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Paunch Manure as a Feed Supplement in Channel Catfish Farming

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PAUNCH MANURE AS A FEED SUPPLEMENT IN CHANNEL CATFISH FARMING

by

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ABSTRACT

Part A of this report examines the feasibility of using dried paunch at 10, 20 and 30% levels in sinking, pelleted feed for pond-rearing of yearling channel catfish to market-size, and at a 10% level in a floating, extruded pelleted feed for cage-culture of yearling catfish. Part B describes the effects of fish culture, using standard feeds and paunch-containing feeds, on water quality of fish ponds. Measurements of fifteen chemical parameters and fecal coliform counts are reported.

Regardless of feed type, pond-reared fish grew faster than the cage-reared fish. There was no significant difference in final weights attained by pond-reared fish given standard, and 10 and 20% paunch feeds but fish given 30% paunch were significantly smaller. In pond culture, feed costs per kg of catfish produced were essentially equal using the standard commercial sinking feed and sinking feed containing 10 and 20% paunch, but costs were greater using sinking feed with 30% paunch. In cage culture, the floating feed with 10% paunch was 22% more expensive per kg of fish flesh produced than a commercial cage culture ration. Neither pond nor cage culture caused deterioration in water quality in any of the ponds to any appreciable degree during one growing season of 24 weeks, and there were few significant differences in water quality in both pond and cage culture between the ponds in which commercial feeds were used and those in which paunch-containing feeds were used.

CONTENTS

FIGURES

FIGURES (Continued)

TABLES

TABLES (Continued)

TABLES (Continued)

TABLES (Continued)

ACKNOWLEDGMENTS

The proposal for EPA was co-authored by R. C. Summerfelt and A. K. Andrews. The latter participated during the pond construction but due to other commitments withdrew from participating once the study commenced. L. G. Hart, with the assistance of Philip Keasling, was in charge of daily feeding and taking samples of fish length and weight; and R. C. Summerfelt wrote Part A of the final report; Bill Fisher of the University Architect's Office prepared the blueprints and specifications for pond construction. The Division of Fish Hatcheries, Bureau of Sport Fisheries and Wildlife provided the experimental fish.

The chemical analyses given in Part B, with the exception of the four parameters which were measured at the pond sites, were performed at the Robert S. Kerr Environmental Research Laboratory by Mr. Michael Cook, Physical Science Technician. The original idea of utilizing paunch manure as a feed supplement in catfish farming was conceived by Mr. S. C. Yin, who also performed the bacteriological analyses and wrote Part B of the report. Mr. Jim Kingery, Mathematical Statistician, was solely responsible for the statistical analyses and the interpretations of the chemical and bacteriological data in Part B. This project would not have been possible without the encouragement and assistance of Mr. Jack Witherow, who was Chief of the Agricultural Wastes Section at RSKERL at the time that the project was approved by EPA. The technical consultations provided by Messrs. Dave Peters and John Matthews in the planning stages of the project are also gratefully acknowledged.

SECTION I

CONCLUSIONS

It is feasible to use dehydrated paunch as a feed constitutent in formulated feeds for pond-rearing channel catfish. Levels of 10 to 20% paunch can be used without producing a significant reduction in growth compared to fish reared on a typical commercial feed. Economically, however, levels of paunch in excess of 20% may increase the feed costs per kg of fish flesh produced. Thus, feed containing up to 20% paunch was as economical as a commercial feed for pond-rearing of channel catfish. For cage culture, however, paunch at 10% substitution level would not produce a desirable economic return. The fish harvest obtained in the present study averaged 1219 kg/ha which was typical for commercial production. At this density only declining fall water temperature but none of the water quality parameters limited growth or production. At production levels typical of average commercial catfish farming, there was no evidence indicating accumulation of metabolic wastes during the course of one growing season.

Under the experimental conditions of the present study, which endeavored to simulate typical catfish farming techniques, both pond and cage culture caused deterioration in water quality compared to ponds without fish, but neither of the two culture methods had impaired the water quality in general to any appreciable degree in one growing season. Moreover, there was no significant difference in water quality between ponds using a typical commercial feed and a feed containing dehydrated paunch. At similar densities, there was no difference in water quality between ponds using cage- and pond-rearing techniques.

SECTION II

RECOMMENDATIONS

This study has shown the feasibility of using dehydrated paunch as a feed constitutent in formulated feeds for pond-rearing of channel catfish. The objective of future nutritional studies with paunch should concentrate on the suitability of paunch as a complete feed for fishes less fastidious in nutritional requirement than the channel catfish. It seems likely that the potential of aquaculture as a means for providing a low cost protein source will be dependent on successful use of waste products. In principle, paunch should be applicable as a feed constituent or a complete feed for pond-rearing of *Tilapia* spp and carp (*Cyprinus carpio*), which are world-wide more important food fish than channel catfish. Moreover, finely ground, unpelletized dehydrated paunch seems to have excellent qualities as a complete feed for several bait minnows.

Water quality parameters in the present study were not limiting growth where average yield was 1219 kg/ha. Water quality studies in static warmwater fish culture need to be concentrated on static pond systems at maximum production densities of 2000-2500 kg/ha when metabolic products limit further increases in density.

PART A

FISH GROWTH AND PRODUCTION USING DRIED PAUNCH

SECTION III[a]

INTRODUCTION

The rumen contents of cattle, referred to as paunch manure, or simply paunch, contains a mixture of gastric juices, microbial flora and the remains of the partially digested food. At the abattoir, the wet weight of the rumen contents ranges from 18-27 kg per animal (Steffen 1969). In 1970, commercial abattoirs killed 35.02 million cattle (U.S. Dept. Agri. 1971) producing 630-945 million kilograms of wet paunch.

Yin et al. (1972) showed that long-term BOD of these materials exceeds 100,000 mg/l. Baumann's (1971) analyses indicated 59.1% of the total BOD of paunch was from the liquid portion and 40.9% was from solid portion. High total BOD and high solids content (13.3%) combine to make paunch a potent water pollutant with high treatment costs. The mixture of blood, paunch and other abattoir waste waters easily overload municipal treatment systems. Field burial has also been expensive, and because of its offensive odor difficulties even arise in hauling fresh paunch to a burial site. Thus, endeavors to find viable alternatives to disposal or conventional treatment were needed.

Dried paunch is nearly odorless and suitable for reuse as an ingredient for animal feeds (Goodrich and Meiske 1969). Baumann (1971 and 1972) described the feasibility of dehydrating paunch to 7% moisture content with gas-fired dryers at the largest U.S. slaughterhouse, located near

[a]This section was written by R. C. Summerfelt.

Council Bluffs, Iowa. The kill capacity of this facility was 250 animals per hour (Baumann 1971); in one 6-month period, 1 January 1971 to 30 June 1971, 184,720 head (avg. weight of 494 kg) were killed in 135 days. This slaughter produced 4.5 million kg of wet paunch with an average wet weight of 24.5 kg per animal. Seventy-five per cent of the total paunch output of this facility was dehydrated (7% moisture content) to an average of 3.85 kg dried weight per animal (Baumann 1971). Dehydrating costs were $8.62 per metric ton.

Studies by Baumann (1971) showed that sales of dried blood were greater than total dehydration costs for both blood and paunch. In 1972, however, dehydrated paunch had a limited market in cattle feeding trials and as a soil conditioner. Marketability of dried (dehydrated) paunch, and eliminating it from slaughterhouse wastes, requires economic incentives that facilitate reuse rather than disposal. If dehydrated paunch allows formulation of lower cost animal feeds, then the animal feed market may transform paunch from an expensive waste treatment problem to a financial gain for the meat-packing industry.

Dehydrated to about 6.2-6.8% moisture, dried paunch contains 12.7-15.3% protein and other desirable food ingredients (Table 1). Variation in composition and food value of dried paunch (Table 1) depends on the drying process and what the cattle were fed before slaughter. High variability in composition of feed stuffs causes problems in quality control in formulated feeds; however, the observed variability of protein in paunch is less than that of many common feed stuffs used in formulating animal feeds (Schoeff 1963). Paunch derived from "finished"

Table 1. Composition (%) of dehydrated paunch.

Component	$\bar{X}$[a]	$\bar{X}$[b]	Beefland Intl. ('70)[c] $\bar{X}_1$	$\bar{X}_2$	$\bar{X}_3$	$\bar{X}$[d]
Moisture	4.0	6.8	17.1	6.5	6.2	6.4
Protein	14.4	12.7	12.2	13.4	14.1	15.3
Fat	1.5	3.1	3.2	3.3	-	4.0
Carbohydrate	-	40.8	39.2	56.2	-	49.0
Crude fiber	39.0	26.2	26.1	19.7	21.3	18.9
Ash	8.4	7.2	7.1	6.9	-	7.2
Calcium	0.79	0.59	0.59	0.28	-	0.63
P_2O_5	0.67	1.47	1.47	0.63	-	0.60
Calories KC/G	1.73	-	-	-	-	4.24

[a]National Research Council, Committee on Animal Nutrition (1964:12).

[b]Baumann (1972) based on 60-90 determinations of each parameter.

[c]Beefland data were diverse: $\bar{X}_1$ was based on 30 samples with 60 determinations, and $\bar{X}_2$ was based on single pooled sample and one determination; $\bar{X}_3$ was the mean of four daily composite samples.

[d]Single determination of random sample from 15-ton batch lot used for formulating fish feed in present study.

cattle, i.e., those on high protein formulated feeds on feed lots are expected to be less variable. Paunch has a protein content greater than the maximum range for maize and most grain sorghums, about equal to the average for oats, slightly less than dehydrated alfalfa, but substantially lower than that in the high protein meals like cottonseed and soybean meals (Table 2). The vitamin content of dehydrated paunch, performed by WARF Institute, Inc. for Beefland International (personal communication), indicates the following vitamin levels in pooled, dehydrated paunch: Vitamin A (retinol), 1377 IU/kg; Vitamin D (calciferol), 10.4 IU/kg; Vitamin E (tocopherol) 13.2 IU/kg; Vitamin B_1 (thiamine), 3.5-4.4 mg/kg; Vitamin B_2 (riboflavin), 9.9 mg/kg; and Vitamin B_{12} (cob lamin), 0.61 mcg/gm. These vitamin levels are above average compared with many common feedstuffs (National Research Council-Committee on Animal Nutrition 1964).

Part A of this report examines the feasibility of using dried paunch at 10, 20 and 30% levels in feed for pond-rearing yearling channel catfish to market-size (0.6 kg), and at 10 and 20% levels for cage-culture of yearling catfish.

The pollution potential of large fish cultural program could have a decided effect on the water quality and aquatic life of the receiving aquatic environment. Hinshaw (1973) reported on alterations in quality of water passing through six trout hatcheries, but there is a sparsity of literature on effects of warmwater fish cultural production on water quality in earthen ponds. Part B describes the effects of pond fish culture using standard feeds and paunch-containing feeds on water

Table 2. Means ($\bar{X}$) and ranges in crude protein in samples of several feed ingredients.

Ingredient	$\bar{X}$[a]	Range[b]
Maize, yellow dent	8.8	7.0 - 10.9
Sorghum, grain	11.3	6.0 - 12.0
Oats, white	12.5	9.1 - 15.5
Dehydrated paunch[c]	13.7	12.2 -15.3
Alfalfa, aerial part, dehydrated and ground	17.4	13.7 - 20.8
Cottonseed meal, solvent extracted	32.9	28.5 - 35.0
Soybean meal, solvent extracted	45.8	42.0 - 47.4

[a]Means from National Research Council, Committee on Animal Nutrition (1964); the as fed category, not on dry weight basis.

[b]Ranges from Schoeff (1963)

[c]Mean and range of values in Table 1, present report.

quality of fish ponds. In all, one physical, one bacteriological, and fifteen chemical parameters were measured.

SECTION IV

METHODS

Twelve 0.1 ha earthen ponds (pond numbers 5-16) were constructed for the purpose of conducting the pond experiments. Two 0.4 ha ponds (pond numbers 2 and 3), already present, were used for the cage culture phases. Pond morphometry is described in Table 3. The ponds, located adjacent to Lake Carl Blackwell (Figure 1), were supplied with water by gravity flow from the lake by a 51 cm main line through the base of the dam. The main line also supplied water to the municipal water treatment plant of Stillwater. An accounting was made of the total water budget for each pond based on water added to fill the ponds, to replace evaporative and seepage losses, and water input from rainfall and runoff from the pond's watershed (Table 4). The water volume used for filling was determined from pond dimensions; volume added to replace seepage and evaporative losses was determined prior to refilling from measurements of the decline in vertical height of the water surface. Rainfall was obtained from measurements of the Outdoor Hydraulics Laboratory, Agricultural Research Service, U.S. Department of Agriculture. Their guage was located about 400 m north of our pond area.

Feeding experiments were designed to simulate open pond and cage cultural systems used in commercial channel catfish production. For the pond cultural system, fish were stocked in 10 (0.1 ha) ponds. Feeds used were a commercial feed, and the same feed formula containing by weight

Table 3. Morphometry and volume of ponds used in fish cultural experiments.

Characteristic	Cage culture pond numbers 2 and 3	Pond culture pond numbers 5 through 16
Length - m	84.14	54.42
Width - m	58.23	18.60
Water surface area - m^2	4,899	1,012
Watershed area - m^2	1,336	511[a]
Average depth - m	1.15	0.83
Water volume - m^3	5,634	840

[a]This was the mean of all 12 ponds; it was larger for ponds located on the ends of the rows.

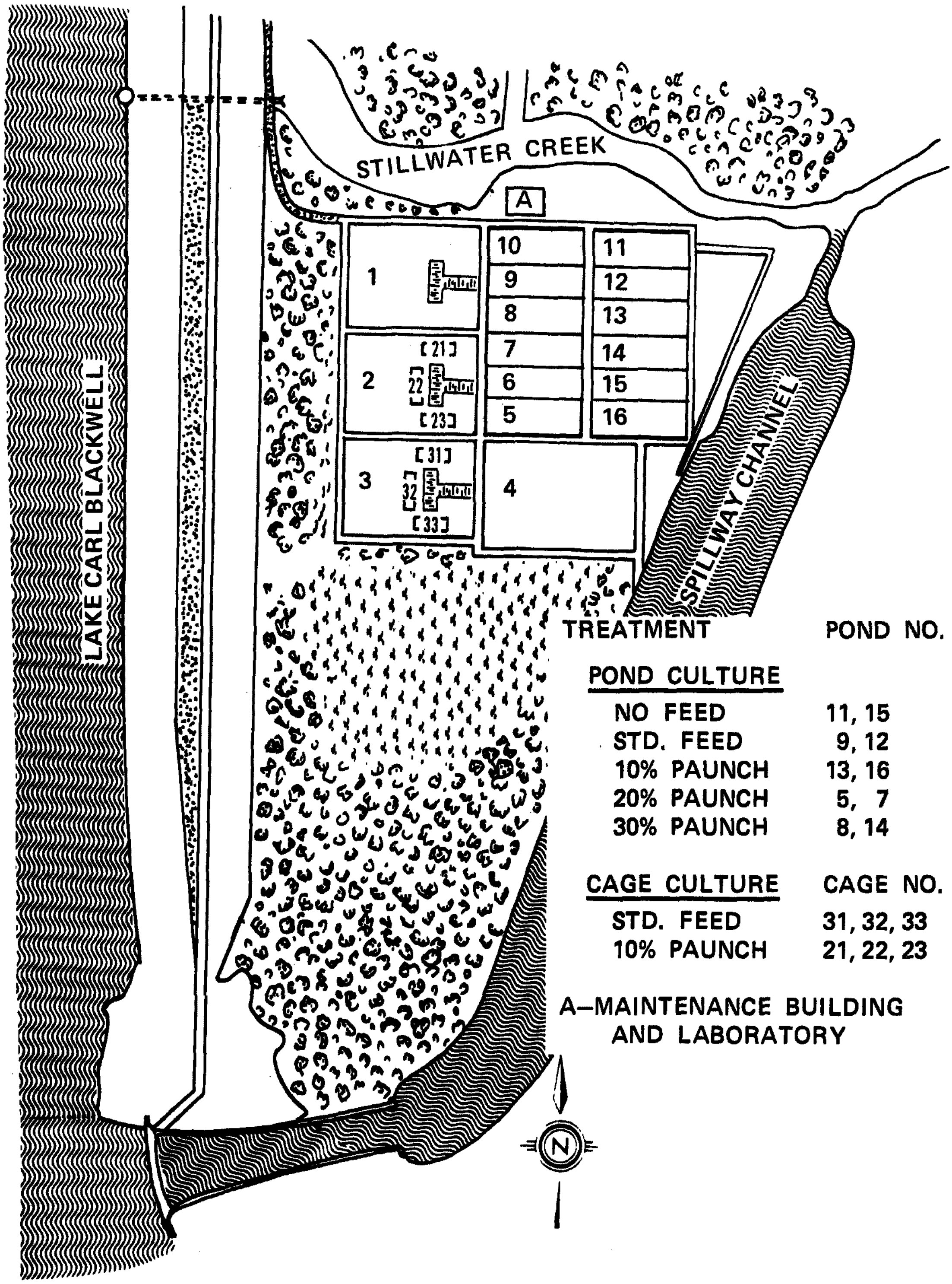

Figure 1. Experimental fish ponds used in pond (5-16) and cage culture (2 and 3) experiments. The tabular inset describes the experimental design. The cages used in ponds 2 and 3 are shown with [ ].

Table 4. Water budget (m^3) by pond number for filling, replacement of evaporative and seepage losses, and contribution of rain to the total water budget for six, 28-day intervals and for the total 168 days of the experiment.[a]

	2[b]	3	5	6	7	8	9	10	11	12	13	14	15	16	Totals (m^3)
Volume for filling	5634	5634	840	840	840	840	840	840	840	840	840	840	840	840	21348
Period 1: May 18-June 15															
Replacement	-	4999	1196	394	419	764	419	234	690	86	86	86	86	283	9742
Rain	-	210	50	50	50	50	50	50	50	50	50	50	50	50	810
Total	-	5209	1246	444	469	814	469	284	740	136	136	136	136	333	10552
Period 2: June 15-July 13															
Replacement	336	1863	247	247	99	555	99	703	444	197	99	247	333	308	5777
Rain	851	851	210	210	210	210	210	210	210	210	210	210	210	210	4222
Total	1187	2714	457	457	309	765	309	913	654	407	309	457	543	518	9999
Period 3: July 13-Aug. 10															
Replacement	1369	4034	900	148	358	99	456	1024	1345	296	333	629	432	358	11781
Rain	62	62	12	12	12	12	12	12	12	12	12	12	12	12	268
Total	1431	4096	912	160	370	111	468	1036	1357	308	345	641	444	370	12049
Period 4: Aug. 10-Sept. 7															
Replacement	5649	2479	419	247	247	136	321	493	752	111	0	259	234	296	11643
Rain	543	543	136	136	136	136	136	136	136	136	136	136	136	136	2718
Total	6192	3022	555	383	383	272	457	629	888	247	136	395	370	432	14361
Period 5: Sept. 7-Oct. 5															
Replacement	5663	2479	419	247	247	136	321	493	752	111	0	259	234	296	9657
Rain	358	358	86	86	86	86	86	86	86	86	86	86	86	86	1748
Total	4021	2837	505	333	333	222	407	579	838	197	86	345	320	382	11405
Period 6: Oct. 5-Nov. 2															
Replacement	752	3108	370	148	345	99	370	407	234	173	111	284	0	123	6524
Rain	925	925	234	234	234	234	234	234	234	234	234	234	234	234	4658
Total	1677	4033	604	382	579	333	604	641	468	407	345	518	234	357	11182
GRAND TOTALS	20142	27545	5119	2999	3283	3357	3554	4922	5785	2542	2197	3332	2887	3232	90896

[a]Surface area of ponds 2 and 3 were 4899 m^2, 5 through 16 were 1012 m^2.

[b]Pond 2 was filled prior to period 1, but drained during period 1 when the water became anoxic, then refilled prior to the start of period 2.

10, 20 and 30% dried paunch. The formulation of feeds containing paunch was designed to make them approximately isonitrogenous (equal levels of protein) and isocaloric (equal energy) (Table 5). Variability shown is due to inequalities in commercial batch lot processing. Fish were fed six of seven days of each of the 24 weeks of the study; the daily ration was given in one or two daily feedings.

Two types of floating feeds were used in the cage culture system, a commercial feed and a feed formulated to contain 10% paunch (Table 5). We originally planned to use floating feeds containing 20% and 30% paunch, as in the open pond experiments, but the vendor refused to proceed further because of a highly objectionable "manure" odor produced when the 10% paunch-fed mixture was mixed with water during the preparation of the expanded pellets.

The size and number of fingerlings needed for stocking the ponds were planned to simulate average commercial yield (kg/ha) while obtaining an "ideal" market size fish within a 168-day growing season. Consideration of these objectives require some perspectives on what is an average yield and "ideal" market size fish. Bardach et al. (1972:180) reported 900 kg/ha as an average annual yield for the catfish farming region which Greenfield (1972:Figure 1) illustrated as an area of the lower Mississippi delta. The Bureau of Sport Fisheries and Wildlife (1970:38-40) state that the "best" stocking density is 3705 yearling channel catfish per hectare when one desires a final average size of about 454 grams. The Bureau of Commercial Fisheries (1970) reported an average annual yield for average and excellent management to be

Table 5. Composition (%) of commercial catfish feeds, sinking feeds containing by weight 10-30% paunch, and a floating feed containing 10% paunch.

Ingredient	Floating feeds		Sinking feeds			
	Commercial	10%	Commercial	10%	20%	30%
Protein, Kjeldahl	38.6	38.7	32.2	34.9	33.5	33.1
Fat, ether extract	3.3	3.1	4.6	3.7	3.7	3.7
Fiber	5.8	5.1	7.9	8.3	10.2	10.7
Calcium	1.22	1.32	0.42	0.53	0.57	0.67
Phosphorus	0.93	1.13	0.98	0.85	0.75	0.73
Calories, KC/G	4.16	4.25	4.15	4.28	4.34	4.32

1,422 to 1,706 kg/ha, respectively. Meyer (1969) reported 2,038 kg/ha as the "upper limit" of production in static water ponds. The "ideal" size channel catfish for the processing plant is said to be 568 grams (1.25 lbs) (Greenfield 1972:20).

The numerical density chosen for stocking the ponds in this study was 260/0.1 ha pond (2600/ha). This density was considered maximum commensurate with use of 70 gram fish and the basic objective of a yield of about 1422 kg and a final average weight of 568 grams. Assuming mortality over the growing season to be about 4%, the number of fish stocked in each pond included 10 fish more than expected to survive the period of study.

The cage culture system was simulated by mooring three cages to "T"-shaped piers in 0.4 ha ponds (ponds 2 and 3, Figure 1). The cages were 0.91 m tall, by 0.91 m wide, and 1.37 m long. The cage frames were constructed of 38 mm wide aluminum angle of 12 mm thickness; brass bolts were used to attach 12.7 x 25.4 mm mesh wire to the frame. The mesh was vinyl-coated, 16 gauge welded wire. The cage had a hinged lid covered with welded wire mesh and 0.2 mm thick aluminum sheeting to provide shade, because an opaque cover is essential to obtain good growth and high survival from channel catfish (Schmittou 1970, Lewis 1969). The cages were buoyed with blocks of cellular polystyrene attached to the outside of the cage. The blocks were positioned to maintain 10 cm of freeboard between the level of water and the top of the cage. This design was used to obtain a submerged depth of 0.81 m and a water volume of 1.0 m^3. Cages were tethered to a pier at a water depth of 1.8 m which allowed about 1 meter between the bottom of the cage and the pond bottom.

Fish were stocked in cages with 1.0 m^3 submerged cage volume at a density suitable for commercial production. Lewis (1970) suggested a stocking density of $200/yd^3$, i.e., 260 m^3. Collins (1970b) described a commercial cage culture system used on an Arkansas reservoir which employed cages containing a volume of 3.18 m^3 (calculated from Collin's report) which was stocked with 1000 channel catfish, i.e., 315 catfish/ m^3. Using a range in stocking densities of 300, 400 and 500 fish per $meter^3$, Schmittou (1970) obtained the lowest conversion factor in cages stocked at $300/m^3$. Eley et al. (1972) said 289 $fish/m^3$ (1000 in a cage 3.456 m^3) of cage volume was "customary practice" in the southern United States. However, previous citations show that no specific number can be regarded as best and numbers used by researchers and commercial fish culturists are highly variable.

