(2) Channel catfish exhibited similar growth and food conversion when held in potassium chloride at a concentration which provided a number of potassium ions similar to the number of sodium ions in a 0.17% sodium chloride solution.

(3) Sodium chloride at a concentration of 0.085% improved growth but did not improve food conversion.

(4) Sodium chloride at a concentration of 0.5% did not improve growth or food conversion.

(5) Sodium sulphate at a concentration calculated to provide a number of sodium ions similar to that in 0.17% sodium chloride gave good growth but resulted in mortality after three or four weeks.

(6) Mortality was greater for fish held in recirculated fresh water than for fish held in salt solutions.

(7) The beneficial effects of salt are thought to result from a reduction in the work required for the fish to maintain a suitable osmotic balance in fresh water.

(8) It would be entirely practical to mix salt water obtained from wells or coastal waters with fresh water to make a salt solution similar to those tested. An inexpensive commercial grade dry salt might also be used. Results of the present study indicate that such a procedure would be profitable.

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POLYCULTURE STUDIES WITH BLUE, WHITE AND CHANNEL CATFISH IN BRACKISH WATER PONDS[1]

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ABSTRACT

This paper includes a discussion of a catfish polyculture experiment conducted in brackish water ponds at the Rockefeller Wildlife Refuge, Grand Chenier, Louisiana. Ponds containing channel catfish (*Ictalurus punctatus*) only served as controls and were compared to other ponds containing various stocking ratios of blue (*I. furcatus*), channel and white catfish (*I. catus*) to determine if production could be increased. Length-weight relationships, coefficients of condition, food conversions, survival and growth data were compared in an analysis of the various stocking combinations.

1 This study was supported in part by the LSU Agricultural Experiment Station and by NOAA through the Sea Grant Program.

These data supported by that of past studies demonstrated that channel catfish grown under monoculture conditions exhibited the best survival, food conversion, coefficient of condition and growth. It is also stressed that we believe the culture of mixed species to be nearing practicality and may be a future requirement in order to realize additional profits from fish farming operations. New species and stocking ratios should be explored to obtain maximum yields.

INTRODUCTION

Six years ago, the Louisiana Wild Life and Fisheries Commission began exploring the possibilities of producing freshwater catfish in brackish coastal waters. This has been a cooperative venture with the Louisiana State University Agriculture Experiment Station.

It was contended that the warmer climate of our vast fertile coastal lands should offer longer growing seasons and possibly thousands of acres of marshlands now idle may possess a potential to catfish farmers. If catfish could be grown in brackish waters unsuitable for any other crop, then a whole new industry awaits coastal waters.

The initial pilot study was in the form of a master's thesis (Perry, 1967). This indicated that under natural conditions both blue (*Ictalurus furcatus*) and channel (*I. punctatus*) catfish were present in coastal marsh waters having salinities ranging up to 11.4 ppt (parts per thousand). It was also found that blue catfish were more common in the more saline waters.

In 1967, pond studies based on these findings were initiated and have been repeated annually. These have demonstrated that channel, blue and white (*I. catus*) catfish could be successfully grown in coastal marsh impoundments too saline for other agricultural crops (Perry and Avault, 1968, 1969). The channel catfish proved to be the best suited for commercial production in coastal areas for 1 to 2 year-old fish. Top production was close to 2,000 pounds per acre.

This work has recently been supported by laboratory bioassey test (Allen and Avault, 1971). These workers found that under controlled laboratory conditions, blues were slightly more tolerant to saltwater than channel catfish. Channel catfish had an upper tolerance of 12 ppt. Allen and Avault (1970) also reported some degree of therapeutic effect of saltwater on channel catfish.

This paper reports on the results of our continued studies directed toward the improvement of growth, food conversion, survival and production by stocking mixed species of catfish.

We had hoped that by mixing blue, white and channel catfish a larger harvest could be obtained. Possibly each of the species would occupy a different niche in the ponds, as it is generally accepted that each fish has different habits. It is stated by several workers that by stocking 10% blue catfish with channel catfish, production would be increased.

STUDY AREA

The research ponds used in our experiments are located on Rockefeller Wildlife Refuge in the coastal marshes of Southwest Louisiana (Figure 1). The 84,000 acre refuge is owned and managed by the Louisiana Wild Life and Fisheries Commission. This area is wedged in between the Gulf of Mexico and the stranded beach ridge complex of Grand Chenier, Louisaiana.

