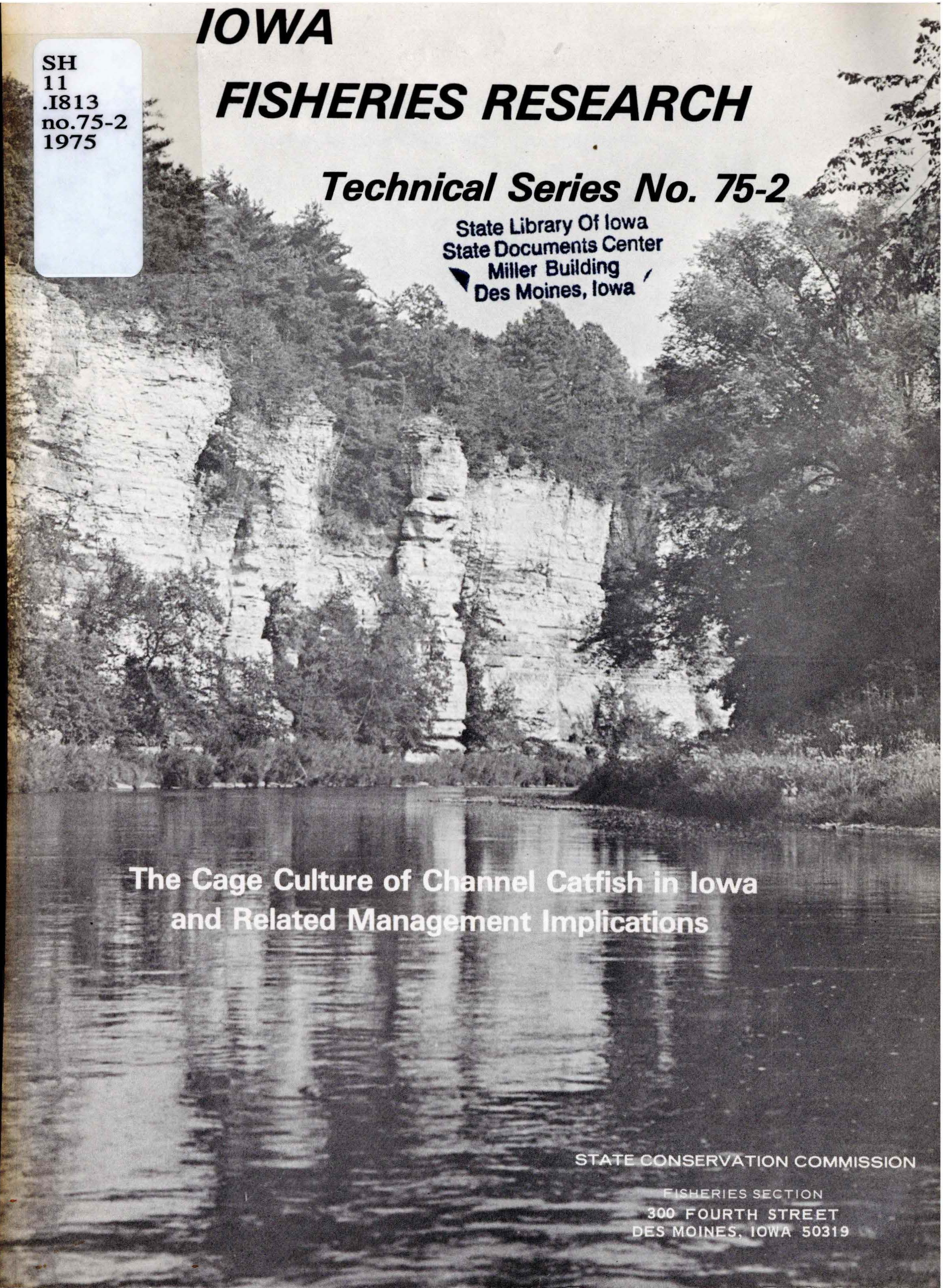
IOWA FISHERIES RESEARCH

Technical Series No. 75-2



The Cage Culture of Channel Catfish in Iowa and Related Management Implications

STATE CONSERVATION COMMISSION
FISHERIES SECTION
300 FOURTH STREET
DES MOINES, IOWA 50319

THE CAGE CULTURE OF CHANNEL CATFISH IN IOWA AND RELATED MANAGEMENT IMPLICATIONS[1]

Larry Mitzner
Fishery Research Biologist

and

Robert Middendorf
Fishery Management Biologist

Technical Series 75-2

Fisheries Section

Jerry M. Conley
Superintendent of Fisheries

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SYNOPSIS

Channel catfish were reared in confinement cages during 1970-1974 at 46 Iowa lakes resulting in the release of 365,254 fish. Catfish were placed in cages during May-June at a mean length of 132 mm (5.5 in) and released in September-October at a mean length and weight of 236 mm (9.3 in) and 125 g (4.4 oz). During confinement catfish were fed a floating pellet ration at 3-4% of their body weight daily. Mean annual conversion ratio was 2.3:1 and ranged from 1.45:1 in 1970 to 2.4:1 in 1974. Overall survival of cage confined channel catfish was 88%, but ranged from 96% in 1970 to 82% in 1973. Disease and low dissolved oxygen were major sources of mortality, while vandalism and faulty cage construction comprised the remaining catfish loss. Cost analysis of the program in 1971 showed the average cost of released catfish was $1.87/kg (85¢/lbs) of which 52% was attributed to labor, 29% feed, 13% materials and 6% fish transportation and handling. Upon release catfish were caught by fishermen at an average of .15 fish per hour, but at some lakes the maximum was .22 fish per hour with best success in late summer. Growth and body condition of channel catfish after release depended mainly on the abundance and availability of natural food, particularly dipteran larvae. Macrobenthic invertebrate density at Williamson Pond decreased 53% as catfish biomass increased 75%. During the same period growth rate was reduced by about 70%, but catfish > 356 mm (14 in) were not adversely affected. Bluegill also showed a decrease in growth rate and body condition of the same magnitude as catfish < 356 mm (14 in). Accomplishments and management implications of the cage culture program were discussed and recommendations were presented for enhancement of the program. Many tangible and intangible benefits were evident, but most important channel catfishing was created at many lakes where it didn't exist before. Since 1970, nearly two million angler hours were devoted to catfishing as a result of cage culture releases, with an estimated catch of 300,000 catfish.

INTRODUCTION

Channel catfish are one of the most widely sought sport fish species in Iowa and have been managed as a fishery resource since the inception of the Iowa Fish Commission in 1874. A recent public survey of Iowa fishermen revealed 16% of the anglers interviewed indicated they preferred to catch channel catfish. In fact, catfish were surpassed only by bullhead and crappie in the poll. Many inland lakes were stocked with catfish from the Mississippi River as early as 1876. Intensive stocking programs using fish from the river continued into the 1950's when hatchery fish became the main source. Hatchery production of 2-3 inch fingerlings was used mainly to stock newly impounded man-made lakes, and to a lesser extent, farm ponds. Recreational lakes that already contained adult fish populations were also stocked with fingerlings to supplement catfish populations.

Stocking success of small fingerling catfish in autumn was satisfactory in newly constructed impoundments, but survival of small channel catfish in lakes with established predator populations, with few exceptions, was poor. The program was reviewed in 1969 and it was apparent catfishing from stocked fingerling catfish in lakes with adult populations was unsatisfactory.

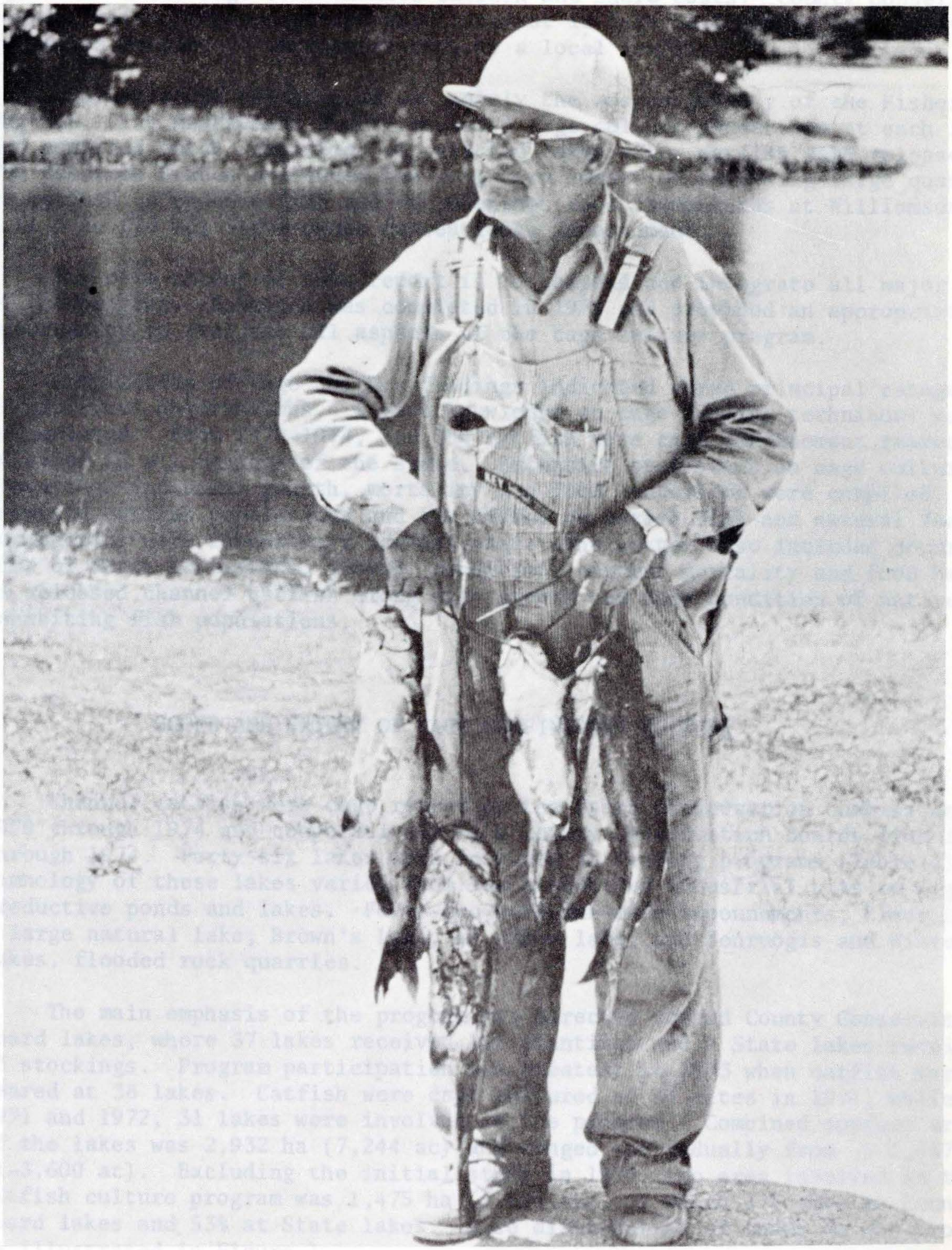
The most auspicious alternative was to plant one-year old hatchery reared catfish. Pond confinement of catfish for an additional year was prohibitive in Iowa because sufficient rearing space was not available and overwintering mortality was excessive in earthen ponds.

Preliminary development of cage confinement rearing in some southern states in the mid-1960's provided a potential for stocking catfish large enough to avoid predation, precluding hatchery pond use after the first year of life. The principle development of cage culture was completed at Southern Illinois University, Auburn University and Arkansas State College (Collins, 1970). Fingerling channel catfish were confined in floating cages and fed commercial, dry rations. Refinement of the technique, including cage construction materials and dimensions, stocking density, and feeding rates were, for the most part, concluded by 1968. Commercial production of catfish for food using confinement culture also contributed to rapid development of the technique.

Cage culture development provided an opportunity for the Fisheries Section to test the technique in Iowa. A preliminary evaluation was conducted in 1970 at four State-owned lakes to determine the feasibility in this state (Conley, 1971). Results proved adequate for program expansion.

The Fisheries Section initiated a statewide cage confinement rearing program the following year to produce channel catfish in cooperation with County Conservation Boards. The Fisheries Section assumed responsibility of providing fingerling catfish and the technical assistance needed to rear fish, while County Boards provided cages and the fish food. The mutual goal of both

[1]Funds for this study were provided by the Federal Aid in Fish Restoration Act (PL 81-681), Project F-88-R, US Fish and Wildlife Service and the Iowa Conservation Commission cooperating.



Nearly 300,000 channel catfish weighing over 100 tons were caught as a result of cage confinement rearing programs.

agencies was to cage rear channel catfish and share costs. County Conservation Boards, which previously expressed interest in lake catfishing, worked with the Fisheries Section to improve fishing at a local level.

Evaluation of the program was solely the responsibility of the Fisheries Section. The Management Branch measured cage culture production at each lake and compiled catch statistics at selected lakes after catfish were released. The Research Branch evaluated the long-term impact of releasing large quantities of catfish on endemic fish and macrobenthos food communities at Williamson Pond, a 11.4 ha (28 ac) State-owned recreational impoundment.

The main intent of this report is to compend and integrate all major aspects of the program. Research was completed in 1975 and provided an appropriate opportunity to evaluate all aspects of the cage culture program.

Compilation of cage culture findings indicated three principal categories of empirical observations. A vast knowledge on cage rearing techniques was accumulated. From 1970-1974, 365,254 catfish were cage confinement reared and released in all regions of the state. Extensive statistics on cage culture production including growth, mortality and food conversion were compiled. Released catfish populations and the affect on native fish and natural food communities were intensively investigated. The latter also included documentation of catch statistics, growth, condition, natural mortality and food habits of released channel catfish along with growth and body condition of native cohabiting fish populations.

SCOPE AND EXTENT OF CAGE CONFINEMENT CULTURE

Channel catfish were cage reared by the State Conservation Commission from 1970 through 1974 and cooperatively with County Conservation Boards from 1971 through 1974. Forty-six lakes were included in rearing programs (Table 1). Limnology of these lakes varied from low productive industrial pits to highly productive ponds and lakes. Forty-two were man-made impoundments; Clear Lake, a large natural lake; Brown's Lake, an oxbow lake; and Yenruogis and Winterfield Lakes, flooded rock quarries.

The main emphasis of the program was directed toward County Conservation Board lakes, where 37 lakes received 115 plantings and 9 State lakes received 23 stockings. Program participation was greatest in 1973 when catfish were reared at 38 lakes. Catfish were cage cultured at 34 sites in 1974, while in 1971 and 1972, 31 lakes were involved in the program. Combined surface area of the lakes was 2,932 ha (7,244 ac) and ranged individually from .5-1,457 ha (1-3,600 ac). Excluding the initial study in 1970, the area involved in the catfish culture program was 1,475 ha (3,644 ac), of which 47% were at County Board lakes and 53% at State lakes. Size distribution of lakes in the program is illustrated in Figure 1.

Table 1. Name, size, location and number of years County Conservation Board and State-owned lakes participated in the channel catfish cage rearing program.

