QUANTITATIVE ANALYSIS OF SMALL SCALE CAGED FISH CULTURE OF CHANNEL CATFISH

By

AECIO MOURA DA SILVA

Engenheiro de Pesca

Universidade Federal Rural de Pernambuco

Recife, Pernambuco, Brazil

1974

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1983

QUANTITATIVE ANALYSIS OF SMALL SCALE CAGED FISH

CULTURE OF CHANNEL CATFISH

Thesis Approved:

O. Eugene Maughan
Thesis Adviser

James H. Shaw

[illegible] Wade

Norman N. Durham
Dean of Graduate College

PREFACE

The quantitative analysis of the dynamics of caged channel catfish can give useful information to maximize yield and to minimize cost and time required for caged fish culture as well as to make fish culture a serious, predictable, economic activity. The objectives of this research were to determine the population dynamic parameters of channel catfish grown in cages with different ratios of blue tilapia, and to develop a basic computer program for clculation of these parameters. Funds were provided by the Programa de Desenvolvimento de Comunidades Rurais -PRODECOR- and the Empresa Brasileira de Pesquisa Agropecuaria - EMBRAPA.

I would like to thank my Graduate Committee, Dr. O. Eugene Maughan, Dr. William D. Warde, and Dr. James Shaw, for their guidance and review of manuscripts. A special note of appreciation is expressed to Dr. Maughan for his suggestions and assistance in this research. I would also like to thank Ken Williams, Donald Schwartz, and Glen Gebhart for their cooperation and aid in field sampling, as well as, to thank Helen Murray for typing this thesis. In addition, I would like to thank my friends of PRODECOR that gave me priceless help to allow me to conclude this study.

To my wife, Marilene, my daughter Maecia, and sons, Gabriel and Fabiano, I extend my gratitude for their patience and understanding during my graduate studies. This thesis is dedicated to my Lord and Savior Jesus Christ.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure | Page

Figure		Page

Figure		Page

Figure | Page

Figure | Page

CHAPTER I

INTRODUCTION

Caged fish culture began in Asia at the beginning of this century, but is now practiced in many countries of the world. In spite of the fact that caged fish culture began almost 100 years ago, it is only in the last three decades that major progress has been made (Hickling 1962; Schmittou 1970; Collins 1971; Jensen 1981). Currently countries like Japan, Thailand, Combodia, Indonesia, Java, Russia, the United States and Brazil conduct research or have commercial operations in caged fish culture (Brown 1969; Swingle 1970).

Caged fish culture consists of high density stocking and feeding of fish in a cage-like enclosure which is held at the surface of a water body. The cage does not normally touch the bottom of the pond, lake, or reservoir. Generally fish culture is conducted in existing relatively pristine waters, but recently there has been increased interest in culturing fish in nutrient enriched waters (Collins 1971; Jensen 1981). For example, Hickling (1962) has evaluated caged carp culture in a sewage stream and found that growth resulted from feeding on benthic organisms which were carried by the currents into the cages. Culture in nutrient rich waters is relatively new in western countries but has a long history in Asia.

Many species of fish have been used in cage culture. However, the following species are the principal ones cultured: carp (<u>Cyprinus</u>

carpio), silver carp (Hypophthalmichtys molitrix), bighead carp (Aritochtys nobilis), blue catfish (Ictalurus furcatus), white catfish (Ictalurus catus), channel catfish (Ictalurus punctatus), and blue tilapia (Tilapia aurea) (Pagon-Font 1975; Galbreath 1979; Jensen 1981). Research on the cage culture of these species has emphasized food habits in fertilized ponds; selectivity in feeding behavior; species comparison of growth rate, feed conversion efficiency, and growth rate of fish in cages compared to growth of those which are free ranging; protein requirements; control of reproduction; feeding stimulation; optimum sotcking combinations between channel catfish (Ictalurus punctatus) and blue tilapis (Tilapia aurea), economic analysis, cage design, diseases, caged culture management, and marketing (Armbrester 1972; Lovell 1972; Schmittou 1970; Bowman 1977; Boyd 1979; Cremer and Smitherman 1980; Jensen 1981; Williams 1982).

In spite of this wealth of research information, there has been no application of the principles developed in population dynamics to cage culture systems. Most of the literature on population dynamics has been developed for free ranging fish in ponds, lakes, and reservoirs (Borges 1979; Verani 1980; Rocha et al. 1981). However, application of current population dynamics models to fish culture could enhance our understanding of fish behavior, as well as generate predictive models to be applied to fish rearing (Santos 1978).

The need for predictive models in fish culture is particularly great in countries like Brazil. Brazil has a great amount of water resources that are usable for fish culture but is faced with widespread shortages of animal protein. Especially in northeast Brazil, the Ministry of Agriculture through PRODECOR (Rural Community Development

Program) has built thousands of community ponds, lakes, and reservoirs. These ponds could be used to combat this protein shortage through both extensive and intensive fish farming and through use of fish culture in combination with "Microposto de Piscicultura Acoplado a Biodigestor" (Mini fish-Hatchery Linked with Biodegestor) (Silva 1981; Prodecor 1981).

For countries like Brazil, caged fish culture has many advantages over other methods. These advantages in reference to Brazil as adapted from Collins (1978), Schmittou (1970), Jensen (1981), and Williams (1982) are summarized as follows:

1. Many different kinds of water environments can be used to raise fish from fingerlings to harvestable size. If such problems as oxygen depletion, excessive growth of plants, decreased water circulation, vandalism and theft can be overcome, the community reservoirs of northeast Brazil have extensive potential for caged fish culture.

2. Intensive cage fish farming can be performed in open water coincident with extensive open water culture or harvest. On some of Brazil's large waters such flexibility would allow continuous wild harvest simulataneous with caged fish culture.

3. A variety of different fish species can be raised simultaneously in the same water body without the dangers of competition. In Brazil such species as carp, tilapia, and peacock bass (*Cichla ocellaris* Schneider) seem to have great potential for culture.

4. Physical condition and feeding behavior of the fish are easily observed (this advantage is valid elsewhere).

5. Diseases and parasites can be more easily observed and economically treated (this advantage is valid elsewhere).

6. Fish can be harvested as needed without seining or draining the entire body of water. Such flexibility is greatly needed, especially in community lakes of northeast Brazil.

7. Most small, agricultural communities in Brazil are familiar with the types of labor required for managing a cage culture operation.

8. Food production in the rural Prodecor community can be increased, and excess production can be sold to provide an additional source of income. Additional income is a chronic need for agricultural families in Brazil.

9. If there is an existing water environment and local materials are available to build the cages, a small investment is necessary to begin a caged fish culture operation.

In spite of the many advantages to caged fish culture, there are also disadvantages (Schmittou 1970; Collins 1978; Newton 1980; Jensen 1981; Williams 1982). These disadvantages are especially serious in Brazil:

1. Cage material rusts under most conditions; hence, cages must be durable and rust resistent. In poor rural areas of Brazil such resistant materials are often unavailable or prohibitatively expensive.

2. Caged fish must be fed a nutritionally complete floating fish feed. Such feeds are often not available in Brazil, and if available, are very expensive.

3. Caged fish are much more vulnerable to low dissolved oxygen, high ammonia levels, and high carbon dioxide than are fish in open water.

4. Caged fish are very vulnerable to parasites and bacterial diseases.

5. Caged fish are vulnerable to vandalism and theft. These factors may be the most serious limitations for cage fish culture in Prodecor's community reservoirs (disadvantages 3-5 are valid elsewhere).

The primary objective of this research was to develop quantitative models of small scale cage culture of channel catfish (*Ictalurus punctatus*). The specific objectives were: (1) to develop methods applicable to caged fish culture in north and northeast Brazil; (2) to determine population dynamics for caged channel catfish reared in combination with different ratios of blue tilapia, and (3) to develop a basic computer program to predict performance of fishes reared in cages based on the information obtained from population dynamics.

CHAPTER II

METHODS AND MATERIALS

Description of the Study Site

The experiment was performed in three earthen farm ponds of 2.5 ha, 4.0 ha, and 4.0 ha, respectively. The ponds were located southwest of Stillwater, Oklahoma, and were dependent upon rainfall for water input. All three ponds were simultaneously used for fish culture, sport fishing, recreational activities, and to a lesser extent for irrigation and stock watering.

Experimental Procedures

Channel catfish for this experiment were obtained from the Tishomingo Federal Fish Hatchery, Tishomingo, Oklahoma and blue tilapia were obtained from Hickory Ridge Fish Farms, Oklahoma City, Oklahoma.

Four cylindrical plastic mesh, 1 m^3 cages were placed in each of the three ponds. Each pond was considered a block with four treatments, one treatment per cage. Treatments consisted of blue tilapia-channel catfish ratios as follows:

0 blue tilapia - 400 channel catfish

25 blue tilapia - 400 channel catfish

50 blue tilapia - 400 channel catfish

75 blue tilapia - 400 channel catfish

Prior to stocking (6 June 1982), all tilapia and a sample of the channel catfish from each cage were individually weighed and measured. Subsequently, a sample of catfish from each cage was weighed and measured every 28 days. Fish were harvested on 22 October and all tilapia and a sample of the channel catfish weighed and measured. The data were analyzed as suggested by Santos (1978) to obtain a quantitative analysis of the performance of caged channel catfish.

The fish were fed a nutritionally complete 36% protein, floating pelleted ration. Fish were fed all they could eat in approximately 20 minutes once each morning.

Temperature, dissolved oxygen, pH, and Secchi disk visibility were measured weekly between 8:30 and 9:30 A.M. Temperature and dissolved oxygen were measured with a Yellow Springs oxygen and temperature probe. The pH was measured with a Beckman Espandomatic pH meter. Visibility was measured with a Secchi disk.

Population Dynamics Estimated

Estimates of the following population parameters following the methodology of Bertalanffy (1938), Walford (1946), Cushing (1970), Weatherley (1972), and Santos (1978) were developed based on the data collected:

LMAX = Maximumm total length that a fish normally reaches under cage culture conditions. This value corresponds to the asymptotic value of growth in length.

K = Rate at which length reaches the asymptote.

TE = Time factor correction. This factor corrects for the mean total length of the fish at stocking time.

Θ = Constant of the relationship between weight/length. This factor is related to the body form of the fish.

Φ = Condition factor. This so called K-factor is a measure of relative well-being or "plumpness" of the fish.

S* = Survival rate.

M = Mortality coefficient.

Ym = Maximum yield. This value corresponds to the maximum value on the yield curve.

TYm = Instantaneous maximum yield.

YGI = Yield gain index.

Estimation of these values allow a yield curve to be established. Establishment of the yield curve permitted models that predicted the best time for final harvest based on the best production in total weight and numbers of fish to be developed. The procedures (Santos 1978) were as follows:

1. The mathematical relationship of total weight/total length was obtained.

2. The length growth curve was obtained utilizing the Bertalanffy's mathematical model (Bertalanffy 1938). Sampling was maintained at a constant time interval of 28 days.

3. The rate of weight gain was obtained by utilizing the deductive method of Santos (1978).

4. The yield curve, estimated maximum yield, and instantaneous maximum yield were determined.

5. The yield gain index was obtained and an optimal estimated fish density was developed.

Total Weight/Total Length Relationship

The relationship between fish weight ($\overline{W}_T$ = mean total weight) and length ($\overline{L}_T$ = mean total length) over time was developed into a mathematical expression that predicted one factor given values for the others. In addition, the same data were used to predict fish condition by estimating the condition factor values Φ. These two estimations are required to apply the deductive method of Santos (1978) for predicting fish growth.

To obtain the weight/length relationship the empirical data $\overline{W}_T$ and $\overline{L}_T$ from the caged fish were plotted. In this relationship $\overline{L}_T$ was considered the independent variable and $\overline{W}_T$ as the dependent variable. The empirical data were plotted in a scattergram and the increases in $\overline{L}_T$ related to increases in $\overline{W}_T$.

The mathematical expression of this relationship was:

$$\overline{W}_T = \Phi \cdot \overline{L}_T^{\,\Theta} \qquad (2.1)$$

where: $\overline{W}_T$ = mean total weight of the fish at a time T;

$\overline{L}_T$ = mean total length of the fish at a time T;

Φ = condition factor;

Θ = constant related to the body form of the fish (usually equal to 3).

After the establishment of the relationship between length and weight a logarithmic transformation was made to make the data linear. The resulting expression was:

$$\ln\overline{W}_T = \ln\Phi + \Theta \cdot \ln L_T \qquad (2.2)$$

Given this relationship of weight and length, Φ and Θ values were predicted by linear regression. From the total weight/total length relationship, it was possible to construct curves showing the linear relationship between the natural logarithm of the mean total weight ($\ln \overline{W}_T$) and the natural logarithm of the mean total length ($\ln \overline{L}_T$), the relationship between the mean total weight ($\overline{W}_T$) and the mean total length ($\overline{L}_T$), and the estimated Θ value.

Having the estimated value of Θ, it was possible to estimate the value of the Φ* (corrected condition factor) for each time that the fishes were sampled. The equation for Φ* was:

$$\Phi^* = \frac{\overline{W}_T}{\overline{L}_T^{\Theta}} \qquad (2.3)$$

These values were then plotted as a function of sample period. Given the Φ*, it was possible to estimate a mean ($\overline{\Phi}$) for the total period of culture. The equation for this variable was:

$$\overline{\Phi} = \frac{\sum_{i=1}^{n} \Phi^*}{n} \qquad (2.4)$$

where: Φ* = the corrected condition factor;

i = number of samples (1,2,....n);

n = total number of samples.

These $\overline{\Phi}$ values were then plotted as a function of treatment.

Growth Curve in Length

The growth curve in length reflects the relationship between the mean length ($\overline{L}_t$) and age (t) of the individual fish. Bertalanffy (1938) predicted growth curves of a population from any measure of the relationship of length with age, using the following expression:

$$\overline{L}_t = LMAX\ [1 - e^{-K(t - to)}] \qquad (2.5)$$

where: $\overline{L}_t$ = mean total length;

LMAX = maximum total length that the individuals normally can reach (generally corresponding to the asymptotic value of growth in length);

e = base of the natural logarithms;

K = rate at which length reaches the asymptote;

t = projected length at age of the individuals;

to = the age of the individuals at the time of birth.

Santos (1978) has adapted this equation to intensive culture. He concluded that for the great majority of fishes utilized in intensive fish culture, the mean length at birth is near zero and unimportant when compared with the maximum total length that the fishes can normally reach. Therefore <u>to</u> can be assumed to be zero. This determination is further strengthened when <u>to</u> is calculated as being equal to:

$$to = -\frac{1}{K} \cdot \ln \frac{LMAX - Lo}{LMAX} \qquad (2.6)$$

where: $\overline{Lo}$ = the mean length of the individuals at the time of birth. In this calculation using empirical data, it can be seen that <u>to</u> has no effect on the curve.

Santos (1978) has further concluded that since the individual age of fish in intensive culture corresponds to the individual age at stocking time (t_e) plus the culture time (T), the real age of th fish (t) can be expressed as $t = T + t_e$. (2.7)

In addition, since fish prior to stocking are in different environmental conditions than during culture, modifications surely occur in individual growth curves. Moreover, since we wished to analyze only the fish length and weight as a function of culture time, a correction factor (TE) can be estimated from the linear relationship between the relative culture time (T*) and the relative length (L_T*). As a result of these substitutions and definitions, the expression of the Bertanlaffy's growth curve, adapted for intensive fish culture can be represented by the following formula:

$$\overline{L}_T = LMAX\ [1 - e^{-K(T + TE)}] \qquad (2.8)$$

where: $\overline{L}_T$ = mean total length of the fish at the end of culture time T;

LMAX = maximum total length that the fish normally can reach under culture conditions (generally, corresponding to the asymptotic value of growth in length);

e = base of the natural logarithms;

K = rate at which length reaches the asymptote;

T = period of culture;

TE = time factor correction.

In order to verify the validity of this equation, the data were utilized in the FORD-WALFORD (Walford 1946) transformation in which the existence of the linear relationship between the individual length (L_t) at a time (t), and the individual length [$L_{(t + \Delta t)}$] at a subsequent time (t + Δt) was tested. In this transformation t was assumed to be constant. Since the modified Bertalanffy equation appeared reliable, it was possible to estimate the values of A and B using linear regression.

$$L_{(T + \quad T)} = A + B \cdot \overline{L}_T \qquad (2.9)$$

where: $\overline{L}_{(T + \Delta T)}$ = mean total length at a time (T + ΔT) of culture;

$\overline{L}_T$ = mean total length at a time (T) of culture;

A = straight line intercept;

B = straight line slope coefficient.

Having calculated these values, LMAX was estimated using the following expression:

$$LMAX = \frac{A}{1-B} \tag{2.10}$$

The time factor correction of the modified Bertanlaffy equation was estimated from an individual age correction factor developed from natural populations. This process, described by Santos (1978), consists of relating the relative culture time (T*) with the relative length (L_T*) in the following formula:

$$L_T* = \frac{\ln(LMAX - \bar{L}_T)}{LMAX} \tag{2.11}$$

The values of A' and B' parameters were estimated by linear regression, given the linear correlation coefficient (r) of the following expression:

$$L_T* = A' + B' \cdot T* \tag{2.12}$$

In this equation L_T* = relative length of the fish at a time T* of culture, which was obtained using the equation (2.11).

T* = Relative culture time.

A' = Straight line intercept.

B' = straight line slope coefficient.

In addition, the K parameter was estimated by the relationship K = -B', and the time factor correction (TE) was estimated by the (2.13) formula:

$$TE = \frac{A'}{B'} \tag{2.14}$$

The mathematical expression for the theoretical growth curve in length was developed after estimating LMAX, K, and TE. The equation was then tested and the relationship between the equation and the empirical data verified ($r > 0.9$). a To verify the data graphically, the K values were plotted as function of the individual estimated values of LMAX. Since these values closely approximated the predicted mathematical function, the procedure appeared valid.

Growth Curve in Weight

The growth curve in weight as adapted to intensive fish culture is described in Santos (1978). This curve represents the relationship between the mean total weight ($\overline{W}_T$) of fish and culture time (T).

The mathematical model of this curve was deduced from two basic points that have been previously determined:

- The mathematical expression of the weight/length relationship.

$$\overline{W}_T = \phi \cdot \overline{L}_T^{\Theta} \qquad (2.15)$$

- The mathematical expression of the growth curve in length.

$$\overline{L}_T = LMAX\ [1 - e^{-K(T + TE)}] \qquad (2.16)$$

Combining these two expressions resulted in the following mathematical expression for the growth curve in weight:

$$\overline{W}_T = WMAX\ [1 - e^{-K(T + TE)}]^{\Theta} \qquad (2.17)$$

where: WMAX = Maximum total weight that normally the fish can reach under caged conditions. This maximum value corresponds to the asymptotic value of growth in weight, calculated by the formula:

$$WMAX = \phi \cdot LMAX^{\Theta} \qquad (1.17a)$$

Having estimated WMAX, K, TE, and Θ, the theorical growth curve in weight was graphically tested, against empirical data, and K values plotted as a function of the respective estimated values of WMAX parameter. The plotted data verified the response predicted by the equations for each stocking density and treatment.

Yield Curve

The yield or biomass curve measures total yield (Y_T) as a function of culture time (T). To obtain the yield formula from the growth curve formula one must calculate the survival rate at constant intervals of time. In order to determine the number of fish surviving over a constant period the following data were utilized:

1. The number of fingerlings stocked at the start of the experiment -R.
2. The number of fish surviving at the end of the experiment -N.
3. The monthly survival rates - $S^*_{\Delta T}$
4. The survival rate for the entire period of the experiment

$$- \frac{N}{R} \qquad (2.18)$$

S^*_T was estimated by the following formula:

$$S^*_{\Delta T} = \sqrt[n]{\frac{N}{R}} \qquad (2.19)$$

However, since we considered the survival rate $S^*_{\Delta T}$ constant over the interval (ΔT) of culture time, the mathematical expression becomes:

$$N_T = (S^*_{\Delta T})^T \qquad (2.20)$$

where: N_T = number of fish at a time T of culture.

Yield is defined as follows:

$$Y_T = N_T \cdot \overline{W}_T \qquad (2.21)$$

where: Y_T = total yield at a time T of culture.

$\overline{W}_T$ = mean total weight of the fish at a time T of culture.

We defined Y_T as a function of the growth curve, and obtained the following equation:

$$Y_T = R \cdot S^{*T}{}_{\Delta T} \cdot WMAX\ [1 - e^{-K(T + TE)}]^{\Theta} \qquad (2.22)$$

This equation provided the theoretical yield curve for each treatment.

One characteristic of the yield curve is that there is a maximum point corresponding to the theoretical maximum yield over a given culture time. This theoretical maximum was estimated by projecting the zero point on the yield curve, and by the following expression:

$$Ym = R \cdot e^{M \cdot TE} \cdot WMAX \left(\frac{M}{M + \Theta \cdot K}\right)^{\frac{M}{K}} \cdot \left(\frac{\Theta \cdot K}{M + \Theta \cdot K}\right)^{\Theta} \qquad (2.23)$$

where: Ym = maximum yield;

M = mortality coefficient.

The mortality coefficient was estimated with the following formula:

$$M = -\ln S^{*}{}_{\Delta T} \qquad (2.24)$$

The instantaneous maximum yield (TYm) corresponded to:

$$TYm = -\frac{1}{K} \cdot \ln\left(\frac{M}{M + \Theta \cdot K}\right) + TE \qquad (2.25)$$

The proportion between Ym and TYm was used to obtain the yield gain indices-YGI from the following formula:

$$YGI = \frac{Ym}{TYm} \qquad (2.26)$$

Utilizing the yield gain index, we can then graphically obtain the maximum stock density.

CHAPTER III

RESULTS

Total Weight/Total Length Relationship

In all cages the total weight/total length relationship of channel catfish followed the mathematical expression $\overline{W}_T = \Phi \cdot \overline{L}_T^{\Theta}$ (equation 2.1) predicted by Santos (1978). When the constants of this equation were estimated by linear regression from the logarithmic transformation of the empirical data ($\overline{W}_T$ and $\overline{L}_T$) (Tables 1-4), the following linear relationship was revealed (Tables 5-7, Figures 1-24):

$$\ln \overline{W}_T = \ln \Phi + \Theta \cdot \overline{\ln} L_T \qquad (3.1)$$

The estimated values of Θ (Table 5) for each cage of channel catfish in this experiment ranged from 3.155 to 3.436. The estimated average value assuming that Θ was a constant, was 3.401 (Table 6, Figures 25-27) for the experiment (Santos 1978). This value was then entered back into the original equation in an iterative procedure and new "corrected" condition factors (Φ*) and mean condition factors ($\overline{\Phi}$) were developed for each cage at each sampling period (Tables 6 and 7, Figures 28-30).

Estimated condition factors (Appendix A, Figures 31-42) increased immediately after stocking as the species became adapted to culture conditions. However, in the second month, the condition factor began a slight decrease that generally continued until the fish were harvested.

Table 1. Mean total length and mean total weight of channel catfish for each treatment in each ponds (empirical data).

Pond	Date	400 Catfish 0 Tilapia L_T (mm)	400 Catfish 0 Tilapia W_T (gr)	400 Catfish 25 Tilapia L_T (mm)	400 Catfish 25 Tilapia W_T (gr)	400 Catfish 50 Tilapia L_T (mm)	400 Catfish 50 Tilapia W_T (gr)	400 Catfish 75 Tilapia L_T (mm)	400 Catfish 75 Tilapia W_T (gr)
1	06-06-82 (stocking)	135.57	19.30	135.57	19.30	135.57	19.30	135.57	19.30
1	07-02-82	166.00	47.85	165.60	44.90	165.10	48.85	168.05	51.75
1	07-30-82	192.10	69.10	192.00	70.15	202.80	88.90	199.90	84.30
1	08-27-82	224.20	107.45	214.75	91.45	218.10	94.65	220.90	102.50
1	09-24-82	256.60	158.10	258.00	156.95	253.85	152.30	241.85	126.10
1	10-22-82 (harvesting)	263.85	174.20	271.55	187.70	264.90	186.95	272.95	199.00
2	06-06-82 (stocking)	135.57	19.30	135.57	19.30	135.57	19.30	135.57	19.30
2	07-02-82	161.95	47.75	158.20	45.05	162.35	45.35	171.25	59.65
2	07-30-82	199.25	88.60	213.00	106.10	210.35	110.30	224.15	123.10
2	08-27-82	240.90	153.55	253.00	176.55	247.60	155.70	266.10	208.50
2	09-24-82	262.80	216.70	280.15	257.70	280.65	255.85	293.25	284.35

Table 1. Continued.

		Treatment							
		400 Catfish 0 Tilapia		400 Catfish 25 Tilapia		400 Catfish 50 Tilapia		400 Catfish 75 Tilapia	
Pond	Date	L_T (mm)	W_T (gr)	L_T (mm)	W_T (gr)	L_T (mm)	W_T (gr)	L_T (mm)	W_T (gr)
2	10-22-82 (harvesting)	284.40	247.30	299.65	299.30	301.90	304.10	309.70	333.50
3	06-22-82 (stocking)	135.57	19.30	135.57	19.30	135.57	19.30	135.57	19.30
3	07-02-82	172.90	56.25	177.25	58.00	179.70	61.15	172.85	54.95
3	07-30-82	217.70	113.10	232.45	135.40	225.20	126.80	221.80	118.50
3	08-27-82	263.95	203.20	276.65	232.20	267.10	208.10	276.30	234.55
3	09-24-82	303.75	342.35	320.10	388.75	316.10	363.55	316.60	379.00
3	10-22-82 (harvesting)	317.80	384.65	328.08	436.05	329.05	441.55	333.05	456.60

Table 2. Mean total length, mean total weight, and total yield of channel catfish as estimated by the equations (theoretical data).

		Treatment											
		0			25			50			75		
Pond	Date	L_T (mm)	W_T (gr)	Y_T (gr)	L_T (mm)	W_T (gr)	Y_T (gr)	L_T (mm)	W_T (gr)	Y_T (gr)	L_T (mm)	W_T (gr)	W_T (gr)
1	06-06-82	131.1	17.8	7136.3	131.9	17.9	7157.1	132.1	18.7	7489.6	137.4	21.3	8520.7
1	07-02-82	167.7	41.2	16441.3	164.9	38.3	15115.8	168.8	43.2	16966.0	167.4	41.7	15431.2
1	07-30-82	198.9	73.6	29312.6	195.4	68.1	26526.5	199.8	76.6	29534.7	195.5	70.8	25831.2
1	08-27-82	255.5	112.8	44838.9	223.4	107.4	41273.3	225.9	116.2	43997.8	222.0	109.0	37996.0
1	09-24-82	248.2	156.3	62008.6	249.2	155.7	59029.2	247.8	159.3	59200.5	246.9	156.4	52074.1
1	10-22-82	267.5	201.8	79898.9	272.9	212.1	79338.7	266.2	203.3	74208.3	270.2	212.7	67644.8
2	06-06-82	131.9	20.3	8116.0	129.2	18.6	7457.6	130.9	19.2	7697.6	131.6	19.6	7855.4
2	07-02-82	168.7	46.9	18595.2	172.7	50.1	17940.9	171.9	48.6	19428.6	182.0	59.1	23620.8
2	07-30-82	202.4	87.1	34252.9	211.5	99.7	32011.7	209.6	95.5	38122.9	224.2	120.1	48001.5
2	08-27-82	233.3	141.2	55011.8	246.0	166.8	47983.3	244.3	160.9	64154.1	259.6	197.8	78999.8
2	09-24-82	261.5	208.2	80485.6	276.8	249.0	64191.7	276.3	244.4	97366.6	289.3	285.9	114124.2
2	10-22-82	287.3	286.9	109864.4	304.2	343.3	79301.1	305.7	344.8	137230.4	314.2	378.6	151053.9

Table 2. Continued.

		Treatment											
		0			25			50			75		
Pond	Date	L_T (mm)	W_T (gr)	Y_T (gr)	L_T (mm)	W_T (gr)	Y_T (gr)	L_T (mm)	W_T (gr)	Y_T (gr)	L_T (mm)	W_T (gr)	W_T (gr)
3	06-06-82	129.8	18.8	7511.9	128.8	17.8	7118.6	129.8	18.4	7363.2	128.5	17.9	7169.6
3	07-02-82	179.8	56.9	22738.9	187.6	64.1	25544.7	183.9	60.3	23974.5	181.9	58.5	23341.9
3	07-30-82	223.4	119.2	47516.8	235.9	139.7	55545.0	230.4	129.7	51308.5	229.0	128.0	50981.5
3	08-27-82	261.4	203.3	80954.2	275.7	237.1	93980.9	270.4	223.3	87847.6	270.6	225.6	89692.6
3	09-24-82	294.5	305.0	121281.5	308.3	346.8	137040.0	304.6	335.1	131094.0	307.2	347.4	137863.3
3	10-22-82	323.4	419.2	166434.9	335.1	460.3	181368.1	334.0	458.6	178377.3	339.5	488.2	193318.0

Table 3. Initial and final lengths and weights of channel catfish in each pond.

Pond	Treat	Fish per cage	Mean initial length (mm)		Mean initial weight (gr)		Mean final length (mm)		Mean final weight (gr)	
			Tilapia	Catfish	Tilapia	Catfish	Tilapia	Catfish	Tilapia	Catfish
1	0	400	-	135.57	-	19.3	-	263.85	-	174.20
1	25	425	113.31	135.57	32.20	19.3	226.13	271.55	275.13	187.70
1	50	450	117.47	135.57	38.66	19.3	219.57	264.90	247.38	186.95
1	75	475	113.92	135.57	33.12	19.3	218.80	272.95	239.71	199.00
2	0	400	-	135.57	-	19.3	-	284.40	-	247.30
2	25	425	116.64	135.57	34.96	19.3	237.42	299.65	291.08	299.30
2	50	450	117.3	135.57	38.72	19.3	235.44	301.90	287.10	304.10
2	75	475	117.5	135.57	39.61	19.3	234.39	309.70	302.43	333.50
3	0	400	-	135.57	-	19.3	-	317.80	-	384.65
3	25	425	113.12	135.57	32.36	19.3	230.40	328.08	268.62	436.05
3	50	450	115.9	135.57	36.84	19.3	223.77	329.05	254.65	441.55
3	75	475	116.8	135.57	37.02	19.3	227.49	333.05	271.54	456.60

Table 4. Harvest parameters of channel catfish in each pond and treatment.

Pond	Treat	Net production (gr) Tilapia	Net production (gr) Catfish	Total net production (gr)	Harvestable size (%) Tilapia	Harvestable size (%) Catfish	Final survival (%) Tilapia	Final survival (%) Catifsh	Feed conversion Amount feed (gr)	Feed conversion Ratio	Culture period (days)
1	0	-	61471.00	61471.00	-	0	-	99.00	134000	2.18	140
1	25	5247.86	62479.80	67727.66	77.0	5.0	88.0	93.50	146000	2.15	140
1	50	9693.86	60516.75	70210.61	66.0	5.0	94.0	91.25	150800	2.15	140
1	75	14535.41	55562.00	70097.41	55.0	0.0	95.0	79.50	152000	2.17	140
2	0	-	86995.90	86995.90	-	15.0	-	95.70	190600	2.19	140
2	25	2618.96	61418.30	64037.26	75.0	15.0	48.0	57.75	187800	2.93	140
2	50	9260.90	113311.80	122572.70	69.0	35.0	78.0	99.5	254800	2.08	140
2	75	18804.21	125346.50	144150.71	69.0	45.0	96.0	99.7	296200	2.05	140
3	0	-	144986.65	144986.65	-	85.0	-	99.2	259200	1.79	140
3	25	5100.64	164083.70	169184.34	45.0	95.0	88.0	98.5	303200	1.79	140
3	50	8344.00	164042.00	172386.00	45.0	65.0	80.0	97.25	291800	1.69	140
3	75	17589.00	173093.60	190682.60	51.0	90.0	100.0	99.0	331400	1.74	140

Table 5. Component values obtained by linear regressions between the natural logarithms of L_T and W_T of channel catfish for each treatment.

Pond	Treat	N	A_x (mm)	A_y (gr)		11	r
1	0	6	135.57-263.85	19.30-174.20	3.167	-12.46	0.99400
1	25	6	135.57-271.55	19.30-187.70	3.155	-12.42	0.99543
1	50	6	135.57-264.90	19.30-186.95	3.189	-12.56	0.99038
	75	6	135.57-272.95	19.30-199.00	3.162	-12.42	0.98964
2	0	6	135.57-284.40	19.30-247.30	3.366	-13.41	0.99348
2	25	6	135.57-299.65	19.30-299.30	3.331	-13.23	0.99476
2	50	6	135.57-301.90	19.30-304.10	3.352	-13.36	0.99498
2	75	6	135.57-309.70	19.30-333.50	3.320	-13.18	0.99444
3	0	6	135.57-317.80	19.30-384.08	3.430	-13.78	0.99769
3	25	6	135.57-328.08	19.30-436.05	3.430	-13.83	0.99879
3	50	6	135.57-329.05	19.30-441.55	3.427	-13.78	0.99832
3	75	6	135.57-333.05	19.30-456.60	3.420	-13.74	0.99833

N = Number of pairs of empirical data analyzed

A_x = Amplitude of X variable (mean total length = L_T)

A_Y = Amplitude of Y variable (mean total weight = W_T)

= Slope linear regression

ln = = Linear coefficient of linear regression

r = Linear correlation coefficient

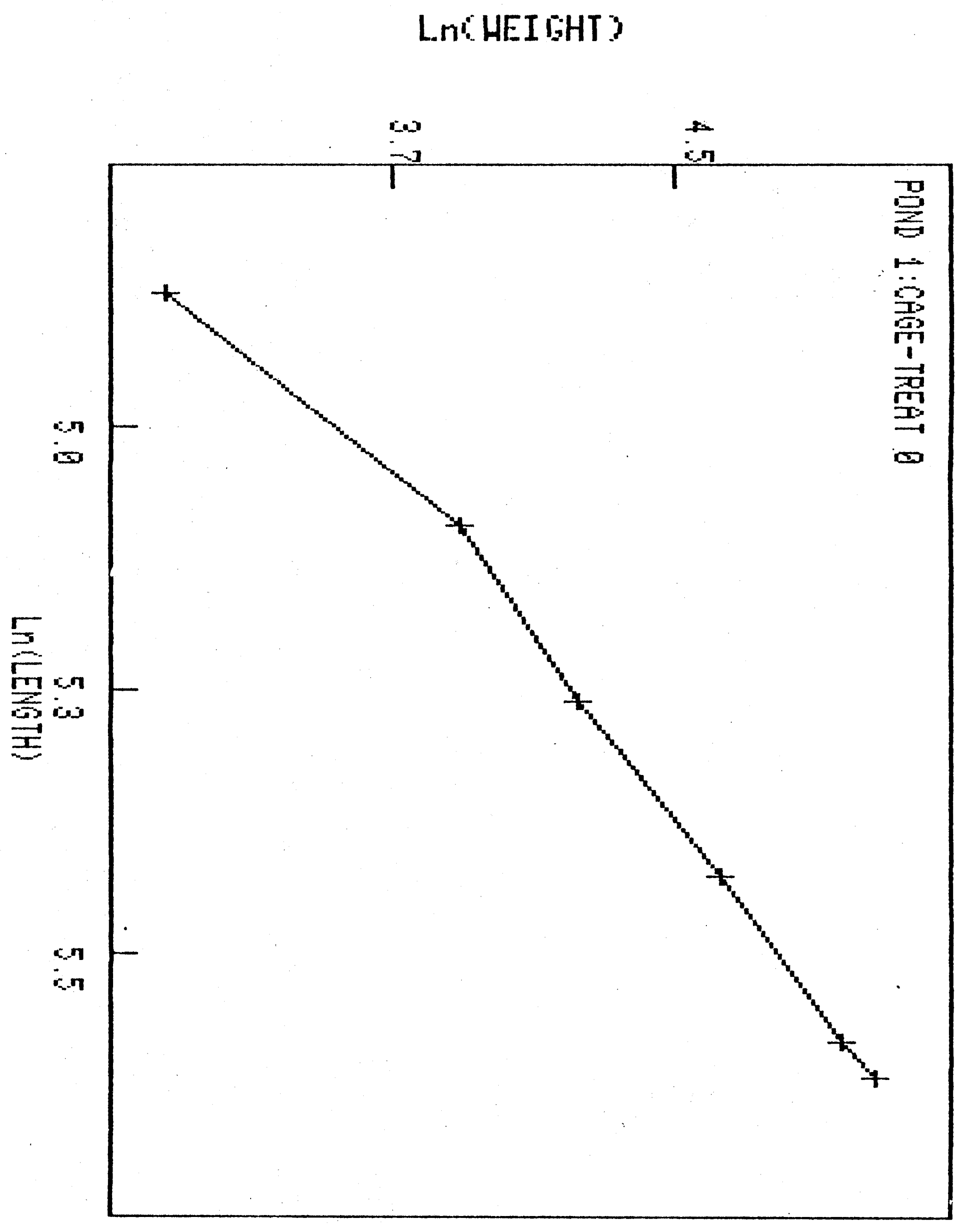
Table 6. "Corrected" monthly condition factors ($\Phi^* \cdot 10^{-6}$) assuming is constant (Θ = 3.401).

