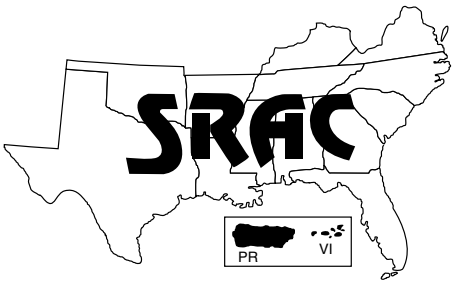
SRAC Final Project Report No. 6002

Southern
Regional
Aquaculture
Center



July 2007

Verification of Recommended Management Practices for Major Aquaculture Species

Final Project Report on the
SRAC Regional Research Project

Verification of Recommended Management Practices for Major Aquaculture Species

SRAC No. 6002

Compiled by
Carole R. Engle

Southern Regional Aquaculture Center
P.O. Box 197
Stoneville, Mississippi 38776

Telephone: 601-686-9311
Fax: 601-686-3569

Cover photos (clockwise from top left):
Aerial view of catfish ponds used in verification
Determining stocking size distribution of catfish in verification
Rice-crawfish verification pond
Harvesting
Center: Measuring size distribution of catfish at harvest

Preface

The project summarized in this report was developed and funded through the Southern Regional Aquaculture Center, one of five regional aquaculture research and Extension centers established by Congress in 1985 and administered by the United States Department of Agriculture. The five centers are located in the northeastern, north-central, southern, western and tropical Pacific regions of the country. The Southern Regional Aquaculture Center began organizational activities in 1987, and the first research and Extension projects were initiated in 1988. The thirteen states and two territories included in the Southern Region are Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, U.S. Virgin Islands and Virginia.

The regional aquaculture centers encourage cooperative and collaborative research and Extension educational programs in aquaculture having regional or national applications. Center programs complement and strengthen research and Extension educational programs provided by the Department of Agriculture and other public institutions.

The mission of the centers is to support aquaculture research, development, demonstration, and Extension education to enhance viable and profitable domestic aquaculture production for the benefit of consumers, producers, service industries, and the American economy. Projects developed and funded by the centers are based on regional industry needs and are designed to aid commercial aquaculture development in all states and territories. The centers are organized to take advantage of the best aquaculture science, educational skills and facilities in the United States. Center programs ensure effective coordination and a region-wide, team approach to projects jointly conducted by research, Extension, government, and industry personnel. Interagency collaboration and shared funding are strongly encouraged.

Project Participants

University of Arkansas at Pine Bluff (Lead Institution)	Carole Engle, David Heikes, Steven Killian, Pierre-Justin Kouka
Auburn University	Michael Masser, Jerry Crews, Greg Whitis, David Cline, Claude Reeves
Clemson University	William "Rockie" English, Tom Schwedler, Johnny Jordan, Jack Whetstone
Louisiana State University	Jimmy Avery, Greg Lutz
North Carolina State University	Harry Daniels, Steven Gabel, Michael Frinsko, Rebecca Dunning

Contents

List of Tables

Executive Summary

This document summarizes the results of the Southern Regional Aquaculture Center (SRAC) project *Verification of Recommended Management Practices for Major Aquaculture Species*. The primary goal of this project was to start verification programs in participating states, with an emphasis on developing the interdisciplinary process and internal committees within each state. This project was unusual for SRAC in that it was strictly an Extension, not a research, project. The intent was to develop the yield verification process as a new Extension tool in the participating states, document the process, and develop guidelines for Extension personnel in other states who might want to start similar programs. The management protocols developed for catfish and crawfish and the published guidelines for developing aquaculture verification programs can help other states add verification to their Extension tools.

Development of Verification Programs

Verification programs were developed in five states and covered the verification of catfish foodfish production in levee ponds, watershed ponds, hybrid watershed/levee ponds, and cages. One program included catfish fingerling production. The crawfish verification program covered rice-crawfish production, crawfish production in a permanent crawfish pond, and crawfish production behind two successive rice crops. Management protocols were developed for each verification program. In all, there were 21 cooperators, 29 ponds and six cages involved in this project.

Guidelines for Verification Programs

The project participants published SRAC Publication No. 5000 (Engle et al. 2004), which describes verification and discusses the process: forming the interdisciplinary verification committee, summarizing the relevant research base, developing the management plans, selecting the cooperators, and collecting and synthesizing the data. The publication discusses key points in implementing verification programs, such as the frequency of farm visits, the role of county Extension agents and specialists, the role of cooperators, the production cycles, and the resources required for a successful verification program. The publication concludes with a discussion of the results, benefits and potential problems and pitfalls.

Recommended Management Protocols

The management protocols used during this project were published by each state. It is important to note that management protocols evolve over time to reflect the most recent research results.

Project Background

Research verification trials are joint research-Extension efforts that demonstrate and test Extension's research-based recommendations. They help reduce the time between the discovery of new methods and the adoption of those methods by farmers (Miley 1986). Researchers and Extension personnel also learn whether or not recommendations need to be adjusted or new lines of research initiated, based on the feedback obtained through the verification program. The adoption of improved practices usually increases industry yields, and when they are demonstrated on farms, producers can better relate to the results. The analysis of on-farm results also allows for the comparison of key parameters such as feed conversion, yield, survival, and cost of production to overall industry averages and verifies the validity of the management recommendations.

Research verification programs are common in agriculture, but had not been used in aquaculture Extension in the U.S. prior to this project.

Catfish yield verification began in 1993 with a pilot program in Arkansas (Heikes 1995). The program sought to: 1) verify that current Extension recommendations could produce profitable yields; 2) estimate the cost of production for individual ponds and the corresponding feed conversion ratio (FCR), yield and survival; 3) identify research needs and update Extension recommendations; 4) develop an interdisciplinary management approach to help maximize net profits; 5) develop a protocol for future trials; and 6) provide practical field experience for Extension fisheries specialists, researchers and county Extension agents.

Cooperators agreed to manage verification ponds according to Extension recommendations for a period of 3 years. In addition to generating an excellent production and economic database, these trials also led to the development of new methods for describing fingerling populations being stocked into foodfish ponds as an indirect method of estimating fish inventory, among others. Several lines of research at the University of Arkansas at Pine Bluff were initiated as a direct result of problems encountered in the verification ponds. Over a 3-year period, production data were verified from four catfish ponds with an average annual marketable yield of 4,971 pounds per acre. The estimated 1996 Arkansas state average was 2,508 pounds per acre (USDA 2002).

Specific benefits identified in the pilot program were: 1) identification of problem areas that required further research; 2) improved and refined Extension recommendations; 3) increased county agent expertise; 4) improved county and state educational programs; and 5) refinement of specific management protocols for future trials.

Project Objectives

Goal: To initiate verification programs in participating states, emphasizing the development of the interdisciplinary process and internal committees within each state.

Objective 1: To develop and implement verification programs of recommended management practices for catfish and crawfish production systems in participating states.

Objective 2: To publish guidelines for developing infrastructure, implementing programs, and assessing the results and benefits of aquaculture management verification.

Objective 3: To publish the recommended management plans developed in Objective 1.

Objective 1: To develop and implement verification programs of recommended management practices for catfish and crawfish production systems in participating states

Aquaculture verification programs were initiated in five states (Alabama, Arkansas, Louisiana, North Carolina and South Carolina; Table 1). Interdisciplinary verification committees were formed and management protocols drafted for the following species/production systems in the five states:

1. Alabama
   A. Catfish foodfish production in levee ponds
   B. Catfish foodfish production in hybrid watershed/levee ponds
   C. Catfish foodfish production in watershed ponds
   D. Catfish foodfish production in cages
2. Arkansas
   A. Catfish foodfish production in levee ponds
   B. Catfish fingerling production
3. Louisiana
   A. Rice-crawfish production
   B. Crawfish production in a permanent crawfish pond
   C. Crawfish production behind two successive rice crops
4. North Carolina
   A. Catfish foodfish production in levee ponds
5. South Carolina
   A. Catfish foodfish production

Alabama

The Extension Fisheries team established recommendations for catfish production in ponds and cages. Five ponds in West Alabama (three with channel/blue hybrid catfish and two with channel catfish) and five cage systems (two in East Central and three in Southeast Alabama) were enrolled in the program.

