ISSN 0048-377X

Vol. 19 January-December 1986 Nos. 1 and 2

THE PHILIPPINE JOURNAL *of* FISHERIES

Published by the

BUREAU OF FISHERIES AND AQUATIC RESOURCES
Arcadia Bldg., 860 Quezon Avenue
Quezon City, Philippines
(P. O. Box 623, Manila, Philippines)

The PHILIPPINE JOURNAL OF FISHERIES

Official Publication of the Bureau of Fisheries and Aquatic Resources
Arcadia Bldg., 860 Quezon Avenue, Q.C.
Philippines

Vol. 19 **January-December 1986** **Nos. 1 and 2**

INTENSIVE CULTURE OF CHANNEL CATFISH (*Ictalurus punctatus*) IN MULTIPLE RACEWAY SYSTEM

by

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ABSTRACT

A comparisòn of growth parameters of channel catfish *(Ictalurus punctatus)* reared in four raceway sections using multiple reuse system was made. Results showed that the growth of catfish in each raceway section was influenced by water quality, initial fish size and stocking density. Assuming that the water quality did not fall below certain critical values, the smaller fish were found to have faster weight increase than the larger ones.

INTRODUCTION

The purpose of this study is to determine the growth rate of channel catfish *(Ictalurus punctatus)* in raceways using multiple reuse system. For the past ten years, water quality management has been given due emphasis in the intensive culture of aquatic animals (Colt and Armstrong 1981). In a high density raceway system, control of some environmental variables such as dissolved oxygen, water temperature and ammonia concentration is required. Since the production of catfish in a raceway is expressed in terms of pounds of fish produced per cubic foot of water per second the critical factors involved in catfish production are water quality, initial fish size and stocking density.

The quality of the water entering and leaving the system indicates what the fish have put into and taken out of the water. The most important parameters are dissolved oxygen consumed and ammonia added (Ray 1981). The loss of dissolved oxygen in one raceway section can be partially recovered by aeration as the water drops from two to three feet to the next section. Little or nothing can be done to eliminate ammonia accumulation. The use of a biological filter is impractical because several thousand gallons of water per minute flows through the system. Rocks can be placed along the water supply canal that leads to the raceway. Algae will grow on the rocks and remove the ammonia. The disadvantage of this method is the occurrence of oxygen depletion during darkness. The best method of eliminating the accumulation of ammonia in the system is by "flushing" and cleaning the entire system so that all the metabolic wastes are removed. Colt and Tchobanoglous (1978) found that sublethal concentrations of ammonia can reduce growth rate and are detrimental to fish health.

MATERIALS AND METHODS

Channel catfish were observed in four raceway sections for 22 days in July 1981. The experimental site was located in the Snake River canyon near Buhl, Idaho. Each raceway section was 24 feet long, 10 feet wide and 4 feet deep (7.3 m x 3.0 m x 1.2 m). The sections were arranged four in a series with a 2-foot drop between sections. The raceway sections were labelled S-1, S-2, S-3 and S-4 (top to bottom). The average water depth was 3.2 feet with a total water volume of 770 cubic feet per section (21.8 cubic meters). Five geothermal wells, with an average temperature of 32°C and a total capacity of 7,000 gallons per minute (26.5 m^3/min), supplied hot water to a man-made lake where it mixed with colder water (10-18°C) to obtain the desired culture temperature of 27°C to 29°C. From this reservoir, water was pumped into the raceways.