The research ponds, one-tenth acre each, were constructed in such a manner as to allow freshwater-saltwater manipulations in order to obtain desired salinity concentrations. Pond bottoms have a high mineral content identical with the surrounding chenier plains marshes. The average depth is 4 feet. The salinities of the refuge waters range from 0.1 ppt to 30 ppt. The typical saltmarsh flora of wiregrass (*Spartina patens*) and saltmarsh grass (*Distichlis spicata*) is dominant in the non-impounded areas.

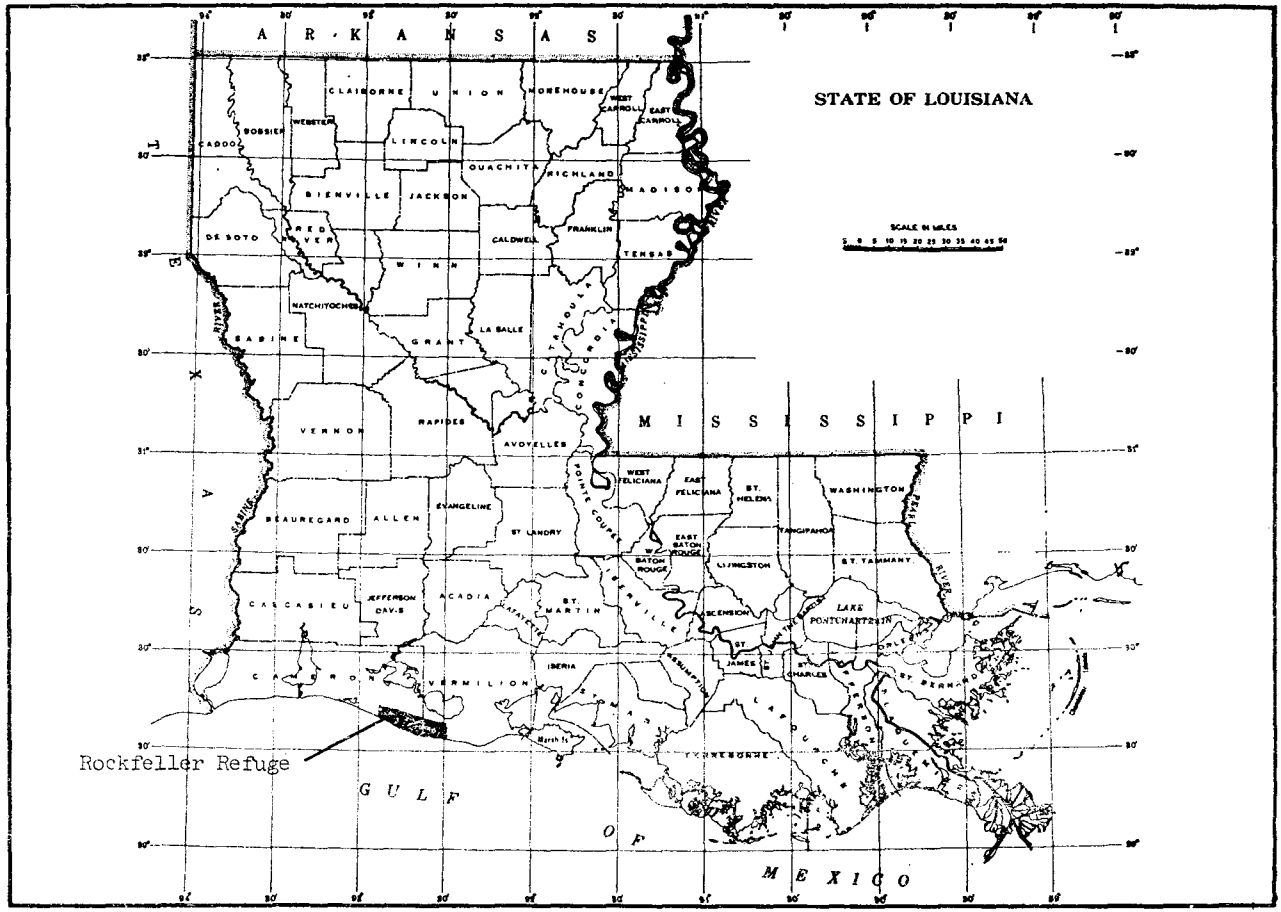

FIGURE 1. Rockefeller Wildlife Refuge, Grand Chenier, Louisiana

STUDY METHODS

Stocking

On March 19, 1970, fingerling white catfish were obtained from Auburn, Alabama and transported by truck to the refuge ponds. The fish ranged from 3 to 5 inches in total length and averaged 4.5 inches. The average weight was 10 grams. The fingerling blue catfish ranged from 5 to 7 inches and averaged 6.5 inches in total length. These fish, averaging 23 grams, were transported from Dumas, Arkansas, March 24, 1970. The channel catfish were donated to the study by the Richland Development Corporation Fish Farm located in Monroe, Louisiana, April 2, 1970. These fish were uniform in total length ranging from 4 to 5 inches. The average total length was 4.75 inches. The average weight of the channel catfish was 10 grams. All of the catfish stocked originally came from freshwater hatcheries