Impoundment	County	Hectares	Acres	Years of cage rearing
Morman Trail	Adair	14	35	1973-74
Hannen	Benton	18	45	1971-74
Hickory Hill	Black Hawk-Tama	23	55	1971-73
Don Williams	Boone	66	160	1971-74
Fontana Mills	Buchanan	24	60	1971-73-74
Swan	Carroll	53	130	1971-74
Cold Springs	Cass	7	16	1971-74
Clear[a]	Cerro Gordo	1,457	3,600	1970
Nelson	Crawford	6	15	1971-74
Wapello[a]	Davis	116	287	1970-74
Slip Bluff	Decatur	10	25	1972-74
Silver	Delaware	14	35	1973-74
Spring	Greene	20	49	1971-74
Stoehr	Grundy	1	2	1974
Briggs Wood	Hamilton	28	70	1974
Eldred-Sherwood	Hancock	10	25	1971-73
Moorehead	Ida	5	12	1972-74
Iowa	Iowa	39	96	1972-74
Mariposa	Jasper	8	19	1971-74
Kent	Johnson	12	30	1971-74
MacBride[a]	Johnson	385	950	1971-73
Central	Jones	10	25	1971-74
Yenruogis	Keokuk	4	10	1973-74
Smith	Kossuth	21	53	1971-73
Red Haw[a]	Lucas	29	72	1974
Williamson[a]	Lucas	10	25	1971-73
Keomah[a]	Mahaska	33	82	1973-74
Marion	Marion	3	8	1971-74
Dog Creek	O'Brien	12	30	1971-73-74
Pioneer	Page	1	3	1974
Easter	Polk	92	228	1971-72
Thomas Mitchell	Polk	4	10	1973
Arrowhead	Pottawattamie	8	20	1971-74
Diamond	Poweshiek	53	130	1971-74
Game Ponds[a]	Ringgold	2	6	1971-73
Loch Ayr[a]	Ringgold	38	95	1970-72
Odetta-Cody	Scott	5	12	1971-74
Manteno	Shelby	5	11	1971-74
Winterfield	Sioux	4	10	1971-73
Hickory Grove	Story	45	110	1971-74
Otter Creek	Tama	28	70	1973-74
Marr	Washington	< 1	1	1971-74
Badger	Webster	24	60	1971-74
Meyers	Winneshiek	14	35	1971-74
Brown's[a]	Woodbury	162	400	1970-71
Little Sioux	Woodbury	5	12	1973-74

[a] State-owned lakes.

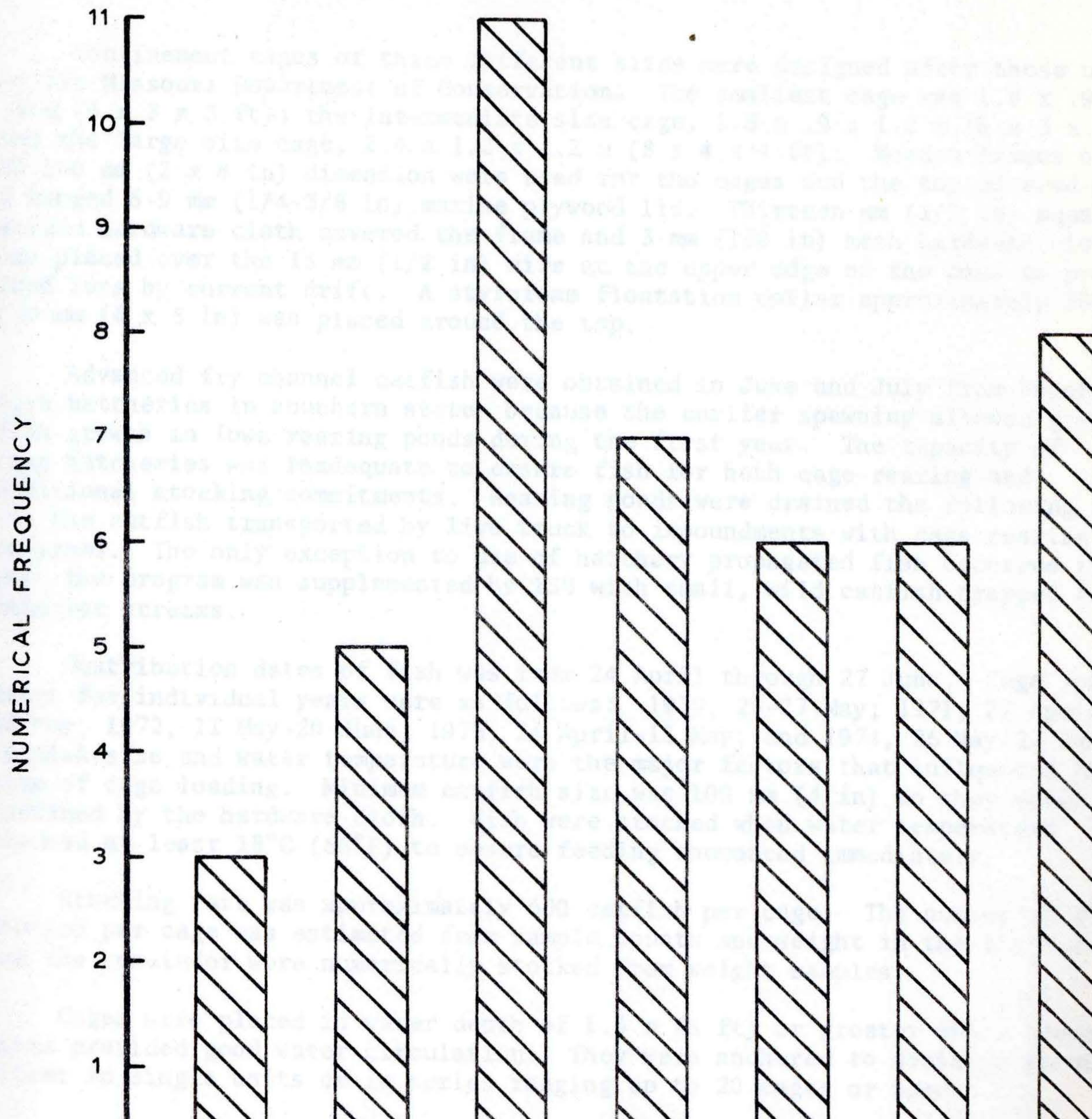


Figure 1. Size-frequency distribution, in surface area, of lakes in the cage culture program from 1970-74.

CAGE CONFINEMENT REARING TECHNIQUE

Confinement cages of three different sizes were designed after those used by the Missouri Department of Conservation. The smallest cage was 1.8 x .9 x .9 m (6 x 3 x 3 ft); the intermediate size cage, 1.8 x .9 x 1.2 m (6 x 3 x 4 ft); and the large size cage, 2.4 x 1.2 x 1.2 m (8 x 4 x 4 ft). Wooden frames of 50-100 mm (2 x 4 in) dimension were used for the cages and the top covered with a hinged 6-9 mm (1/4-3/8 in) marine plywood lid. Thirteen mm (1/2 in) square welded hardware cloth covered the frame and 3 mm (1/8 in) mesh hardware cloth was placed over the 13 mm (1/2 in) wire at the upper edge of the cage to prevent food loss by current drift. A styrofoam floatation collar approximately 100-130 mm (4 x 5 in) was placed around the top.

Advanced fry channel catfish were obtained in June and July from Federal fish hatcheries in southern states because the earlier spawning allowed greater fish growth in Iowa rearing ponds during the first year. The capacity of Iowa hatcheries was inadequate to ensure fish for both cage rearing and additional stocking commitments. Rearing ponds were drained the following spring and the catfish transported by live truck to impoundments with cage rearing programs. The only exception to use of hatchery propagated fish occurred in 1972 when the program was supplemented by 15% with small, wild catfish trapped from interior streams.

Distribution dates of fish was from 24 April through 27 June. Cage loading dates for individual years were as follows: 1970, 25-27 May; 1971, 22 April-15 May; 1972, 11 May-20 June; 1973, 24 April-15 May; and 1974, 26 May-27 June. Catfish size and water temperature were the major factors that influenced the time of cage loading. Minimum catfish size was 100 mm (4 in) so they would be confined by the hardware cloth. Fish were stocked when water temperature reached at least 18°C (65°F) to ensure feeding commenced immediately.

Stocking rate was approximately 600 catfish per cage. The number of fish stocked per cage was estimated from sample counts and weight in the first cage and the remainder were numerically stocked from weight samples.

Cages were placed in water depth of 1.5 m (5 ft) or greater where prevailing winds provided good water circulation. They were anchored to docks or in midwater either in single units or in series ranging up to 20 cages or more.

Catfish were fed a 32-40% protein floating pellet ration primarily of Purina or Splash brand during confinement. In most instances No. 4 trout chow was fed immediately after the fish were stocked and as fish size increased, large fingerling and developed trout chow or catfish formula was fed. Fish were fed 3-4% of their body weight daily at approximately the same time each day. Feeding frequency varied from 5 days each week at some impoundments to every day at others. Food requirements were adjusted according to fish growth at 3-4 week intervals. Fish were inspected for disease at the same time. Food consumption and fish mortality were recorded at each impoundment.

Confinement reared catfish were released during September or October when water temperature approached 18.3°C (65°F) or when catfish stopped feeding. Severe disease epizootics, dissolved oxygen depletion, and vandalism were reported at several lakes. The fish were usually released early following these incidences. Release dates for individual years were as follows: 1970, 11 September-13 October; 1971, 13 August-4 October; 1972, 13 July-2 October; 1973, 11 July-5 October; and 1974, 12 July-4 October. Catfish were counted, weighed in aggregate and individual subsamples measured in length and weight as they were released.

CAGE CULTURED CHANNEL CATFISH MANAGEMENT

CAGE LOADING

The cage rearing program involved the loading of 416,531 channel catfish over the five years. County Conservation Board lakes were allocated 88% of the fish and 12% were stocked at State-owned lakes (Table 2). In the first year, 1,152 catfish were loaded in the confinement cages followed by 103,280 in 1971; 120,797 in 1972; 116,673 in 1973; and 74,629 in 1974.

Table 2. Total number of fingerling channel catfish loaded in cages at State and County Conservation Board lakes, 1970-1974.

	1970	1971	1972	1973	1974	Total
State-owned	1,152	14,168	10,200	14,400	8,780	48,700
County-owned		89,112	110,597	102,273	65,849	367,831
Total	1,152	103,280	120,797	116,673	74,629	416,531

Fluctuation in the number of stocked fish was due entirely to varied hatchery production and number of lakes in the program. Full allotments for the requested number of fish was achieved only in 1971 and 1973. A shortage occurred in 1972 and the 102,060 hatchery fish were supplemented with 18,620 small, wild catfish from inland rivers. Quotas were proportionately reduced at each lake in 1974 due to a shortage of hatchery fish. Two large State-owned lakes were excluded from the program in 1974 to meet the county needs.

The overall mean weight and length of catfish loaded in cages from 1970-1974 was 17 g (.59 oz) and 117 mm (4.6 in). Body size varied each season with the largest fish loaded in 1970 at 25 g (.89 oz) and 152 mm (6 in), while the smallest fish, 14 g (.47 oz) and 114 mm (4.5 in), were loaded in 1973 (Table 3). Wild catfish cage confined in 1972 increased the average size that year to 20 g (.7 oz) and 142 mm (5.6 in). River catfish were the largest of all fish loaded averaging 54 g (1.9 oz) and 203 mm (8.0 in).

Table 3. Average and range in body length and weight for catfish stocked in confinement cages from 1970-74.

		1970	1971	1972	1973	1974
Mean weight	(g)	25	15	20	14	20
	(oz)	.9	.5	.7	.5	.7
Weight range	(g)	19-35	9-17	9-74	11-17	10-26
	(oz)	.7-1.2	.3-.6	.3-2.6	.4-.6	.4-.9
Mean length	(mm)	152	114	142	114	140
	(in)	6.0	4.5	5.6	4.5	5.5
Length range	(mm)	102-216	75-132	75-230	75-132	75-152
	(in)	4.0-8.5	3.0-5.2	3.0-9.4	3.0-5.2	3.0-6.4

GROWTH OF CAGE CONFINED CATFISH

Growth of the cage confined catfish was rapid. The mean number of days the fish were fed ranged from 99 in 1974 to 134 during 1973. At some lakes confinement length was reduced due to dissolved oxygen depletion and vandalism with some fish released after only 30 days. Lakes where severe mortality occurred or related problems developed were excluded from growth computations.

Mean growth of cage cultured catfish overall was 107 g (4 oz) and 100 mm (3.9 in) (Table 4). Greatest average catfish weight gain was 202 g (7 oz) in 1970. In this year, the weight at loading averaged 25 g (1 oz) and increased at release to 227 g (8 oz). A systematic decrease in gain occurred at most lakes in each succeeding year. As an example, in 1971 the mean net gain was 148 g (5 oz) followed by 96 g (3 oz) in 1972, 94 g (3 oz) in 1973 and 85 g (3 oz) in 1974.

Net gain in 1970 ranged from 125 g (4 oz) during 107 days of feeding at Brown's Lake to 289 g (10 oz) for 117 days at Loch Ayr. In 1971, the range was 48 g (2 oz) after 136 days at Brown's Lake, to 249 g (9 oz) at Mariposa after 139 days. The following season the smallest gain was 29 g (1 oz) at Loch Ayr during 89 days, and the maximum 155 g (5 oz) at Slip Bluff Lake following 118 days of confinement. In 1973, the smallest gain occurred at Swan Lake with 14 g (.5 oz) during 77 days of feeding, while the maximum reported was 196 g (7 oz) at Morman Trail Lake in 134 days. In 1974, catfish were released at Odetta-Cody after 33 days following a gain of 19 g (.7 oz), while the largest gain was at Cold Springs Lake with 155 g (5 oz) after 115 days of confinement.

Table 4. Average growth in weight (g) and length (mm) of all cage reared channel catfish. Values in parenthesis are ounces and inches.

