Iowa State University (ISU). The Office of the Director is located at MSU while the Associate Director's Office is at ISU. It relies on leaders in the aquaculture industry for direction in its programs. An Industry Advisory Council (IAC) sets priorities. A Technical Committee (TC) works with the IAC to formulate programs on priorities. Regional programs are meshed with activities of other centers to avoid duplication. Teams of research and extension aquaculture specialists from midwest universities, public agencies, and the private sector develop and execute projects to solve priority problems. A Board of Directors oversees administration and management of NCRAC's programs.

Since its inception the Center has concentrated on funding projects for emerging species that have good potential as food fish for production in the North Central Region (NCR), such as yellow perch, walleye, and hybrid striped bass. In addition, NCRAC has supported projects on sunfish, salmonids, crayfish, baitfish, aquaculture wastes and effluents, aquaculture drugs, and more recently tilapia. All funded projects are directed at high priority industry needs that include development of new technologies and application of research findings that will benefit diverse constituencies. Therefore, research and extension activities have been integrated into all funded projects to develop and implement educational outreach materials and programs.

MISSION STATEMENT

NCRAC's mission is to enhance aquaculture through education, research, and technology transfer to support a sustainable profitable industry throughout the NCR. Essential to accomplishing this mission is building a North Central aquaculture community representing a partnership between the industry, universities, and public agencies. NCRAC's mission will be accomplished by:

- Developing transferable technology enabling producers to be profitable
- Disseminating relevant educational materials to achieve profitable margins of operation
- Providing demonstrations and regular aquaculture extension programs
- Engaging in research partnerships between industry, universities, and public agencies
- Fostering open dialogue and networking throughout the North Central aquaculture community

Goal 1: NCRAC will research, develop, and extend profitable aquaculture technology, marketing, and economics for a limited number of species and systems. Producer involvement will be strongly emphasized to ensure this information's relevance and timely transferability. A measure of success will be the increased number of profitable operations.

Challenge:
A major challenge facing the North Central aquaculture community is the absence of a shared vision based on an accurate assessment of the region's long term needs. Diversifying NCRAC-funded activities has precluded focusing on a limited number of species that would have the greatest prospect for profitable aquaculture in the North Central states. Additionally, there is an industry perception that NCRAC information is not sufficiently accessible and the research is not relevant to producers' needs.

It is agreed that closer links are needed among researchers, extension, and producers. The minimal number of aquaculture extension personnel in the NCR has significant impact on the producers both in terms of access to information and direct contact.

NCRAC has had limited success in identifying the needed market information for a profitable aquaculture industry.

Finally, promoting systems which are untested, unsubstantiated, and lacking credibility has severely impacted the expansion of a profitable aquaculture industry. This raises the obvious need for a source of unbiased information.

Objective A. **Develop a long-term needs assessment which establishes industry priorities for the NCR. An overarching document identifying the status and needs of NCR aquaculture will be developed.**

Major steps:

1. Identify who will be responsible for developing the overarching document.
2. Create the opportunity for developing white papers for other potential species and/or systems similar to those for tilapia and yellow perch at a cost of $2,500 per paper.
3. State-by-state profiles will be developed outlining each state's needs and ranking of the top three priorities.
4. The IAC will narrow the state priorities to a maximum of 12 and will submit this list for consideration in development of the overarching document.
5. The overarching document with recommendations will be compiled and presented to the Board.

Objective B. **NCRAC activities will increase production of a limited number (three to five) species in open-water and indoor systems that have market demand or potential through technological advancements.**

Major steps:

1. The Board will define a process to select the species and systems.
2. After appropriate consultation with the industry, the Board will designate species/systems for NCRAC concentration.
3. A Project Review Committee will be formed consisting of three IAC and three TC members. After the Board has determined the species/systems focus for NCRAC efforts and there has been a response to the call for proposals, the Project Review Committee will evaluate and make funding recommendations to the Board. Funding-formula guidelines will be used to give preference to those proposals containing collaborative endeavors and matching funds from universities, industry, other state/federal sources, and private corporations/foundations.
4. Funding for the next five to ten years for NCRAC activities will be based on the species/systems selected.

Objective C. **More effectively serve producer needs by creating a closer link between research and extension, enhancing the dissemination of existing information, and building a better network within the North Central aquaculture community.**

Major steps:

1. A concerted effort will be made to increase the number of regional aquaculture extension specialists. If it is permissible within NCRAC's mandate, a sum of monies will be earmarked for seed money, matching funds, or challenge grants. Funding-formula guidelines will be used to give preference to those proposals containing collaborative endeavors and matching funds from industry, other state/federal sources, and private corporations.
2. Over the next five to ten years all research and extension efforts must conform to criteria requiring linkage and relevance to producers needs.
3. Based on a survey of the industry, NCRAC information dissemination will be assessed in order to identify what, if anything, needs to be improved and have greater accessibility. This will include publications, technology transfer workshops, and direct access to aquaculture specialists.
4. The IAC and TC will be charged with making recommendations to improve the NCRAC network. Options to be explored will include electronic communication, enhancing state associations, and sub-regional coalitions.