The fish were fed daily with pelleted commercial feed equivalent to three percent of their total body weight. The feeds were placed in demand feeders made of big drums with a hole at the bottom. Underneath the hole was a rubber stopper connected to an iron rod. When the rod was moved by the catfish, the pellets dropped into the water. Feeds given daily were recorded to calculate the food conversion ratio (FCR) which was computed using the formula:

$$FCR = \frac{F_f}{W_g}$$

where FCR = food conversion ratio
F_f = quantity of feeds fed (lb)
W_g = weight gained (lb)

The total weight increase per day was computed using the formula:

$$TWI = \frac{W_f - W_i}{O_d}$$

where TWI = total weight increase per day (lb)
W_f = final weight (lb)
W_i = initial weight (lb)
O_d = length of observation period, days

The percentage weight increase was computed using the formula:

$$\%W_i = \frac{W_f - W_i}{W_i} \times 100$$

where %WI = percentage weight increase (percent)
W_f = final weight (lb)
W_i = initial weight (lb)

Before the experiment, the initial weight and number of fish in each section were obtained. Based on the data, the initial average weight per fish was computed using the formula:

$$\bar{w} = \frac{W_i}{N_i}$$

where $\bar{w}$ = average weight per fish (lb)
W_i = initial weight of fish in each sample (lb)
N_i = initial number of fish in each sample

The oxygen and water temperature were recorded everyday at about 7 a.m. with the use of a YSI model 51-B oxygen meter. The standard procedure for the calibration of the instrument was followed and the altitude reading was set at 3,000 feet (1,000 meters). The dissolved oxygen readings were taken at the inlet and at the outlet of each section at a depth of two feet. Water temperature readings were taken only at the inlet of each section. Ammonia concentration was measured with a Hach colorimetric unit utilizing the modified Nessler's test for total ammonia nitrogen. These parameters were analyzed daily to find out any significant variations within each raceway and from one raceway section to another. The mean dissolved oxygen, water temperature and ammonia concentration, standard deviation and variance were determined through the statistical analysis.

The dissolved oxygen (DO) loss in each raceway section was computed using the formula:

$$O_L = O_i - O_o$$

where O_L = oxygen loss (consumption from each raceway)

O_i = dissolved oxygen reading at inlet of each raceway section

O_o = dissolved oxygen reading at outlet of each raceway section

The mean dissolved oxygen recovery of the entire raceway system was calculated using the formula:

$$DO_r = \frac{(S\text{-}2_i - S\text{-}1_o) + (S\text{-}3_i - S\text{-}2_o) + (S\text{-}4_i - S\text{-}3_o)}{3}$$

where DO_r = DO recovery from raceways S-1 to S-2; S-2 to S-3 and S-3 to S-4

$S\text{-}2_i, S\text{-}3_i, S\text{-}4_i$ = mean DO readings at the inlet of respective raceway sections

$S\text{-}1_o, S\text{-}2_o, S\text{-}3_o$ = mean DO readings at the outlet of respective raceway sections

Mortalities in each section were recorded each day.

RESULTS AND OBSERVATIONS

Food conversion ratio. A comparison of the food conversion ratio (Table 1) indicates that the highest efficiency was obtained in S_2 with a food conversion ratio of 1.87 which means that for every 1.87 lb of feed, 1 lb of live channel catfish is produced; on the other hand, the least efficient conversion was observed in S_4 (Figure 1).

Average weight gain per fish. At the start of the experiment, the fish in raceway S_2 had the lowest average weight of 0.62 lb/fish, while the fish in raceway S_4 had an average weight of 1.58 lb/fish. Those in S_1 and S_3 nearly had identical initial weights at 0.86 lb and 0.82 lb/fish respectively (Table 2).

In terms of average weight gain per fish, the results from raceway S_1 and S_3 were identical with 0.22 lb and 0.21 lb. The fish in S_2 had an average weight gain of 0.28 lb/fish; while in S_4, 0.32 lb/fish. Percentage weight increases are shown in Figure 2.