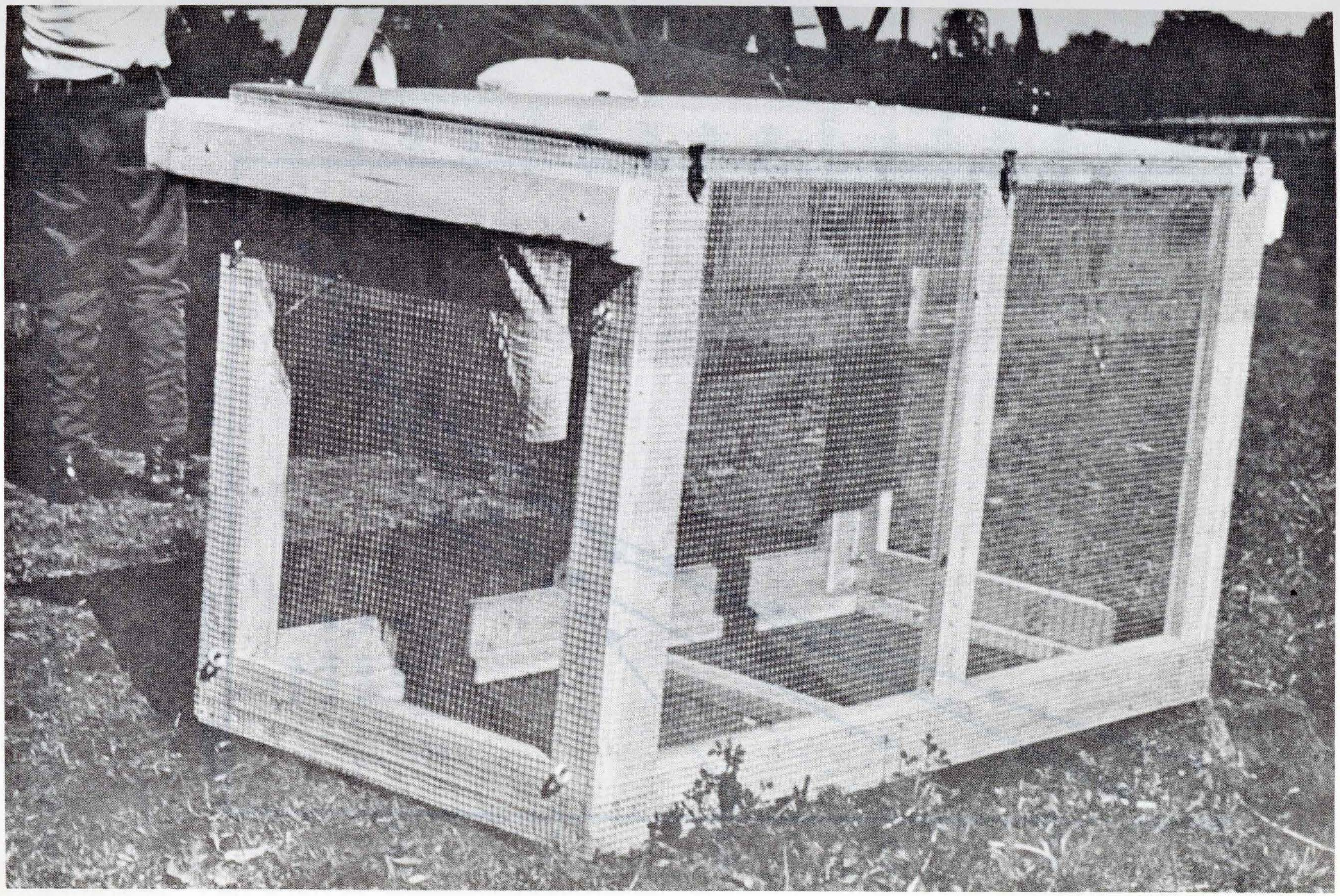
	1970	1971	1972	1973	1974	Average
Weight						
Initial	25 (.9)	15 (.5)	20 (.7)	14 (.5)	20 (.7)	17 (.6)
Release	227 (8.0)	163 (5.7)	116 (4.1)	108 (3.8)	105 (3.7)	124 (4.4)
Net gain	202 (7.1)	148 (5.2)	96 (3.4)	94 (3.3)	85 (3.0)	107 (3.8)
Length						
Initial	144 (5.7)	114 (4.5)	142 (5.6)	114 (4.5)	140 (5.5)	127 (5.0)
Release	272 (10.7)	249 (9.8)	226 (8.9)	224 (8.8)	218 (8.5)	231 (9.1)
Net gain	128 (5.0)	135 (5.3)	84 (3.3)	110 (4.3)	78 (3.1)	100 (3.9)

Seasonal growth in weight was recorded at regular intervals in 1971-1974 at 5 southeastern Iowa lakes (Kent, Central, Hannen, Iowa and Williamson Lakes). In 1971, mean weight at loading on 6 May was 12 g (.4 oz). Weight increased steadily to 20 July when growth greatly accelerated and the final mean weight was 165 g (6 oz) on 15 September (Figure 2). During 1972, weight increased most rapidly after 27 July. Fastest growth rate in 1973 was after 1 August. Growth in 1974 was poorest of all years, with the best growth rate reported during a short interval in July.

Growth of confinement reared catfish was compared in 11 northern and 5 southern region lakes for 1971. At stocking on 15 May the fish in southern impoundments averaged 17 g (.59 oz) compared to 15 g (.55 oz). Weight gain remained static in both regions until 1 June when growth in southern lakes became significantly greater ($P < .05$) than northern lakes. The weight difference averaged 46 g (1.6 oz) between the two groups on 12 September (Figure 3).

CONVERSION OF THE FOOD RATION

Total weight of the catfish upon initial crib confinement for all years was 7,019 kg (15,460 lbs) and after rearing, the weight of released catfish increased to 45,381 kg (99,959 lbs), a net gain of 38,363 kg (84,499 lbs). The catfish were fed 86,605 kg (190,759 lbs) of commercial dry food yielding a conversion ratio of 2.3 kg of food for each kg (2.3:1) of gained body weight (Table 5). The ratio varied widely from 1.2:1 to 7.7:1 at the different lakes. By year, 1970 ranked lowest in food conversion with 1.45:1 which was followed by systematically higher conversions until stabilizing at 2.4:1 during 1972-73-74.



Channel catfish were confinement reared in small mesh, floating wire cages in 46 Iowa lakes.

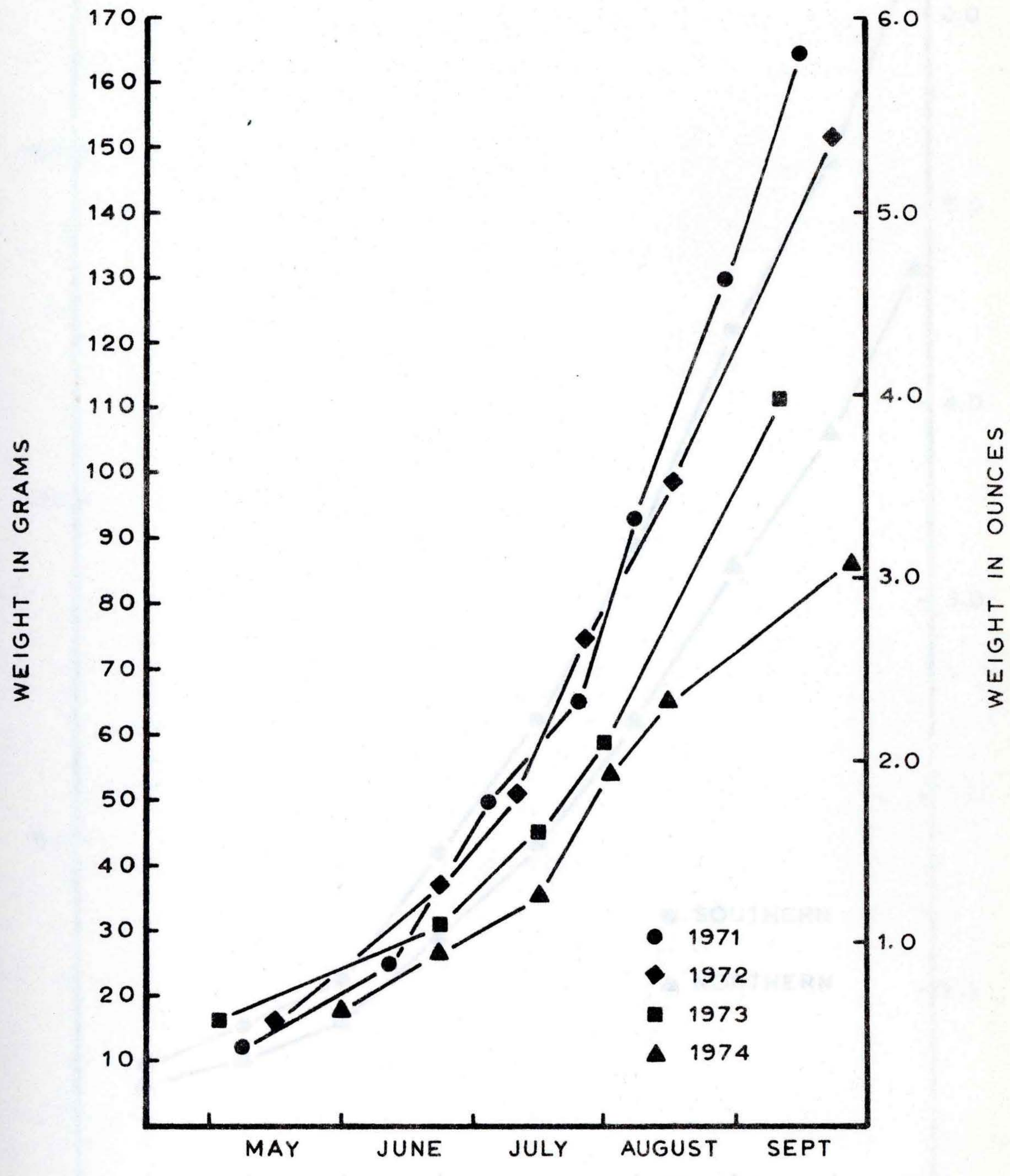


Figure 2. Seasonal weight of cage cultured channel catfish in five southeastern Iowa lakes, 1971-74.

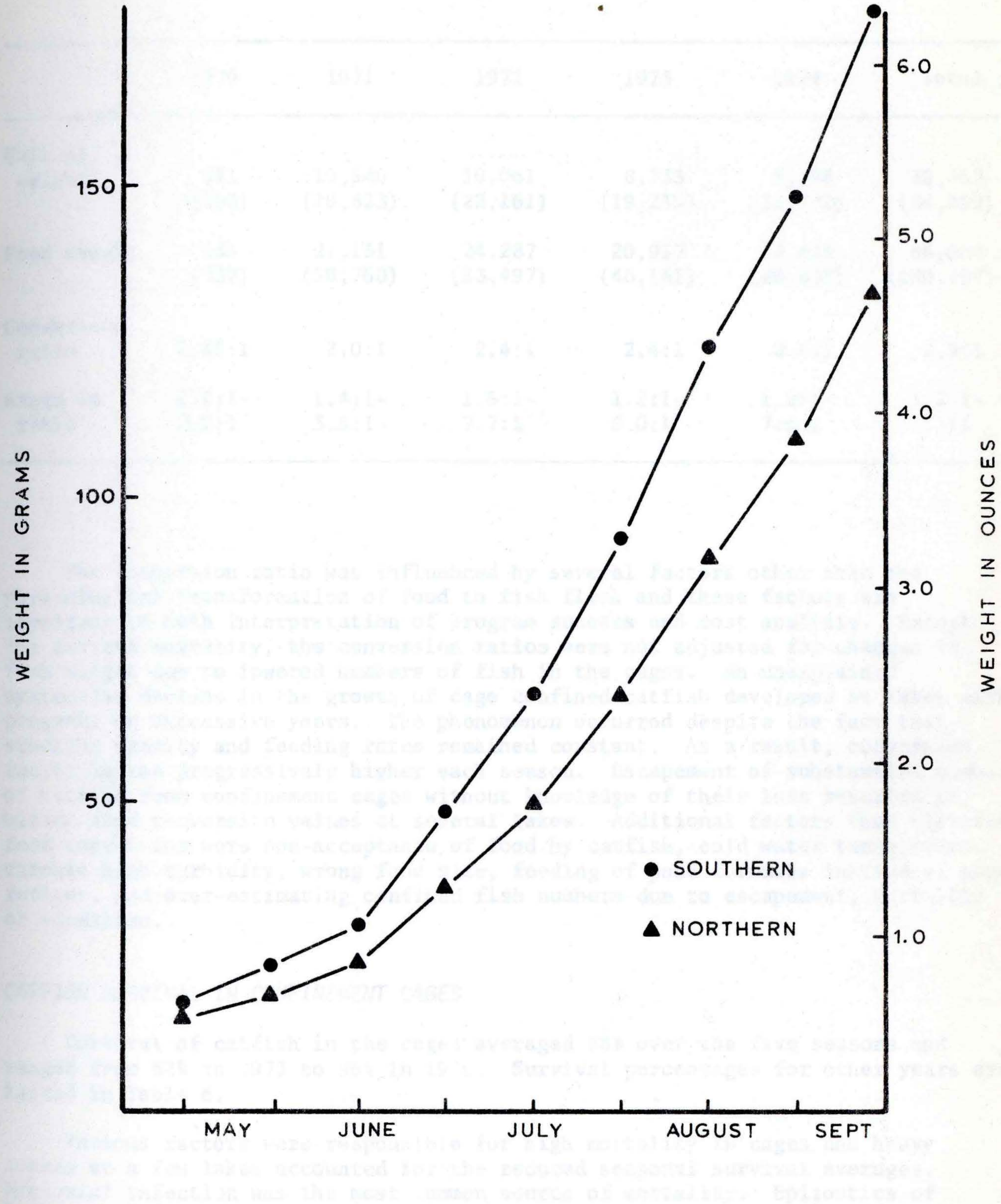


Figure 3. Weight growth comparisons of cage reared channel catfish in 11 northern Iowa lakes and 5 southern Iowa lakes in 1971.

Table 5. Weight gain, food weight in kg (lbs) and food conversion of cage cultured channel catfish.

	1970	1971	1972	1973	1974	Total
Gain in weight	231 (508)	13,540 (29,823)	10,061 (22,161)	8,733 (19,235)	5,798 (12,772)	38,363 (84,499)
Food weight	335 (737)	27,131 (59,760)	24,287 (53,497)	20,957 (46,161)	13,895 (30,605)	86,605 (190,757)
Conversion ratio	1.45:1	2.0:1	2.4:1	2.4:1	2.4:1	2.3:1
Range in ratio	1.2:1-2.0:1	1.4:1-3.8:1	1.5:1-7.7:1	1.2:1-5.0:1	1.2:1-7.6:1	1.2:1-7.7:1

The conversion ratio was influenced by several factors other than the physiological transformation of food to fish flesh and these factors are important to both interpretation of program success and cost analysis. Except for extreme mortality, the conversion ratios were not adjusted for changes in fish weight due to lowered numbers of fish in the cages. An unexplained systematic decline in the growth of cage confined catfish developed at lakes with programs on successive years. The phenomenon occurred despite the fact that stocking density and feeding rates remained constant. As a result, conversion ratios became progressively higher each season. Escapement of substantial numbers of catfish from confinement cages without knowledge of their loss resulted in biased food conversion values at several lakes. Additional factors that elevated food conversion were non-acceptance of food by catfish, cold water temperature, chronic high turbidity, wrong food size, feeding of pond formulas instead of cage rations, and over-estimating confined fish numbers due to escapement, mortality or vandalism.

CATFISH SURVIVAL IN CONFINEMENT CAGES

Survival of catfish in the cages averaged 88% over the five seasons and ranged from 82% in 1973 to 96% in 1970. Survival percentages for other years are listed in Table 6.

Various factors were responsible for high mortality in cages and heavy losses at a few lakes accounted for the reduced seasonal survival averages. Bacterial infection was the most common source of mortality. Epizootics of *Icthyophthirius*, *Aeromonas*, and *Columnaris* caused the death of over 13,000

Table 6. Survival of cage reared channel catfish in the statewide program, 1971-74.

	1970	1971	1972	1973	1974	Combined
Number loaded	1,152	103,280	120,797	116,673	74,629	416,531
Number released	1,110	92,520	107,120	95,642	68,862	365,254
Survival	96%	90%	89%	82%	92%	88%

catfish. Nocturnal dissolved oxygen depletion, mainly from periphyton blocking water circulation through the cages, was reported at seven lakes which resulted in the death of over 11,000 fish. Vandalism and faulty construction caused the loss of about 3,000 fish, but the fish escaping through holes in the cages presumably remained in the lake population and were not completely lost from the fishery. Confinement cages were washed over the spillway at Odetta-Cody Lake during a flash flood causing the death of 1,200 fish.

Significant mortality was reported at about 20% of the lakes and varied between seasons. In 1972, substantial mortality occurred at 8 of the 28 lakes. Contrary, excessive mortality was reported at 4 of 34 lakes in 1974. Stricter environmental requirements for initiation of cage confinement programs would reduce the chances of catastrophic mortality.

COST OF THE CAGE REARING PROGRAM

Expense of the cage culture program was jointly shared by the Fisheries Section and County Conservation Boards. State costs were incurred from fish distribution and service for weighing fish samples, disease diagnosis and fish release. County Conservation Board expense included cage material cost, fish food and labor including cage construction, feeding and release.