In the present study, 345 fish were stocked in each cage. This density was mid-range the densities reported in various experimental works although somewhat greater than what might be considered customary in commercial practice. With three 1 m^3 cages in each 0.49 ha pond stocked with about 345 fish per cage, specific densities were 2112/ha compared with 2600/ha in the pond culture.

Efforts to simulate commercial production of the desired yield and "ideal" average size were hampered by delays in construction and the starting date for the growth experiments. Thus, fish were stocked in mid-May rather than mid-April. In an attempt to extend the season, feeding was continued until 2 November; however, after 15 October water temperatures were generally too low (< 15°C) for growth and in most ponds, there was no significant difference between mean size on 15 October and 2 November.

Fish were stocked in the ponds and cages 16-18 May and the first growth interval was started with the feeding of fish on 18 May. Six growth intervals were planned to allow fitting the growth curve and to examine the relationship between changes in water quality and fish growth. Prior to stocking, the fish were counted into holding tanks and a sample of 25 anesthetized fish was taken to obtain lengths and weights. Fish were anesthetized in a container containing 30-50 ppm quinaldine. We commenced feeding 18 May (t_1), on that date and every 28 days thereafter, 25 fish were seined from the ponds, or dipped from cages to obtain lengths and weights: (t_2) 15 June, (t_3) 13 June, (t_4) 10 August, (t_5) 7 September, (t_6) 5 October, and (t_7) 2 November 1972.

Net production (P_n) was computed for the entire 168 days for each of six growth intervals: (1) 18 May - 15 June, (2) 15 June - 13 July, (3) 13 July - 10 August, (4) 10 August - 7 September, (5) 7 September - 5 October, and (6) 5 October - 2 November 1972. Net production (P_n) was calculated as per example for period 1, $P_n = B_2 - B_1$, where $\hat{N}_t$ = estimate of population number at time t_1 and $\bar{w}_t$ = the average weight of the individuals in the population at time t_1. Samples of 25 fish, weighed and measured prior to stocking and also sampled at 28-day intervals were used to obtain $\bar{w}$, for each collection date (t_1-t_7). Population N was obtained by total count on 18 May (t_1) and again 2 November (t_7) when the ponds were drained. For the other dates (t_2... t_5), N was estimated by calculations based on estimates of average daily mortality derived from an assumption of a linear rate for mortality over 168 days.

Two conversion factors, the S and C factors, are measures of the efficiency with which fish convert feed to fish flesh (Swingle 1958). These conversion factors are defined as follows:

$$S = \frac{\text{kg of feed added}}{\text{kg gain of fish}}, \text{ and } C = \frac{\text{kg of feed added}}{\text{adjusted kg gain of fish}}.$$

The adjusted weight gain for the C factor is the observed gain minus the gain expected without supplementary feed. The gain expected without feeding was estimated by concurrent observations of channel catfish growth in two ponds (pond numbers 11 and 15) which were not given supplemental feed. These fish were stocked at the same time and were of the same initial size as the groups receiving supplemental feed. Weight gains of the fish in ponds 11 and 15 had to be derived from natural foods; their weight gain was averaged and used to estimate the adjusted gain to compute the C factor for fish in the other ponds. Less commonly calculated than the S factor, the C factor is a better expression of the ability of a feed to provide for fish growth. The C factor provides a better comparison of feed conversion between pond and cage culture because fish in cages, like fish reared in raceways, are unable to obtain any significant amount of natural food (Schmittou

1969, 1970; Lewis 1970).

In both pond and cage cultural systems each feed type was considered a treatment and each treatment was replicated. In the pond culture, two replicates were used for each treatment and for the cage culture three cages replicated each treatment (Figure 1). The procedures of analysis of variance were used to determine significance of difference in length and weight of each treatment mean for each growth period. The hypothesis tested was that of no difference in fish size between treatments. Interaction, i.e., difference between replicates for the same treatment was never obtained. The F statistic was derived as the quotient obtained by dividing the among treatment (feed type) mean square by the within treatment error mean square. The latter was the mean square derived from the replicate difference. The pond experiment was analyzed separately from the cage experiment except where differences were explicitly examined. The degrees of freedom for the F statistic in the pond experiments were 3 and 4 for the numerator and denominator mean squares respectively; the d.f. for the cage culture experiments were 1 and 4. In the pond experiments, when a significant F was obtained ($P<.10$), the Duncan's new multiple range test (Steel and Torrie 1960) was used to determine which of the four treatment means (standard feed, feed with 10, 20 or 30% paunch) were significantly ($P<.05$) different from each other.

In addition to the water quality parameters reported by Yin in Part B, six days each week we measured dissolved oxygen and temperature in each pond at the surface and near the bottom, between 0900 and 1000 hours.

SECTION V

RESULTS AND DISCUSSION

Mortality

Stocking density in pond culture was planned for a survival of 250 fish per 0.1 ha pond, assuming a 4% total mortality. The observed numerical density after 168 days averaged 249.1 and the total mortality was 4.18%, excluding pond 12 where poaching was a problem (Table 6). By inspection of the results (Table 6), mortality of stocked fish in the ponds (as opposed to cage-reared fish) for the 168 days of the experiment apparently was a random variable and not related to feed type. The lowest mortality was observed in the two ponds where fish received feed with 30% paunch; highest mortality was in the two ponds where the fish received no feed.

The 4.18% observed mortality over all ponds was lower than the 7% contemplated for commercial production analysis assuming good management (Bureau of Commercial Fisheries 1970:17). Total mortality of less than 1% has been obtained in experimental pond culture of channel catfish (Deyoe and Tiemeier 1973), but this is exceptional, even in experimental ponds. Simco and Cross (1966) reported an average of 5% mortality in 41 experimental ponds over four years. Morris (1972) reported 9.8% mortality over three years in a Missouri Department of Conservation fish culture facility. Thus, mortality of yearling catfish may typically fall between 1-5% in research ponds and 7-10% in the less carefully controlled circumstances commonplace in private or

Table 6. Number of fish stocked (18 May) and estimates, based on total mortality rates, of number of fish present at each sampling date (t_1-t_7) for pond-reared catfish.

Ponds	May 18	June 15	July 13	Aug. 10	Sept. 7	Oct. 5	Nov. 2	Mortality %	Mortality Fish/day
11	260.00	257.67	255.33	252.99	250.65	248.32	246.00	5.38	0.083
15	260.00	255.99	251.99	247.99	243.99	239.98	236.00	9.23	0.143
Std. feed									
9	260.00	259.00	258.00	257.00	256.00	255.00	254.00	2.30	0.036
12	260.00	258.17	256.33	237.49	235.65	233.82	215.00	17.30[b]	0.268[b]
10% paunch									
13	260.00	259.17	258.33	257.49	256.65	255.82	255.00	1.92	0.030
16	260.00	258.50	257.00	255.50	254.00	252.50	251.00	3.46	0.054
20% paunch									
5	260.00	256.17	252.33	248.49	244.65	240.82	237.00	8.84	0.137
7	260.00	258.67	257.33	255.99	254.65	253.32	252.00	3.07	0.048
30% paunch									
8	260.00	259.50	259.00	258.50	258.00	257.50	257.00	1.15	0.018
14	260.00	259.00	258.00	257.00	256.00	255.00	254.00	2.30	0.036
Total[a]	2,340.00	2,323.67	2,307.31	2,290.95	2,274.59	2,258.26	2,242.00		0.066
Percent mortality between 28-day sampling intervals		0.70	0.70	0.71	0.71	0.71	0.72	4.18[c]	

[a]Column totals do not include pond 12 where 34 fish were taken by poachers.

[b]High values due to poaching; when excluding poaching, total mortality was 4.23% and mortality rate was 0.066 fish/day.

state pond culture.

To calculate the amount of feed to offer fish in each pond or cage during any interval between the taking of sample weights, the biomass (B_t) present was estimated from $B_t=\hat{N}_t\bar{w}_t$, where $\hat{N}_t$ = estimate of the number of fish present and $\bar{w}_t$ = mean weight. For t_1 and t_7, N was obtained by total count, but for $t_2 \ldots t_6$, N had to be estimated by assuming a uniform rate of mortality with time (Tables 6 and 7). Over all ponds this rate was 0.065 fish per day for 168 days (Table 6).

A complete fish kill occurred 1 June in pond 2 of the cage culture experiments (cages 21-23) 13 days after stocking (Table 7). Mortality resulted from anoxic conditions incurred because of decomposition of terrestrial vegetation present in the ponds when they were flooded. Cages 21-23 were restocked on 13 June and the experiment restarted. Anoxic conditions reoccurred in ponds 2 and 3 in late September causing a high mortality in several cages between the 7 September and 5 October sample dates. At this time anoxic conditions were due to BOD created by a massive growth of aquatic vegetation, mostly *Najas* and *Chara*. This weed problem and the resultant BOD might have been prevented by using herbicides prior to development of heavy plant growth. Herbicides were not considered because of apprehension that they would have constituted an extraneous variable affecting water quality. As a result of the September mortality, surviving fish from cages 31, 32 and 33 in pond 3 were used to restock two cages (32 and 33) at the original stocking density; likewise, survivors of the three cages in pond 2 were used to make up new populations for two cages (22 and 23).

Table 7. Number of fish stocked (18 May) and number of fish present at each sampling date for cage-reared channel catfish.

Cages	May 18	June 15	June 29	July 13	July 27	Aug. 10	Aug. 24	Sept. 7	Oct. 5	Nov. 2	Mortality %	Mortality Fish/day
Standard feed												
31	336	335	335	335	335	335	335	335	94[e]	-	.003[i]	.009[i]
32	333	333	333	333	333	333	333	333[c]	332	332	.003	.006
33	346	345	345	345	345	345	343	342	340	340	.017	.036
10% paunch												
21	345[a]	349[b]	349	348	348	348	348	348	217[e]	-	.003[i]	.009[i]
22	345[a]	349[b]	349	349	349	349	349	349[d]	349	349	.000	.000
23	345[a]	349[b]	348	348	348	348	348	348[d]	348	348	.003	.006
Total	1015[f]	1013[f] 2060[g]	2059	2058	2058	2058	2056	1372[h] 2055[g]	1369[h]	1369[h]		
Percent mortality between sampling intervals		0.20[j]	0.05	0.05	0.00	0.00	0.10	0.05	0.22[k]	0.00[k]		

[a]All fish died 19 May.

[b]Replacement fish placed in cages 13 June.

[c]Eleven fish died 18 September and were replaced with 11 fish from cage 31 on 5 October.

[d]Fifty-one fish from cage 22 and 11 fish from cage 23 died on 20 September and were replaced with fish from cage 21 on 25 September.

[e]Cage not included in project after 7 September due to massive mortalities.

[f]Includes cages 31, 32 and 33. [g]Include all cages.

[h]Includes cages 22, 23, 32 and 33. [i]Based on values to 7 September.

[j]Based on values from cages 31, 32 and 33. [k]Based on values from cages 22, 23, 32 and 33.

Mortality estimates for the cage-reared fish 13 June to 7 September were 0.3 to 1.7% smaller than mortality for pond-reared fish. There was no indication of differential mortality related to feed type. The observed mortality in the cages as a result of the respiratory demand by the large mass of aquatic plants does lend support to observations which show that caged catfish are more susceptible to low DO than pond-reared fish as the latter have access to more pond surface area per fish than the fish confined to cages (Lewis 1970, 1971; Schmittou 1970). Moreover, where the catfish were allowed access to the substrate, problems with aquatic plants did not occur.

Yield and Net Production

The biomass of fish present at the time of draining is the commercial yield which is not equivalent to either gross or net production as used in the ecological context; however, yield by this definition is the same as used by other fishery workers (Simco and Cross 1966). In the present study, yield was obtained as the product of average weight ($\bar{w}$) times population number (N) counted when the ponds were drained 2 November (Table 8). The average yield per ha in the eight ponds receiving supplemental food was 1219 kg/ha, or 319 kg/ha more than the average commercial yield in Arkansas (Bardach et al. 1972:180). Madwell (1971:9) estimated the average 1970 commercial yield of channel catfish for the entire U.S. at 1345 kg/ha, 10% greater than the average yield obtained in the present study, although less than the 1467 kg/ha obtained in pond 9. The average yield obtained in the present study accomplished the objective of obtaining a reasonably close

Table 8. Yield of channel catfish on 2 November from 0.1 ha ponds and amount of feed added during the 168-day growing season.[a]

Treatment Pond	Yield/pond kg	Amount (kg) Feed added
Standard feed		
9	147.60	201.88
12[b]	110.42	215.45
Avg.	129.01	208.66
Feed with 10% paunch		
13	123.96	211.90
16	132.73	223.02
Avg.	128.35	217.46
Feed with 20% paunch		
5	120.25	216.62
7	126.50	190.95
Avg.	123.38	203.79
Feed with 30% paunch		
8	104.16	178.72
14	109.91	187.02
Avg.	107.04	182.87
No supplemental feed		
11	16.78	0
15	21.85	0
Avg.	19.32	0

[a]Yield times 10 = yield/ha

[b]A 13% loss of fish due to poaching accounts for the low yield.

simulation to yield obtained in commercial production.

The 193.2 kg/ha average yield in the ponds not given supplemental feeding (ponds 11 and 15) was only 15.7% of the average yield of 1219 kg/ha in the 8 ponds where fish were given supplemental feed. Simco and Cross (1966) obtained an average yield of 146.8 kg/ha from stocking fingerling catfish in 0.11 ha experimental ponds without supplemental feed or fertilizer. On the other hand, the catfish harvest in ponds 11 and 15 was 9.1 times larger than 21.30 kg/ha average standing crop for channel catfish in multispecies populations of warmwater fishes in Oklahoma farm ponds (Jenkins 1958). Carlander (1955) calculated a mean channel catfish standing crop of 84.2 kg/ha from four reports of pond populations in Oklahoma and Texas. Without supplemental feeding, Walker and Carlander (1970) estimated a channel catfish yield of 33.7 kg/ha in an apparently eutrophic Iowa farm pond. They stocked 914, 5.4 g, fish/ha, and obtained 90% survival to a 41.4 g average weight after 119-125-day growth interval. In the present study, the maximum yield, observed in pond 9, of 1476 kg/ha was less than the 2631 kg/ha reported by Swingle (1959), 2483 kg/ha reported by Simco and Cross (1966), or the 2038 kg/ha "upper limit" to production in static water ponds reported by Meyer (1969). We did not seek to obtain maximum yield, however, as it would have required larger stocking density and probably would have resulted in a smaller average size at harvest.

The difference between initial and final total weight (B_7-B_1) of channel catfish is a measure of net production. In ponds 11 and 15, where a supplemental feed was not given and growth had to be derived from availability of natural food, net production of channel catfish for the 168-day interval averaged 2.37 kg/pond or 23.7 kg/ha. This is much less than the estimated range of 45 to 117 kg/ha for mixed farm pond fish populations in this area (Whiteside 1973), but mixed species are expected to better utilize the natural carrying capacity than a single species (Carlander 1955).

Few observations on net production of channel catfish from natural food resources were available for comparison. Swingle (1959) obtained a maximum channel catfish production of 202 kg/ha in fertilized ponds in Alabama for a 188-day period. Computations from data given by Walker and Carlander (1970) for a highly eutrophic 6.29 ha Iowa pond indicate a 28.8 kg/ha net production. Lewis (1971) stated that channel catfish production on natural foods would be about 102 kg/ha; however, context of Lewis's statement suggests that he was referring to yield rather than production. Net production in ponds 11 and 15 was 13.1% of the estimated average standing crop ($\bar{B}$) where B was estimated by the formula, $\bar{B} = (B_1 + B_7)/2$. No statistical test was made of the significance of difference between the mean yield by treatment. Visual inspection of the difference in yield between treatments suggested that even though feeds were approximately isonitrogenous and isocaloric, there was a negative relationship between yield and the percentage of dehydrated paunch in the feed

(Table 9, Figure 2). To quantify the magnitude of this relationship, a correlation between yield (the dependent variable) and percentage of paunch in the feed (the independent variable) was computed using a transformation of 1 + percent of paunch in the feed to eliminate the use of 0% for the standard feed. The yield from pond 12 was excluded because of excessive mortality related to poaching. The correlation coefficient (r) was -0.94 which is significant ($P<0.1$). The coefficient of determination (r^2 X 100) indicates that the percentage of paunch in the feed accounted for 88% of the variability in the yield.

Because the amount of feed given each day was a function of mean size of the fish, as determined from mean weights of samples taken every 28 days, the total amount of feed added to the ponds was less for fish with slower growth, as in ponds 8 and 14 where the fish were given the feed containing 30% paunch. Because slower growing fish were given less food, the possibility existed that yield would become a function of total quantity of feed given rather than the kind of feed. The correlation between yield and the total amount of feed was not significant ($r = 0.54$, $P>0.05$, $df = 5$).

Growth

Growth was calculated for each pond from measurements of length and weight from a sample of 25 fish collected every 28 days. Analysis of variance (AOV) of differences in treatment mean length ($\bar{\ell}_1$ and $\bar{\ell}_7$) and mean weight ($\bar{w}_1$ and $\bar{w}_7$) between the initial (t_1) and final (t_7) sample dates (18 May - 2 November) showed a significant growth ($P<.05$) for all

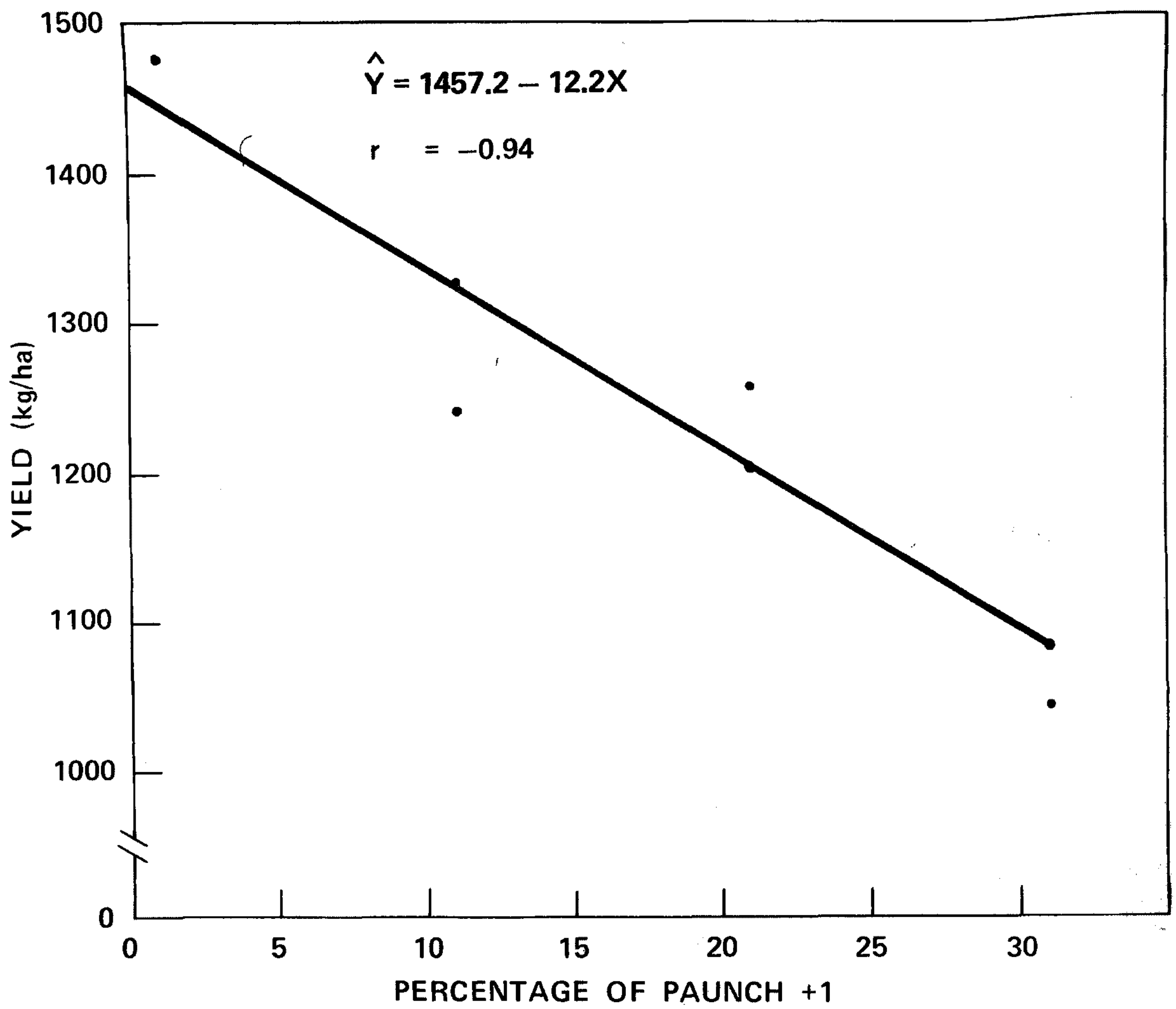

Figure 2. Relationship between observed yield (kg/ha X 10) of channel catfish from 0.1 ha ponds and percentage of paunch in the feed.

but treatment 1 (Table 9). The latter were fish not receiving any supplemental feed and their sample mean weights changed little from beginning to end of the growth experiment (Figure 3).

Excluding fish not receiving supplemental feed, growth curves of pond-reared fish, expressed as changes in wet weight during the course of the experiment, appeared sigmoid for all but fish in the treatment receiving standard feed (Figure 3). Declining water temperature in October and November is the most probable cause for declining growth rate, rather than feed type or water quality, but there was an apparent interaction between growth, feed type and water temperature. Mean growth rate of fish given standard feed (ponds 9 and 12) was linear throughout the growth interval in spite of declining water temperatures from mid-September through 2 November (Figure 4). Moreover, pronounced differences in average weight at the termination of the study between the fish receiving feed containing 30% paunch and weight of fish in the other treatment indicates that the quality of the feed acting alone or in concert with temperature also limited growth. It also reveals that examination for differences in feed quality must include the full production cycle since differences in fish growth were small prior to October 5. Hastings (W. H. Hastings, Fish Farming Experimental Station, Stuttgart, Arkansas: personal communication) has concluded that growth of catfish at different temperatures is a function of whether the protein is of animal or plant origin.

Table 9. Analysis of variance of difference in treatment mean condition factor (K_{TL}), length and weight of pond-reared (TRTS 1-5) and cage-reared (TRTS 6+7) channel catfish between 18 May and 2 November.

TRT No.	Feed Type (cage or pond No.)		18 May (t_1)	2 Nov. (t_7)	Sign. of F %
		Ponds			
1	None	K_{TL}	0.66	0.67	10.0
	(11+15)	Length (mm)	212.6	227.0	10.0
		Weight (g)	65.2	80.4	10.0
2	Std. sinking	K_{TL}	0.66	0.94	1.0
	(9+12)	Length (mm)	218.9	385.6	0.5
		Weight (g)	71.2	547.4	0.5
3	10% paunch	K_{TL}	0.67	0.86	0.5
	(13+16)	Length (mm)	212.8	388.4	0.5
		Weight (g)	66.4	507.4	0.5
4	20% paunch	K_{TL}	0.70	0.87	1.0
	(5+7)	Length (mm)	216.4	384.2	0.5
		Weight (g)	71.4	502.7	0.5
5	30% paunch	K_{TL}	0.67	0.84	2.5
	(8+14)	Length (mm)	219.7	367.2	0.5
		Weight (g)	72.5	419.0	0.5
		Cages			
6	Std. Floating	K_{TL}	0.66	0.97	0.5
	(31, 32, 33)	Length (mm)	202.0	335.5	0.5
		Weight (g)	57.7	360.2	0.5
7[a]	10% paunch	K_{TL}	0.68	0.93	2.5
	(21, 22, 23)	Length (mm)	227.0	321.7	0.5
		Weight (g)	82.8	313.2	0.5

[a]Treatment 7 started 15 June; thus, the analysis is for the difference between length, weight and condition factor between 15 June and 2 November.