Objective D. **NCRAC will serve as an unbiased information source on the feasibility (both technological and economic) of NCR aquaculture systems and will only promote those that are credible.**

Major steps:

1. NCRAC will identify "experts" who are unbiased and willing to serve as contacts/information sources regarding "credible" aquaculture.
2. NCRAC needs to develop informational materials and utilize the aquaculture network to promote itself as an available source for "credible" information to assess promoted systems.
3. NCRAC will make a concerted effort to have contact with or knowledge of regional aquaculture consultants.

Goal 2: NCRAC will build a strong aquaculture community through partnerships in the North Central states.

Challenge:
There has been a lack of cohesiveness between the industry and the academic community as well as within the academic community. Many within the industry and the university (research and extension) community perceive that they do not have sufficient opportunity to be fully engaged in NCRAC activities and decision making processes and are unclear about their potential roles and responsibilities for building a successful NCR aquaculture industry. Many state associations are neither well organized nor representative of the aquaculture industry. There are only tentative connections between producers, state agencies, and university research and extension personnel.

Aquaculture in the NCR can best be described as a "fledgling" industry. Participants' capacities must be enhanced to more fully maximize existing opportunities. There is a need for a more coherent/recognized industry voice to take advantage of funding possibilities, better use research results, and maximize networking.

Objective A. **Identify and implement a process so that NCRAC roles, responsibilities, and governance are understood, enabling full membership participation.**

Major steps:

1. Assess NCRAC's Operations Manual to determine if it sufficiently communicates members' roles, responsibilities, and governance.
2. Develop more effective supplementary materials if needed.
3. The Board will review the governance procedures of NCRAC with particular emphasis on industry participation in decision making. Reference will be made to other RACs and similar industry/university partnerships. A Board determination will be shared with the membership.

Objective B. **Initiate the NCRAC leadership training program to build capacity within the North Central states' aquaculture community to more effectively voice the community's concerns, funding opportunities, and increase networking.**

Major steps:

1. Ascertain leadership training opportunities within universities and those provided by the states and federal governments.
2. Identify a liaison for each state who will determine local leadership development needs and interests. The liaison will be provided with basic leadership literature, a methodology for making that determination, and administrative assistance. A report will be prepared by the Center to the Board.
3. A prototype model for building strong state aquaculture associations through leadership training will be developed utilizing the Iowa Aquaculture Association.
4. In collaboration with a TC and IAC representative, a proposed leadership development plan and budget will be developed.
5. With Board approval the leadership development program will be proposed to Washington.
6. The leadership development program will be implemented over a two year period and externally assessed by Washington representatives to determine whether it should be refunded, altered, or abandoned.

Goal 3: Enhance aquaculture's stature in the North Central states and NCRAC's image within the industry and among its key stakeholders, e.g., elected officials (federal, state, and local), public agencies, politically influential agricultural organizations, professional organizations, and other Regional Aquaculture Centers.

Challenge:
The general public in the North Central states is unaware of aquaculture. This is reflected in aquaculture's lack of influence around policy issues impacting the industry and producers' frequent inability to obtain capital from financial institutions. In some states in the region, traditional agricultural interests have lined up against aquaculture as have some states' natural resource agencies. Aquaculture's image in the NCR is largely misunderstood, frequently misperceived, and virtually invisible. The persistence of this poorly defined image will perpetuate missed opportunities for funding, coalition building, and influencing policy makers as well as future generations.

Objective A. **NCRAC, in alliance with the industry, will work to develop a political strategy to raise the awareness and importance of aquaculture. The primary outcome of this strategy will be to identify elected officials who will champion aquaculture in the political arena.**

Major steps:

1. Use university liaison offices and legislative tours to make key lawmakers and staffers more aware of aquaculture.
2. Collectively identify federal legislators from the NCR who are willing to champion aquaculture.
3. Network producers and facilitate their contacts with potential political supporters.
4. Develop a targeted information campaign to North Central congressional representatives, particularly those who are on agriculture and appropriation committees.

Objective B. **Develop allies among local and state agriculture, natural resource, and environmental groups to increase the awareness, importance, and acceptance of aquaculture within the region.**

Major steps:

1. Inventory each state to identify potential partners and possible contacts.
2. Seek opportunities whereby NCRAC and the aquaculture industry can jointly support multiple agency programs, conferences, and workshops.
3. Use university extension contacts and others to develop entrées to key agriculture organizations, e.g., Farm Bureau and commodity groups, as well as state departments of agriculture.
4. Identify and disseminate models from different states which have successfully forged partnerships in the region.