Ponds

Table 2 presents data from the ponds in the Alabama catfish verification program. Channel catfish were stocked in two of the five ponds. These ponds were 11.1 and 17 acres in size (Table 2). The ponds were stocked with fingerlings of 265 and 44 pounds per 1,000 fish at 4,855 or 5,469 head per acre. Overall feed input was 43,534 and 55,980 pounds per acre, respectively, with average daily feed rates of 30 and 44 pounds per acre per day.

Table 1. States participating in the verification project, types of production systems verified, and species included.

State	Production system/pond type	Species	Number of ponds
Alabama	Ponds	Catfish, channel	2
	Ponds	Catfish, hybrid channel/blue	3
	Cages	Catfish	5
Arkansas	Ponds	Catfish foodfish	4 northeast AR 2 southeast AR
	Ponds	Catfish fingerlings	2 northeast AR 2 southeast AR
Louisiana	Rice-crawfish	Crawfish	6
	Permanent crawfish	Crawfish	1
	Crawfish behind two rice crops	Crawfish	2
North Carolina	Ponds	Catfish foodfish	2
South Carolina	Ponds	Catfish foodfish	2

Table 2. Summary of catfish pond foodfish verification, Alabama.

Pond ID	Unit	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
Type of fish		Hybrid	Hybrid	Channel	Channel	Hybrid
Pond specifics						
Surface area	acre	6.5	9	17	11.1	10
Production period	years	3	3	4	4	1
Stocking data						
Weight stocked	lb/ac/yr	533	152	1,286	241	229
Number stocked	no./ac/yr	5,014	4,071	4,855	5,469	5,759
Average weight stocked	lb/1,000 fish	106	37	265	44	40
Production inputs						
Total feed fed	lb/ac	41,382	40,157	43,534	55,980	10,588
	lb/ac/yr	13,794	13,386	10,884	13,995	10,588
Average daily feeding rate	lb feed/ac/d	54	43	30	44	29
Net FCR[a]		1.87	2.1	2.83	2.14	1.56
Production						
Total yield by weight	lb/ac/yr	7,569	6,415	5,097	6,744	7,193
Total yield by number	no./ac/yr	3,192	3,077	2,696	3,031	4,945
Net yield (lb/ac/yr)[2]	lb/ac/yr	7,036	6,263	3,811	6,503	6,964
Average fish weight	lb	2.37	2.08	1.89	2.23	1.47
Survival	%	64	76	56	55	86
Marketed yield						
Annual marketable yield	lb/ac/yr	7,176	6,364	6,560	7,632	7,243
Gross FCR[b]		1.92	2.10	1.66	1.83	1.46

[a]Net feed conversion ratio = total feed/net yield.
[b]Gross feed conversion ratio = total feed/marketed yield.

The three ponds stocked with hybrid catfish were 6.5, 9 and 10 acres in size (Table 2). Hybrid fingerlings were stocked at an average weight of 106, 37 and 40 pounds per 1,000 fish at rates of 5,014, 4,071 and 5,759 head per acre per year. Total feed fed was 41,382, 40,157 and 10,588 pounds per acre per year, with an average daily feed rate of 54, 43 and 29 pounds of feed per acre per day.

The total weight of channel catfish harvested from ponds was 5,097 and 6,744 pounds per acre per year, with an average marketed weight of 1.89 and 2.23 pounds. Net production was 3,811 and 6,503 pounds per acre per year, with a survival of 56 percent and 55 percent. The gross feed conversion ratio was 1.66 and 1.83, while the net feed conversion ratio was 2.83 and 2.14.

Total weight of hybrid catfish harvested was 7,569, 6,415 and 7,193 pounds per acre per year, with an average market weight of 2.37, 2.08 and 1.47 pounds. Net production was 7,036, 6,263 and 6,964 pounds per acre per year, with survivals of 64 percent, 76 percent and 86 percent. The gross feed conversion was 1.92, 2.10 and 1.46, while the net feed conversion ratio was 1.87, 2.1 and 1.56.

Table 3 presents estimated annual costs and returns for catfish pond foodfish yield verification in Alabama. Net returns ranged from -$444 per acre to $1,644 per acre, with break-even prices above total costs that ranged from $0.51 to $0.83 per pound.

Cages

Three cages of catfish, two 6-foot x 12-foot x 4-foot (10.7 cubic yards) cages and one 4-foot x 8-foot x 4-foot cage (4.7 cubic yards), were reared in this trial (Table 4). The two 10.7-cubic-yard cages were made of 0.5-inch, hexagon-shaped, flexible mesh (poly propylene) and the 4.7-cubic-yard cage was constructed from 1-inch x 0.5-inch, rectangular, welded wire, PVC coated. The cages had tops and feed rings to minimize loss of feed pellets. Cages

Table 3. Estimated annual costs and returns (per acre) for catfish pond foodfish yield verification, Alabama.

Item	Unit	$/unit	Total $/acre					
			1	2	3	4	5	Average
Income								
Fish sales	lb	0.74	5,601	4,747	3,772	4,991	5,323	4,887
Operating costs								
Stockers	lb	0.84	446		1,081			764
Fingerlings, hybrids	inch	0.0189		385			544	464
Fingerlings, channels	inch	0.01				273		273
Feed	lb	0.12	1,655	1,606	1,306	1,679	1,271	1,503
Aeration								
Electric	$/ac/yr		207	128	116	125	112	138
Tractor	gallon	$	215	292	22	98	3	126
Harvesting and hauling	lb	0.045	341	289	229	303	324	297
Other operating costs	ac	567	567	567	567	567	567	567
Interest on operating costs[a]			257	245	249	228	212	238
Total operating costs	$		3,688	3,512	3,570	3,273	3,033	3,415
Total ownership costs[b]	$/ac	646	646	646	646	646	646	646
Total costs	$		4,334	4,158	4,216	3,919	3,679	4,061
Net returns to land and risk	$/ac		1,267	589	-444	1,072	1,644	826
Break-even price to cover:								
Operating costs	$/lb		0.48	0.54	0.70	0.49	0.42	0.53
Total costs	$/lb		0.57	0.65	0.83	0.58	0.51	0.63

[a]10 percent for 9 months.
[b]Taken from Engle and Whitis (2000).

Table 4. Summary of catfish cage foodfish verification, Alabama.

Pond ID	Unit	Cage 1	Cage 2	Cage 3	Cage 4	Cage 5	Mean
Cage specifics							
Cage size	Cubic yard	10.7	10.7	10.7	10.7	4.7	9.5
Production period	d	141	141	139	207	188	163
Stocking data							
Weight stocked	lb/cubic yard	33.1	30.0	28.9	18.7	13.4	24.8
Number stocked	no./cubic yard	137	140	142	141	160	144
Average weight stocked	lb/1,000 fish	242	214	203	133	84	175
Production inputs							
Total weight of feed fed	lb/cubic yard	170.7	194.3	190.8	331.5	271.9	231.8
Average daily feeding rate	lb/cubic yard/d	1.2	1.4	1.4	1.6	1.4	1.4
Net FCR[a]		1.64	1.74	1.77	1.71	1.58	1.69
Production							
Total yield by weight	lb/cubic yard/yr	137.4	141.7	136.8	212.1	185.1	162.6
Total yield by number	no./cubic yard	123.0	126.5	135.0	133.4	153.6	134.3
Average fish weight	lb	1.12	1.12	1.01	1.59	1.20	1.21
Net yield	lb/cubic yard	104.3	111.7	107.9	193.4	171.7	137.8
Survival	%	90	90	95	95	96	93

[a]Net feed conversion = total feed/net yield.

were positioned in a 2-acre pond in water approximately 6 feet deep, and had to be serviced by boat. Two airlifts were placed on each cage and operated from June through September during the hours of 9:00 p.m. to 6:00 a.m. A regenerative blower (0.75 hp) was used to operate the airlifts. Fish were fed a 36% protein floating catfish fingerling diet daily at 3 percent of biomass. The daily feed allocation was adjusted approximately every 2 weeks by estimating fish growth from feed consumption based on a 2:1 FCR. Feeding was observed to ensure that all feed was consumed. The fish were not sampled in order to reduce the disease outbreak that can be induced by handling.