and were stocked into our brackish water ponds with equal amounts of acclimation. Also, a prophylactic treatment of 15 ppm (parts per million) formalin and 1 ppm acriflavine was given to the fish during transport to the ponds.

Three stocking combinations were selected for this study. Each combination was replicated in three ponds including the control ponds which were stocked with channel catfish only. A total of 12 one-tenth acre ponds were needed for the study. The three stocking combinations selected were as follows: (1) 68 channel, 66 blue, 66 white catfish; (2) 100 channel, 50 blue, 50 white catfish; (3) 180 channel, 20 blue, 20 white catfish and the control consisted of 200 channel catfish per pond (Figure 2). Each pond was stocked with the equivalent of 2,000 fish per acre.

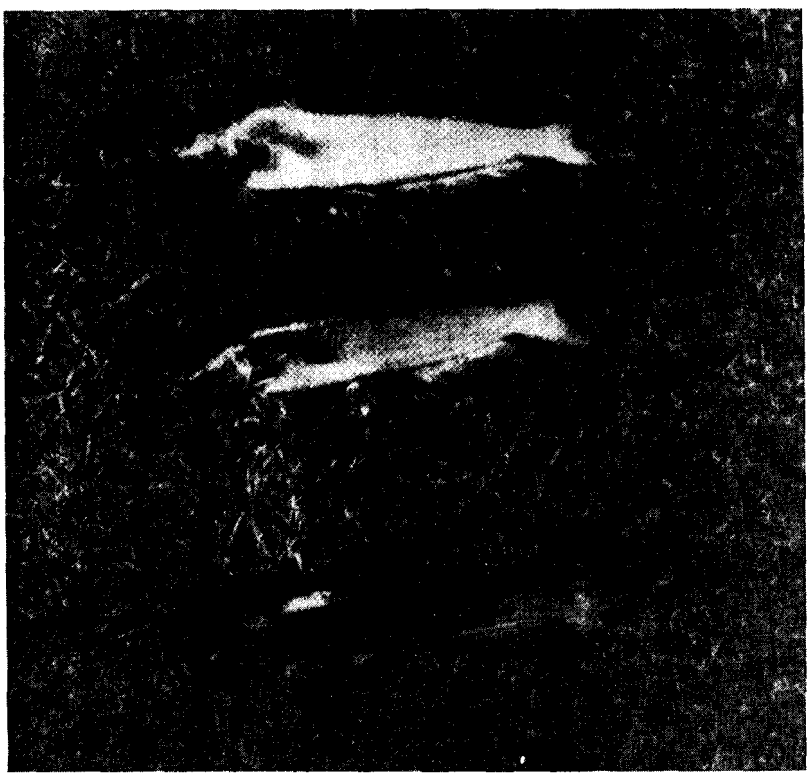

FIGURE 2. Species selected for our studies were blue, channel and white catfish pictured from top to bottom).

Feeding

Feeding was begun on March 20, 1970 and continued for approximately 218 days. Initially the fish were fed a 0.2 pound mixture of one-fourth floating and three-fourth sinking feed rations until they were accustomed to the floating. At this time the feeding rate was dropped to the generally accepted 3 percent body weight of a floating feed. A 30-foot nylon bag seine and a 5-foot 3/8-inch square mesh cast net were used in obtaining fish for the recalculation of feeding rates.

