EXPERIMENTAL CAGE CULTURE OF CHANNEL CATFISH IN VIRGINIA

by

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INTRODUCTION

Production of channel catfish, *Ictalurus punctatus* (Rafinesque), in agricultural waters is a new and promising farm industry. During the past decade, channel catfish farming in the United States has become a multi-million dollar enterprise. Most catfish production occurs in the central Mississippi Delta Region, but the industry has recently expanded into other states. Annual catfish production has risen from 12,500,000 kg in 1968 to an estimated 35,400,000 kg in 1972 (Jones, 1969).

Cage culture is a production method that has recently received considerable attention. Cage culture consists of rearing fish from fingerlings to marketable size in containers (cages) enclosed on all sides by wooden slats, hardware cloth, or netting that allows free circulation of water through the enclosure. Raising fish in cages has been practiced in Asia for about 100 years, but until recently it had gained little attention elsewhere (Thiemmedh, 1961). Cage culture has a number of advantages over pond culture: (1) several types of aquatic environments may be used, such as lakes, rivers, reservoirs, irrigation canals, and estuaries; (2) different species can be cultured together, i.e. channel catfish in cages and largemouth bass and bluegill in open water; (3) feeding activity and general health of fish can be readily observed; (4) harvest is easily accomplished by removing cages from the water; and (5) diseases and parasites can be efficiently treated. Disadvantages include: (1) the relatively high cost of cages; (2) the necessity of providing a nutritionally-complete feed; and (3) a greater susceptibility of fish to lower concentrations of dissolved oxygen.

There are many cage designs currently in use. The most common cage shape is rectangular. A wood or angle-iron frame is covered with nylon netting, plastic mesh, or galvanized mesh wire and floated by styrofoam blocks or metal drums. Cage size is limited because waste products must disperse rapidly to surrounding water, but the cage must be deep enough to prevent fish from fighting (Lewis, 1969).

Cage location affects catfish production. Cages that produce the best yield are usually those with a large surface area exposed to water currents. Water exchange in the cage must be sufficiently frequent to dilute waste products and replenish dissolved oxygen (Schmittou, 1969). To further enhance water circulation, cages should be placed at least 0.5 m from the bottom (Hatcher, n.d.).

Water temperature is one of the most important factors affecting fish growth. Temperature affects metabolic rate which influences both food conversion efficiency and growth rate. Optimum food conversion and maximum growth in channel catfish have been attained at temperatures between 29°C and 30°C (West, 1966; Avault, 1971). Catfish production is poor when water temperature is below 20°C, and catfish usually cease feeding when water temperature is lower than 10°C (Simco and Cross, 1966; Collins, 1970).

Daily feeding rates of 2 to 5% of the body weight are acceptable (Swingle, 1958). Inefficient food conversion rates are obtained at feeding rates in excess of 5%. Most efficient utilization of food occurs at rates between 2 to 4%. Growth rates decrease as feeding rates are reduced below 2%, and the time required to produce a marketable fish increases. In cases where feed has an exceptionally high protein content, feeding at levels of 3% or more may be inefficient (Hastings, 1969). Catfish receiving one-half of their feed twice daily have more efficient food conversion rates than those fed once per day (Deyoe et al., 1968; Collins, 1970)

Estimations of the optimum stocking density (largest number of fish that can be efficiently reared to marketable size in a given volume of cage) vary between researchers due to variations in pond size and characteristics. Schmittou (1969) recommended a stocking rate of 500 fish per cubic meter of cage, while Collins (1970) indicated that the optimum stocking density appeared to be between 200 and 300 fish per cubic meter of cage. Schmittou worked with ponds varying from 0.5 to 4.2 ha in size while Collins conducted his research in a shallow bay, approximately 0.04 ha in area.

Virginia presently does not have a commercial channel catfish industry. In a feasibility survey, Smith (1972) estimated that of the 1500 farm ponds in Pittsylvania County, Virginia, 790 were suitable for catfish culture. Use of these ponds could result in the establishment of a limited catfish industry producing an estimated 860,000 kg of marketable fish per year. Field trials indicated that it is biologically feasible to raise channel catfish in at least some Pittsylvania County ponds (Holmes, 1971), but due to the relatively short growing season, Holmes recommended a stocking size of at least 150 mm.