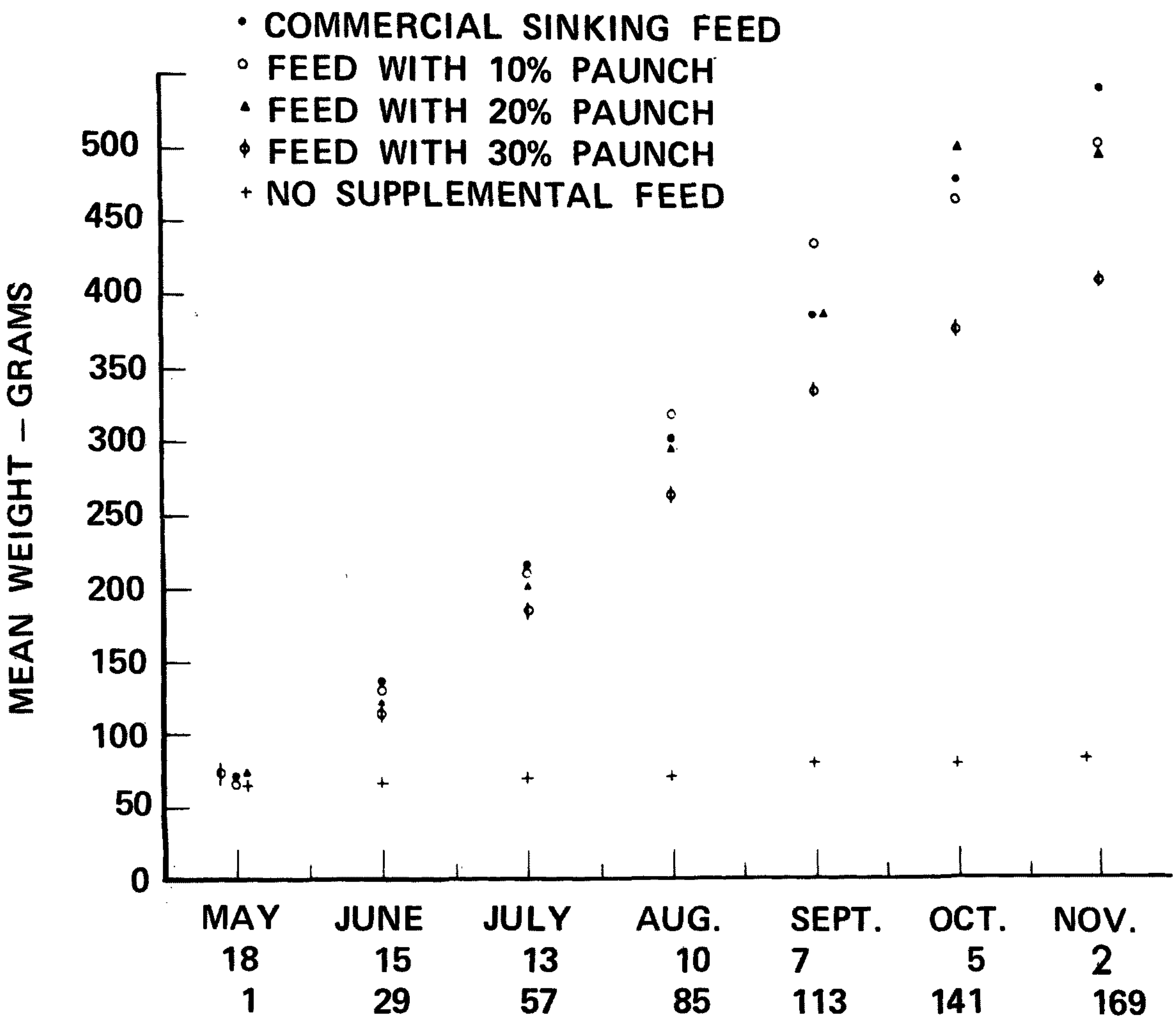

Figure 3. Comparative growth of pond-reared channel catfish, 18 May to 2 November 1972, for five experimental treatments. A point represents the mean of two replicates of each treatment.

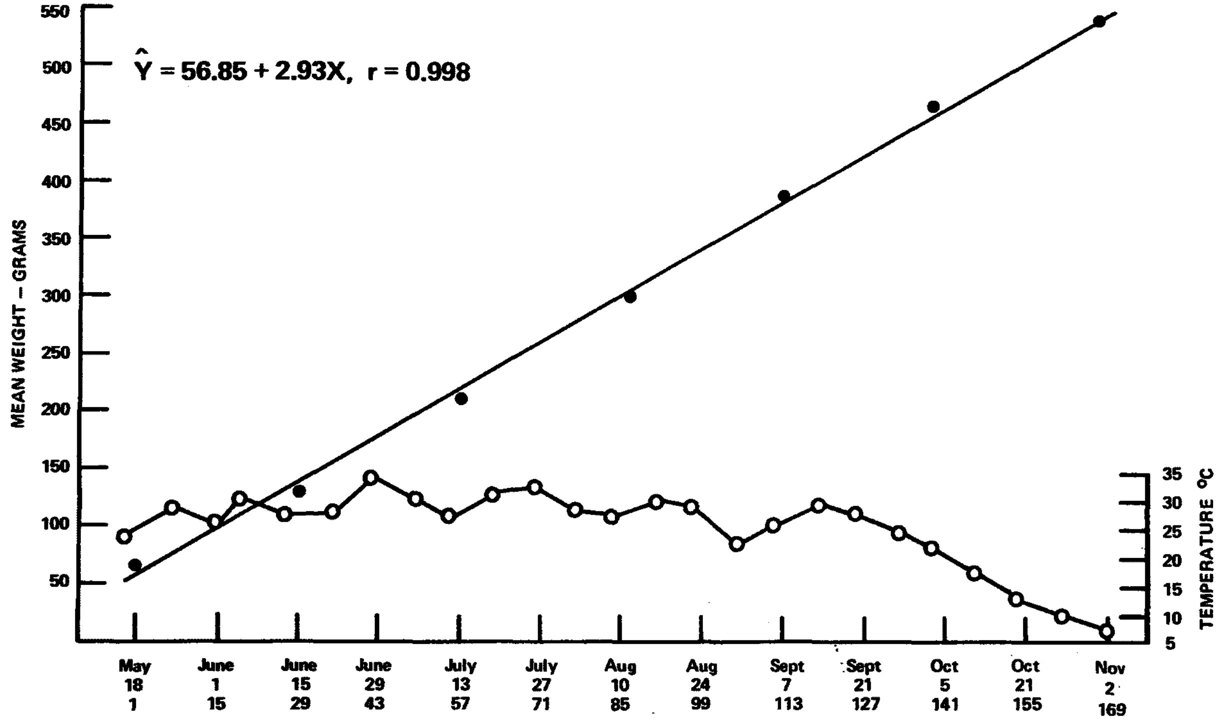

Figure 4. Linearity of pond-reared channel catfish growth (fish weights are solid circles) for fish fed standard sinking feed, and weekly observations on water temperature (open circles), 18 May–2 November. In the regression the X variable is the sampling day of the total growth interval, $\hat{Y}$ is the estimate of mean body weight for the same day.

An AOV of the significance of the differences between treatment mean weights for pond-reared fish for each collection showed no initial difference in treatment mean weight (Table 10). Thus, the groups were initially homogeneous, comprised of randomly established strata subdivided from a single initial population. The fish not given supplemental feedings were omitted from all statistical analyses after 18 May as they were expected to deviate from the other groups on subsequent dates.

For pond-reared fish receiving standard, or 10, 20 and 30% paunch feeds, differences among treatment means of catfish body weight for each collection date between 18 May and 7 September were nonsignificant ($P>.10$). On 5 October, the differences among treatment means of body weight were significant ($P<.025$), and the Duncan's multiple range test showed that the group receiving feed containing 30% dried paunch was significantly smaller than the other groups. When the ponds were drained (2 November) a similar difference was noted (the computed F statistic exceeded the tabular F at the 10% level), and the Duncan's multiple range test, using a 5% level of significance, again showed that the treatment mean of the fish receiving 30% paunch was smaller than the other treatments. These findings were basically duplicated in the analyses of differences among treatment means of catfish body length except that a significant difference was noted between several treatments on 15 June which was not observed in subsequent periods and therefore may be attributed to sampling error (Table 10).

Table 10. Analysis of differences in treatment mean lengths and weights of pond-reared channel catfish fed a standard sinking feed (std) and sinking feeds containing 10, 20, and 30% dried paunch. When the significance of the F statistic was ≤ 10%, then Duncan's multiple range test was used to determine the significance of difference between the means. Where the Duncan's test was applied, any means not underscored by the same line was significantly different at the 5% level.

Date	Mean length (mm)					Mean weight (g)				
	Std.	10	20	30	Sign. of F statistic[a]	Std.	10	20	30	Sign. of F statistic[a]
18 May	218.9	212.8	214.8	219.1	NS>10.0	71.2	66.4	71.4	72.5	NS>10.0
15 June	252.2	246.0	247.2	240.1	1.0	135.2	130.6	118.8	112.7	NS>10.0
13 July	285.5	283.3	282.9	279.8	NS>10.0	214.8	210.1	200.5	186.9	NS>10.0
10 August	321.3	327.0	323.5	313.0	NS>10.0	301.9	320.2	296.9	262.5	NS>10.0
7 September	349.9	355.3	349.3	343.2	NS>10.0	388.4	421.0	390.0	337.0	NS>10.0
5 October	373.2	372.4	377.5	356.4	10.0	483.2	471.3	505.5	379.9	2.5
2 November	385.6	388.1	384.2	366.0	10.0	547.4	507.4	502.7	419.0	10.0

[a]Percentage points for the distribution of F.

It was shown that final average yield was a linear function of percent of paunch in the diet (Figure 2), but lack of differences in average weights or lengths at harvest between fish given standard feed and feed containing 10 and 20% paunch shows that up to 20% level, paunch did not significantly affect final size of pond-reared fish over the 168-day growing season.

As noted above, growth rates of pond-reared fish in most treatments declined between 7 September and 2 November. Mean monthly water temperature declined between 7 September and 2 November, and the temperature in the last half of the last growth interval was low enough to anticipate a reduced growth rate. An analysis of variance showed that differences in treatment mean lengths and weights between 5 October and 2 November were non-significant with the exception of fish receiving 30% paunch (Table 11). The fish from the latter treatment had a significant increase in body length between the same dates but not in body weight. Thus, there was a non-significant growth increment between 5 October and 2 November for all treatments but fish receiving feed containing 30% paunch.

For cage-reared fish, an analysis of variance of the difference between two treatment means was computed for each of the 9 sampling dates (Table 12). The two treatments were started 18 May, but a complete fish kill occurred in cages held in pond 2 on 1 June due to an oxygen depletion caused by decomposition of terrestrial vegetation present at the time the pond was filled. The cages in pond 2 were

Table 11. Analysis of variance of differences in treatment means of length, weight, and condition factor between 5 October and 2 November for each treatment.

TRT-feed type		Mean lengths (mm)			Mean weights (g)			Condition factor (K_{TL})		
		Oct. 5	Nov. 2	Sign. of F statistic	Oct. 5	Nov. 2	Sign. of F statistic	Oct. 5	Nov. 2	Sign. of F statistic
					PONDS					
No.										
1	None	226.2	225.0	NS[a]	77.7	80.4	NS	0.66	0.67	NS
2	Std. sinking	373.2	385.6	NS	483.2	547.4	NS	0.91	0.94	NS
3	10% paunch	372.4	388.1	NS	471.3	507.4	NS	0.90	0.86	NS
4	20% paunch	377.5	384.2	NS	505.5	502.7	NS	0.92	0.87	NS
5	30% paunch	356.4	366.0	10.0[b]	379.9	419.0	NS	0.82	0.84	NS
					CAGES					
6	Std. floating	335.5	331.4	NS	384.4	360.2	NS	0.96	0.97	NS
7	10% paunch	316.6	321.8	NS	302.8	313.2	NS	0.93	0.93	NS

[a]NS - F statistic was non-significant when $P>0.10$

[b]$P<.10 > .05$

Table 12. Analysis of variance of differences from 15 June through 2 November in treatment mean lengths, weights and condition factor for cage-reared channel catfish fed standard (SF) feed or 10% (FF_{10}) paunch-substituted, floating feed.

Date	Mean lengths (mm)			Mean weights (g)			Mean condition factor (K_{TL})		
	SF	FF_{10}	Sign. of F statistic[a]	SF	FF_{10}	Sign. of F statistic[a]	SF	FF_{10}	Sign. of F statistic[a]
15 June	225.2	227.0	NS[b]	102.5	82.8	0.5	0.88	0.68	0.5
29 June	243.0	237.1	NS	129.5	111.1	NS	0.87	0.80	2.5
13 July	253.6	252.2	NS	153.6	149.6	NS	0.85	0.83	10.0
27 July	272.6	262.2	NS	179.9	157.7	NS	0.89	0.89	NS
10 August	274.0	268.6	NS	188.7	171.9	NS	0.86	0.84	10.0
24 August	295.7	276.2	0.5	234.0	194.2	5.0	0.91	0.92	NS
7 September	306.1	295.4	0.5	271.4	238.7	0.5	0.91	0.90	NS
5 October	331.4	316.6	5.0	360.2	302.8	5.0	0.95	0.93	NS
2 November	335.5	321.8	5.0	384.4	313.2	5.0	0.97	0.97	NS

[a]Percentage points for the distribution of F (Snedecor and Cochran 1967, Table A).

[b]Non-significant when P>0.10%

restocked on 13 June and the feeding experiment resumed 15 June. At this time there was a significant difference between the treatment mean weights for fish fed the standard feed and the fish fed the feed with 10% paunch; however, there was no significant difference in the two treatment means after 14 days of feeding (29 June), or thereafter until the 24 August when the difference was significant at the 5% level. At the termination of the study (2 November), the mean weights of the fish receiving standard feed were 18.5% larger than the fish fed with feed containing 10% paunch, and the two treatment means of body weight were significantly different ($P<.05$) (Figure 5).

Difference in final mean weight of caged fish in the treatment given the standard feed (335.5 g) and the caged fish given 10% paunch (321.8 g) was significant (Table 12). Because cage-reared channel catfish are unable to supplement their diet with natural food, deficiencies in the feed ingredients are more likely to become limiting for them than for pond-reared fish with similar feed deficiencies.

Comparison of growth of pond- and cage-reared fish was done for fish in treatments receiving the complementary food type: i.e., lengths and weights of the pond-reared fish fed the standard sinking feed were compared with the cage-reared fish fed the standard floating pellets (Table 13); also, cage-reared fish fed the 10% paunch feed were compared with the pond-reared fish fed the 10% paunch feed (Table 14). In comparing the pond-reared fish on standard sinking feed with the cage-reared fish on standard floating feed, the calculated F value for the AOV was non-significant on 18 May, but it

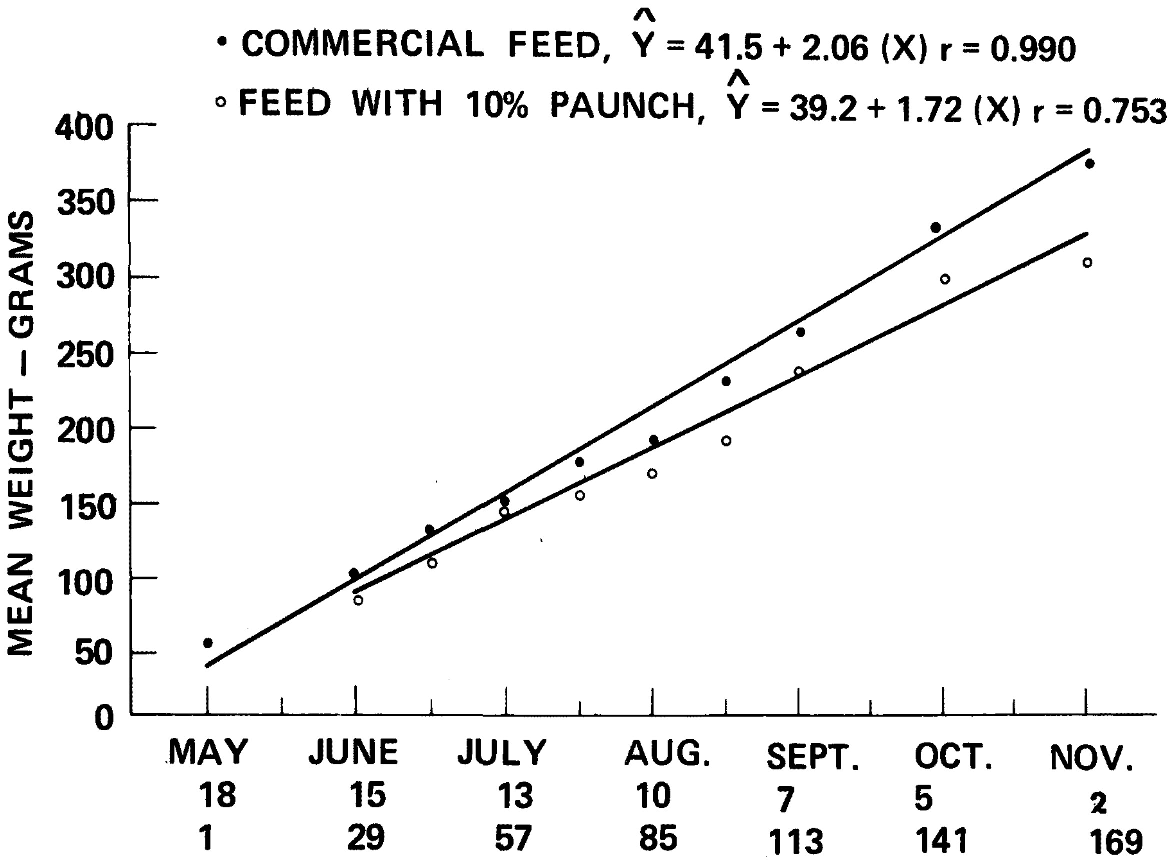

Figure 5. Growth comparison of cage-reared channel catfish fed commercial floating feed and a floating feed containing 10% paunch.

Table 13. Summary of analysis of variance of differences in treatment means of length, weight and condition factor of pond-reared channel catfish fed standard sinking (SF_{std}) feed compared with cage-reared fish fed standard floating (FF_{std}) feed.

Date	Mean length (mm)			Mean weight (g)			Mean condition factor (K_{TL})		
	SF_{std}	FF_{std}	Sign. of F statistic[a]	SF_{std}	FF_{std}	Sign. of F statistic[a]	SF_{std}	FF_{std}	Sign. of F Statistic[a]
18 May	218.9	202.0	NS[b]	71.2	57.7	NS[b]	0.66	0.66	NS[b]
15 June	252.2	225.2	0.5	135.2	102.5	2.5	0.82	0.87	NS
13 July	285.5	253.6	2.5	214.8	153.6	2.5	0.93	0.89	NS
10 August	321.3	274.0	1.0	301.9	188.7	2.5	0.89	0.86	NS
7 September	349.9	306.1	0.5	388.4	271.4	0.5	0.89	0.91	NS
5 October	373.2	331.4	5.0	483.2	360.2	10.0	0.91	0.95	NS
2 November	385.6	335.5	1.0	547.4	384.4	1.0	0.94	0.97	NS

[a]Percentage points for the distribution of F (Snedecor and Cochran 1967, Table A).

[b]Non-significant when $P>0.10\%$

Table 14. Summary of analysis of variance of differences in treatment means of channel catfish length, weight, and condition factor for pond-reared fish fed a 10% paunch substituted sinking feed (SF_{10}) and cage-reared fish fed a 10% paunch substituted floating feed (FF_{10}).

Date	Mean length (mm)			Mean weight (g)			Mean condition factor (K_{TL})		
	SF_{10}	FF_{10}	Sign. of F statistic[a]	SF_{10}	FF_{10}	Sign. of F statistic[a]	SF_{10}	FF_{10}	Sign. of F statistic[a]
15 June	246.0	227.0	0.5	130.6	82.8	0.5	0.85	0.68	0.5
13 July	283.3	252.2	0.5	210.1	149.6	5.0	0.90	0.89	NS
10 August	327.0	268.6	0.5	320.2	171.9	0.5	0.90	0.84	10.0
7 September	355.3	295.4	0.5	421.0	238.7	0.5	0.93	0.90	5.0
5 October	372.4	316.6	1.0	471.3	302.8	0.5	0.90	0.93	NS
2 November	388.1	321.8	2.5	507.4	313.2	2.5	0.86	0.92	NS

[a]Percentage points for the distribution of F (Snedecor and Cochran 1967, Table A).

[b]Non-significant when P>0.10%

was significant on every date thereafter (Table 13). Thus, in this study, pond-reared fish fed the standard commercial feed were always larger than cage-reared fish fed the standard floating feed. At the time of draining, the mean weight of pond-reared fish receiving standard feed (547.4 g) was 42.40% greater than the mean weight of the cage-reared fish (384.4 g) fed standard cage feed; the difference was highly significant ($P<.01$). The large difference in the average growth rate (slope) between the two groups accounted for the large difference in final size of fish reared by pond and cage methods (Figure 6).

All differences in mean length and weight of pond-reared and cage-reared fish fed the feed containing 10% paunch were significant ($P\leq.05$) (Table 14). Thus, regardless of feed type, pond-reared fish grew much better than cage-reared fish, and the former were significantly larger than their counterparts in cages throughout the experimental interval. The slower growth of fish in the cages may be attributable to factors other than feed quality <u>per se</u> as feed conversion (S factor) was better (i.e., lower) in cages than the ponds (Table 16).

Condition Factor

A condition factor (K_{TL}) was computed from length-weight measurements of 25 fish from each pond on each sample date. Analysis of variance of differences in treatment means for K_{TL} on 18 May, the commencement of the study, and the treatment means on 2 November, the termination of the the study, showed there was a significant increment ($P<.005$)

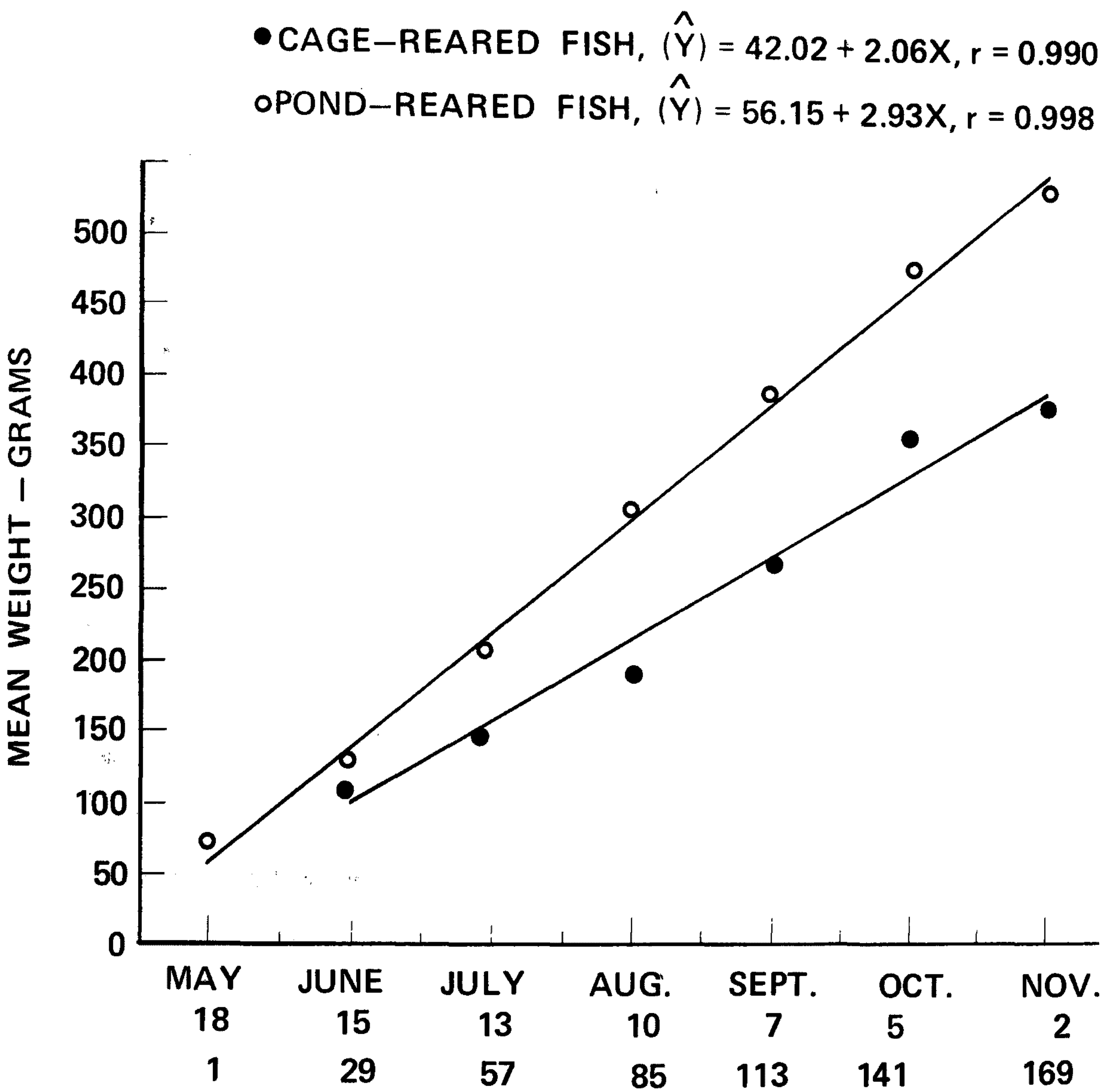

Figure 6. Growth comparison of pond-reared and cage-reared channel catfish fed commercial floating and commercial sinking feeds, respectively.