Water Chemistry

A Model R-S-5 Beckman salinity meter was used during the study for salinity determinations. Oxygen concentrations were periodically checked using both the Winkler titration method and a Precision Galvanic Cell oxygen analyser. A Taylor Model 76J temperature recorder was used throughout the study. Records of minimum-maximum temperatures were recorded at a depth of 3.5 feet below the surface. This gave a more accurate picture of the temperature extremes that the fish actually experienced in the shallow ponds. Portable Colormetric Hach pH Test Kits Nos. 17N and 17H were used for pH determinations.

Harvest

The water had to be pumped from the ponds since they were constructed below sea level. The fish were then collected with dip nets and held in separate holding tanks until the ponds were empty. Then total and standard lengths were measured to the nearest millimeter and weights were recorded to the nearest gram for a comparison of the catfish species (Figure 3).

Condition Factors and Length-Weight Relationship

Length-weight relationships were calculated for all members of each species collected from two randomly selected ponds, one from each of treatments 2 and 3. We did not have sufficient data to compute treatment 1 and the control. Using the procedures of Lagler (1956), each species was separately compared as to affects of treatment upon rate of growth. Data from an earlier study (Perry and Avault, 1969) was included for a comparison with the growth of each species in monoculture. Blue and channel catfish were also compared with wild catfish collected from nearby waters.

The length-weight relationships were first calculated by averaging the lengths and weights in 10 millimeter total length increments. The length-weight relationships were based on the average measurement expressed logarithmically. This relationship is $\text{Log } W = \text{Log } a + b \text{ Log } L$

where W = weight in grams
L = total length in millimeters.

The coefficients of condition were also calculated for these ponds according to the procedures described by Lagler (1956). The species were compared as to affects of treatment upon plumpness. Data permitted the calculation of condition factors from stocking until harvest as an indication of the various treatments upon growth. Also, a comparison was made with fish grown in monoculture. The metric system was used because this coefficient includes the greaters portion of the body weight of fish, where:

$$K = \frac{W\,10^5}{L^3}$$

where W = weight in grams
L = standard length in millimeters
and 10^5 = a factor to bring the K value near unity.

FIGURE 3. At the termination of the study, data such as total length, standard length and weight was recorded for production comparisons.

TABLE 1. Salinity Data in PPT (Parts Per Thousand) of Catfish Ponds, Rockefeller Wildlife Refuge, 1970.

Pond	March	April	May	June	July	August	September	October	November	December	Pond per Average
B-18	3.2	3.4	4.1	6.0	6.1	6.7	6.6	4.0	3.9	3.2	4.7
B-19	3.4	3.5	4.5	6.9	6.2	8.6	8.7	4.1	4.0	3.8	5.4
B-20	3.4	3.5	4.5	5.7	5.0	5.0	5.1	4.3	4.0	3.8	4.4
B-21	3.5	3.5	4.7	5.0	5.2	5.9	5.8	4.9	4.8	4.1	4.7
B-22	3.6	3.5	3.9	6.5	5.7	7.9	7.8	4.1	4.0	3.9	5.1
B-23	3.5	3.5	4.3	5.9	5.4	5.8	5.7	4.0	4.0	3.8	4.6
B-24	3.5	3.4	4.0	5.6	5.2	5.6	5.5	3.9	3.8	3.7	4.4
B-25	3.4	3.5	4.5	5.5	5.1	6.0	6.1	4.5	4.4	3.6	4.7
B-26	3.7	3.6	5.0	5.6	5.2	9.2	8.9	4.6	4.4	3.2	5.3
B-33	3.2	3.1	3.0	3.3	3.5	4.2	4.3	4.2	4.1	3.0	3.6
B-34	3.4	3.5	3.6	3.7	3.3	4.1	4.1	4.0	3.6	3.4	3.7
B-44	3.4	4.2	4.9	4.4	5.0	5.2	5.0	4.9	4.1	3.8	4.7
Average Monthly	3.4	3.5	4.2	5.3	5.1	6.2	6.1	4.3	4.1	3.6	4.6

Food Conversion

Food conversions were calculated according to the method described by Swingle, 1958, where:

$$S = \frac{\text{pounds of feed fed}}{\text{total pounds fish produced by natural plus feed added}}$$

Percent survival, average weight and percent by harvestable size (larger than 0.5 pound) were calculated for each treatment.

Results and Discussion

Pond Hydrography

The average pond salinity was 3.4 ppt when the fish were stocked (Table 1). An average high of 6.2 ppt existed in August which declined to 3.6 ppt at harvest. The average salinities per pond were rather constant among the ponds throughout the growing season. Water temperature of the relatively shallow ponds fluctuated considerably (Figure 4). Temperatures were always above 45° F. and below 90° F. The pH values varied from 7.5 to 9.0.