In an attempt to refine cage culture techniques in Virginia, strains of channel catfish from different southeastern regions were grown in cages during the 1972 growing season. Cage culture was used because most Virginia farm ponds cannot be easily drained or have irregular bottoms making conventional harvest methods difficult. Specific objectives of this research were: (1) to determine if there was a difference in the yield of three strains of channel catfish; and (2) to evaluate the feasibility of growing channel catfish in cages moored in small farm ponds in Virginia.

STUDY AREAS

Roher Pond, a 0.6 ha tobacco irrigation impoundment, is located in northern Pittsylvania County and was selected based on Smith's (1972) determination that the pond was suitable for either cage or pond culture. Roher Pond has a mean depth of 1.0 m and a maximum depth of 3.0 m. The pond is located in a depression surrounded on two sides by wooded land, but has excellent wind exposure in the north-south direction. Runoff and springs are the only water sources.

Salem Pond, located at the Veterans Administration Hospital, Roanoke County, was also selected. This pond is larger and deeper than Roher Pond, having a surface area of 1.4 ha, and a mean and maximum depth of 1.3 m and 4.0 m, respectively. The pond is rectangular and was created by filling a borrow pit with water pumped from the Roanoke River. Other water sources include runoff and springs.

METHODS

Three strains of channel catfish (*Ictalurus punctatus*) were acquired from commercial dealers in Arkansas (Leon Hill Catfish Hatchery, Lonoke), Kansas (Four Corners Fish Farm, Topeka), and North Carolina (Hunting Valley Fish Farm, Chapel Hill). Each strain was native to the state from which it was obtained.

Eighteen cages, purchased from the Pockman Manufacturing Company, were used. Cage dimensions were modified so that 1.0 cubic meter of water was contained within each cage. Cages were covered by 12 x 25 mm mesh galvanized wire and had a styrofoam floatation collar. A 0.8 x 0.3 x 0.3 m, 6 mm mesh, galvanized wire feeding well was attached to the top-center of each cage to prevent feed from washing out of the cage during feeding. Two ropes (approximately 6 m apart) were stretched across each pond. Five cages were attached to one rope and four to the other so that they were spaced approximately 2 m apart.

Fish were fed once daily six days per week at the rate of 3.0% body weight. The calculated amount of food for each cage was weighed and then placed in the feeding well to minimize food loss. Purina Floating Trout Chow (Developer 6) was used throughout the experiment.

Records of water temperatures for each pond were maintained by suspending Ryan Recording Thermographs 0.75 m below the surface of the water. Monthly mean and range of water temperatures were later determined for both ponds.

In May, test lots of 330 fish of each strain (Arkansas, Kansas, and North Carolina) were counted and randomly assigned to separate cages with three replicates in each pond. The Arkansas strain was considered to be the control because it originated from commercial brood stock currently used by many catfish farmers in the southeast.

A sample of 200 fish was weighed during stocking to determine the mean weight of the fish in each cage. Sampling was not conducted during the growing season as Holmes (1971) and W. Lewis (pers. comm.) indicated that this disturbance would cause the fish to temporarily stop feeding. At the end of the study, the fish in each cage were counted and weighed, and a sample of 50 fish was randomly selected to determine a coefficient of condition for the fish in each cage.

For each pond, analysis of variance was used to determine if there was a significant difference between treatments (strains) in terms of yield, survival, mean weight, food conversion, coefficient of condition, and percent marketable fish. Duncan's new multiple-range test was used to make comparisons between treatment means.

Roher Pond was selected for a financial analysis. The North Carolina strain was used to determine the cost of the fingerlings as the high shipping charges incurred in the purchase of the other two strains was unrealistic for a production operation. Costs and revenues were determined in a manner similar to that used by Pfieffer (1971).

RESULTS

Feeding was initiated immediately after the May stocking and fish began to consume the food within a few days. Feeding continued for 63 days in Salem Pond and 139 days in Roher Pond. During those periods, fish in Salem Pond were fed 485 kg of food while those in Roher Pond consumed 2,290 kg. Feeding activity appeared to be normal and continued without interruption throughout the growing season. The fish in each cage consumed their allotment of food within 15 minutes.