Channel catfish were stocked into cages (4.7 to 10.7 cubic yards each) at stocking densities of 13.4 to 33.1 pounds per cubic yard (Table 4). Weights at stocking ranged from 84 to 242 pounds per 1,000 fish. Feed input ranged from 170.7 to 331.5 pounds per cubic yard, with an average daily feeding rate of 1.2 to 1.6 pounds of feed per cubic yard per day.

The total weight of catfish harvested from the cages was 136.8 to 212.1 pounds per cubic yard per year, with an average market weight of 1.01 to 1.59 pounds. Net production ranged from 104.3 to 193.4 pounds per cubic yard, with survival rates of 90 percent to 96 percent. Net feed conversion ratios ranged from 1.58 to 1.77.

Annual costs and returns were estimated for the cage verification trials (Table 5). Net returns above all costs (cash and non-cash) were negative. However, net returns above cash costs alone ranged from $26 per cubic yard to $62 per cubic yard. Break-even prices above operating costs ranged from $0.52 per pound to $0.66 per pound, while break-even prices to cover all costs (cash and non-cash) ranged from $1.22 to $1.75 per pound.

Some lessons were learned from these trials.

- The fingerlings stocked in cages should be well graded, similar in size, and from a strain known to grow well in cages.

Table 5. Estimated annual costs and returns (per cubic yard) for catfish cage foodfish yield verification, Alabama.

Item	Unit	$/unit	Total $/acre					
			1	2	3	4	5	Average
Income								
Fish sales	lb	0.74	102	105	101	157	137	120
Operating costs								
Stockers	stocker	0.30	41	42	43	42	48	43
Feed	lb	0.12	20	23	23	40	33	28
Aeration								
Electric	hp-hr	total	0	0	3	3	4	2
Harvesting and hauling	lb	0.045	6	6	6	10	8	7
Other operating costs[a]	ac		16	16	16	16	16	16
Total operating costs	$		83	87	91	111	109	96
Total ownership costs	$/cubic yard	148	148	148	148	148	148	148
Total costs	$		231	235	239	259	257	244
Net return to land and risk	$/acre		-129	-130	-138	-102	-120	-124
Net returns above cash operating costs	$/acre		35	34	26	62	44	40
Break-even price to cover:								
Operating costs	$/lb		0.60	0.61	0.66	0.52	0.59	0.60
Total costs	$/lb		1.68	1.66	1.75	1.22	1.39	1.54

[a]Includes interest on operating capital.

- Large fingerlings or stockers should be stocked in cages and fish should be harvested in one growing season.
- Sampling of catfish should be avoided during the culture period.
- Oxygenated water should be pumped through the cages (by airlifts, aerators, etc.), especially in hot culture months.
- Each cage of fish should be harvested totally and handled quickly, particularly if fish are to be kept alive for fish-out operations or vat storage.

Arkansas

An interdisciplinary verification committee consisting of researchers, Extension specialists, economists, county Extension agents and cooperating producers was formed in 1997. The verification committee developed a set of recommended management practices for commercial catfish culture based on current research, practical experience, and previous yield verification trials. These management practices formed the basis for the specific management protocol used in the catfish yield verification trials. Record-keeping forms were developed and printed in booklet form on waterproof paper. A spreadsheet computer program and sampling methodology were developed to be used with the Fishy 3.2 record-keeping program. A literature search was conducted to ensure that the management protocols reflected a progressive, practical and profitable management scenario.

The Arkansas catfish verification program conducted trials on six foodfish ponds (four in northern Poinsett and St. Francis Counties and two in southern Chicot County) and two fingerling ponds across the delta production area. Data on production inputs and yield were collected weekly, summarized, and posted on the Arkansas CYVT Web site (*www.uaex.edu/aquaculture/arcyvp.htm*).

Results of the Arkansas Foodfish Verification Program

Production characteristics. Pond A was a freshly re-worked 8.75-acre levee style pond that was part of an integrated catfish and row-crop farming operation located in Poinsett County (Table 6). This pond had one graveled levee and was equipped with one 10-hp paddlewheel aerator resulting in an aeration level of 1.14 hp per acre. Pond A was initially stocked in April and June of 1998 and production inputs were verified through two full growing seasons and two full winters before final inventory numbers were obtained in May 2000. Fingerlings stocked in Pond A were grown in a separate pond on the same farm from fry stocked in the previous year, and were transferred to the verification pond via hauling truck. The initial 1998 stocking occurred in two stages. The first stage (April) consisted of approximately 4,392 head per acre, averaging 0.158 pounds. The second stage (June) consisted of an additional 4,029 head per acre averaging 0.033 pounds. The second stocking occurred in May 1999 and consisted of 4,609 head per acre averaging 0.082 pounds. Overall, Pond A was stocked with 6,515 head per acre per year, with fish averaging 0.092 pounds. Fish were fed once daily (weather permitting) to satiation with 32% floating catfish feed. Overall feed input was 11,156 pounds per acre per year. Electric paddlewheel aeration was typically used for 8 to 12 hours per night during the growing season, resulting in an average of 1,670 hp-hours per acre per year. Emergency tractor aeration averaged 12.6 hours per acre per year.

The first harvest in Pond A occurred in April 1999, with 4,372 pounds per acre being sold at an average weight of approximately 1.99 pounds. The second harvest was in May 2000, with an additional 6,399 pounds per acre reaching a market weight of 2.12 pounds. Overall, the annual marketed yield obtained from Pond A was 5,714 pounds per acre per year at an average weight of 2.10 pounds (Table 6). Net production (including the ending inventory) averaged 6,498 pounds per acre per year at an average weight of 1.52 pounds. Overall survival was 71 percent. The gross feed conversion ratio (gross FCR = total feed per pounds fish marketed) was 1.95 and the net feed conversion ratio (net FCR = total feed per overall net production) was 1.72.

Ponds B and Pond C were newly constructed levee style ponds on the same catfish farm in Chicot County and were 13.5 and 13.6 acres, respectively. These ponds shared a common gravel levee and each had two 10-hp paddlewheel aerators, resulting in an aeration level of 1.48 and 1.49 hp per acre for Pond B and Pond C, respectively. Each of

these ponds was initially stocked in April 1998 and production inputs were verified through three full growing seasons and three full winters before final inventory numbers were obtained in April 2001.

Fingerlings were purchased from a commercial fingerling producer. The initial stocking density was approximately 6,622 head per acre of fingerlings averaging 0.049 pounds. Bacterial infections caused heavy post-stocking mortalities in both ponds so an additional 1,115 head per acre of fish averaging 0.043 pounds were stocked into each pond 1 month later in an attempt to compensate for fish lost. Unfortunately, fish available for this replacement stocking were smaller than desired. In April 1999, 5,790 head per acre and 5,969 head per acre of fish averaging 0.029 pounds were stocked into Ponds B and Pond C, respectively. The third stocking occurred in the fall of 1999, when 7,003 fingerlings per acre, averaging 32 pounds per 1,000 fish, were stocked into Pond B and 7,363 fingerlings per acre, averaging 44 pounds per 1,000 fish, were stocked into Pond C. Overall, Pond B was stocked with 6,861 head per acre per year of fish averaging 38 pounds per 1,000 fish and Pond C was stocked with 7,020

Table 6. Summary of catfish pond foodfish verification data, Arkansas.