Harvest

With supplemental feeding the straight channel catfish ponds gave the best returns (Table 2). The S-conversion of 2.4 was considerably better than the other three treatments. Treatment 3 (180 channel, 20 blue, 20 white) was the nearest with an average S-factor of 2.7.

The channel catfish only pond had the highest average percent survival of 90 percent. Survival rates for the three treatments were 59, 78 and 85 percent. Under mixed culture, average percent survival was the highest for channel catfish, 80 percent, and lowest for the blue catfish, 61 percent. These survival rates are similar to our 1968 monoculture results, 91 percent for channel and 70 percent for blue catfish grown separately in ponds (Perry and Avault, 1969). Survival rates for white catfish in polyculture and separately were 71 and 86 percent respectively.

The control ponds had the largest average size of fish, 0.72 pound. Treatment 2 (100 channel, 50 blue, 50 white) was a close second with 0.71 pound. The channel, blue and white catfish grown together averaged 0.64, 0.71 and 0.68 pounds respectively. Under polyculture conditions the white and channel catfish had the smallest average weight, 0.53 pound. Table 3 has been included to give a species analysis by treatment. Whites consistently averaged a little more than the others. All of our earlier studies had shown channel catfish to outgrow white and blue catfish respectively.

The average total weight harvested was 1,300 pounds per acre for the channel, 1,280 pounds per acre for treatment 3, 1,110 pounds for treatment 2, and 760 pounds (1,140 pounds not including a pond that had 100 percent mortality due to oxygen deficiency) per acre for treatment 1 (68 channel, 66 blue, 66 white). An analysis of variance of the weight recovered showed the treatments to be statistically nonsignificant ($F = 0.54$, d.f. $= 4.347$, $P < 0.05$). A closer analysis revealed that the yield would have to increase 41.4 pounds before the treatment would be significant at the 0.05 level.

In 1967 with supplemental feeding channel, white and blue catfish gave an average net production of 1,344, 890 and 430 pounds per acre, respectively in monoculture studies (Perry and Avault, 1968). The channel catfish outgrew the rest averaging 1.3 pounds, had the best S-conversion factors, and had the highest percent survival, with the blues having the lowest of these. The 1968 study results followed the same general pattern. The channel, white and blue catfish gave an average net production of 1,808, 1,511 and 1,121 pounds per acre, respectively. A top pond production of 1,960 pounds per acre was obtained in a channel catfish pond.

Length and weight data complete enough to analyze percent harvestable fish was collected only from four ponds, 2 from treatment 2 and 2