Water temperatures during the study ranged from 18°C to 26°C (May 4 to July 15) in Salem Pond and 17°C to 27°C (May 4 to October 5) in Roher Pond (Table 1). Monthly mean temperatures between the ponds were not found to be significantly different. Water temperature remained above the point at which channel catfish have been observed to cease feeding (10°C). However, water temperatures never reached 29°C, the optimum temperature for efficient food conversion and maximum growth rate.

During June, an aquatic weed problem developed in Salem Pond. Southern niad (*Najas guadalupensis*) was observed growing in the shallow half of the pond. Aerators were used continuously to prevent a sudden drop in the dissolved oxygen concentration and Karmex (an aquatic weed toxicant) was applied at the rate of 1.0

Table 1. Monthly range and mean water temperatures for Salem and Roher Ponds

Pond	Month	Temperature (C) Low	High	Mean
Salem	May	21	23	21.2
	June	18	25	22.7
	July	22	26	23.9
Roher	May	17	18	17.6
	June	18	23	19.9
	July	21	27	23.0
	August	23	27	24.8
	September	22	27	24.1
	October	19	21	20.0

mg/l to the affected area of the pond. Unfortunately, the dissolved oxygen level near the cages dropped to less than 1.0 mg/l (even with the aerators) during the early morning of July 13. The low dissolved oxygen concentration caused a complete fishkill in the cages. Channel catfish free in the pond were presumed to have moved to the more highly oxygenated half of the pond while those confined in cages could not escape and died. All necessary data was taken immediately after the fishkill.

The caged fish in Roher Pond fed actively and seemed to behave normally throughout the growing season. However, on the morning of October 2 approximately 98% of the fish were found dead. No abnormal behavior was noted during the previous evening feeding. Temperature and oxygen readings taken at 10:00 a.m. on October 2 showed the pond to be stratified with 4.5 mg/l of dissolved oxygen at a depth of one meter. Samples of fish tissue were taken to be analyzed for herbicides and pesticides and a complete water and sediment analysis was later conducted. Results did not indicate toxic levels of herbicides, pesticides, or heavy metals, and the water quality appeared to be normal. However, it is assumed that the fishkill in Roher Pond was also a result of reduced dissolved oxygen levels, occuring in the early morning.

The yield (total weight) of fish in each cage (replicate) was determined by weighing the fish in lots and summing the weights of each lot (Table 2). Analysis of variance showed a significant difference in the yield of the three strains in Salem and Roher Ponds ($P<0.01$ and $P<0.001$, respectively). Duncan's new multiple-range test did not indicate a significant difference between the Arkansas and North Carolina strains, but the lower yield of the Kansas strain was found to be significantly different from the other two ($P<0.05$).

Survival of the fish in each cage was determined on a percentage basis by dividing the number of survivors before the fishkills by the number of fish stocked (Table 3). Analysis of variance showed no significant difference in strain survival for either pond.

The mean weight of the fish was calculated by dividing the yield by the number of survivors before the fishkills (Table 4). Significant differences were found in the mean weight of the fish in both ponds ($P<0.05$ Salem Pond; $P<0.01$ Roher Pond). Duncan's test again showed no significant differences between the Arkansas and North Carolina strains, but did indicate a significant ($P<0.05$) difference with regard to the Kansas strain which had lower mean weight values.

Table 2. Yield of three strains of channel catfish in Salem and Roher Ponds

		Yield (kg)		Mean Yield (kg)	
Strain	Cage	Salem	Roher	Salem	Roher
Arkansas	1	45.7	154.3		
	2	44.3	152.8	45.0[a]	152.2[b]
	3	44.9	149.6		
Kansas	1	40.7	138.5		
	2	33.9	135.8	35.8	136.4
	3	32.7	134.8		
North Carolina	1	42.7	147.1		
	2	44.0	150.6	43.3[a]	150.2[b]
	3	43.2	152.8		

[a]Values not significantly different at $\alpha = 0.05$ from other strains in Salem Pond

[b]Values not significantly different at $\alpha = 0.05$ from other strains in Roher Pond