		Pond			
	Unit	A	B	C	Average
Pond specifics					
Surface area	acre	8.75	13.50	13.60	11.95
Verification start date	date	4/9/98	4/10/98	4/10/98	n.a.
Verification end date	date	5/10/00	4/25/01	4/26/01	n.a.
Production period	year	2.0	3.0	3.0	2.7
Aeration level	hp/acre	1.14	1.48	1.49	1.36
Stocking data					
Weight stocked	lb/ac/year	602	258	290	383
Number stocked	no./ac/year	6,515	6,861	7,020	6,799
Average weight stocked	lb/1,000 fish	92	38	41	57
Production inputs					
Total feed	lb	195,238	373,213	409,500	n.a.
Feed	lb/ac/year	11,156	9,215	10,037	10,136
Electric paddlewheel	hp-hr/ac/year	1,670	data not available	data not available	1,670
Tractor paddlewheel	hour/ac/year	12.6	data not available	data not available	12.6
Production (including ending inventory)					
Total yield by weight	lb/ac/year	7,100	3,777	4,457	5,111
Total yield by number	head/ac/year	4,657	2,858	5,067	4,194
Average fish weight	lb/fish	1.52	1.32	0.88	1.24
Survival	%	71	42	72	62
Net yield	lb/ac/year	6,498	3,518	4,166	4,728
Net FCR[a]		1.72	2.62	2.41	2.25
Marketed yield					
Marketed in 1998	lb/ac	0	0	0	0
Marketed in 1999	lb/ac	4,372	2,723	4,242	3,779
Marketed in 2000	lb/ac	6,399	6,249	6,812	6,487
Annual marketed yield	lb/ac/year	5,714	2,991	3,685	4,130
Average fish weight marketed	lb/fish	2.10	1.74	1.65	1.83
Gross FCR[b]		1.95	3.08	2.72	2.59

[a]Net feed conversion ratio = total feed/net yield.
[b]Gross feed conversion ratio = total feed/marketed yield.

head per acre per year of fish averaging 41 pounds per 1,000 fish. Fish were fed once daily (weather permitting) to satiation with 32% floating catfish feed. Feeding response was sporadic and highly variable from day to day in both ponds throughout the study. Data on paddlewheel aeration were not recorded on this farm.

Pond B was first harvested in the fall of 1999, with 2,723 pounds per acre sold at an average weight of 1.87 pounds. This pond was also harvested in February, June, August and October of 2000, resulting in 6,249 pounds per acre marketed at an average weight of 1.7 pounds. Overall, the annual marketed yield obtained from Pond B was 2,991 pounds per acre per year at an average weight of 1.74 pounds (Table 6). Overall net production in Pond B was 3,518 pounds per acre per year at an average weight of 1.32 pounds. Overall survival was 42 percent. Gross FCR was 3.08 and net FCR was 2.62.

Pond C was harvested in April and October of 1999 with a total of 4,242 pounds per acre marketed at 1.48 pounds. Subsequent harvests occurred in February, June, July, August and October of 2000, with 6,812 pounds per acre marketed at an average weight of 1.77 pounds. Overall, the annual marketed yield from Pond C was 3,685 pounds per acre per year at an average weight of 1.65 pounds (Table 6). Overall net production in Pond C was 4,166 pounds per acre per year at an average weight of 0.88 pounds. Overall survival was 72 percent. Gross FCR was 2.72 and net FCR was 2.41.

For all foodfish ponds, an average of 6,799 head per acre per year were stocked and these fish averaged 57 pounds per 1,000 fish (Table 6). Average total feed input was 10,136 pounds per acre per year. No fish were marketed during the first full year of production in any pond because an insufficient number of fingerlings reached market size within the first year. During the second year of production, an average of 3,779 pounds per acre were marketed. During the third year of production, an average of 6,487 pounds per acre were marketed. When expressed as an average of the first 3 years of production, the marketed yield was 4,130 pounds per acre per year at an average harvest weight of 1.83 pounds. The average overall net production was 4,728 pounds per acre per year at an average weight of 1.24 pounds. Survival across all ponds averaged 62 percent. The overall average gross FCR was 2.59 and the overall average net FCR was 2.25.

Economic analysis. An enterprise budget was developed for each foodfish verification pond to estimate average annual costs and returns per acre (Table 7). Incomes were the product of a catfish market price of $0.74 per pound and the average yield during the program (pounds per acre per year), including the ending inventory. The catfish market price of $0.74 per pound was the national average price paid to producers by processors during the period of the yield verification program (USDA 2002). Costs for fingerlings, feed and aeration were based on the average quantity used annually per acre in each verification pond. Other variable costs (including repairs and maintenance, pond renovation, chemicals, telephone, water quality, labor, management, accounting, legal, and bird scaring ammunition) and fixed costs (including depreciation on production facilities and equipment, interest on investments, and insurance) were prorated on a per-acre basis from Engle and Kouka (1996) based on a 320-land-acre farm. The break-even price per pound of fish to cover operating costs was the quotient of the operating costs per acre divided by the average yield (pounds per acre per year). The break-even price per pound of fish to cover total costs was the quotient of the total costs per acre (the sum of operating costs and fixed costs) divided by the average yield (pounds per acre per year).

Break-even prices were compared to market prices to determine the profit margins per pound of product sold. For the three foodfish verification ponds, the estimated break-even prices were lower than the national average catfish market price of $0.74 per pound, which resulted in a profit (Table 7). The estimated break-even prices per pound to cover total expenses (excluding land) ranged from $0.48 to $0.72 per pound and averaged $0.61 per pound (Table 7). The lowest break-even price of $0.48 per pound was obtained in Pond A. A lower break-even price does not necessarily result in higher profit because net returns are also influenced by yields. However, among the three ponds studied here, Pond A also had the highest yield and consequently the highest net return. Estimated net returns varied greatly among ponds, ranging from $80 to $1,847 per acre and averaging $669 per acre. Those differences in break-even prices and net returns were

in part the result of different fingerling sizes, food conversion ratios, and survival rates among ponds. Fingerlings stocked in Ponds B and Pond C averaged only 38 and 41 pounds per 1,000 fish, respectively, compared to 92 pounds per 1,000 fish for the fingerlings stocked in Pond A. Fingerlings stocked in Ponds B and Pond C were smaller than the minimum fingerling size of 60 to 70 pounds per 1,000 fish specified in the program's management protocol. Moreover, the FCRs in Ponds B and C were higher than in Pond A (Table 6), which resulted in higher feed costs. Pond B also had the lowest survival rate. Consequently, Pond A, which was stocked with the largest fingerlings and had the highest yields, the lowest FCR, and one of the best survival rates, also had the highest net returns.

Results of the Fingerling Verification Program

Production characteristics. Two levee-style fingerling production ponds located at a large fingerling production facility in Desha County were used for 2 consecutive years, resulting in four independent fingerling verification trials (Table 8). Ponds 15a and 16a were stocked with fry in 1998 and harvested through May 1999. Ponds 15b and 16b were stocked with fry in June 1999 and harvested through May 2000. Each pond was 6 acres and had a 10-hp paddlewheel aerator, resulting in 1.67 hp per acre. All ponds were completely drained before stocking and remaining puddles were treated with rotenone to eliminate any remaining catfish finger-

Table 7. Estimated annual costs and returns (per acre) for catfish pond foodfish yield verification, Arkansas.