Complete cost analyses were maintained at 28 lakes in 1971. The total program cost was $25,387 to produce 13,528 kg (29,823 lbs) of fish at an average cost of $1.87/kg (85¢/lbs). Individual lake programs ranged from $1.08/kg (49¢/lbs) at Mariposa Lake to $10.19/kg ($4.62/lbs) at Manteno Lake.

Labor was by far the greatest single expenditure accounting for 52% of the total (Figure 4). County Boards and the Fisheries Section shared labor cost almost equally at 27% and 25%, respectively. Fish food costs ranked second accounting for 29% of the program expense. Cage construction and materials were depreciated on a four year replacement schedule that accounted for 13% of the annual expenses. The remaining 6% was attributed to pond draining, fish grading and transporting catfish to the lakes and was funded by the Fisheries Section. The County Conservation Boards paid for 69% of the program costs, while the Fisheries Section was responsible for 31%.

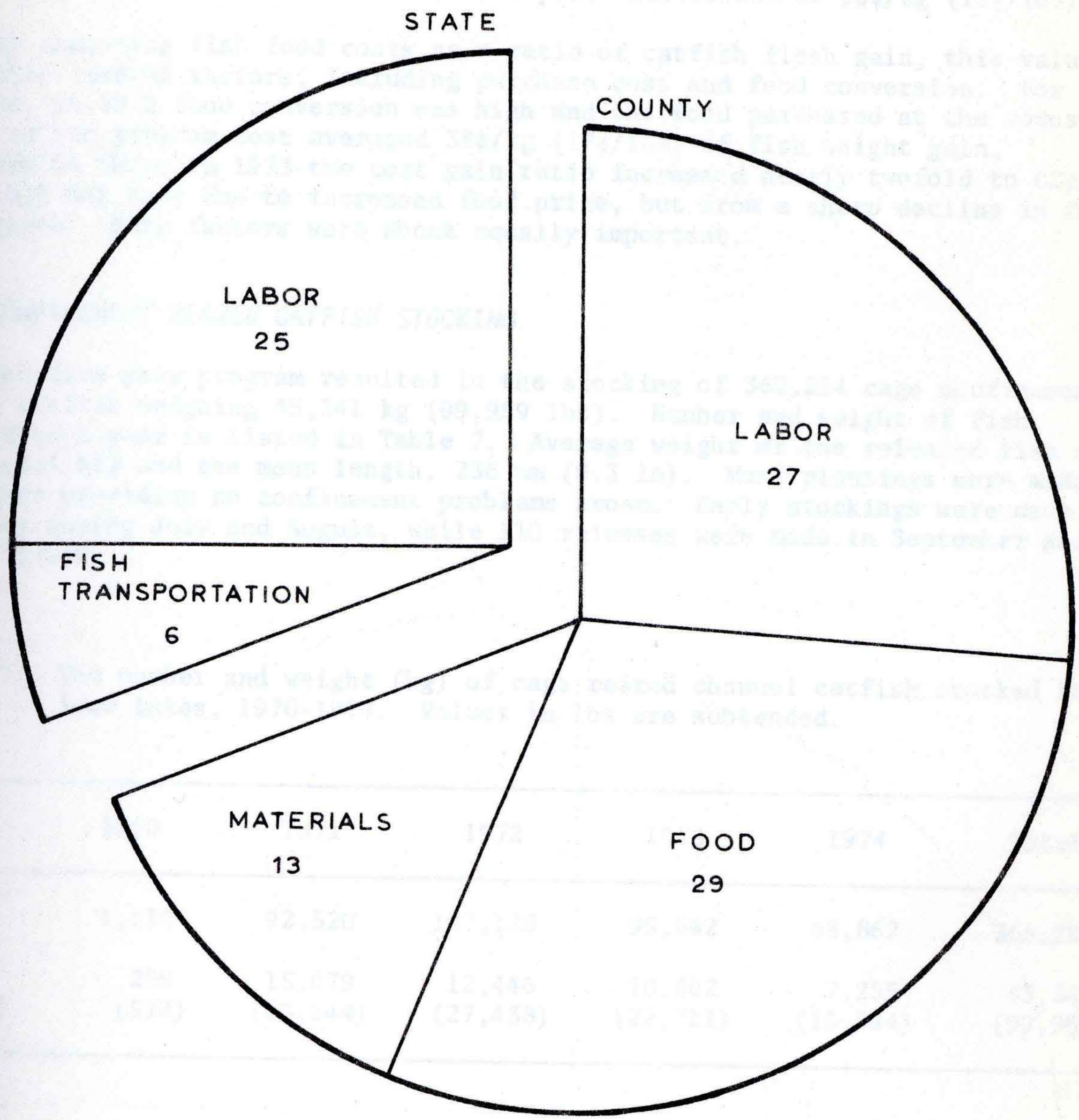


Figure 4. Cost distribution, in percent, of the channel catfish cage confinement program in 1971 for the Fisheries Section and County Conservation Boards.

Total program costs were recorded only in 1971, but food costs were computed each year and ranged widely between years and among boards. The most expensive food was purchased in 1973 at an average cost of 39¢/kg (18¢/lbs) ranging from 31¢-51¢/kg (14¢-23¢/lbs). In 1970, food price was lowest at 26¢/kg (12¢/lbs).

By computing fish food costs as a ratio of catfish flesh gain, this value reflected several factors, including purchase cost and food conversion. For example, in 1970 food conversion was high and the food purchased at the lowest cost, so the program cost averaged 38¢/kg (17¢/lbs) of fish weight gain. Contrary to this, in 1973 the cost gain ratio increased nearly twofold to 62¢/kg (28¢/lbs) not only due to increased food price, but from a sharp decline in food conversion. Both factors were about equally important.

CAGE CONFINEMENT REARED CATFISH STOCKING

The five year program resulted in the stocking of 365,254 cage confinement reared catfish weighing 45,341 kg (99,959 lbs). Number and weight of fish stocked each year is listed in Table 7. Average weight of the released fish was 125 g (4.4 oz) and the mean length, 236 mm (9.3 in). Most plantings were made in September providing no confinement problems arose. Early stockings were made 21 times during July and August, while 110 releases were made in September and 7 in October.

Table 7. The number and weight (kg) of cage reared channel catfish stocked in Iowa lakes, 1970-1974. Values in lbs are subtended.

	1970	1971	1972	1973	1974	Total
Number	1,110	92,520	107,120	95,642	68,862	365,254
Weight	259	15,079	12,446	10,302	7,255	45,341
(lbs)	(572)	(33,244)	(27,438)	(22,711)	(15,994)	(99,959)

Body weight of cage reared fish systematically declined each year of the program despite identical feeding rates and confinement densities. Mean weight of the fish released during the initial year of the program was 234 g (8 oz). The four following years (1971-74) average weight declined to 163 g (6 oz), 116 g (4 oz), 108 g (4 oz) and 105 g (4 oz), respectively.

Cage reared catfish were stocked in 4,138 ha (10,224 ac) of public fishing waters at an average density of 88/ha (36/ac) and a biomass of 10.9 kg/ha (9.7 lbs/ac). Stocking density at County lakes was consistently higher than State lakes, 18.9 kg/ha (16.9 lbs/ac) in the former compared to 2.2 kg/ha (2 lbs/ac) in the latter. The prinicpal reason for the disparity was that the size of State-owned impoundments averaged significantly higher than County lakes, 248 ha (613 ac) and 18.8 ha (46.4 ac). Fingerling fish were not available for cage loading at the same rate in both types of lakes.

RELEASED CATFISH POPULATIONS

Except for trout fisheries, little has been reported about the short and long term benefits of stocking large fish in lakes near full production. In southern Illinois, Lewis (1963) evaluated plantings of catchable-sized warmwater fish in a lake at carrying capacity and recommended some criteria for future investigations. Paramount among the suggestions was an accounting of the direct contribution of stocked fish to the sport fishery. Proportional returns of stocked fish must also be determined along with the effects of stocked fish on native fish populations.

For these reasons, intensive investigations were conducted at Williamson Pond, a small State-owned lake in Lucas County. Vital statistics of fish and macrobenthic populations were determined before channel catfish were reared and stocked for three consecutive years. At the same time vital statistics of released catfish were collected during this period. Native fish and macrobenthic fish-food communities were simultaneously monitored until 90% of the released catfish were removed from the population by natural and fishing mortality. Supplementary data were also available from Cold Springs, Kent and Mariposa Lakes.

Cage culture methods at Williamson were identical and the stocking density similar to other lakes. Stocking density in 1971 was 152 catfish/ha (62/ac) followed by 161/ha (66/ac) in 1972 and 410/ha (168/ac) in 1973. The average statewide stocking density for County Board lakes in the five years was 151/ha (61/ac) and ranged from 37/ha (15/ac) to 692/ha (280/ac).

Williamson Pond is located three miles east of Williamson in Lucas County and was constructed in 1910 by the Rock Island Railroad Company and purchased in 1952 by the Iowa Conservation Commission. Maximum depth is 5.8 m (19 ft) and mean depth, 2.5 m (8.2 ft). Water storage volume is 285,000 m^3 (232 ac-ft) and volume development, 1.2; the basin configuration is slightly concave toward the surface. Thermal stratification occurs from June-September with metalimnion depth at 1.5-3.5 m (5-11.5 ft) and complete oxygen depletion in the hypolimnion. Fourteen macrobenthos and four fish sampling stations were established for the study (Figure 5).

The upper watershed contains mixed row crops and pasture, while the watershed near the lake is comprised of mature oak-hickory timber. Much of the woodland in the upper basin was cleared in the 1950's for grain crop production. The large watershed ratio of 1:61, along with land clearing, resulted in large scale sedimentation and chronic water turbidity. Seasons with excessive summer rainfall, as in 1973 and 1974, greatly decreased submergent vegetation growth in the lake.

Williamson Pond was drained and restocked with fish in 1953 after surveys showed high populations of bigmouth buffalo and carp. Fish species presently inhabiting the lake include bluegill, white and black crappie, largemouth bass, redear sunfish, green sunfish, black bullhead, channel catfish and carp. Relative

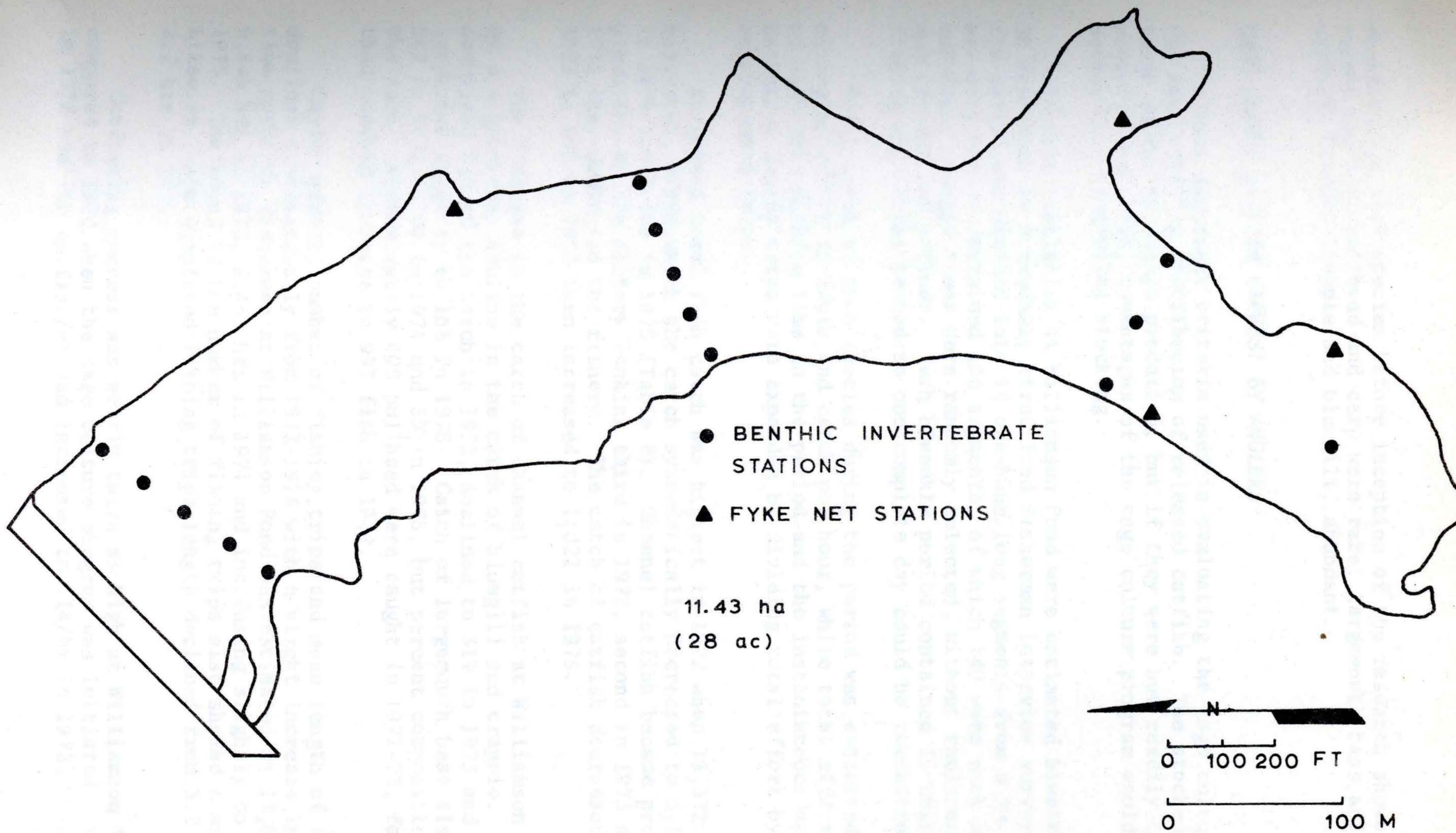


Figure 5. Map of Williamson Pond and sampling stations used in the investigation, 1970-74.

abundance of fish species before inception of the research showed green sunfish, redear sunfish, bullhead and carp were rare; largemouth bass and channel catfish, common; crappie and bluegill, abundant.

CAGE REARED CATFISH HARVEST BY ANGLERS

A most important criteria used in evaluating the cage culture program was the total fishing contribution of released catfish. The stocked catfish were large enough to escape predation, but if they were not readily caught or natural mortality was high, advantages of the cage culture program would be little better than fingerling stocking.

Harvest statistics at Williamson Pond were estimated biweekly from 15 April-30 September by a randomly stratified fisherman interview survey. Each day in the period was divided into 14 one-hour long segments from 8 AM-10 PM. The biweekly period contained 196 segments, of which 140 were week days and 56 week-end days. Sample times were randomly selected, without replacement, from week day and weekend day periods. Each biweekly period contained 14 units from the entire fishing day in the period so one complete day could be reconstructed.

Total catch of each species during the period was estimated as the product of angler effort in hours and catch per hour, while total effort was the product of available fishing time in the period and the instantaneous angler count. Estimated angler trips were expanded by dividing total effort by the mean length of completed trips.

Estimated total fish catch was highest in 1972 when 13,372 fish were harvested, after which the catch systematically decreased to 3,843 in 1973, 2,043 in 1974 and 1,624 in 1975 (Table 8). Channel catfish became progressively more prevalent in the fishery ranking third in 1972, second in 1973 and 1974 and by 1975 they dominated the fishery. The catch of catfish decreased from 1,384 in 1972 to 693 in 1974 then increased to 1,021 in 1975.