Table 1. **Comparative food conversion ratio of channel catfish reared in different raceway sections.**

Raceway Section	Total Initial Weight (lb)	Total Final Weight (lb)	Total Weight Gain (lb)	Quantity of Feeds (lb)	Food Conversion Ratio
S_1	2.983	3,728	745	2,132	2.86
S_2	2,445	3,490	1,045	1,951	1.87
S_3	2,983	3,704	721	2,384	3.30
S_4	2,363	2,466	103	995	9.70

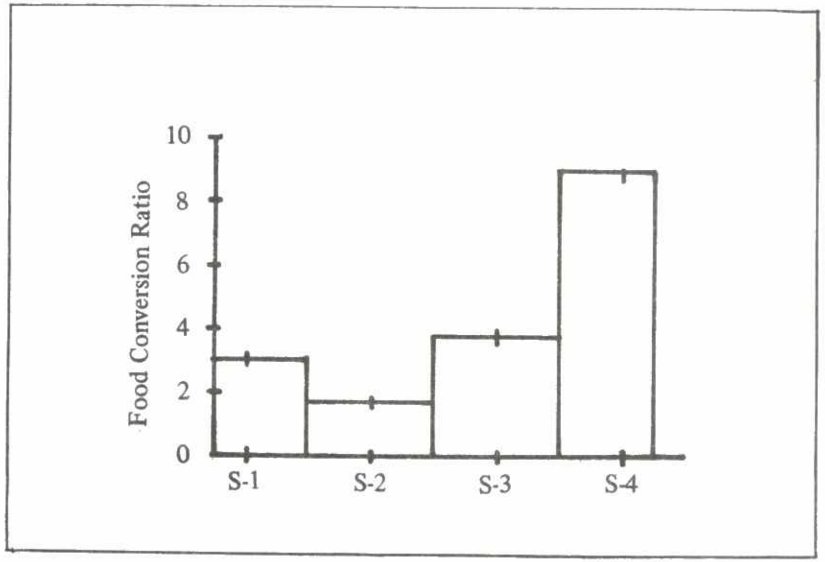

Figure 1. **Food conversion ratio of channel catfish raised in the four raceway sections.**

Table 2. Average weight gain of channel catfish reared in different raceway sections.

Raceway section	Initial No. of fish	Total Initial Weight of fish (lb)	Initial Average Weight/fish (lb)	Final No. of fish	Total Final Weight of fish (lb)	Final Average Weight/fish (lb)	Average Weight Gain/fish
S_1	3,474	2,983	0.86	3,452	3,728	1.08	0.22
S_2	3,922	2,445	0.62	3,878	3,490	0.90	0.28
S_3	3,618	2,983	0.82	3,596	3,704	1.03	0.21
S_4	1,496	2,363	1.58	1,298	2,466	1.90	0.32

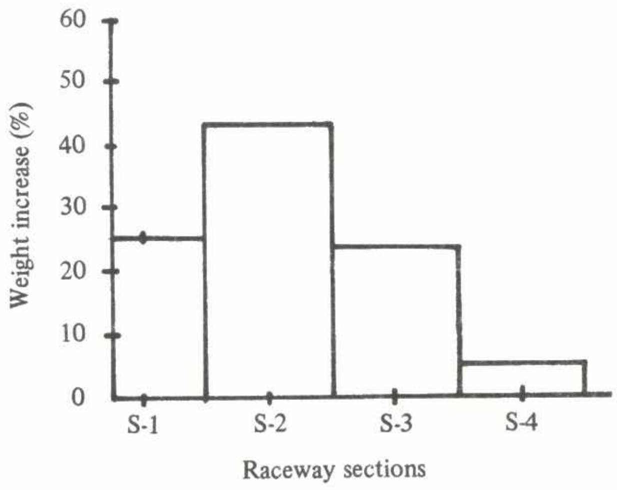

Figure 2. Percentage weight increase of channel catfish in the four raceway sections.

Table 3. Comparative total weight gain of channel catfish reared in different raceway sections.