Pond	Date	Treatments 0	25	50	75
1	06-06-82	1.08161	1.08161	1.08161	1.08161
1	07-02-82	1.34677	1.27416	1.40058	1.39699
1	07-30-82	1.18188	1.20371	1.26638	1.26114
1	08-27-82	1.08816	1.07221	1.05281	1.09173
1	09-24-82	1.01170	0.98592	1.01095	0.98690
1	10-22-82	1.01394	0.99069	1.07355	1.03213
2	06-06-82	1.08161	1.08161	1.08161	1.08161
2	07-02-82	1.46174	1.49247	1.37667	1.51019
2	07-30-82	1.34023	1.27908	1.38755	1.24760
2	08-27-82	1.21779	1.18537	1.12449	1.17903
2	09-24-82	1.27854	1.22332	1.20719	1.15552
2	10-22-82	1.11535	1.13016	1.11944	1.12565
3	06-06-82	1.08161	1.08161	1.08161	1.08161
3	07-02-82	1.37842	1.30613	1.31425	1.34789
3	07-30-82	1.26592	1.21264	1.26484	1.24481
3	08-27-82	1.18121	1.14042	1.16186	1.16708
3	09-24-82	1.23433	1.17272	1.14462	1.18687
3	10-22-82	1.18912	1.20973	1.21275	1.20360

Table 7. Condition factor ($\Phi \cdot 10^{-6}$), mean condition factor ($\bar{\Phi} \cdot 10^{-6}$), weight/length constants [treatment (Θ) and total Θ obtained from the total weight/length relationship], of channel catfish.

Pond	Treat	Parameters $\Phi \cdot 10^{-6}$	Θ	Total Θ	$\Phi \cdot 10^{-6}$
1	0	3.8519	3.167	3.401	1.12068
1	25	4.0470	3.155	3.401	1.10138
1	50	3.5140	3.189	3.401	1.14765
1	75	4.0466	3.162	3.401	1.14175
2	0	1.4970	3.366	3.401	1.24923
2	25	1.7900	3.331	3.401	1.23200
2	50	1.5800	3.352	3.401	1.21623
2	75	1.8840	3.320	3.401	1.21660
3	0	1.0310	3.430	3.401	1.22178
3	25	0.9800	3.430	3.401	1.18887
3	50	1.0350	3.427	3.401	1.19665
3	75	1.0740	3.420	3.401	1.20531

Figure 1. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 0 (number of tilapia) at pond 1.



Ln(WEIGHT)
3.7
4.5
POND 1:CAGE-TREAT 0
5.0
5.3
5.5
Ln(LENGTH)

Figure 2. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 25 (number of tilapia) at pond 1.

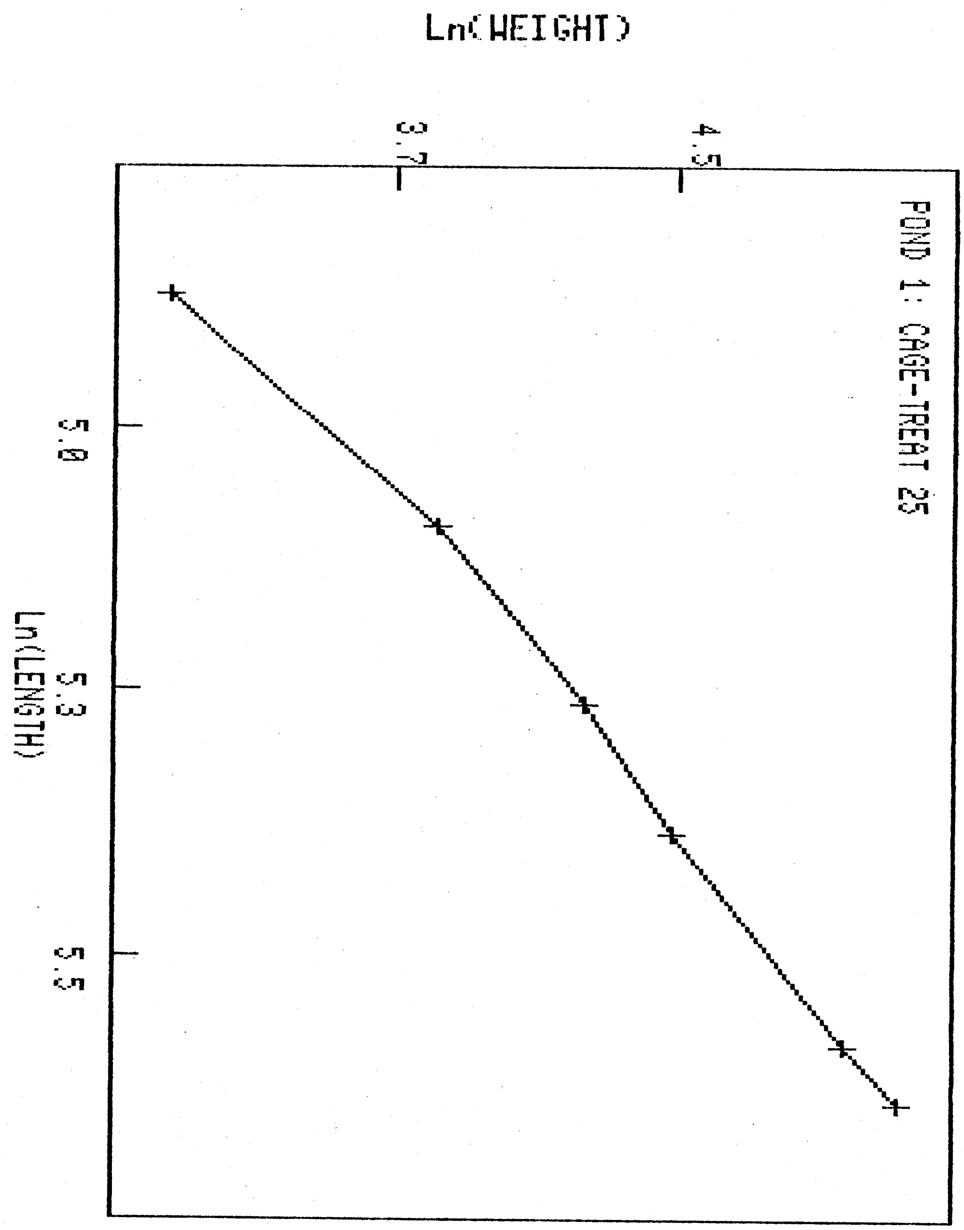

POND 1: CAGE-TREAT 25
Ln(WEIGHT)
3.7
4.5
5.0
5.3
5.5
Ln(LENGTH)

Figure 3. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 50 (number of tilapia) at pond 1.

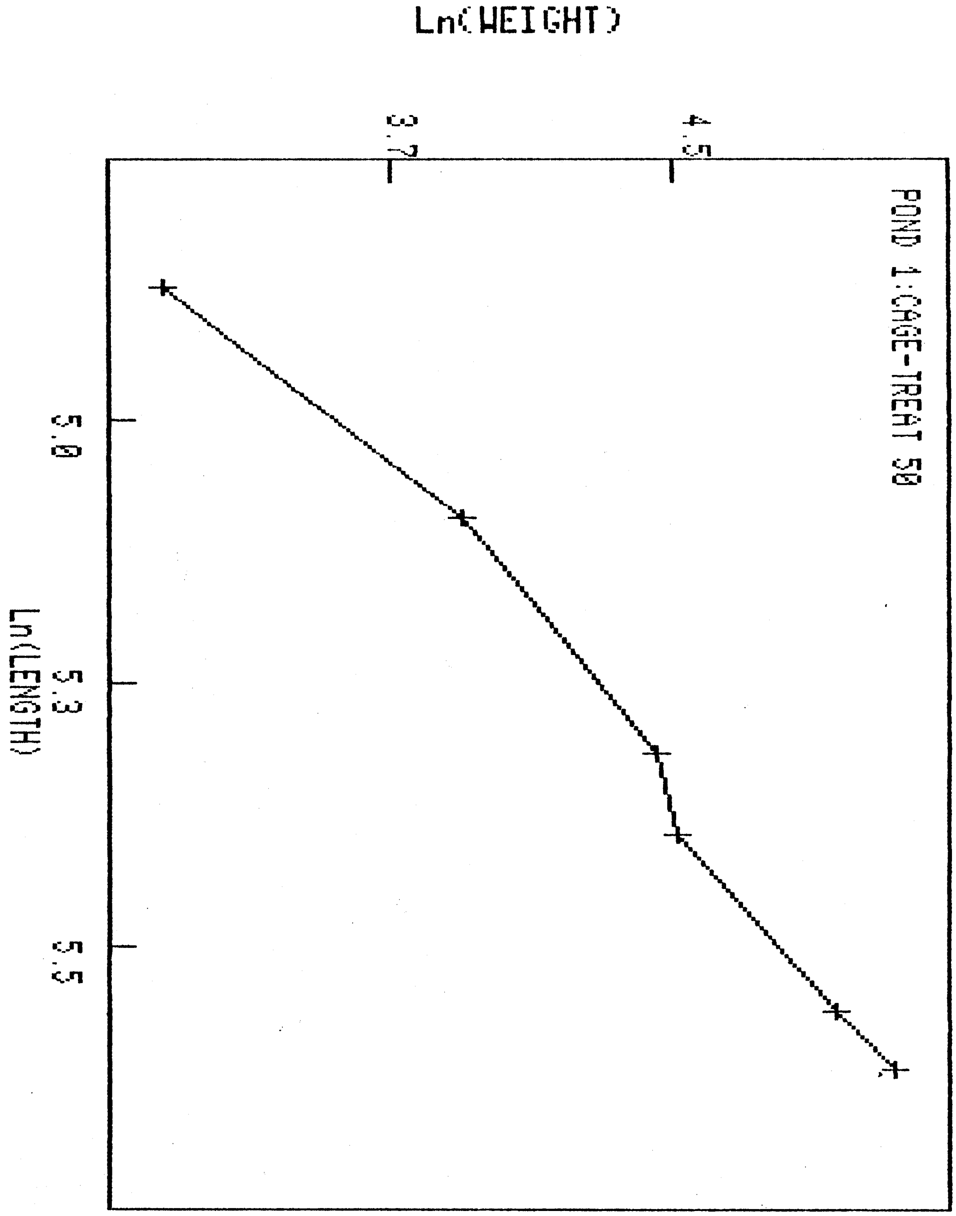

Ln(WEIGHT)
3.7
4.5
POND 1:CAGE-TREAT 50
5.0
5.3
5.5
Ln(LENGTH)

Figure 4. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 75 (number of tilapia) at pond 1.

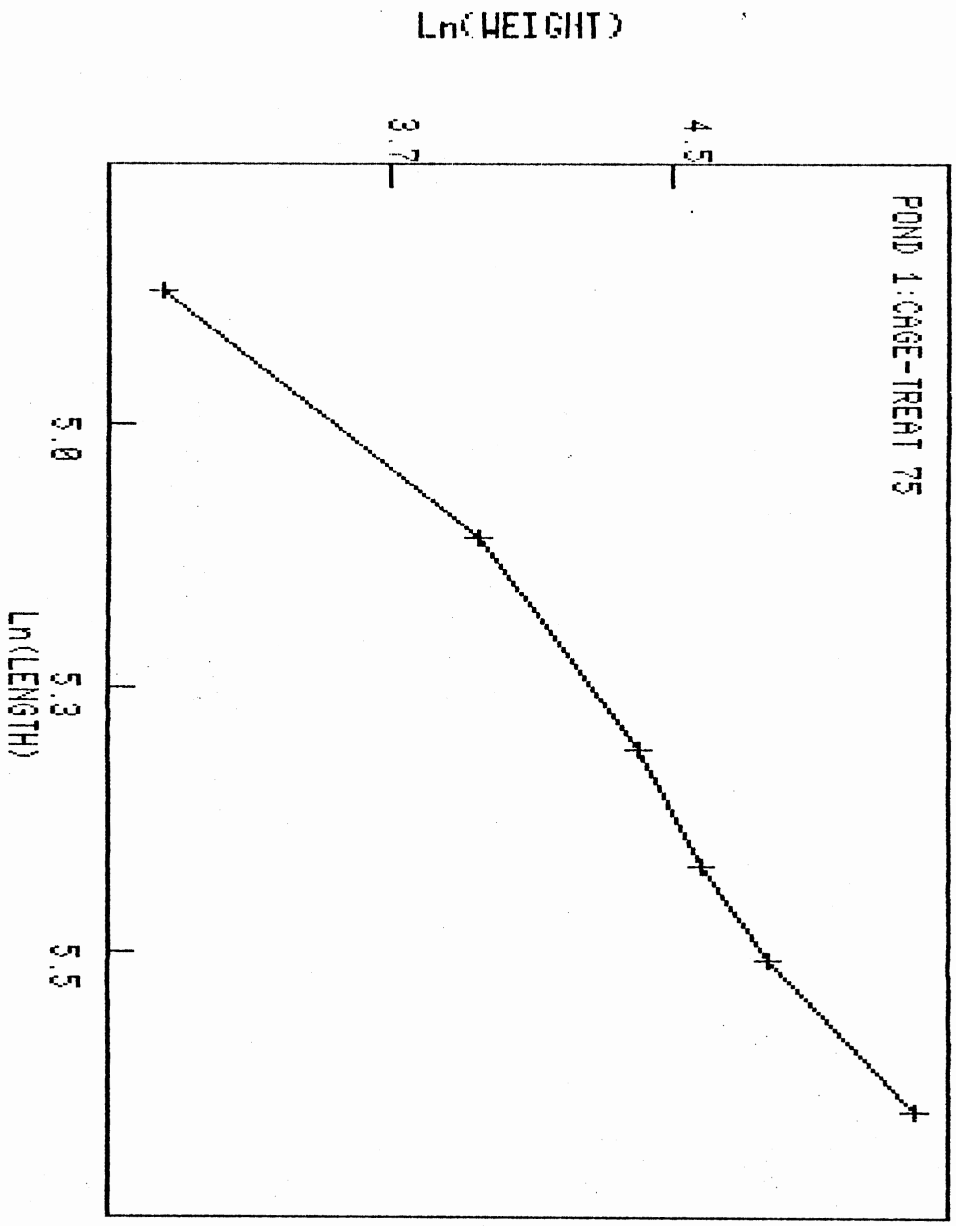

POND 1:CAGE-TREAT 75
Ln(WEIGHT)
3.7
4.5
Ln(LENGTH)
5.0
5.3
5.5

Figure 5. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 0 (number of tilapia) at pond 2.

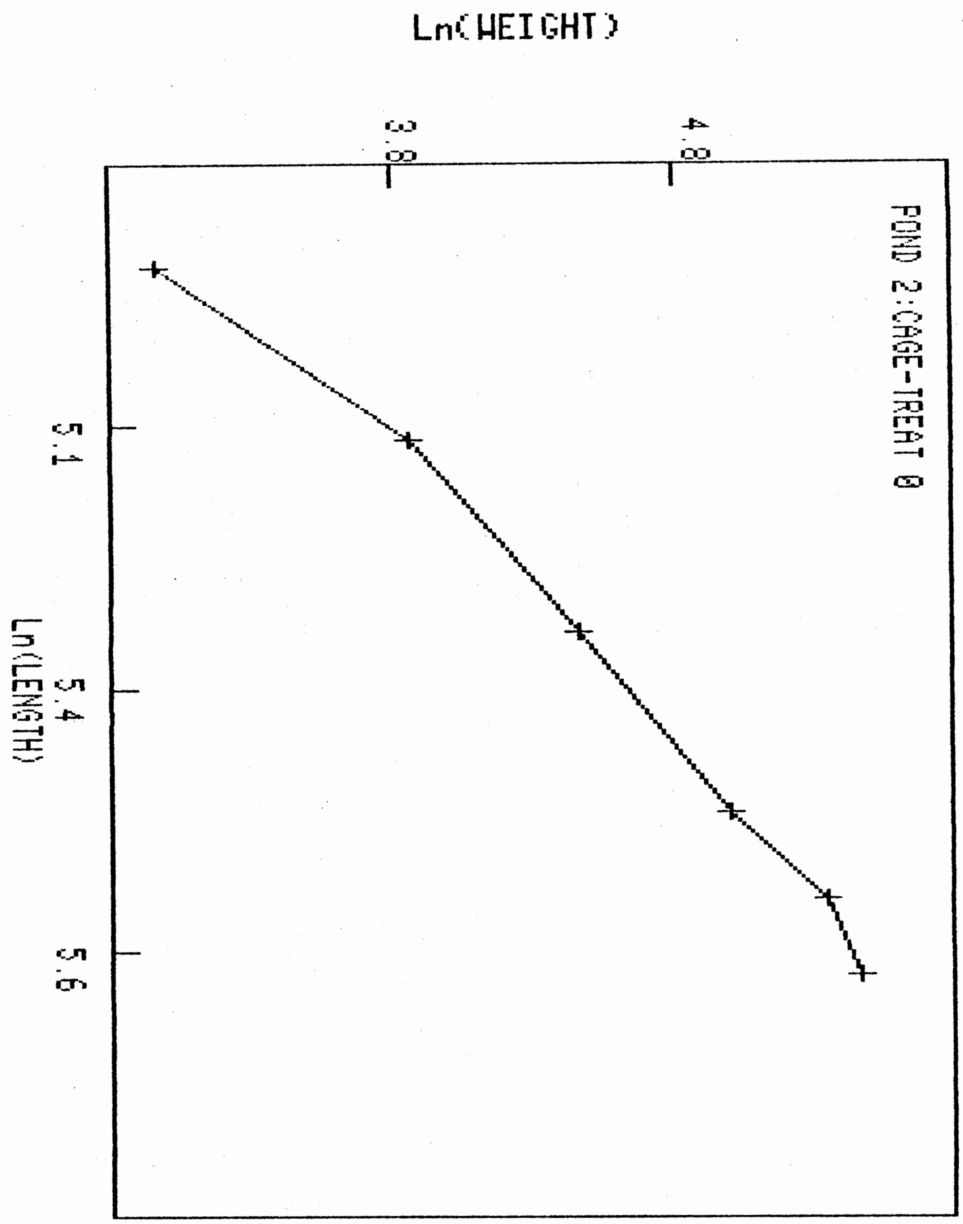

Ln(HEIGHT)
3.8
4.8
POND 2:CAGE-TREAT 0
5.1
5.4
5.6
Ln(LENGTH)

Figure 6. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 25 (number of tilapia) at pond 2.

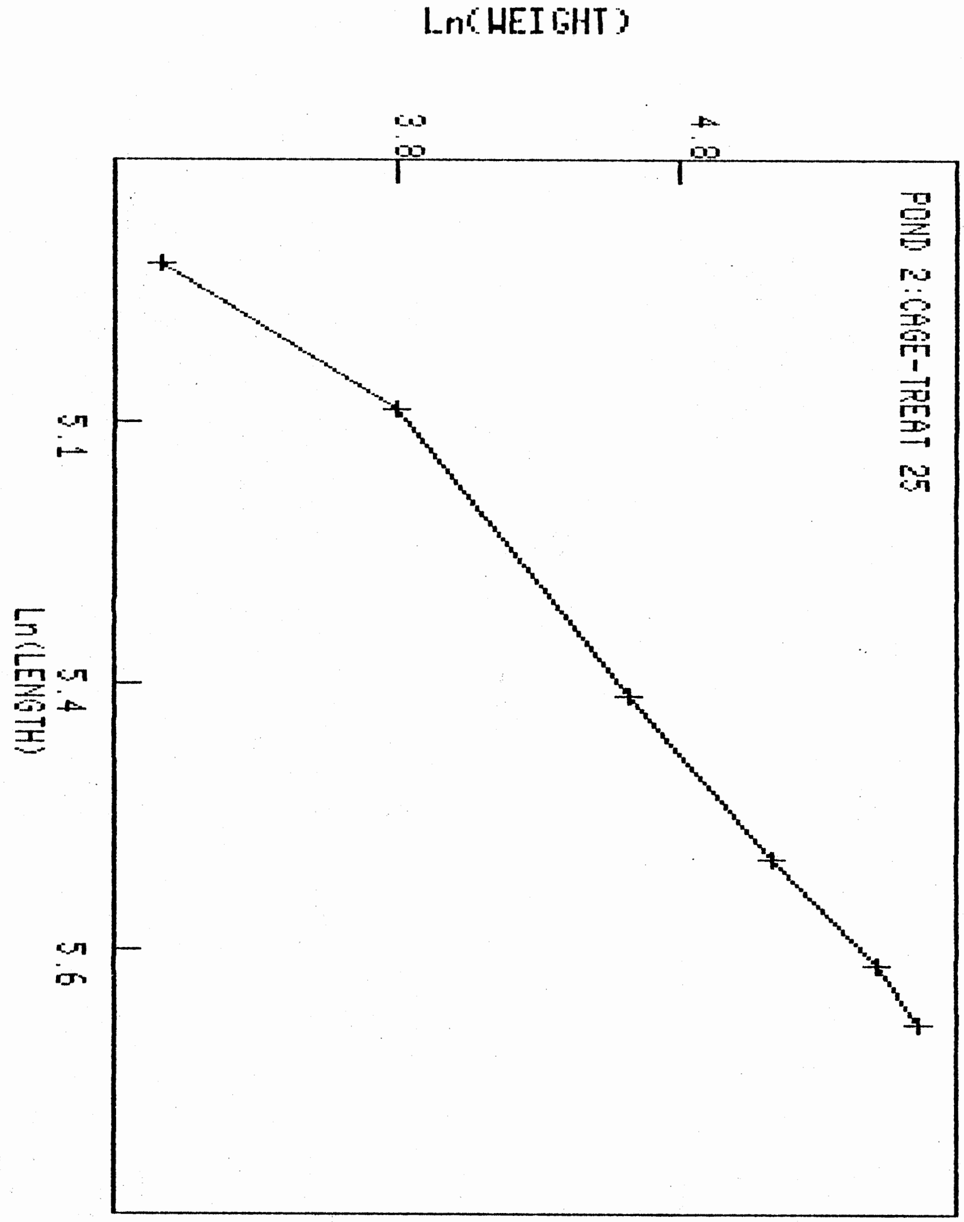

Ln(WEIGHT)
3.8
4.8
POND 2:CAGE-TREAT 25
5.1
5.4
5.6
Ln(LENGTH)

Figure 7. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 50 (number of tilapia) at pond 2.

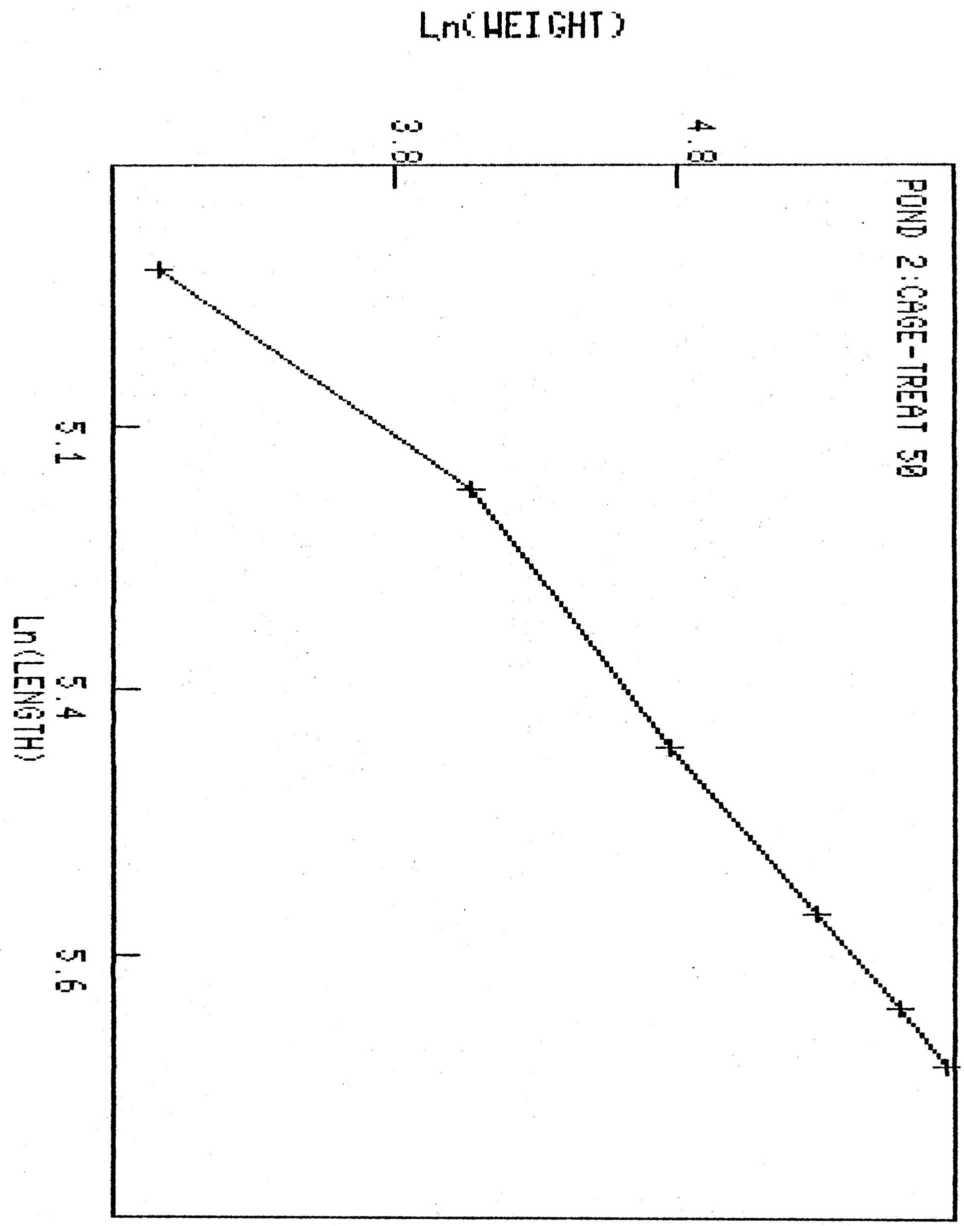

POND 2:CAGE-TREAT 50
Ln(WEIGHT)
3.8
4.8
Ln(LENGTH)
5.1
5.4
5.6

Figure 8. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 75 (number of tilapia) at pond 2.

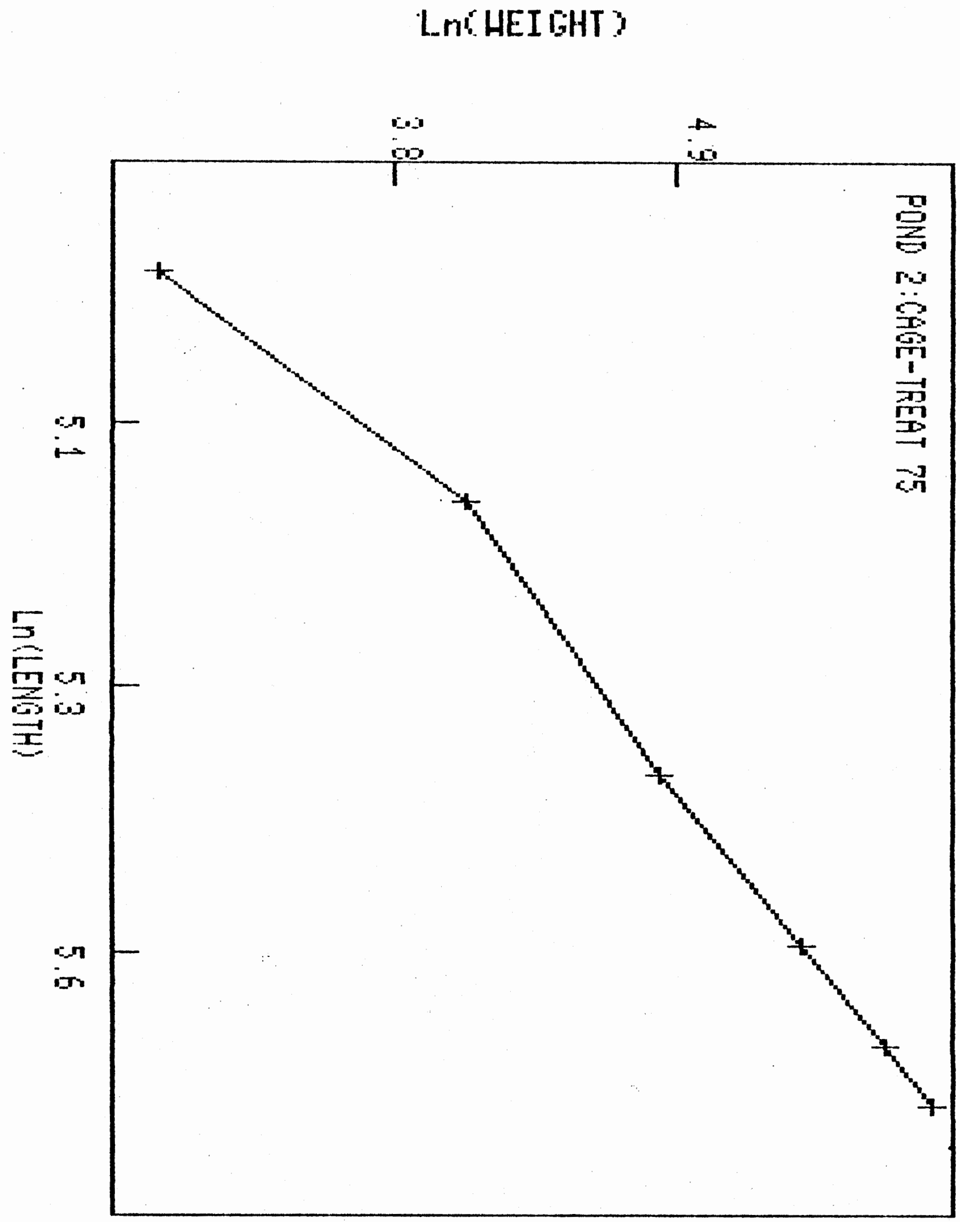

POND 2:CAGE-TREAT 75
Ln(HEIGHT)
3.8
4.9
5.1
5.3
5.6
Ln(LENGTH)

Figure 9. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 0 (number of tilapia) at pond 3.

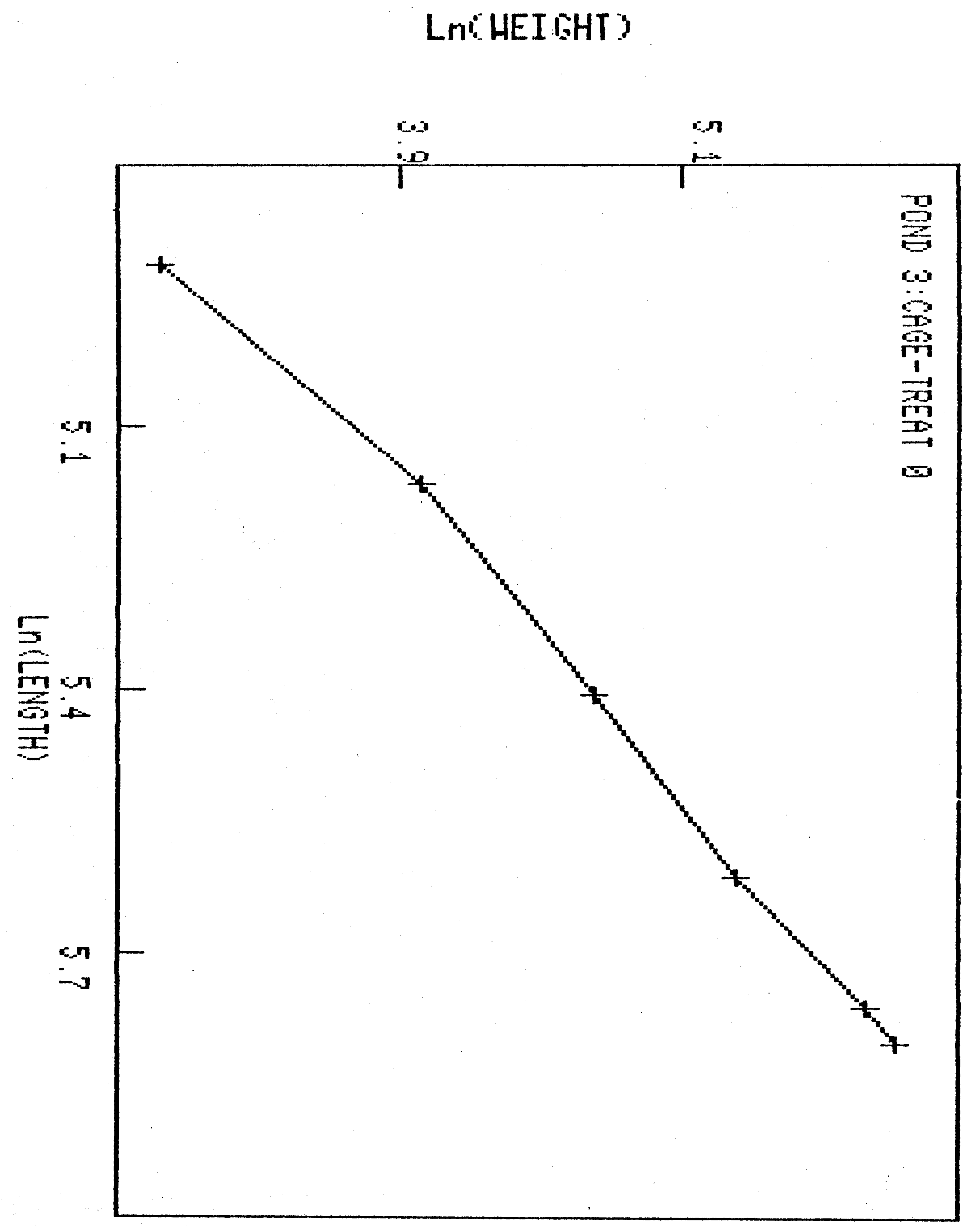

Ln(WEIGHT)
3.9
5.1
POND 3:CAGE-TREAT 0
5.1
5.4
5.7
Ln(LENGTH)

Figure 10. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 25 (number of tilapia) at pond 3.

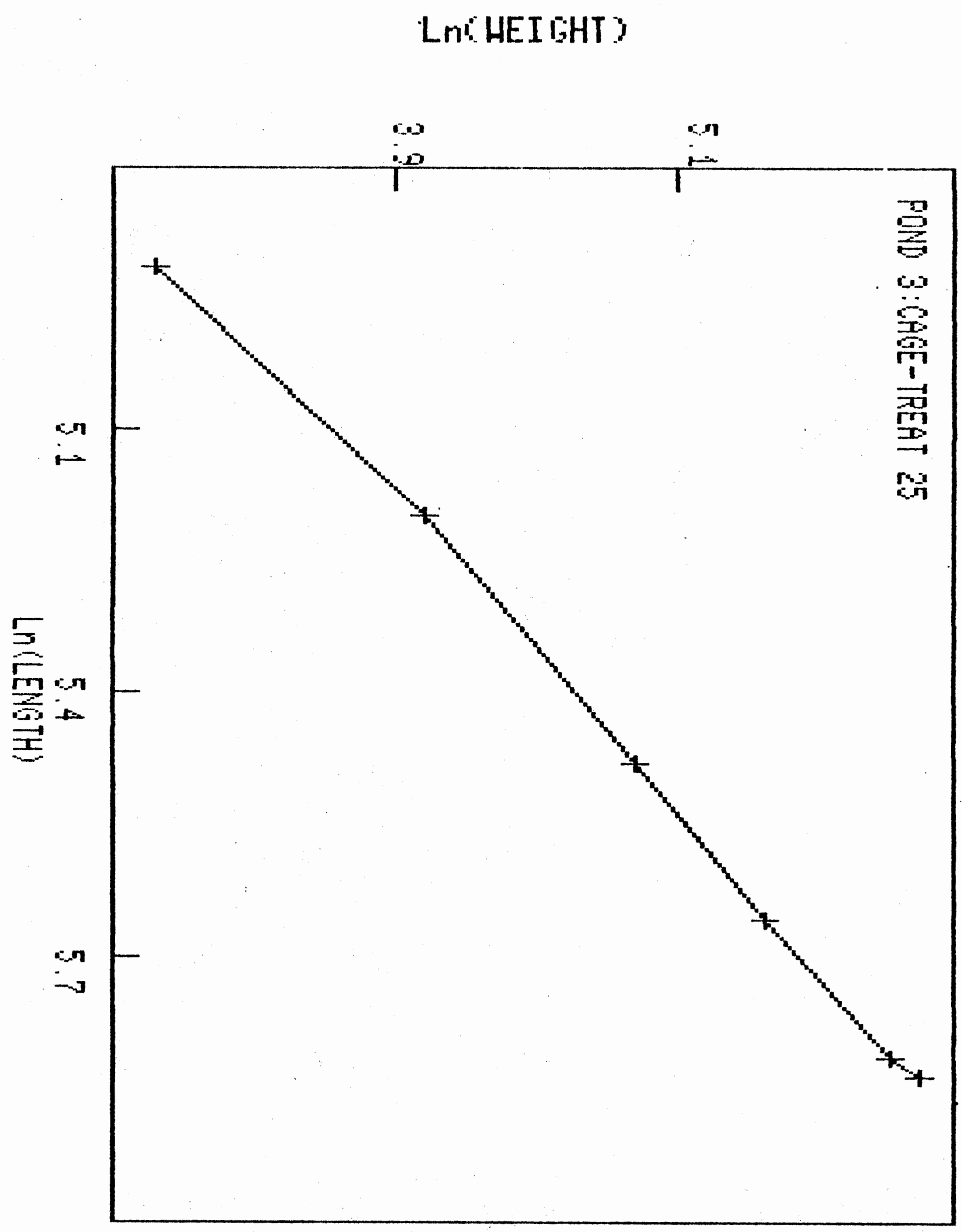

Ln(WEIGHT)
3.9
5.1
POND 3:CAGE-TREAT 25
5.1
5.4
5.7
Ln(LENGTH)

Figure 11. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 50 (number of tilapia) at pond 3.