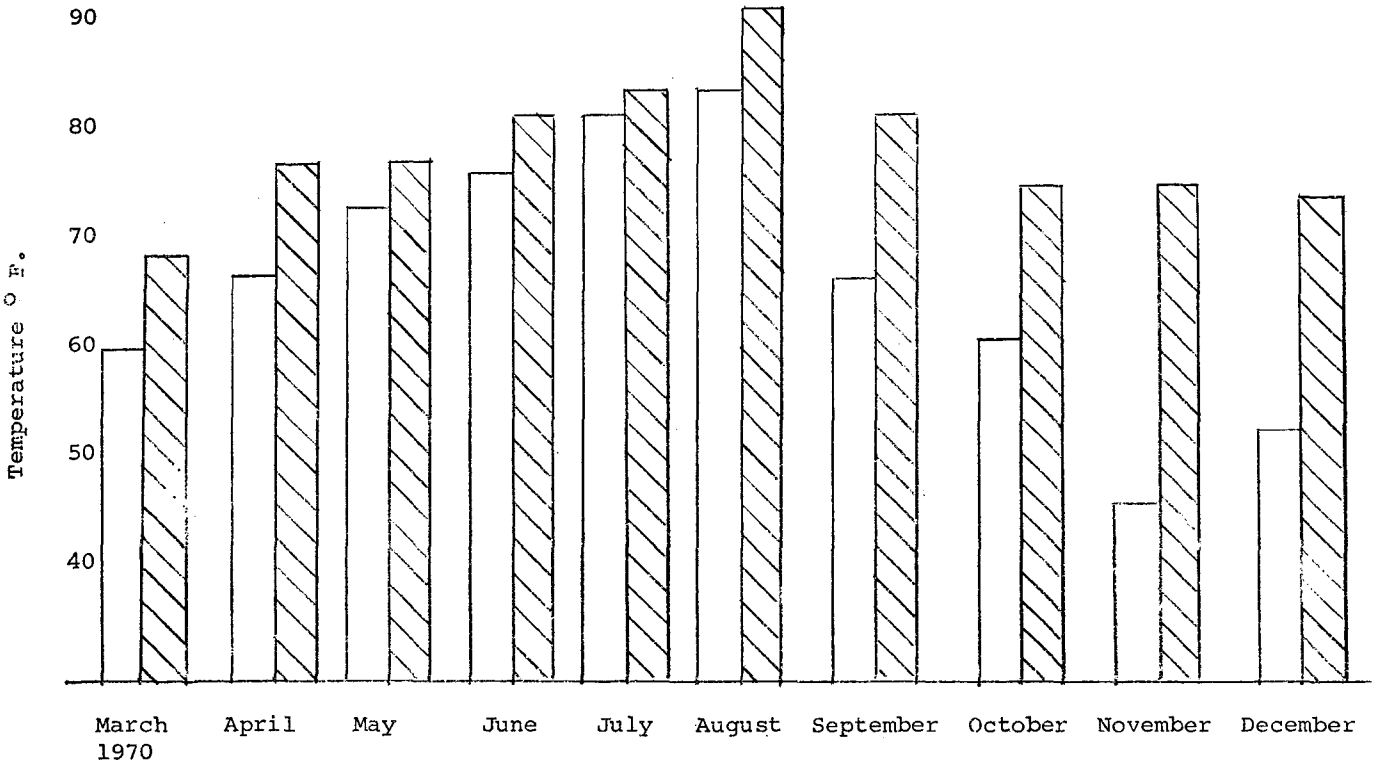

FIGURE 4. **Monthly minimum-maximum range of temperatures recorded 3.5 feet below the surface of Rockefeller Research ponds, 1970.**

TABLE 2. Average growth data for mixed species of blue, channel and white catfish grown in 0.1 acre ponds, Rockefeller Wildlife Refuge, 1970.*

	Treatment 1	Treatment 2	Treatment 3	Control
Number Stocked per Pond				
Channel	68	100	180	200
Blue	66	50	20	0
White	66	50	20	0
Average Weight Stocked (lbs.)	6.5	6.0	5.0	4.7
Average Size of Fish Stocked (lbs.)	0.03	0.03	0.02	0.02
Average Weight Recovered (lbs.)	114**	111	128	130
Average Size Recovered (lbs.)	0.64	0.71	0.68	0.72
Survival Percent	59	78	85	90
S Conversion	4.1	3.3	2.7	2.4

* Three ponds used for each treatment and control.
** Not including the pond that had 100% mortality due to oxygen deficiency.

TABLE 3. Production and growth data by species of blue, channel and white catfish grown in Polyculture studies, Rockefeller Wildlife Refuge, 1970.*

Species Stocked	Treatment 1**			Treatment 2			Treatment 3			Control
	Blue	Channel	White	Blue	Channel	White	Blue	Channel	White	Channel
Number Stocked per Pond	66	68	66	50	100	50	20	180	20	200
Average Number Recovered per Pond	35	45	38	30	88	37	14	157	16	180
Percent Survival	53	66	58	60	88	74	70	87	80	90
Average Size Fish Stocked (lbs.)	0.05	0.02	0.02	0.05	0.02	0.02	0.05	0.02	0.02	0.02
Average Weight Recovered per Pond (lbs.)	19.8	34.2	22.3	18.9	65.1	27.7	5.7	108.0	14.5	129.5
Average Size (lbs.) Fish Recovered	0.56	0.76	0.59	0.63	0.74	0.75	0.41	0.69	0.91	0.72

* Three ponds used for each treatment and control.
** This treatment includes a pond that had 100% mortality due to oxygen deficiency.

from treatment 3. This indicated that treatment 2 resulted in a higher percent harvestable size fish. Considering all species combined, treatment 2 averaged 82% over 0.5 pound and 37% over 0.75 pound, whereas treatment 3 averaged 72% over 0.5 pound and 36% over 0.75 pound (Table 4). This seemed to be due to the presence of more white catfish in the stocking ratio and less blue catfish. This might suggest that the assumptions of some workers might be improved by stocking a certain percentage of white catfish with channel catfish rather than stocking blue catfish. An analysis of the controls would have proven valuable if this data was collected.