Table 15. Analysis of differences in condition factor of pond-reared channel catfish fed the standard sinking feed (X_1), feeds containing 10 (X_2), 20 (X_3), and 30% (X_4) dried paunch, compared with condition factor of fish not given supplemental feed (X_5). When the percentage points for the computed F was $\leq$ 10%, then Duncan's multiple range test was used to determine the significance of difference between the means. Where Duncan's test is applied, any means not underscored by the same line are significantly different at the 5% level.

Date	Rank Order of Condition Factor					Sign. of F statistic (%)
	1st	2nd	3rd	4th	5th	
18 May	0.70X_3	0.67X_2	0.67X_4	0.66X_5	0.66X_1	5.0
15 June	0.89X_4	0.85X_2	0.82X_1	0.77X_3	0.65X_5	NS
13 July	0.93X_1	0.90X_2	0.87X_3	0.83X_4	0.63X_5	1.0
10 August	0.90X_2	0.89X_1	0.86X_3	0.83X_4	0.65X_5	0.5
7 September	0.93X_2	0.90X_3	0.89X_1	0.82X_4	0.64X_5	0.5
5 October	0.92X_3	0.91X_1	0.90X_2	0.82X_4	0.66X_5	0.5
2 November	0.94X_1	0.87X_3	0.86X_2	0.84X_4	0.67X_5	0.5

in the K_{TL} for all treatment means except the treatment mean of fish not given any feed (Table 12).

An AOV of the difference among treatment means K_{TL} was done for all sample dates (Table 15). The computed F was significant ($P \leq .10$) for all but the 15 June collection. The significant difference obtained at the commencement of the study (18 May) was attributable to a significantly larger treatment mean K_{TL} for fish which were to be fed 30% paunch. Thus, the treatment means were not initially homogeneous, but the heterogeneity disappeared by the end of the first growth interval (15 June) when the condition factors of all treatments were alike. The K_{TL} of fish fed 30% paunch was fourth ranked on all but the 18 May and 15 June samples. Thus, the initially larger K_{TL} of the group receiving 30% paunch feed did not result in it having a larger K_{TL} on subsequent sample dates and, in fact, the K_{TL} of fish in the treatment receiving 30% paunch were fourth ranked on all but the first two sample dates, larger only than fish in the treatment not receiving supplemental feed (Table 15).

Rankings of the K_{TL} of the other treatments over the five samplings between 13 July and 2 November were different on each sampling date, placing in question the importance of the final difference in the K_{TL} between the fish on standard feed and fish in the treatments receiving 10 and 20% paunch (Table 15). On 2 November, the Duncan's test showed no difference between the treatment mean K_{TL} of fish receiving standard feed and feed with 20% paunch, but there was a difference between the treatment mean K_{TL} of fish receiving standard feed and treatment means for fish receiving 10 and 30% paunch. On 5 October there was no difference between treatment means of fish receiving standard feed and fish given feed with 10 and 20% paunch.

The initial (15 June) treatment mean condition factor of cage-reared fish fed standard feed was significantly larger than the treatment K_{TL} of cage-reared fish to be fed 10% paunch (Table 11). This initial difference is attributable to the fact that the fish receiving the standard feed had been eating for two weeks, whereas the fish to be used for the 10% paunch treatment had been held without regular feedings up to that date. A difference also occurred between the two mean weights for the same treatments on 15 June (Table 11). The difference between the condition factor of cage-reared fish in the two treatments persisted through 10 August but was non-existant thereafter as there was a non-significant difference in the treatment means for the 24 August through 2 November samples (Table 11).

Although a significant difference was observed in growth in length and weight of the cage-reared fish on these two treatments from 24 August through 2 November, the difference in condition factor between the two treatments on the same dates was non-significant. Although fish fed standard feed grew faster than fish receiving feed with 10% paunch, the latter group were equally as robust and not lean for their length.

Channel catfish reared in ponds and fed standard sinking feed grew faster than the cage-reared catfish on standard floating feed; however, the difference in mean condition factor between the two treatment means was always non-significant (P>10%) (Table 13). Fish given sinking feed with 10% paunch grew faster than cage-reared fish given a floating feed containing 10% paunch, but the difference in K_{TL} between these two treatments was non-significant on the last two sample dates (Table 14).

Feed Conversion

For our pond-reared fish, the nutritional efficiency of the feeds are described with S and C conversion factors (Table 16). The average weight gain per pond due to natural food production was obtained from the replicate treatment ponds 11 and 15 where the fish were not given supplemental feed. The gain attributable to natural foods was 2.37 kg/pond (23.70 kg/ha). This gain was subtracted from total gain per pond to obtain the adjusted weight gain used in computing the C factor.

The treatment mean S conversion factor of pond-reared fish varied from 1.78 to 2.07 for fish given 20% paunch and fish given 30% paunch, respectively (Table 16). The difference (0.29) between these treatment means was non-significant ("t" = 1.55, P 0.10, df = 2) using a "t" test for independent samples with a pooled variance.

Not shown here are feed conversions (S factor) computed for each growth interval using estimates of population number derived from assumptions of average mortality rates (Table 6). These were used along with average temperatures for the interval to determine the correlation between temperature and feed conversion. Six of the 14 correlation coefficients were negative and significant indicating that conversion

Table 16. Channel catfish conversion factors of fish reared in ponds and given a standard commercial feed or feeds containing 10, 20 and 30% paunch, and conversion factors of cage-reared fish given a standard feed or feed with 10% paunch.

Treatment pond	Feed added (kg)	Weight gain (kg)		Conversion factor	
		Total	Adjusted	S[1]	C[1]
		PONDS			
Std. feed					
Pond 9	201.88	128.10	125.73	1.58	1.60
Pond 12	215.45	92.87	90.50	2.32	2.38
TRT Avg.	208.66	110.48	108.12	1.89	1.93
10% paunch					
Pond 13	211.90	105.76	103.39	2.00	2.05
Pond 16	223.02	116.38	114.01	1.92	1.96
TRT Avg.	217.46	111.07	108.70	1.92	2.00
20% paunch					
Pond 5	216.62	101.69	99.32	2.13	2.18
Pond 7	190.52	106.94	104.57	1.79	1.82
TRT Avg.	203.57	104.32	101.94	1.78	2.00
30% paunch					
Pond 8	178.72	84.66	82.29	2.11	2.17
Pond 14	187.02	91.71	89.34	2.04	2.09
TRT Avg.	182.87	88.18	85.82	2.07	2.13
		CAGES			
Std. feed					
Cage 32	153.53	94.72	-	1.62	-
Cage 33	147.08	139.08	-	1.06	-
TRT Avg.	150.30	116.90	-	1.28	-
10% paunch					
Cage 22	124.87	84.80	-	1.47	-
Cage 23	118.04	75.74	-	1.56	-
TRT Avg.	121.45	80.27	-	1.51	-

[1]See text for explanation.

factors were inversely related to water temperature. Feeding when water temperatures are below 20°C is inefficient and should be only at the rate sufficient to provide maintenance (Simco and Cross 1966). Our S factors would be better, therefore lower, had less feed been given after 5 October when temperatures were less than 20°C (Figure 4).

The C factor for pond-reared fish was always larger than the corresponding S factor (Table 16), reflecting the fact that the S factor includes some weight gain due to natural foods. As the adjusted weight gain used in computation of the C factor was the same for all treatments, the C factor does not increase the accuracy of comparison among treatment conversion factors for pond-reared fish; however, it is more accurate to compare the C factor of pond-reared fish to the S factor of the cage-reared fish as the latter received little natural food. As often noted by other investigators, cage-reared fish are totally dependent upon feed provided by the fish culturist (Schmittou 1970). The S conversion factor of cage-reared fish given standard feed was 1.28, compared with 1.51 for cage-reared fish given floating feed with 10% paunch; the difference by the "t" test was non-significant (P>.10).

By inspection, the average feed conversion factor (S factor) for the cage-reared fish was smaller, i.e., better, than the S or C conversion factor of the pond-reared fish. Assuming no real treatment difference exists among the treatment mean conversion factors for pond-reared fish, or between treatment means for cage-reared fish, then a test of the difference in the pooled mean conversion factor of pond- and cage-reared fish can be made using the conversion factors of each pond without regard to feed type as independent observations on the performance of pond-reared fish, and the conversion factor of each cage as independent observations on performance of cage-reared fish. The mean conversion factor from eight ponds of pond-reared fish was 1.98 compared with 1.42 for four observations of cage-reared fish. The difference between these group means was significant ("t" = 3.88, P<.01, df = 10). Although differences among ponds or between cages were non-significant, the differences between the means of the two strata were highly significant.

The validity of comparisons of S factors from one fish cultural facility to the next are questionable as the size of S factor is confounded by differences in basic productivity of the ponds (Swingle 1958). Large differences in the S factor obtained from a set of ponds at one facility to another set of ponds at some other facility would be anticipated to be as much or more of a function of basic fertility in the ponds (resulting from differences in age, water supply, and management history) at it would be due to differences in quality of the feed. The C factor should be used both for comparing values from different facilities as well as for comparing conversion from one year to the next at the same cultural facility, as it reduces effects of changes in basic productivity with extraneous variables.

At the time of the study our ponds were freshly excavated from the alluvium of the former flood plain of Stillwater Creek. S factors obtained in the present study for the standard and paunch-containing feeds were higher than reports by several investigators (Table 17), but much lower than S factors computed from data on survival, growth and feed utilization for commercial producers in the Mississippi Delta (Bureau of Commercial Fisheries 1970).

For cage culture, S factors obtained in the present study are more comparable to those of others. Caged fish are presumed to receive little natural food so the S conversion factor of caged fish is a better performance measure of the feed quality than the S factor in pond culture. Many other cage culture experiments, however, have used a commercial trout feed containing a 40% protein level, formulated for raceway culture of trout. The S factors obtained in the present cage-culture study was equal to or lower than all but Heman and Norwat's (1971) observations using a commercial trout feed (Table 18). The S factor obtained with the 10% paunch feed was lower than most reports but about equal to findings of Lewis (1969) and Collins (1972) (Table 17).

Feed Costs/kg Fish Produced

Using retail prices of the two commercial feeds for March 1972, estimates of the cost of the paunch-containing feeds, and observed feed conversion factors, the feed costs per kg of catfish produced were calculated for each feed type (Table 18). Estimates of the costs of paunch-containing feeds were provided by the feed company (Daymond

Table 17. Channel catfish feed conversion factor (S factors) under pond and cage culture systems for research and commercial projects.

CAGE CULTURE	S Factor	POND CULTURE	S Factor
Research projects		Research projects	
Present study-Oklahoma		Present study-Oklahoma	
Standard feed	1.28	Standard feed	1.89
Feed with 10% paunch	1.51	Feed with 10% paunch	1.92
Collins (1971)-Arkansas	1.32	Feed with 20% paunch	1.78
		Feed with 30% paunch	2.07
Collins (1972)-Oklahoma		Bureau of Sport Fisheries & Wildlife (1970:39)-Arkansas	1.3-1.5
63-178 mm size group			
211 fish/m^3	1.69		
281 fish/m^3	1.45		
351 fish/m^3	1.51	Deyoe and Tiemeier (1973)-Kansas	1.26-1.41
203-229 mm size group			
211 fish/m^3	1.51	Kelley (1968:67)-Alabama	
281 fish/m^3	1.46	Avg. for Auburn No. 2	
351 fish/m^3	1.58	feed	1.70
Conley (1971)-Iowa	1.2-2.0	Meyer (1969)-Arkansas	1.3-2.2
Feit (1971)-Nebraska	1.2-1.3	Morris (1972)-Missouri (floating feed)	
Heman & Norwat (1971)-Missouri			
174 fish/m^3	0.97	6,741 fish/ha	0.83
348 fish/m^3	1.11	8,988 fish/ha	0.92
522 fish/m^3	1.11	11,235 fish/ha	1.06
		13,482 fish/ha	1.22
Lewis (1969)-Illinois	1.5	15,729 fish/ha	1.19
Schmittou (1969)-Alabama	1.25	17,976 fish/ha	1.23
		20,224 fish/ha	1.11
Schmittou (1970)-Alabama		Commercial projects[a]	
300 fish/m^3	1.26	Mississippi Delta	
400 fish/m^3	1.29	(Arkansas, Louisiana,	
500 fish/m^3	1.34	Mississippi)	
Commercial production		With avg. management	3.22
Collins (1970)-Texas	1.30	With excellent management	2.67

[a]Computations made from data given by Bureau of Commercial Fisheries (1970:Tables 2 and 4). The S factors shown underestimate the apparent conversion because the initial weight of fish was not given, therefore, it was not subtracted from the harvest weight to obtain the weight gain.

Table 18. Comparative feed costs to produce channel catfish using the standard feeds and feeds with various levels of paunch.[a]

Culture System feed type	Cost of feed $/kg	Conversion factor S	Conversion factor C	Cost of feed $/kg S	Cost of feed $/kg C
Pond Culture-Sinking Feed					
Standard commercial	0.106	1.89	1.93	0.20	0.20
Feed with 10% paunch	0.104	1.92	2.00	0.20	0.21
Feed with 20% paunch	0.115	1.78	2.00	0.20	0.23
Feed with 30% paunch	0.137	2.07	2.13	0.28	0.29
Cage Culture-Floating Feed					
Standard commercial	0.176	1.28	-	0.22	-
Feed with 10% paunch	0.178	1.51	-	0.27	-

[a]Costs of feed with paunch are based on feed costs and price of paunch when the study was initiated (March 1972), when paunch was quoted at $22.05/metric ton. As late as May 1973, paunch was available at $33.07/metric ton.

Shelton, personal communication) using computations of \$22.05 per metric ton, f.o.b. Omaha, as the price of dehydrated paunch. For the sinking pond feeds, except at the 10% level, the price of paunch-containing feeds was more than the standard feed and cost of the feed with 30% paunch was the most expensive. Although dehydrated paunch costs less than any other feed constituent, at 20% and 30% levels of paunch, it was substituting for some intermediate priced ingredients, requiring more of the more expensive high protein (fish and soybean) meals to maintain the nearly isonitrogenous (i.e., equal protein) levels. For the cage-culture feed, even the 10% paunch feed costs more than the standard feed.

The cost of a feed is best measured by the cost per kg of fish flesh produced rather than the cost of the feed per unit weight of feed because a higher price feed may give a conversion factor with a resultant lower cost per unit weight of the fish produced. Using observed C and S conversion factors and the estimated feed costs, cost per kg of fish was computed (Table 18). With S conversion factors, fish production costs were the same (\$0.20/kg) with standard, 10 and 20% paunch feeds, whereas with 30% paunch, the costs per kg increased 40% to \$0.28/kg. When using the C conversion factor, the costs per kg of fish produced using standard and 10% paunch feeds were basically the same (\$0.20 and \$0.21) allowing for rounding errors, but feed costs per kg of fish produced were substantially higher for the feed with 30% paunch. The cost of the 10% paunch floating feed was 22.7% greater than the standard floating feed.

Considering that (1) the 10% paunch feed costs less per pound of feed, (2) the conversion factors for the 10% paunch feed were basically the same as obtained with the standard feed, and (3) there was no significant difference in final average length or weight between fish reared on the standard and 10% paunch feeds, it is concluded that as much as 10% paunch can be incorporated in feed for pond culture of channel catfish without causing any reduction in survival or growth, and without an increase in production costs.

Inter-Relationship Among Physicochemical Variables in the Ponds Without Fish

The relationships, expressed as correlation coefficients, among temperature, 15 chemical parameters, fecal coliform count, water volume and period are examined for pond 6 (Table 19) and pond 10 (Table 20) which did not contain channel catfish. Using the Mann-Whitney non-parametric test, Yin (Part B) found no significant difference between the median for any of the 15 chemical parameters between ponds 6 and 10 except for fecal coliforms (Part B, Table 24). Differences between various chemical parameters in the control ponds (no fish or feed) versus the experimental ponds (fish and feed) are examined in Part B of this report.

Water quality relationships in control ponds without fish or enrichment from feeding fish serve as baseline measurements to establish relationships between chemical variables which can be compared to the relationships observed in ponds 9 and 12 which received standard feed,

Table 19. Matrix of correlation coefficients for 14 chemical variables, water temperature, number of fecal coliforms, and the water budget over six, 28-day intervals (periods 1-6) for pond 6, no fish and no feed.[a]

	°C	DO	BOD	COD	TOC	pH	TS	VSS	TSS	NH_3-N	N-total	P-total	P-ortho	BOD/COD	COD/TOC	FC	H_2O
°C		-0.22	-0.57	0.39	0.08	-0.19	-0.16	-0.54	0.18	0.58	0.60	0.52	0.80	-0.58	0.44	-0.20	0.11
DO	-0.22		-0.29	-0.55	-0.56	0.92*	-0.77	-0.39	-0.88*	-0.48	-0.31	-0.17	-0.44	0.48	-0.54	0.02	-0.65
BOD	-0.57	-0.29		0.25	0.60	-0.44	0.46	0.88*	0.34	0.03	0.13	-0.59	0.00	0.30	0.15	-0.25	0.70
COD	0.39	-0.55	0.25		0.85*	-0.49	0.26	0.48	0.39	0.65	0.28	0.25	0.76	-0.82*	0.99***	0.01	0.78
TOC	0.08	-0.56	0.60	0.86*		-0.49	0.57	0.64	0.33	0.32	0.41	0.16	0.62	-0.49	0.79	0.12	0.95**
pH	-0.19	0.92*	-0.44	-0.49	-0.49		-0.59	-0.49	-0.98**	-0.64	-0.38	0.19	-0.46	0.28	-0.46	0.41	-0.68
TS	-0.16	-0.77	0.46	0.26	0.57	-0.59		0.37	0.50	-0.15	0.29	0.27	0.12	-0.12	0.19	0.36	0.59
VSS	-0.54	-0.39	0.88*	0.48	0.64	-0.49	0.37		0.44	0.25	-0.17	-0.53	0.00	-0.05	0.42	-0.17	0.67
TSS	0.18	-0.88*	0.34	0.39	0.33	-0.98**	0.50	0.44		0.67	0.24	-0.23	0.35	-0.27	0.38	-0.44	0.53
NH_3-N	0.58	-0.48	0.03	0.65	0.32	-0.64	-0.15	0.25	0.67		0.26	-0.18	0.69	-0.57	0.69	-0.63	0.44
N-total	0.60	-0.31	0.13	0.28	0.41	-0.38	0.29	-0.17	0.24	0.26		0.21	0.77	-0.05	0.22	-0.32	0.55
P-total	0.52	-0.17	-0.59	0.25	0.16	0.19	0.27	-0.53	-0.23	-0.18	0.21		0.32	-0.59	0.28	0.72	-0.04
P-ortho	0.80	-0.44	0.00	0.76	0.62	-0.46	0.12	0.00	0.35	0.69	0.77	0.32		-0.61	0.74	-0.28	0.66
BOD/COD	-0.58	0.48	0.30	-0.82*	-0.49	0.28	-0.12	-0.05	-0.27	-0.57	-0.05	-0.59	-0.61		-0.88*	-0.27	-0.35
COD/TOD	0.44	-0.54	0.15	0.99***	0.79	-0.46	0.19	0.42	0.38	0.69	0.22	0.28	0.74	-0.88*		0.02	0.70
FC	-0.20	0.02	-0.25	0.01	0.12	0.41	0.36	-0.17	-0.44	-0.63	-0.32	0.72	-0.28	-0.27	0.02		-0.16
H_2O	0.11	-0.65	0.70	0.78	0.95**	-0.68	0.59	0.67	0.53	0.44	0.55	-0.04	0.66	-0.35	0.70	-0.16	
Period	-0.70	0.76	0.15	-0.49	-0.23	0.79	-0.25	0.03	-0.82*	-0.80	-0.46	-0.16	-0.68	0.56	-0.52	0.39	-0.39

[a] See Part B for explanation of abbreviations; *P<.05, **P<.01, ***P<.001

Table 20. Matrix of correlation coefficients for 14 chemical variables, water temperature, number of fecal coliforms, and the water budget over six, 28-day intervals (periods 1-6) for pond 10, no fish and no feed.

	°C	DO	BOD	COD	TOC	pH	TS	VSS	TSS	NH_3-N	N-Total	P-Total	P-Ortho	BOD/COD	COD/TOC	FC	H_2O
°C		-0.05	-0.76	0.64	0.38	0.00	0.02	0.08	-0.06	0.60	0.41	0.61	0.79	-0.67	0.50	-0.93**	0.26
DO	-0.05		0.16	-0.18	-0.80	0.84*	-0.45	0.08	-0.71	0.20	0.00	-0.40	-0.57	0.19	0.26	0.05	0.66
BOD	-0.76	0.16		-0.64	-0.59	0.44	-0.62	-0.67	-0.34	-0.91*	0.10	-0.84*	-0.81	0.79	-0.40	0.82*	-0.25
COD	0.64	-0.18	-0.64		0.36	-0.20	0.19	0.37	-0.19	0.60	0.04	0.34	0.56	-0.91*	0.88*	-0.40	0.55
TOC	0.38	-0.80	-0.59	0.36		-0.80	0.55	0.23	0.77	0.27	0.18	0.58	0.74	-0.57	-0.13	-0.45	-0.51
pH	0.00	0.84*	0.44	-0.20	-0.80		-0.86*	-0.44	-0.87*	-0.20	0.40	-0.62	-0.58	0.30	0.22	0.10	0.47
TS	0.02	-0.45	-0.62	0.19	0.55	-0.86*		0.80	0.74	0.55	-0.69	0.74	0.51	-0.32	-0.07	-0.20	-0.11
VSS	0.08	0.08	-0.67	0.37	0.23	-0.44	0.80		0.30	0.83*	-0.65	0.50	0.24	-0.51	0.31	-0.19	0.41
TSS	-0.06	-0.71	-0.34	-0.19	0.77	-0.87*	0.74	0.30		0.10	-0.21	0.58	0.47	-0.04	-0.60	-0.19	-0.73
NH_3-N	0.60	0.20	-0.91*	0.60	0.27	-0.20	0.55	0.83*	0.10		-0.25	0.64	0.51	-0.73	0.53	-0.65	0.55
N-Total	0.41	0.00	0.10	0.04	0.18	0.40	-0.69	-0.65	-0.21	-0.25		-0.30	0.06	-0.14	-0.04	-0.31	-0.24
P-Total	0.61	-0.40	-0.84*	0.34	0.58	-0.62	0.74	0.50	0.58	0.64	-0.30		0.89*	-0.42	0.07	-0.75	-0.06
P-Ortho	0.79	-0.57	-0.81	0.56	0.74	-0.58	0.51	0.24	0.47	0.51	0.06	0.89*		-0.60	0.20	-0.80	-0.12
BOD/COD	-0.67	0.19	0.79	-0.91*	-0.57	0.30	-0.32	-0.51	-0.04	-0.73	-0.14	-0.42	-0.60		-0.70	0.53	-0.39
COD/TOC	0.50	0.26	-0.40	0.88*	-0.13	0.22	-0.07	0.31	-0.60	0.53	-0.04	0.07	0.20	-0.70		-0.22	0.86*
FC	-0.93**	0.05	0.82*	-0.40	-0.45	0.10	-0.20	-0.19	-0.19	-0.65	-0.31	-0.75	-0.80	0.53	-0.22		-0.08
H_2O	0.26	0.66	-0.25	0.55	-0.51	0.47	-0.11	0.41	-0.73	0.55	-0.24	-0.06	-0.12	-0.39	0.86*	-0.08	
Period	-0.74	0.50	0.92*	-0.61	-0.84*	0.63	-0.60	-0.46	-0.54	-0.69	-0.07	-0.84*	-0.92**	0.78	-0.23	0.79	0.08

[a]See Part B for explanation of abbreviations; *P<.05, **P<.01, ***P<.001

and ponds 8 and 14 which received the feed containing 30% paunch. The null-hypothesis for testing these correlations was that r was from a random sample of paired variables having a correlation coefficient of zero. The null-hypothesis was rejected and the calculated r considered significant when the probability of obtaining a given r was less than or equal to the P level of 0.05.