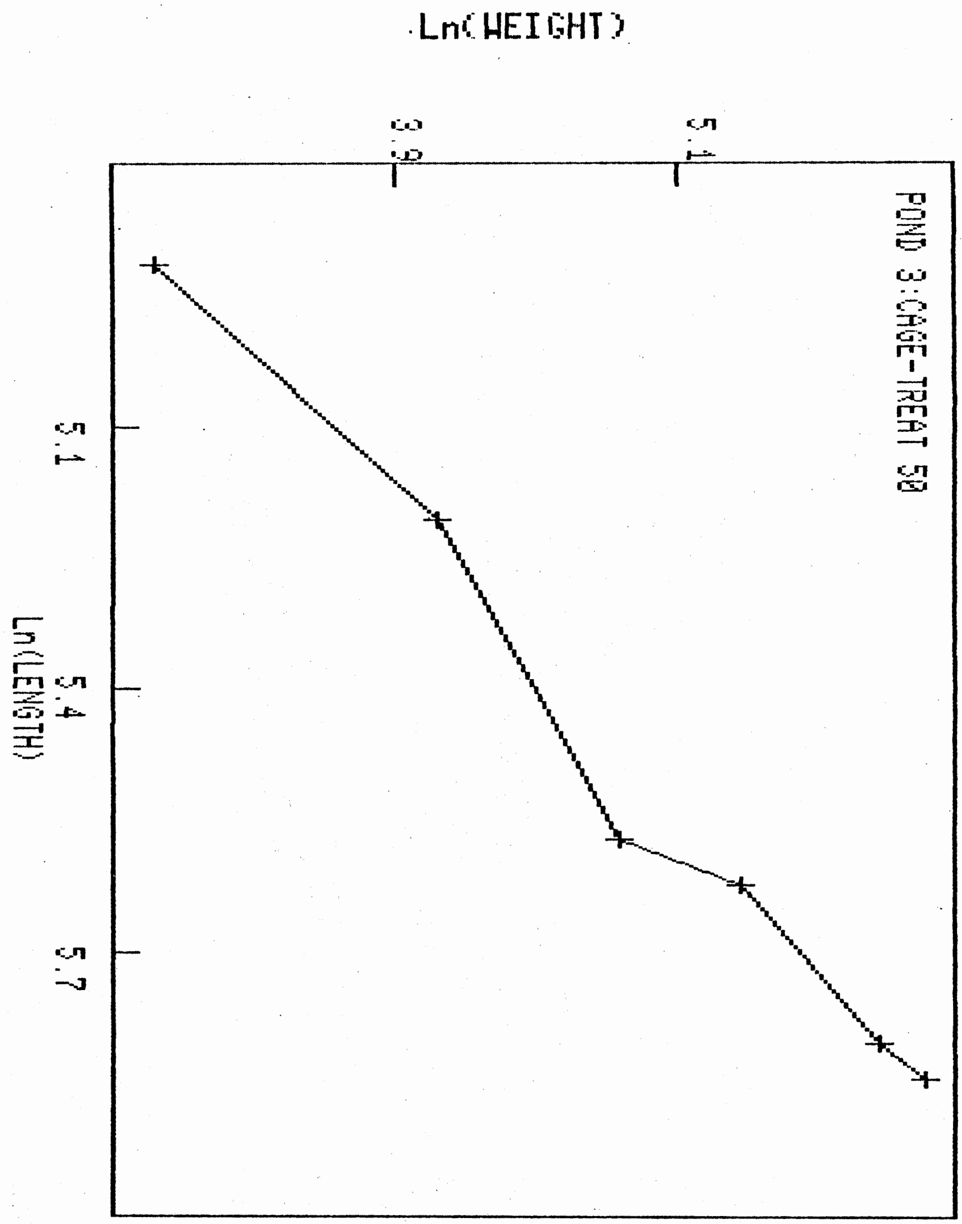

Ln(WEIGHT)
3.9
5.1
POND 3:CAGE-TREAT 50
5.1
5.4
5.7
Ln(LENGTH)

Figure 12. Linear relationship between the natural logarithm of the mean total weight and mean total length for channel catfish in treatment 75 (number of tilapia) at pond 3.

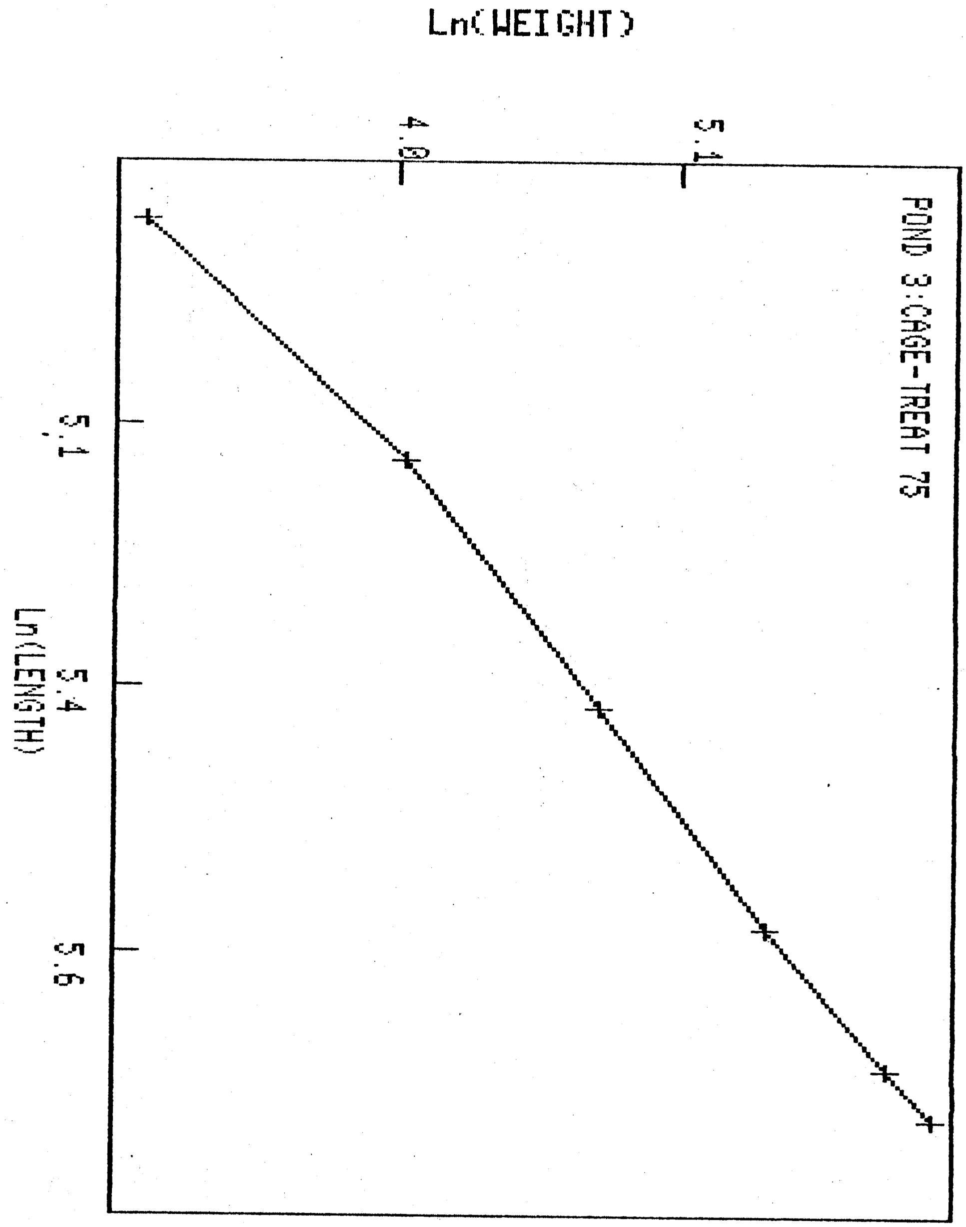

Ln(WEIGHT)
4.0
5.1
POND 3:CAGE-TREAT 75
5.1
5.4
5.6
Ln(LENGTH)

Figure 13. Relationship between total weight and mean total length for channel catfish in treatment 0 (number of tilapia) at pond 1.

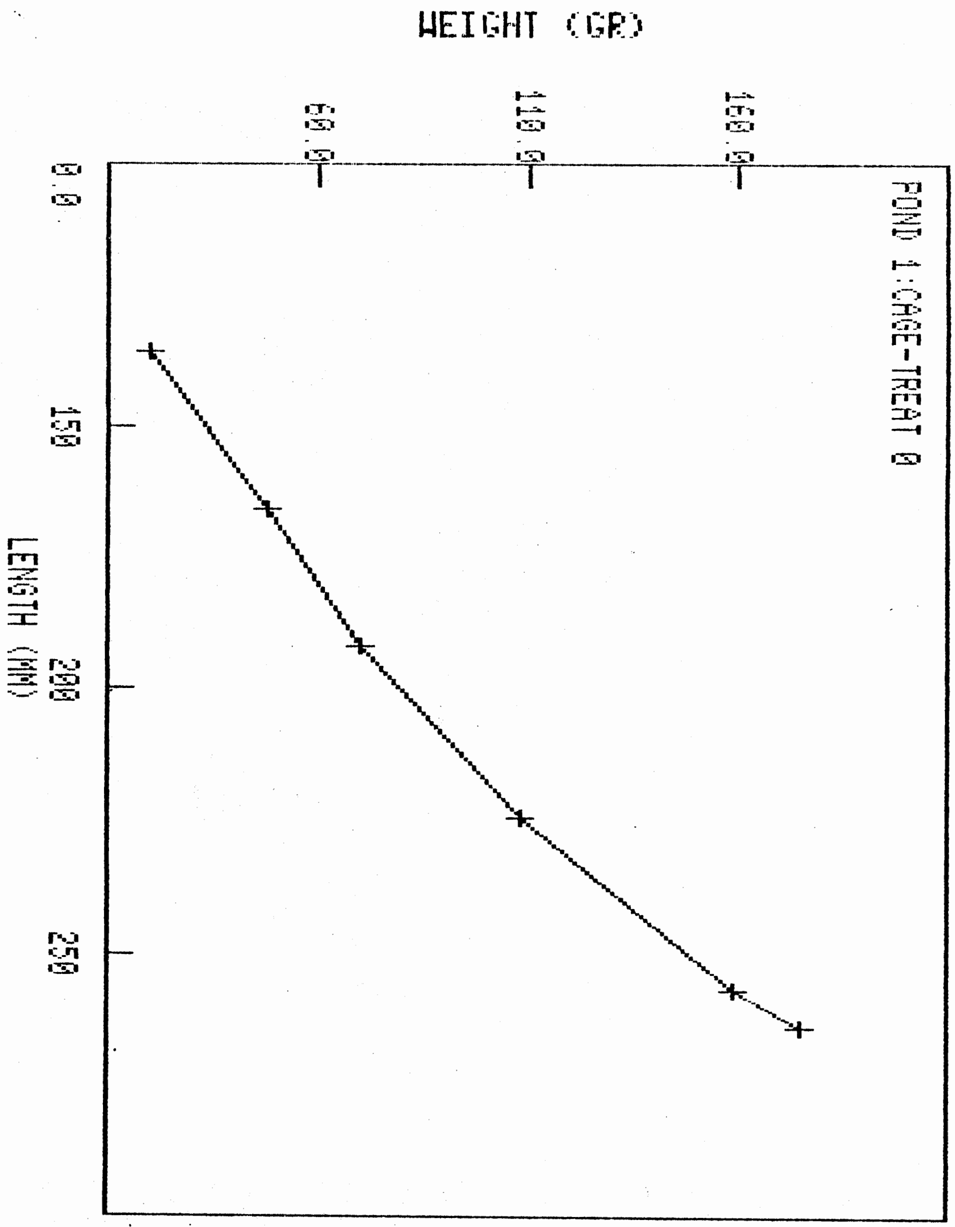

POND 1:CAGE-TREAT 0
WEIGHT (GR)
LENGTH (MM)
0.0
60.0
110.0
160.0
150
200
250

Figure 14. Relationship between total weight and mean total length for channel catfish in treatment 25 (number of tilapia) at pond 1.

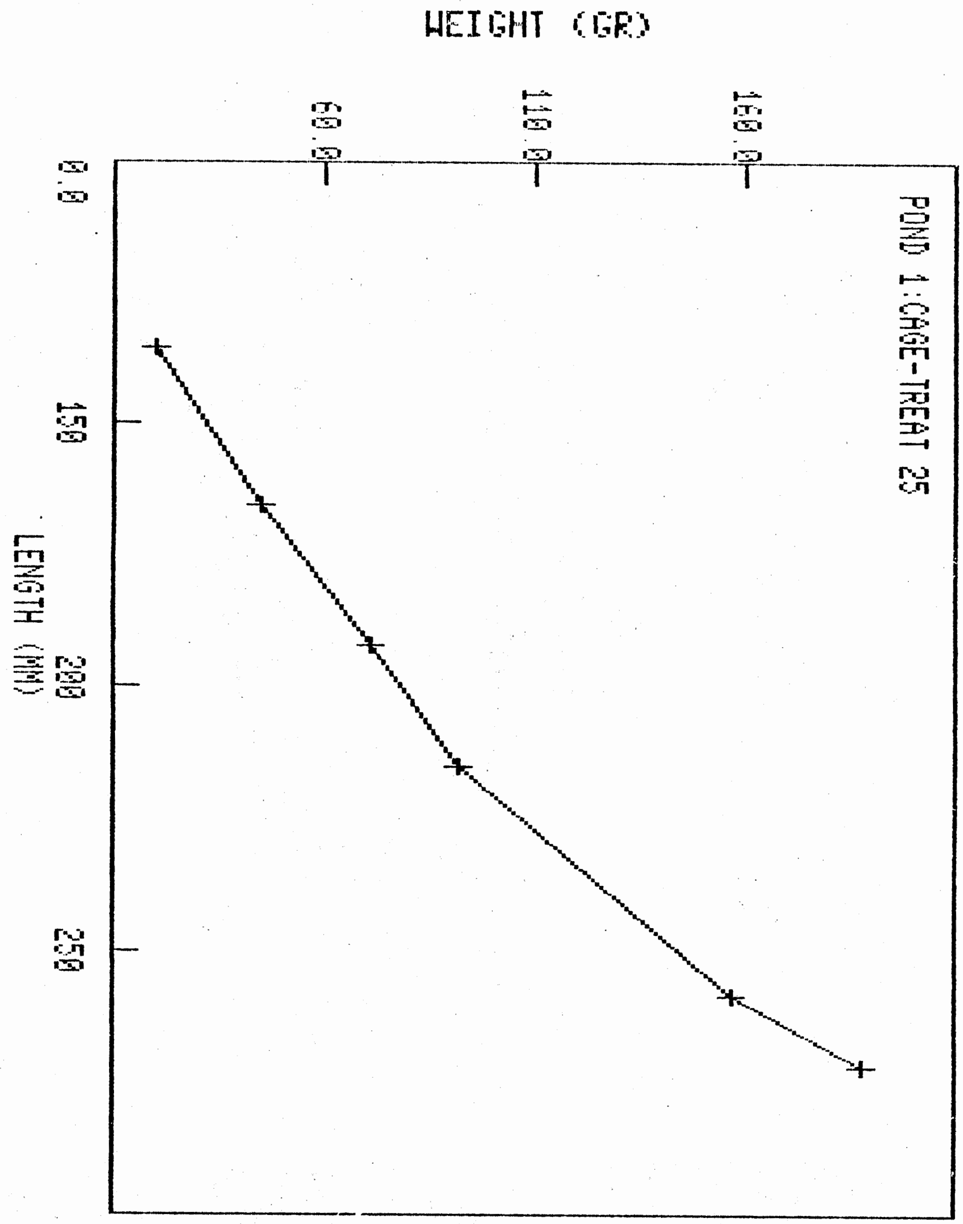

POND 1:CAGE-TREAT 25
WEIGHT (GR)
160.0
110.0
60.0
0.0
150
200
250
LENGTH (MM)

Figure 15. Relationship between total weight and mean total length for channel catfish in treatment 50 (number of tilapia) at pond 1.

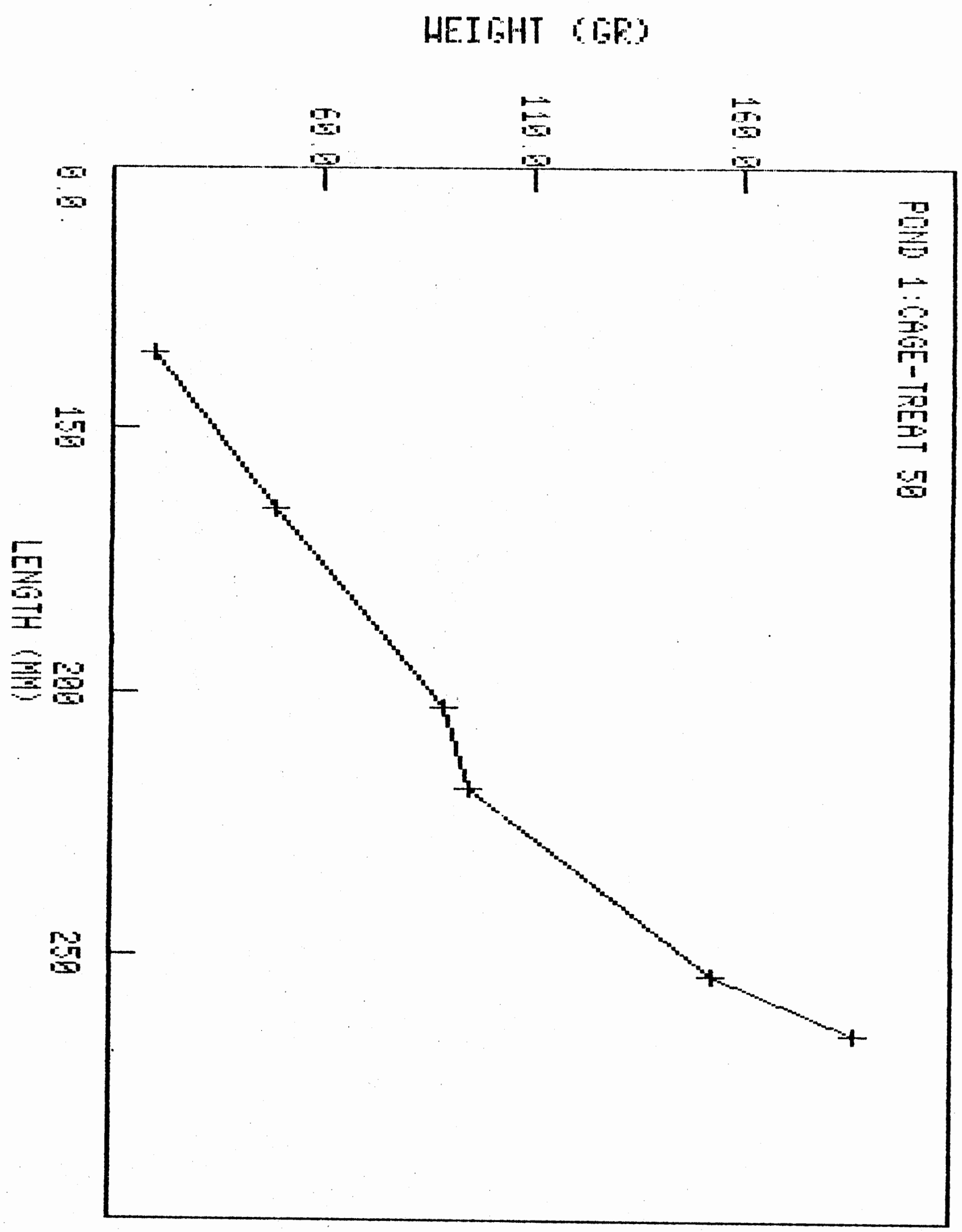

WEIGHT (GR)
60.0
110.0
160.0
0.0
150
200
250
LENGTH (MM)
POND 1:CAGE-TREAT 50

Figure 16. Relationship between total weight and mean total length for channel catfish in treatment 75 (number of tilapia) at pond 1.

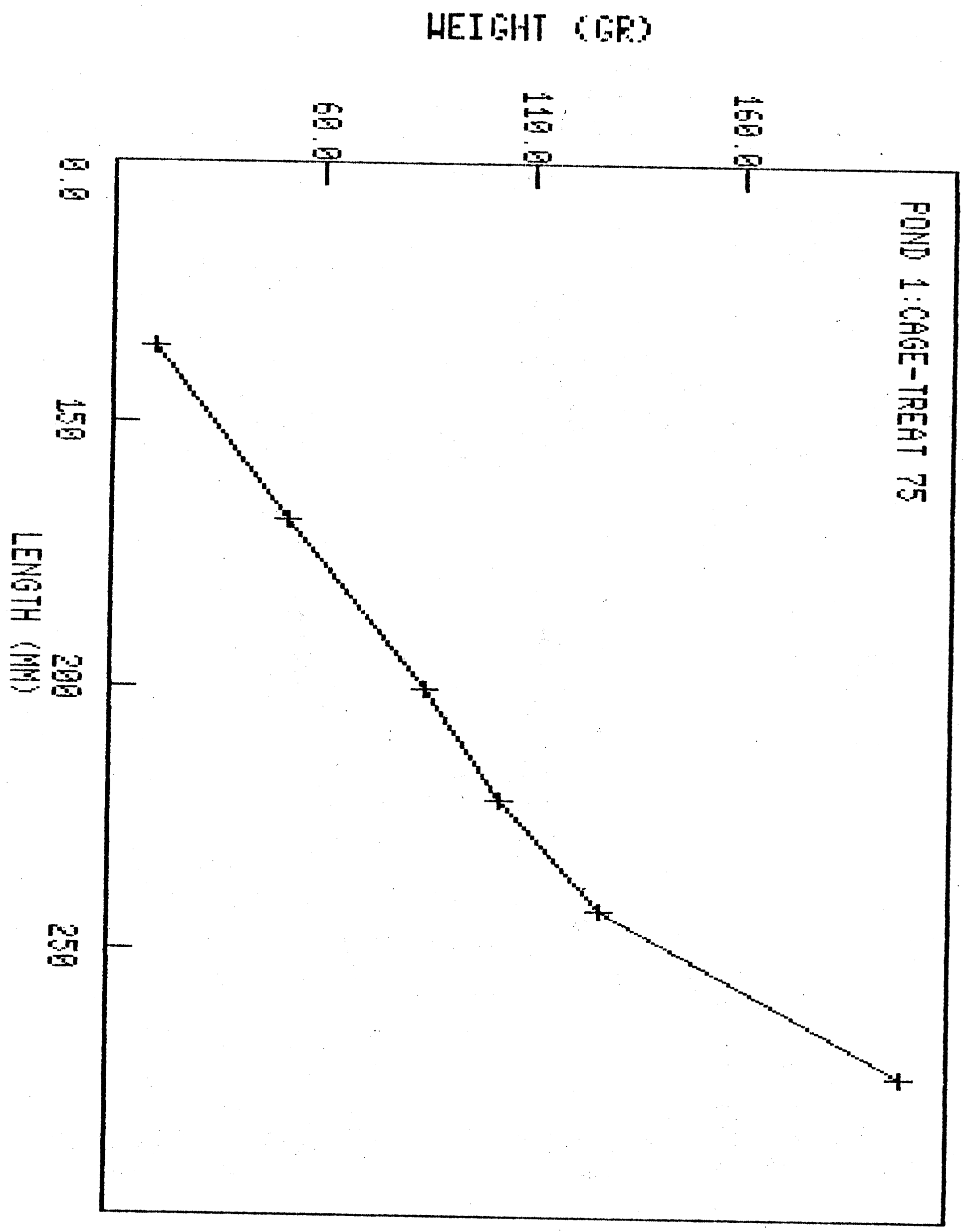

POND 1:CAGE-TREAT 75
WEIGHT (GR)
LENGTH (MM)
0.0
60.0
110.0
160.0
150
200
250

Figure 17. Relationship between total weight and mean total length for channel catfish in treatment 0 (number of tilapia) at pond 2.

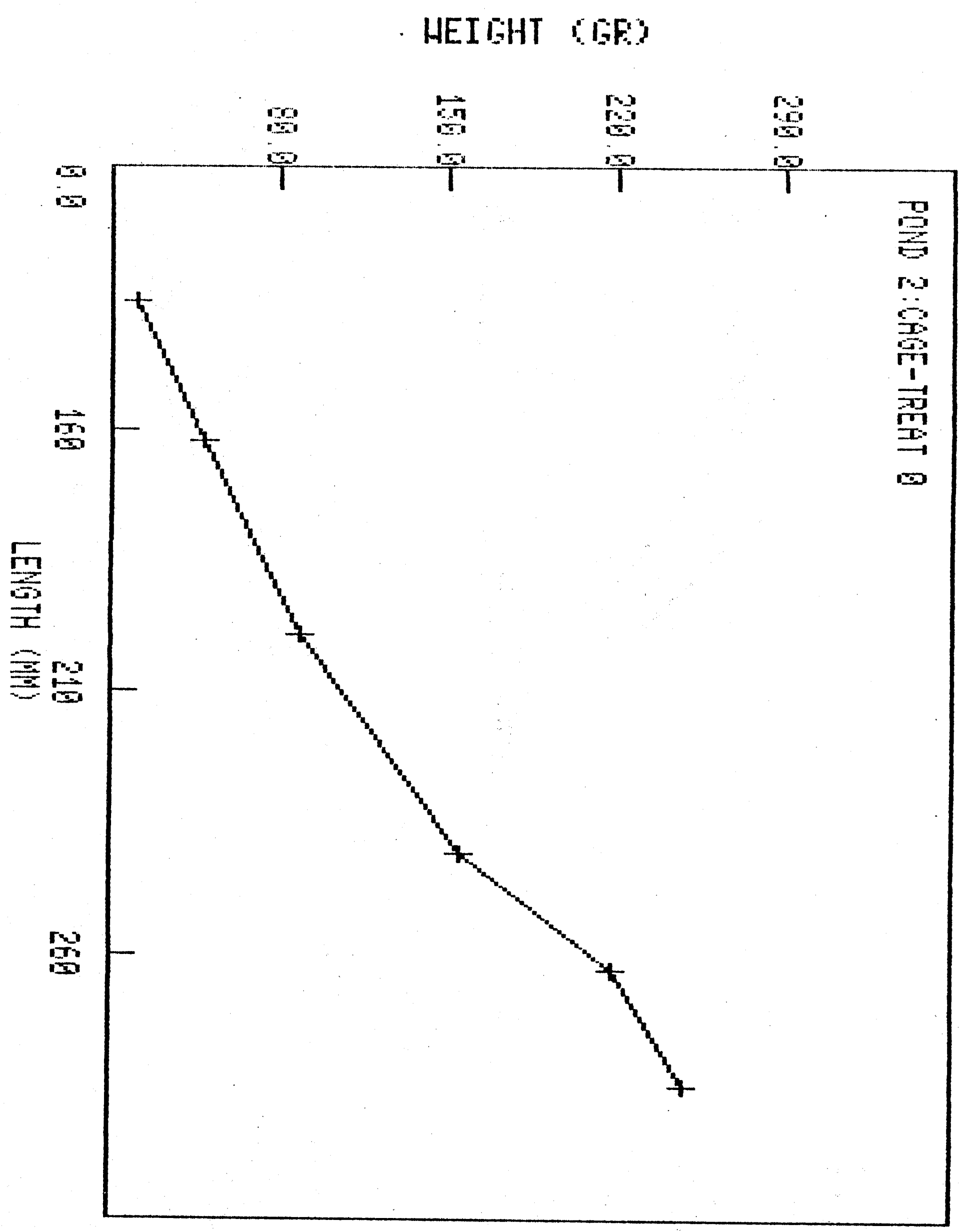

POND 2:CAGE-TREAT 0
WEIGHT (GR)
80.0
150.0
220.0
290.0
LENGTH (MM)
0.0
160
210
260

Figure 18. Relationship between total weight and mean total length for channel catfish in treatment 25 (number of tilapia) at pond 2.

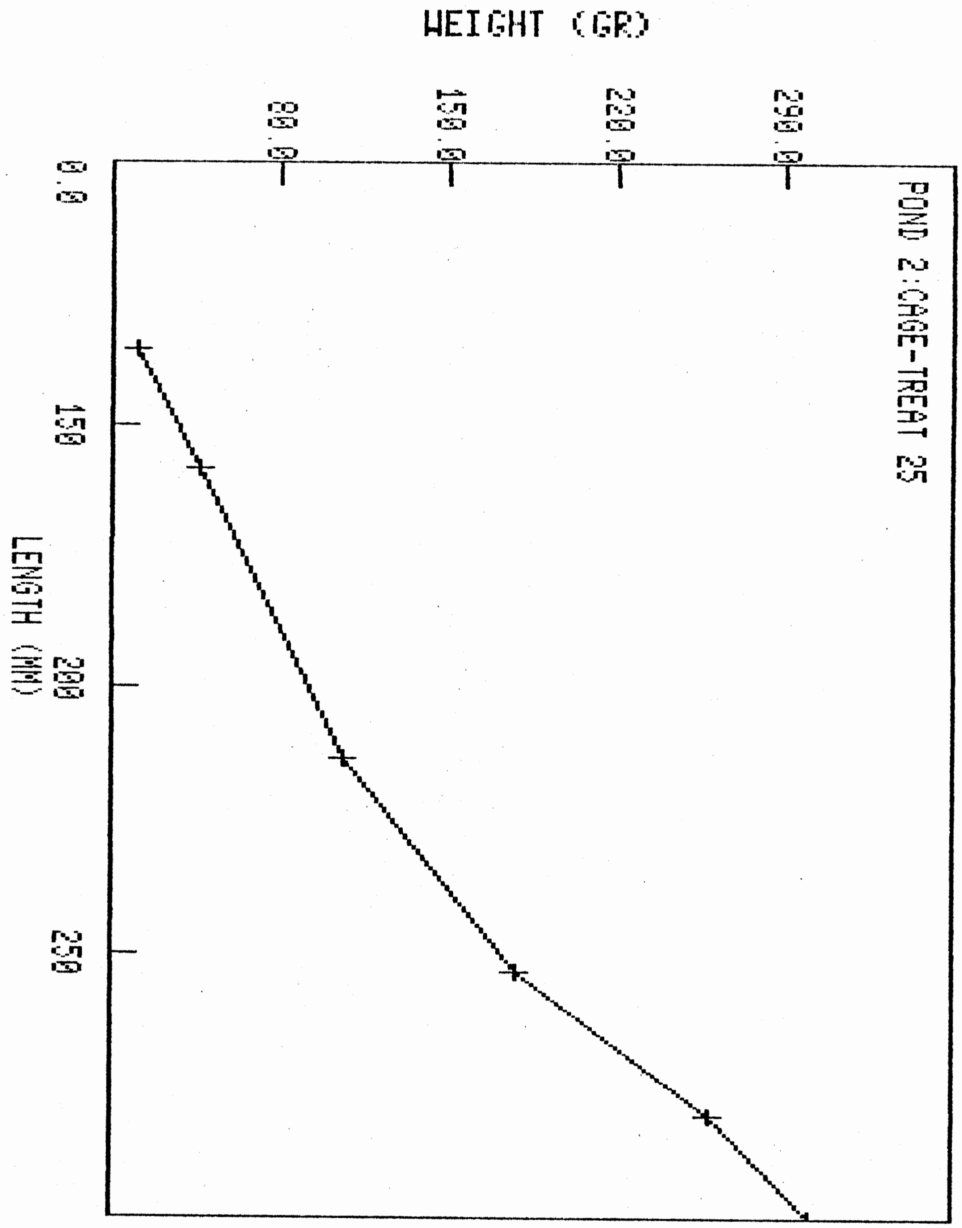

WEIGHT (GR)
80.0
150.0
220.0
290.0
0.0
150
200
250
LENGTH (MM)
POND 2:CAGE-TREAT 25

Figure 19. Relationship between total weight and mean total length for channel catfish in treatment 50 (number of tilapia) at pond 2.

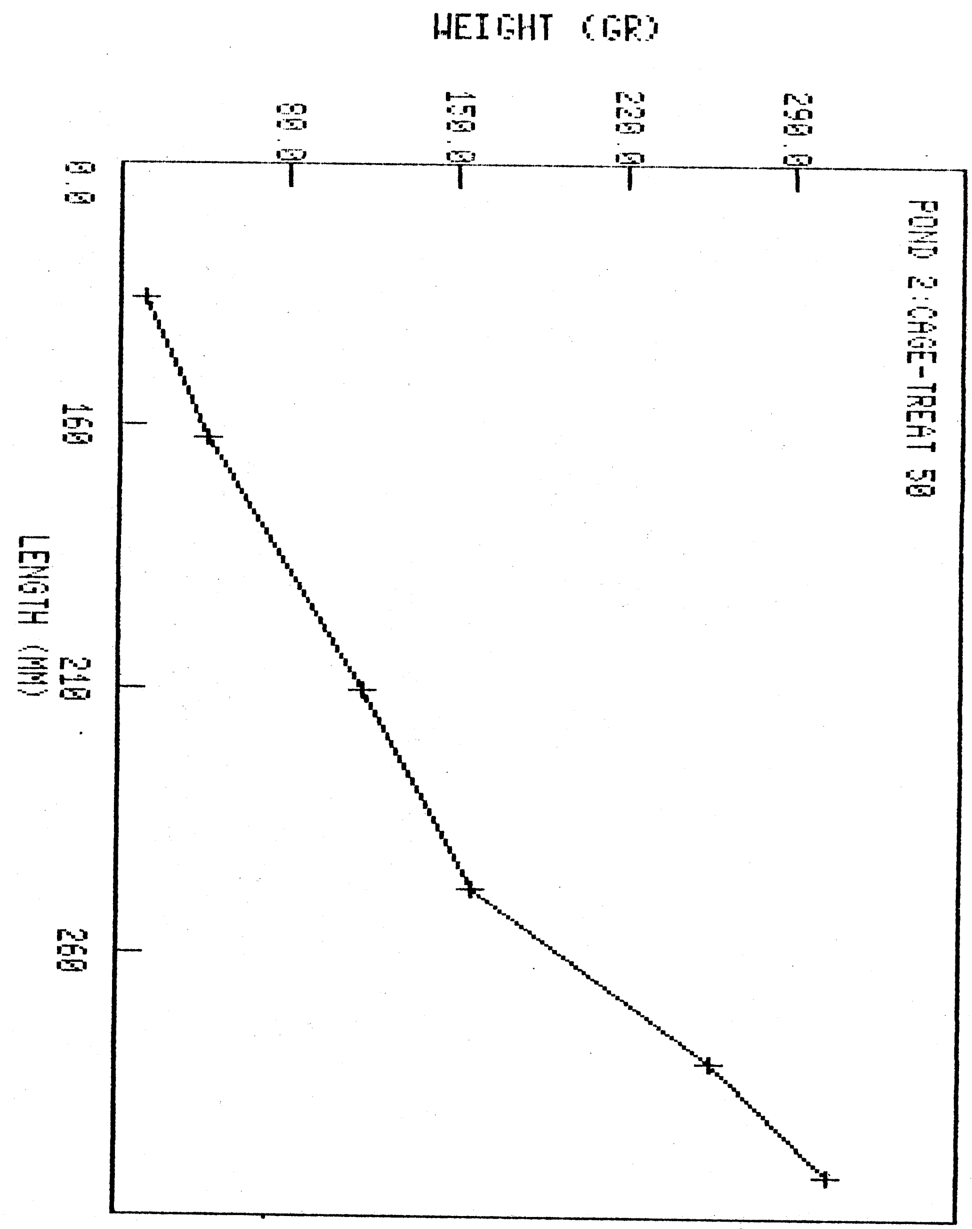
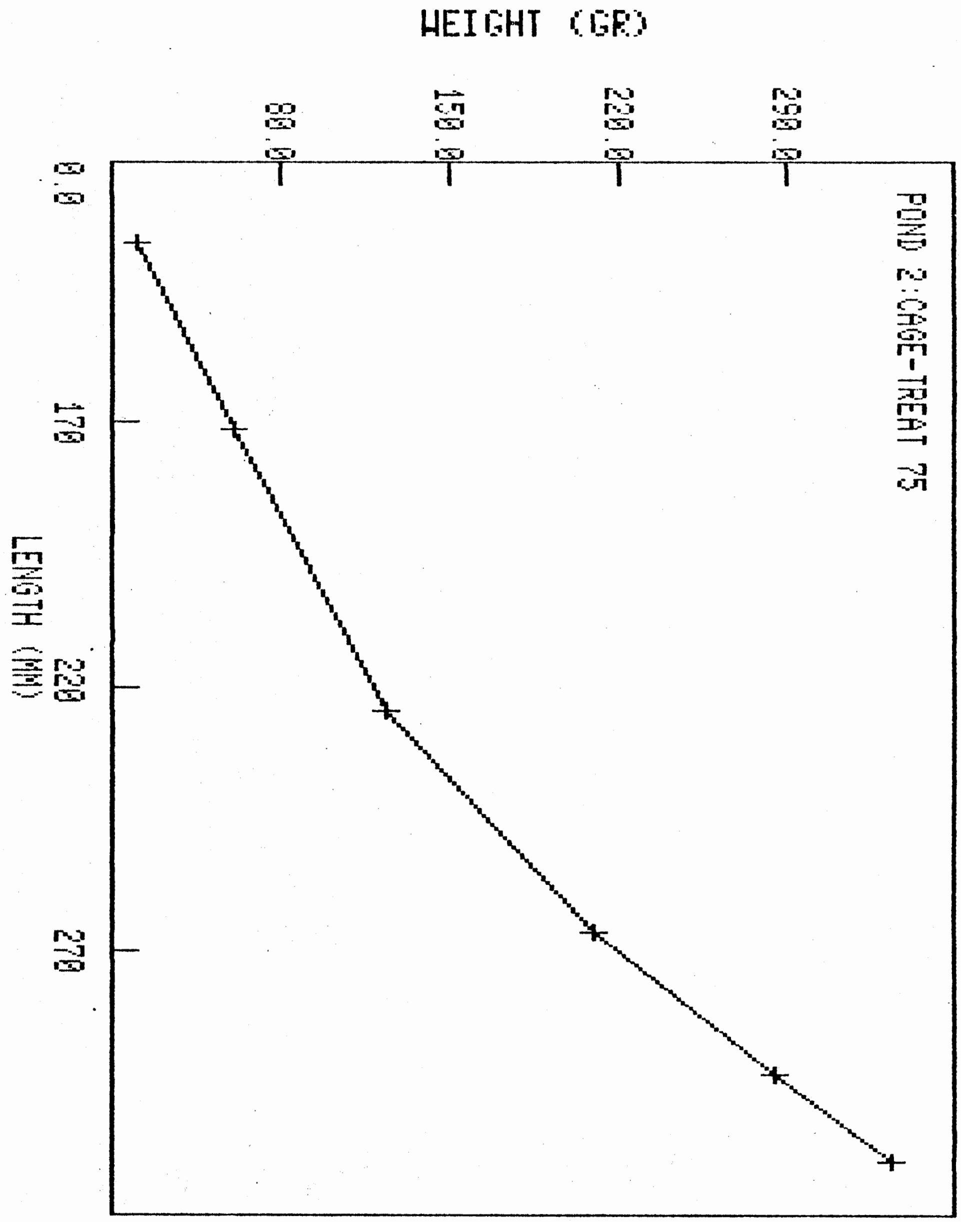

WEIGHT (GR)
80.0
150.0
220.0
290.0
POND 2:CAGE-TREAT 50
0.0
160
210
260
LENGTH (MM)

Figure 20. Relationship between total weight and mean total length for channel catfish in treatment 75 (number of tilapia) at pond 2.