TABLE 4. Percent of harvestable size catfish grown in treatments 2 and 3, Rockefeller Wildlife Refuge, 1970*

Species	Treatment 2		Treatment 3	
	over .50 lbs.	over .75 lbs.	over .50 lbs.	over .75 lbs.
Blue	78	14	75	18
White	88	51	92	53
Channel	81	40	69	34
Combined	82	37	72	36

* Incomplete data prohibited calculations for treatment 1 and the control.

Growth curves prepared from feed adjustment data give a good indication of the rapid growth put on by the channel and blue catfish (Figure 5).

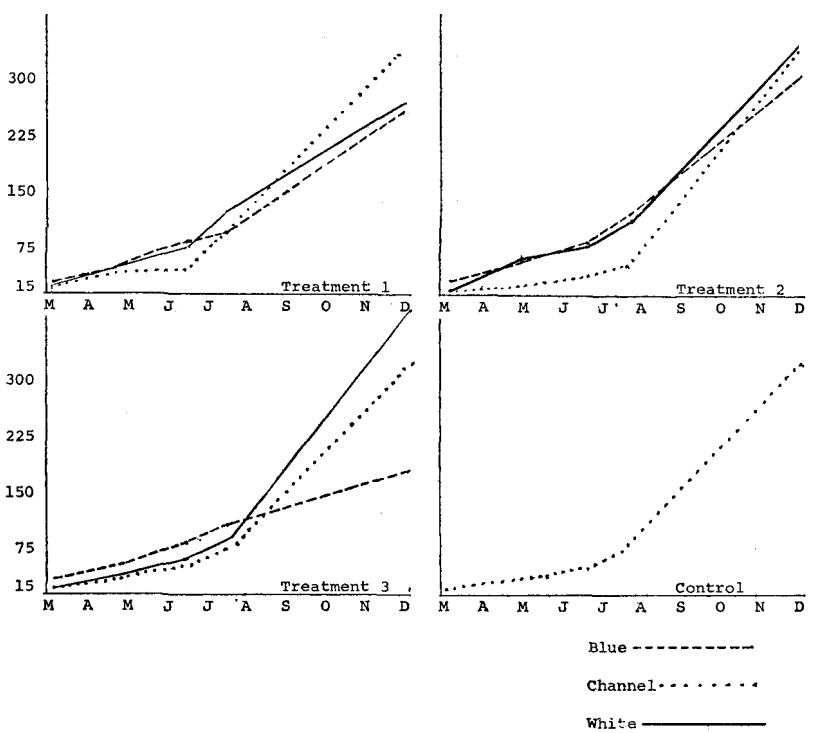

FIGURE 5. Growth curve calculated from food adjustment data for each treatment and the control, Rockefeller Wildlife Refuge, 1970.

It should be pointed out that the difference in size of the fingerlings at the time of stocking did not affect the results appreciably. In our 1967 studies, the blue fingerlings were a little smaller than the others and in 1968 they were larger. Both years they gave the lowest production. The blue catfish were twice as large as the channel and white catfish at stocking in 1970.

Length-Weight

Length-weight relationships were calculated for two treatments and compared with the 1968 study and to fish collected from nearby brackish waters (Table 5). When these data were compared the slope of the line (b) established for the monocultured catfish was constantly greater than the slopes of others except for the channel catfish in 1968. Treatment 3 was the better of the two treatments. Since the length-weight regression line is a relative measure of condition, the above difference between the slopes can be interpreted to measure a difference in condition between the groups which changes in size.

Coefficient of Condition

Coefficients of condition (K) were calculated for each of the species when stocked March 19, 1970. Twice during the growing season, average coefficients for each species in each treatment were calculated. At harvest, December 10, 1970, complete length and weight data collected on treatments 2 and 3 allowed coefficients to be calculated. When grown under polyculture conditions, the weighed K values for the white, channel and blue catfish were 1.94, 1.79 and 1.43 respectively. The weighed K values for these species at the time of stocking were 1.29, 1.33 and 1.11. The coefficients of condition for these three species of fish together were close to our 1968 monoculture values. We had weighed K values of 2.15, 1.70 and 1.49 for white, channel and blue catfish respectively. These data along with our early data supported Simco and Cross (1966) findings of a condition advantage of fed fish over wild fish. Coefficients of condition increased in fed fish over the study period (Table 6). Generally, this data indicates this increase. The existing irregularities may be due to a limited sample size and the presence of some short spined fish in some samples.