Objective C. **Develop promotional materials that will enhance aquaculture's image in the midwest and NCRAC's contribution to the industry.**

Major steps:

1. Develop two glossy publications for distribution to the general public and key stakeholders: (1) "Why aquaculture in the midwest?" and (2) "NCRAC's role in aquaculture development."

2. Include NCRAC articles in the promotional materials of agency and organizational partners.
3. Use university communication offices to broadly disseminate articles and news releases favorable to aquaculture.

Objective D. **In collaboration with 4-H, Sea Grant, and local science centers, actively promote aquaculture.**

Major steps:

1. Complete a 4-H module that will be made available throughout the NCR.
2. Promote and facilitate dissemination of CD-ROMs (e.g., "Getting Started in Aquaculture") to schools, libraries, and local science centers.

Goal 4. NCRAC will increase the funding available to support NCR aquaculture through collaboration, partnering, and more active state-level involvement.

Challenge:

The federal funds available to enhance "viable and profitable commercial aquaculture production" in the 12 North Central states are limited. Many within the industry and associated universities maintain that if the total budget was concentrated in one state alone, it would still be insufficient to truly address the need. If NCRAC is to achieve the expected regional results, it is necessary to increase funding. By using existing funding as "core" funding for the Center, it is imperative that the aquaculture community collaborate with NCRAC to more vigorously explore a variety of funding sources and mechanisms to increase support.

Objective A. **NCRAC participants will significantly increase the private sector contribution to priority projects through a Center-supported, coordinated effort of local state leadership.**

Major steps:

1. On a state-by-state basis the state coordinators, with assistance from the Center, will compile a regional database of existing and potential aquaculture stakeholders. This effort will be initiated by the respective university development officers.
2. NCRAC will ask other Regional Aquaculture Centers how they have broadened support within the private sector.
3. NCRAC will develop and distribute a "promotional" package to assist local efforts in projecting positive and professional images of the industry and NCRAC.
4. At the state level, the local coordinator and industry representatives will contact and explore private sector funding possibilities. Examples will vary by state, but possibilities include grain marketing boards, ethanol plants, and power companies.
5. NCRAC will compile the locally developed information and serve as a clearinghouse to keep states informed about each others' activities.

Objective B. **NCRAC will increase public funding to its projects.**

Major steps:

1. A state-by-state inquiry will be made into unallocated federal and state funds which could be used to support NCRAC activities.
2. Once potential funds have been identified, NCRAC will seek potential researchers and producers who:
    a) are interested in collaborating,
    b) are qualified to cooperate on a joint project, and
    c) meet funding requirements.
3. To the degree possible, NCRAC will assist in developing funding proposals or grant applications as long as these efforts are consistent with NCRAC's mission, procedures, and direction.
4. Progress on such efforts will be regularly disseminated to each state coordinator for distribution to local members.

Objective C. **NCRAC will establish at least one multistate coalition to garner additional funds for a regional project.**

Major steps:

1. Solicit interest among the 12 states to ascertain the level of interest in a collaborative project. This will largely be the responsibility of the state coordinator and local producers.
2. NCRAC will support convening interested parties in developing strategies and will establish contacts to further their communication.

SOME COMMONLY USED ABBREVIATIONS AND ACRONYMS

AquaNIC	Aquaculture Network Information Center
BG × GS	male bluegill × female green sunfish
BOD	Board of Directors
°C	degrees Celsius
CCP	common carp pituitary
CES	Cooperative Extension Service
cm	centimeter
°F	degrees Fahrenheit
FDA	Food and Drug Administration
ft, ft^3	foot, cubic foot
g	gram(s)
gal	gallon(s)
h	hour(s)
ha	hectare(s)
HACCP	Hazard Analysis Critical Control Points
IAC	Industry Advisory Council
in	inch(es)
INAD	Investigational New Animal Drug
ISU	Illinois State University Iowa State University
kg	kilogram(s)
L	liter(s)
m, m^3	meter, cubic meter
mg	milligram(s)
min	minute(es)
mL	milliliter(s)
mm	millimeter(s)
MSU	Michigan State University
N	nitrogen
N	number
NADA	New Animal Drug Applications
NCR	North Central Region
NCRAC	North Central Regional Aquaculture Center
OSU	Ohio State University
oz	ounce(s)
P	phosphorus
P	probability
ppm	parts per million
PSU	Pittsburg State University
Purdue	Purdue University
RAC(s)	Regional Aquaculture Center(s)
RAS	recirculating aquaculture systems
SD	standard deviation
sec	second(s)
SIUC	Southern Illinois University-Carbondale
TC	Technical Committee (TC/E = Technical Committee/ Extension; TC/R = Technical Committee/Research)
TL	total length
UM	University of Minnesota University of Missouri
USD	University of South Dakota
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
UW-Madison	University of Wisconsin-Madison
UW-Milwaukee	University of Wisconsin-Milwaukee
YOY	young-of-the-year
yr	year(s)