WEIGHT (GR)
80.0
150.0
220.0
290.0
POND 2:CAGE-TREAT 75
0.0
170
220
270
LENGTH (MM)

Figure 21. Relationship between total weight and mean total length for channel catfish in treatment 0 (number of tilapia) at pond 3.

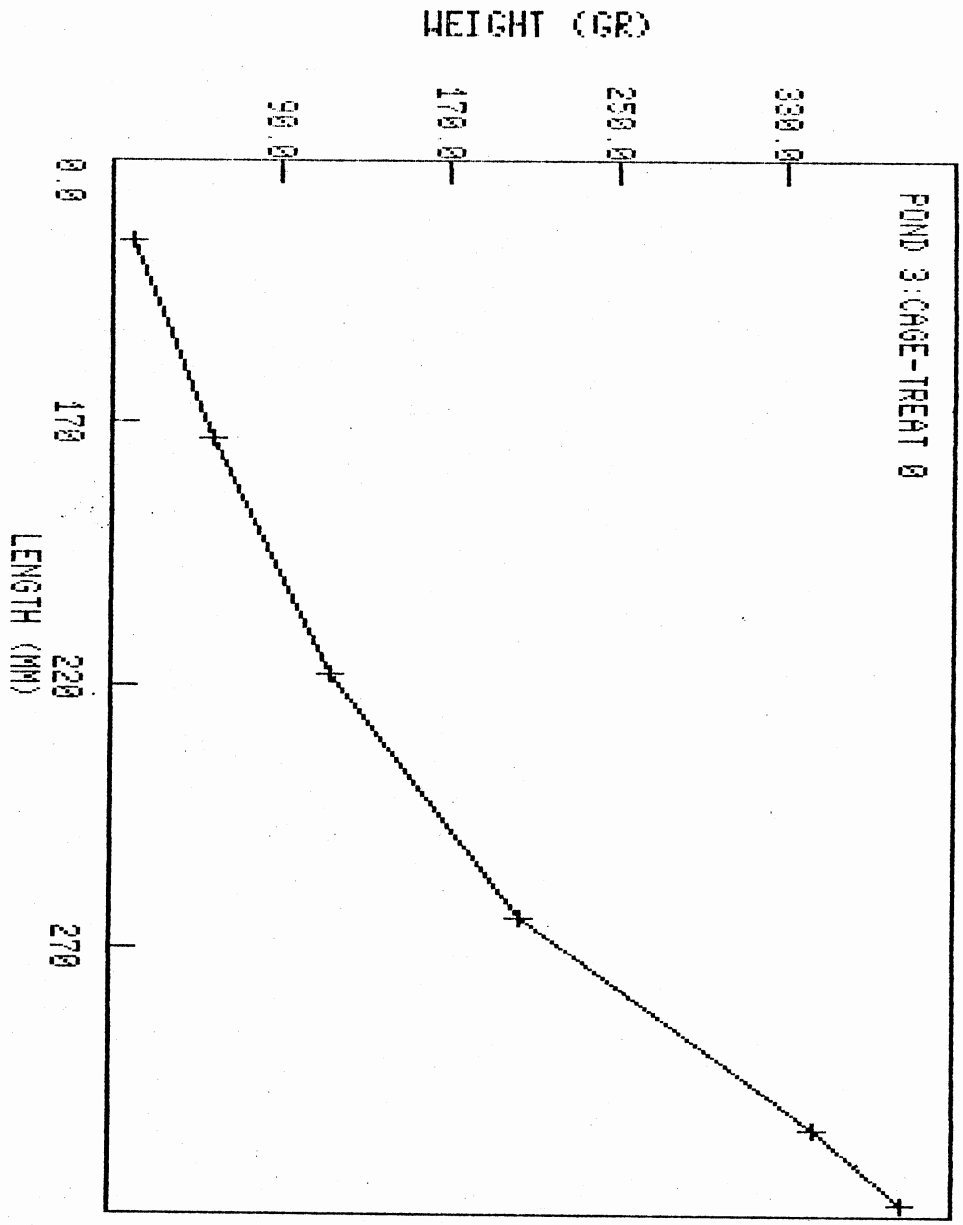

POND 3:CAGE-TREAT 0
WEIGHT (GR)
90.0
170.0
250.0
330.0
0.0
170
220
270
LENGTH (MM)

Figure 22. Relationship between total weight and mean total length for channel catfish in treatment 25 (number of tilapia) at pond 3.

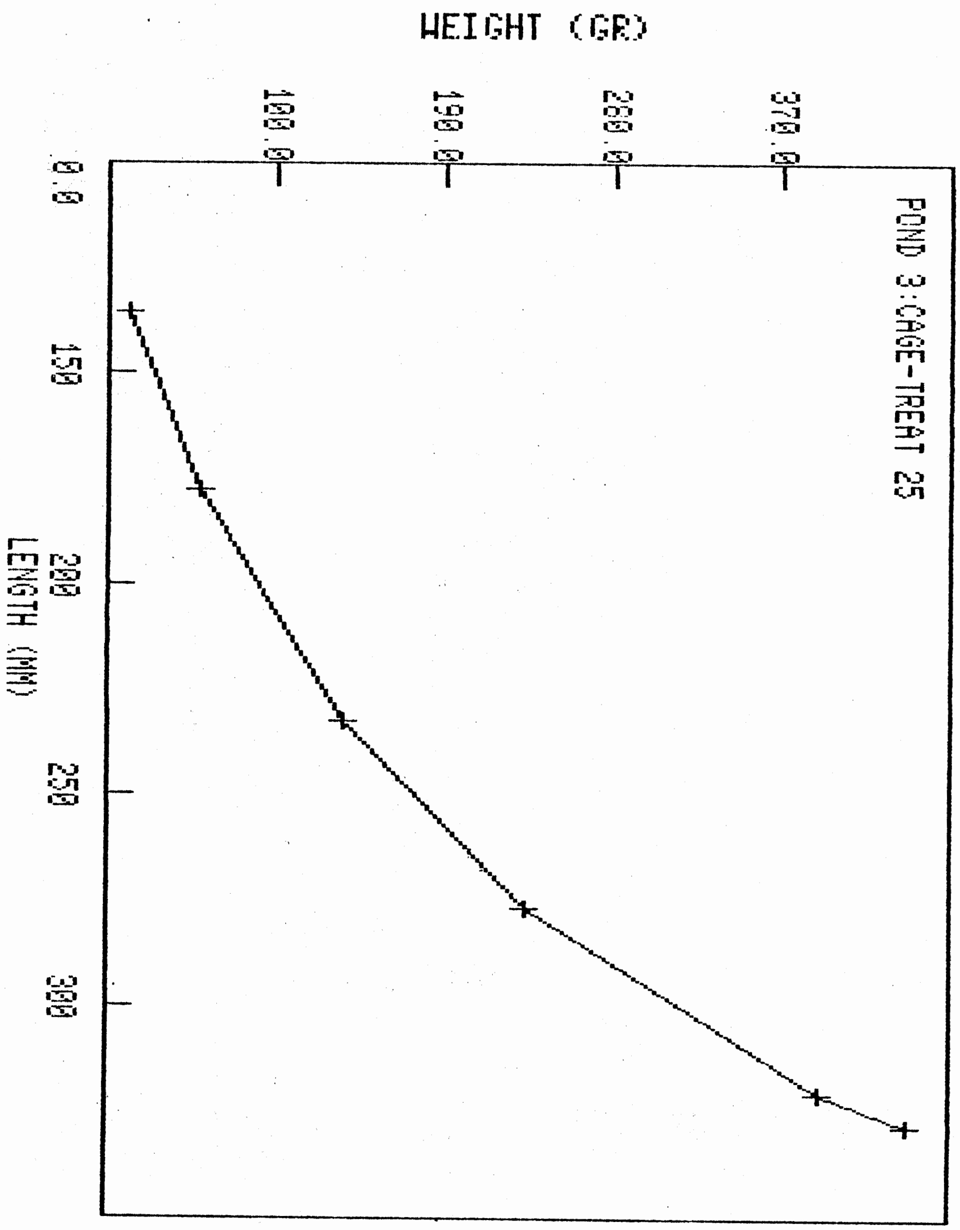

POND 3:CAGE-TREAT 25
WEIGHT (GR)
0.0
100.0
190.0
280.0
370.0
150
200
250
300
LENGTH (MM)

Figure 23. Relationship between total weight and mean total length for channel catfish in treatment 50 (number of tilapia) at pond 3.

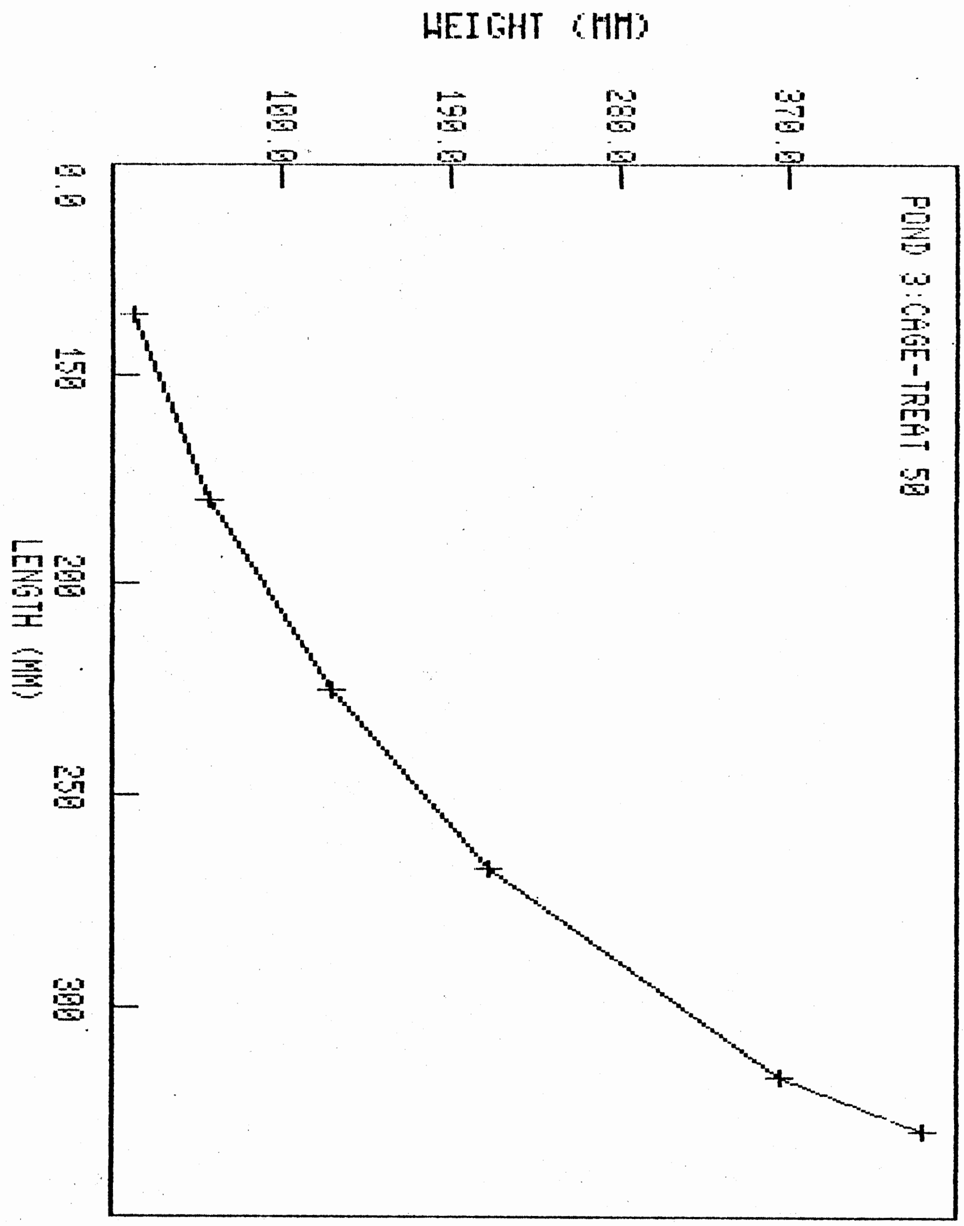

POND 3:CAGE-TREAT 50
WEIGHT (MM)
370.0
280.0
190.0
100.0
0.0
150
200
250
300
LENGTH (MM)

Figure 24. Relationship between total weight and mean total length for channel catfish in treatment 75 (number of tilapia) at pond 3.

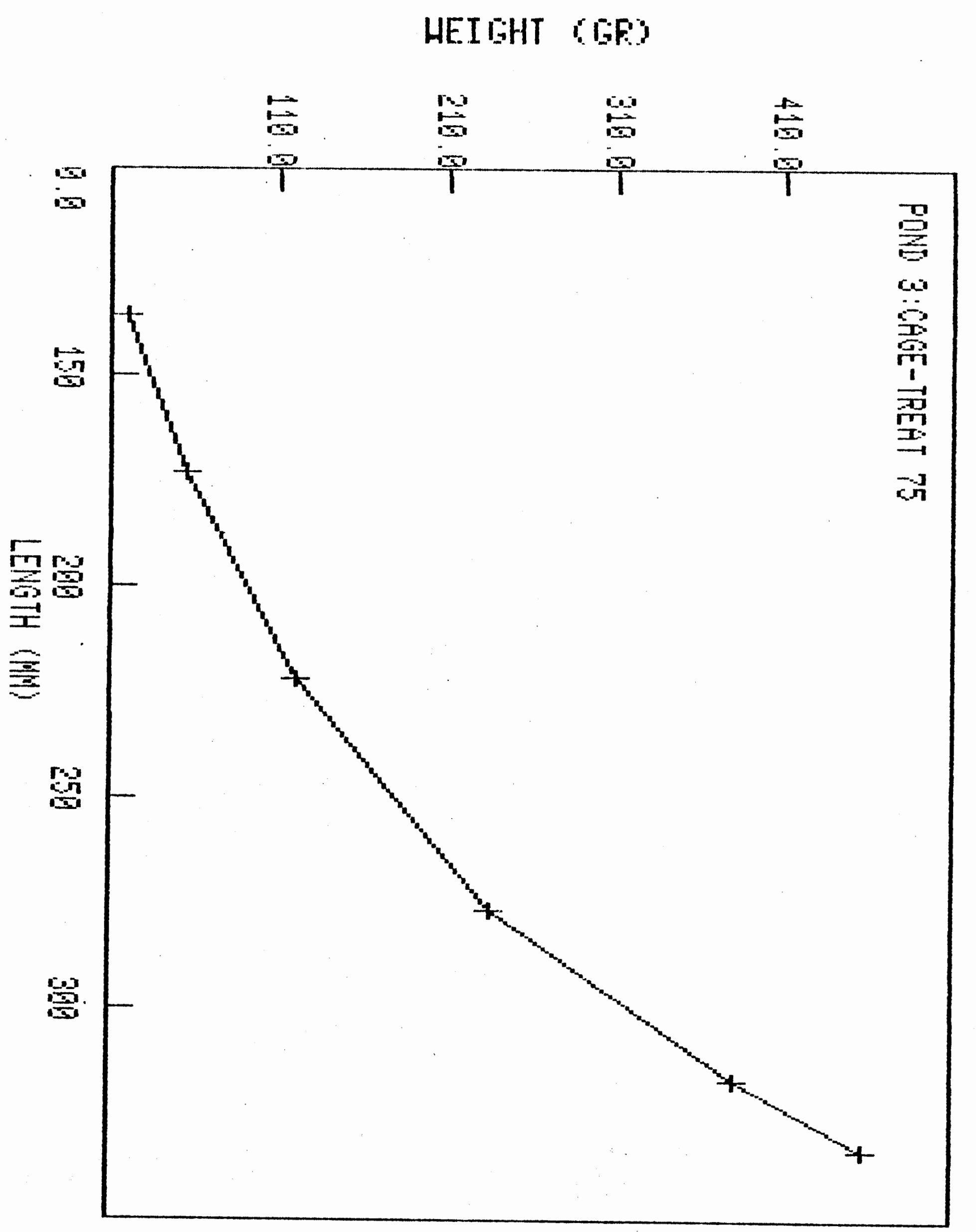

POND 3:CAGE-TREAT 75
WEIGHT (GR)
410.0
310.0
210.0
110.0
0.0
150
200
250
300
LENGTH (MM)

Figure 25. Estimated values of the weight/length constant (Θ) for channel catfish in treatments 0, 25, 50, and 75 (number of tilapia) at pond 1.

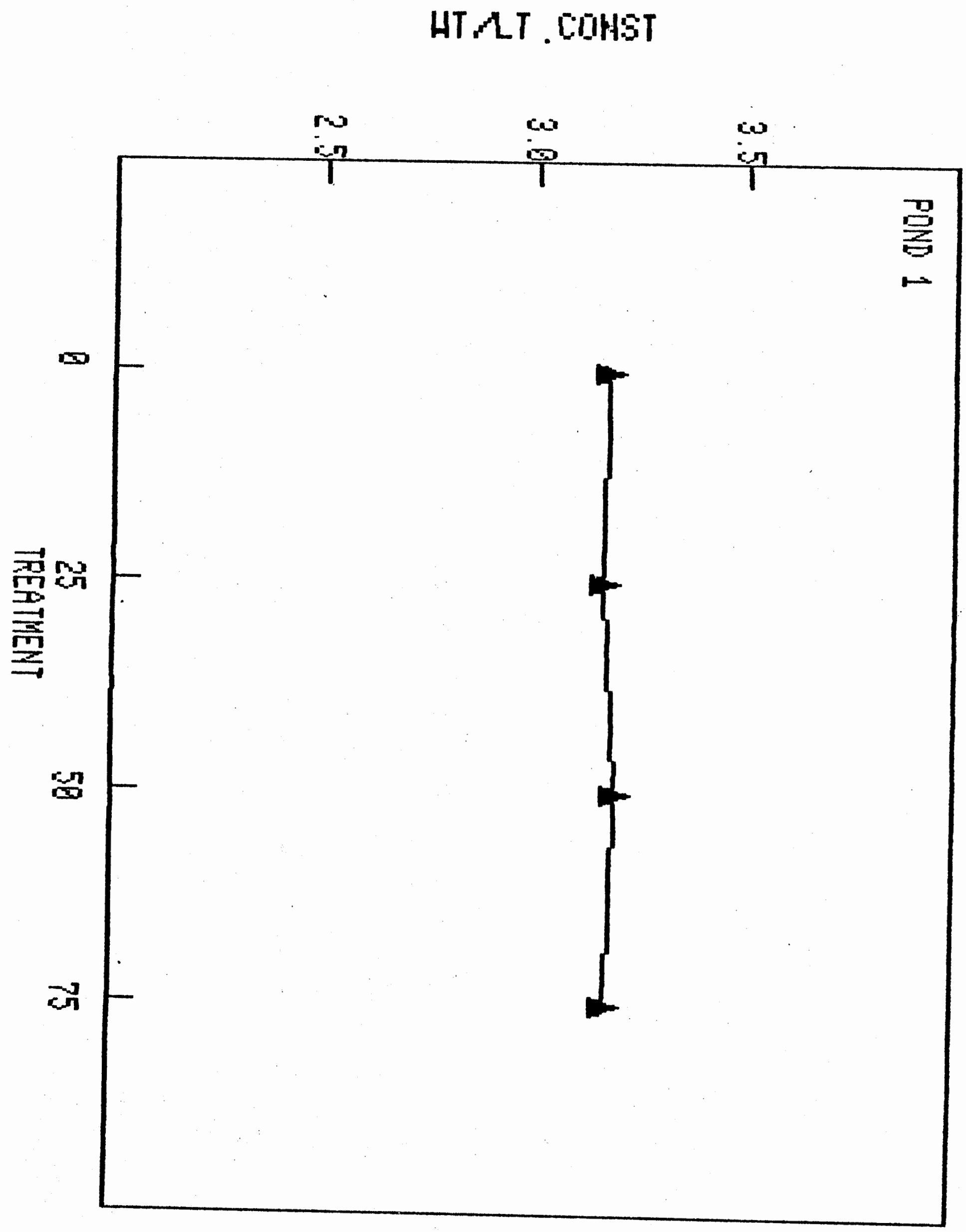

WT/LT.CONST
POND 1
2.5
3.0
3.5
0
25
50
75
TREATMENT

Figure 26. Estimated values of the weight/length constant (Θ) for channel catfish in treatments 0, 25, 50, and 75 (number of tilapia) at pond 2.

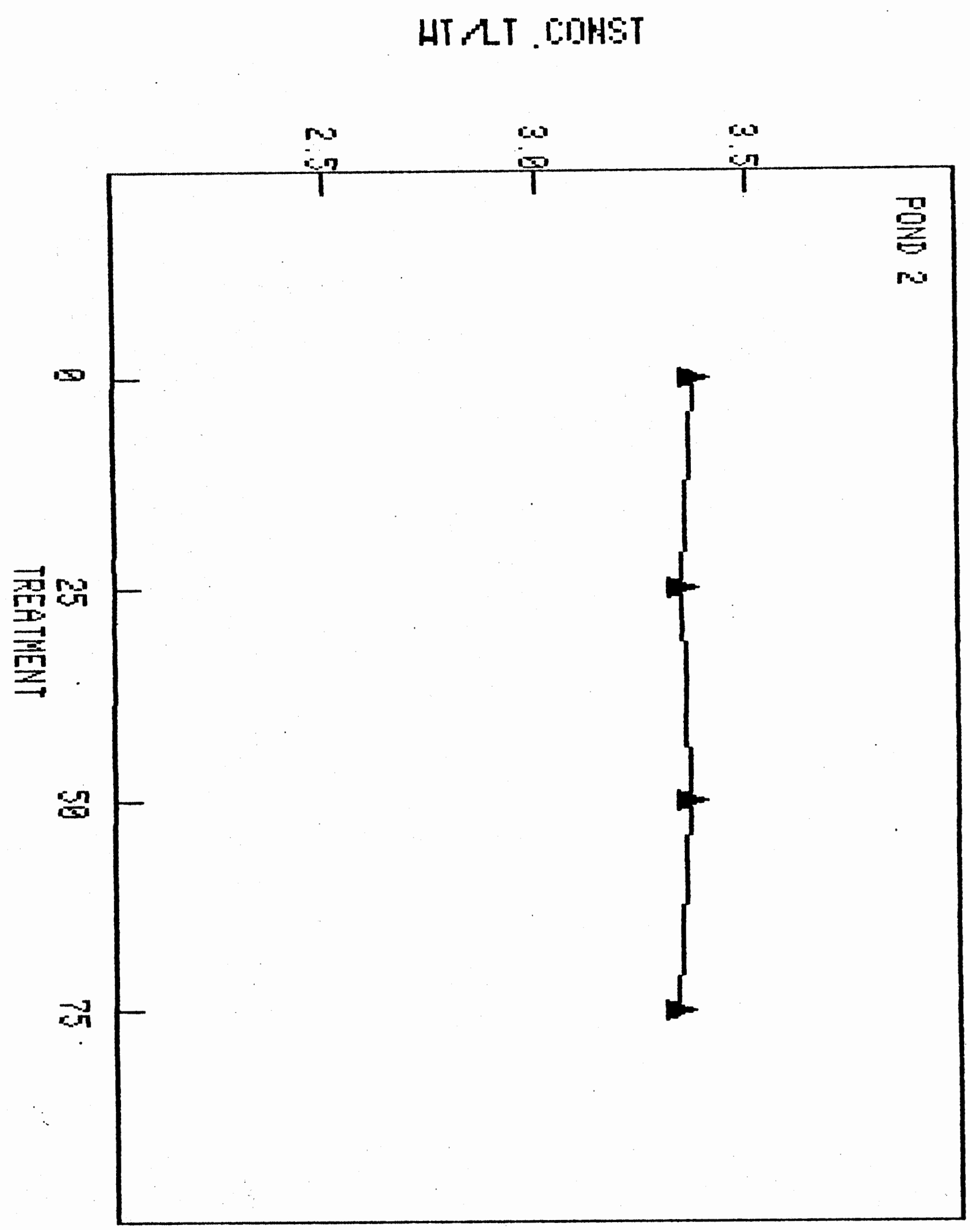

WT/LT.CONST
POND 2
2.5
3.0
3.5
0
25
50
75
TREATMENT

Figure 27. Estimated values of the weight/length constant (Θ) for channel catfish in treatments 0, 25, 50, and 75 (number of tilapia) at pond 3.

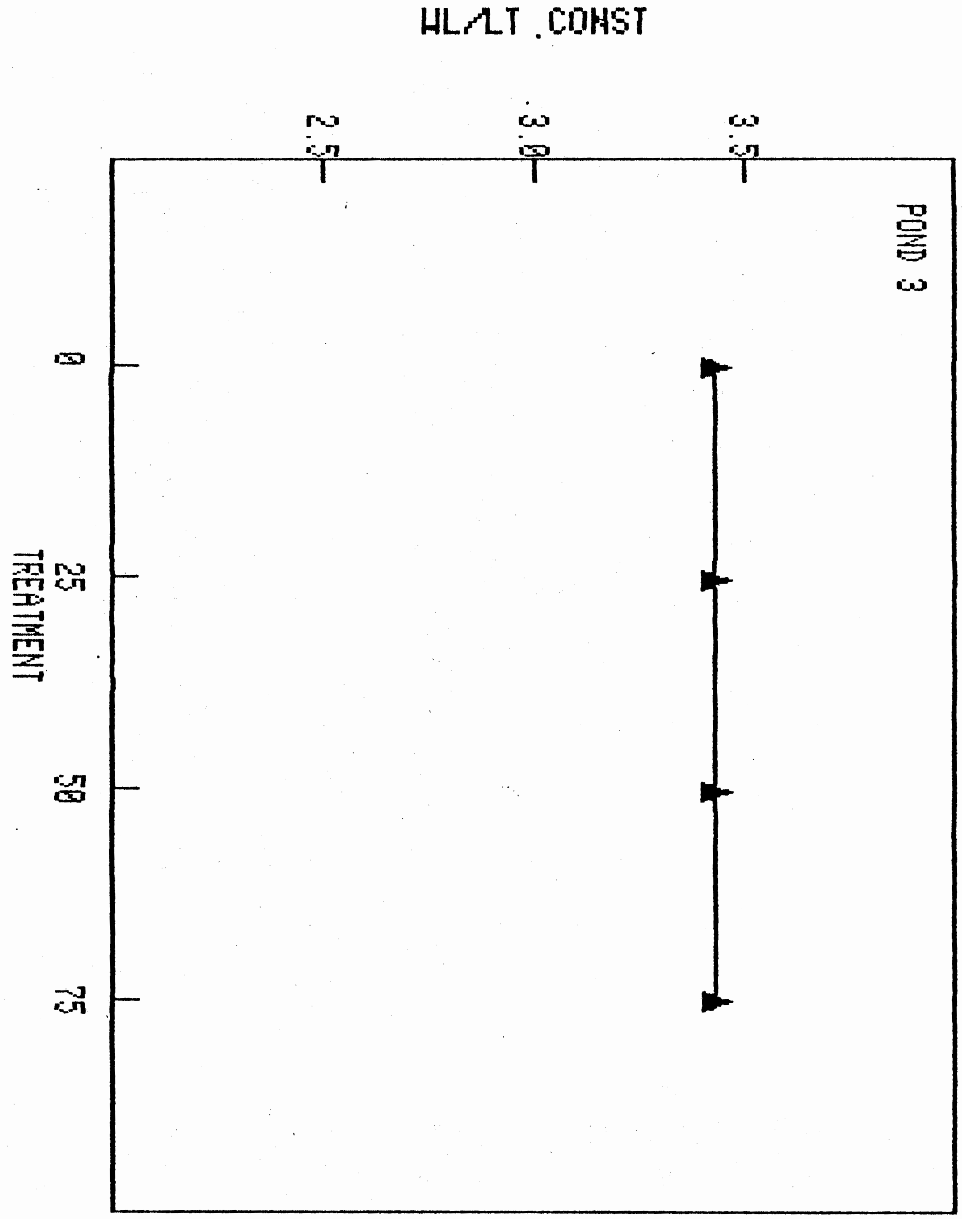

WL/LT .CONST
POND 3
2.5
3.0
3.5
0
25
50
75
TREATMENT

Figure 28. Estimated values of the "corrected" condition factor ($\overline{\phi} \cdot 10^{-6}$) for channel catfish in treatments 0, 25, 50, and 75 (number of tilapia) at pond 1.

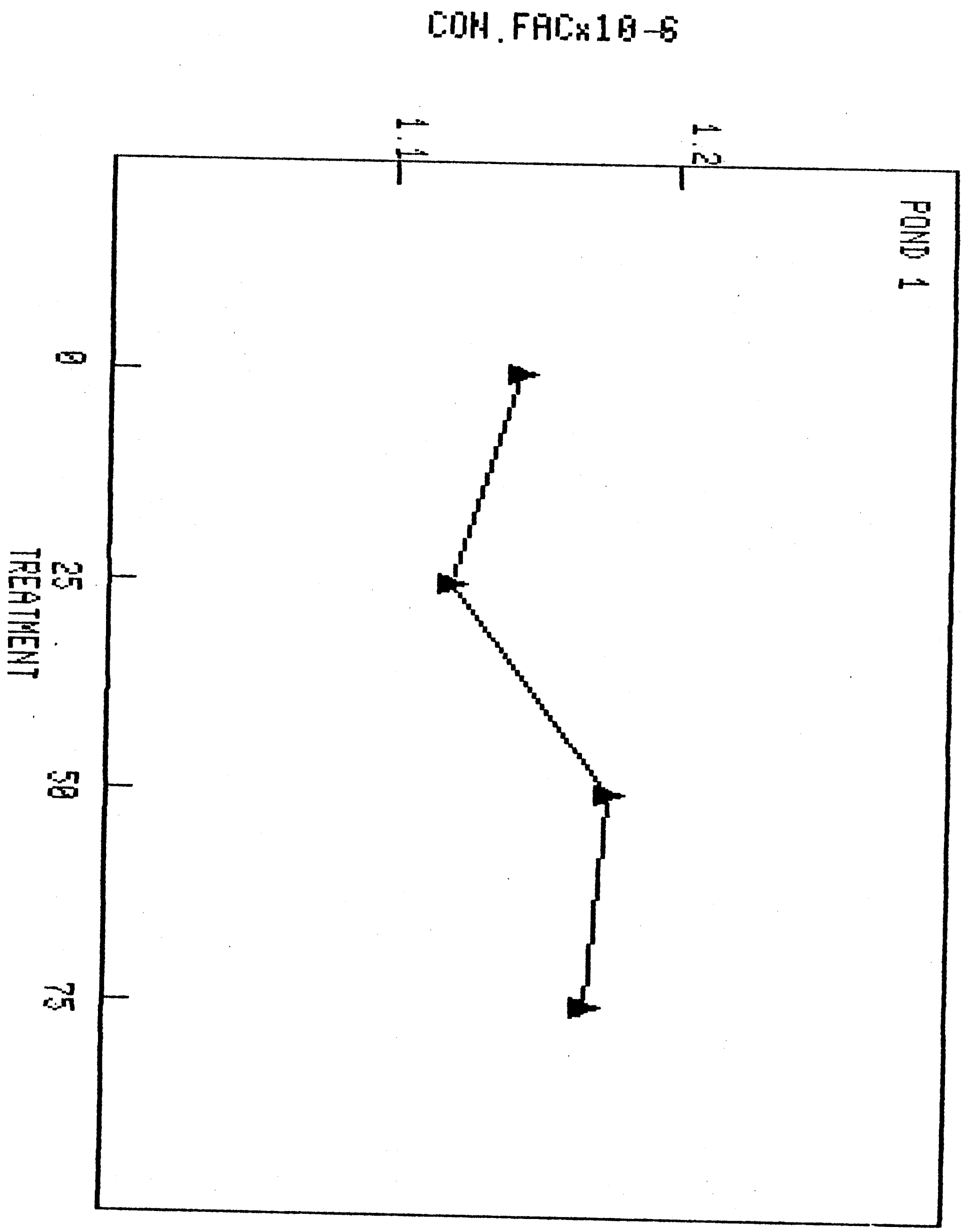

CON.FACx10-6
1.1
1.2
POND 1
0
25
50
75
TREATMENT

Figure 29. Estimated values of the "corrected" condition factor ($\overline{\phi} \cdot 10^{-6}$) for channel catfish in treatments 0, 25, 50, and 75 (number of tilapia) at pond 2.