Item	Unit	$/unit	Total $/ac			
			A	B	C	Average
Income	lb/ac/yr	0.74[f]	5,254	2,795	3,298	3,782
Fish sales[a]						
Operating costs						
Fingerlings	in	0.01	456	343	351	383
Feed	lb	0.12	1,339	1,106	1,204	1,216
Aeration						
Electric	hp-hr	0.08	134	data not available	data not available	134
Tractor[b]	gal diesel	1.30[g]	56	data not available	data not available	56
Harvesting and hauling	lb	0.045	320	170	201	230
Other operating costs[c]	ac	567.00	567	567	567	567
Interest on operating capital[d]	$	0.01	22	16	17	14
Total operating costs	$		2,894	2,202	2,340	2,600
Total ownership costs[e]	$1/ac	513	513	513	513	513
Total costs			3,407	2,715	2,853	3,113
Net return to land and risk	$/acre		1,847	80	445	669
Break-even price to cover:						
Operating costs	$/lb		0.41	0.58	0.53	0.51
Total costs	$/lb		0.48	0.72	0.64	0.61

[a]Overall yield from Table 6, including the ending inventory, multiplied by the price.
[b]3.4 gallons of diesel used per hour of PTO operation.
[c]Includes repairs and maintenance, pond renovation, chemicals, telephone, water quality, labor, management, accounting, legal, and bird scaring ammunition (Engle and Kouka 1996).
[d]Interest on operating capital is charged for 9 months.
[e]Excluding land (Engle and Kouka 1996).
[f]National average market price during the period of the yield verification program (USDA 2002).
[g]National average on-highway diesel price during the period of the yield verification program (USDE 2002).

lings or trash fish. Water preparation was similar for all ponds. Within the first few days of pumping, the ponds were treated with 100 pounds (16.67 pounds per acre) of inorganic fertilizer (50-50 mixture of diammonium phosphate and urea) and 1,500 pounds (250 pounds per acre) of cottonseed meal. Fry were stocked within 7 to 10 days of initial fill. No further fertilizer treatments were required for any pond.

Pond 15a was stocked with 42.32 pounds of fry on June 15, 1998, resulting in an estimated 100,211 fry per acre. The first harvest of fingerlings occurred on March 12, 1999, when 2,863 pounds per acre (44,623 head per acre) of fingerlings averaging 64 pounds per 1,000 fish and 6.2 inches were harvested. The remaining fingerlings were fed through May 22, 1999, when an additional 1,828 pounds per acre (24,425 head per acre) of fingerlings averaging 0.077 pounds (6.6 inches) were harvested. By the end of the 1-year production cycle, 4,692 pounds per acre of fingerlings averaging 68 pounds per 1,000 fish (6.3 inches) had been harvested. Overall survival in Pond 15a was 69 percent, with 69,048 head per acre harvested at a FCR of 1.71.

Pond 16a was stocked with 40.06 pounds of fry on June 9, 1998, resulting in an estimated 101,142 fry per acre. The first harvest of fingerlings occurred on September 3, 1998, when 515 pounds per acre (13,214 head per acre) of fingerlings averaging 39 pounds per 1,000 fish (5.2 inches) were harvested. A second harvest occurred on March 12, 1999, when 3,247 pounds per acre (43,521 head per acre) of fingerlings averaging 75 pounds per 1,000 fish (6.5 inches) were removed. The remaining fingerlings were fed through May 22, 1999, when an additional 1,770 pounds per acre (20,726 head per acre) averaging 85 pounds per 1,000 fish (6.85 inches) were harvested. By the end of the 1-year production cycle, 5,532 pounds per acre of fingerlings averaging 71

Table 8. Summary of catfish pond fingerling verification data, Arkansas.

		Pond				
	Unit	15a	16a	15b	16b	Average
Pond specifics						
Surface area	acre	6	6	6	6	6
Verification start date	date	6/15/98	6/9/98	6/24/99	6/22/99	n.a.
Verification end date	date	5/22/99	5/24/99	6/30/00	5/16/00	n.a.
Production interval	year	1	1	1	1	1
Aeration level	hp/acre	1.67	1.67	1.67	1.67	1.67
Stocking data						
Weight stocked	lb/ac/year	7.05	6.68	8.44	8.75	7.70
Number stocked	head/ac/year	100,211	101,142	101,114	101,023	100,873
Average weight stocked	lb/1,000 fish	0.070	0.066	0.083	0.087	0.077
Production inputs						
Total feed	lb	48,030	50,250	50,870	63,055	n.a.
Feed	lb/ac/year	8,005	8,375	8,478	10,509	8,842
Electric paddlewheel	hp-hr/ac/year	940	1,050	590	330	728
Tractor paddlewheel	hour/ac/year	7	14	4	31	14
Production (including ending inventory)						
Total yield	lb/ac/year	4,692	5,532	4,200	6,797	5,305
Total yield	head/ac/year	69,048	77,461	59,255	94,796	75,140
Net yield	lb/ac/year	4,685	5,525	4,191	6,788	5,297
Survival	%	69	77	59	94	74
Average fish weight	lb/1,000 fish	68	71	71	72	70
Average length	inch	6.3	6.4	6.4	6.5	6.4
Net FCR[a]		1.71	1.51	2.02	1.55	1.70

[a]Net feed conversion ratio = total feed/net yield.

pounds per 1,000 fish (6.4 inches) had been harvested. Overall survival in Pond 16a was 77 percent, with 77,461 head per acre harvested at a FCR of 1.51.

Pond 15b was stocked with 50.62 pounds of fry on June 24, 1999, resulting in an estimated 101,114 fry per acre. The first harvest of fingerlings occurred on March 14, 2000, when 2,531 pounds per acre (31,530 head per acre) of fingerlings averaging 80 pounds per 1,000 fish (6.7 inches) were harvested. The remaining fingerlings were fed through June 28, 2000, when an additional 1,668 pounds per acre (27,725 head per acre) of fingerlings averaging 60 pounds per 1,000 fish (6.05 inches) were harvested. By the end of the 1-year production cycle, 4,200 pounds per acre of fingerlings averaging 71 pounds per 1,000 fish (6.4 inches) had been harvested. Overall survival in Pond 15a was 59 percent, with 59,255 head per acre harvested at a FCR of 2.02.

Pond 16b was stocked with 52.47 pounds of fry on June 22, 1999, resulting in an estimated 101,023 fry per acre. The first harvest of fingerlings occurred on January 20, 2000, when 1,221 pounds per acre (14,363 head per acre) of fingerlings averaging 85 pounds per 1,000 fish (6.85 inches) were harvested. A second harvest occurred on March 7, 2000, when 3,876 pounds per acre (39,957 head per acre) of fingerlings averaging 97 pounds per 1,000 fish (7.15 inches) were removed. The remaining fingerlings were fed through May 8, 2000, when an additional 1,700 pounds per acre (40,476 head per acre) of fingerlings averaging 42 pounds per 1,000 fish (5.3 inches) were harvested. By the end of the 1-year production cycle, 6,797 pounds per acre of fingerlings averaging 72 pounds per 1,000 fish (6.45 inches) had been harvested. Overall survival in Pond 16b was 94 percent, with 94,796 head per acre harvested at a FCR of 1.55.

The average for all ponds was 7.7 pounds of fry (100,873 fry per acre) stocked. Ponds were topped either once or twice before the final harvest to selectively remove fish larger than 5 inches. Total feed input averaged 8,842 pounds per acre per year. Overall net production for the fingerling ponds was 5,305 pounds per acre per year. Overall fingerling survival was 74 percent, with 75,140 head per acre per year harvested at a FCR of 1.70.