Raceway Section	Total Initial Weight of Fish (lb)	Total Final Weight of Fish (lb)	Total Weight Gain 22 Days	%	Per Day
S_1	2,983	3,728	745	24.97	33.86
S_2	2,445	3,490	1,045	42.74	47.51
S_3	2,983	3,704	721	24.41	32.78
S_4	2,363	2,466	103	4.30	4.69

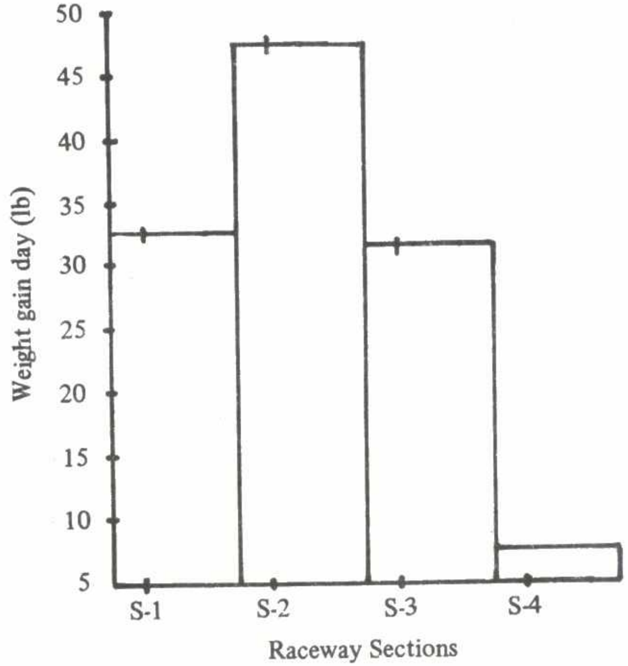

Figure 3. Daily weight gain of channel catfish raised in a multiple reuse raceway system.

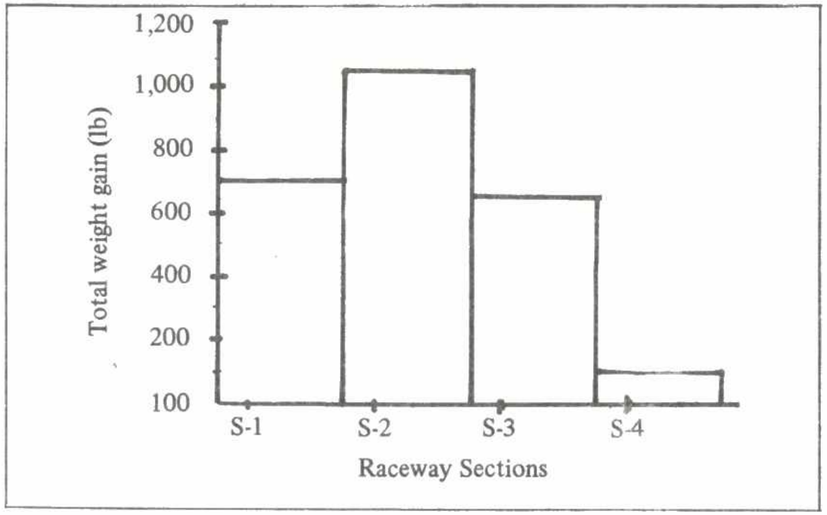

Figure 4. **Total weight gain of channel catfish raised in a multiple reuse raceway system.**

Total weight gain. A comparison of the total weight gain after 22 days of culture indicated that raceway S_2 had the highest total weight gain of 42.74 percent (Table 3). Raceways S_1 and S_2 showed almost identical total weight gain of 24.97 percent and 24.21 percent, respectively, and the lowest which is only 4.30 percent, was registered by the samples in raceway S_4. The total weight gain per day also followed the same trend (Figures 3 & 4).