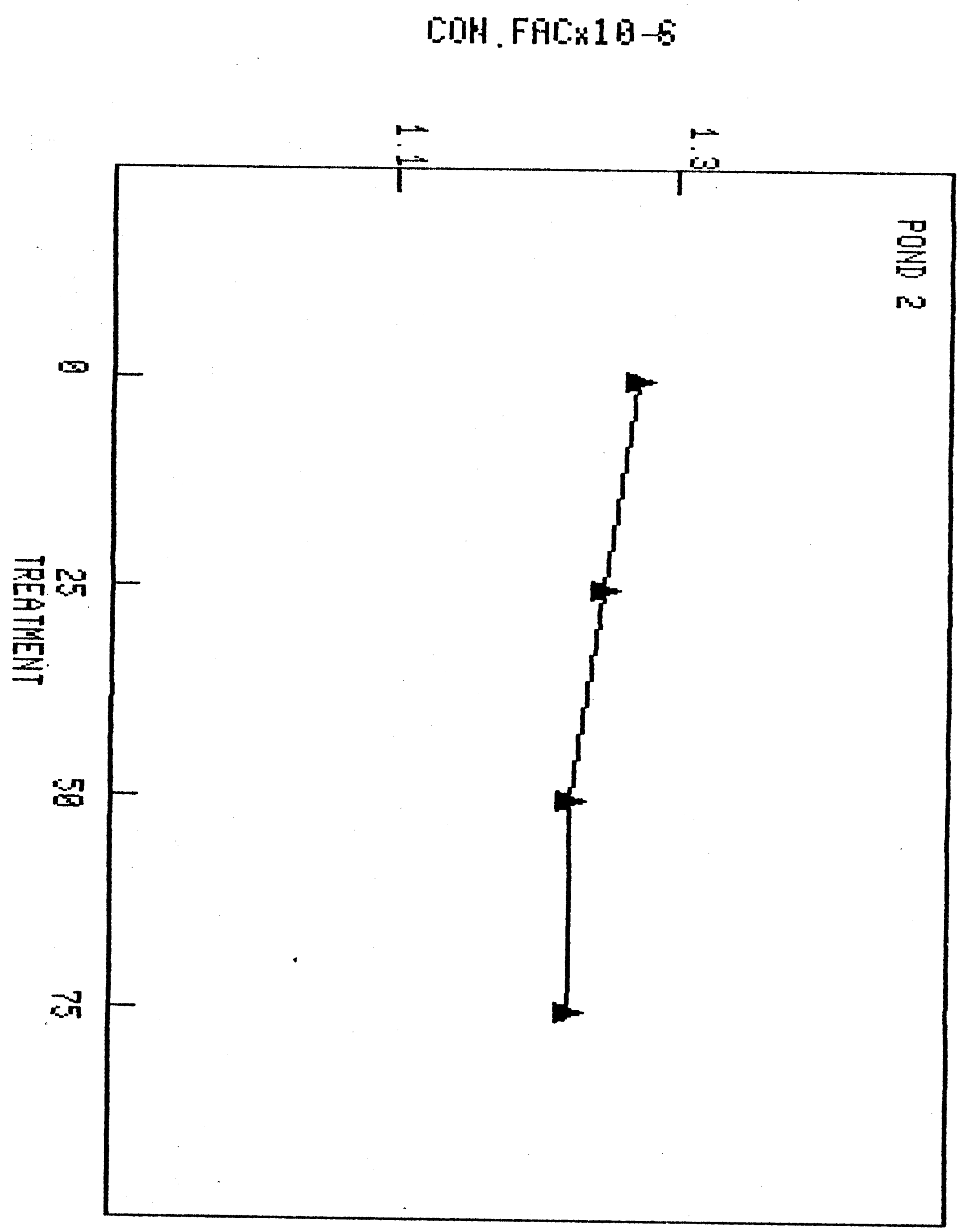
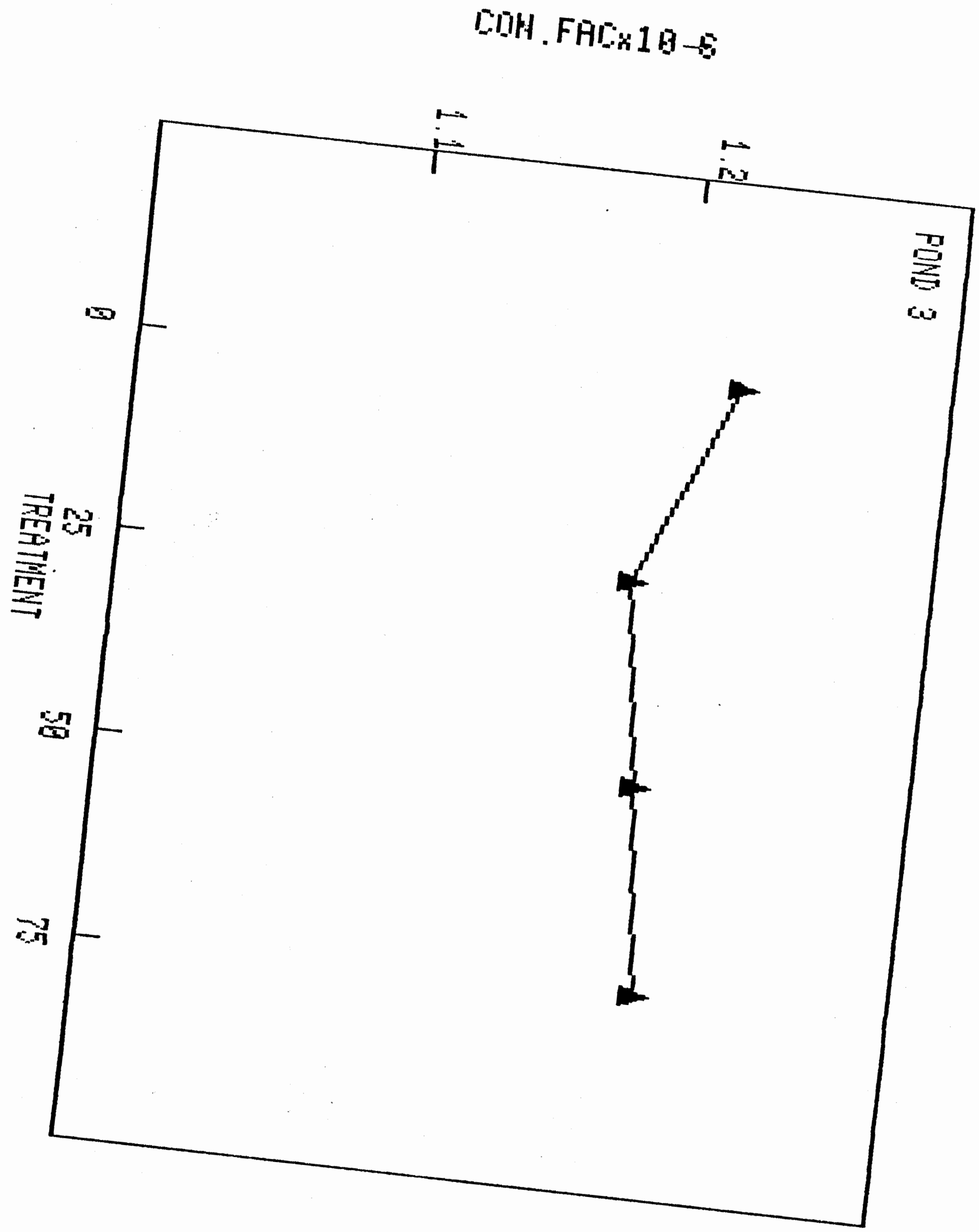

CON.FACx10-6
1.1
1.3
POND 2
0
25
50
75
TREATMENT

Figure 30. Estimated values of the "corrected" condition factor ($\overline{\phi} \cdot 10^{-6}$) for channel catfish in treatments 0, 25, 50, and 75 (number of tilapia) at pond 3.


CON.FACx10-6
1.1
1.2
POND 3
0
25
50
75
TREATMENT

However, in pond 3 (Table 6, Appendix A, Figures 40-42) it was observed that in the last two months of culture, the condition factors in all treatments tended to increase.

The mean condition factors (Table 7) of the treatments ranged in this experiment from a high 3.514×10^{-6} to a low 1.88×10^{-6}. In addition, the mean corrected values of the condition factor (Table 7) ranged from 1.101×10^{-6} to 1.249×10^{-6}.

Growth Curve in length

The linear transformation of FORD-WALFORD (Walford 1946) of these data followed the relationship predicted by Von Bertalanffy's adjusted expression (Santos 1978) for channel catfish growth curve in length (Tables 8 and 9). The comparison of these data with the linear relationship between relative length (L_T*) and relative time (T*) and the mathematical expression of growth in length (Table 10, Appendix B, Figures 43-54) showed excellent agreement between the predicted theoretical values and the empirical data ($r > 0.9$).

The predicted LMAX for my data ranged from 364.19 mm to 649.09 mm. In ponds 1 and 3 the largest predicted LMAX values occurred in the treatment with 400 channel catfish and 75 tilapia. In pond 2 the largest LMAX value occurred in the treatment with 400 channel catfish and 50 tilapia. However, overall the largest values for both theoretical predictions and the empirical data occurred in the treatment with 400 channel catfish and 75 tilapia for the entire culture period (140 days). In this experiment LMAX and K were inversely related among treatments in each pond.

Table 8. Equations for the mean total weight/mean total length relationship and the linear regression or the logarithms of W_T of L_T for each treatment.

Pond	Treat	$W_T = \Phi \cdot L_T^{\Theta}$	$\ln W_T = \ln \Phi + \Theta \cdot \ln L_T$
1	0	$\overline{W}_T = 3.852 \times 10^{-6} \cdot \overline{L}_T^{3.167}$	$\ln \overline{W}_T = -12.41 + 3.167 \cdot \ln \overline{L}_T$
1	25	$\overline{W}_T = 4.047 \times 10^{-6} \cdot \overline{L}_T^{3.155}$	$\ln \overline{W}_T = -12.42 + 3.155 \cdot \ln \overline{L}_T$
1	50	$\overline{W}_T = 3.514 \times 10^{-6} \cdot \overline{L}_T^{3.189}$	$\ln \overline{W}_T = -12.56 + 3.189 \cdot \ln \overline{L}_T$
1	75	$\overline{W}_T = 4.047 \times 10^{-6} \cdot \overline{L}_T^{3.152}$	$\ln \overline{W}_T = -12.42 + 3.162 \cdot \ln \overline{L}_T$
2	0	$\overline{W}_T = 1.497 \times 10^{-6} \cdot \overline{L}_T^{3.366}$	$\ln \overline{W}_T = -13.41 + 3.366 \cdot \ln \overline{L}_T$
2	25	$\overline{W}_T = 1.790 \times 10^{-6} \cdot \overline{L}_T^{3.331}$	$\ln \overline{W}_T = -13.23 + 3.331 \cdot \ln \overline{L}_T$
2	50	$\overline{W}_T = 1.580 \times 10^{-6} \cdot \overline{L}_T^{3.352}$	$\ln \overline{W}_T = -13.36 + 3.352 \cdot \ln \overline{L}_T$
2	75	$\overline{W}_T = 1.884 \times 10^{-6} \cdot \overline{L}_T^{3.320}$	$\ln \overline{W}_T = -13.18 + 3.320 \cdot \ln \overline{L}_T$
3	0	$\overline{W}_T = 1.031 \times 10^{-6} \cdot \overline{L}_T^{3.430}$	$\ln \overline{W}_T = -13.78 + 3.430 \cdot \ln \overline{L}_T$
3	25	$\overline{W}_T = 0.980 \times 10^{-6} \cdot \overline{L}_T^{3.430}$	$\ln \overline{W}_T = -13.83 + 3.430 \cdot \ln \overline{L}_T$
3	50	$\overline{W}_T = 1.035 \times 10^{-6} \cdot \overline{L}_T^{3.427}$	$\ln \overline{W}_T = -13.78 + 3.427 \cdot \ln \overline{L}_T$
3	75	$\overline{W}_T = 1.074 \times 10^{-6} \cdot \overline{L}_T^{3.420}$	$\ln \overline{W}_T = -13.74 + 3.420 \cdot \ln \overline{L}_T$

Table 9. Equations for the regression of the FORD-WALFORD transformations $[L_{(T+\Delta T)} = f(L_T)]$, the relationship between relative length (L_T*) and relative time (T*), and the estimated linear correlation coefficient (r) for each treatment.

Pond	Treat	Linear regression between L_T and $L_{(T+\Delta T)}$	r	Linear regression between $L^* = \ln\frac{(LMAX - L_T)}{LMAX}$ and T*	r
1	0	$\bar{L}_{(T+\Delta T)} = 52.58 + 0.861\ \bar{L}_T$	0.98007	$L_T^* = -0.42329 - 0.15897\ T^*$	0.99193
1	25	$\bar{L}_{(T+\Delta T)} = 42.09 + 0.923\ \bar{L}_T$	0.97293	$L_T^* = -0.27640 - 0.08323\ T^*$	0.99261
1	50	$\bar{L}_{(T+\Delta T)} = 55.70 + 0.847\ \bar{L}_T$	0.96989	$L_T^* = -0.45030 - 0.17257\ T^*$	0.99339
1	75	$\bar{L}_{(T+\Delta T)} = 39.56 + 0.937\ \bar{L}_T$	0.99103	$L_T^* = -0.24486 - 0.06249\ T^*$	0.99747
2	0	$\bar{L}_{(T+\Delta T)} = 46.03 + 0.919\ \bar{L}_T$	0.98635	$L_T^* = -0.26510 - 0.08862\ T^*$	0.99603
2	25	$\bar{L}_{(T+\Delta T)} = 54.51 + 0.897\ \bar{L}_T$	0.97256	$L_T^* = -0.28060 - 0.11557\ T^*$	0.99343
2	50	$\bar{L}_{(T+\Delta T)} = 48.98 + 0.924\ \bar{L}_T$	0.98633	$L_T^* = -0.22630 - 0.08291\ T^*$	0.99663
2	75	$\bar{L}_{(T+\Delta T)} = 68.49 + 0.846\ \bar{L}_T$	0.98513	$L_T^* = -0.35190 - 0.17590\ T^*$	0.99550
3	0	$\bar{L}_{(T+\Delta T)} = 62.98 + 0.879\ \bar{L}_T$	0.98578	$L_T^* = -0.28760 - 0.13750\ T^*$	0.99453
3	25	$\bar{L}_{(T+\Delta T)} = 76.79 + 0.832\ \bar{L}_T$	0.97903	$L_T^* = -0.32990 - 0.19696\ T^*$	0.99133
3	50	$\bar{L}_{(T+\Delta T)} = 68.91 + 0.865\ \bar{L}_T$	0.98409	$L_T^* = -0.29196 - 0.15255\ T^*$	0.99404
3	75	$\bar{L}_{(T+\Delta T)} = 64.41 + 0.889\ \bar{L}_T$	0.98345	$L_T^* = -0.25011 - 0.12570\ T^*$	0.99384

Table 10. Equation for the growth curve in length ($\bar{L}_T$) for each treatment of caged channel catfish in each pond.

Pond	Treat	Growth Curve in length : $\bar{L}_T$ = LMAX $[1 - e^{-K(T + TE)}]$
1	0	$\bar{L}_T = 379.88\ [1 - e^{-0.15894(T + 2.66)}]$
1	25	$\bar{L}_T = 546.01\ [1 - e^{-0.08250(T + 3.33)}]$
1	50	$\bar{L}_T = 364.19\ [1 - e^{-0.17257(T + 2.61)}]$
1	75	$\bar{L}_T = 632.43\ [1 - e^{-0.06249(T + 3.92)}]$
2	0	$\bar{L}_T = 566.19\ [1 - e^{-0.08860(T + 2.99)}]$
2	25	$\bar{L}_T = 527.89\ [1 - e^{-0.11557(T + 2.43)}]$
2	50	$\bar{L}_T = 646.09\ [1 - e^{-0.08290(T + 2.72)}]$
2	75	$\bar{L}_T = 443.65\ [1 - e^{-0.17590(T + 2.00)}]$
3	0	$\bar{L}_T = 519.19\ [1 - e^{-0.13750(T + 2.09)}]$
3	25	$\bar{L}_T = 458.06\ [1 - e^{-0.19696(T + 1.67)}]$
3	50	$\bar{L}_T = 512.55\ [1 - e^{-0.15255(T + 1.91)}]$
3	75	$\bar{L}_T = 580.67\ [1 - e^{-0.12570(T + 1.99)}]$

Growth Curve in Weight

Equation 2.17a was used to estimate the values of WMAX (maximum mean weight that channel catfish can reach under intensive culture) for each treatment. The mathematical equation for the growth curve in weight was then developed (Tables 11-13, Appendix C, Figures 55-66) utilizing the deductive method of Santos (1978). There was excellent agreement between the empirical data and the predicted theoretical values of growth in weight ($r > 0.9$).

The estimated WMAX values ranged from 590.08 g to 4,393.84 g. In ponds 1 and 3 the largest WMAX values occurred in the treatment with 400 channel catfish and 75 blue tilapia. In pond 2 the largest WMAX occurred in the treatment with 400 channel catfish and 50 tilapia. In addition, within each pond the WMAX values showed the same inverse relationship with K that was observed for LMAX values.

In this experiment, the heaviest fish were obtained in the treatment that had 400 catfish and 75 tilapia (Tables 1-3). The largest theoretical weights were also predicted for fish in the cages containing 400 channel catfish and 75 tilapia. However, the empirical weight values were quite variable. The average weight values for individual fish in ponds 1, 2 and 3 were 197.93 g, 368.17 g, and 492.28 g, respectively. The differences between fish in this treatment in ponds 1 and 3 was 294.35 g, and in ponds 2 and 3 was 124.11 g. The percentage of harvestable size fish (catfish with weight equal or greater than 340 g) also varied within treatments among ponds. Harvestable fish made up 0%, 45%, and 90% in ponds 1, 2, and 3, respectively (Table 4).

Table 11. Equation for the growth curve in weight ($\overline{W}_T$) for caged channel catfish for each treatment in each pond.

Pond	Treat	Growth Curve in weight : W_T = WMAX $[1 - e^{-K(T + TE)}]^{\Theta}$
1	0	$\overline{W}_T = 665.09\ [1 - e^{-0.15894(T + 2.66)}]^{3.401}$
1	25	$\overline{W}_T = 2244.79\ [1 - e^{-0.08250(T + 3.33)}]^{3.401}$
1	50	$W_T = 590.09\ [1 - e^{-0.17257(T + 2.61)}]^{3.401}$
1	75	$\overline{W}_T = 3836.04\ [1 - e^{-0.06249(T + 3.92)}]^{3.401}$
2	0	$\overline{W}_T = 2880.53\ [1 - e^{-0.08860(T + 2.99)}]^{3.401}$
2	25	$\overline{W}_T = 2238.65\ [1 - e^{-0.11557(T + 2.43)}]^{3.401}$
2	50	$\overline{W}_T = 4393.80\ [1 - e^{-0.08290(T + 2.72)}]^{3.401}$
2	75	$\overline{W}_T = 1223.90\ [1 - e^{-0.17590(T + 2.00)}]^{3.401}$
3	0	$\overline{W}_T = 2098.13\ [1 - e^{-0.13750(T + 2.09)}]^{3.401}$
3	25	$\overline{W}_T = 1333.31\ [1 - e^{-0.19696(T + 1.67)}]^{3.401}$
3	50	$\overline{W}_T = 1967.01\ [1 - e^{-0.15255(T + 1.91)}]^{3.401}$
3	75	$\overline{W}_T = 3028.46\ [1 - e^{-0.12570(T + 1.99)}]^{3.401}$

Table 12. Equation for the yield curve (Y_T) of caged channel catfish for each treatment in each pond.

Pond	Treat	Yield Curve : $W_T = R \cdot S^T \cdot WMAX\ [1 - e^{-K(T + TE)}]^{\Theta}$
1	0	$Y_T = 400 \cdot (0.9980^T) \cdot 665.09\ (1 - e^{-0.15894\ (T + 2.66)}]^{3.401}$
1	25	$Y_T = 400 \cdot (0.9866^T) \cdot 2244.79\ (1 - e^{-0.08250\ (T + 3.33)}]^{3.401}$
1	50	$Y_T = 400 \cdot (0.9818^T) \cdot 590.09\ (1 - e^{-0.98180\ (T + 2.61)}]^{3.401}$
1	75	$Y_T = 400 \cdot (0.9551^T) \cdot 3836.04\ (1 - e^{-0.06249\ (T + 3.92)}]^{3.401}$
2	0	$Y_T = 400 \cdot (0.9914^T) \cdot 2880.53\ (1 - e^{-0.08860\ (T + 2.99)}]^{3.401}$
2	25	$Y_T = 400 \cdot (0.9478^T) \cdot 2238.65\ (1 - e^{-0.11557\ (T + 2.43)}]^{3.401}$
2	50	$Y_T = 400 \cdot (0.9989^T) \cdot 4393.80\ (1 - e^{-0.08290\ (T + 2.72)}]^{3.401}$
2	75	$Y_T = 400 \cdot (0.9995^T) \cdot 1223.90\ (1 - e^{-0.17590\ (T + 2.00)}]^{3.401}$
3	0	$Y_T = 400 \cdot (0.9984^T) \cdot 2098.13\ (1 - e^{-0.13750\ (T + 2.09)}]^{3.401}$
3	25	$Y_T = 400 \cdot (0.9970^T) \cdot 1333.31\ (1 - e^{-0.19696\ (T + 1.67)}]^{3.401}$
3	50	$Y_T = 400 \cdot (0.9944^T) \cdot 1967.01\ (1 - e^{-0.15255\ (T + 1.91)}]^{3.401}$
3	75	$Y_T = 400 \cdot (0.9980^T) \cdot 3028.46\ (1 - e^{-0.12570\ (T + 1.99)}]^{3.401}$

Table 13. Predicted values for population characteristics of channel catfish (methods of calculation following Santos 1978).

Pond	Treat	LMAX (mm)	K	TE	Total Θ	$\Phi \cdot 10^{-6}$	WMAX (gr)	M	S_T	Ym (gr)	TYm (month)	YGI
1	0	379.88	0.15894	2.66	3.401	1.12068	665.09	0.002	0.9980	246057	32.06	7557.56
1	25	546.01	0.08250	3.33	3.401	1.10138	2244.79	0.013	0.9866	486547	33.8	14374.70
1	50	364.19	0.17257	2.61	3.401	1.14765	590.09	0.018	0.9818	153861	17.7	8712.20
1	75	632.43	0.06249	3.92	3.401	1.14175	3836.03	0.046	0.9551	265530	23.7	11184.00
2	0	566.19	0.08860	2.99	3.401	1.24923	2880.53	0.009	0.9914	756266	37.3	20248.20
2	25	527.89	0.11557	2.43	3.401	1.23200	2238.65	0.110	0.8960	119146	10.7	11096.01
2	50	646.09	0.08290	2.72	3.401	1.21623	4393.84	0.001	0.999	1626367	65.3	24894.20
2	75	443.65	0.17590	2.00	3.401	1.21660	1223.90	0.001	0.999	478899	38.3	12511.33
3	0	519.09	0.13750	2.09	3.401	1.22178	2098.13	0.001	0.999	781998	39.7	19713.62
3	25	458.06	0.19696	1.67	3.401	1.18887	1333.31	0.003	0.997	485863	25.8	18854.82
3	50	512.25	0.15255	1.91	3.401	1.19665	1967.01	0.006	0.994	649485	27.9	23303.45
3	75	580.67	0.12570	1.99	3.401	1.19665	3028.46	0.002	0.998	1098609	40.7	27006.67

Yield Curve

The yield curve for each treatment, the mortality index, monthly survival, maximum yield, time of maximum yield, and yield index are shown in Tables 12, 13, and Appendix D, Figures 67-78. Data from the treatment with 400 catfish and 25 tilapia in pond 2 were biased because an unknown predator (probably a turtle) made holes in the cage and allowed large numbers of channel catfish and tilapia to escape (Table 4). As a result, the determination of the yield curve, mortality index, monthly survival, maximum yield, time of maximum yield, an the yield gain index for this treatment were affected. The data were used in analysis in spite of these difficulties.

The estimated maximum yield (Ym) ranged from 119,146.00 g to 1,626,367.70 g. As was seen for LMAX and WMAX, Ym values were highest in ponds 1 and 3 for the treatment with 400 channel catfish and 75 blue tilapia. In pond 2 the highest Ym value was in the treatment with 400 channel catfish and 50 blue tilapia (Table 13). However, the yield gain index (YGI) predicted the highest yield over all ponds in cages containing 400 catfish and 75 tilapia.

Empirical data for the entire culture period showed the highest actual yield in ponds 2 and 3 in the treatment with 400 catfish and 75 tilapia. In pond 1 the highest yield occurred in the treatment with 400 channel catfish and 25 tilapia.

CHAPTER IV

DISCUSSION

The quantitative techniques outlined by Santos (1978) for aquaculture have not previously been used in the United States. However, South American fisheries biologists have published several works that have utilized this methodology (Silva 1975; Costa and Rocha 1978; Cruz and Araujo 1978; Pinheiro et al. 1978; Silva et al. 1978; Melo et al. 1979; Pereira 1980; Peret 1980; Verani 1980). In addition, South American crustacean biologists (Borges 1979; Verani et al. 1980) have also used the procedure of Santos (1978).

In spite of this wide usage in South America there is no information that applies directly to channel catfish. Consequently, this discussion is limited to the results obtained in this research and cannot be compared with data from similar works.

Since 1979, Langston University, the Oklahoma Cooperative Fishery Reserch Unit, and Oklahoma State University (Maughan et al. 1981; Williams 1982) have been conducting research on small scale caged fish culture. This research has focused on the growth of channel catfish alone or associated with other species like blue tilapia. The principal emphasis has been on food conversion, cage design, and management practices. My work has focused on the application of principles used in population dynamics to the rearing of channel catfish under caged culture conditions and the development of estimates of important population parameters. These parameters will be valuable tools that will permit improved fish culture in Brazil and also be useful to extension agents and fish farmers.

Total Weight/Total Length Relationship

The weight/length relationship (Cushing 1970; Weatherley 1972; Verani 1980) is generally used to:

1) determine the timing and duration of gonadal development;
2) estimate the mean weight of the population given mean length;
3) measure the condition of the population resulting from alterations in the food supply; and
4) compare two or more monospecific populations.

In the expression $\overline{W}_T = \phi \cdot \overline{L}_T^{\Theta}$ (equation 2.1) the weight/length relationship constant (Θ) can vary by region, life stage, and sex. However, Θ is usually relatively constant within a species under similar conditions (Le Cren 1951; Cushing 1970; Weatherley 1972). In the great majority of the fish species values of Θ range from 2.5 to 4.0, and for fish species with isometric growth the value of Θ is approximately 3.0 (Le Cren 1951; Weatherley 1966; Santos 1978).

In this research Θ varied only slightly from 3. Variation was probably related to characteristics of the species, and slightly different environmental conditions between ponds (Table 14, Figures 25-27).

The close agreement between the predicted Θ and my calculated Θ indicated high reliability for the procedures outlined by Santos (1978). In addition, the agreement gives impetus for greater use of the procedures as a predictive model for caged fish channel catfish

Table 14. Mean monthly dissolved oxygen, temperature (mean derived from a weekly average of surface, mid-cage, and bottom of the cage readings), pH, and Secchi disk visibility.

Pond	Date	Mean dissolved oxygen ± stand deviation (mg/l)*	Mean temperature (°C) ± stand deviation*	Mean pH ± stand deviation*	Mean Secchi disk (cm) ± stand deviation
1	Jun	4.14 ± 1.45	24.84 ± 2.41	7.54 ± 0.29	47.5 ± 15.00
1	Jul	5.64 ± 0.89	29.03 ± 0.58	8.23 ± 0.22	87.5 ± 22.17
1	Aug	6.94 ± 0.49	26.24 ± 1.24	8.32 ± 0.53	115.0 ± 10.00
1	Sep	6.12 ± 0.68	24.31 ± 2.90	7.55 ± 0.31	78.75 ± 10.31
1	Oct	5.98 ± 0.61	19.85 ± 3.41	7.28 ± 0.39	112.5 ± 12.58
2	Jun	5.49 ± 1.22	26.64 ± 1.90	8.05 ± 0.04	52.50 ± 5.00
2	Jul	4.93 ± 0.47	28.68 ± 0.48	8.45 ± 0.05	107.50 ± 5.00
2	Aug	6.28 ± 0.44	25.83 ± 2.04	8.60 ± 0.14	172.50 ± 32.02
2	Sep	5.15 ± 0.72	24.63 ± 2.77	7.63 ± 0.31	140.00 ± 8.16
2	Oct	5.34 ± 1.84	20.03 ± 3.31	7.35 ± 0.92	110.00 ± 8.16

Table 14. Continued.

Pond	Date	Mean dissolved oxygen ± stand deviation (mg/l)*	Mean temperature (°C) ± stand deviation*	Mean pH ± stand deviation*	Mean Secchi disk (cm) ± stand deviation
3	Jun	6.02 ± 0.51	25.99 ± 1.81	8.09 ± 0.01	45.00± 19.15
3	Jul	5.85 ± 0.40	28.37 ± 0.55	8.75 ± 0.10	80.00± 14.14
3	Aug	6.69 ± 0.60	25.52 ± 1.32	8.70 ± 0.32	85.00± 17.32
3	Sep	6.95 ± 0.84	24.19 ± 2.89	8.28 ± 0.17	87.50± 22.17
3	Oct	6.87 ± 1.83	20.04 ± 3.18	7.50 ± 0.78	95.00± 19.15

culture in Brazil.

The condition factor (Φ) values as obtained in my experiment did not distinguish between males and females, and did not allow measurement of individual variation weight and length. Weatherley (1972) has determined the principal differences in condition factor in mature males and females and immature fish were attributable to their sexual cycle. In addition, condition factor can also vary because of differences in biological characteristics such as fat condition, gonadal development, or environmental acclimation. These biological factors can in turn be affected by environmental conditions, parasite level, food supply, and isometric growth or allometric growth (Le Cren 1951; Verani 1980).

In this research, variations observed in condition factors had a different pattern than those cited by Verani (1980) for Sarotherodon niloticus. In my study condition factor increased at the beginning of the experiment but generally decreased from the second month to the end of the culture period. In pond 1, this decrease progressed to such an extent that condition factors at harvest were smaller than at stocking (Appendix A, Figures 31-34). The lowest overall treatment yield all occurred in this pond. The most probable explanation of low condition factor and yield in pond 1 is that the farmer fed fish only on alternate days. Randolph and Clemens (1976) have reported that alternate day feeding required two days in which feed was obtained in order to return to the pre-deprivation rate of growth. Williams (1982) has also pointed out that alternate day feeding in regions with short growing seasons might result in a large number of sub-harvestable fish.

In pond 2, condition factors showed the same trend as in pond 1, but fish were in better condition at harvest than at stocking

(Appendix A, Figures 35-38). In this pond the farmer fed the fish 6 days per week, and the numbers of harvestable fish were higher than in pond 1.

In pond 3, conditions showed the same initial trend as in pond 1 and 2 (Appendix A, Figures 39-42), but then generally increased in the last two months of the study. Values at harvest were close to those found in the second month of the study. Fish in this pond were fed daily and had the highest overall yield. In addition, this pond had the highest number of harvestable fish, and the best estimated (experiment design precluded verification of actual food consumed by each species) food conversions (Table 3 and 4).

In summary, the between pond condition factor reflected the management practice of the pond owner and should be considered on a relative and not an absolute basis.

Growth Curve in Length

The theoretical mean total length values (Table 2) demonstrated excellent agreement with the empirical mean total length values found in this research (Table 1). However, the theoretical LMAX values found in this study had no relationship with the actual fish lengths observed (Appendix E, Figures 79-81). In open water conditions, LMAX has been shown to vary directly with maximum length reached during culture, species ratio, and predator-prey ratio (Costa and Rocha 1978; Pinheiro et al. 1978; Borges 1979; Verani 1980). The differences between my results and those of other workers may have resulted from the special conditions inherent in caged fish culture, primarily the short growing season (5-6 months in Oklahoma). However, further studies should be performed.

Several reports have suggested that LMAX is affected by factors such as food supply and density (Beverton and Holt 1957; Cushing 1970;Weatherley 1972), while K is genetically or physiologically determined. In addition, it is known that there is a mathematical interaction between these two factors. Unfortunately, there is no literature on the evaluation of this interaction.

LMAX and K have not previously been determined for channel catfish under caged culture conditions. Therefore, additional studies and research are needed to determine how LMAX and K vary with different conditions.

Growth Curve in Weight

The determination of growth in weight is extremely important in intensive aquaculture, because: [1] growth in weight determines the yield curve; and [2] the growth curve estimates theoretical values of total mean weight ($\overline{W}_T$) at any time during the culture cycle (T). In addition, given the growth curve in weight, caged fish growth under the same environmental conditions but under different density, type of rations, feeding rates, species ratios, species growth, cage design, and management practices can be predicted.

As a result of this research, intensive aquaculture and caged fish culture in Brazil will have reliable tools to compare and analyze population data, to determine the best cage culture combinations, and to predict time to harvest to obtain optimal weights in caged fish farming (Santos 1978; Verani 1980). In addition, the results found in this study can be extended and utilized by extension agents in Brazil to improve fish culture techniques, increase food production, and, consequently, raise the fish farmers' income.

The theoretical mean total weight values found in this study (Table 2) showed close agreement with the empirical mean total weight values (Table 1). Nevertheless, theoretical WMAX values had no relationship with empirical length data found in this research (Appendix F, Figures 82-84). However, as can be seen (Tables 1 and 2), the theoretical growth curve followed precisely the empirical points, and the maximum theoretical weight was directly correlated with the maximum weight attained in the experiment (Tables 1 and 2). Therefore, the theoretical growth curve in weight seems to be verified by the growth performance attained in this experiment (Appendix C, Figures 55-66).

Since these analyses have not previously been performed for caged catfish, more data must be obtained in order to verify the results of this experiment.

Yield Curve

The yield curve is one of the most important components of quantitative analysis for intensive fish farming. With this curve it is possible to estimate the theoretical maximum yield, as well as, the optimum time to harvest to obtain maximum production. Santos (1978) has pointed out that the greatest challenge in intensive fish farming is to maximize initial density, initial age, type of rations, fertilization levels and types, temperature, pH, oxygen level, aeration, ration components, etc., in order to reach the maximum yield, at the minimum time.

In pond 2 in the cage with 400 catfish and 50 tilapia (Table 13) the projected maximum theoretical yield would not be reached for 65.3 months. Obviously an in-pond-time of over 5 years is not economically practical and therefore one must attempt to maximize production but minimize time. The yield gain index can be used to obtain information of this type. Therefore for the fish farmer, analysis of the yield curve, based on the yield gain index is very important. In the cage in pond 3 containing 400 catfish and 75 tilapia, the theoretical yield gain index was closely approximated by the empirical data. In this context, the YGI can give valuable and practical information for the decision-making process. Nevertheless, the yield gain index like other parameters of population dynamics must be considered on a relative basis with other components of the system.

As can be seen in this experiment, the quantitative analysis of the dynamics of channel catfish can give useful information. This information if correctly used will allow one to maximize yield and to minimize cost and time required for caged fish culture. In the future, the information obtained in this research will be tested in Brazil, in particular the community reservoirs of Northeast Brazil.

The unique nature of this research does not allow extensive comparison with data from similar works. I hope that the methodology utilized in this experiment and the data developed will be tested against similar data for different conditions, areas, countries, etc. I hope that in the near future the programs and equations developed in this research will allow fish farming, and intensive aquaculture to have a stronger background for serious, predictable, economic activities.

CHAPTER V

SUMMARY

Quantitative analysis of the population dynamics of caged channel catfish will permit one to maximize yield and to minimize cost and time required for caged fish culture, as well as, to allow fish farming, and intensive aquaculture to have a stronger background for serious, predictable, economic activities.

In spite of this wealth of informations that can be obtained by quantitative analysis, there has been no study on the population dynamics of fish species under cage culture conditions. These analyses are extremely important in understanding and predicting the performance of caged fish.

In this study, four ratios of Tilapia aurea, 0 tilapia, 25 tilapia, 50 tilapia, and 75 tilapia were raised for 140 days in 1 m^3 cages with 400 channel catfish. Each experiment was replicated in 3 ponds. In all cages, the total weight/total length relationship of channel catfish followed the mathematical expression $\overline{W}_T = \phi \cdot \overline{L}_T^{\Theta}$ (equation 2.1) predicted by Santos (1978). The mean condition factor of the treatments ranged in this experiment from a high 3.514×10^{-6} to a low 1.88×10^{-6}. In addition, the mean corrected condition factor ranged from 1.101×10^{-6} to 1.249×10^{-6}.

The mathematical expressions of growth in length and in weight showed excellent agreement between the predicted theoretical values and the empirical data. The estimated LMAX values ranged from 364.19 mm to 649.09 mm, and the predicted WMAX values from 590.08 g to 4,393.84 g in this study. In addition, within each pond LMAX and WMAX values showed inverse relationships with K values.

The yield curve for each treatment, the mortality index, monthly survival, maximum yield, time of maximum yield, and yield gain index were developed. The yield gain index predicted the highest yield over all ponds in cages containing 400 channel catfish and 75 tilapia.

The unique nature of this study does not allow extensive comparison with data from similar works. Therefore, it is suggested that additional studies and reseach must be performed to verify the results of this experiment. The information obtained in this study will be tested in the community reservoirs of northeast Brazil.

LITERATURE CITED

Ambrester, W., Jr. 1972. The growth of caged Tilapia aurea (Steindachner) in fertile farm ponds. Proc. Ann. Conf. Southeast. Assoc. Game Fish Comm. 25:446-441.

Bertalanffy, L. Von. 1938. A quantitative theory of organic growth. Human Biology 10(2):181-213.

Beverton, R. J. M., and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fishery Investment, London. 533 pp.

Borges, G. A. 1979. Aspectos quantitativos do cultivo do camarao *Panaeus* (Melicestus) *brasiliensis* (Latreille, 1817) em viveiro. Dissertaçao de Mestrado. Departamemto de Ciencias Biologicas, Universidade Federal de Sao Carlos. Sao Paulo, Brasil. 63 pp.

Bowman, D. B. 1977. A comparison of *Tilapia mossambica* (Peters) and *Tilapia aurea* (Steindachner) as pond fishes in El Salvador, Central America. Unpublished M.S. Thesis, Oklahom State University, Stillwater. 53 pp.

Boyd, C. E. 1979. Water quality in warmwater fish ponds. Craftmaster Printers, Inc., Opelika, Alabama. 359 pp.

Brown, E. E. 1969. The fresh water cultured fish industry of Japan. University Georgia, College Agri. Exp. Stations, Research Report 41. 11 pp.