Table 3. Survival of three strains of channel catfish in Salem and Roher Ponds

Strain	Cage	Survival (%) Salem	Survival (%) Roher	Mean Survival (%) Salem	Mean Survival (%) Roher
Arkansas	1	98	98		
	2	96	96		
	3	96	90		
				96.7[a]	94.7[b]
Kansas	1	98	100		
	2	97	98		
	3	82	100		
				92.3[a]	99.3[b]
North Carolina	1	80	82		
	2	82	84		
	3	94	98		
				85.3[a]	88.0[b]

[a]Values not significantly different at $\alpha = 0.05$ from other strains in Salem Pond

[b]Values not significantly different at $\alpha = 0.05$ from other strains in Roher Pond

Table 4. Mean weight of three strains of channel catfish in Salem and Roher Ponds

		Mean Weight (g)		Average Mean Weight (g)	
Strain	Cage	Salem	Roher	Salem	Roher
Arkansas	1	141	477		
	2	139	482	140[a]	487[b]
	3	141	503		
Kansas	1	126	419		
	2	105	420	117	416
	3	121	408		
North Carolina	1	161	542		
	2	162	537	154[a]	517[b]
	3	139	473		

[a]Values not significantly different at $\alpha = 0.05$ from other strains in Salem Pond

[b]Values not significantly different at $\alpha = 0.05$ from other strains in Roher Pond

Food conversion (the efficiency of converting food to flesh) was determined by dividing the amount of food fed over the growing season by the weight gain per cage (Table 5). Analysis of variance showed a significant difference in the food conversion of the fish in Salem Pond ($P<0.05$) and Roher Pond ($P<0.001$). Duncan's test showed no significant difference in food conversion in both ponds between Arkansas and North Carolina strains, but the Kansas strain which had a poor food conversion value was found to be significantly different ($P<0.05$).

Coefficient of condition, a statistic that indicates the relative robustness of a fish in numerical terms, was determined by the method of Lagler (1952) with the exception that weight was multiplied by a factor of 10^5 to bring the value of coefficient of condition (total length) near unity (Carlander, 1969) (Table 6). Analysis of variance showed a significant difference between the strains in Salem Pond ($P<0.01$) and Roher Pond ($P<0.01$). Duncan's test showed a significant ($P<0.05$) difference between North Carolina and both Arkansas and Kansas strains in Salem Pond and a significant difference in all three strains in Roher Pond. In Salem Pond the North Carolina strain had the best coefficient of condition, but in Roher Pond the Kansas strain had the best coefficient of condition.

Table 5. Food conversion of three strains of channel catfish in Salem and Roher Ponds

Strain	Cage	Food Conversion		Mean Food Conversion	
		Salem	Roher	Salem	Roher
Arkansas	1	1.81	1.84		
	2	1.90	1.86	1.86[a]	1.87[b]
	3	1.86	1.90		
Kansas	1	2.17	2.07		
	2	3.01	2.12	2.80	2.11
	3	3.22	2.14		
North Carolina	1	2.01	1.94		
	2	1.92	1.89	1.97[a]	1.90[b]
	3	1.98	1.86		

[a]Values not significantly different at $\alpha = 0.05$ from other strains in Salem Pond

[b]Values not significantly different at $\alpha = 0.05$ from other strains in Roher Pond

Table 6. Coefficient of condition of three strains of channel catfish in Salem and Roher Ponds

		Coefficient of Condition		Mean Coefficient of Condition	
Strain	Cage	Salem	Roher	Salem	Roher
Arkansas	1	0.86	0.87		
	2	0.80	0.88	0.82[a]	0.88[b]
	3	0.80	0.88		
Kansas	1	0.88	0.95		
	2	0.91	0.97	0.86[a]	0.96[b]
	3	0.78	0.97		
North Carolina	1	1.23	0.90		
	2	1.23	0.94	1.17	0.92[b]
	3	1.06	0.90		

[a]Values not significantly different at $\alpha = 0.05$ from other strains in Salem Pond

[b]Values not significantly different at $\alpha = 0.05$ from other strains in Roher Pond

A sample of fish from each cage was separated into weight classes to estimate the percentage of marketable fish (Table 7). Mitchell and Usry (1967) indicate that the minimum size acceptable for processing is 340 g. The number of fish in the sample above this weight were designated as marketable. Due to the July fishkill in Salem Pond, none of the fish attained a marketable size. In Roher Pond analysis of variance showed a significant difference between strains ($P<0.05$), and Duncan's test indicated a significant difference between the Kansas strain and both the Arkansas and North Carolina strains ($P<0.05$) which had a greater percentage of marketable fish.