SUMMARY

Some workers are achieving better production by mixing such species of fish as fat head minnows, buffalo and catfish. Other researchers are stocking such exotic species as tilapia with catfish. The authors, presently, shy away from the latter as the tilapia is not found naturally in our state's waters and may prove to be a serious detriment if released. There is still a lot to be learned about this creature before it can be indiscriminately scattered about.

In summary, it may be concluded from this study that the stocking of channel catfish only in brackish water conditions resulted in the better food conversion, survival, coefficient of condition, slightly greater growth and production. Treatment 3 was second possibly because of a greater number of channel catfish and lesser blue catfish. The white catfish did surprisingly well. In this study the fish, when analyzed by species, had growth almost equal to and in some instances, superior to the channel catfish. This may indicate that white and channel catfish stocking combinations may give better yields than blue and channel catfish as suggested by some. This should be investigated.

Polyculture may be a tool of the future and may be necessary to obtain maximum yields. Different species and combinations of these species will have to be studied.

ACKNOWLEDGEMENTS

We are extremely grateful to Brandon Carter, Biologist Aid, and James Savoie, Student Laborer, for their valuable assistance and enthusiastic interst exhibited during the course of the entire study. Thanks

TABLE 5. Length-weight regression data comparing species in Polyculture, with Monculture and wild fish

Item	Treatment 2 Polyculture			Treatment 3 Polyculture			1968 Study Monoculture			Wild Fish	
	Blue	White	Channel	Blue	White	Channel	Blue	White	Channel	Blue	Channel
Log a	−5.224	−4.446	−6.199	−5.797	−5.492	−6.584	−7.566	−5.487	−5.530	−5.471	−5.840
b	3.055	2.799	3.475	3.270	3.217	3.625	3.985	3.237	3.196	3.140	3.316
n	11	13	17	9	7	21	11	17	15	21	25
Length range (mm)	284–381	224–350	200–385	270–372	276–347	188–403	282–388	205–360	272–415	137–435	127–424
Weight range (g)	192–470	112–524	62–589	146–454	230–480	50–669	178–502	104–605	164–589	15–908	14–590

TABLE 6. Condition factors K_{sl} calculated for catfish grown in Polyculture studies, Rockefeller Wildlife Refuge, 1970

	Treatment 1			Treatment 2			Treatment 3			Control
	Blue	White	Channel	Blue	White	Channel	Blue	White	Channel	Channel
Stocked (March 1970)	1.11	1.29	1.33	1.11	1.29	1.33	1.11	1.29	1.33	1.33
April, 1970	1.46	...	1.73	1.77	2.32	1.46	1.62	1.54	1.45	1.70
July, 1970	1.66	2.04	...	1.50	1.84	1.51	1.34	1.88	1.64	2.00
Harvest (December, 1970)	...	...	...	1.45	2.04	1.78	1.41	1.96	1.80	...

are also given to Edmonde Jaspers, Marion Burnside, Don Clark and Bobby Faulk for their help in the harvest operations.

We are extremely grateful to Mr. James T. Davis and Mr. J. E. Smith of the Richland Development Corporation, a subsidiary of Pennzoil United, for their donation of the channel catfish fingerlings used in this study.

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EFFECT OF VITAMIN FORTIFICATION IN AUBURN NO. 2 FISH FEED

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ABSTRACT

Vitamin fortification of the Auburn No. 2 pelleted fish feed increased net production of channel catfish an average of 19.3 percent in feeding tests conducted in replicated earthen ponds between April 13 and November 9, 1970. A stocking density of 4,000 fingerlings acre was used and the fish were fed 6 days per week. In comparison to a second commercial catfish feed containing identical vitamin fortification the fortified Auburn No. 2 feed produced an increase in net production of 39.5 percent.

Feed conversion, gain per day and average weight of fish at harvest were all superior with the fortified Auburn No. 2 feed when compared to the other two rations.

INTRODUCTION

Auburn No. 2 fish feed with a composition of 35 per cent soybean oil meal, 35 per cent peanut cake, 15 per cent fish meal, and 15 per cent distillers dried solubles and containing 46 per cent protein, has given satisfactory production as a supplemental feed for both catfish and bait