Collins, C. M. 1978. Catfish cage culture. Publ. 13, Kerr Foundation, Inc., Poteau, Oklahoma. 22.

Collins, R. A. 1971. Cage culture of catfish in reservoir lakes. Proc. Ann. Conf. Southeast. Assoc. Game Fish Comm. 24:489-496.

Costa, F. J. C. B., and F. P. Rocha. 1978. Aspectos quantitativos do cultivo de tainha (Mugil curema Vallenciannes, 1836), Itamarace-PE, Resumo do I Simp. Bras. de Aquicultura. Recife, UFRPE/SUDENE. 1:14-17.

Cremer, C. M., and R. O. Smitherman. 1980. Food habits and growth of silver and bighead carp in cages and ponds. Aquaculture 20:57-64.

Cruz, J. F., and R. A. Araujo. 1978. Cultivo experimental de tainha (Mugil curema Vallenciannes, 1836). Resumo do I Simp. Bras. de Aquiculture. Recife, UFRPE/SUDEPE 1:81-82.

Cushing, D. H. 1970. Fisheries biology. A study in population dynamics. Univ. Wisconsin Press, Madison, Wisconsin. 200 pp.

Galbreath, P. F. 1979. Effects of stocking rate of young-of-the-year tilapia on the production of marketable sie fish in cages. Unpublished M.S. Thesis, Auburn Univ. 52 pp.

Gribanov, L. V., A. N. Korneev, and L. A. Korneeva. 1968. Use of thermal waters for commercial production of carps in floats in the U.S.S.R. Proc. World Symposium Warm Water Pond Fish Culture (1966), FAO Fish Report 44(5):218-226.

Hickling, C. F. 1962. Fish culture. Faber and Faber, London. 295 pp.

Jansen, J. 1981. Home-grow fish from cages. Alabama Coop. Extension Service, Auburn Univ. Circ. ANR-269. 4 pp.

Le Cren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). J. Anim. Ecol. 20:201-219.

Lovell, R. T. 1972. Protein requirements of cage-cultured channel catfish. Proc. Ann. Conf. Southeast Assoc. Game Fish Comm. 26:352-361.

Maughan, O. E., G. E. Gebhart, D. P. Schwartz, and K. Williams. 1981. Feasibility of caged fish culture in north central Oklahoma farm ponds. Ann. Report (1980), Coop. Res., Langston Univ. 31 pp.

Melo, J. T. C., F. Alzuguir, and F. S. A. Toledo. 1979. Ensaio em piscicultura intensiva de Tilapia rendalli (Bouleger, 1896): analise quantitativa. Revista Brasileira de Biologia 39(2):377-381.

Newton, S. H. 1980. Review of cage culture activity indicates continuing interest. Aquaculture (U.S.) 7(1):32-36.

Pagon-Font, F. A. 1975. Cage culture as a mechanical method for controlling reproduction of Tilapia aurea (Steindachner). Aquaculture (Neth.) 6:243-247.

Pereira, J. A. 1980. Aspectos da fase de pre-estocagen em piscicultura intensiva. Dissertaçao Mestrado. Departamento de Ciencias Biologicas. Universidade Federal de Sao Carlos, Sao Paulo, Brasil. 68 pp.

Peret, A. C. 1980. Aspectos da influencia da densidade populacional em cultivo intensivo com curimata-comum Prochilodus cearensis Steindachner (Prochilodontidae-Prochildoinae). Dissertaçao de Mestrado. Departamento de Ciencias Biologicas. Universidade Federal de Sao Carlos, Sao Paulo, Brasil. 87 pp.

Pinheiro, F. A., J. W. B. Silva, and J. O. Chacon. 1978. Analise quantitativa em um ensaio de criaçao de bagre branco (Selenaspis herzbergii (Bloch, 1974), em viveiro do centro de pesquisas ictiologicas "Roldoph von Ihering", Pentecoste, Ceara, Brasil. Resumos do I Simp. Bras. de Aquicultura, Recife, UFRPE/SUDENE 1:83-84.

Prodecor. 1981. Programa de desenvolvimento de comunidades rurais. Plano basico de a¢ao. Ministerio da Agricultura, Secretaria Geral. Brasilia, Brasil. 37 pp.

Randolph, K. N., and H. P. Clemens. 1976. Some factors influencing the feeding behavior of channel catfish in culture ponds. Trans. Am. Fish. Soc. 105(6):718-724.

Rocha, I. P., J. A. Pereira, and J. R. Verani. 1981. Analise quantitativo de um cultivo do camarao "rosa" Panaeus brasiliensis (Latreille, 1817) no base de piscicultura de Itamaraca, PE(Brasil). Anais do II Congresso Brasileiro de Engeharia de Pesca 1:437-450.

Santos, E. P. 1978. Dinamica de popula¢ao aplicada a pesca e piscicultura. Hucitec, Editora Universidade de Sao Paulo, Brasil. 129 pp.

Schmittou, H. R. 1970. The culture of channel catfish, Ictalurus punctatus (Rafinesque) in cages suspended in ponds. Proc. Ann. Conf. Southeast Game Fish Comm. 23:226-244.

Silva, A. B., A. C. Sobrinho, L. L. Lovshin, J. W. B. Silva, and F. R. Melo. 1978. Analise quantitativa de um ensaio preliminar sobre a cria¢ao intensiva de pirapitinga Colossoma bidens Spix. Resumos do I Simp. Bras. de Aquiculture. Recife. UFRPE/SUDENE 1:69-73.

Silva, A. M. 1981. Microposto de piscicultura acoplado a biodigestor. Ministerio da Agricultura, Fundo Federal Agropecuario, Prodecor, Instituto de Pesquisas da Marinha. Brasilia, Brasil. 55 pp.

Silva, J. E. 1975. Cultivo de tainha (Mugil curema Vallenciannes, 1836) em condi¢oes experimentais. Estudo da varia¢ao da biomassa. Disserta¢ao de Mestrado. Instituto de Bio-Ciencias, Departmento de Fisiologia Geral., Universidade de Sao Paulo, Brasil. 74 pp.

Swingle, H. S. 1970. The inland fisheries program of Thailand. Auburn Univ. Agri. Exp. Station, Auburn, Alabama. 156 pp.

Verani, J. R. 1980. Controle populacional em cultivo intensivo consorciado entre a tilapia do nilo, Sarotherodon niloticus (Linnaeus, 1757) e o tucunare comum, Cichla ocellaris Schneider, 1801. Aspectos quantitativos. Disserta¢ao de Mestrado, Departamento de Ciencias Biologicas, Universidade Federal de Sao Carlos, Sao Paulo, Brasil. 116 pp.

Verani, J. R., J. A. Pereira, G. A. Borges, and D. B. G. Lara. 1980. Analise quantitativa no cultivo do "camarao sugpo" Panaeus monodon Fabricius, 1798. I Simposio Brasileiro de Aquicultura, Academia Brasileira de Ciencias, Rio de Janeiro 1:267-274.

Walford, L. A. 1946. A new graphic method of describing the growth of animals. Biological Bulletin 90(2):141-147.

Weatherley, A. H. 1966. The ecology of fish growth. Nature, London 212:1321-1324.

Weatherley, A. H. 1972. Growth and ecology of fish populations. Academic Press, Inc., New York. 293 pp.

Williams, K. W. 1982. Polyculture of caged channel catfish and Tilapia aurea in small ponds. Unpublished M.S. Thesis, Okla. State Univ., Stillwater. 136 pp.

APPENDICES

APPENDIX A

ESTIMATED ("CORRECTED") MONTHLY CONDITION FACTORS ($\phi^* \cdot 10^{-6}$) FOR CHANNEL CATFISH

Figure 31. Estimated monthly condition factors ($\phi^* \cdot 10^{-6}$) for channel catfish in treatment 0 (number of tilapia) at pond 1.

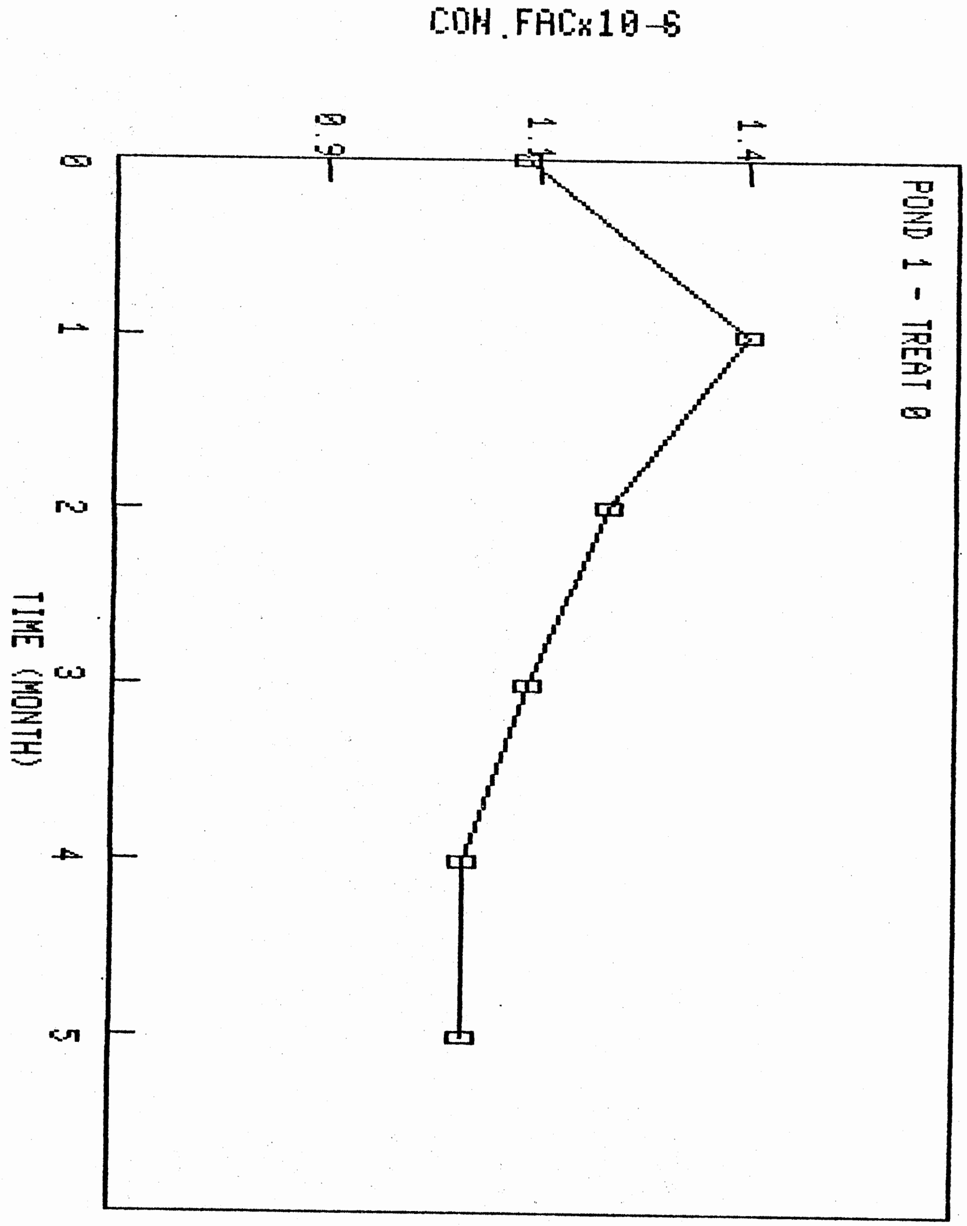
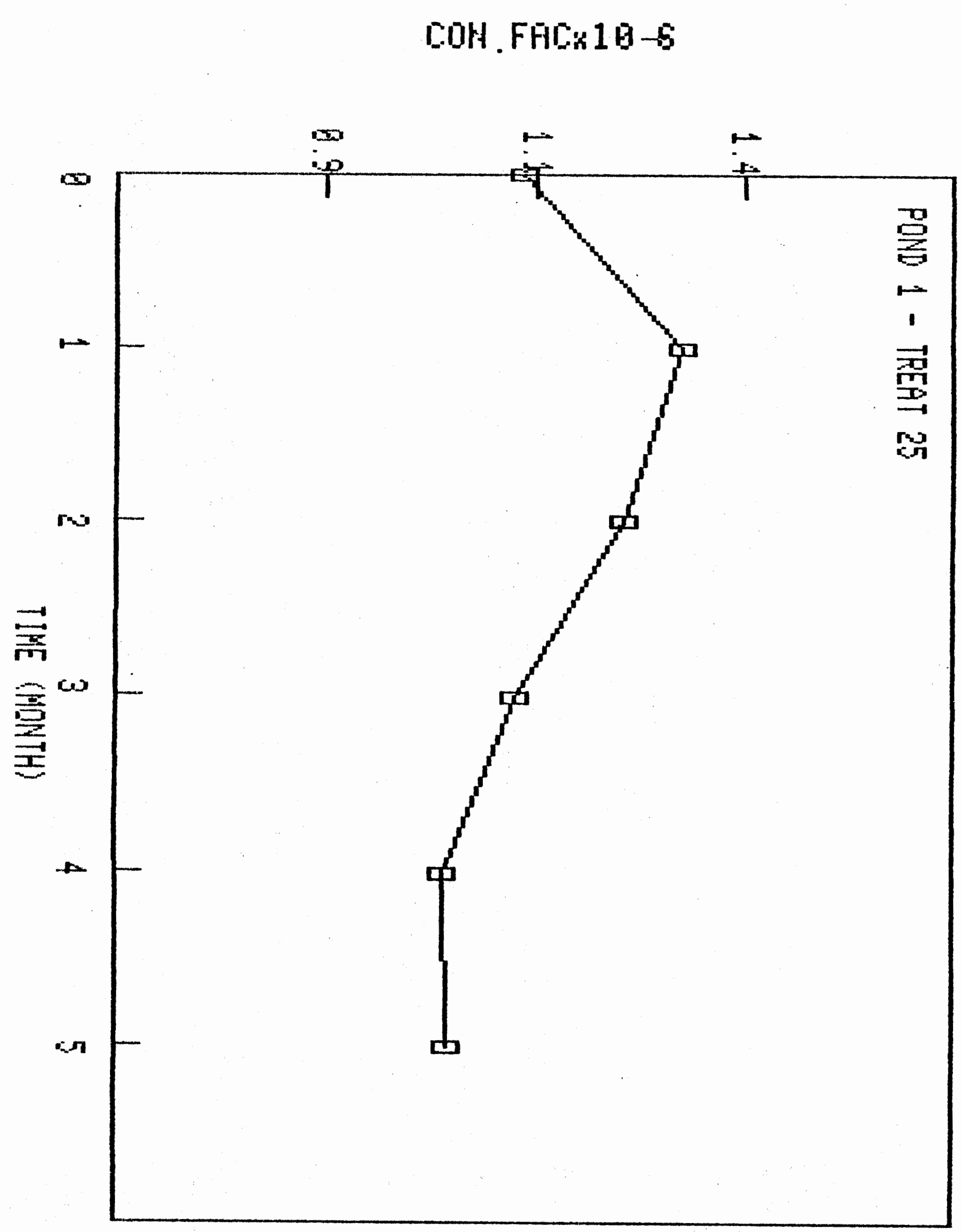
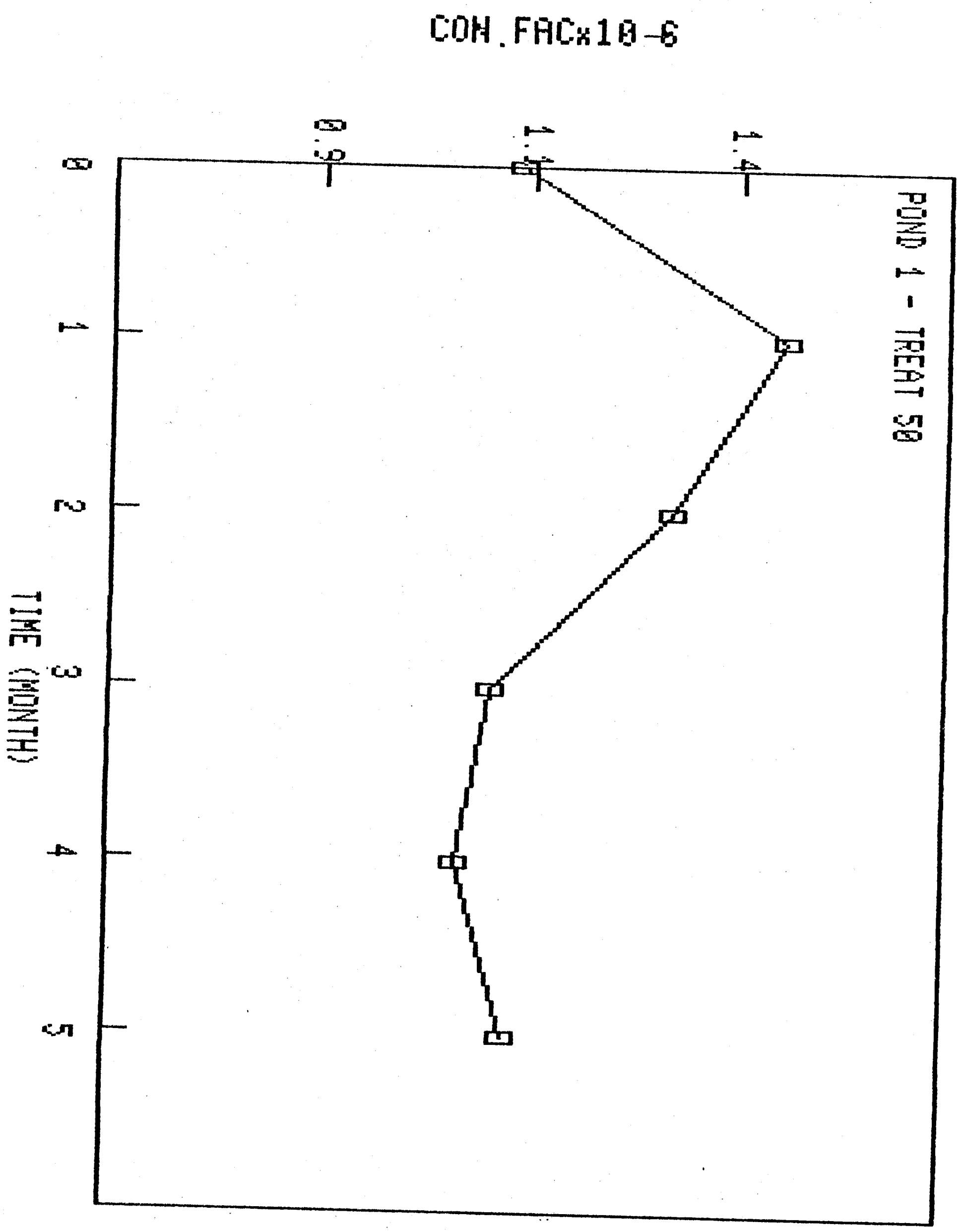

CON.FACx10-6
POND 1 - TREAT 0
1.4
1.1
0.9
0
1
2
3
4
5
TIME (MONTH)

Figure 32. Estimated monthly condition factors ($\phi^* \cdot 10^{-6}$) for channel catfish in treatment 25 (number of tilapia) at pond 1.



CON.FACx10-6
POND 1 - TREAT 25
1.4
1.1
0.9
0
1
2
3
4
5
TIME (MONTH)

Figure 33. Estimated monthly condition factors ($\phi^* \cdot 10^{-6}$) for channel catfish in treatment 50 (number of tilapia) at pond 1.



CON.FACx10-6
POND 1 - TREAT 50
1.4
1.1
0.9
0
1
2
3
4
5
TIME (MONTH)

Figure 34. Estimated monthly condition factors ($\phi^* \cdot 10^{-6}$) for channel catfish in treatment 75 (number of tilapia) at pond 1.

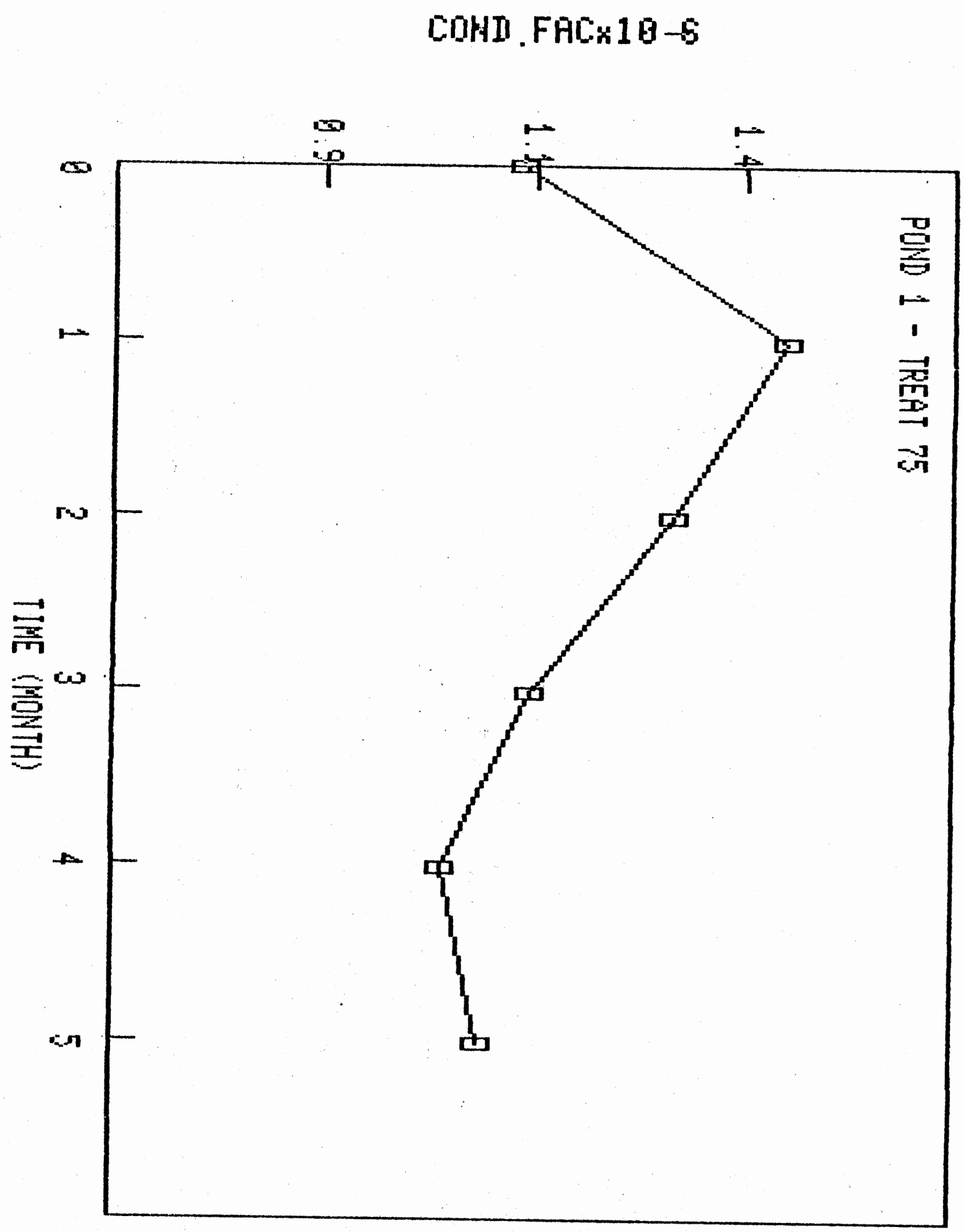

COND.FACx10-6
1.4
1.1
0.9
POND 1 - TREAT 75
0
1
2
3
4
5
TIME (MONTH)

Figure 35. Estimated monthly condition factors ($\phi * \cdot 10^{-6}$) for channel catfish in treatment 0 (number of tilapia) at pond 2.

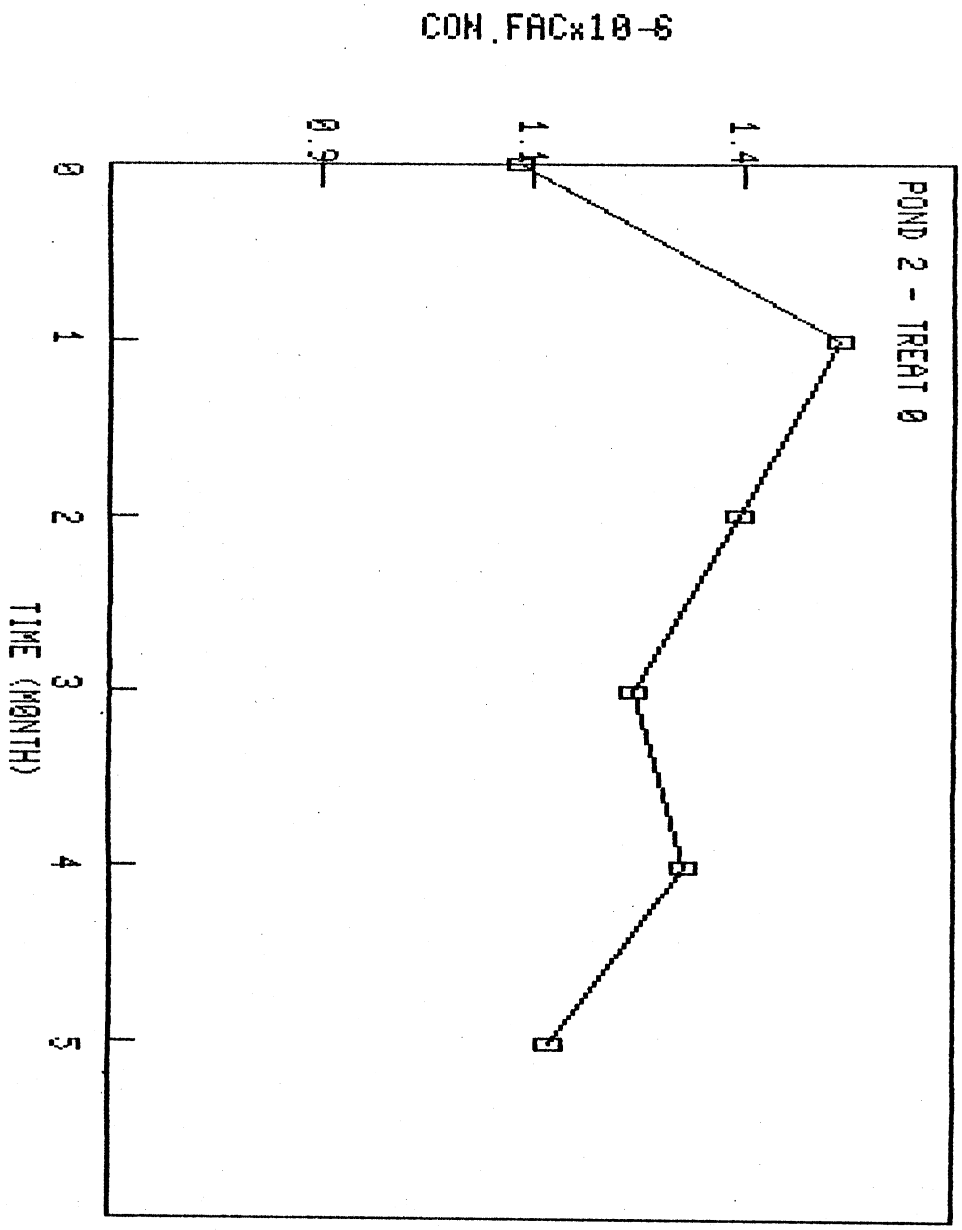

POND 2 - TREAT 0
CON.FACx10-6
0.9
1.1
1.4
0
1
2
3
4
5
TIME (MONTH)

Figure 36. Estimated monthly condition factors ($\phi^* \cdot 10^{-6}$) for channel catfish in treatment 25 (number of tilapia) at pond 2.

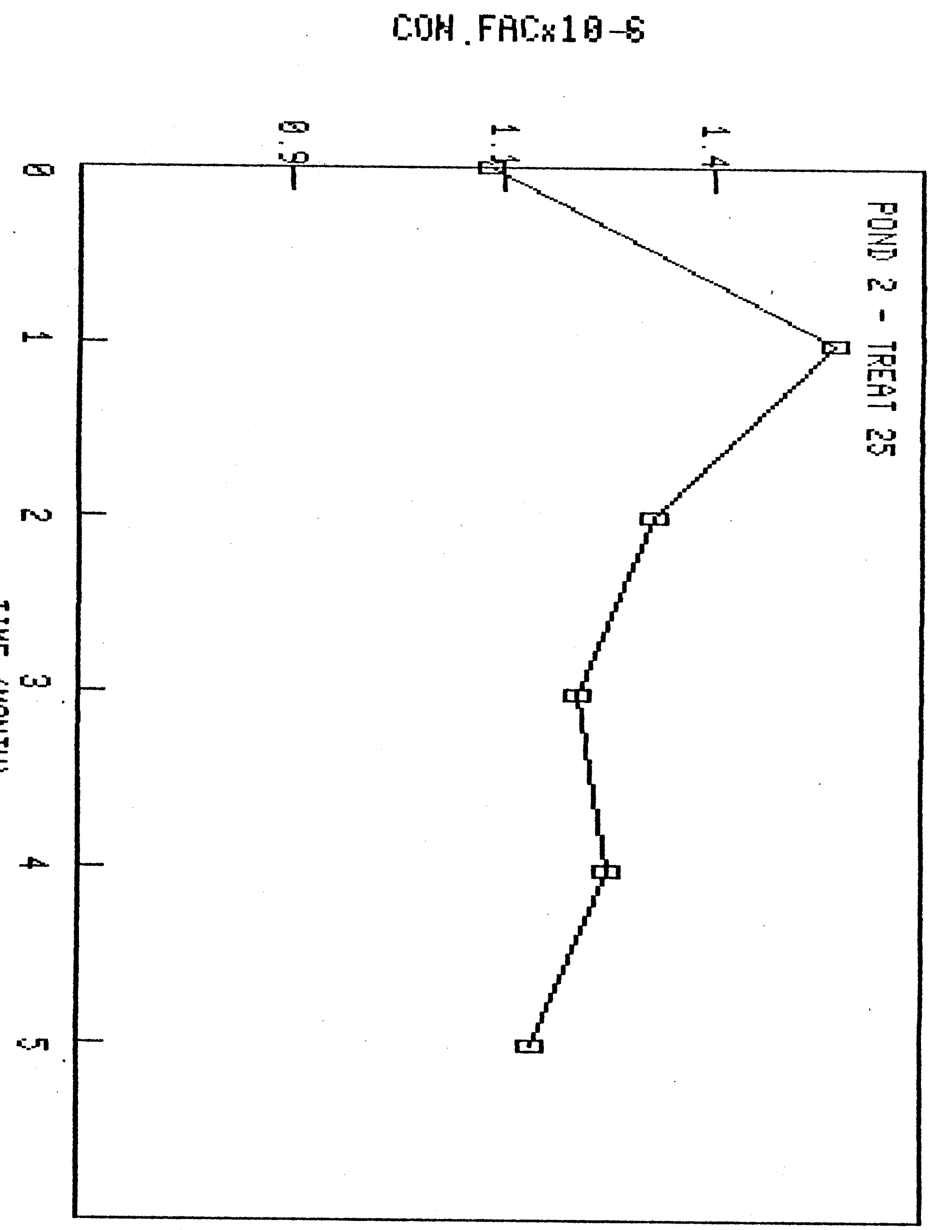

CON.FACx10-6
0.9
1.1
1.4
POND 2 - TREAT 25
0
1
2
3
4
5
TIME (MONTH)

Figure 37. Estimated monthly condition factors ($\phi^* \cdot 10^{-6}$) for channel catfish in treatment 50 (number of tilapia) at pond 2.

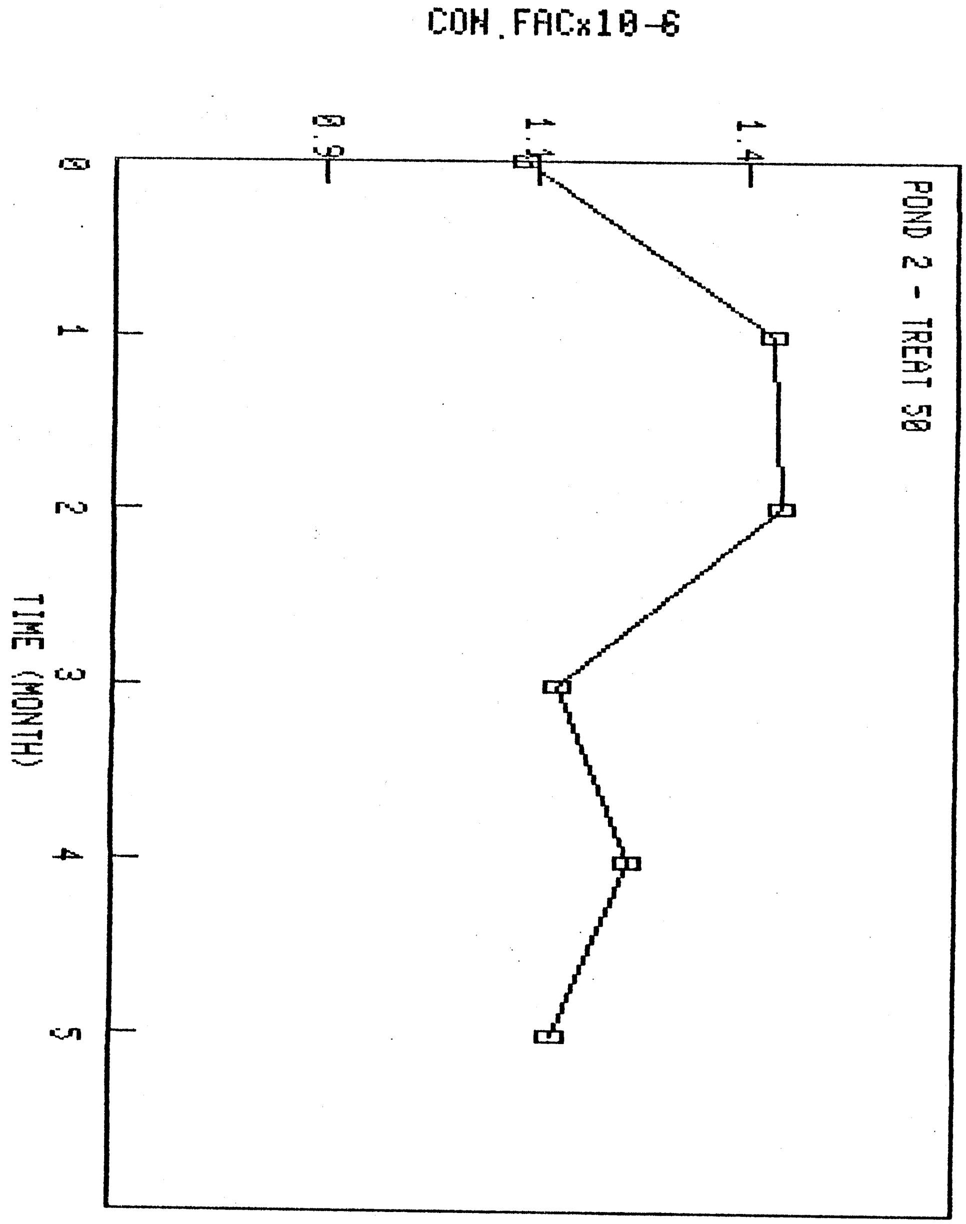

CON.FACx10-6
POND 2 - TREAT 50
1.4
1.1
0.9
0
1
2
3
4
5
TIME (MONTH)

Figure 38. Estimated monthly condition factors ($\phi * \cdot 10^{-6}$) for channel catfish in treatment 75 (number of tilapia) at pond 2.