The financial analysis conducted for Roher Pond shows cage culture of channel catfish profitable if the fish can be sold for more than $.610 per kg ($.277/lb.). Costs and revenues indicate that catfish farming can become an income supplement for small operations in at least the southern portion of Virginia if a market exists (Table 8).

Table 7. Percent marketable fish of three strains of channel catfish in Salem and Roher Ponds

		Marketable Fish (%)		Mean Marketable Fish (%)	
Strain	Cage	Salem	Roher	Salem	Roher
Arkansas	1	0	96		
	2	0	96	0[a]	97.0[b]
	3	0	98		
Kansas	1	0	64		
	2	0	88	0[a]	77.3
	3	0	80		
North Carolina	1	0	92		
	2	0	90	0[a]	92.0[b]
	3	0	94		

[a]Values not significantly different at $\alpha = 0.05$ from other strains in Salem Pond

[b]Values not significantly different at $\alpha = 0.05$ from other strains in Roher Pond

Table 8. Financial analysis of channel catfish cage production in Roher Pond excluding pond construction costs

ANNUAL EXPENSES	
Fingerlings (2,000, 175 mm, @ $.075 each)	$150.00
Food (308.6 kg, @ $0.25/kg)	77.15
Labor	
Daily checking and feeding (69.5 hrs @ $1.65/hr)	114.66
Harvesting (3.0 hrs @ $1.65/hr)	4.95
Equipment	
Cages (amortized at 8% for 3 years) (6 cages @ $52.00 each x 0.388)	121.05
Feed scale (amortized at 8% for 3 years) ($22.00 x 0.388)	8.54
Oxygen kit (amortized at 8% for 3 years) ($14.00 x 0.388)	5.43
Rope (amortized at 8% for 3 years) (550 m @ $12.00 x 0.388)	4.65
Interest on borrowed capital (fingerlings @ 8%)	12.00
(food and labor @ 4%)	7.89
TOTAL	$506.32
Returns (expected)	
829 kg fish @ $0.66/kg ($0.30/lb)	547.14
@ $0.88/kg ($0.40/lb)	728.52
Less expenses	-506.32
Net returns to land management and other fixed costs before taxes/year/0.6 ha pond	
@ $0.66/kg ($0.30/lb)	40.82
@ $0.88/kg ($0.40/lb)	222.20

Table 8. (Continued)

BREAKEVEN PRICE*	
	\$0.610/kg (\$0.277/lb)

*Transportation cost excluded the breakeven price for the Arkansas and Kansas strains was \$0.574/kg (\$0.260/lb) and \$0.801/kg (\$0.364/lb), respectively.

DISCUSSION

The following results should be considered in the evaluation of the three channel catfish strains: (1) statistical analysis indicates the Kansas strain was significantly different from the Arkansas and North Carolina strains with respect to yield, mean weight, percent marketable fish, and food conversion; (2) the Kansas strain had lower mean values for every statistic with the exception of a higher coefficient of condition in Roher Pond; and (3) in this study, the North Carolina fish would have to be sold for more than $.610 per kg to make the operation profitable.

Yield is dependent upon food supply, competition, survival, and food conversion (basically temperature dependent). In this study the amount of food and the temperature remained constant between cages and the level of competition in the cages was assumed to be the same because the fish were of the same species and size. Usually with a low survival, a low yield can be expected. However, the Kansas strain had the best overall survival, but the yield was the lowest. This was due to the smaller size of the fish. Furthermore, the North Carolina strain had the lowest survival, but was not significantly different in yield from the Arkansas strain. Because survival does not seem to directly influence yield in this study, food conversion would most likely be the factor to affect yield. Yields obtained in the study do appear to follow this hypothesis. The Arkansas strain had the lowest mean food conversion and produced the greatest yield while the Kansas strain had the highest food conversion and produced the lowest yield. Food conversion rates compare favorably with commercial catfish farming operations. Adrian and McCoy (1971) reported that the average food conversion for commercially grown channel catfish was approximately 1.90, but Collins (1970) obtained an average food conversion of 1.32 for caged channel catfish under research conditions.