Economic analysis. An enterprise budget was developed for each fingerling verification pond to estimate average annual costs and returns per acre (Table 9). Incomes were the product of the total yield (head per acre per year), average fingerling length (inches), and a fingerling price of $0.01 per inch. Costs for fry, feed and aeration were based on the average quantity used annually per acre in each verification pond. Other variable costs (including repairs and maintenance, pond renovation, chemicals, telephone, water quality, labor, management, accounting, legal, and bird scaring ammunition) and fixed costs (including depreciation on production facilities and equipment, interest on investments, and insurance) were prorated on a per-acre basis from Engle and Kouka (1996), based on a 320-land-acre farm. Total costs per acre were divided by the number of fingerlings produced per acre to obtain the cost per fingerling for each pond. Similarly, the total cost per acre divided by the yield (pounds per acre) gave an estimated cost per pound of fingerlings. The cost per inch of fingerlings was estimated by dividing the total cost per acre by the total number of inches of fingerlings produced per acre in each pond.

Break-even prices were compared to market prices to determine the profit margins per pound of product sold. For the four fingerling verification ponds, the estimated break-even prices per inch were lower than the standard fingerling market price of $0.01 per inch, which resulted in a profit. The estimated break-even prices per inch to cover total expenses (excluding land) ranged from $0.0049 to $0.0070 per inch and averaged $0.0058 per inch (Table 9). Estimated net returns to land and risk ranged from $1,116 to $3,132 per acre and averaged $2,073 per acre.

Areas of the program that need further improvement. Inconsistent data collection at the verification sites was one of the most important problems. The length of the program (3 years), personnel turnover, farm structure changes, and turnover in Extension staff made cooperation and data collection difficult. Toward the end of the program period, cooperators were less likely to inform Extension staff about all stocking and harvesting events and to keep accurate records. A system should be developed to facilitate communication, data collection, and data transfer between cooperators and Extension staff.

Also, more financial data from cooperators should be collected to generate better cost of production estimates. A financial management protocol could be integrated into the production management protocol. Cooperators would benefit from such a financial management protocol. By keeping better financial records, cooperators would have better tools with which to analyze the financial performance of their enterprises and plan for the future.

Louisiana

The verification committee was formed, a literature review completed, and fisheries/aquaculture agents, specialists and administrators were trained in verification procedures. Management protocols were developed for three crawfish production scenarios. The first scenario is a rice-crawfish rotation in which a rice crop is planted and harvested for the grain. After the grain is harvested, the remaining stubble is

Table 9. Estimated annual costs and returns (per acre) for catfish pond fingerling yield verification, Arkansas.

Item	Unit	$/unit	Pond				Average
			15a	15b	16a	16b	
Income							
Fish production[a]	lb	0.01	4,350	4,958	3,792	6,114	4,804
Operating costs							
Fry	1,000 fry	0.963	97	97	97	97	97
Feed	lb	0.12[g]	961	1,005	1,107	1,261	1,061
Aeration							
Electric	hp-hr	0.08	75	85	47	26	58
Tractor[b]	gal diesel	1.30[f]	9	18	5	40	18
Harvesting	lb	0.045	211	249	189	306	239
Other operating costs[c]	ac	567.00	567	567	567	567	567
Interest on operating capital[d]	$	0.10	144	152	151	172	155
Total operating costs	$		2,064	2,173	2,163	2,469	2,217
Total ownership costs[e]	ac	513	513	513	513	513	513
Total costs			2,577	2,686	2,676	2,982	2,730
Net return to land and risk			1,773	2,272	1,116	3,132	2,073
Break-even price to cover operating costs							
Cost per lb	$/lb		0.44	0.39	0.52	0.36	0.43
Cost per fingerling	$/fingerling		0.030	0.028	0.037	0.026	0.030
Cost per inch	$/inch		0.0047	0.0044	0.0057	0.0041	0.0047
Break-even price to cover total costs							
Cost per lb	$/lb		0.55	0.49	0.64	0.44	0.53
Cost per fingerling	$/fingerling		0.037	0.035	0.045	0.032	0.037
Cost per inch	$/inch		0.0059	0.0054	0.0070	0.0049	0.0058

[a]Fish production = total yield (head/ac/year) x average fish length (inch).
[b]3.4 gallons of diesel used per hour of PTO operation.
[c]Includes repairs and maintenance, pond renovation, chemicals, telephone, water quality, labor, management, accounting, legal, and bird scaring ammunition (Engle and Kouka 1996).
[d]Interest on operating capital is charged for 9 months.
[e]Excluding land (Engle and Kouka 1996).
[f]National average on-highway diesel price during the period of the yield verification program (USDE 2002).
[g]The 20-year average feed price from 1977 to 1996 (Engle and Kouka 1996).

fertilized, flooded and allowed to serve as forage for the crawfish. In the second scenario, a permanent crawfish pond is constructed and managed solely for cultivating crawfish. In the third scenario, crawfish are grown behind two successive rice crops. Five cooperators (three from Vermillion Parish, one from St. Martin Parish, and one from Acadia Parish) participated in the crawfish yield verification project. There were nine ponds enrolled in the project, with six ponds evaluating the rice-crawfish rotation, one pond evaluating the permanent pond scenario, and two ponds evaluating crawfish behind double-crop rice.

The production season began in October 1998 and ended in June 1999. Agents collected pre-production samples of water, forage and soil. Forage depletion was monitored monthly. Farmers were given recommendations on trap density, bait usage and harvest regimes.

At least two of the cooperators had harvesters quit during the height of the harvest season. Because these workers had been given primary responsibility for keeping records, only partial data were collected.

North Carolina

A five-member committee consisting of industry, university and Extension representatives established recommended catfish management protocols. These protocols were implemented on three channel catfish production ponds on three separate farms. Some of the cooperators adopted the recommended management protocols for the rest of their ponds.

Pond management. Pond size ranged from 12 to 17 acres (Table 10). Pond A was on the largest commercial farm in North Carolina and was managed by a full-time crew with years of channel catfish culture experience. Pond B was one of three ponds on a farm that is more typical of the small, part-time catfish producers in North Carolina. Pond B was stocked in the summer of 1997 and Pond A was stocked in the spring of 1998. Both ponds were harvested during the spring of 2000—an average production period of 2.4 years. This period encompassed two full growing seasons and three winters. Pond A had been recently refilled after some maintenance work on the dike. The owners of Pond B

Table 10. Catfish yield verification data, North Carolina, 2000.

	Unit	Pond A	Pond B	Average
Pond specifics				
Surface area	ac	12	17	15
Verification start date	month/yr	3/98	5/97	
Verification end date	month/yr	3/00	3/00	
Production period	yr	2	2.8	2.4
Production inputs				
Weight stocked	lb/ac/yr	511	191	351
Number stocked	no./ac/yr	6,917	3,782	5,350
Average weight stocked	lb/1,000 fish	70	50	60
Total feed	lb/ac/yr	7,500	3,839	5,670
Aeration				
Electric paddlewheel	hr/ac/yr	153	86	120
Emergency tractor	hr/ac/yr	6	10	8
Production				
Net yield	lb/ac/yr	4,909	2,461	3,685
Total number harvested	no./ac/yr	3,655	1,286	2,471
Average fish weight	lb/fish	1.34	1.91	1.62
Survival	%	53	34	44
Annual marketed yield	lb/ac/yr	4,721	2,366	3,544
Average fish weight marketed	lb	1.3	1.9	1.6
FCR				
Gross[a]		1.59	1.62	
Net[b]		1.53	1.56	

[a]Gross feed conversion ratio = total feed/net yield.
[b]Net feed conversion ratio = total feed/net yield.

were very reluctant to drain the pond and instead seined repeatedly with a fingerling net before the initial stocking for the verification trial.

Pond A was stocked at an overall average rate of 6,917 per acre, while Pond B was stocked at a lower rate of 3,782 per acre (Table 10). Pond B was initially stocked with very small fish. Although the average size of these fingerlings—4.25 inches—was within the recommendations of the protocol, there was a wide size variation and the average weight of the fish stocked was only 0.03 pounds.