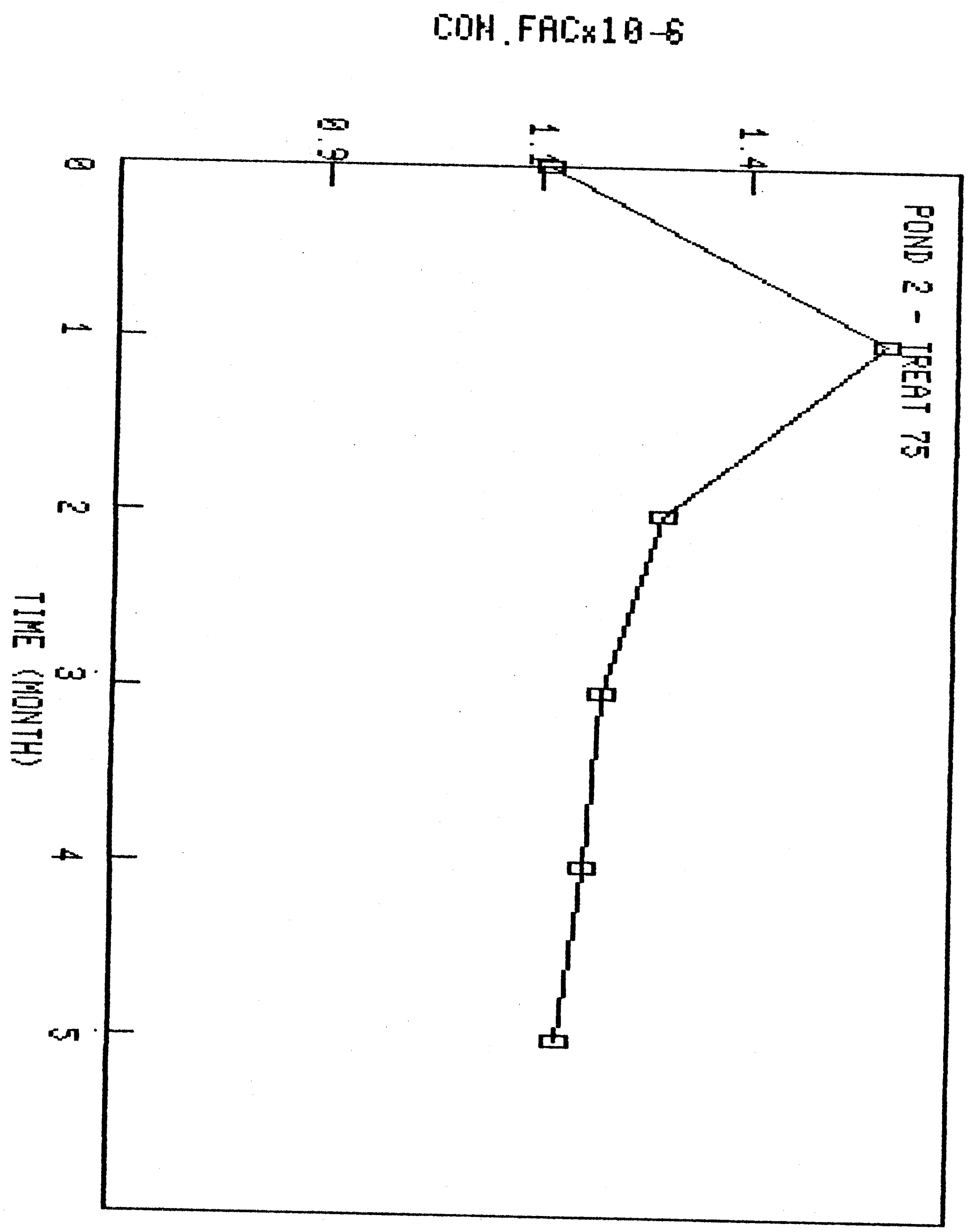

CON.FACx10-6
POND 2 - TREAT 75
1.4
1.1
0.9
0
1
2
3
4
5
TIME (MONTH)

Figure 39. Estimated monthly condition factors ($\phi^* \cdot 10^{-6}$) for channel catfish in treatment 0 (number of tilapia) at pond 3.

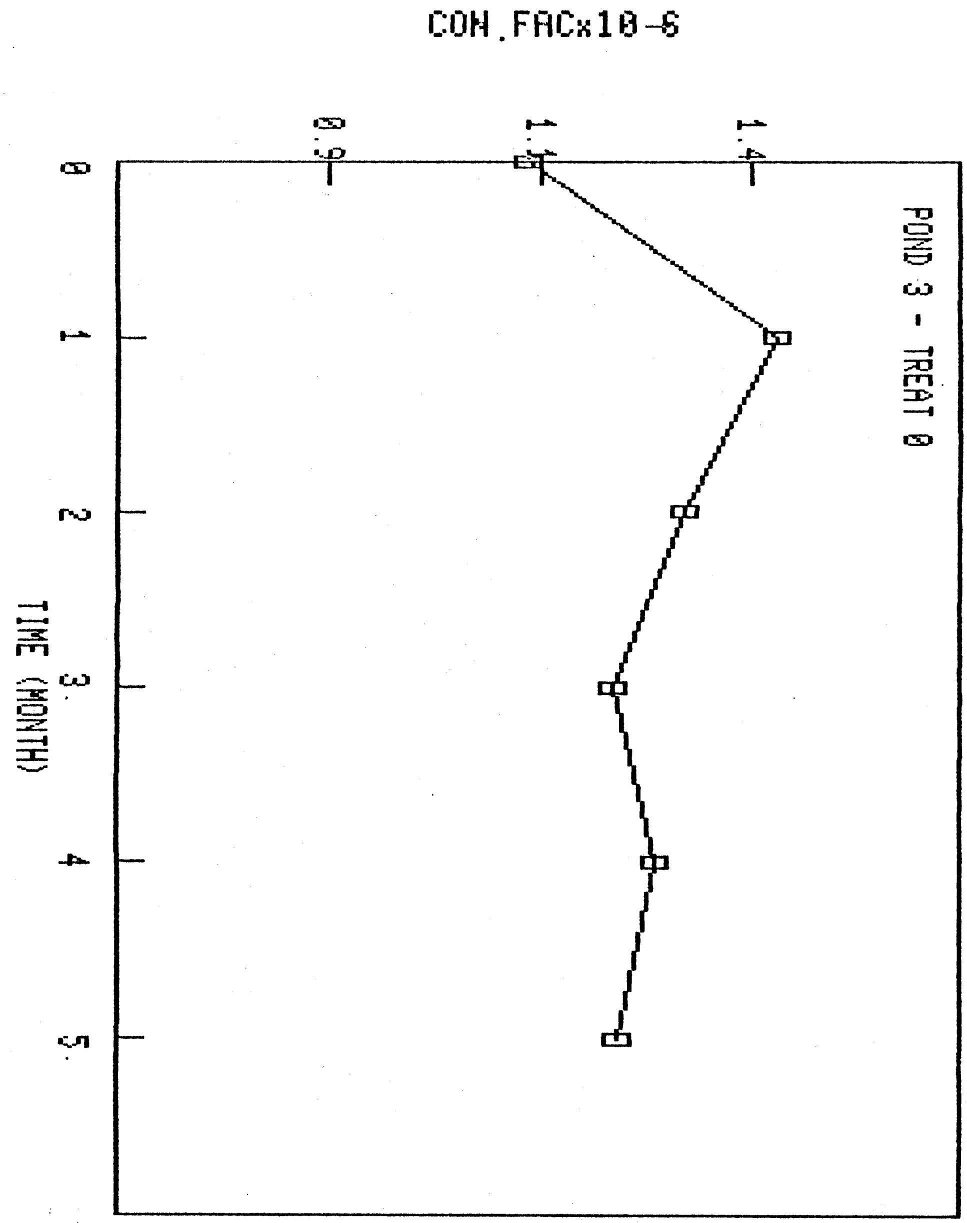

POND 3 - TREAT 0
CON.FACx10-6
1.4
1.1
0.9
0
1
2
3
4
5
TIME (MONTH)

Figure 40. Estimated monthly condition factors ($\phi * \cdot 10^{-6}$) for channel catfish in treatment 25 (number of tilapia) at pond 3.

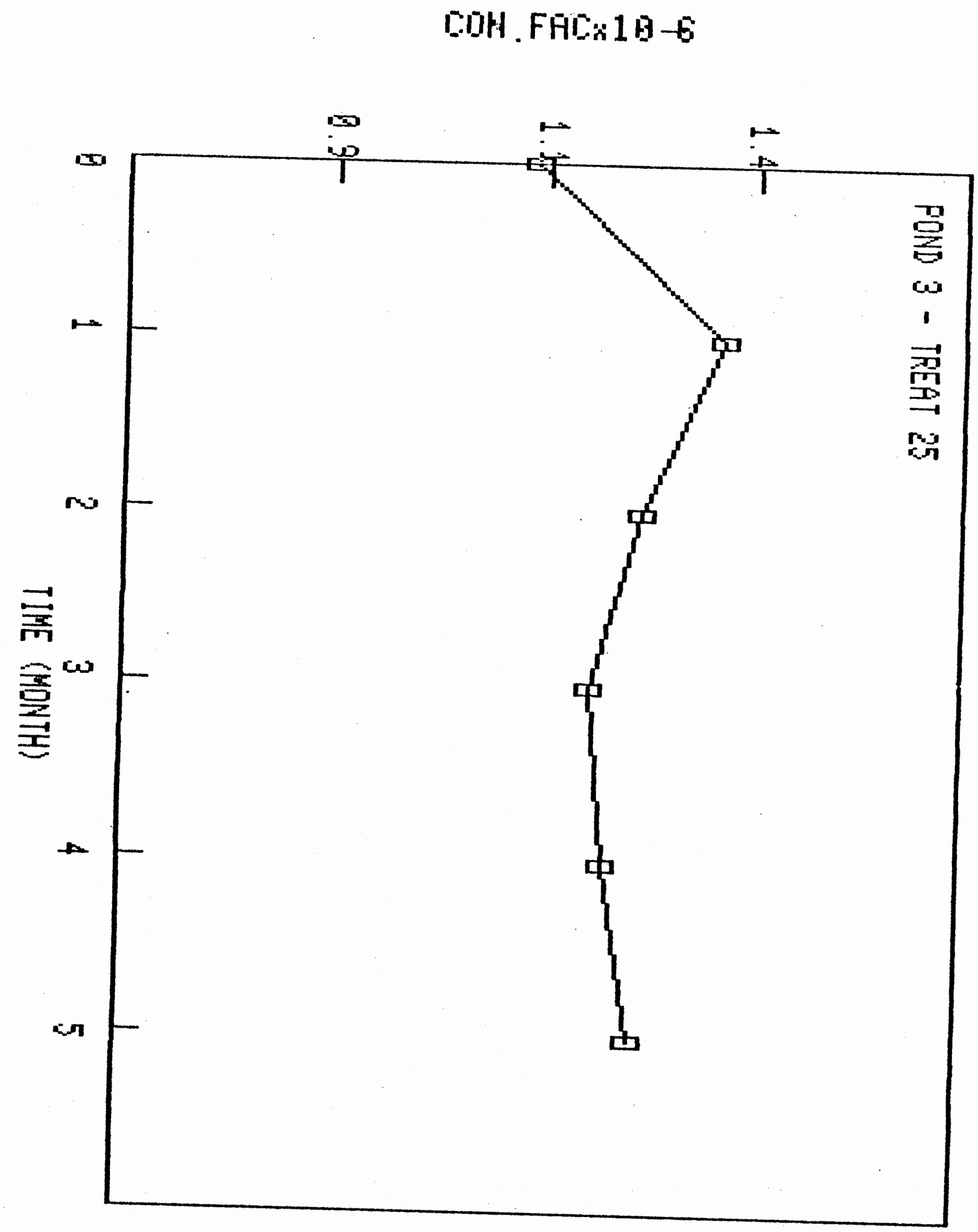

CON.FACx10-6
1.4
1.1
0.9
POND 3 - TREAT 25
0
1
2
3
4
5
TIME (MONTH)

Figure 41. Estimated monthly condition factors ($\phi * \cdot 10^{-6}$) for channel catfish in treatment 55 (number of tilapia) at pond 3.

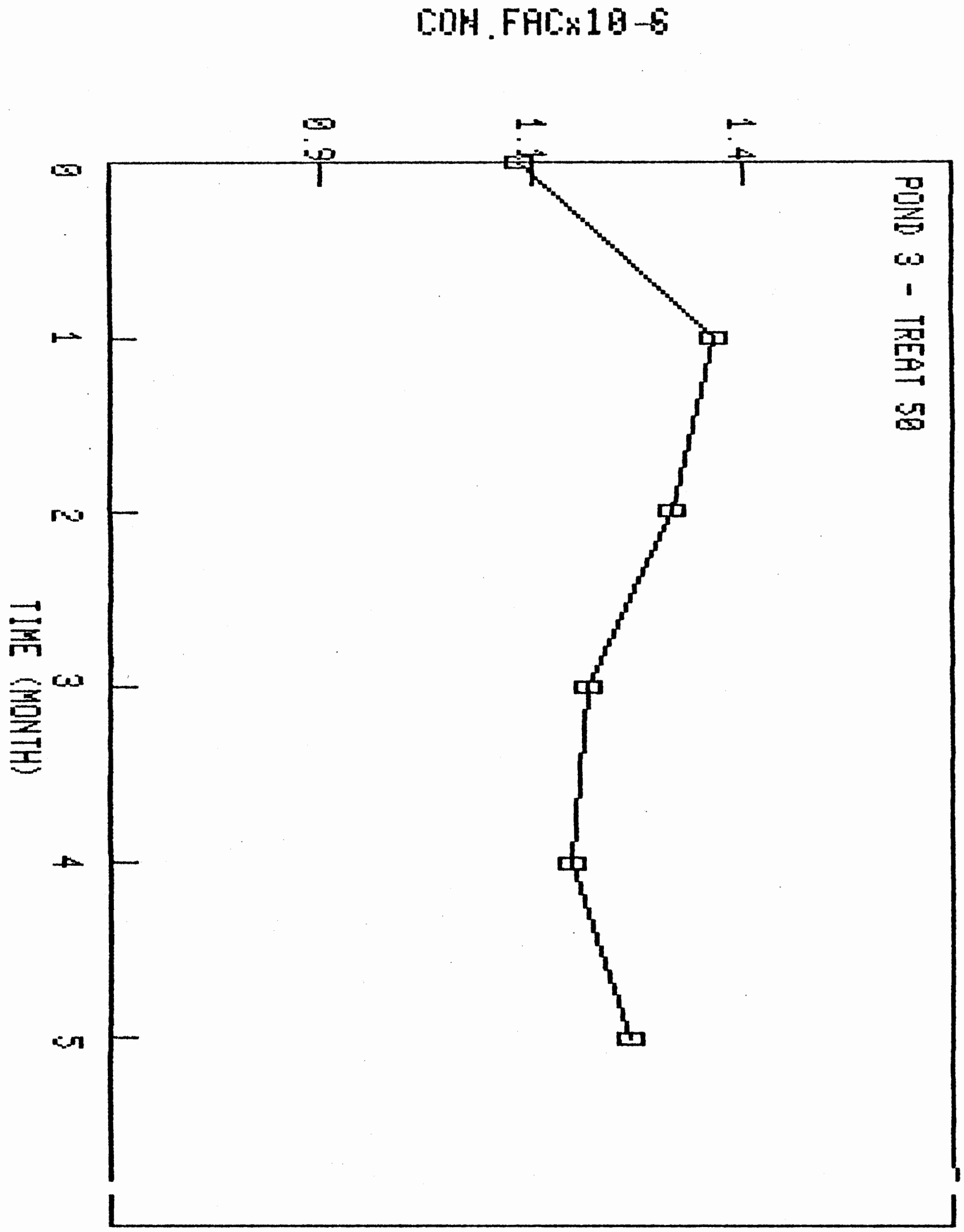
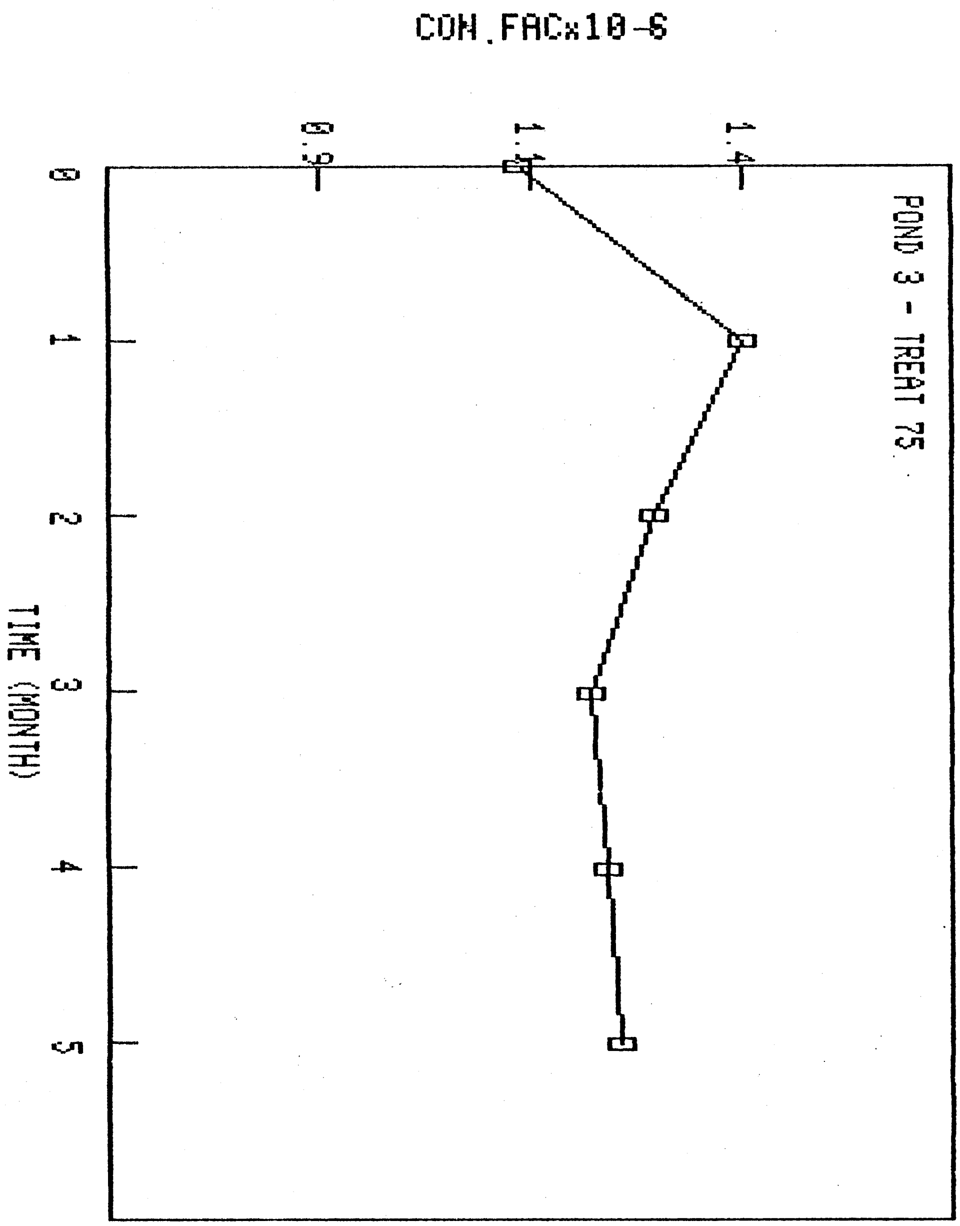

CON.FACx10-6
POND 3 - TREAT 50
1.4
1.1
0.9
0
1
2
3
4
5
TIME (MONTH)

Figure 42. Estimated monthly condition factors ($\phi * \cdot 10^{-6}$) for channel catfish in treatment 75 (number of tilapia) at pond 3.


CON.FACx10-6
POND 3 - TREAT 75
1.4
0.9
0
1
2
3
4
5
TIME (MONTH)

APPENDIX B

GROWTH CURVE IN LENGTH FOR

CHANNEL CATFISH

Figure 43. Growth curve in length for channel catfish in treatment 0 (number of tilapia) at pond 1.

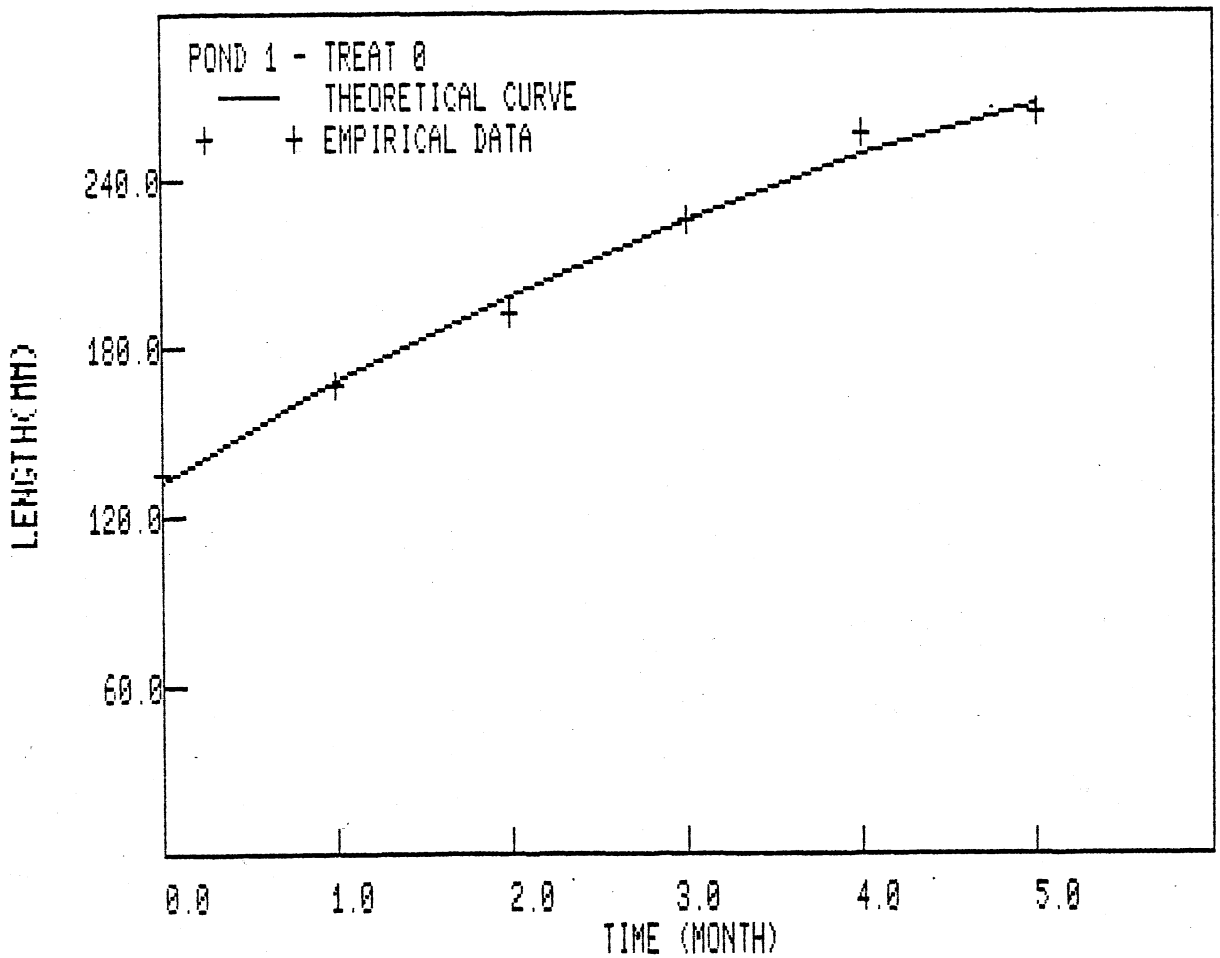

POND 1 - TREAT 0
THEORETICAL CURVE
EMPIRICAL DATA
240.0
180.0
120.0
60.0
LENGTH(MM)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 44. Growth curve in length for channel catfish in treatment 25 (number of tilapia) at pond 1.

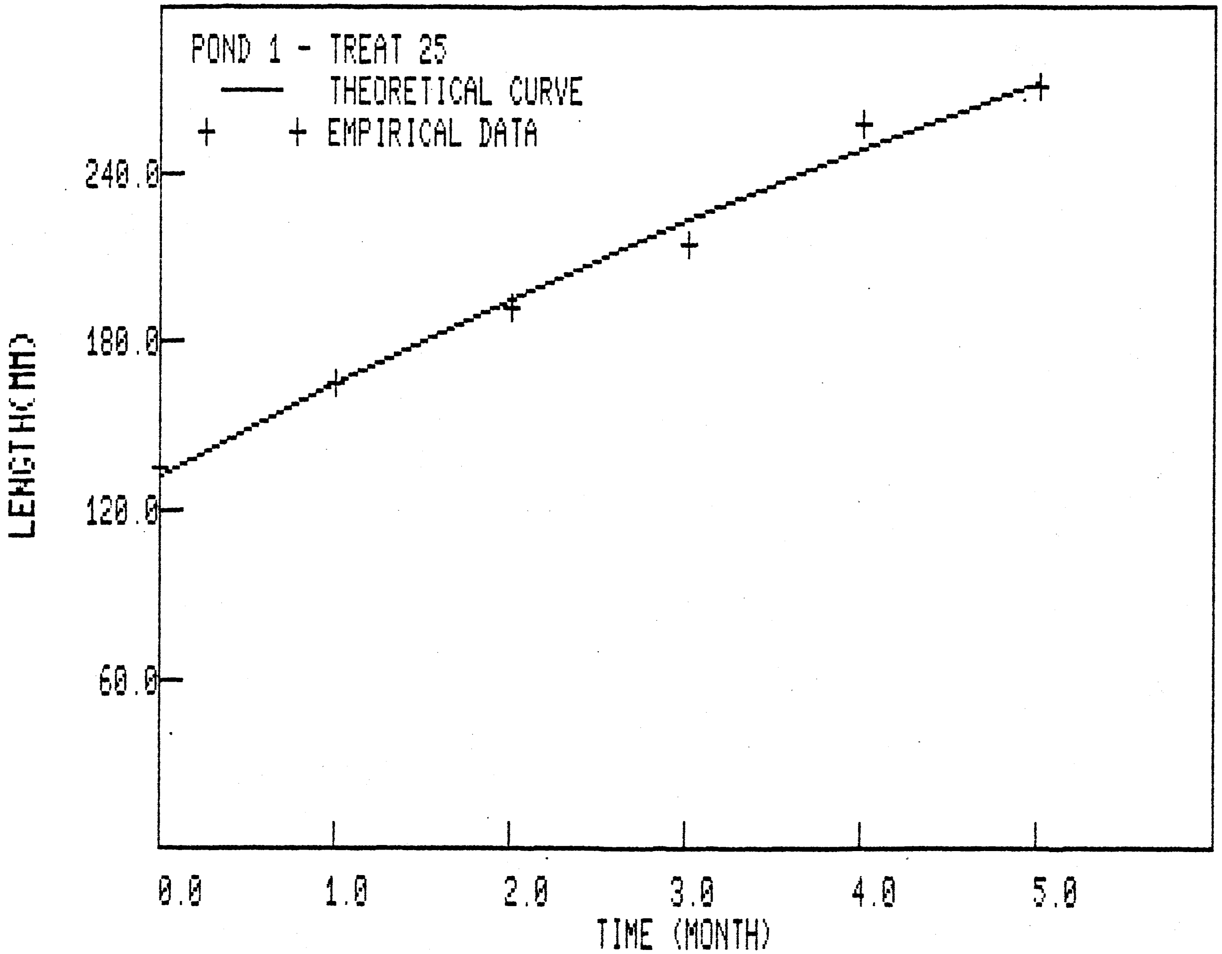

POND 1 - TREAT 25
THEORETICAL CURVE
EMPIRICAL DATA
240.0
180.0
120.0
60.0
LENGTH(MM)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 45. Growth curve in length for channel catfish in treatment 50 (number of tilapia) at pond 1.

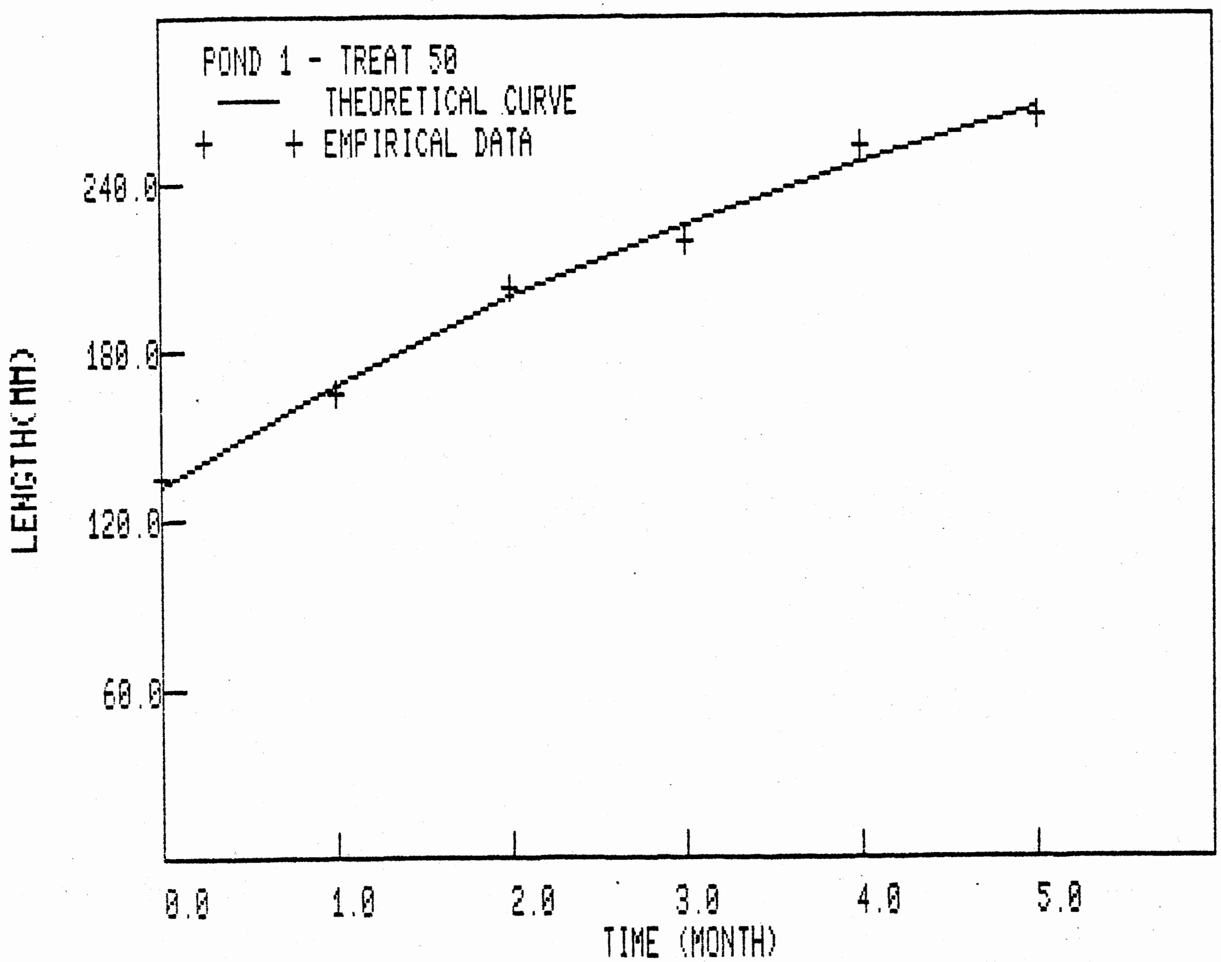

POND 1 - TREAT 50
THEORETICAL CURVE
EMPIRICAL DATA
LENGTH(MM)
240.0
180.0
120.0
60.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 46. Growth curve in length for channel catfish in treatment 75 (number of tilapia) at pond 1.

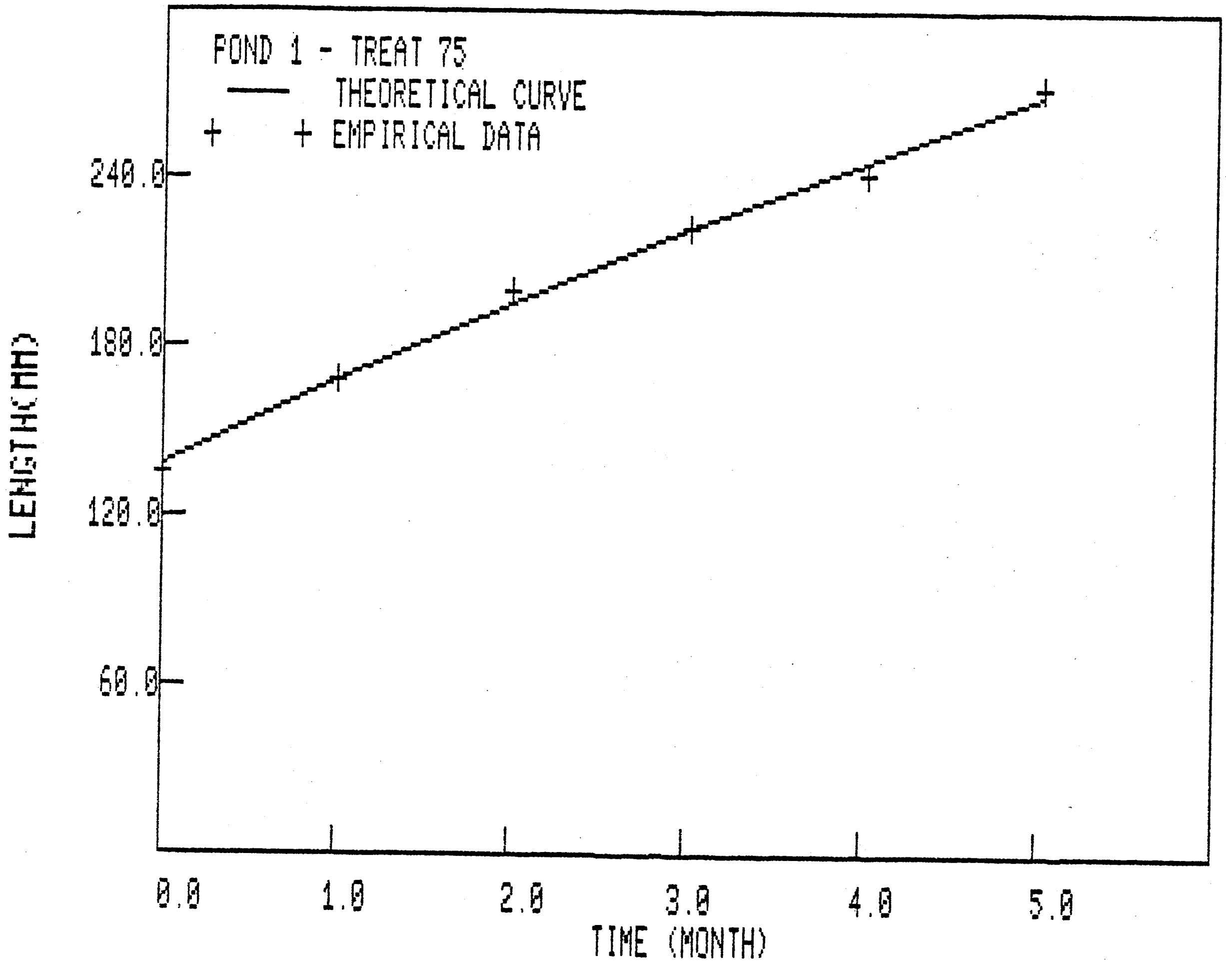

POND 1 - TREAT 75
THEORETICAL CURVE
+ EMPIRICAL DATA
240.0
180.0
120.0
60.0
LENGTH(MM)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 47. Growth curve in length for channel catfish in treatment 0 (number of tilapia) at pond 2.

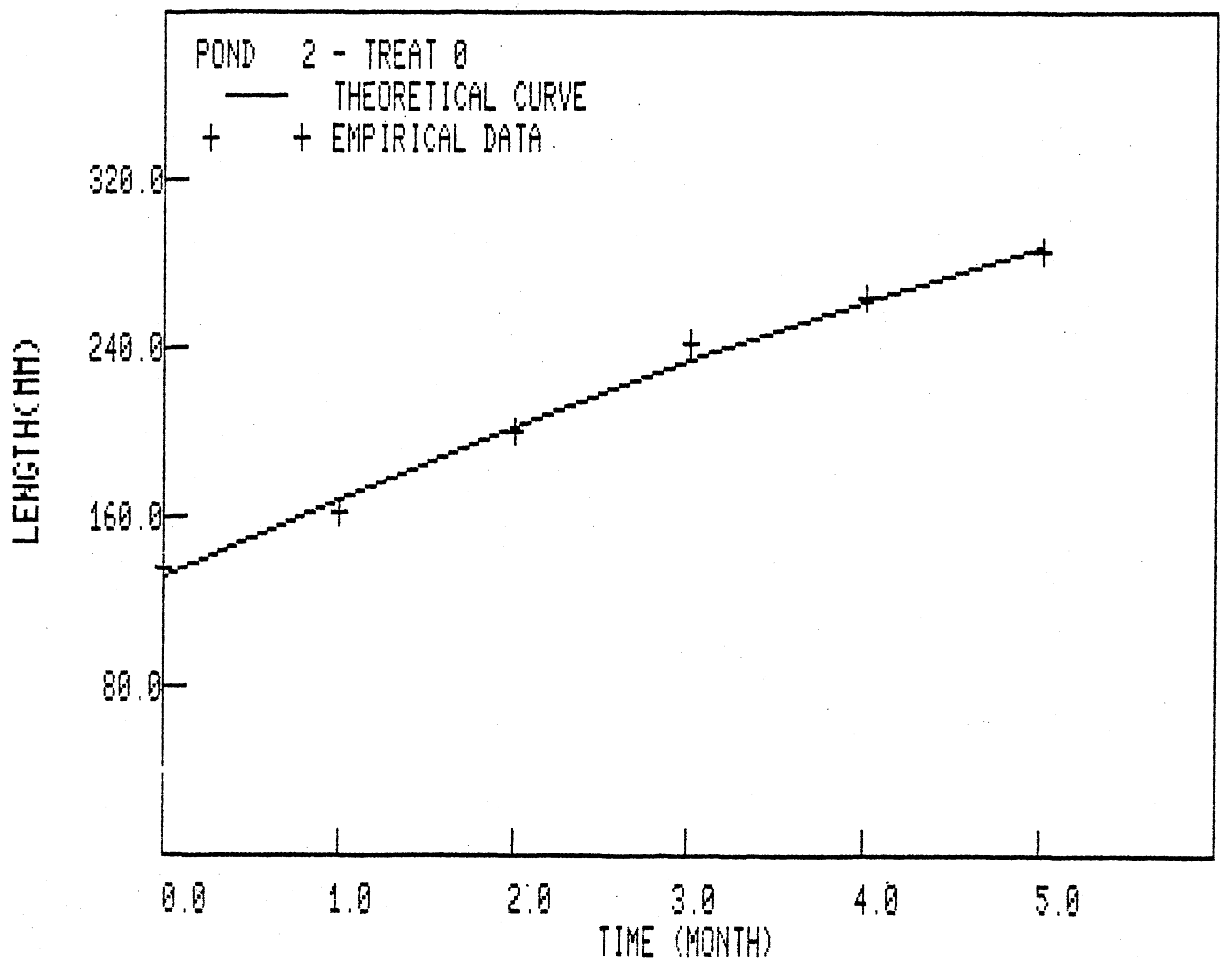

POND 2 - TREAT 0
THEORETICAL CURVE
EMPIRICAL DATA
320.0
240.0
160.0
80.0
LENGTH(MM)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 48. Growth curve in length for channel catfish in treatment 25 (number of tilapia) at pond 2.