The increase in the catch of channel catfish at Williamson Pond was attended by a significant decline in the catch of bluegill and crappie. These fish comprised 82% of the catch in 1972, declined to 31% in 1973 and 14% in 1974, and increased slightly to 16% in 1975. Catch of largemouth bass also decreased from 547 in 1972 to 64 in 1974 and 59 in 1975, but percent composition remained about the same. Approximately 400 bullhead were caught in 1972-73, followed by more than twofold increase to 997 fish in 1974.

Angler effort, number of fishing trips and mean length of completed trips declined systematically from 1972-1974 with a slight increase in 1975. Total time spent by fishermen at Williamson Pond was estimated at 12,937 hrs in 1972, 9,846 hrs in 1973, 5,468 hrs in 1974 and increasing slightly to 5,848 hrs in 1975. The trend in the number of fishing trips also showed a similar decline. Likewise, mean completed fishing trips length declined from 3.2 hrs in 1972 to 2.2 hrs in 1975.

Catfishing success was nearly twice as high at Williamson Pond in 1975 compared to 1972 when the cage culture program was initiated. Mean catch effort in 1972 was .10 catfish/hr and increased to .14/hr in 1973. Catch success in

Table 8. Catch statistics of channel catfish at four lakes in the cage confinement program, 1972-75.

	Williamson Pond				Cold Springs			Kent	Mariposa
Catch statistics	1972	1973	1974	1975	1972	1973	1974	1972	1973
Total number fish caught	13,372	3,843	2,043	1,624	5,236	1,608	3,545	12,973	12,998
Total channel catfish	1,384	1,365	693	1,021	2,617	1,308	869	1,035	1,321
% catfish	10.3	35.5	33.9	62.9	50.0	81.3	24.5	8.0	10.2
Total hours	12,937	9,846	5,468	5,848	11,872	10,960	8,416	9,450	19,532
Catfish/hr	.10	.14	.13	.17	.22	.12	.10	.11	.05
% catfishing	36	57[a]	70[a]			67[a]	59[a]	11[a]	38[a]

[a]Most sought after fish species.

1974 was about the same, .13 catfish/hr, while the greatest success of .17/hr was reported the following year. Catch success was always highest in late summer and following release of caged fish.

Size of cage reared channel catfish taken by fishermen was generally small, since many were caught within a year after stocking. Mean weight of fish caught in 1972 following release in 1971 was 219 g (.49 lbs), while those released in 1973 and caught in 1974 averaged 172 g (.38 lbs). Two years after release the catfish averaged 392 g (.86 lbs) and after three years mean weight was 712 g (1.59 lbs).

Anglers at Williamson Pond preferred catfish and bullhead while preference for crappie and bluegill, which were most important before the cage rearing program, diminished proportionately. In 1972, 36% of the anglers interviewed preferred channel catfish, but in the following season, 57% expressed a desire to catch catfish (Table 8). In 1974, 70% were fishing for catfish. Crappie and bluegill fishing decreased from 26% in 1972 to 6% in 1974. Fishermen expressing no preference decreased from 37% in 1972 to 15% in 1974. The popularity of catfish became progressively higher at Williamson Pond during the study while bluegill and crappie declined because of their small size.

Sport fish harvests were also monitored at Cold Springs, Mariposa and Kent Lakes. Sampling methods were similar to those used at Williamson Pond, and the expanded fishery statistics comparable.

At Cold Springs Lake, a 6.5 ha (16 ac) man-made impoundment in Cass County, 8,659 channel catfish were reared and stocked during 1971-1973. Catch was estimated monthly from April-October in 1972 and April-September in 1973-74.

Total fishing effort at Cold Springs Lake was 11,872 hrs, 10,960 hrs and 8,416 hrs in each of the three seasons. Estimated catch totalled 5,236 fish in 1972, 1,608 in 1973, and 3,545 in 1974. Crappie and channel catfish dominated the fishery. Channel catfish dominated the catch by weight, but declined numerically from 2,615 in 1972 to 1,308 in 1973 and 869 in 1974. Without adjustments for natural mortality, approximately 55% of the released catfish were harvested. Maximum exploitation was 85% in 1972 from the 1971 stocking. Annual harvest rate of each group decreased thereafter.

Overall catch success during the three year survey averaged .15 catfish/hr and varied from .10/hr in 1974 to .22/hr in 1972.

Size structure of the catch was larger at Cold Springs than at Williamson Pond. Catfish weight averaged 409 g (.9 lbs) in 1972 followed by 635 g (1.4 lbs) in 1973 and 816 g (1.8 lbs) in 1974.

Fishermen preference at Cold Springs Lake in 1973 showed 67% were catfishermen, while 18% were fishing for largemouth bass and 14% indicated no preference. In 1974, the proportion of channel catfish anglers decreased to 59%. Bass fishermen comprised 13% of the sample, while crappie fishermen contributed 3%. Anglers expressing no choice comprised 25%.

Kent Lake is a 12 ha (30 ac) man-made impoundment located in Johnson County. Approximately 3,000 catfish were released annually from 1971-1974. Total harvest of fish was estimated in 1972 from April-September, while in 1973 only catch effort, angler preference, and species composition of the catch were determined.

Total fishing effort was 9,450 hrs in 1972 at Kent Lake with an estimated catch of 12,973 fish. Bullhead comprised about 80% of the fishery; catfish, 8%; and green sunfish, largemouth bass and bluegill the remainder. Species composition of the catch in 1973 was again dominated by bullhead, 68%, but channel catfish became more important, increasing to 19% while other species comprised 13%.

Overall mean catch rate in 1972 was .11 catfish/hr, which increased to .17/hr the next year. Like most lakes with cage rearing programs, fishing success was always highest following release of cage reared fish.

A majority of the Kent Lake fishermen indicated little species preference; 73% were noncommital. Eleven percent of the fishermen sought catfish, while 9% were bullhead fishermean and < 1% were bass fishermen.

The fishery at Mariposa Lake, a 7.7 ha (19 ac) man-made lake in Jasper County was monitored in 1973 from June-August. Density of catfish released at Mariposa was the highest of all lakes in the program. In two years 10,164 cage reared fish were stocked in the lake.

Total catch for June-August was 12,998 fish after 19,532 hrs of angling. Bluegill made up about 86% of the fishery, channel catfish about 10% and largemouth bass approximately 4%. Catch success of .05 catfish/hr, represented the poorest of all censused lakes. Angling success for catfish was highest in early summer, but censuses were not conducted following release of cage reared fish.

Channel catfish were quite popular at Mariposa Lake with 38% of the anglers indicating they preferred catfish to other species. Twenty-seven percent of those interviewed sought bass or bluegill and 35% expressed no choice.

POST RELEASE GROWTH AND CONDITION OF CAGE CONFINED CATFISH

While channel catfish were confined, growth was rapid and body condition high. But, after release from the cribs they became entirely dependent on natural food and growth rate and body condition decline precipitously. Some decreased growth and body condition was expected following release, but the magnitude of decelerated growth was unpredictable, particularly with the lake at or near maximum biomass.

Growth rate and body condition of the released catfish at Williamson Pond were determined by successive measurements of length and weight from recaptured, marked catfish. During the study, 2,606 catfish or 32% of the released fish were marked with serially numbered dart tags. Four hundred forty-six were tagged in 1971, 1,010 in 1972 and 1,150 in 1973.

The mean length of marked and released catfish was 276 mm (10.9 in) in 1971 (Table 9). By the end of the first year after release, mean length increased to 319 mm (12.6 in) and after two years length increased to 420 mm (16.5 in). In 1974, the mean length of recaptured fish from this age group was 439 mm (17.3 in).

Table 9. Mean total length in mm (in) of three subpopulations of cage cultured and released channel catfish.

	Body length of catfish			
	1971	1972	1973	Mean increment
At loading	119 (4.7)	102 (4.0)	97 (3.8)	
				150 (5.9)
At release	276 (10.9)	254 (10.0)	237 (9.3)	
				43 (1.7)
October, 1972	319 (12.6)			
				87 (3.4)
October, 1973	420 (16.5)	327 (12.8)		
				26 (1.0)
October, 1974	439 (17.3)	358 (14.0)	265 (10.4)	

Mean body length of the catfish released in 1972 was 254 mm (10 in). Growth rate was greater for this subpopulation during this first year; by October mean length was 327 mm (12.8 in). In 1974, growth rate was less than the previous year and by autumn total length was 358 mm (14 in). Catfish released in 1973 averaged 237 mm (9.3 in) in body length. By October, 1974, mean length increased to 265 mm (10.4 in). Comparison of the growth history of the 1971-73 cage reared fish after release is illustrated by Figure 6.

Examination of the growth increments for each subpopulation showed greatest growth was in 1973 followed in descending order by 1972 and 1974. Mean annual growth increment in 1973 was 87 mm (3.4 in). The 1971 subpopulation grew 101 mm (3.9 in) in 1973, while the 1972 release group grew 73 mm (2.9 in). Growth in 1972 was 50% less with a mean annual increment of 43 mm (1.7 in). Poorest growth occurred in 1974 with an average length increment of 26 mm (1 in), which ranged from 19 mm (.7 in) for the 1971 subpopulation to 31 mm (1.2 in) for the 1972 group.

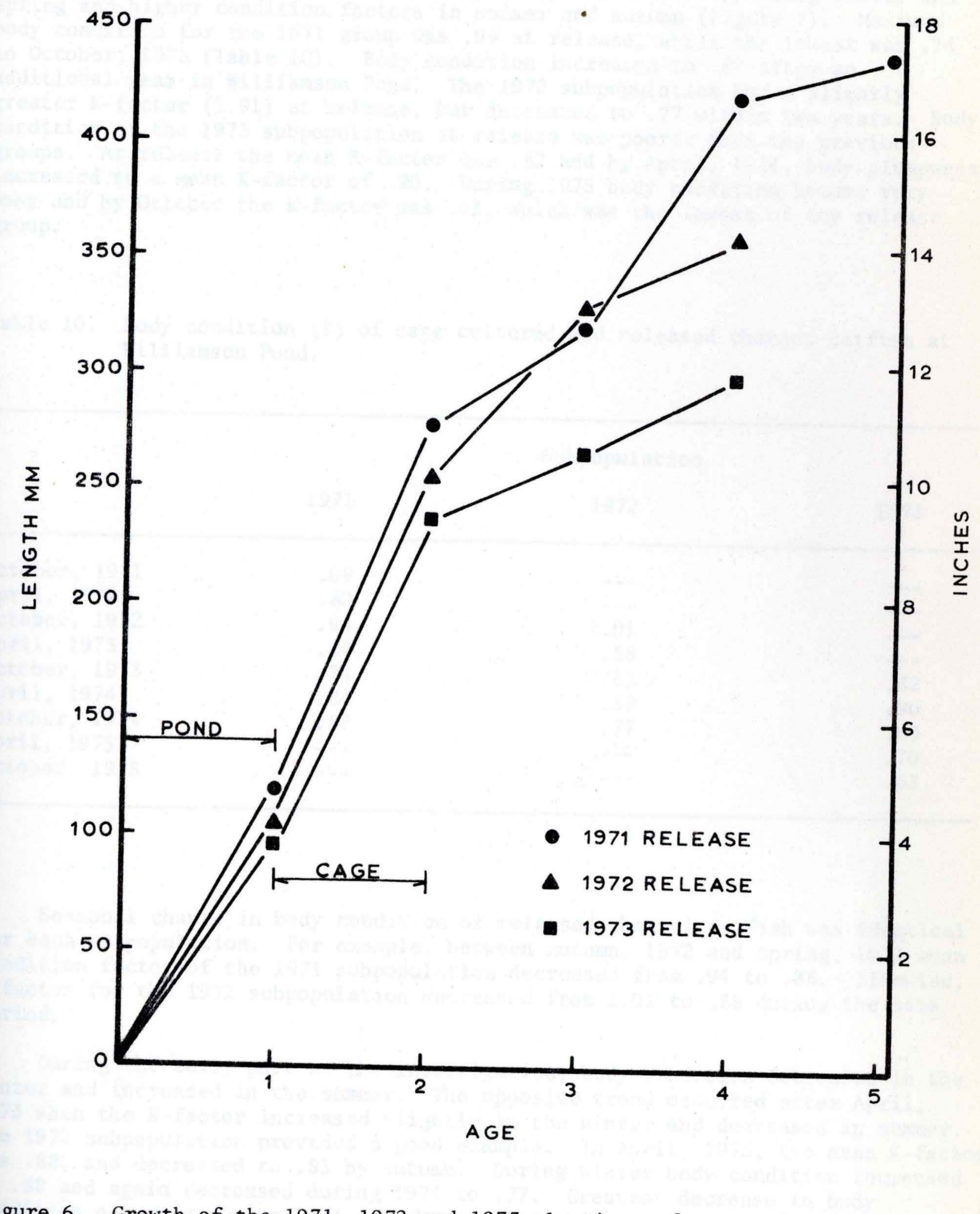


Figure 6. Growth of the 1971, 1972 and 1973 plantings of cage cultured channel catfish.

Channel catfish body condition was high at release, but decreased steadily thereafter. The overall trend was for poorer body condition during winter and spring and higher condition factors in summer and autumn (Figure 7). Maximum body condition for the 1971 group was .99 at release, while the lowest was .74 in October, 1973 (Table 10). Body condition increased to .87 after an additional year in Williamson Pond. The 1972 subpopulation had a slightly greater K-factor (1.01) at release, but decreased to .77 within two years. Body condition of the 1973 subpopulation at release was poorer than the previous groups. At release the mean K-factor was .82 and by April, 1974, body plumpness increased to a mean K-factor of .90. During 1975 body condition became very poor and by October the K-factor was .63, which was the lowest of any release group.

Table 10. Body condition (K) of cage cultured and released channel catfish at Williamson Pond.

	Subpopulation		
	1971	1972	1973
October, 1971	.99	---	---
April, 1972	.80	---	---
October, 1972	.94	1.01	---
April, 1973	.88	.88	---
October, 1973	.74	.83	.82
April, 1974	.84	.88	.90
October, 1974	.87	.77	.60
April, 1975	---	---	.70
October, 1975	---	---	.63

Seasonal change in body condition of released channel catfish was identical for each subpopulation. For example, between autumn, 1972 and spring, 1973 mean condition factor of the 1971 subpopulation decreased from .94 to .88. Likewise, K-factor for the 1972 subpopulation decreased from 1.01 to .88 during the same period.

During the early part of the investigation, body condition decreased in the winter and increased in the summer. The opposite trend occurred after April, 1973 when the K-factor increased slightly in the winter and decreased in summer. The 1972 subpopulation provided a good example. In April, 1973, the mean K-factor was .88, and decreased to .83 by autumn. During winter body condition increased to .88 and again decreased during 1974 to .77. Greatest decrease in body condition occurred during 1974, which was also the season with poorest growth.