The inter-relationships of various physicochemical parameters, expressed by the correlation coefficients, in the two control ponds (6 and 10) were the same for some parameters but different for others. One hazard of obtaining a large number of correlation coefficients between two parameters is that of obtaining significant correlations due to chance. From a probabilistic standpoint, therefore, it seems prudent to consider only those correlations which were significant in both ponds. The probability of obtaining by chance alone two significant correlations for the same parameters in two separate ponds should be a highly unlikely event (i.e., low probability). Thus, considering only those correlations between the two same parameters which were significant in both replicates greatly reduces the likelihood of placing importance on a chance event.

The only parameters which provided significant correlations in both control ponds were: (1) DO with pH; (2) COD with BOD/COD; (3) COD with COD/TOC; and (4) TSS and pH. The BOD/COD and COD/TOC relationships are discounted due to the redundancy of COD in both the dependent and independent variables. The relationship between pH and DO is apparently due to algal uptake of CO_2 during photosynthesis. The negative relationship between TSS and pH appears to be that of a supressing effect of suspended solids on algal photosynthesis. Thus, as TSS increases, pH declined due to lack of algal removal of CO_2 and bicarbonates. The DO in pond 6 declined with increasing TSS as shown by the significant negative relationship between TSS and DO ($r = -0.89$), albeit the correlation between DO and TSS ($r = -0.71$) in pond 10 was nonsignificant ($P>.05$).

Inter-Relationship Between Fish Growth, Fish Biomass and Fish Production to the Physicochemical Variables

In ponds (numbers 11 and 15) without fertilization or feeding, fish production (kg/ha) was too limited to make fish farming economical. Supplemental feeding is needed to increase the carrying capacity beyond what the pond can provide from its natural fertility. Carrying capacity in static water ponds is still finite, and when limits to production in static water ponds are reached the environment becomes polluted from excess feed and metabolic wastes. Meyer (1969) reported 2,038 kg/ha as the "upper limit" to channel catfish production in static water, which is considerably less than maximum spatial densities obtained in raceway or cage culture.

Water quality analyses conducted during the course of the catfish growth studies presented an uprecedented opportunity to assess the potential limitations of water quality factors on fish growth and production at fish densities commonly employed in commercial catfish culture. Correlations between water quality parameters and fish growth, average standing biomass of fish and net production are of foremost importance if the fish culturist is to manipulate water quality to enhance fish production. Also, the impact on stream water quality of fish farms effluents requires understanding of the relationships between standing crop of fish and standard measures of water quality. Although water quality studies on fish production ponds have been reported heretofore, the present situation was unprecedented in kinds and frequency of measurements of water quality parameters measured during the course of the growing season for a typical, static water, commercial catfish production system.

Fish growth during each of the six growth intervals (t_1) 18 May - 15 June; (t_2) 15 June - 13 July; (t_3) 13 July - 10 August; (t_4) 10 August - 7 September; (t_5) 7 September - 5 October; (t_6) 5 October - 2 November is the change in mean weight during each interval, for example for t_1, $\bar{w}_2 - \bar{w}_1$, where $\bar{w}_2$ = weight on 15 June and $\bar{w}_1$ the weight on 18 May. The relationship between these six measures of fish growth and monthly means of four weekly measurements of water temperature, 14 water quality parameters and volume of inflow of water (rain and supply water) used to maintain level (replace seepage and evaporation) are examined separately for fish from ponds 9 and 12 (Table 21) where they were given standard feed, and ponds 8 and 14 (Table 22) received sinking feed with 30% paunch. For reasons noted previously, only those independent variables which gave significant correlations in both ponds are discussed.

Table 21. Relationship between channel catfish growth ($\Delta\bar{w}$), mean biomass ($\bar{B}$) and net production (P_n), water quality and other parameters in six, 28-day intervals (18 May to 2 November) for ponds 9 and 12 where fish were given a standard commercial feed.

Independent Variables	Pond 9			Pond 12		
	$\Delta\bar{w}$	$\bar{B}$	Pn	$\Delta\bar{w}$	$\bar{B}$	Pn
Growth ($\Delta\bar{w}$)		0.73	0.99***		-0.26	0.94*
Mean biomass ($\bar{B}$)	0.73		0.65	-0.26		0.40
Net production (Pn)	0.99***	0.65		0.94*	0.51	
Temperature (C)	-0.68	-0.79	-0.63	0.79	-0.66	-0.28
Dissolved oxygen (DO)	-0.09	-0.10	-0.12	-0.10	-0.17	-0.55
Biological oxygen demand (BOD)	-0.02	-0.40	0.00	0.25	0.20	-0.37
Chemical oxygen demand (COD)	0.03	-0.51	0.10	0.26	0.31	-0.33
Total organic carbon (TOC)	-0.17	-0.49	-0.17	0.13	0.14	-0.46
pH	-0.06	-0.02	-0.05	0.14	0.09	-0.46
Total solids (TS)	0.73	0.48	0.78	0.36	0.78	0.50
Volitile suspended solids (VSS)	-0.30	-0.53	-0.27	0.36	0.09	-0.29
Total suspended solids (TSS)	-0.52	-0.89*	-0.39	0.30	-0.25	-0.77
NH_3-Nitrogen	-0.72	-0.89*	-0.67	0.29	0.13	0.83
Nitrogen-Total	-0.04	-0.05	-0.03	0.11	0.58	-0.16
Phosphorus-Total	-0.24	-0.23	-0.24	0.56	0.21	0.21
Phosphorus-Ortho	0.74	0.67	0.69	0.20	0.51	-0.10
BOD/COD	0.19	0.51/3	0.08	0.37	0.19	-0.26
COD/TOC	0.09	-0.42	0.17	0.34	0.49	0.13
Fecal coliforms	0.44	0.65	0.41	-0.47	0.57	-0.56
Total water	0.39	0.55	0.28	-0.53	0.27	-0.29

*Where $P < 0.050 > 0.010$
**Where $P < 0.010 > 0.001$
***Where $P < 0.001$

Table 22. Relationship between channel catfish growth ($\Delta\bar{w}$), mean biomass ($\bar{B}$), net production (P_n), water quality and other parameters in six, 28-day intervals (18 May to 2 November) for ponds 8 and 14 where the fish were given a feed containing 30% paunch.

Independent Variables	Pond 8			Pond 14		
	$\Delta\bar{w}$	$\bar{B}$	Pn	$\Delta\bar{w}$	$\bar{B}$	Pn
Growth ($\Delta\bar{w}$)		0.20	0.87*		0.40	0.50
Mean biomass ($\bar{w}$)	0.20		-0.18	0.40		-0.40
Net production (Pn)	0.87*	-0.18		0.50	-0.40	
Temperature (C)	0.30	-0.68	0.54	0.19	-0.66	0.61
Dissolved oxygen (DO)	-0.32	0.54	-0.57	0.64	0.25	0.25
Biological oxygen demand (BOD)	0.40	0.31	0.44	0.59	0.42	0.05
Chemical oxygen deman (COD)	0.63	-0.10	0.86*	0.69	0.14	0.57
Total organic carbon (TOC)	0.77	0.50	0.68	0.55	0.30	0.09
pH	-0.01	0.66	-0.37	0.36	0.50	-0.35
Total solids (TS)	0.31	0.97**	-0.03	0.88*	0.20	0.63
Volitile suspended solids (VSS)	0.58	-0.06	0.67	0.94**	0.15	0.59
Total suspended solids (TSS)	0.83*	-0.26	0.98**	0.11	-0.49	0.54
NH_3-Nitrogen	-0.21	-0.83*	0.24	0.18	-0.73	0.73
Nitrogen-total	0.73	0.68	0.49	0.64	0.51	0.03
Phosphorus-Total	0.97**	0.00	0.95*	0.89*	0.31	0.33
Phosphorus-Ortho	0.91*	-0.14	0.97*	0.46	-0.25	0.62
BOD/COD	-0.34	0.38	-0.56	0.52	0.63	-0.27
COD/TOC	0.35	-0.37	0.67	0.62	-0.04	0.88*
Fecal coliforms	0.46	0.83*	0.14	0.00	0.91*	-0.66
Total water	-0.31	0.29	-0.53	0.92**	0.17	0.77

*Where $P < 0.050 > 0.010$ **Where $P < 0.010 > 0.001$

Fish Growth ($\Delta\bar{w}$) and Water Quality Parameters

In ponds 9 and 12, where fish received standard sinking feed, the only significant correlations occurring in both ponds for the same variable set was between fish growth and net production. Thus, a high correlation existed between growth per 28-day interval and net production in the same interval (Table 21), an obvious relationship, yet not a single significant correlation was obtained between growth and the water quality parameters. Apparently, in these two ponds, none of the physicochemical variables became limiting and fish growth was independent of the range in these chemical variables. In ponds 8 and 14 the only correlation significant in both ponds was between fish growth and total phosphorus ($T\text{-}PO_4$). This suggests that $T\text{-}PO_4$ in the water was a function of the quantity of paunch-containing feed given the fish.

Fish Biomass and Water Quality Parameters

There were no significant correlations, duplicated in both ponds 9 and 12, between fish biomass (i.e., standing crop of fish) and the 14 water quality parameters; in ponds 8 and 14, only the positive correlation between fish biomass and number of fecal coliforms was duplicated in both ponds. It seems that fecal coliforms were *per se* more specifically associated with the feed than the biomass of fish. There was no suggestion of a positive correlation between fish metabolites, such as NH_3-N or VSS, with fish biomass. To the contrary, in pond 9 NH_3-N was negatively correlated with fish biomass ($r = -0.89$), indicating a higher NH_3-N concentration at the beginning of the growing season when fish biomass was minimal. Fish density in this study was apparently insufficient to cause accumulation of density dependent metabolites limiting fish growth. Thus, the final densities of fish in ponds 8 and 14, or 9 and 12 were insufficient to provide a negative feedback affecting growth.

Simco and Cross (1966) observed a negative correlation between average fish weight and morning-oxygen levels. Their interpretation was that plankton-biomass developed when standing crop of fish was high, causing high afternoon oxygen levels from algal photosynthesis, and low morning-oxygen levels from respiration. They found positive correlations between diurnal change in pH (difference between afternoon and morning) and average size of catfish in ponds receiving supplemental feed, an observation supporting the algal-bloom effect resulting from fertilization in ponds receiving supplemental feed. In the present study, pH was positively correlated with average biomass in ponds 8 and 14, corroborating findings by Simco and Cross, but our correlations were non-significant and the observations were not verified by ponds 9 and 12. In the present study, fish biomass was negatively correlated with DO in ponds 9 and 12, but the correlation was non-significant ($P>.10$), and in ponds 8 and 14 the correlation was positive, but non-significant. Apparently, our ponds did not develop a sufficient algal bloom to verify the findings of Simco and Cross (1966). In most ponds studied by Simco and Cross, correlations between total alkalinity, morning and afternoon, and average weight of catfish were non-significant. Effluents of warmwater fish cultural facilities have been suspected of affecting water quality in receiving water by reducing dissolved oxygen, increasing temperature, and adding: BOD, COD, NH_3-N, total-N, T-PO_4 and other fish metabolites and remains of partially decomposed fish feed. DO levels in ponds with fish (see Appendix) had a higher average DO than ponds without fish. In pond 10, for example, where fish were given feed with 30% paunch, the mean DO on 25 days was 8.72±1.37 (± standard deviation) compared with 8.64±1.38 in pond 6, a control pond without fish or enrichment from fish feed. BOD levels, a commonly used index of pollution, averaged 1.22±0.47 mg/l in pond 6 (control) and 1.4±0.55 mg/l in pond 10 (30% paunch); again showing no significant difference ("t" test, $P>.10$). By comparison, a municipal effluent, after secondary sewage treatment which removes 90% of the settleable solids, would have a BOD of 22.5 mg/l, and tertiary municipal effluent would have a BOD of about 2-4 mg/l (Willoughby, Larsen and Bowen 1972). Thus, the average BOD load of the pond effluents would be about half that of municipal sewage receiving tertiary treatment.

Regarding phosphorous enrichment, the better tertiary-type treatment processes for sewage, consisting of lime, or alum precipitation, do not generally remove more than 90% of the typical influent phosphorus values, leaving effluents with about 1.25 mg/l, assuming 10-15 total phosphorus in untreated wastewater (Rohlich and Uttormark 1972). Total phosphorus in one of our control ponds (pond 6), averaged 0.036±0.016 mg/l (36 ug/l), and in pond 9 and pond 10, where fish were given standard and 30% paunch feeds, total-P averaged 0.088±0.038 and 0.039±0.017 mg/l, respectively.

Thus, consideration of several chemical parameters of water quality showed that culture ponds receiving either a standard feed or a feed with 30% paunch had relatively trivial increases above the baseline levels of ponds without fish, and that effluent concentrations of BOD or phosphorous from these fish ponds were considerably below that of municipal effluents receiving tertiary treatment.

Fish Production and Water Quality

There were no significant correlations in either pond 9 or 12 between fish production and the water quality parameters (Table 21). Where fish were given feed containing 30% paunch, significant correlations were obtained between fish production (P_n) and several water quality parameters in one replicate (pond 8), but as these were not verified in the other replicate (pond 14), correlations may be largely due to chance. The significant positive correlations in pond 8 between fish production and COD, TSS and VSS are worth noting; however, they may be indicative of water quality alterations during intervals of rapid growth and high production when excess food and greater amounts of waste products are produced. These positive correlations occurred in ponds 8 and 14 where the feed contained 30% paunch but not in the ponds using standard feed.

PART B

WATER QUALITY CHANGES WITH FISH CULTURE

SECTION VI[a]

INTRODUCTION

Analyses of samples of cattle paunch contents, both fresh and dried, performed at the Environmental Protection Agency's Robert S. Kerr Environmental Research Laboratory in Ada, Oklahoma, showed that the long-term, ultimate biochemical oxygen demand of these materials exceeds 100,000 mg/l. When paunch is incorporated into fish feed, therefore, the possibility exists that the paunch in any uneaten feed left in the water may cause a serious problem, depleting the oxygen in the water to the extent that it may be detrimental to fish. Moreover, there is little published information relative to the effects of intensive catfish culture on water quality in ponds. Thus, it was decided to monitor the water quality of selected ponds during the experimental period of this project.

With commercial catfish farming a rapidly developing industry in this country, the data obtained will be valuable not only for the evaluation of the practicability of using paunch as a fish feed constituent, but it would also provide general information relative to the effects of intensive catfish culture on water quality in ponds.

[a]This section was written by S. C. Yin

SECTION VII

SAMPLING AND ANALYTICAL PROCEDURES

This portion of the project was a cooperative effort between Oklahoma State University (O.S.U.) and the Robert S. Kerr Environmental Research Laboratory. Water samples were collected by O.S.U. personnel, fixed with acid or other reagent(s) where necessary, and then refrigerated immediately. EPA personnel from the Kerr Laboratory in Ada, Oklahoma, were responsible for transporting the samples to their laboratory to be analyzed, except for pH, dissolved oxygen (DO), temperature (Temp.) and carbon dioxide (CO_2), which were measured at the site of the ponds by O.S.U. personnel. The samples were kept in ice chests en route, and were processed for analyses not more than thirty hours after collection of the first portions of the composite samples.

The following parameters were analyzed in the laboratory: biochemical oxygen demand (5-day) (BOD), chemical oxygen demand (COD), total organic carbon (TOC), ammonia (NH_3-N), total Kjeldahl nitrogen (T. Kjeld.-N), nitrite (NO_2-N), nitrate (NO_3-N), total phosphate (T-PO_4), orthophosphate (O-PO_4), total solids (TS), total suspended solids (TSS), volatile suspended solids (VSS), and fecal coliforms (Fec. coli.). All chemical analytical procedures were done according to EPA's manual--*Methods for Chemical Analysis of Water and Wastes*, 1971. Fecal coliform analysis was done by the membrane filter technique as described in the 13th edition of *Standard Methods for the*

Examination of Water and Wastewater.

During the 24-week period of the experiment, samples were collected and analyzed once a week. Samples were taken every Wednesday from the surface of the deep end of each pond, near the feeding site. Composite samples were prepared by pooling samples collected at 1000, 1400 and 1800 hours. Every fourth week samples were collected at 1000 and 1800 hours and were pooled and labeled day samples; samples collected at 2200 hours and 0600 hours the following morning were pooled and labeled night samples.

Ponds included in the water quality studies were numbers 2, 3, 6, 8, 9, 10, 12, and 14 (Table 23).

Table 23. Disposition of ponds.

Pond #	Size of pond (hectare)	Type of culture	No. of fish stocked in each pond	Kind of feed
6 & 10	0.1	-	None	None
8 & 14	0.1	Pond	260	30% paunch in feed
9 & 12	0.1	Pond	260	Standard commercial feed
2	0.5	Cage	1013[a]	10% paunch in feed
3	0.5	Cage	1047[a]	Standard commercial feed

[a]The fish were in three cages; approximately equal numbers in each cage.

SECTION VIII

RESULTS, STATISTICAL ANALYSES AND DISCUSSION

Data from the water quality analyses are tabulated in Appendix A. This study was originally planned as a completely randomized design with subsampling. The choice of this design dictates the use of the parametric analysis of variance to test the hypothesis of no difference in water quality due to feed composition used in the various ponds. Figures 7-12 show the differences in two parameters--BOD and T.Kjeld.-N--within the following pairs of ponds: 8 and 14, 9 and 12, and 12 and 14. Considerable differences in BOD and T.Kjeld.-N occurred within each of the two ponds in each of the two sets of replicate ponds; i.e., ponds 8 and 14 and ponds 9 and 12. From the middle of July to the end of the experiment, the water quality of ponds 12 and 14 exhibited similar trends that were different from those of the other ponds. These differences could not be explained by the rainfall and water replacement data (Table 4). Ponds 12 and 14 were located on the east side of the facility, while all the remaining ponds included in the water quality analyses are on the west side (Figure 1). Trends in levels of various water quality parameters in ponds 12 and 14 were different from their respective replicates on the west side, suggesting that an unknown factor related to location influenced water quality, which created a large difference between the replicates. Consequently, it was

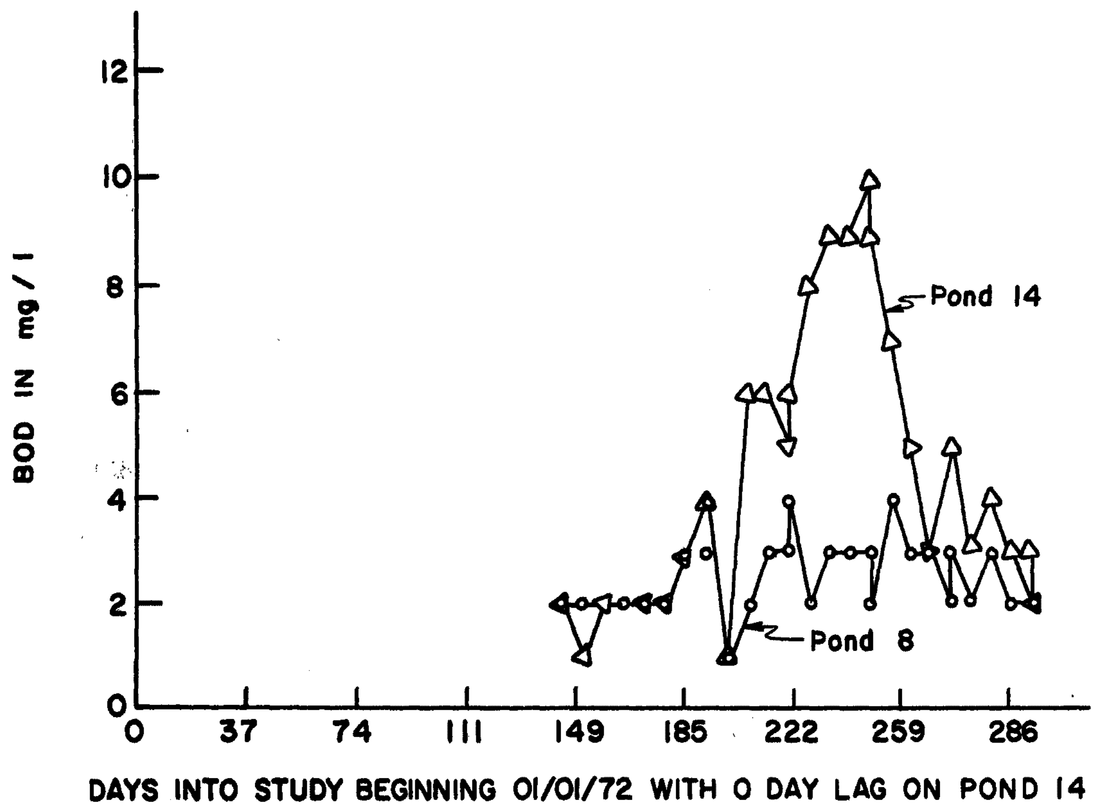

Figure 7. Biochemical oxygen demand in pond 8 and pond 14.