Table 4. **Comparative mortality rates of channel catfish reared in different raceway sections.**

Raceway Section	Initial No. of Fish	Final No. of Fish	Mortality	
			No.	%
S_1	3,474	3,452	22	0.6
S_2	3,922	3,878	44	1.1
S_3	3,618	3,596	22	0.6
S_4	1,496	1,298	198	13.2

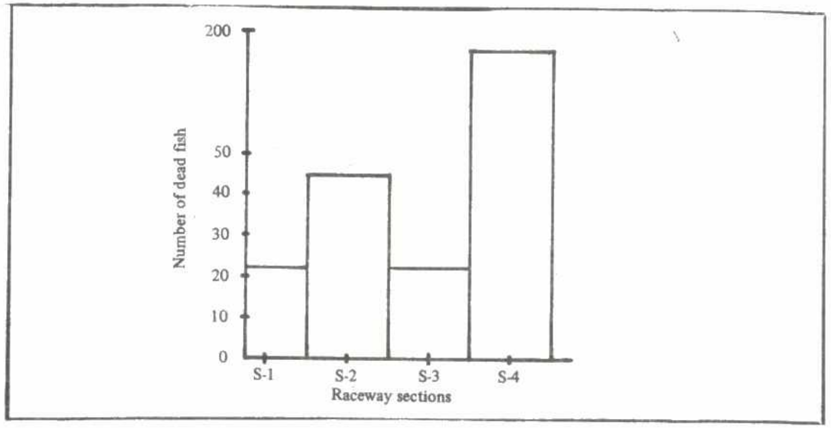

Figure 5. **Mortality of channel catfish raised in a multiple reuse raceway system.**

Mortality. The highest mortality of 13.2 percent registered in raceway S_4 and the least, 0.6 percent occurred in S_1 and S_3 (Table 4). The initial average weight per fish for both S_1 and S_3 were also identical, 0.82 lb (Table 2), which might be the optimum size for stocking to minimize mortality (Figure 5).

Increase in density. Another criteria for the measurement of growth efficiency is the increase in density per cubic foot of the raceway system. Raceway S_2 manifested the highest increase in density of 40 percent followed by S_4 which was 30 percent and by S_1 and S_3 which were identical at 23 percent (Table 5).

Table 5. **Comparative increase in densities of channel catfish reared in different raceway sections.**

Raceway Section	Initial Density (lb/cu ft)	Final Density (lb/cu ft)	Increase in Density (lb/cu ft)	% Increase in Density
S_1	3.9	4.8	0.9	23
S_2	3.2	4.5	1.3	40
S_3	3.9	4.8	0.9	23
S_4	3.1	3.2	0.1	30

Water quality. Dissolved oxygen, water temperature and ammonia level did not pose serious threats of massive mortalities during the experiment although these parameters exhibited significant fluctuations on a daily basis and from one raceway section to another. These parameters did not fall below the accepted levels reported to adversely affect physiological activities of the fish. The mean dissolved oxygen that was entering the system was 6.4 ppm and the reading at the outlet of raceway S-4 was 5.5 ppm (Table 6 and Figure 6).

Table 6. **Mean dissolved oxygen readings of the water entering and leaving each raceway section.**

Section	Mean DO, ppm	Standard Deviation	Variance
S-1_i	6.4	0.351	0.18
S-1_o	5.9	0.470	0.21
S-2_i	6.4	0.404	0.16
S-2_o	5.7	0.445	0.19
S-3_i	6.2	0.422	0.17
S-3_o	5.4	0.428	0.18
S-4_i	6.0	0.433	0.18
S-4_o	5.5	0.491	0.23