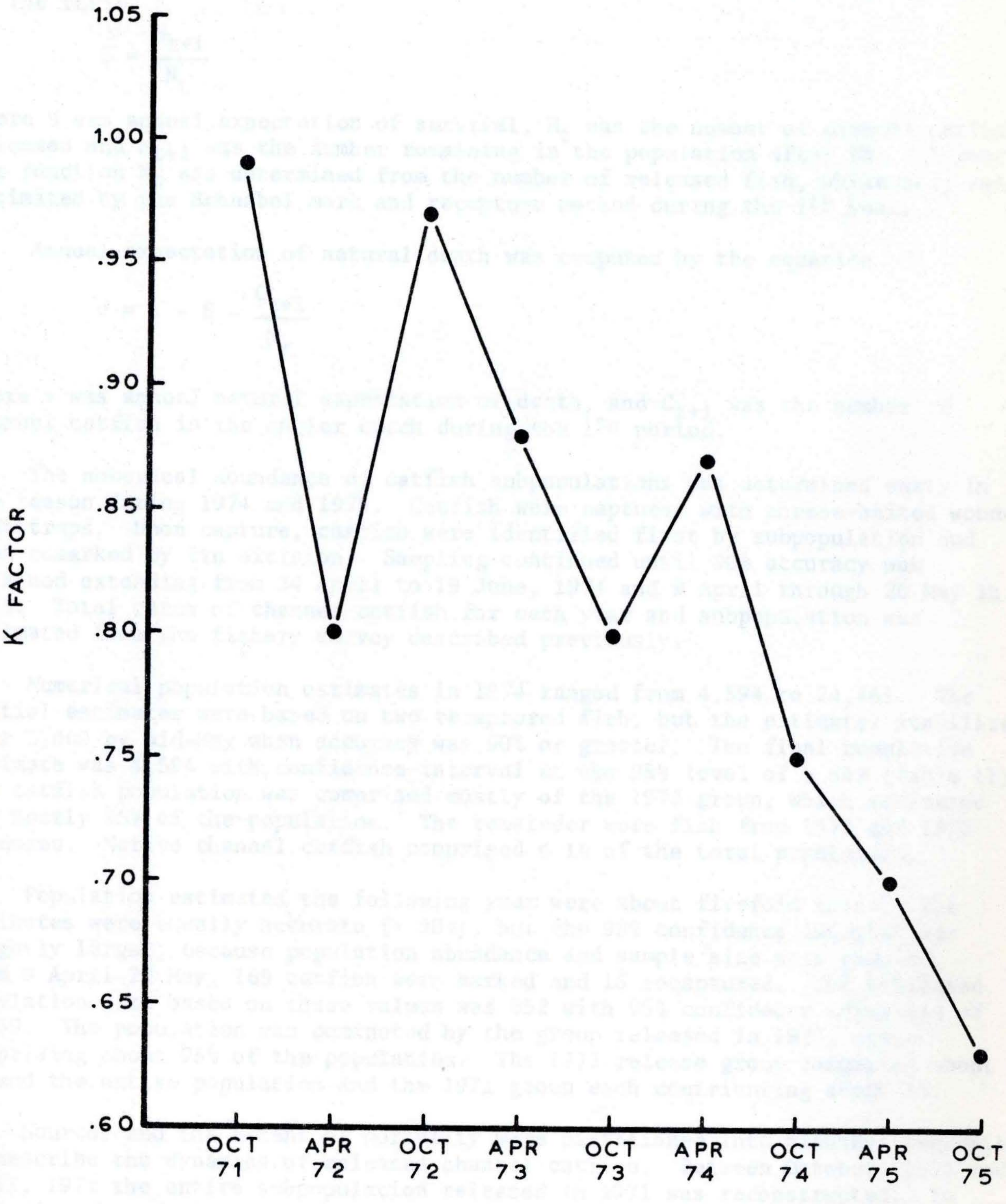


Figure 7. Condition factor, K, of cage reared and released channel catfish at Williamson Pond.

SOURCES AND EXTENT OF MORTALITY OF RELEASED CATFISH

Survival of each subpopulation of released channel catfish was estimated as the ratio

$$S = \frac{N_{t+i}}{N_t}$$

where S was annual expectation of survival, N_t was the number of channel catfish released and N_{t+i} was the number remaining in the population after the i^{th} year. The function N_t was determined from the number of released fish, while N_{t+i} was estimated by the Schnabel mark and recapture method during the i^{th} year.

Annual expectation of natural death was computed by the equation

$$v = 1 - S - \frac{C_{t+i}}{N_t}$$

where v was annual natural expectation of death, and C_{t+i} was the number of channel catfish in the angler catch during the i^{th} period.

The numerical abundance of catfish subpopulations was determined early in the season during 1974 and 1975. Catfish were captured with cheese-baited wooden slat traps. Upon capture, catfish were identified first by subpopulation and then remarked by fin excision. Sampling continued until 90% accuracy was attained extending from 24 April to 19 June, 1974 and 9 April through 20 May in 1975. Total catch of channel catfish for each year and subpopulation was estimated from the fishery survey described previously.

Numerical population estimates in 1974 ranged from 4,594 to 24,461. The initial estimates were based on two recaptured fish, but the estimates stabilized near 5,000 by mid-May when accuracy was 90% or greater. The final cumulative estimate was 4,594 with confidence interval at the 95% level of ± 648 (Table 11). The catfish population was comprised mostly of the 1973 group, which accounted for nearly 95% of the population. The remainder were fish from 1971 and 1972 releases. Native channel catfish comprised < 1% of the total population.

Population estimates the following year were about fivefold lower. The estimates were equally accurate (> 90%), but the 95% confidence interval was slightly larger, because population abundance and sample size were reduced. From 9 April-20 May, 169 catfish were marked and 18 recaptured. The estimated population size based on these values was 852 with 95% confidence intervals of ± 269. The population was dominated by the group released in 1973, again comprising about 95% of the population. The 1972 release group comprised about 3% and the native population and the 1971 group each contributing about 1%.

Sources and the extent of mortality were partitioned into biannual segments to describe the dynamics of released channel catfish. Between October, 1971 and April, 1974 the entire subpopulation released in 1971 was reconstructed. In this time the population was reduced from 1,743 at release to 50 fish (Table 12). Anglers reported catching 1,693 fish from October, 1971 through April, 1974. Natural mortality was negligible. From April, 1974 through 1975, 10 additional fish were reported in the fishery leaving five in the population, while 35 succumbed to natural causes.

Confined channel catfish were daily fed with a 32-40% protein pellet of two sizes at 3-4% their body weight.

Table 11. Population estimates of channel catfish in Williamson Pond in April, 1974 and 1975 with confidence interval at the 95% level.

	Number captured	Cumulative number marked	Cumulative number recaptured	Population estimate	Confidence interval
1974					
24 April	14	0	0		
26 April	72	14	0		
29 April	269	86	1	24,142	
2 May	70	354	2	24,461	± 14,184
6 May	48	423	8	8,653	± 3,533
8 May	122	457	17	7,351	± 2,367
10 May	173	569	35	6,383	± 1,587
13 May	85	724	47	6,063	± 1,347
15 May	51	796	56	5,813	± 1,206
17 May	41	837	67	5,371	± 1,037
20 May	21	867	69	5,479	± 1,045
21 May	25	884	74	5,408	± 1,003
23 May	59	893	85	5,328	± 933
2 June	108	941	114	4,864	± 753
3 June	78	941	126	4,983	± 740
19 June	26	941	142	4,594	± 648
1975					
9 April	13	0	0		
10 April	16	13	0		
11 April	1	29	0		
15 April	23	30	0		
18 April	23	53	2	1,073	± 623
21 April	43	76	6	888	± 394
24 April	28	119	10	849	± 324
28 April	34	153	17	773	± 249
20 May	16	169	18	852	± 269

Table 12. The chronological change in population numbers of cage reared channel catfish in Williamson Pond following release. Number in the catch is denoted by (C) and number reduced by natural mortality (n)

	Subpopulations											
	1971			1972			1973			Combined		
	C	N	n	C	N	n	C	N	n	C	N	n
1971 October	49	1,743	---							49	1,743	---
1972 April	1,139	1,694	---							1,139	1,694	---
1972 October	0	555	---	87	1,840	279				87	2,395	279
1973 April	505	555	---	764	1,474	279				1,269	2,029	279
1973 October	0	50	---	0	431	279	27	4,708	344	27	5,189	623
1974 April	10	50	18	19	152	52	646	4,337	1,440	675	4,539	1,510
1974 October	0	22	17	0	81	52	0	2,251	1,439	0	2,354	1,508
1975 April		5			29			812			846	

Similar computations were made for each subpopulation. Natural mortality was most important in the 1973 group. In October that year there were 4,708 fish in the population and by the next spring 4,337 remained. Twenty-seven were reported in the catch; therefore, it follows that 344 died of natural causes. By April, 1975, the population declined to 812, of which 646 were accounted for in the catch. The remainder (2,879) was attributed to loss by natural mortality.

Catch statistics, population abundance and natural mortality were combined for each subpopulation (Table 12). Examination of these statistics showed natural mortality became increasingly important as population abundance increased. Natural mortality caused < 2% of the deaths in the 1971 subpopulation, while 51% of the 1972 release group died of natural causes. Highest natural mortality was 69% in the 1973 subpopulation. During the study, 8,291 channel catfish were reared and released, of which 3,246 were caught by anglers and 4,199 succumbed to natural mortality. In April, 1975, 846 remained in the population. When all subpopulations were combined, angler catch comprised 39%; natural mortality, 51%; and 10% remained at large.

Survival in autumn and winter was much greater than in spring and summer (Figure 8). The primary reason for increased summer mortality was, of course, angler harvest. Mortality due to catch during fall and winter was 4% or less. Winter survival was higher during the first year (97%), but became progressively less. By 1974-1975 winter survival was reduced to 36%.

POPULATION WEIGHT OF CATFISH

Channel catfish population weight at Williamson Pond was influenced by several related variables. Foremost was the biomass of the cage reared catfish released into the population. Secondarily, growth, weight loss in the winter, angler harvest and natural mortality were influential factors.

Weight of the catfish population before cage reared fish were released was estimated at 228 kg (502 lbs). In September, 1971, following stocking of cage reared fish, biomass increased abruptly to 541 kg (1,192 lbs) (Figure 9). Part of the released catfish were caught that autumn, and during winter survivors lost about 5% of their body weight, and by April the following year biomass was estimated at 486 kg (1,070 lbs).

Continued angler harvest in 1972 further reduced the catfish standing stock to 284 kg (626 lbs) by September. When the 1972 subpopulation was released the biomass increased to 584 kg (1,286 lbs). Fall harvest, winter weight loss and natural mortality subsequently reduced the population weight to 460 kg (1,013 lbs) by April, 1973. Natural mortality and harvest during the summer further reduced the biomass to 291 kg (641 lbs) prior to the stocking of the 1973 group.

Release of the 1973 group increased the total catfish population weight to 824 kg (1,815 lbs). Few catfish were harvested in the fall, and growth in autumn and early spring offset natural mortality. By May, 1974, the estimated population weight was 921 kg (2,029 lbs). Natural mortality was most influential during 1974 and combined with fishing mortality and the accompanying decelerated growth rate the population weight decreased to 429 kg (945 lbs). Winter mortality and weight loss accounted for a further decline to 153 kg (337 lbs) by May, 1975.

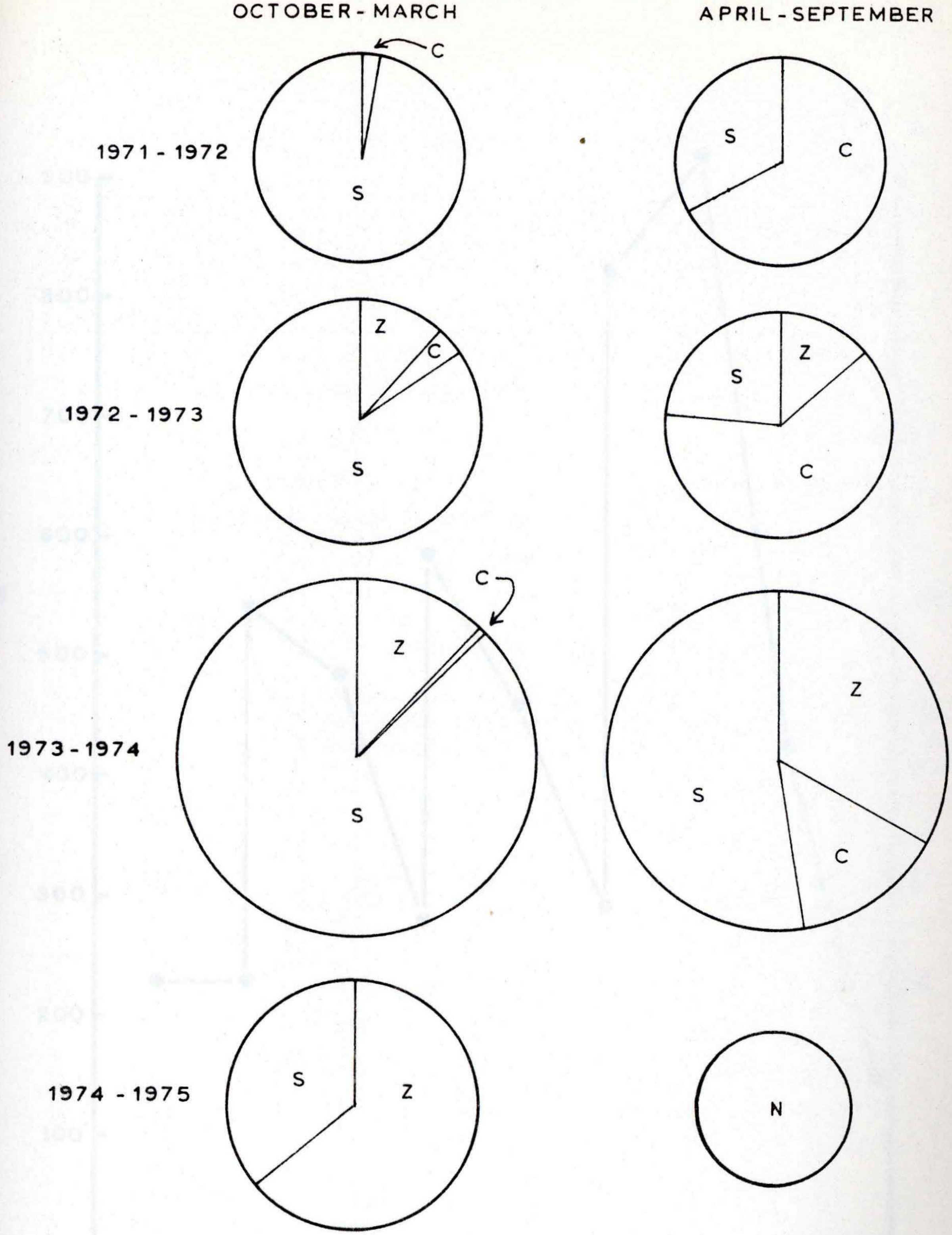


Figure 8. Proportion of survival (S), natural mortality (Z) and fishing mortality (C) of cage cultured and released channel catfish at Williamson Pond during autumn-winter and spring-summer. Area of circles are proportional to population size. The final descriptor indicates population size, N, on April, 1975.