All ponds were fed twice daily with 32% protein floating catfish pellets. Pond A received more feed on a per acre basis but was also stocked at a slightly higher rate (Table 10). Feeding practices on both farms were very efficient, as the feed conversion ratios averaged 1.6.

Dissolved oxygen concentrations were monitored throughout the spring, summer and fall. Electric aeration was used nightly during the growing season and emergency aerators were turned on if oxygen concentrations dropped below 4 ppm. Water quality was monitored weekly during the summer.

Pond A had three acute disease episodes caused by ESC and *Aeromonas*. Medicated feed was used to treat these outbreaks. Although Pond B did not experience a noticeable disease problem, it did have a significant bird depredation problem during the winter and spring of 1998. In both these cases it was difficult to verify the exact number of fish lost.

Fish production and survival. Harvests were begun when feed records estimated there were a sufficient number of 1.5-pound fish to constitute a full truckload. The producer was responsible for coordinating the harvests and notifying the aquaculture agent so that harvest data could be verified. Samples were checked for off-flavor by the processing plant or the aquaculture agent. None of the ponds in the verification trial experienced off-flavor problems during the project.

Total production, average weight and survival were quite different between the two ponds (Table 10). Pond A had annual production of 4,721 pounds per year with 53 percent survival and an average weight of 1.3 pounds for harvested fish. Pond B had only 2,461 pounds per acre with 34 percent survival and an average weight of 1.9 pounds for harvested fish. The catfish yield verification program has concluded that the lower production and survival of fish in Pond B were caused by the small size of the fish stocked. These fish had difficulty eating the size pellet that was offered and may have died from starvation or been cannibalized by larger fish. Cannibalism, starvation and bird depredation would explain the lower survival in Pond B. Additionally, Pond B was not harvested as often as Pond A. The longer period between harvests allowed the fish to grow beyond the target size and resulted in the high average weight at the end of the study. Evidently some of these larger fish were in the pond before the trial began, as several individuals weighed more than 5 pounds

Yield. Yield in the verification ponds is shown in Table 10. The annual marketed yield is the annual farm yield in pounds sold per acre over the 2 to 3 years of production. Annual marketed yield in the verification ponds ranged from 2,366 pounds per acre per year in Pond B to 4,721 pounds per acre per year in Pond A. The average marketed yield was 3,544 pounds per acre per year. The average weight of fish marketed ranged from 1.3 pounds in Pond A to 1.9 pounds in Pond B, with an overall average marketed weight of 1.6 pounds.

Overall net yield is an indicator of the biological production of fish in each pond. This value was obtained by subtracting the pounds of fish stocked from the total pounds of live fish accounted for through the end of the study (including the scrap). Thus, overall net yield measures the increase in fish weight regardless of the actual weight of fish sold. Overall net yield ranged from 2,461 pounds per acre per year in Pond B to 4,909 pounds per acre per year in Pond A. The average overall net yield for the verification trials was 3,685 pounds per acre per year.

Net feed conversion ratio (FCR) was calculated by dividing the total pounds of feed applied by the increase in fish weight. Most producers, however, would calculate feed conversion by simply dividing the total amount of feed applied to the pond by the total pounds of fish marketed, regardless of the weight of fish stocked. We have reported this feed conversion calculation as gross FCR. Net FCR ranged from 1.53 in Pond A to 1.56 in Pond B. Gross FCR ranged from 1.59 in Pond A to 1.62 in Pond B.

Economic analysis. A primary objective of the yield verification trial is to demonstrate that recommended management protocols will improve farm income. Although the yield verification trial was not designed as a research study, the two ponds in this trial offer a useful comparison of the apparent effects of not following the stocking practices recommended in the management protocols. The initial stocking of Pond B was done with smaller than recommended fingerlings. As there were no significant disease episodes during the production period and large, older fish were found in the first harvests, we conclude that the large, older fish cannibalized the fingerlings. This cannibalism was apparently quite significant because the survival in Pond B (34 percent) was much lower than in Pond A (53 percent) (Table 11). This significantly lowered the net return for Pond B. Pond B lost $350 per acre per year, while Pond A had a profit of $418 per acre per year.

Operating expenses are those that require cash outlays during the year. The catfish farmers in the study tabulated the following operating expense items: fingerlings (number), feed (total pounds), electrical aerator use (hours), emergency PTO aerator use (hours), and labor (hours). The costs of fingerlings, feed, electricity, diesel and labor were based on prices reported in eastern North Carolina in 2000. Harvesting and hauling expense was based on the price charged by the single large processor in North Carolina.

Other operating expenses, including labor, repairs and maintenance, chemicals, bird depredation devices, etc., were based on estimated average costs to eastern North Carolina catfish farmers (Dunning, 2001). Interest on operating capital was charged for nine months of the year at a rate of 10 percent.

Fixed expenses represent the cost of owning and using ponds and equipment. Fixed expenses were based on information in Dunning (2001), and are included in the economic analysis at $599 per acre (Table 11). Total expenses were $3,076 per acre per year for Pond A and $2,171 per acre per year for Pond B. The break-even price to cover total expens-

Table 11. Estimated annual costs and returns (per acre) for catfish pond foodfish yield verification, North Carolina, 2000.

Item	Unit	Price/unit	Pond A	Pond B
Income	$	0.74	3,494	1,821
Operating expenses				
Fingerlings	number	0.08	553	303
Feed				
32% protein	lb	0.12	900	461
medicated	lb	0.22	33	–
Aeration				
electric	hp-hr	0.08	12	2
tractor	hr	1.2	7	8
total			20	10
Harvesting and hauling	lb	0.045	212	111
Other operating costs	acre	567	567	567
Interest on operating capital[a]		0.10	173	110
Total operating costs			2,477	1,572
Total fixed costs[b]			599	599
Total costs			3,076	2,171
Net returns to land and risk			418	-350
Break-even price to cover:				
Operating costs			0.52	0.64
Total costs			0.65	0.88

[a]Interest on operating capital is charged at 10 percent for 9 months.
[b]Dunning (2001).

es was $0.63 per pound for Pond A and $0.88 per pound for Pond B. The average price paid for catfish during the study period was $0.74 per pound. At this price, Pond A had a net return of $418 per acre and Pond B had a loss of $350 per acre.

South Carolina

The verification committee was formed, the management protocol to be implemented developed, and a cooperator identified. Background information on financial and production performance was evaluated. A change in farm managers in the middle of the year caused some delays in implementing the rotational plan. The proposed phased rotation management plan was updated to work with the farm's current inventory levels, and modified to work within the farm's restrictions of capital and equipment.

In August 1998, a 12-acre stocker pond was stocked with approximately 240,000 fingerlings weighing 60 pounds per 1,000 fish. They were fed until mid-October when approximately 60,000 fingerlings weighing about 200 pounds per 1,000 fish were moved to a vacated pond. The fish were fed until August 15, 1999 and a portion of the fish were harvested (12,000 pounds) and sold to the processing plant. The fish were seined with a 1 ⅜-inch sock to estimate true average size of the fish. The average size of the fish harvested was 1.38 pounds. Personnel changes at the farm meant that no accurate information was available on the actual feed fed and no conversion rates could be calculated. The stockers were moved at approximately the correct time and size and were within 5 percent of the targeted market size at harvest projected by the model. For reasons outside of this program, the farm later terminated its catfish operation. South Carolina's involvement with yield verification ended with it.