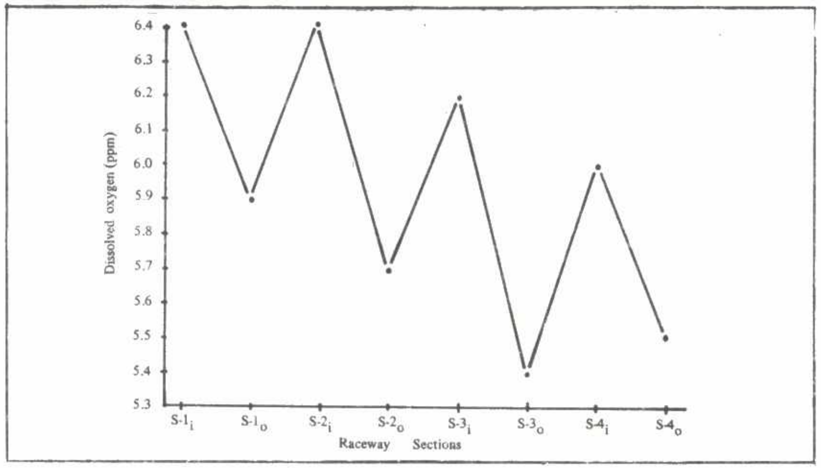

Figure 6. **Mean dissolved oxygen readings from each raceway section (inlet and outlet) during the experiment.**

Oxygen loss was high in raceway sections S-2 and S-3 with an average of 0.8 and 0.7 ppm, respectively. In raceway sections S_1 and S_4, the dissolved oxygen loss was 0.5 ppm (Table 6 and Figure 7).

Table 7. **Mean dissolved oxygen recovery in each raceway section.**

Section	Mean DO Loss (ppm)	Mean DO Recovery (ppm)
S_1	0.5	
S_2	0.7	0.5
S_3	0.8	0.8
S_4	0.5	0.6

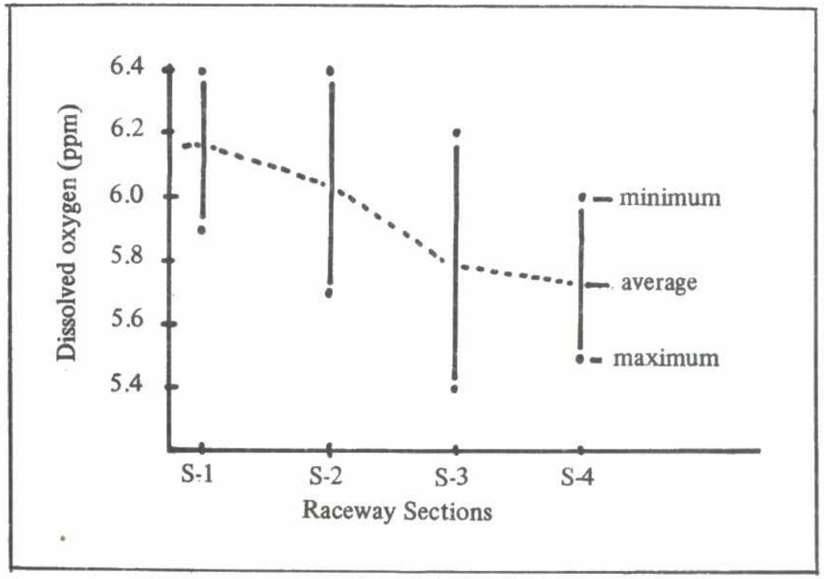

Figure 7. Dissolved oxygen loss in each raceway section.

The mean water temperature throughout the experiment was 23.4°C (74°F) (Table 8). However, by midmorning, the water temperature rose to 26.6° – 29.4°C (80-85°F).

Table 8. **Mean water temperature readings in each raceway section.**

Section	Mean Temperature (^{o}C)	Standard Deviation	Variance
S_1	23.4	1.14	1.24
S_2	23.4	1.14	1.24
S_3	23.4	1.41	1.24
S_4	23.4	1.41	1.24