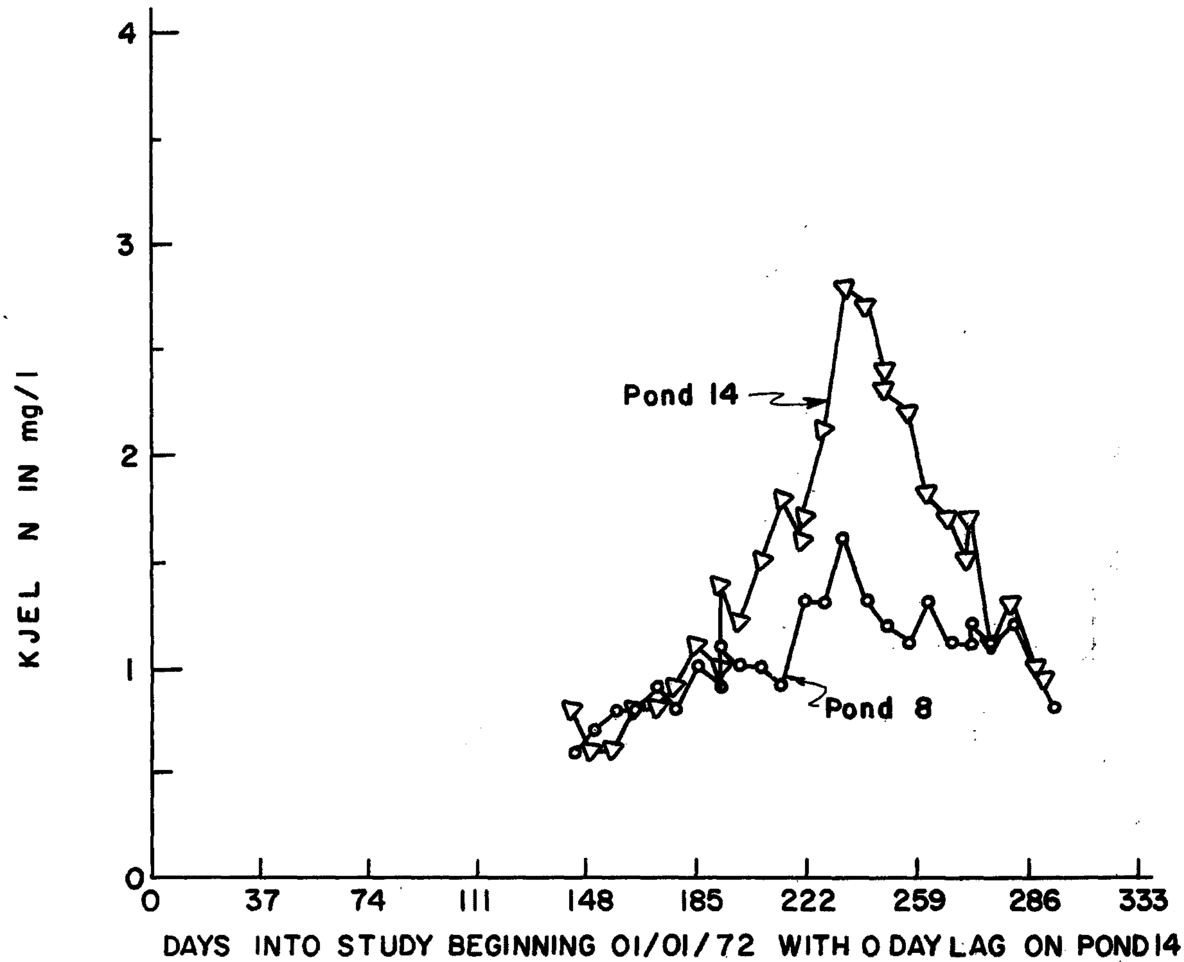

Figure 8. Kjeldahl nitrogen in pond 8 and pond 14.

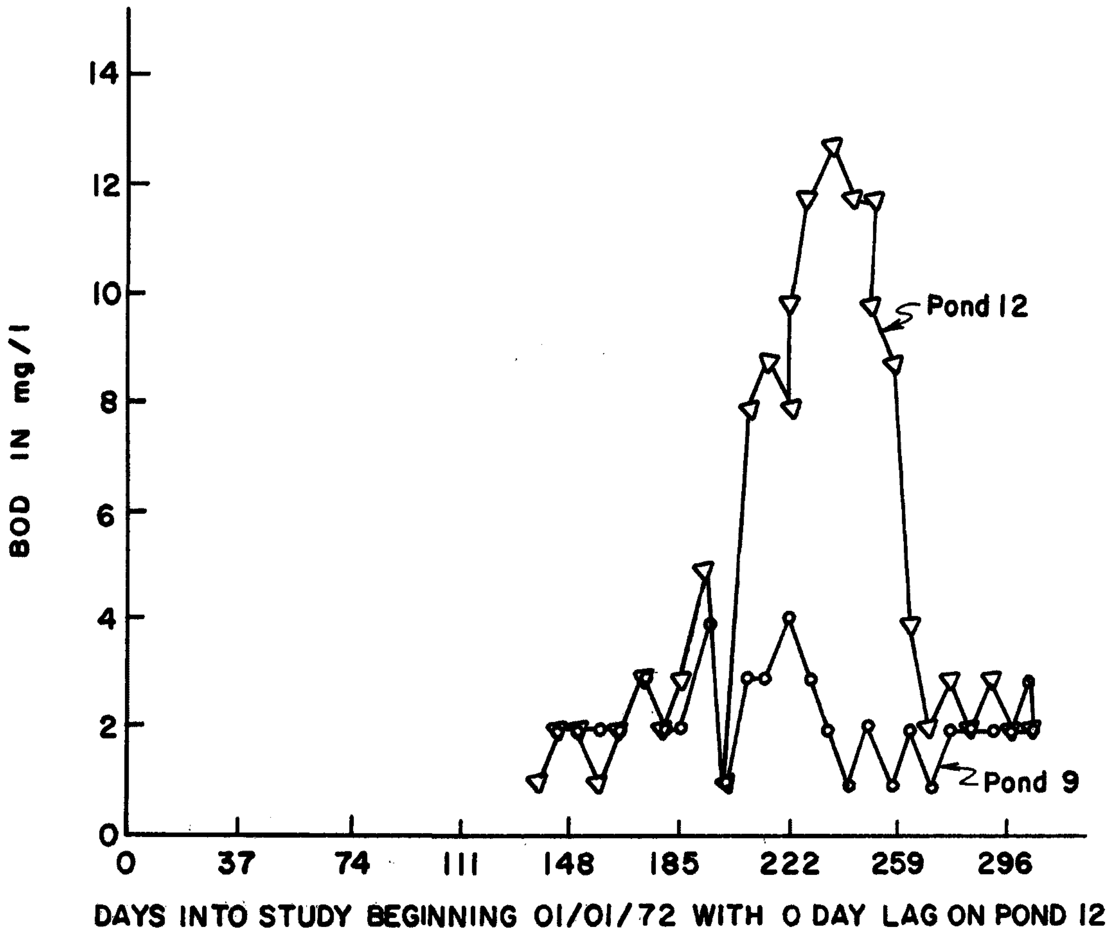

Figure 9. Biochemical oxygen demand in pond 9 and pond 12.

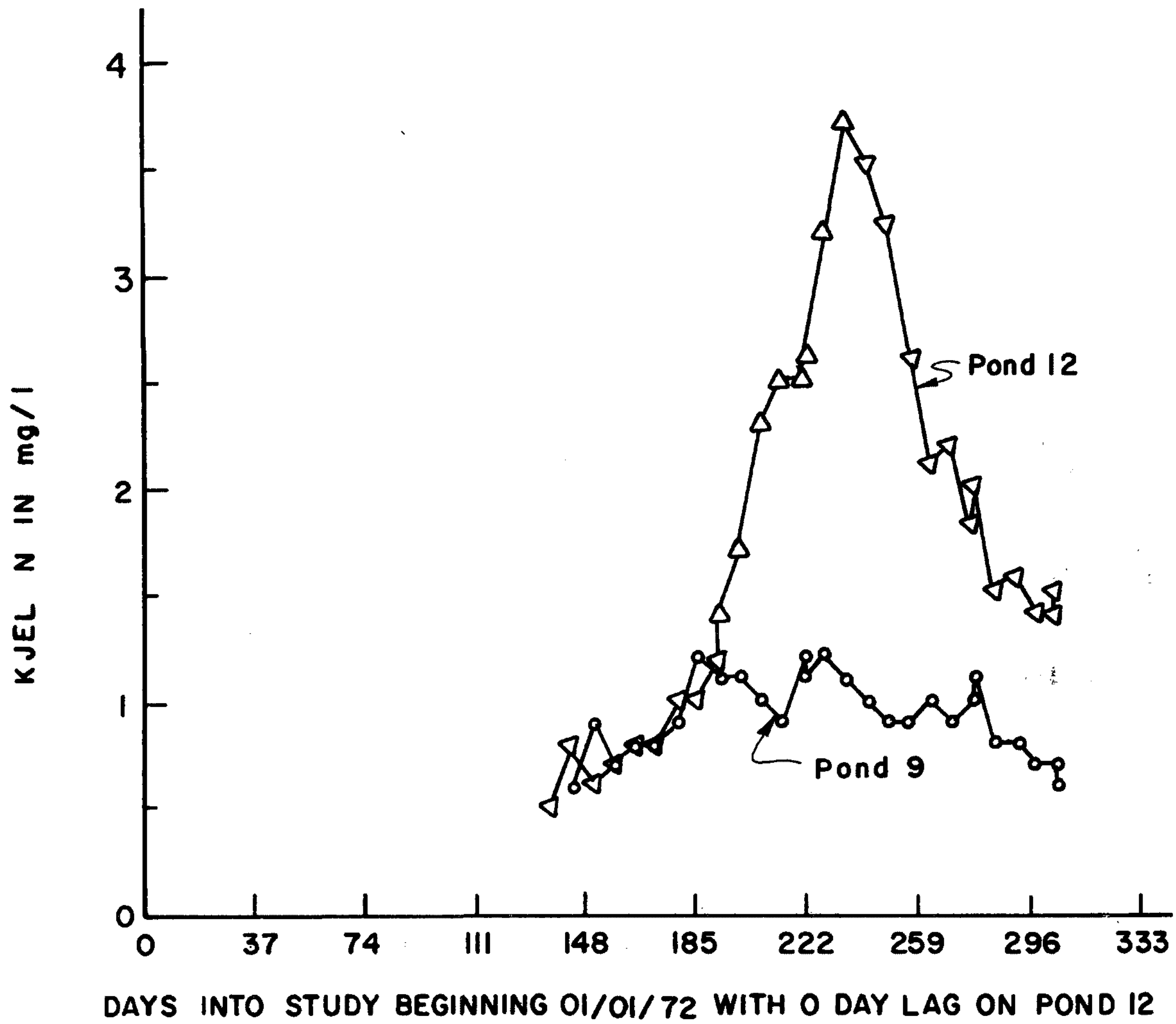

Figure 10. Kjeldahl nitrogen in pond 9 and pond 12.

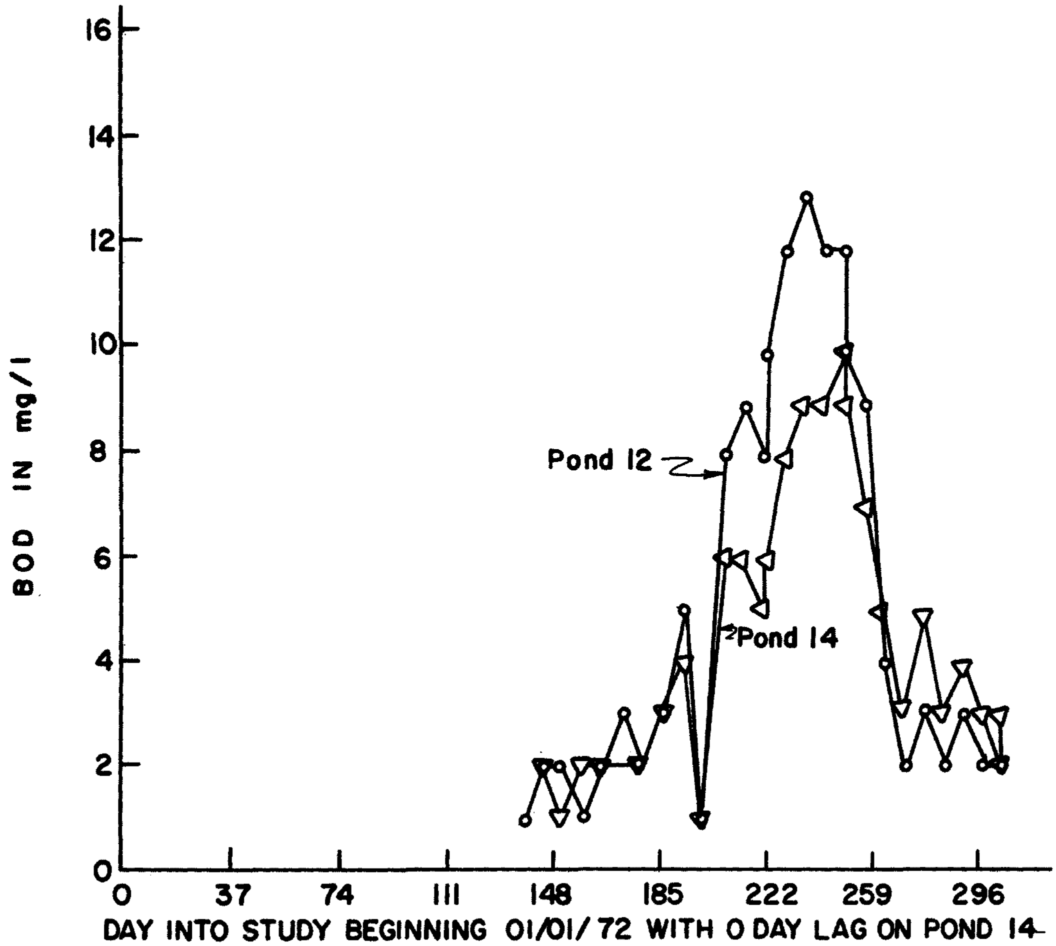

Figure 11. Biochemical oxygen demand in pond 12 and pond 14.

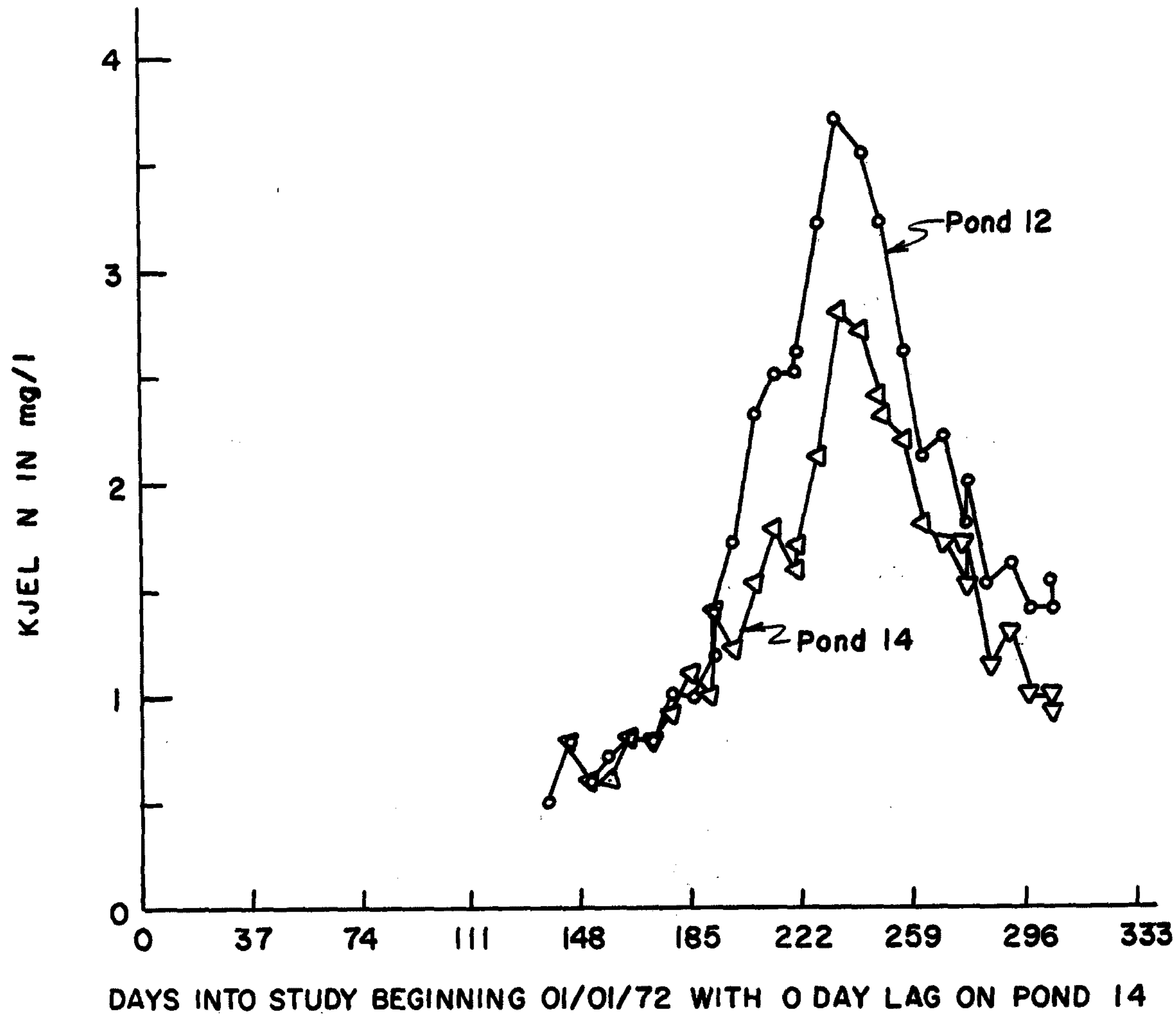

Figure 12. Kjeldahl nitrogen in pond 12 and pond 14.

decided to exclude one replicate pond for each feed composition from the water quality analyses, and to use non-parametric (distribution free) techniques to analyze the remaining data (Siegal 1956).

Differences in water quality parameters between treatments were examined with the following protocol:

1. Null hypothesis - There is no difference in water quality between treatments.

   Alternate hypothesis - The water quality for each treatment is different, but no *a priori* prediction of the direction of differences can be made.

2. Statistical test - The water quality measurements made on samples from the two (or three) ponds represent independent groups of measurements and each parameter is measured on at least an ordinal scale. For these reasons, the Mann-Whitney U test was chosen in the two-sample case, while the Kruskal-Wallis one-way analysis of variance test was selected in the three-sample case.

3. Significance level - The critical point for rejection was set at the 5% level. The region of rejection consists of all calculated values of the test statistic which are so large that the probability associated with their occurrence under the null-hypothesis is less than or equal to the chosen significance level.

Question No. 1

Are there any significant differences in water quality parameters between ponds treated alike; i.e., pond 6 versus pond 10, pond 8 versus pond 14, and pond 9 versus pond 12?

Answer No. 1

Tables 24, 25, and 26 show the calculated values of Z (Mann-Whitney test) for each pair of replicate ponds and each of the 17 water quality parameters.

Pond 6 versus pond 10: Reject the null-hypothesis for fecal coliform and accept for the rest of the parameters. No tests were made for NO_2-N and NO_3-N due to insufficient data.

Pond 8 versus pond 14: Reject the null-hypothesis for DO, BOD, COD, pH, CO_2, TS, T.Kjeld.-N, TOC, and Fec. coli.; for the remaining parameters, the null-hypothesis is accepted. Due to insufficient data, no test was made on NO_2-N.

Pond 9 versus pond 12: Reject the null-hypothesis for all parameters but temp., DO, CO_2, and Fec. Coli. Again, due to insufficient data, no tests on NO_2-N and NO_3-N were made.

There was no significant difference in water quality between control ponds 6 and 10, with the exception of fecal coliform. Replicate ponds 8 and 14, in which pond culture was practiced and where feed containing 30% paunch was used, however, showed significant differences in

Table 24. Comparison of distributions in pond 6 and pond 10.

Variable	Pond 6			Pond 10			Z Value
	Median	N_1	Range	Median	N_2	Range	
Temp	26.80	31	22.70	26.80	31	24.20	-0.295
DO	9.10	31	6.00	8.70	31	6.60	-0.415
BOD	1.00	30	1.60	1.00	31	1.70	-1.401
COD	24.00	30	74.00	24.00	31	60.00	-0.652
pH	9.00	30	1.20	9.00	30	1.50	-0.170
CO_2	0.00	30	0.00	0.00	30	0.00	0.000
TS	284.5	30	128.00	284.00	31	215.00	-0.259
VSS	1.00	29	4.50	2.00	27	5.00	-0.091
TSS	6.00	30	25.00	5.00	30	28.00	-0.394
NH_3-N	0.01	27	0.28	0.02	30	0.49	-0.247
T.Kjeld-N	0.60	30	1.10	0.60	31	0.90	-0.142
T-PO_4	0.03	30	0.07	0.03	31	0.06	-0.158
O-PO_4	0.01	25	0.01	0.01	27	0.03	-1.395
TOC	10.00	30	6.50	10.00	31	14.00	-0.378
Fec. coli	0.00	30	207.0	1.50	30	187.00	-0.961

Table 25. Comparison of distributions in pond 8 and pond 14.

Variable	Pond 8 Median	N_1	Range	Pond 14 Median	N_2	Range	Z Value
Temp	26.50	31	23.40	26.65	30	24.20	-0.202
DO	7.10	31	7.00	7.85	30	7.40	-2.093
BOD	2.00	30	3.00	4.00	30	9.00	-2.965
COD	36.00	30	58.00	44.00	30	66.00	-2.406
pH	8.5	30	0.90	8.70	30	1.10	-3.270
CO_2	0.00	30	2.00	0.00	30	1.50	-2.084
TS	376.00	30	189.00	352.00	30	169.00	-2.099
VSS	6.00	30	13.60	6.50	30	31.00	-1.427
TSS	19.00	30	41.00	22.50	30	43.00	-1.265
NH_3-N	0.06	29	0.78	0.08	29	0.90	-0.171
NO_3-N	0.06	6	0.04	0.04	8	0.03	15.00*
T.Kjeld-N	1.05	30	1.00	1.35	30	2.20	-2.362
T. PO_4	0.08	30	0.18	0.09	30	0.17	-1.921
O-PO_4	0.03	30	0.05	0.03	30	0.05	-1.375
TOC	14.50	30	9.00	15.25	30	10.80	-2.290
Fec. coli.	5.50	30	218.00	16.00	30	432.00	-2.090

*U Value

Table 26. Comparison of distributions in pond 9 and pond 12.

Variable	Pond 9			Pond 12			Z Value
	Median	N_1	Range	Median	N_2	Range	
Temp	26.50	31	23.40	26.65	30	23.70	-0.173
DO	7.20	31	7.20	7.50	30	8.30	-1.162
BOD	2.00	30	3.00	3.00	31	12.00	-2.598
COD	32.50	30	66.00	45.00	31	63.00	-3.671
pH	8.50	30	0.80	8.60	30	1.30	-2.085
CO_2	0.00	30	2.00	0.00	29	2.00	-1.035
TS	331.50	30	150.00	374.00	31	181.00	-2.518
VSS	3.00	30	11.90	6.00	31	26.30	-2.381
TSS	15.00	30	38.00	22.00	31	49.00	-2.377
NH_3-N	0.07	29	0.67	0.33	30	1.17	-2.132
T.Kjeld-N	0.90	30	0.60	1.60	31	3.20	-3.851
T. PO_4	0.08	30	0.17	0.12	31	0.27	-3.632
O-PO_4	0.03	28	0.03	0.04	31	0.06	-3.632
TOC	12.00	30	9.50	15.50	31	17.00	-3.895
Fec. coli.	4.00	30	96.00	4.00	31	52.00	-0.530

nine of the water quality parameters measured. For ponds 9 and 12, which were replicate pond cultures where standard commercial feed was used, there were significant differences in eleven of the water quality parameters measured. These results indicate and statistically verify the earlier statement made after visual examination of the results that there is an extraneous source of variation. Therefore, it was decided to eliminate ponds 12 and 14 from further analysis. Pond 10 was also deleted from further consideration because the replicate pond (pond 6) had a greater number of higher medians and would give a more conservative analysis.

Question No. 2

Are there significant differences between the daytime and nighttime samples in water quality of all the ponds monitored?

Answer No. 2

Table 27 shows the U or Z values (Mann-Whitney test) for each of the 17 water quality parameters.

Day versus night: Reject the null-hypothesis for temperature and accept for the remaining parameters.

Question No. 3

Of the three ponds in the pond culture (ponds 6, 8, and 9) which received different treatments, i.e., without fish or feed, with fish receiving feed containing 30% paunch, and with fish receiving standard commercial feed, respectively, is there any significant difference

Table 27. Comparison of distributions in two time periods.

Variable	Day Median	Day N_1	Day Range	Night Median	Night N_2	Night Range	Z Value
Temp	26.15	48	18.20	25.80	48	18.50	-2.180
DO	8.45	48	6.30	7.50	48	7.40	-1.506
BOD	2.00	48	11.00	2.00	48	9.00	-0.117
COD	32.00	48	72.00	31.50	48	70.00	-0.803
pH	8.80	48	1.50	8.75	48	1.80	-1.823
CO_2	0.00	48	4.50	0.00	48	2.80	-0.104
TS	307.00	48	260.00	318.50	48	206.00	-0.718
VSS	3.00	48	31.00	2.00	45	27.00	-0.425
TSS	12.00	48	44.00	10.00	47	44.00	-0.230
NH_3-N	0.05	47	0.73	0.06	48	0.78	-0.579
NO_2-N	0.04	3	0.07	0.04	3	0.08	3.500*
NO_3-N	0.05	6	0.04	0.03	7	0.04	18.500*
T.Kjeld.-N	0.80	48	2.8	0.80	48	2.80	-0.129
T. PO_4	0.07	48	0.25	0.08	48	0.20	-0.007
O-PO_4	0.03	46	0.05	0.03	47	0.05	-0.023
TOC	12.25	48	12.50	12.00	48	17.00	-0.227
Fec. coli.	3.50	48	432.00	3.50	48	324.00	-0.227

*U Value

in water quality that can be attributed to the differences in treatment?