Objective 2: To publish guidelines for developing infrastructure, implementing programs, and assessing the results and benefits of aquaculture management verification

A Southern Regional Aquaculture Center Publication (No. 5000) entitled "Guidelines for Developing Aquaculture Research Verification Programs" was published in 2004 (*http://srac.tamu.edu*). This fact sheet gives an overview of the history of verification programs in agriculture and of the pilot catfish verification program in Arkansas. The publication summarizes the infrastructure required for an effective aquaculture verification program. The interdisciplinary verification committee is formed to develop the management protocol to be used in the verification program and to oversee the overall direction and recommendations of the program. The committee also summarizes the relevant research base for the program selected. Management protocols and plans are developed and modified based on detailed discussions among committee members. The publication points out examples in which a particular feed that produces the best growth might not be the most economical. The fact sheet discusses the criteria that make for a good cooperator and procedures for collecting and synthesizing data. It outlines key factors required to implement the program, including the frequency of farm visits, the role of county Extension agents and specialists, the role of cooperators, production cycles, and resources required.

Methods of assessing the results and benefits of verification programs are also presented in the fact sheet, with examples from various programs. The problems and pitfalls that can derail a program, the risk involved with cooperators, and suggestions for minimizing risk are presented.

Finally, the publication describes ways to disseminate information obtained through verification trials.

Effects of Verification Programs

Alabama

The project demonstrated that hybrid catfish can be stocked in a multiple batch production system if understocked fish are not in the 0.75-pound range at the time of a partial harvest. Hybrid catfish of about 0.75 pound will become "gilled" in a 1.75-inch mesh net. Also, seine crews must realize that hybrids are not as willing to swim through the throat of a sock during the socking phase. Hybrids are more likely than channel catfish to school together and go over the float line if given the chance.

Cooperators realized the importance of sampling food size fish at harvest and entering accurate average weights to better approximate head inventories and reduce overstocking. One producer who formerly stocked ponds at 12,000 to 15,000 fish per acre reduced his stocking rates because of the production data from his verification pond. It became apparent that the average size fish sold was 2 pounds and not 1.25 pounds. The routine use of a 1.75-inch mesh net leaves a large number of fish smaller than 1.25 pounds.

In these verification trials the individual cost components of catfish production were tracked and the total inputs and production were determined. As a result, cooperators learned

- that marketing fish on a timely basis is as important as producing the crop,
- that water volume in ponds and water quality parameters have a definite correlation and may affect catfish production levels, and
- that the total draining of ponds at harvest may not be a viable practice, especially given the recent drought conditions in southeast Alabama.

From these trials, records were developed with which to compare current catfish production to production in previous years (costs of production and selling price of catfish). Also, closer attention will be paid to water quality parameters and how these may affect catfish production.

Arkansas

The catfish yield verification program was an excellent way to demonstrate best management practices for producing food-size channel catfish. The program is a necessary intermediate step between small-pond research and the development of Extension's recommendations to farmers. It was also an excellent way to teach county Extension agents more about catfish production. The process of developing the specific management protocols for the verification ponds was especially beneficial to research and Extension personnel. It encouraged an open dialogue with producers and provided a structure for on-farm interaction with them.

Of particular interest is the impact that this program has had on producers in the northern half of Arkansas. Before this program, county agents had very little exposure to catfish producers and many producers had been turning to non-Extension sources of information for years. Since this program began, word has spread through fish farmer networks that Extension has important information and the county agents have seen a tremendous increase in the number of aquaculture-related calls in their counties.

Details of the Arkansas Catfish Yield Verification Program can be found at *www.uaex.edu/aquaculture*. Arkansas has continued its verification programs, which were expanded in 2004 to include baitfish verification.

Verification programs are resource intensive and require considerable monitoring on the part of Extension specialists and county agents. Travel funds can be a financial burden in implementing such programs. Kaliba and Engle (2005) measured the rate of return to the Arkansas economy from the investment in time and financial resources that these trials require. They showed a total economic benefit of $67 million from 1993 to 2002. The average internal rate of return on the cost of the program was 3.4 percent. This study showed that verification programs can be economically viable in terms of the investment of public funds and the returns that accrue to the state or region.

Louisiana

The major impact of this project was the interest it generated among field agents, who saw the value of participating in a proactive program. Two of the cooperators reported improved catch rates with the higher trap densities. Some cooperators have shared previous years' records with agents in an attempt to further refine their production practices. Agents have learned more about the importance of population structure at the end of the previous season, summer management of natural forage or rice, precipitation patterns while crawfish are aestivating in burrows, pesticide use, and fall flooding protocols.

North Carolina

The cooperating farmers expressed satisfaction with the results of this project and, where practical, have implemented the same practices on the rest of their ponds.

References

Dunning, R. 2001. Catfish: inputs, outputs, and economics. North Carolina Department of Agriculture and Consumer Services. Raleigh, North Carolina.

Engle, C.R., J. Avery, H. Daniels, D. Heikes and G. Lutz. 2004. Guidelines for developing aquaculture research verification programs. Southern Regional Aquaculture Center Publication No. 5000. Stoneville, Mississippi.

Engle, C. R. and P. J. Kouka. 1996. Effects of inflation on the cost of producing catfish. The Catfish Bargaining Association. Belzoni, Mississippi.

Engle, C.R. and G. N. Whitis. 2000. Costs and returns of catfish production in watershed ponds. Cooperative Extension Program Fact Sheet FSA 9084, University of Arkansas at Pine Bluff. Pine Bluff, Arkansas.

Heikes, D.L. 1995. Catfish yield verification trials. Interim Report. Cooperative Extension Program, University of Arkansas at Pine Bluff. Pine Bluff, Arkansas.

Kaliba, A.R. and C. R. Engle. 2005. Economic Impact of the Catfish Yield Verification Trials. *Journal of Applied Aquaculture* 17(4):25-46.

McKinney, N., R. Klerk and W. Mayhew. 1994. Arkansas Wheat Research Verification Trials. Cooperative Extension Service, University of Arkansas. Little Rock, Arkansas.

Miley. 1986. Technology transfer through crop research verification trials. National Cropping Systems Workshop sponsored by the Extension Committee on Organization and Policy. St. Louis, Missouri.

Slaton, N., C. Stuart, Jr. and R.S. Helms. 1994. 1994 Rice Research Verification Trials. Cooperative Extension Service, University of Arkansas. Little Rock, Arkansas.

United States Department of Agriculture. 2002. Catfish production. National Agricultural Statistics Service, Washington, D.C.

Publications and Presentations

Daniels, H., S. Gabel, M. Frinsko and R. Dunning. Channel catfish production manual: recommended management practices for North Carolina producers.

Engle, C.R., J. Avery, H. Daniels, D. Heikes and G. Lutz. 2004. Guidelines for developing aquaculture research verification programs. Southern Regional Aquaculture Center Publication No. 5000, Stoneville, Mississippi.

Heikes, D.L. 1998. Catfish Yield Verification Update. Poster presentation. Catfish Farmers of Arkansas Annual Convention. Little Rock, Arkansas. January 22-23, 1998.

Heikes, D.L. and C. Davidson. 1998. Catfish Verification Web Site. Poster presentation. 1890 Extension System-Wide Conference. Atlanta, Georgia. June 22-25, 1998.

Heikes, D.L. 1998. Catfish Fingerling Verification. Presentation. Catfish Farmers of Arkansas Annual Convention. Little Rock, Arkansas. January 22-23, 1998.

Pomerleau, S. and J. Trimpey. 2005. Catfish research verification shows promise. *The Catfish Journal* 19(6):13.

Pomerleau, S. 2004. Catfish research verification program update. *Catfish Channel* 44: November 2004.

Pomerleau, S. 2004. Aquaculture research verification. Aquaculture/Fisheries Center Field Day. Pine Bluff, Arkansas.

Pomerleau, S. 2004. A new start for aquaculture research verification programs. *Arkansas Aquafarming* 21(1):5.

Pomerleau, S. 2004. New staff for the aquaculture verification programs. *Arkansas Aquafarming* 21(1):5.

This publication was supported in part by the Southern Regional Aquaculture Center through
Grant No. 2005-38500-15815 from the United States Department of Agriculture.