The overall survival of the strains was high in comparison to Holmes' (1971) study when a mean survival of 60.4% was obtained for caged fish, but was lower when compared to experimental cage culture where survival rates of approximately 97% were obtained (Schmittou, 1969). The number of survivors in each cage seemed to influence the mean weight of the fish. Generally, fish producing a greater yield should have a greater mean weight, and conversely, fish producing lower yields should have low mean weights if survival remains constant. The Arkansas and North Carolina strains produced essentially the same yield, but due to the lower survival of the North Carolina strain greater mean weight values were obtained.

Formulas have been developed by relating length and weight to represent the relative plumpness of a fish in numerical terms. The coefficient of condition has been derived for this use; objective comparisons can be made with this coefficient under different geographical or time situations (Bennett, 1971). A robust fish will show a higher coefficient than a thin specimen and will usually yield more useable flesh after processing. Conflicting results were obtained with regards to the coefficient of condition of the strains. In Salem Pond, the North Carolina strain had the highest coefficient while in Roher Pond the Kansas strain had the greatest coefficient of condition. Possibly, a comparison of this nature cannot be validly made because coefficients of condition are known to vary with age and pond environments (Lagler, 1952).

Due to the July fishkill at Salem Pond, none of the fish reached a marketable size. The quantity of fish attaining a marketable size is an important consideration in catfish farming, as profits will be substantially diminished if only a small percentage of the yearly crop of fish is marketed. Approximately 89% of the fish in Roher Pond were of a market-size (>340 g). Generally, Duncan's new multiple-range test does not show any significant differences between the Arkansas and North Carolina strains. If high shipping costs are not incurred, the Arkansas or North Carolina strains would appear to produce the greatest profit on a yearly basis. High shipping costs can be reduced by combining orders of fish so that they arrive on the same shipment, or the farmers could eventually establish a fingerling production facility. However, at the present time it would be more reasonable to utilize the North Carolina strain. The hatchery producing these fish is within a reasonable shipping distance from most locations in southern Virginia. Transportation costs, therefore, would be substantially reduced.

With regard to the methodology of cage culture, some suggestions can be made as a result of the study. Emphasis should be placed on selecting a suitable pond, and the various physical and chemical parameters of the pond must be carefully considered. The dissolved oxygen levels of the ponds utilized in this study appeared to have caused the major problems. Hatcher (n.d.) recommends a dissolved oxygen level of at least 5 mg/l. At levels lower than this the fish may not die, but can be stressed. The resultant weakening of the fish makes them more susceptible to disease. Ponds used for cage culture should have most of their surface area exposed to wind action or receive adequate flushing to aerate the water and permit dilution of waste products. Rooted aquatic weeds should be kept to a minimum level as respiration during the night and overcast days will lower the dissolved oxygen level in the pond. The cages should be placed far enough apart and in positions relative to each other so that wind-induced water currents and water circulation will not be inhibited. Finally, cage culture in small still-water farm ponds is not generally recommended for southern Virginia as the chances of oxygen depletion are high during hot summer months when there is no facility for aeration.

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(ABSTRACT)

Three strains of channel catfish, *Ictalurus punctatus* (Rafinesque), from the southeastern United States were cultured in cages to select a strain that would attain a marketable size during the relatively short Virginia growing season. The strains were compared in terms of yield, survival, mean weight, food conversion, coefficient of condition, and percent marketable fish. Statistical analysis indicated that the Kansas strain was significantly different from both the Arkansas and North Carolina strains, but the latter two were not significantly different with respect to yield, mean weight, food conversion, and percent marketable fish. A financial analysis, conducted to evaluate the feasibility of culturing channel catfish in cages moored in small farm ponds, showed that the fish would have to be sold for more than $.610 per kg ($.277/lb.) to make the operation profitable. Cage culture of channel catfish is possible in Virginia, but is not generally recommended for small still-water farm ponds.