Answer No. 3

Calculated H values (Kruskal-Wallis test) for 15 of the 17 water quality parameters (Table 28) demand rejecting the null-hypothesis for all parameters except temperature. Because insufficient data were obtained for NO_2-N and NO_3-N, these two parameters were excluded.

Water quality of pond 6, the control pond with no fish and no feed added, was significantly better than that of ponds 8 and 9 (Table 28). A Mann-Whitney test was performed on the data of ponds 8 and 9 to evaluate the null-hypothesis of no difference in water quality (Table 29). Again, tests for NO_2-N and NO_3-N were omitted because of insufficient data. The null-hypothesis is rejected for TS and TOC, and accepted for the remaining parameters.

Question No. 4

Is there a significant difference in one or more water quality parameters between the two ponds in which cage culture was practiced, i.e., between ponds 2 and 3?

Answer No. 4

The null-hypothesis is rejected for DO, T.Kjeld.-N, T-PO_4, and TOC, and accepted for the remaining parameters (Table 30). As in the previous tests, NO_2-N and NO_3-N were omitted because of insufficient data.

Table 28. Kruskal-Wallis one-way analysis of variance.

Variable	Pond 6			Pond 8			Pond 9			H Value
	Median	N_1	Average rank	Median	N_2	Average rank	Median	N_3	Average rank	
Temp	26.80	31	47	26.50	31	46	26.50	31	47	0.03
DO	9.10	31	64	7.10	31	38	7.20	31	38	19.00
BOD	1.00	30	22	2.00	30	60	2.00	30	53	39.78
COD	24.00	30	32	36.00	30	56	32.50	30	47	13.83
pH	9.00	30	66	8.50	30	33	8.50	30	36	30.80
CO_2	0.00	30	37	0.00	30	49	0.00	30	49	9.51
TS	284.50	30	22	376.00	30	64	331.50	30	49	39.62
VSS	1.00	29	26	6.00	30	58	3.00	30	49	24.37
TSS	6.00	30	19	19.00	30	61	15.00	30	55	47.09
NH_3-N	0.01	27	29	0.06	29	49	0.07	29	49	12.60
T.Kjeld.-N	0.06	30	20	1.05	30	62	0.90	30	53	42.06
T. PO_4	0.03	30	19	0.08	30	57	0.08	30	59	44.97
O-PO_4	0.01	25	18	0.03	30	53	0.03	28	50	36.57
TOC	10.00	30	25	14.50	30	62	12.00	30	48	31.99
Fec. coli.	0.00	30	33	5.50	30	52	4.00	30	51	10.74

Table 29. Comparison of distributions in pond 8 and pond 9.

Variable	Pond 8 Median	N_1	Range	Pond 9 Median	N_2	Range	Z Value
Temp	26.50	31	23.40	26.50	31	23.40	-0.183
DO	7.10	31	7.00	7.20	31	7.20	-0.035
BOD	2.00	30	3.00	2.00	30	3.00	-1.332
COD	36.00	30	58.00	32.50	30	66.00	-1.335
pH	8.50	30	0.90	8.50	30	0.80	-0.512
CO_2	0.00	30	2.00	0.00	30	2.00	-0.123
TS	376.00	30	189.00	331.50	30	150.00	-2.795
VSS	6.00	30	13.60	3.00	30	11.90	-1.497
TSS	19.00	30	41.00	15.00	30	38.00	-1.392
NH_3-N	0.06	29	0.78	0.07	29	0.67	-0.101
T.Kjeld.-N	1.05	30	1.00	0.90	30	0.60	-1.943
T. PO_4	0.08	30	0.18	0.08	30	0.17	-0.454
O-PO_4	0.03	30	0.05	0.03	28	0.03	-0.778
TOC	14.50	30	9.00	12.00	30	9.50	-2.347
Fec. coli.	5.50	30	218.00	4.00	30	96.00	-0.118

Table 30. Comparison of distributions in pond 2 and pond 3.

Variable	Pond 2 Median	N_1	Range	Pond 3 Median	N_2	Range	Z Value
Temp	26.30	31	21.50	27.00	31	22.50	-0.338
DO	7.10	31	10.20	9.20	31	9.30	-2.203
BOD	2.00	30	7.00	2.00	30	2.00	-0.319
COD	26.50	30	52.00	24.00	30	55.00	-0.712
pH	9.05	30	2.80	9.30	30	2.20	-1.362
CO_2	0.00	30	12.30	0.00	30	3.30	-0.719
TS	282.50	30	157.00	265.00	30	137.00	-1.463
VSS	2.00	29	9.00	2.00	30	7.00	-0.352
TSS	5.00	30	43.00	4.00	30	13.00	-0.937
NH_3-N	0.03	29	0.27	0.03	29	0.13	-0.848
T.Kjeld.-N	0.75	30	1.10	0.65	30	0.40	-2.398
T. PO_4	0.07	30	0.91	0.04	30	0.10	-3.824
O-PO_4	0.03	30	0.05	0.01	27	0.02	-5.633
TOC	12.00	31	10.00	10.00	30	10.00	-2.107
Fec. coli.	1.00	31	15.00	0.00	30	37.00	-0.828

The results of the above statistical analyses can be summed up as follows:

1. With the exception of fecal coliforms, there was no significant difference in water quality between ponds 6 and 10. This was to be expected, since these are the two control ponds where no fish was stocked and no feed was put in during the experimental period. The fecal coliform parameter will be discussed in detail later.

2. An extraneous source of variation caused each of the replicates in the two sets of replicate ponds analyzed--pond 8 versus pond 14 (feed containing 30% paunch in pond culture) and pond 9 versus pond 12 (standard commercial feed in pond culture)--to differ significantly from each other in water quality. Rainfall and water replacement data do not account for these differences. But since both ponds 12 and 14 were located on the east side of the facility and since both exhibited identical trends in water quality parameters, it was concluded that whatever extraneous source(s) of variation which caused the replicate ponds to differ was related to the location of the ponds.

3. Of the seventeen water quality parameters measured, temperature was the only one which showed a significant difference between the day and night measurements. Water temperatures were lower at night than during the day. The fact that no

significant difference was detected for DO and CO_2 between the two time periods reflects the observation that algal biomass in the ponds was not excessive.

4. All water quality parameters but temperature were significantly different between ponds 6, 8, and 9. The control pond (pond 6) had the best water quality.

Murphy and Lipper (1970) found that under laboratory tank conditions, channel catfish produced 0.0049 pound of BOD per pound of live weight daily. Eley et al. (1972) studied the effects of caged catfish culture on water quality in an Arkansas lake. They found significantly lower amounts of DO and NO_3-N and increases in turbidity, alkalinity, T-PO_4, phosphate phosphorus, organic nitrogen, BOD, and bacteria in the culture area as compared to other lake areas.

Our findings with static water, pond culture of channel catfish, where fresh water was added only to maintain a constant water level, showed that a deterioration in water quality did occur when compared to the control pond, but none of these values deviated from baseline levels in the control ponds to such a degree as to cause concern. Moreover, water quality in ponds where the fish were given standard commercial feed or feed containing 30% paunch had not deteriorated toward the end of the study period as compared to their corresponding median values. Thus, it can be concluded that the pond cultures, using either standard commercial feed or feed containing 30% paunch, had not caused the water quality in these ponds to be deteriorated to any appreciable degree in one growing season.

5. Between ponds 8 and 9, i.e., the 30% paunch-containing feed pond culture and the standard commercial feed pond culture, respectively, the former had significantly higher TS and TOC, while the other thirteen parameters were not significantly different between the two ponds (Table 29). The increases for TS and TOC were so minor that they are not considered meaningful and may be interpreted as having negligible total effect on water quality.

6. There were no significant differences in eleven water quality parameters between ponds 2 and 3 (the cage culture ponds), the only significant differences being that pond 2 (feed containing 10% paunch) had significantly lower DO and higher T.Kjeld.-N, T-PO_4, and O-PO_4. These four differences cannot be directly attributed to the effects of the 10% paunch floating feed used in pond 2, because pond 2 was an old pond in which vegetation was present at the start of the experiment, and this pre-existing vegetation undoubtedly had some influence on the water quality. It can be stated that in cage culture, the use of a floating pellet feed containing 10% paunch does not appear to have an adverse effect on most water quality parameters as compared to the use of a standard commercial floating pellet feed.

Also, comparing the median values of all the parameters of ponds 2 and 3 in Table 30 with those of pond 6 in Table 28, it can be seen that cage culture of channel catfish at yields of about 1200 kg/ha, whether feeding them with standard commercial floating pellet feed or with floating pellet feed containing 10% paunch, does not deteriorate the water quality in the pond to any appreciable degree in one growing season.

The single bacteriological water quality parameter monitored in this study was fecal coliforms. Geldreich and Clarke (1962) studied the bacterial pollution indicators of several species of freshwater fish, including channel catfish. They suggested that the intestinal flora of fish is related in varying degrees to the level of contamination of water and food in the environment and presented strong evidence that there is no permanent coliform or streptococcal flora in the intestinal tract of fish. The decision to include fecal coliforms in this study was made to determine if catfish culture using either standard commercial feed or feed containing dried cattle paunch will cause a change in density of this important bacterial indicator of pollution in the water of the ponds. Although no fecal coliform analysis was made on the dried paunch material used in the formulation of the fish feed, it is not likely that this material was contaminated with fecal coliforms, because the dehydration temperatures should have greatly reduced the bacterial flora. Also, in pelletizing the feed, the feed ingredients had to be moistened with steam before extrusion and being cut into pellets. This steam treatment should also serve to reduce the bacterial flora in the feed. Thus, it is not expected that the finished feed pellets would be contaminated with fecal coliforms.

In view of the above-mentioned knowledge with regard to fecal coliforms, it is not likely that the highly variable numbers of fecal coliforms found in the water samples (in one instance as high as over 400 per 100 ml of water) originated from the paunch, or the feed, or the fish. Rather, these bacteria presumably came from some other extraneous source(s) such as insects, wild animals, water fowl and rainfall runoff water that might have entered the ponds (Geldrich et al. 1962, Geldrich et al. 1964). Thus, fecal coliform-feed relationships must be termed inconclusive. Nevertheless, it can be assumed that paunch material in the fish feed did not contribute to any increase in fecal coliforms in the ponds.

SECTION IX

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SECTION X

APPENDICES

APPENDIX A

WATER QUALITY DATA OF PONDS

Appendix A

Pond 2

Date*	Temp °C	DO mg/l	BOD mg/l	COD mg/l	pH	CO_2 mg/l	TS mg/l	VSS mg/l	TSS mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	T. Kjeld.-N mg/l	T. PO_4 mg/l	O-PO_4 mg/l	TOC mg/l	Fec. coli. #/100 ml
5-17	23.5	4.8	2	22			328	2	6	0.10	<0.02	<0.02	0.6	0.05	0.01	9.0	0
5-24	27.5	0.7	8	52	7.4	11.5	331	10	20				1.6	0.19	0.03	18.0	1
5-31	25.4	2.0	6	56	7.3	12.3	315	9	15	0.08			1.4	0.18	0.02	18.0	0
6-07	30.1	7.9	5	27	7.9	1.0	321	2	5	0.17			1.0	0.12	0.03	13.0	1
6-14 (D)	26.7	5.5	3	36	8.3	4.5	318	4	10	0.23			0.8	0.13	0.03	12.0	6
6-14 (N)	26.0	5.9	2	30	7.9	2.8	369	5	7	0.15			0.7	0.13	0.03	12.0	5
6-21	27.0	7.8	2	37	8.1	2.7	364	7	8	0.28			0.8	0.11	0.05	12.0	0
6-28	31.3	7.1	1	41	8.2	0.7	323	3	5	0.07			0.7	0.07	0.03	11.0	0
7-05	26.8	10.5	1	45	8.4	0.0	226	2	3	0.07			0.7	0.06	0.02	15.5	0
7-12 (D)	27.5	9.2	3	27	9.3	0.0	214	1	4	0.05			0.7	0.06	0.02	14.5	1
7-12 (N)	27.3	10.6	3	64	9.1	0.0	244	2	5	0.05			0.8	0.07	0.03	19.0	5
7-19	29.5	10.1			10.1	0.0										11.5	0
7-26	30.8	10.7	2	20	10.1	0.0	239	2	3	0.10			0.7	0.08	0.03	12.5	0
8-02	28.2	10.6	1	24	9.8	0.0	212	1	10	0.01			0.7	0.05	0.02	10.0	0
8-09 (D)	26.3	6.8	1	12	9.5	0.0	240	4	4	0.03			0.8	0.07	0.04	12.5	0
8-09 (N)	25.5	5.8	1	36	9.1	0.0	251	2	2	0.04			0.8	0.08	0.04	12.0	2
8-16	29.5	8.7	2	32	9.6	0.0	299	3	6	0.01			0.8	0.05	0.03	9.5	15
8-23	28.2	5.2	2	16	8.9	0.0	285	1	8	0.03			0.7	0.11	0.03	9.5	0
8-30	24.0	2.8	2	24	8.6	0.0	279	<1	1	0.05			0.8	0.07	0.04	10.5	0
9-06 (D)	24.8	6.3	2	26	9.3	0.0	271	1	1	0.02			1.0	0.08	0.04	11.5	0
9-06 (N)	25.5	6.7	1	24	9.5	0.0	285	1	1	0.03			0.8	0.07	0.03	12.5	0
9-13	29.8	10.4	1	20	9.8	0.0	263	1	2	0.01			0.8	0.07	0.03	12.5	0
9-20	28.2	7.2	2	20	9.6	0.0	274	1	3	0.01			0.8	0.07	0.03	10.0	2
9-27	25.0	3.4	2	32	8.4	0.0	294	2	10	0.03	<0.03	<0.03	0.5	0.07	0.03	11.0	11
10-04 (D)	21.8	8.4	2	33	9.1	0.0	286	1	4	0.03	<0.03	<0.03	0.7	0.06	0.02	10.0	2
10-04 (N)	19.8	6.3	2	29	8.9	0.0	280	1	2	0.05	<0.03	<0.03	0.7	0.06	0.03	11.0	2
10-11	23.0	5.8	1	14	9.3	0.0	270	1	44	0.02	<0.03	<0.03	0.7	0.07	0.02	13.0	1
10-18	16.8	5.1	3	12	8.6	0.0	300	6	6	0.01	<0.03	<0.03	0.8	0.17	0.06	10.5	10
10-25	12.2	9.3	2	24	9.1	0.0	327	2	10	0.02	<0.03	<0.03	0.7	0.95	0.03	12.5	2
11-01 (D)	11.0	10.8	1	16	9.0	0.0	247	1	3	0.02	<0.03	<0.03	0.6	0.05	0.03	9.0	4
11-01 (N)	9.8	10.9	2	20	8.9	0.0	260	1	3	0.02	<0.03	<0.03	0.6	0.04	0.03	12.0	1

*All dates are for year 1972
D = Day
N = Night

Pond 3

Date	Temp °C	DO mg/1	BOD mg/1	COD mg/1	pH	CO_2 mg/1	TS mg/1	VSS m/gl	TSS mg/1	NH_3-N mg/1	NO_2-N mg/1	NO_3-N mg/1	T. Kjeld.-N mg/1	T.PO_4 mg/1	O-PO_4 mg/1	TOC mg/1	Fec. coli. #/100 ml
5-17	24.0	6.2															
5-24	27.0	5.0	2	18	7.8	3.3	305	3	14				0.6	0.07	0.03	10.0	0
5-31	23.9	7.0	2	24	7.9	2.3	250	4	9	0.14			0.5	0.08	0.03	17.0	1
6-07	29.5	7.3	2	19	8.1	3.3	292	0	1	0.03			0.6	0.06	0.01	12.0	0
6-14 (D)	27.3	8.0	2	32	8.6	2.0	287	2	3	0.03			0.6	0.05	0.02	11.0	1
6-14 (N)	27.0	7.0	3	30	8.2	1.0	330	0	5	0.09			0.7	0.08	0.02	10.0	3
6-21	27.5	11.3	2	24	9.0	0.0	308	3	8	0.12			0.6	0.04	0.01	12.0	1
6-28	32.0	10.2	1	39	9.5	0.0	260	2	4	0.02			0.8	0.04	0.01	12.0	0
7-05	26.5	10.8	2	43	9.5	0.0	193	1	2	0.04			0.7	0.04	0.01	14.5	2
7-12 (D)	28.0	9.3	2	59	9.6	0.0	239	4	5	0.05			0.6	0.04	0.01	12.5	0
7-12 (N)	27.5	10.3	2	59	9.3	0.0	233	2	3	0.06			0.8	0.04	0.02	18.0	0
7-19	30.0	10.4	2	32	9.9	0.0	315	2	3	0.07			0.6	0.07	0.01	12.5	0
7-26	31.0	12.5	2	28	9.9	0.0	241	2	2	0.10			0.6	0.04	0.01	11.8	0
8-02	29.2	13.2	2	6	9.7	0.0	214	0	1	0.01			0.6	0.03	0.01	10.0	0
8-09 (D)	27.0	9.8	2	30	9.4	0.0	245	4	4	0.01			0.6	0.05	0.01	9.5	0
8-09 (N)	26.6	7.5	2	28	8.9	0.0	243	2	4	0.06			0.7	0.04	0.01	10.0	0
8-16	30.2	11.6	1	32	9.7	0.0	294	2	5	0.01			0.8	0.02	0.01	9.5	0
8-23	28.2	6.0	2	32	9.3	0.0	271	2	4	0.02			0.8	0.06	0.01	9.5	0
8-30	24.5	3.9	2	24	8.7	0.0	260	1	1	0.06			0.8	0.04	0.02	10.0	0
9-06 (D)	26.0	10.4	2	28	9.8	0.0	258	1	1	0.02			0.8	0.12	0.01	13.5	0
9-06 (N)	25.8	9.2	2	24	9.7	0.0	259	1	1	0.03			0.8	0.08	0.01	11.0	0
9-13	29.8	8.8	2	16	10.0	0.0	254	3	5	0.02			0.9	0.04	0.01	12.0	0
9-20	28.3	6.2	2	4	9.2	0.0	270	1	5	0.01			0.9	0.04	0.01	9.5	20
9-27	25.0	6.9	2	24	8.6	0.0	275	3	7	0.01	<0.03	<0.03	0.7	0.07	0.01	10.0	15
10-04 (D)	21.8	10.5	2	6	9.1	0.0	290	2	13	0.04	<0.03	<0.03	0.5	0.07	0.02	10.0	0
10-04 (N)	20.3	6.5	2	24	9.0	0.0	283	2	10	0.10	<0.03	<0.03	0.8	0.07	0.02	10.0	0
10-11	23.3	6.9	1	20	9.5	0.0	292	2	5	0.01	<0.03	<0.03	0.6	0.03	<0.01	9.0	7
10-18	16.8	6.8	2	25	8.8	0.0	297	7	11	0.04	<0.03	<0.03	0.7	0.08	0.02	9.5	37
10-25	11.8	11.2	1	20	9.4	0.0	320	3	7	0.02	<0.03	<0.03	0.6	0.03	0.01	9.0	1
11-01 (D)	10.3	10.7	1	20	9.3	0.0	234	1	3	0.02	<0.03	<0.03	0.5	0.04	<0.01	10.0	14
11-01 (N)	9.5	12.9	2	16	9.2	0.0	233	0	1	0.01	<0.03	<0.03	0.5	0.03	<0.01	8.0	3

Pond 6

Date	Temp °C	DO mg/1	BOD mg/1	COD mg/1	pH	CO_2 mg/1	TS mg/1	VSS mg/1	TSS mg/1	NH_3-N mg/1	NO_2-N mg/1	NO_3-N mg/1	T. Kjeld-N mg/1	T. PO_4 mg/1	O-PO_4 mg/1	TOC mg/1	Fec. coli. #/100 ml
5-17	23.0	6.5															
5-24	27.5	7.5	2	20	8.4	0.0	324	2	27				0.7	0.05	0.02	10.0	0
5-31	24.4	8.5	1	20	8.3	0.0	265	3	8	0.16			0.6	0.03	0.01	12.0	2
6-07	30.2	7.3	1	17	8.6	0.0	298	0.5	2	0.05			0.5	0.03	0.01	10.0	0
6-14 (D)	26.8	7.4	1	28	8.8	0.0	313	1	6	0.13			0.8	0.03	0.01	8.0	0
6-14 (N)	26.5	7.3	1	28	8.4	0.0	357	1	5	0.13			0.4	0.03	0.01	11.0	0
6-21	26.8	8.4	1	31	8.6	0.0	351	1	7	0.29			0.4	0.04	0.02	9.0	0
6-28	32.0	7.2	1	37	8.7	0.0	320	4	8	0.15			1.5	0.04	0.01	10.0	0
7-05	26.8	8.4	2	40	8.5	0.0	247	2	12	0.04			0.6	0.04	0.02	14.5	0
7-12 (D)	27.8	8.0	2	78	8.6	0.0	260	4	8	0.18			0.5	0.03	0.02	12.5	0
7-12 (N)	27.3	9.7	1	55	8.4	0.0	282	2	9	0.21			0.5	0.03	0.01	14.0	1
7-19	30.2	9.0	0.4	28	9.0	0.0	249	2	3	0.26			0.6	0.07	0.01	11.0	0
7-26	31.2	9.8	1	26	9.2	0.0	278	3	8	0.29			0.5	0.05	0.02	9.0	1
8-02	28.8	9.3	1	20	9.3	0.0	245	1	5	0.01			0.5	0.02	0.01	9.0	0
8-09 (D)	26.8	9.4	1	28	9.2	0.0	282	4	6	0.01			0.6	0.03	0.01	9.5	0
8-09 (N)	25.8	9.1	1	28	8.9	0.0	274	4	7.5	0.01			0.6	0.03	0.01	9.5	0
8-16	30.2	9.6	1	35	9.5	0.0	332	1	5	0.01			0.7	0.06	0.01	9.5	1
8-23	28.2	7.7	1	36	9.2	0.0	282	2	9	0.01			0.7	0.08	0.01	10.0	65
8-30	23.8	7.1	1	24	8.8	0.0	288	1	2	0.01			0.6	0.02	0.01	12.0	207
9-06 (D)	26.0	9.9	1	23	9.4	0.0	288	1	2	0.01			0.6	0.07	0.01	10.5	0
9-06 (N)	26.0	9.6	1	20	9.4	0.0	296	<1	2	0.01			0.6	0.03	0.01	11.5	0
9-13	30.0	10.2	1	16	9.5	0.0	277	1	4	0.01			0.6	0.03	0.01	10.0	6
9-20	28.3	9.6	1	4	9.3	0.0	274	1	2	0.01			0.7	0.02	<0.01	9.5	14
9-27	24.8	9.1	1	20	9.1	0.0	278	1	4	0.01	<0.03	<0.03	0.6	0.03	0.01	11.0	0
10-04 (D)	22.0	9.9	2	16	9.2	0.0	292	1	4	0.01	<0.03	<0.03	1.3	0.03	<0.01	9.0	0
10-04 (N)	20.8	9.4	2	20	9.0	0.0	287	1	2	0.02	<0.03	<0.03	0.5	0.05	0.01	9.0	0
10-11	23.8	6.8	1	12	9.4	0.0	306	1	3	0.01	<0.03	<0.03	0.4	0.02	<0.01	9.0	1
10-18	16.8	6.9	1	25	9.0	0.0	310	5	6	0.01	<0.03	<0.03	0.6	0.05	<0.01	10.5	18
10-25	12.0	10.7	2	16	9.2	0.0	312	4	6	<0.01	<0.03	<0.03	0.4	0.01	<0.01	9.0	0
11-01 (D)	9.8	11.8	2	24	8.9	0.0	229	1	8	<0.01	<0.03	<0.03	0.4	0.03	0.01	12.5	76
11-01 (N)	9.3	12.5	2	16	9.1	0.0	229	1	6	0.01	<0.03	<0.03	0.4	0.04	0.01	8.5	22