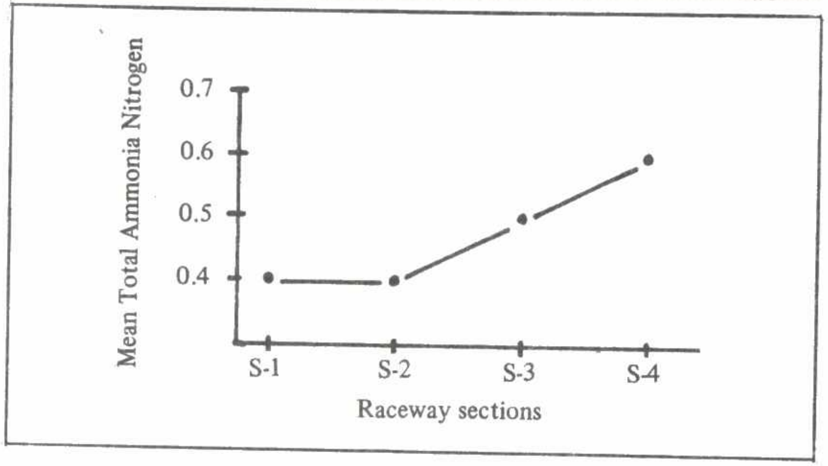

Figure 8. **Total ammonia nitrogen fluctuations from one raceway section to another.**

Total ammonia nitrogen reading fluctuated daily from one raceway section to another. An increase was recorded in each section as the water descended from raceway section S-1 down to S-4 (Table 9 & Figure 8).

Table 9. **Mean total ammonia nitrogen reading in each raceway section.**

Section	Mean Total Ammonia N	Standard Deviation	Variance
S_1	0.4	0.075	0.01
S_2	0.4	0.075	0.01
S_3	0.5	0.067	0.00
S_4	0.6	0.056	0.00

DISCUSSION/CONCLUSION

The growth rate of fish in a high density culture system depends on the water quality, initial fish size and stocking density. Growth rate has been expressed as either increased length or increased weight of the fish during a specified period of time. Its influence on productivity is most evident when the estimated growth rate exceeds the actual growth rate (Klontz, et al 1979). Lovell (1976) reported that channel catfish eat and grow maximally at 30°C (86°F). At water temperatures below that level, the fish will tend to eat less. The metabolic rate and feeding activity of channel catfish are also affected by the dissolved oxygen concentration in the water. High levels of ammonia are common in raceway systems and have been reported to cause stress to the fish which will adversely affect feeding activity and growth rate.

In this study, the highest growth rate, total weight gain and percentage weight increase and the lowest food conversion ratios were recorded in section S-2. Section S-4 yielded the poorest results in all aspects. It is interesting to note that section S-2 yielded the most desirable results instead of section S-1 as we had theoretically expected. This outcome of the study may be due to the differences in fish sizes in each raceway section at the start of the experiment. The mean weight in section S-2 was 0.62 lb while in sections S-1 and S-3, was 0.86 and 0.82 lb, respectively. The growth rate, total weight gain, percentage weight increase and food conversion ratio of sections S-1 and S-3 were almost identical. On the other hand, the initial mean weight per fish in section S-4 was 1.58 lb. From these results, conclusions can be made that smaller fish have a more rapid growth rate than the larger ones, assuming that water quality does not fall below critical levels.

Although there were some daily fluctuations of dissolved oxygen, the minimum DO reading was 5.5 ppm which was within the optimum range for survival and growth. The water must contain 5-6 ppm dissolved oxygen to support healthy fish populations (Klontz, 1980). Simco (1976) reported that the feeding activity of channel catfish in a closed recirculating system induced a sharp decrease in dissolved oxygen. Feeding activity decreased when the dissolved oxygen level was 3.0 ppm and ceased at 2.0 ppm. Smitherman and Boyd (1974) suggested that the optimum dissolved oxygen level for growth and health of channel catfish in ponds was between 2-5 ppm.

The optimum water temperature for anabolic enzyme activity may be the optimum temperature for growth in fish since enzymes control the rate of every biological activity such as feeding, digestion, food conversion and energy production (Parker and Davis 1981). Ammonia enters the aquatic environment from the microbial decomposition of water and from nitrogenous wastes excreted by the fish. The total ammonia nitrogen recorded in this experiment were probably so negligible as to cause any growth retardation and fish toxicity.

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