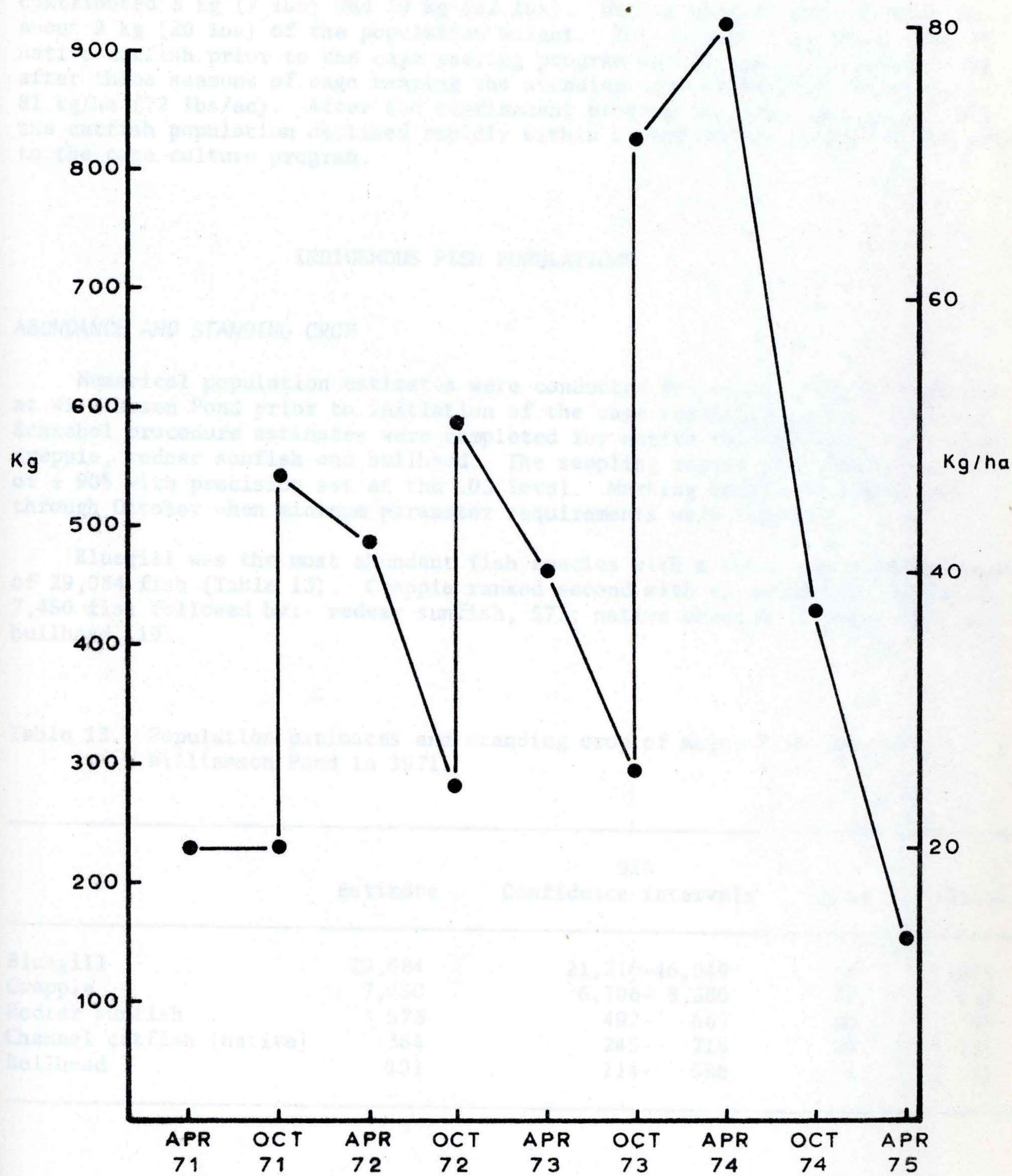


Figure 9. Population weight of cage cultured and released channel catfish at Williamson Pond, 1971-75.

The final estimate showed the 1973 subpopulation was predominant, making up about 131 kg (289 lbs) of the biomass, while the 1971 and 1972 groups each contributed 3 kg (7 lbs) and 10 kg (22 lbs). Native channel catfish made up about 9 kg (20 lbs) of the population weight. The estimated standing crop of native catfish prior to the cage rearing program was 20 kg/ha (18 lbs/ac) and after three seasons of cage rearing the standing crop of catfish increased to 81 kg/ha (72 lbs/ac). After the confinement program was discontinued in 1973 the catfish population declined rapidly within a year to the density found prior to the cage culture program.

INDIGENOUS FISH POPULATIONS

ABUNDANCE AND STANDING CROP

Numerical population estimates were conducted for cohabiting fish species at Williamson Pond prior to initiation of the cage rearing program. Separate Schnabel procedure estimates were completed for native channel catfish, bluegill, crappie, redear sunfish and bullhead. The sampling regime provided for accuracy of ± 90% with precision set at the .05 level. Marking continued from April through October when minimum parameter requirements were achieved.

Bluegill was the most abundant fish species with a total estimated population of 29,084 fish (Table 13). Crappie ranked second with an estimated population of 7,450 fish followed by: redear sunfish, 573; native channel catfish, 364; and bullhead, 191.

Table 13. Population estimates and standing crop of major fish species at Williamson Pond in 1971.

	Estimate	95% Confidence intervals	kg/ha	(lbs/ac)
Bluegill	29,084	21,210-46,049	221	(197)
Crappie	7,450	6,706- 8,380	71	(63)
Redear sunfish	573	492- 687	10	(9)
Channel catfish (native)	364	245- 715	20	(18)
Bullhead	191	114- 586	4	(4)

Standing crops of fish populations were extrapolated from the population estimates and the mean weight of fish captured. Total weight of the fish population in Williamson Pond was 326 kg/ha (291 lbs/ac) before the cage rearing

After confinement rearing the catfish were released at a body size that prevented predation by other fish.

program, of which 221 kg/ha (197 lbs/ac) was bluegill, 71 kg/ha (63 lbs/ac) crappie, 10 kg/ha (9 lbs/ac) redear sunfish, 20 kg/ha (18 lbs/ac) native channel catfish, and 4 kg/ha (4 lbs/ac) bullhead.

Relative abundance indices were determined from fyke net catches from 1971-75 to ascertain changes in species abundance accompanying the cage rearing program. Fish were netted for four consecutive days each month from May-August throughout the study period (Figure 4). Least squares analysis of variance in catch effort was used to identify significant differences in relative abundance between years. When resulting F-values were not significant at the 95% level, the abundance of that species was considered unchanged.

Bluegill catch effort showed a significant decline from 1972-1975 despite quite uniform year class structure in the population (Table 14). From 1972 through 1975 bluegill catch effort decreased 56%. However, further analyses indicated that although there was a systematic decline in population abundance the change was not significantly lower until the last year. Catch effort in the other years was the same at the minimum testing level of probability. Black crappie catch effort also changed significantly during the study, but low catches (0-2.5 FND) throughout the period made the validity questionable. White crappie, redear sunfish and bullhead abundance indices remain stable during the study. Native channel catfish were caught too infrequently for meaningful comparison.

Table 14. Mean fish per net day (FND) of major fish species in pound nets at Williamson Pond in 1971-1975.

	1971	1972	1973	1974	1975
Bluegill*	6.4	11.2	8.6	6.3	2.8
White crappie	6.1	11.5	10.2	7.0	15.6
Black crappie*	2.6	2.5	1.3	0	2.5
Redear sunfish	5.8	4.5	.7	2.5	3.1
Bullhead	.2	.9	.9	3.9	.8

*Significant change in population.

GROWTH RATE AND BODY CONDITION

Growth and body condition of bluegill, crappie and native channel catfish were measured from 1967-1974 by standard age and growth procedures to identify any latent affect of the annual instantaneous increase in catfish biomass by 55 kg/ha (49 lbs/ac) through the cage rearing program.

Bluegill growth at Williamson Pond was slightly less than the statewide average reported by Mayhew (1965) for similar Iowa impoundments. Estimated total body length for the first five years of life was 42, 97, 133, 156 and 182 mm (1.6, 3.8, 5.2, 6.1 and 7.2 in), respectively. White crappie growth was extremely slow achieving a mean length of 228 mm (9 in) after seven years, which was near the minimum statewide value. Growth of native channel catfish was about equal to the statewide average attaining 68, 170, 251, 314, and 375 mm (2.7, 6.7, 9.9, 12.4, and 14.8 in) in the first through fifth year of life.

Growth indices based on the proportion of growth for all age groups occurrin within each calendar year were computed for the three fish species. All index values were adjusted to a base of 0, and values greater than the base indicated above average growth increment and those less than the base indicated below average growth increments.

Comparable growth rate statistics were available from 1967 through 1974. Of these, bluegill growth was below average in four years and three of these occurred after initiation of the cage rearing program (Table 15). Except for 1973, mean growth rate steadily declined after 1971.

Table 15. Percent deviation in growth from mean annual increment for bluegill, crappie and native channel catfish at Williamson Pond where an index of zero is average growth.

	Bluegill	White crappie	Channel catfish
1967	26	5	21
1968	- 3	- 8	-39
1969	6	- 5	-11
1970	5	17	- 9
1971	- 4	26	27
1972	- 5	-20	6
1973	17	-13	20
1974	-47	0	[a]

[a] No native catfish were sampled in 1974.

White crappie growth was above average, from 5% to 26%, in three of five years from 1967 through 1971. From 1972-74 growth rate ranged from average to 20% below average.

Native channel catfish showed the opposite trend from bluegill and crappie with growth rate from 6% to 27% above average after initiation of the cage rearing program. Prior to the program growth indices ranged from -39 in 1972 to +21 in 1967.

The trends in K-factors nearly followed growth patterns for bluegill, crappie and native channel catfish. From 1972-74 the condition factors of bluegill decreased from 2.33 to 1.73 (Table 16). White crappie K-factors were 1.41 in 1972, 1.21 in 1973 and 1.15 in 1974. Channel catfish condition increased from .89 in 1972 to .98 in 1974.

Table 16. Body condition factor (K) for bluegill, crappie and native channel catfish at Williamson Pond after release of cage reared channel catfish.

	Bluegill	White crappie	Channel catfish
1972	2.33	1.41	.89
1973	1.85	1.21	.86
1974	1.73	1.15	.98

FOOD HABITS OF CHANNEL CATFISH

Food habits of native and released channel catfish at Williamson Pond were defined to establish the trophic structure of each group released and determine the extent of inter- and intra-specific competition. Stomach contents of 168 catfish were examined in 1972-1974. Monthly samples were taken from April-October each year with each catfish subpopulation represented. Content volume was measured and individual food items identified. An electivity index of benthic organisms consumed for food was used to determine selection following Ivlev's equation. Selection of other food items, such as fish, was not determined because food occurrence in the environment could not be adequately quantified.

Stomach content volume ranged up to 44 ml. Mean volume in 1972 was 2.4 ml, while volume in 1973 was 6.0 ml and 2.0 ml in 1974. Occurrence of empty stomachs increased systematically during the study. In 1972, 17% of the catfish stomachs contained no food items, while 22% were empty in 1973 and 39% in 1974.

The three most important sources of food in order of importance by volume were macrobenthic invertebrates, catfish food waste from the cage culture program and fish. Benthic invertebrates comprised 52% of the food volume in 1972, 34% in 1973, and 92% in 1974 (Table 17). Benthos were found in 83% of the stomachs in 1972 and decreased thereafter to 78% in 1973 and 61% in 1974.

Fish were also foraged, but much more infrequently than benthos. In 1972, fish remains comprised 6% of the stomach contents by volume followed by 9% and 8% during the next two seasons. By percentage, stomachs containing fish remains comprised 14% of the sample in 1972, and increased to 54% in 1973. Fish remains were found in 16% of the stomachs in 1974.

Table 17. Major food composition in channel catfish stomachs at Williamson Pond from April-October, 1972-1974.

Group	Percent food composition by volume			Percent of each group contained in stomachs		
	1972	1973	1974	1972	1973	1974
Invertebrates	52	34	92	83	78	61
Fish	6	9	8	14	54	16
Catfish food waste	42	67	0	3	30	0
Empty				17	22	39

Catfish food waste and excrement from cage confinement was an important part of the ration in 1973, when this item made up 67% of the food volumes and occurred in about one-third of the sample catfish. Waste feeding caused the stomach content volume to increase to 6 ml during 1973. In 1972, 3% of the stomachs contained catfish food, but accounted for 42% of the volumetric ration. Stomachs with catfish food waste had a mean volume of 15 ml, but ranged up to 44 ml. Cage rearing ceased after 1973 at Williamson Pond so no stomachs contained food waste after that season.

The composition of macrobenthic invertebrates in catfish diets was dominated by *Chironominae* and *Culicidae* (Table 18). These combined taxa accounted for 55% of the benthos consumed in 1972, 88% in 1973 and 80% in 1974. Midges were found in 31% of the stomachs in 1974 and 87% in 1972. *Tanypodinae* was important in 1972 accounting for 37% of the food items. In 1973 and 1974, occurrence decreased to 1% and 5%. *Ceratopogonidae, Odonata, Ephemeroptera, Mollusa* and *Annelida* were consumed occasionally, but numerically contributed < 5% of the invertebrates consumed by catfish.

Chironominae were positively selected for as food by catfish with a mean electivity of +.14 and ranges of +.76 in June to -.78 in August. Mean electivity of *Culicidae* was +.20 which ranged from complete selection in May and June to complete rejection in August. Other invertebrate taxa were slightly negative or zero.

Table 18. Percent composition of benthic invertebrates found in channel catfish stomach contents at Williamson Pond from April-October, 1972-1974.

	Percent composition of food in stomach contents			Percent of the stomachs containing each item		
Taxa	1972	1973	1974	1972	1973	1974
Chironominae	43	19	72	54	64	20
Tanypodinae	37	1	5	47	2	14
Culicidae	12	69	7	33	60	11
Ceratopogonidae	5	0	1	28	0	8
Odonata	2	1	< 1	17	18	1
Ephemeroptera	< 1	2	3	3	12	5
Mollusca	1	< 1	0	3	2	0
Annelida	1	< 1	1	6	4	5
Unidentified	4	4	4	20	62	11
Other	0	5	8	0	28	20

INVERTEBRATE MACROBENTHOS POPULATIONS

The aim of this study segment was to document the benthic invertebrate density before catfish were released in 1971 and measure changes that occurred from 1972-1974 following the release of cage cultured catfish. The largest catfish biomass in the lake at one time was 824 kg (1,815 lbs) in 1973 and daily consumption of benthic invertebrates by catfish would have a large impact on the food supply.

Macrobenthos invertebrates were sampled biweekly from April-October in 1971-1974 with a 76 mm (3 in) diameter core sampler. Fourteen stations were located along four lateral transects with triplicate core samples taken at each station. Area of the core sample was 45.36 cm^2 at each station so total sample area for each period was .2 m^2 (2.1 ft^2). Sampling depth was distributed so all strata were represented. Stations 1, 5, 6, 10, 11 and 13 were located at depths of 1-2 m (3-6.6 ft) while Stations 2, 12 and 14 were at depths of 2-3.5 m (6.6-11.5 ft). Stations 3, 4, 7, 8 and 9 were located in the deep water ranging from 3.5-5.5 m (11.5-18 ft). Substrate samples were separated through a No. 30 seive and preserved in 5% formalin for future separation. Organisms were identified, enumerated, and weighed to the nearest .001 g for extrapolation of total population weight.

MACROBENTHOS SPECIES COMPLEX

Invertebrates were dominated by dipteran larvae which accounted for 82.2% of the organisms in 1971 and 68.3% in 1974. In all years, *Culicidae* dominated ranging from 47.9% in 1973 to 25.7% in 1974 (Table 19). Second most numerous in the sample were *Chironominae* which ranged from 17.6%-26.4%. *Tanypodinae* comprised 19.4% of the macrobenthos in 1974 compared to 6.8% in 1973. In 1973, *Tanypodinae* ranked second, but in other years they were third and fourth. Other taxa which contributed less than 5% were *Ephemeroptera*, *Odonata*, *Ceratopogonidae*, *Mullusca*, *Decapoda*, and *Amphipoda*.

Table 19. Percent composition of macrobenthos invertebrates in substrate core samples at Williamson Pond, 1971-74.