Pond 8

Date	Temp °C	DO mg/1	BOD mg/1	COD mg/1	pH	CO_2 mg/1	TS mg/1	VSS mg/1	TSS mg/1	NH_3-N mg/1	NO_2-N mg/1	NO_3-N mg/1	T. Kjeld.-N mg/1	T. PO_4 mg/1	O-PO_4 mg/1	TOC mg/1	Fec. coli. #/100ml
5-17	22.9	6.4															
5-24	27.3	7.6	2	24	8.4	0.0	324	3	23				0.6	0.07	0.02	11.5	1
5-31	25.0	6.7	2	22	7.9	1.7	266	6	12	0.41			0.7	0.06	0.02	13.0	0
6-07	30.3	6.6	2	22	8.5	2	319	0.4	3	0.21			0.8	0.05	0.01	10.0	0
6-14 (D)	27.0	7.2	2	28	8.7	1.5	415	2	29	0.19			0.8	0.06	0.03	12.0	1
6-14 (N)	26.3	6.6	2	34	8.3	1.0	405	1	24	0.32			0.8	0.08	0.03	12.0	0
6-21	27.2	7.6	2	43	8.3	0.3	386	9	30	0.54			0.9	0.10	0.03	12.0	2
6-28	32.7	6.9	2	46	8.5	0.0	362	6	9	0.57			0.8	0.07	0.03	12.0	0
7-05	27.5	8.1	3	50	8.3	0.0	300	6	20	0.07			1.0	0.08	0.03	15.5	0
7-12 (D)	27.0	6.2	4	40	8.3	0.0	366	10	34	0.74			0.9	0.08	0.04	15.0	7
7-12 (N)	26.5	7.1	3	78	8.0	0.0	373	9	21	0.79			1.1	0.09	0.04	17.0	6
7-19	30.2	8.3	1	36	8.6	0.0	317	11	16	0.56			1.0	0.09	0.03	15.3	2
7-26	30.8	8.3	2	38	8.6	0.0	373	8	19	0.50			1.0	0.08	0.03	8.5	5
8-02	28.5	8.2	3	40	8.6	0.0	378	8	25	0.02			0.9	0.10	0.04	15.0	13
8-09 (D)	26.8	6.6	4	47	8.4	0.0	415	13	38	0.03			1.3	0.17	0.04	14.5	14
8-09 (N)	25.8	5.5	3	40	7.9	0.0	417	14	44	0.04			1.3	0.23	0.06	16.5	2
8-16	29.7	7.2	2	49	8.6	0.0	455	8	29	0.03			1.3	0.17	0.05	16.5	6
8-23	28.8	6.6	3	56	8.6	0.0	400	5	36	0.04			1.6	0.15	0.05	17.5	14
8-30	23.3	5.2	3	36	8.1	1.0	374	6	29	0.13			1.3	0.09	0.04	16.5	218
9-06 (D)	25.8	7.5	3	24	8.5	0.5	278	5	16	0.05			1.2	0.07	0.02	15.0	8
9-06 (N)	25.3	6.2	2	40	8.4	1.5	414	5	18	0.07			1.2	0.08	0.03	15.0	4
9-13	29.3	8.0	4	20	8.6	0.0	369	6	18	0.03			1.1	0.06	0.02	13.0	4
9-20	27.8	9.6	3	24	8.7	0.0	407	6	19	0.01			1.3	0.06	0.02	14.5	124
9-27	25.0	6.6	3	32	8.4	0.0	387	5	18	0.03	<0.03	<0.03	1.1	0.09	0.02	13.5	6
10-04 (D)	22.0	7.8	2	37	8.6	0.0	397	4	14	0.05	<0.03	0.03	1.1	0.07	0.02	12.0	0
10-04 (N)	20.8	6.8	3	33	8.4	0.0	366	5	22	0.06	<0.03	0.03	1.2	0.11	0.02	13.0	2
10-11	23.5	6.1	2	28	8.4	0.0	401	6	15	0.05	<0.03	<0.03	1.1	0.05	0.01	14.5	4
10-18	17.3	6.6	3	37	8.6	0.0	425	10	19	0.08	<0.03	0.04	1.2	0.06	0.02	14.5	34
10-25	12.3	8.6	2	28	8.7	0.0	422	2	11	0.06	<0.03	0.07	1.0	0.07	0.01	11.5	8
11-01 (D)	10.0	11.0	2	32	8.6	0.0	327	1	10	0.04	<0.03	0.07	0.8	0.05	0.02	15.0	118
11-01 (N)	9.3	12.2	2	28	8.8	0.0	342	1	9	0.04	<0.03	0.07	0.8	0.05	0.02	12.5	80

Pond 9

Date	Temp °C	DO mg/l	BOD mg/l	COD mg/l	pH	CO_2 mg/l	TS mg/l	VSS mg/l	TSS mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	T. Kjeld.-N mg/l	T. PO_4 mg/l	O-PO_4 mg/l	TOC mg/l	Fec. coli. #/100ml
5-17	23.3	6.1															
5-24	27.7	7.7	2	28	8.4	0.0	323	6	19				0.6	0.05	0.02	12.0	1
5-31	24.9	7.0	2	24	8.0	1.0	279	2	16	0.41			0.9	0.10	0.02	17.0	1
6-07	30.3	7.2	2	22	8.7	0.3	324	0.1	4	0.23			0.7	0.06	0.01	12.0	0
6-14 (D)	27.0	7.3	2	36	8.7	2.0	420	8	42	0.38			0.8	0.12	0.03	12.0	1
6-14 (N)	26.5	6.7	2	31	8.3	0.5	422	2	30	0.27			0.8	0.07	0.03	12.0	0
6-21	27.5	8.5	3	43	8.4	0.3	386	6	27	0.45			0.8	0.08	0.03	9.5	1
6-28	33.2	7.1	2	45	8.7	0.0	350	9	22	0.39			0.9	0.08	0.03	12.0	2
7-05	29.8	8.5	2	52	8.6	0.0	279	6	16	0.08			1.2	0.10	0.03	14.5	0
7-12 (D)	27.0	7.2	4	44	8.6	0.0	324	12	31	0.44			1.1	0.09	0.03	14.5	5
7-12 (N)	26.5	7.6	4	82	8.2	0.0	345	11	37	0.55			1.1	0.10	0.04	18.5	13
7-19	30.5	9.3	1	40	8.7	0.0	302	10	14	0.63			1.1	0.11	0.03	15.0	0
7-26	31.2	8.1	3	40	8.6	0.0	333	9	24	0.68			1.0	0.11	0.03	15.0	2
8-02	28.5	8.5	3	36	8.6	0.0	303	3	15	0.02			0.9	0.08	0.02	13.0	0
8-09 (D)	27.0	7.5	4	32	8.4	0.0	333	9	14	0.02			1.1	0.09	0.03	9.0	11
8-09 (N)	25.8	6.5	4	40	8.2	0.0	350	8	28	0.02			1.2	0.10	0.03	18.5	0
8-16	29.8	7.9	3	39	8.7	0.0	378	4	14	0.01			1.2	0.09	0.02	10.5	22
8-23	28.3	5.1	2	40	8.4	0.0	340	2	11	0.06			1.1	0.21	0.02	10.5	11
8-30	23.3	5.0	1	16	7.9	2.0	311	1	22	0.11			1.0	0.06	0.04	12.5	39
9-06 (D)	25.8	6.7	2	24	8.4	0.0	330	2	16	0.06			0.9	0.07	0.02	14.0	89
9-06 (N)	25.3	6.2	2	24	8.4	1.0	367	2	15	0.07			0.9	0.10	0.02	11.0	63
9-13	29.3	7.0	1	16	8.5	0.0	321	3	14	0.06			0.9	0.17	0.02	10.0	9
9-20	27.7	6.4	2	24	8.6	0.0	324	2	15	0.03			1.0	0.07	0.02	10.0	58
9-27	24.8	5.0	1	18	8.3	0.7	320	2	14	0.08	<0.03	<0.03	0.9	0.06	0.01	11.0	4
10-04 (D)	21.5	8.0	2	33	8.6	0.0	347	2	15	0.07	<0.03	<0.03	1.0	0.08	0.03	12.0	96
10-04 (N)	20.8	6.2	2	33	8.5	0.0	288	2	19	0.11	<0.03	0.03	1.1	0.08	0.02	10.0	28
10-11	23.5	5.9	2	24	8.6	0.0	429	1	7	0.04	<0.03	<0.03	0.8	0.04	<0.01	13.0	2
10-18	17.5	6.7	2	33	8.4	0.0	347	6	15	0.04	<0.03	<0.03	0.8	0.06	0.01	13.5	2
10-25	12.7	8.9	2	24	8.6	0.0	380	4	10	0.03	<0.03	<0.03	0.7	0.04	<0.01	11.0	4
11-01 (D)	10.3	10.8	3	22	8.5	0.0	282	3	14	0.05	<0.03	<0.03	0.7	0.08	0.03	13.5	62
11-01 (N)	9.8	12.2	2	16	8.7	0.0	296	1	10	0.04	<0.03	<0.03	0.6	0.05	0.03	10.0	46

Pond 10

Date	Temp °C	DO mg/1	BOD mg/1	COD mg/1	pH	CO_2 mg/1	TS mg/1	VSS mg/1	TSS mg/1	NH_3-N mg/1	NO_2-N mg/1	NO_3-N mg/1	T. Kjeld.-N mg/1	T. PO_4 mg/1	O-PO_4 mg/1	TOC mg/1	Fec. coli. #/100ml
5-17	23.2	6.2	2	20			335	4	29	0.50			0.6	0.05	0.02	8.0	1
5-24	27.5	7.6	2	30	8.4	0.0	334	4	24				0.7	0.07	0.04	12.0	0
5-31	25.6	8.0	1	20	8.2	0.0	249	5	11	0.24			0.5	0.05	0.01	22.0	
6-07	30.2	7.2	1	21	9.0	0.0	317	0.2	2	0.10			0.6	0.03	0.01	10.0	0
6-14 (D)	27.0	8.0	1	24	9.0	0.0	342	1	11	0.03			0.6	0.05	0.02	10.0	0
6-14 (N)	26.8	7.9	1	28	8.7	0.0	326	0	1	0.03			0.4	0.03	0.01	12.0	0
6-21	28.3	8.7	1	31	8.8	0.0	328	1	2	0.20			0.5	0.03	0.01	10.0	0
6-28	33.7	7.8	1	39	8.7	0.0	292	4	6	0.06			0.6	0.08	0.01	12.0	0
7-05	28.0	8.4	2	37	8.6	0.0	220	3	5	0.08			0.5	0.04	0.02	11.5	0
7-12 (D)	27.0	8.5	1	28	8.9	0.0	381	4	10	0.15			0.4	0.03	0.02	11.0	33
7-12 (N)	26.5	10.8	1	66	8.8	0.0	296	5	6	0.12			0.4	0.03	0.02	14.0	10
7-19	30.2	8.7	1	32	9.4	0.0	254	3	3	0.38			0.5	0.07	0.01	11.0	0
7-26	31.0	11.3	1	24	9.1	0.0	269	3	4	0.13			0.5	0.03	0.01	9.5	1
8-02	29.0	10.2	1	26	9.5	0.0	322	3	4	0.01			0.6	0.02	0.01	10.0	0
8-09 (D)	27.8	10.1	2	32	9.2	0.0	263	4	4	0.01			0.6	0.03	0.01	9.5	1
8-09 (N)	26.5	9.5	2	30	8.9	0.0	270	<1	<1	0.01			0.6	0.03	0.01	10.0	0
8-16	30.3	9.7	2	35	9.7	0.0	312	2	5	0.01			0.8	0.03	0.01	10.0	9
8-23	28.7	7.4	2	36	9.1	0.0	267	<1	3	0.01			0.7	0.05	0.01	10.5	11
8-30	23.8	7.3	1	24	8.7	0.0	235	<1	3	0.01			0.6	0.02	0.01	13.0	43
9-06 (D)	26.0	9.5	1	20	9.1	0.0	166	1	3	0.01			0.6	0.03	0.01	10.5	25
9-06 (N)	26.0	9.8	2	20	9.2	0.0	284	<1	2	0.01			0.6	0.05	0.01	8.5	19
9-13	29.5	10.1	2	6	9.6	0.0	226	1	3	0.02			0.7	0.03	0.01	8.5	1
9-20	27.8	9.2	1	18	9.3	0.0	255	1	2	0.01			0.7	0.02	<0.01	9.0	13
9-27	25.0	9.3	1	24	9.1	0.0	263	1	3	0.01	<0.03	<0.03	0.6	0.03	0.01	10.0	8
10-04 (D)	22.5	8.5	2	22	9.1	0.0	295	1	11	0.02	<0.03	<0.03	0.6	0.06	0.02	9.0	20
10-04 (N)	20.8	8.9	2	29	9.0	0.0	287	3	10	0.02	<0.03	<0.03	1.3	0.06	0.02	10.0	23
10-11	23.7	6.7	2	16	9.2	0.0	291	2	6	0.02	<0.03	<0.03	0.6	0.03	<0.01	9.0	2
10-18	18.7	7.8	2	25	9.0	0.0	283	5	6	0.01	<0.03	<0.03	0.5	0.04	<0.01	8.0	15
10-25	13.0	10.5	0.3	16	9.0	0.0	327	2	6	0.02	<0.03	<0.03	0.4	0.02	<0.01	11.0	1
11-01 (D)	10.8	11.2	2	20	8.8	0.0	245	1	7	0.01	<0.03	<0.03	0.4	0.04	0.02	10.0	187
11-01 (N)	9.5	12.8	1	20	9.0	0.0	256	1	6	0.01	<0.03	<0.03	0.4	0.03	0.02	11.0	108

Pond 12

Date	Temp °C	DO mg/1	BOD mg/1	COD mg/1	pH	CO_2 mg/1	TS mg/1	VSS mg/1	TSS mg/1	NH_3-N mg/1	NO_2-N mg/1	NO_3-N mg/1	T. Kjeld.-N mg/1	T. PO_4 mg/1	O-PO_4 mg/1	TOC mg/1	Fec. coli. #/100 ml
5-17			1	22			336	4	22	0.60			0.5	0.05	0.03	9.0	1
5-24	28.0	7.6	2	24	8.3	<0.1	346	5	24				0.8	0.07	0.03	14.0	0
5-31	24.4	7.2	2	24	8.1	1.0	254	2	18	0.43			0.6	0.05	0.01	16.5	4
6-07	30.0	6.8	1	20	9.0	0.0	313	0.7	4	0.18			0.7	0.06	0.01	12.5	4
6-14 (D)	27.0	7.4	2	34	8.6	2.0	426	2	42	0.19			0.8	0.12	0.05	13.0	2
6-14 (N)	26.0	6.8	2	32	8.3	1.0	435	6	45	0.19			0.8	0.13	0.04	11.0	10
6-21	28.2	8.1	3	35	8.5	0.0	408	8	36	0.36			0.8	0.08	0.04	12.0	3
6-28	33.2	6.9	2	45	8.4	0.0	350	7	20	0.27			1.0	0.09	0.02	14.0	8
7-05	28.0	8.4	3	49	8.4	0.0	275	6	20	0.09			1.0	0.12	0.01	16.5	3
7-12 (D)	27.0	7.9	5	44	8.6	0.0	349	11	24	0.44			1.2	0.12	0.03	16.0	16
7-12 (N)	26.5	8.6	5	78	8.3	0.0	419	11	31	0.56			1.4	0.13	0.04	20.0	5
7-19	30.0	9.2	1	58	8.8	0.0	350	13	15	0.63			1.7	0.27	0.04	15.5	7
7-26	30.7	11.5	8	62	8.8	0.0	374	19	28	1.20			2.3	0.32	0.03	19.0	0
8-02	28.0	8.7	9	55	8.8	0.0	348	3	5	0.03			2.5	0.21	0.04	21.0	0
8-09 (D)	26.8	9.1	10	76	8.8	0.0	374	27	36	0.04			2.6	0.28	0.05	18.5	19
8-09 (N)	26.0	6.6	8	64	8.4	0.0	404	27	41	0.04			2.5	0.16	0.04	25.0	11
8-16	31.2	11.6	12	83	9.3	0.0	415	11	20	0.05			3.2	0.17	0.06	25.0	46
8-23	28.5	10.5	13	80	9.4	0.0	314	22	53	0.06			3.7	0.28	0.06	25.0	32
8-30	23.3	7.2	12	73	8.8	0.0	364	24	42	0.08			3.5	0.21	0.07	26.0	14
9-06 (D)	25.8	8.6	12	66	9.0	0.0	376	16	27	0.06			3.2	0.19	0.05	15.5	0
9-06 (N)	25.8	6.1	10	64	8.9	0.0	380	19	36	0.05			3.2	0.18	0.05	23.5	0
9-13	29.3	7.2	9	53	8.7	0.0	375	16	35	0.06			2.6	0.20	0.05	18.5	0
9-20	27.7	3.9	4	44	8.4	0.0	374	8	16	0.40			2.1	0.12	0.03	15.0	28
9-27	26.0	3.6	2	44	8.3	2.0	381	2	16	0.70	0.08	0.03	2.2	0.19	0.04	10.0	2
10-04 (D)	22.5	7.3	3	45	8.7	0.0	414	2	20	0.40	0.11	0.04	1.8	0.11	0.04	15.0	0
10-04 (N)	21.0	6.2	3	45	8.7	0.0	380	3	20	0.38	0.11	0.03	2.0	0.12	0.04	18.0	4
10-11	23.3	5.4	2	37	8.4	0.0	361	3	10	0.30	<0.03	0.04	1.5	0.08	0.02	14.0	4
10-18	17.7	6.1	3	49	8.5	0.0	389	6	9	0.35	<0.03	0.05	1.6	0.18	0.02	16.5	4
10-25	12.8	8.5	2	33	8.6	0.0	379	2	9	0.40	<0.03	0.08	1.4	0.05	0.03	13.5	0
11-01 (D)	10.5	10.7	2	36	8.6	0.0	301	3	22	0.44	0.04	0.06	1.4	0.10	0.04	14.0	52
11-01 (N)	9.5	11.9	2	36	8.8	0.0	311	2	19	0.45	0.04	0.06	1.5	0.10	0.04	13.0	44

Pond 14

Date	Temp °C	DO mg/l	BOD mg/l	COD mg/l	pH	CO_2 mg/l	TS mg/l	VSS mg/l	TSS mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	T. Kjeld.-N mg/l	T. PO_4 mg/l	O-PO_4 mg/l	TOC mg/l	Fec. coli. #/100 ml
5-24	27.7	7.3	2	28	8.4	0.0	323	5	26				0.8	0.08	0.03	15.0	9
5-31	24.8	7.5	1	20	8.2	0.0	256	2	16	0.38			0.6	0.05	0.01	14.0	0
6-07	30.2	7.1	2	20	9.1	0.0	325	1	2	0.21			0.6	0.05	0.01	12.5	0
6-14 (D)	26.8	7.4	2	34	8.7	1.5	425	5	45	0.14			0.8	0.08	0.06	11.5	3
6-14 (N)	26.3	6.7	2	32	8.4	0.5	395	2	35	0.26			0.8	0.08	0.04	12.5	3
6-21	27.3	7.8	2	42	8.5	0.0	400	6	33	0.31			0.8	0.08	0.05	12.5	1
6-28	33.2	6.9	2	43	8.5	0.0	351	7	20	0.48			0.9	0.07	0.02	13.0	0
7-05	27.2	8.0	3	54	8.3	0.0	294	6	25	0.07			1.1	0.10	0.04	15.5	1
7-12 (D)	27.3	7.6	4	61	8.5	0.0	353	11	24	0.31			1.0	0.08	0.03	15.5	16
7-12 (N)	26.5	8.0	4	86	8.4	0.0	387	11	31	0.36			1.4	0.09	0.03	17.0	9
7-19	30.2	8.7	1	48	8.8	0.0	322	14	15	0.47			1.2	0.12	0.03	14.0	11
7-26	31.2	8.9	6	49	8.6	0.0	382	17	32	0.92			1.5	0.15	0.04	15.5	6
8-02	28.3	8.8	6	50	8.7	0.0	339	2	3	0.03			1.8	0.13	0.03	18.5	0
8-09 (D)	26.8	8.5	6	54	8.7	0.0	393	32	40	0.04			1.7	0.22	0.05	16.3	2
8-09 (N)	25.8	7.1	5	58	8.4	0.0	386	19	37	0.03			1.6	0.11	0.04	21.0	22
8-16	31.0	10.5	8	65	9.2	0.0	410	13	20	0.05			2.1	0.13	0.05	20.0	16
8-23	28.7	8.6	9	80	9.3	0.0	356	8	23	0.08			2.8	0.20	0.05	21.0	40
8-30	23.5	7.9	9	61	9.1	0.0	331	17	39	0.06			2.7	0.17	0.05	22.3	174
9-06 (D)	25.0	9.4	10	54	9.3	0.0	341	12	16	0.04			2.4	0.12	0.03	20.5	44
9-06 (N)	25.5	7.5	9	52	9.2	0.0	357	11	24	0.04			2.3	0.09	0.03	18.5	72
9-13	29.5	8.3	7	45	9.1	0.0	330	12	33	0.03			2.2	0.15	0.03	18.5	28
9-20	27.7	6.3	5	36	8.8	0.0	341	8	22	0.02			1.8	0.09	0.03	15.5	120
9-27	26.0	4.9	3	40	8.4	0.0	350	2	20	0.30	<0.03	0.04	1.7	0.10	0.03	14.0	112
10-04 (D)	22.0	8.0	5	41	8.7	0.0	363	5	21	0.08	0.04	0.03	1.5	0.08	0.02	15.0	96
10-04 (N)	20.5	7.1	5	45	8.7	0.0	376	6	27	0.10	0.03	0.03	1.7	0.09	0.03	14.0	120
10-11	23.5	6.1	3	35	8.6	0.0	330	4	12	0.04	<0.03	0.04	1.1	0.06	0.02	13.5	64
10-18	16.5	6.9	4	41	8.6	0.0	372	10	16	0.02	<0.03	0.03	1.3	0.10	0.02	15.5	164
10-25	12.8	9.0	3	24	8.7	0.0	366	6	12	0.05	<0.03	0.03	1.0	0.08	0.01	12.5	16
11-01 (D)	10.3	11.2	2	28	8.8	0.0	289	3	20	0.09	<0.03	0.05	1.0	0.06	0.03	13.8	432
11-01 (N)	9.0	12.3	3	28	8.8	0.0	309	3	19	0.09	<0.03	0.06	0.9	0.07	0.03	13.0	324

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16. Abstract
Part A of this report examines the feasibility of using dried paunch at 10, 20 and 30% levels in feed for pond-rearing yearling channel catfish to market-size, and at a 10% level for cage-culture of yearling catfish. Part B describes the effects of fish culture, using standard feeds and paunch-containing feeds, on water quality of fish ponds. In all, one physical, one bacteriological, and fifteen chemical parameters were measured.

Regardless of feed type, pond-reared fish grew faster than the cage-reared fish. There was no significant difference in final weights attained by fish given standard, and 10 and 20% paunch feeds but fish given 30% paunch were significantly smaller. Feed costs per kg of catfish produced using the standard commercial sinking feed and sinking feed containing 10% paunch were essentially equal, but feed costs for making sinking feed with 10 and 20% paunch were greater than the standard. The costs of making a floating feed containing 10% paunch for raceway or cage culture of channel catfish were uneconomical. Neither the pond culture nor the cage culture caused deterioration in water quality in any of the ponds to any appreciable degree in one growing season of 24 weeks, and there was no significant difference in water quality in general between the ponds in which commercial feeds were used and those in which paunch-containing feeds were used--this was true in both pond and cage cultures.

17a. Descriptors

Aquaculture, Water pollution, Agriculture wastes, Abatement, Beef cattle, Water quality

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