Taxa	1971	1972	1973	1974
Culicidae	38.6	46.1	47.9	25.7
Chironominae	26.4	17.8	17.6	22.9
Tanypodinae	15.4	6.9	6.8	19.4
Annelida	7.5	19.3	22.8	18.5
Ephemeroptera	4.1	1.0	1.0	5.4
Odonata	2.2	2.5	.6	.1
Ceratopogonidae	1.8	1.0	.3	.3
Mullusca	1.6	2.6	1.5	5.7
Other	2.4	3.0	1.5	2.1

MACROBENTHOS INVERTEBRATE DISTRIBUTION

The first step in expansion of enumeration data of benthos samples was to establish the areal distribution of invertebrate taxa by station and diversity. Cluster analysis was used to define numerical relationships of *Chironominae*, *Tanypodinae*, *Culicidae* and *Annelida* at all sampling stations. These analyses showed diversity of Stations 6 and 11 were most nearly alike. The second most closely associated stations were 3 and 4, followed by 7 and 8, 1 and 5, 10 and 13, and 12 and 14. Further analyses showed Stations 1, 5, 6, 10, 11 and 13 nearly identical, but differed widely from 2, 12 and 14. Likewise, Stations 3, 4, 7, 8 and 9 had similar taxa, but differed greatly from the two former groups.

Substrate depth was the most important factor influencing the station groups. Stations 1, 5, 6, 10, 11 and 13 were near shore, while 2, 12 and 14 were at mid-depth and 3, 4, 7, 8 and 9 were deep.

There were occasional differences of macrobenthic invertebrates distribution depending on the depth and intensity of thermal stratification at Williamson Pond. At times benthos occurring below the metalimnion was wholly unavailable to fish. Stratification usually commenced in May and lasted through mid-September each year. The thermocline was deep in spring and autumn, but nearer the surface in mid-summer.

Before stratification developed, all of the substrate was available for food searching by fish. As stratification became pronounced progressively less area of the bottom was utilized. By 1 May, stratification was well defined and about 90% of the substrate located above the thermocline. As the thermocline became more defined and moved upward, the substrate area available to fish declined until mid-July, when 31-77% of the benthic invertebrates were unavailable. By 1 October, location of the thermocline deepened and 94-100% of the benthic organisms were again available for food.

MACROBENTHOS INVERTEBRATE BIOMASS

Population weight of macrobenthos above the thermocline during the study averaged 61 kg/ha (54 lbs/ac). Greatest invertebrate benthic weight occurred in August, 1971, at 206 kg/ha (184 lbs/ac), while minimum population weight was 2 kg/ha (2 lbs/ac) in July, 1973 (Table 20).

Table 20. Population weight of benthic invertebrates in kg/ha (lbs/ac) above the thermocline at Williamson Pond, 1971-74.

	1971		1972		1973		1974	
Early June	53	(47)	91	(81)	67	(60)	53	(47)
Late June	83	(74)	21	(19)	55	(49)	18	(16)
Early July	18	(16)	102	(91)	2	(2)	35	(31)
Late July	32	(29)	122	(109)	43	(38)	18	(16)
Early August	206	(184)	96	(86)	61	(55)	73	(65)
Late August	65	(58)	65	(58)	38	(34)	37	(33)
Early September	49	(44)	42	(38)	56	(50)	31	(28)
Late September	61	(54)	106	(95)	72	(64)	40	(36)
Early October	19	(17)	66	(59)	79	(71)	43	(38)
Late October	86	(77)	123	(110)	58	(52)	47	(42)
Mean	67	(60)	83	(74)	53	(47)	39	(35)

Mean population weight increased from 67 kg/ha (60 lbs/ac) in 1971, before catfish were released, to 83 kg/ha (74 lbs/ac) in 1972. Thereafter, macrobenthic population weight continually decreased to 39 kg/ha (35 lbs/ac) in 1974. After 1972 the invertebrate biomass never surpassed 79 kg/ha (71 lbs/ac) on any sample date.

Comparison of the mean macrobenthos invertebrate density above the thermocline by analysis of variance in substrate samples revealed a significant downward trend occurred between 1972 and 1974 following stocking of cage reared catfish, especially after two years of the program. The lowered density of natural food was undoubtedly a paramount factor in decreased growth rate, lower body condition and increased natural mortality.

ACCOMPLISHMENTS, NEEDS AND MANAGEMENT IMPLICATIONS

Channel catfish were confinement reared in floating cages at 46 State and County owned recreational lakes to consolidate several management problems involving this important sport fish. For more than two decades catfish populations were perpetuated by periodic plantings of hatchery reared fingerling or wild trapped adults. Success of the program varied; while adult plantings were quite successful, the cost was exorbitant. Fingerling plantings usually met with nearly total mortality from predation. By and large, the approach was unsatisfactory in light of the ever increasing demand by anglers for catfishing in these impoundments.

The primary strategy of cage confinement rearing was to produce catfish with body size large enough to minimize predation, and at the same time yield a secondary benefit of almost instantaneous increased fishing success from the larger, rapid growing individuals that were released. The impact on cohabiting fish species following mass releases of cage reared catfish was unknown, and posed an enigma that required research.

The prinicpal objective of confinement rearing was quite easily attained. Small catfish placed in the confinement cages grew rapidly and survival in confinement was over 85% at most lakes. Within 100 days of confinement a vast majority of the released fish were able to escape predation, which was an improvement over previous fingerling stockings.

Short term benefits from the program appeared immediately following release of cage reared fish. Within the first month many of the stocked fish were caught by fishermen, having some characteristics of a "put and take fishery". Catch statistics reported in sport fishery surveys indicated about 70% of the released cage reared fish were harvested within one year. Harvest continued at a somewhat reduced level in subsequent years until the entire cohort was decimated by angling or natural mortality. Longevity of a cage reared group was seldom more than three years with about 95% attrition within this time. The remainder, although small in number, succumbed to natural causes.

The cage rearing program, coupled with significantly improved fishing for channel catfish in nearly all impoundments, fostered a wealth of cooperation between County Conservation Boards and the Fisheries Section. Perhaps the major long term benefit from the program was the opportunity for Fishery Management Biologists to promote related practices of resource management to County agency members.

Cage confinement rearing programs also served as a catalyst for furthur establishment of "good will" with fishermen. Catfishing soon became increasingly popular at lakes in the program and generated greater fishing effort and enjoyment where little previously existed. Many letters and comments from fishermen praised the catfishing quality, attesting to the overall short term success of the program.

In five years, nearly 400,000 channel catfish were cage reared in the statewide program. Of these, approximately 300,000 weighing in excess of 100 tons have been caught or will be caught in future years. The program generated more than two million hours of fishing in the five year span. Nearly one-half of the fishermen interviewed during the study sought catfish in lakes where catfishing was nearly non-existent.

Short term success and benefits from cage confinement rearing programs were readily apparent, but several problems developed that must be rectified for program enhancement. Paramount among these is selection of lakes with the necessary requirements for cage confinement rearing. Lakes without adequate environmental criteria should be eliminated, for it is wasteful to initiate cage rearing programs only to have chronic, excessive mortality from low dissolved oxygen or epizootics. Shallow lakes choked with submerged vegetation usually resulted in temporary nocturnal dissolved oxygen depletion inside the confinement cribs and catastrophic loss of fish. A vast majority of the mortality reported for caged fish was caused by this factor and bacterial diseases. Epizootics occurred frequently where water circulation through the cages was inadequate. Instructions to County Board personnel for routine exterior cage brushing to eliminate periophyton growth would reduce this problem. Prophylatic control of disease was impractical unless water inside the confinement cages was isolated from the lake water, and this was often impossible. Food containing antibiotic preparations helped control bacterial infections at most lakes.

Growth of cage confined fish in some impoundments, such as industrial ponds and pits, was chronically slow. The exact cause was not identified, but low fertility seemed the most logical cause. After cage reared fish were released in excavated pits, growth and body condition diminished rapidly from the lack of natural food, particularly macrobenthic invertebrates.

Several alternatives are apparent to establish catfish populations in lakes with inveterate low dissolved oxygen or epizootics. Fish might be released prior to the onset of total oxygen depletion, thereby allowing catfish to seek locations with life supporting oxygen concentrations. Even then, many fish might die depending on the severity of the crisis. Populations might also be maintained at sufficient densities through stocking of hatchery reared fish of approximately the same body size of cage reared fish. Again, early planting is mandatory where the probability of oxygen depletion is high.

Cost analyses of the program revealed nearly one-third of the expenditures were attributable to commercial food, and represented a category where costs might be reduced by prudent procedures. Gross errors in selecting correct ration sizes and estimating the number of fish loaded in cribs were most important to cost benefit ratios. Feeding of pellets too large for the fish to consume occurred frequently, especially closely following cage loading when the fish are quite small. Imprecise weighing of subsamples and inaccurate computation of feeding schedules also led to wasted food. A regular schedule of not more than 21 days between recalculation of the feeding schedule must be maintained and daily rations precisely adjusted. Daily recording of feeding observations are beneficial for early identification of escapement, mortality or disease symptoms. Lakes with chronic problems should be eliminated from the program.

The minimum recommended size of catfish for cage loading is 55/kg (25/lbs). Fish with this size or larger would minimize any loss through the 1/2 inch hardware cloth and ensure the correct food ration schedule. Quite strong evidence was apparent that even if escapement of smaller fish at loading was prevented by smaller mesh, growth was insufficient to reach a body size to minimize predation upon release. Smaller mesh size would only compound reduced water circulation through the cages which ultimately results in even more serious consequences.

Faulty confinement crib construction was responsible for the loss of catfish and wasted food. Rusted and broken wire was the main problem. Solution of this problem is quite simple by close, routine inspection and replacement of damaged hardware cloth during cage storage. Commercial fish growers recommend vinyl-coated wire which seems superior to galvanized mesh. County Boards should be made aware of the new product when wire replacement is necessary.

Some County Boards, in the interest of cost reduction, purchased food of pond formula that did not contain all ingredients of a complete ration. Proper diet for confined catfish is absolutely essential for growth and resistence to disease pathogens. Balanced, floating rations containing not less than 30% protein must be fed at least five consecutive days, and preferably seven days, each week at 3% of the biomass per confinement crib each day. Further experimentation is recommended for feeding 1.5% of the body weight twice each day to determine if this schedule might improve the conversion ratio. However, until these data are evaluated continuation of the once per day schedule is suggested.

Food costs might be significantly reduced through centralized purchasing agreements by several County Boards. Catfish rations could be purchased in larger lots, affecting bulk rates, and the cost prorated to each Board on the basis of their program needs. An additional benefit would be realized by ensuring the purchase of the correct formula and pellet size. Fisheries Section personnel in the management districts are suggested as coordinators of bulk purchases.

Labor costs comprised more than 50% of the program expenditures and were about equally divided between both agencies. Alternatives for reducing labor costs are quite limited since a large portion of State costs were related to periodic sampling for recomputation of feeding regimens, which are vital program procedures. County Board labor costs for feeding might be substantially reduced by installing larger, more permanent cribs equipped with automatic feeding units. A single unit might replace up to six smaller confinement cages that are loaded at the same density. This arrangement would eliminate the constant burden of hand feeding each crib and the feeding schedules would be precisely maintained. There are several disadvantages though; fish sampling in larger confinement areas is more difficult, inspection for disease and treatment of epizootics are more troublesome and handling of larger cribs for storage is more difficult. Construction costs would not greatly differ. The use of larger cribs with automatic feeders would be feasible only for long term programs in larger lakes.

Twenty-six of the 30 lakes with cage rearing programs for two or more years exhibited systematically declining growth rate of fish in confinement despite identical feeding rates and loading densities. Apparently a growth inhibitor of unknown substance developed following successive years of cage rearing. This phenomenon has not been reported in other cage confinement rearing programs. Further investigation is needed to identify the cause of the consistent decline in growth since it is important to conversion ratios and elevates cost benefits. The Fisheries Section does not possess the biochemistry or genetics expertise needed to isolate the phenomenon, but related research oriented agencies could be contracted to solve the problem. Solution and correction would greatly increase the size of confinement reared fish at release with potentially wider implications to hatchery production.

Optimum stocking rates from confinement rearing programs were difficult to assess, since each lake and population was somewhat unique by having varying catch rates, natural mortality and growth. The latter two factors are density dependent and associated mainly with natural food availability, vulnerability and specific competition. The most prevalent error in program strategy was continual overstocking of lakes that approached maximum carrying capacity. Broad generalized stocking recommendations seem unwise because of the wide environmental diversity necessitating almost individual program rationale. However, the data from lakes with long term programs were indicative of some criteria that appeared in the population structure when the density surpassed optimum levels. Overstocking occurred when one or more of the four following conditions were evident: (a) less than 50% of the catfish population is not harvested each year; (b) mean body condition (K) of the catfish at large is .70 or lower (C < 25); (c) annual growth increment of the most recently released cohort is 30 mm or less (1.2 in) in the succeeding season; (d) summer biomass of the macrobenthic invertebrate population, particularly dipteran larvae, is 5 g/m^2 or less (230 organisms/ft^2) above the thermocline.

Regardless of the complexity of biological relationships, the Williamson Pond research showed strong evidence of severe interspecific competition of bluegill and crappie with increased catfish populations when the stocking density exceeded 410/ha (168/ac). Contrary, the cohabiting native catfish population seemed to benefit from the program.

The relative abundance of bluegill in sample net catches diminished significantly as the catfish population increased from stocking cage reared fish. Accompanying the decline in population density was a decreased harvest from a significant fishery early in the study to very low catches during the last segment. Part of the decline was attributed to the vastly increased fishing for catfish. Prior to the program about one fisherman in four was fishing for catfish, and by conclusion of the research nearly 70% were catfishermen. At the same time, 36% of the fishermen interviewed in 1972 were fishing for bluegill which declined to about one fisherman in twelve during the last year.

Concomitantly with a declining population density of bluegill growth was also significantly reduced at Williamson Pond during the confinement rearing program. Growth increments were below average in three of the four years. Condition factors exhibited the same systematic decline as the catfish population density increased. Crappie growth and body condition showed the identical trend except the magnitude was lower. Growth indices of the larger native catfish which were not dependent on macrobenthos were higher in three of the four years and body condition increased during the study.

These results demonstrate quite conclusively that the cage rearing program had a substantial deleterious effect on the well being of bluegill populations, probably from competition for macrobenthic invertebrates for food. Intensive confinement rearing programs might well lead to the demise of established bluegill fisheries. Awareness of the probable results must be considered in long term rearing program development. Crappie competition was much lower in magnitude, but some depression was evident. Food wastes and excrement from the caged fish was apparently a significant benefit as a food source for released catfish, since it was the second most important item consumed. The readily available food wastes were undoubtedly responsible for increased growth and body condition of catfish in the lake.

The most prevalent common problem in lakes with low harvest of released fish was dense stands of submergent vegetation. Control by chemical or biological means is essential to effectively utilize the released catfish, otherwise over-stocking becomes a chronic problem and benefits of the program proportionately reduced. Restrictive rules prohibiting night fishing prevented fish harvest rates at some lakes. Catfish success is notoriously higher after dark and should be encouraged at all impoundments.

Public information in the form of news media releases and fishing clinics might be used to increase the harvest of released catfish. A brochure describing the details of confinement fish rearing following a popular style format is needed for distribution, not only for the promotion of public lake fishing but also for those people interested in confinement culture in private ponds.

Success of the cage confinement rearing program in public fishing lakes differed greatly between water and it is difficult to summarize broadly the accomplishments of this endeavor as a fishery management technique. But, as a direct result of the program, the average fisherman that fished for catfish in one of the impoundments caught one fish that weighed slightly more than a pound after fishing slightly over four hours. The cost to the agencies that produced this fish, including that incurred during the first year of life in a fish hatchery, was about $1.30. A cost benefit ratio of this magnitude seems reasonable in light of the fact little catfishing existed in these lakes prior to initiation of the program.

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