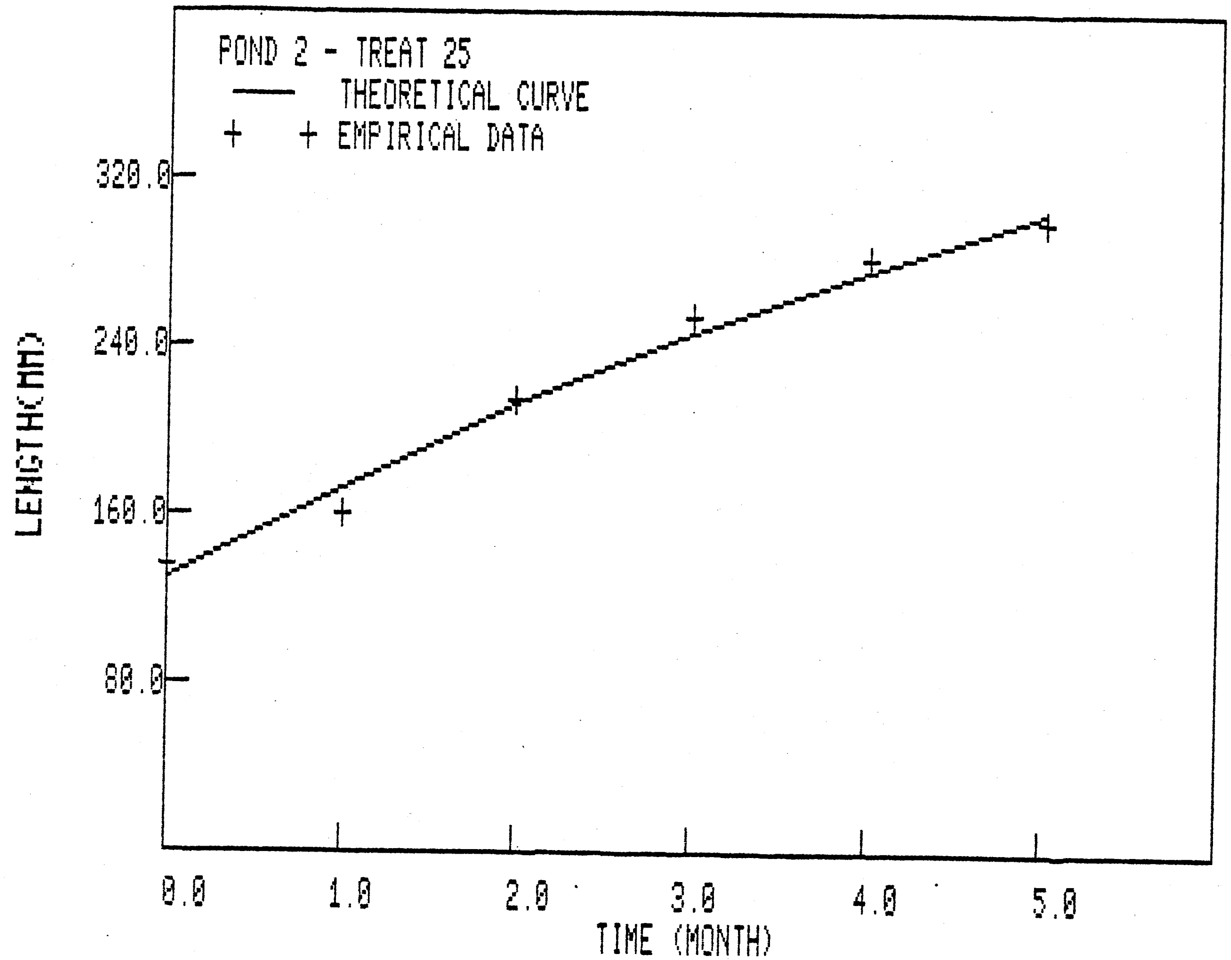

POND 2 - TREAT 25
THEORETICAL CURVE
+ EMPIRICAL DATA
LENGTH(MM)
320.0
240.0
160.0
80.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 49. Growth curve in length for channel catfish in treatment 50 (number of tilapia) at pond 2.

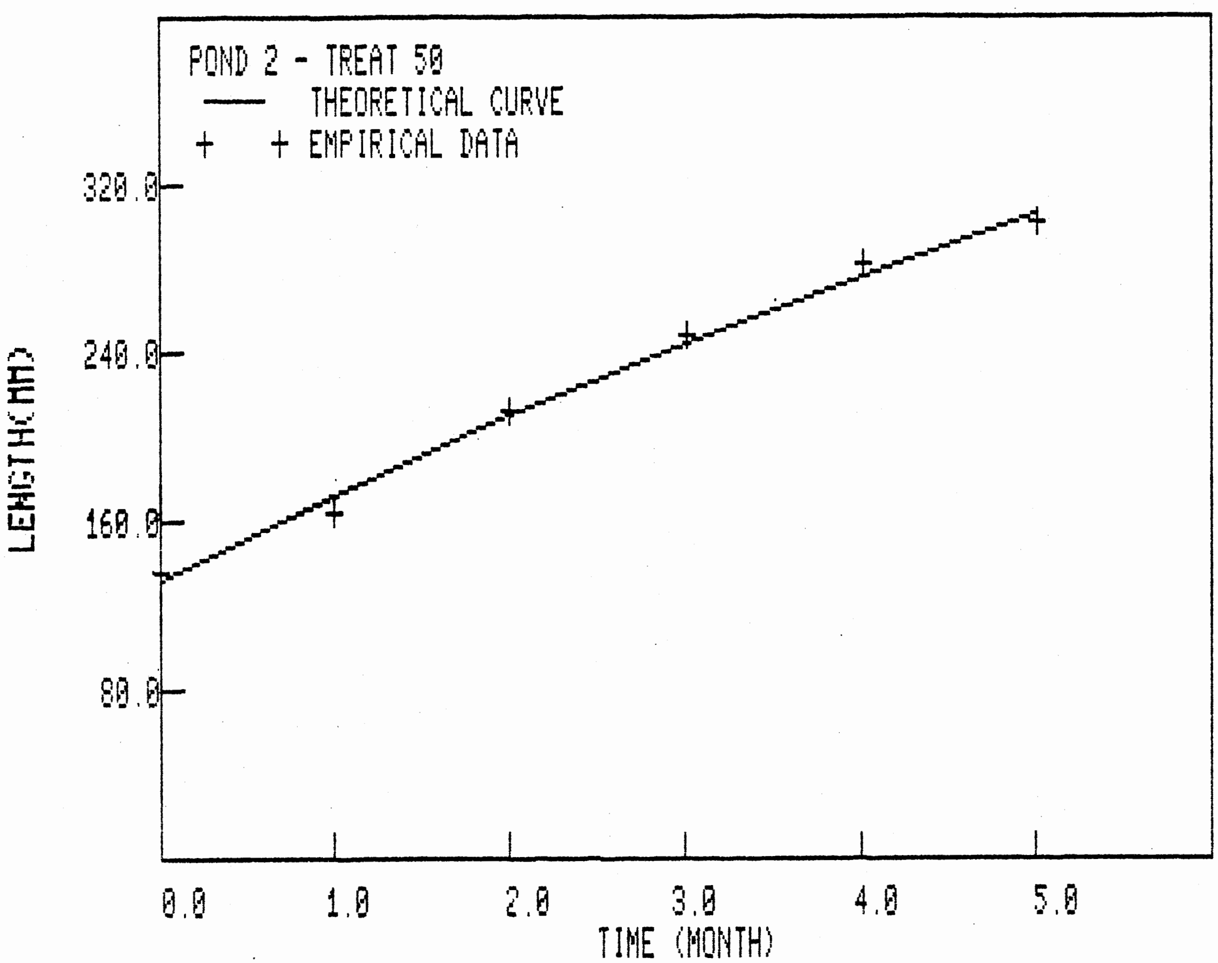

POND 2 - TREAT 50
THEORETICAL CURVE
+ + EMPIRICAL DATA
320.0
240.0
160.0
80.0
LENGTH(MM)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 50. Growth curve in length for channel catfish in treatment 75 (number of tilapia) at pond 2.

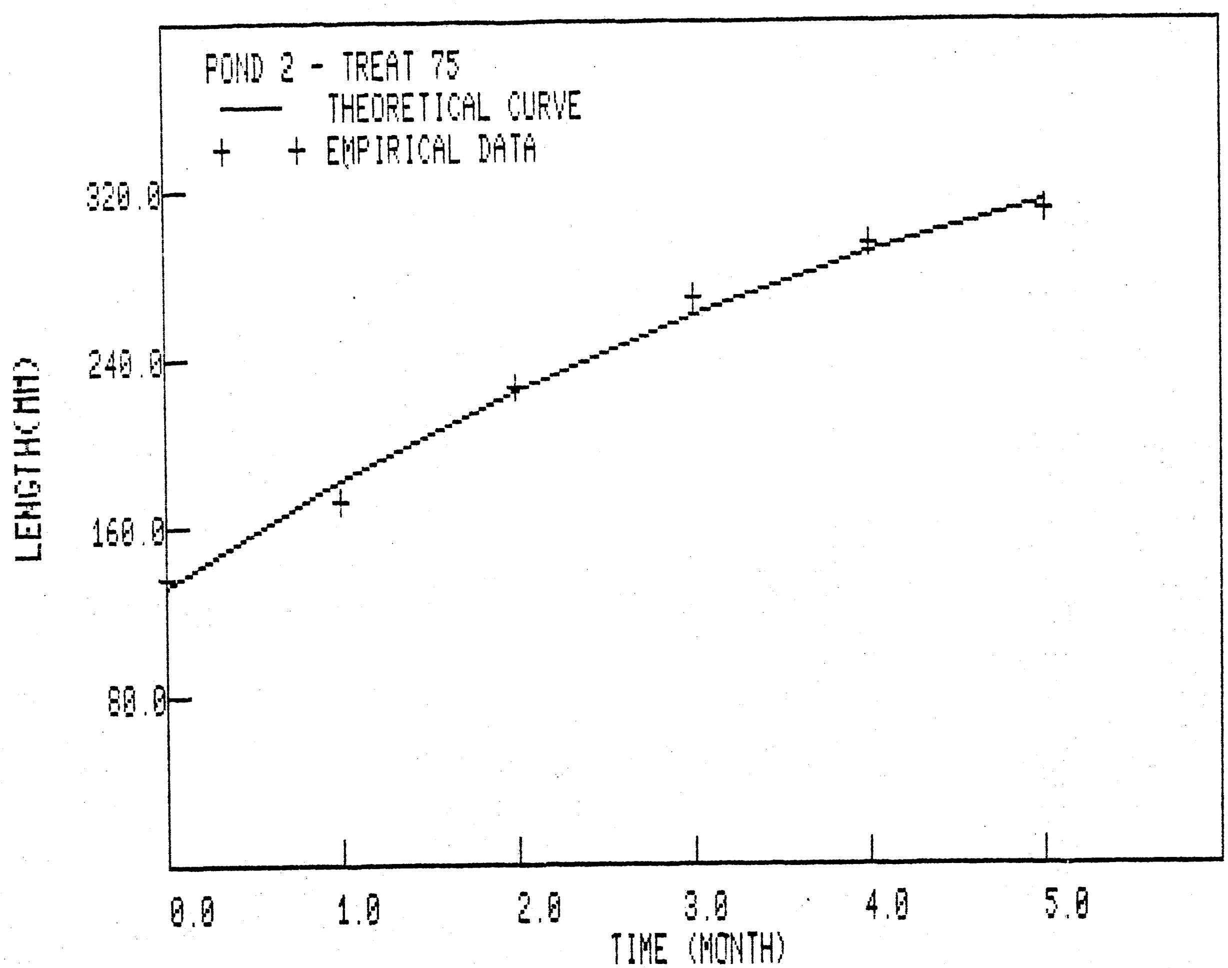

POND 2 - TREAT 75
THEORETICAL CURVE
+ + EMPIRICAL DATA
LENGTH(MM)
320.0
240.0
160.0
80.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 51. Growth curve in length for channel catfish in treatment 0 (number of tilapia) at pond 3.

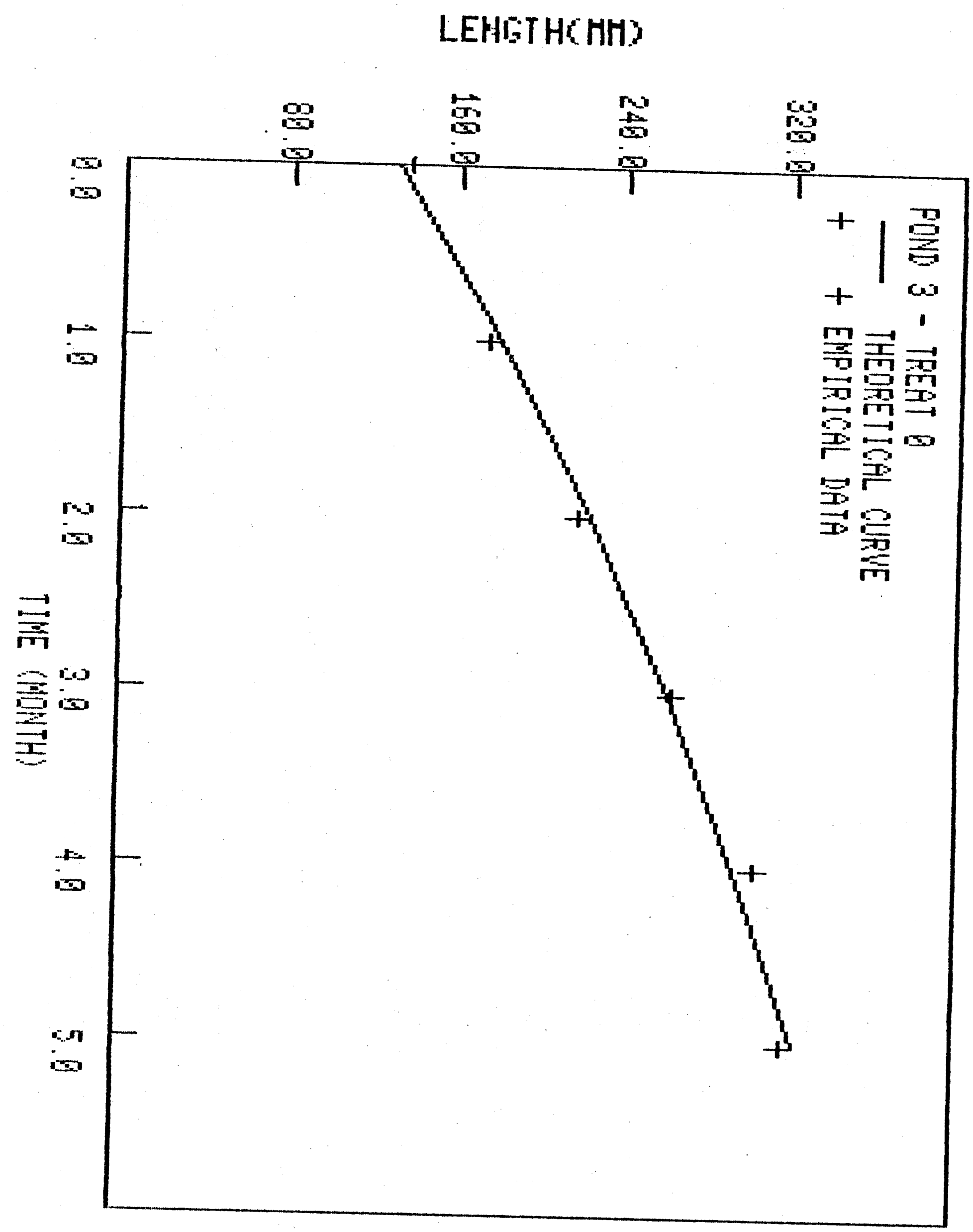

POND 3 - TREAT 0
THEORETICAL CURVE
+ + EMPIRICAL DATA
LENGTH(MM)
320.0
240.0
160.0
80.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 52. Growth curve in length for channel catfish in treatment 25 (number of tilapia) at pond 3.

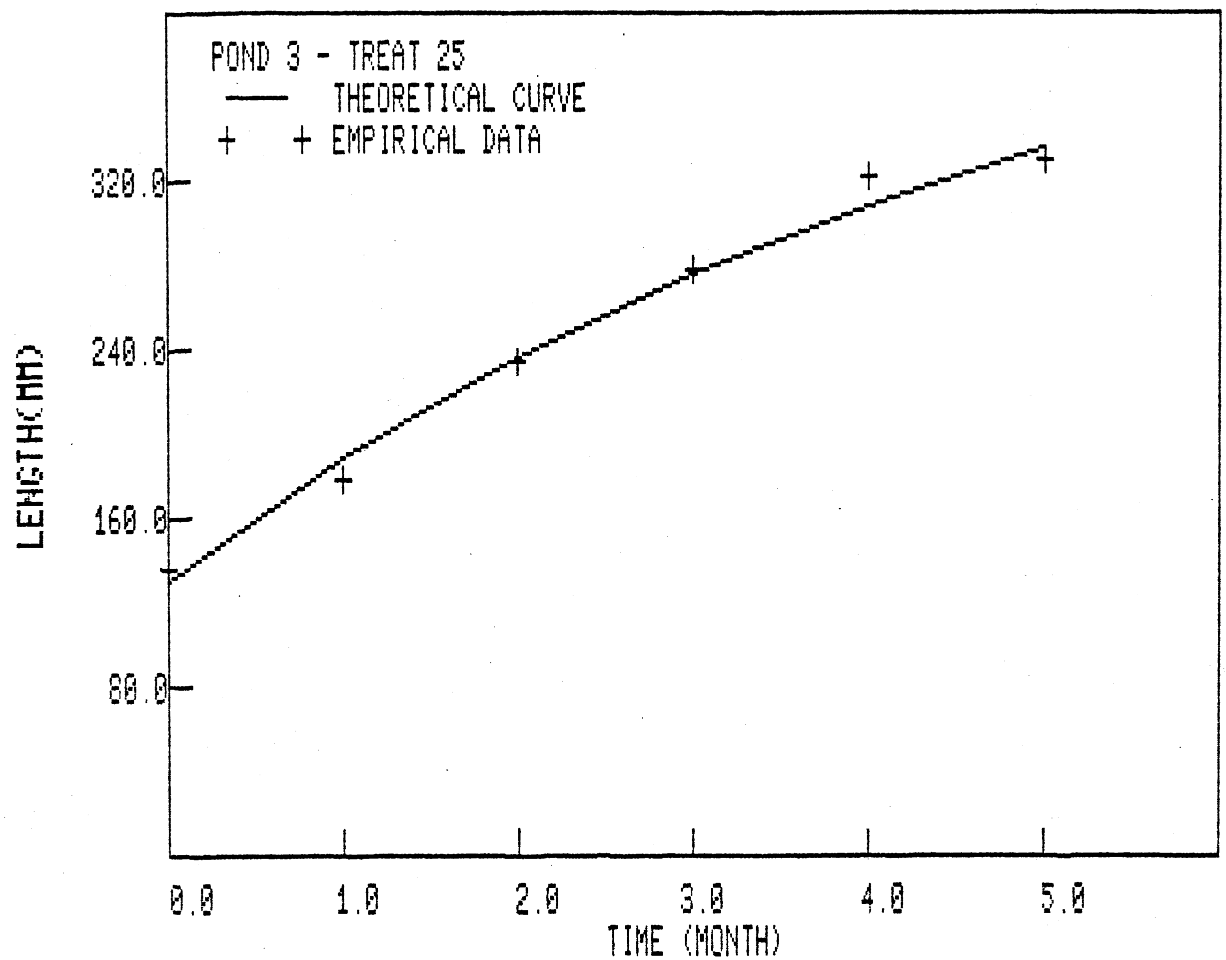

POND 3 - TREAT 25
THEORETICAL CURVE
EMPIRICAL DATA
320.0
240.0
160.0
80.0
LENGTH(MM)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 53. Growth curve in length for channel catfish in treatment 50 (number of tilapia) at pond 3.

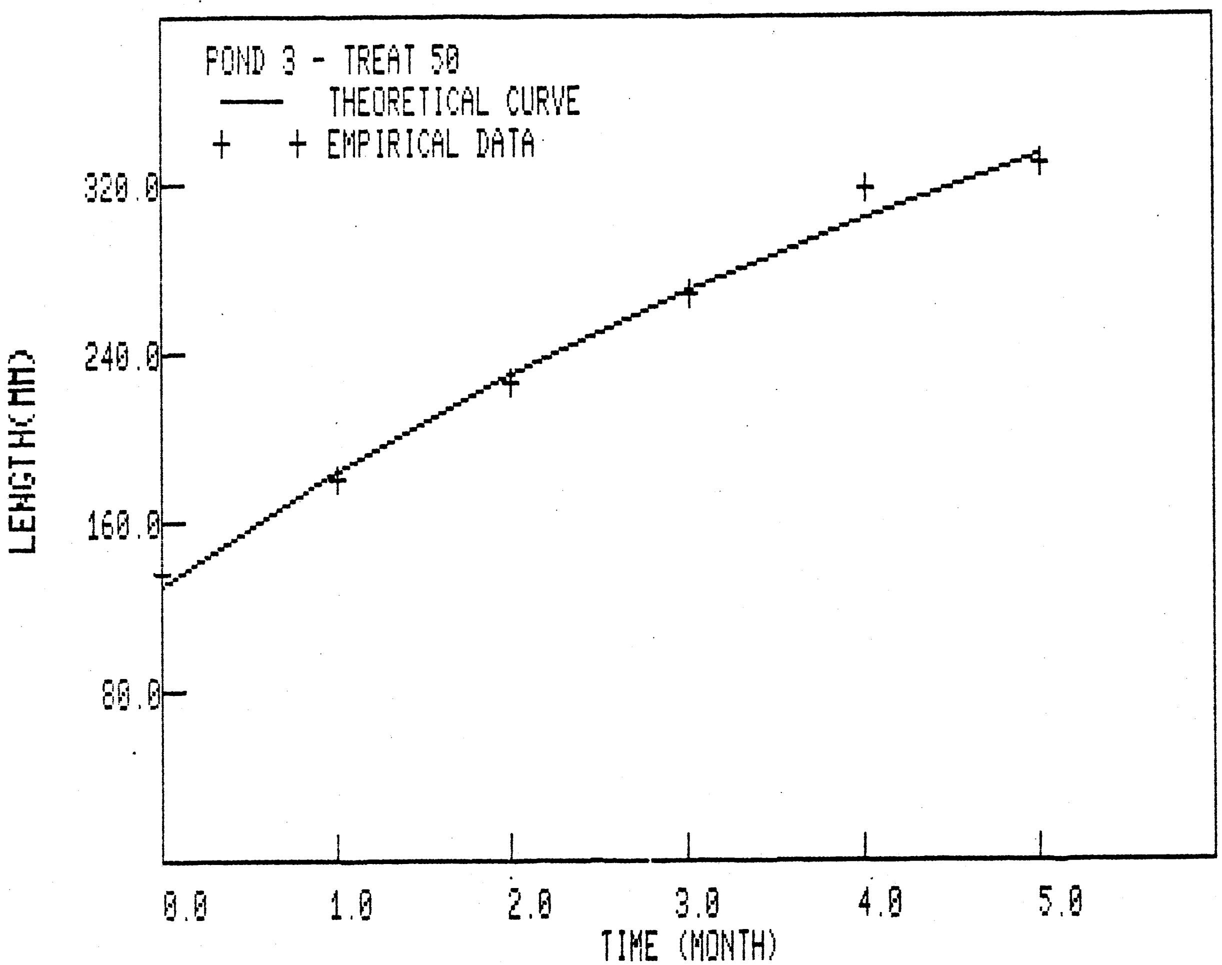
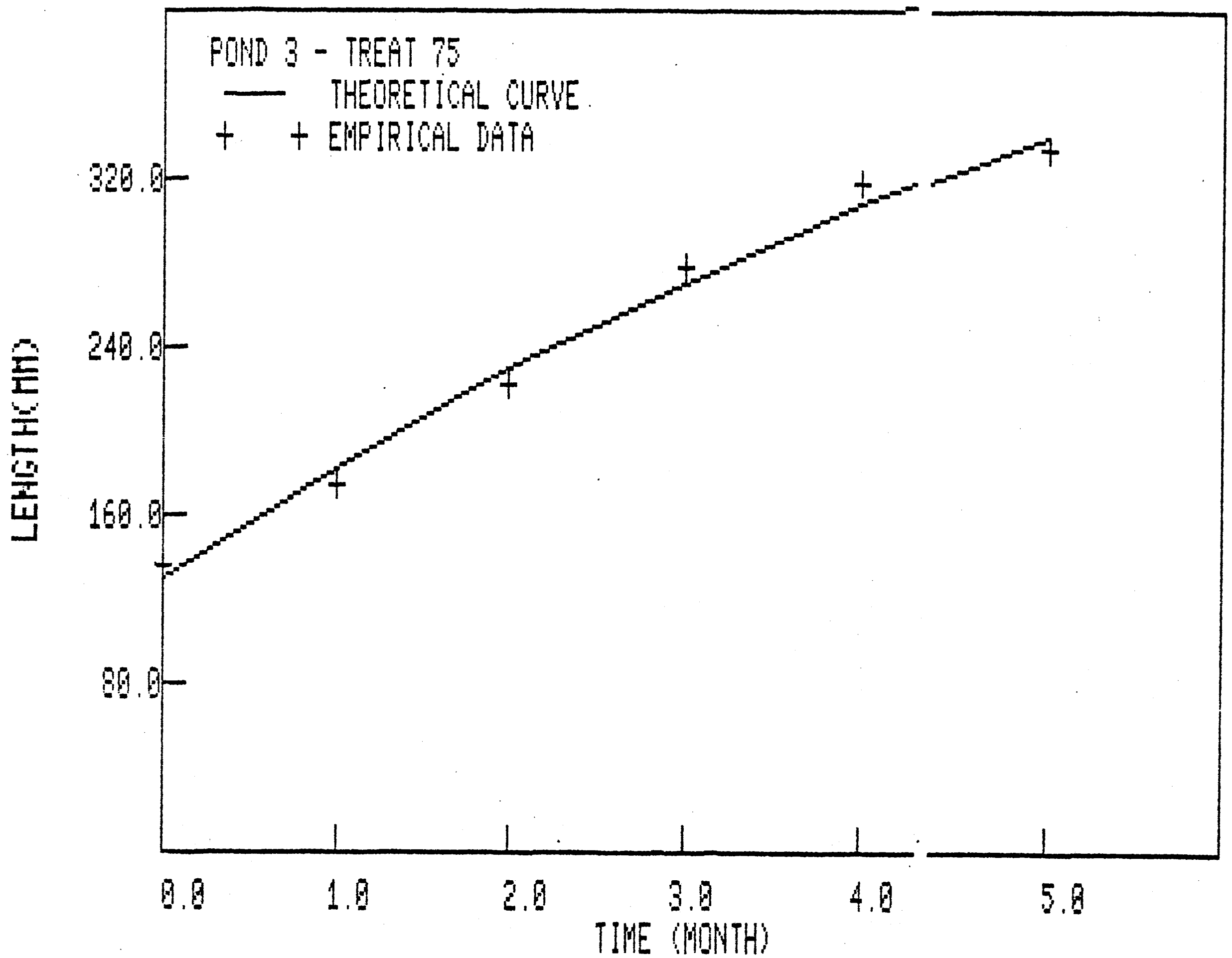

POND 3 - TREAT 50
THEORETICAL CURVE
+ EMPIRICAL DATA
320.0
240.0
160.0
80.0
LENGTH(MM)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 54. Growth curve in length for channel catfish in treatment 75 (number of tilapia) at pond 3.



POND 3 - TREAT 75
THEORETICAL CURVE
+ EMPIRICAL DATA
320.0
240.0
160.0
80.0
LENGTH(MM)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

APPENDIX C

GROWTH CURVE IN WEIGHT FOR CHANNEL CATFISH

Figure 55. Growth curve in weight for channel catfish in treatment 0 (number of tilapia) at pond 1.

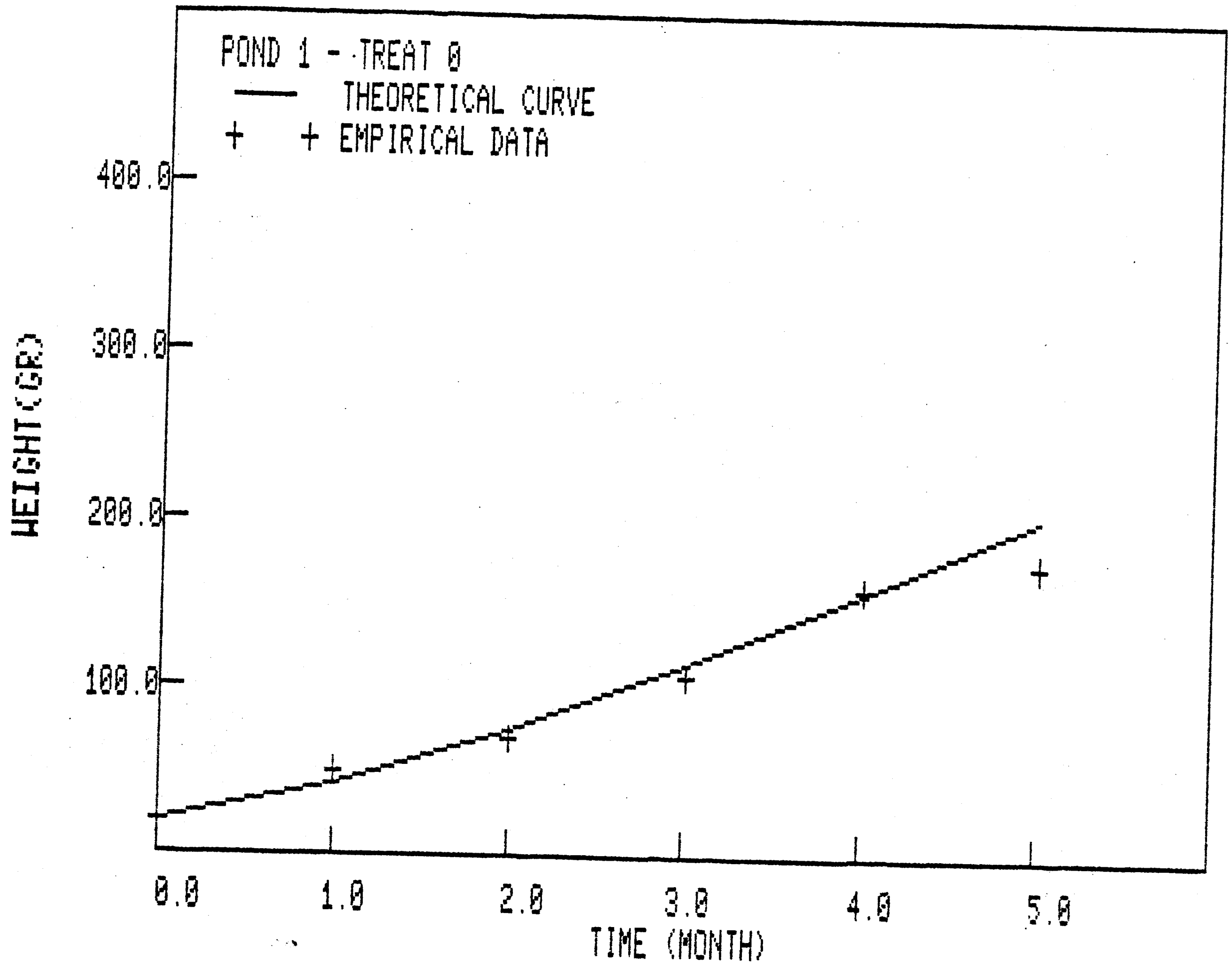

POND 1 - TREAT 0
THEORETICAL CURVE
+ EMPIRICAL DATA
400.0
300.0
200.0
100.0
WEIGHT(GR)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 56. Growth curve in weight for channel catfish in treatment 25 (number of tilapia) at pond 1.

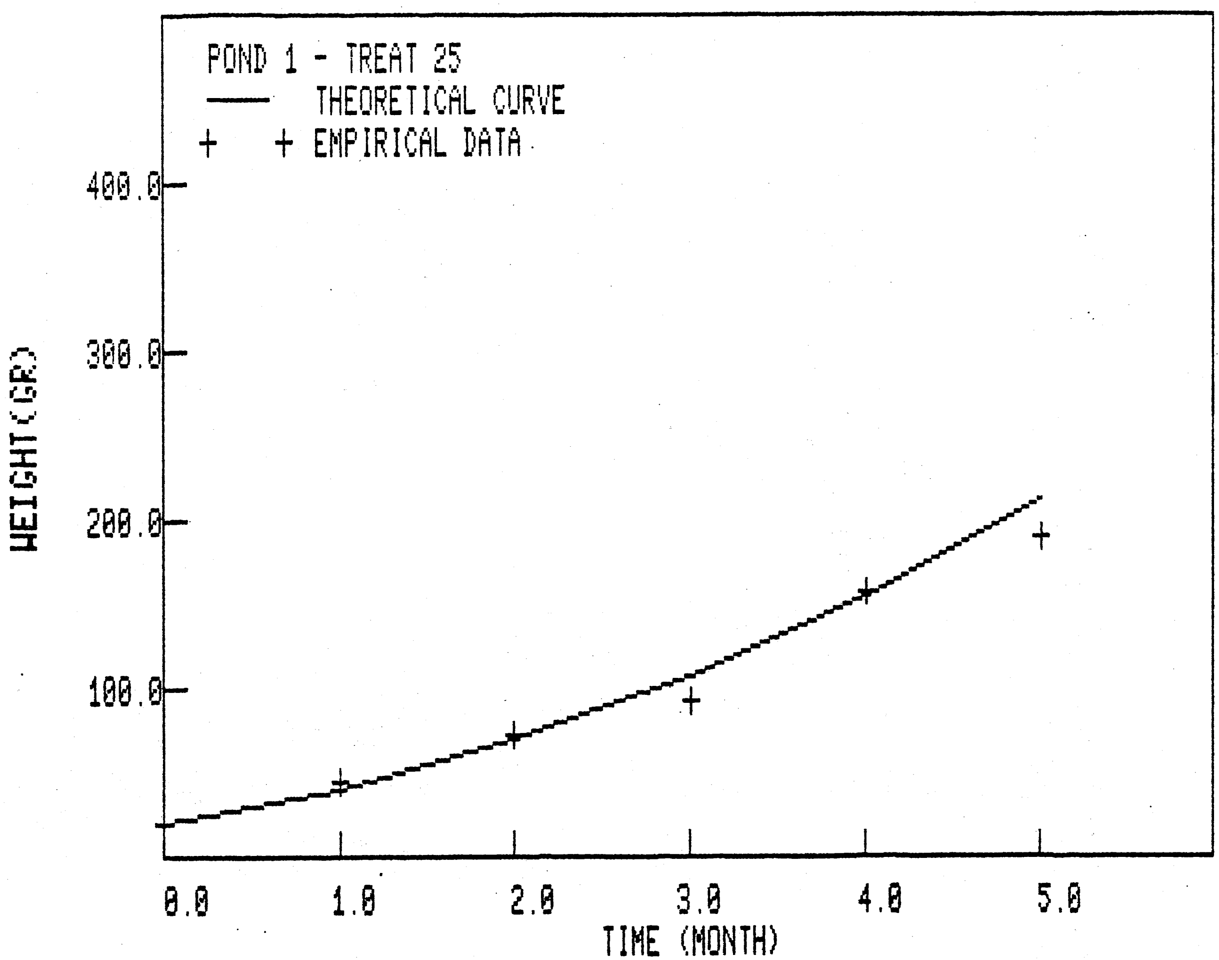

POND 1 - TREAT 25
THEORETICAL CURVE
EMPIRICAL DATA
WEIGHT(GR)
400.0
300.0
200.0
100.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 57. Growth curve in weight for channel catfish in treatment 50 (number of tilapia) at pond 1.

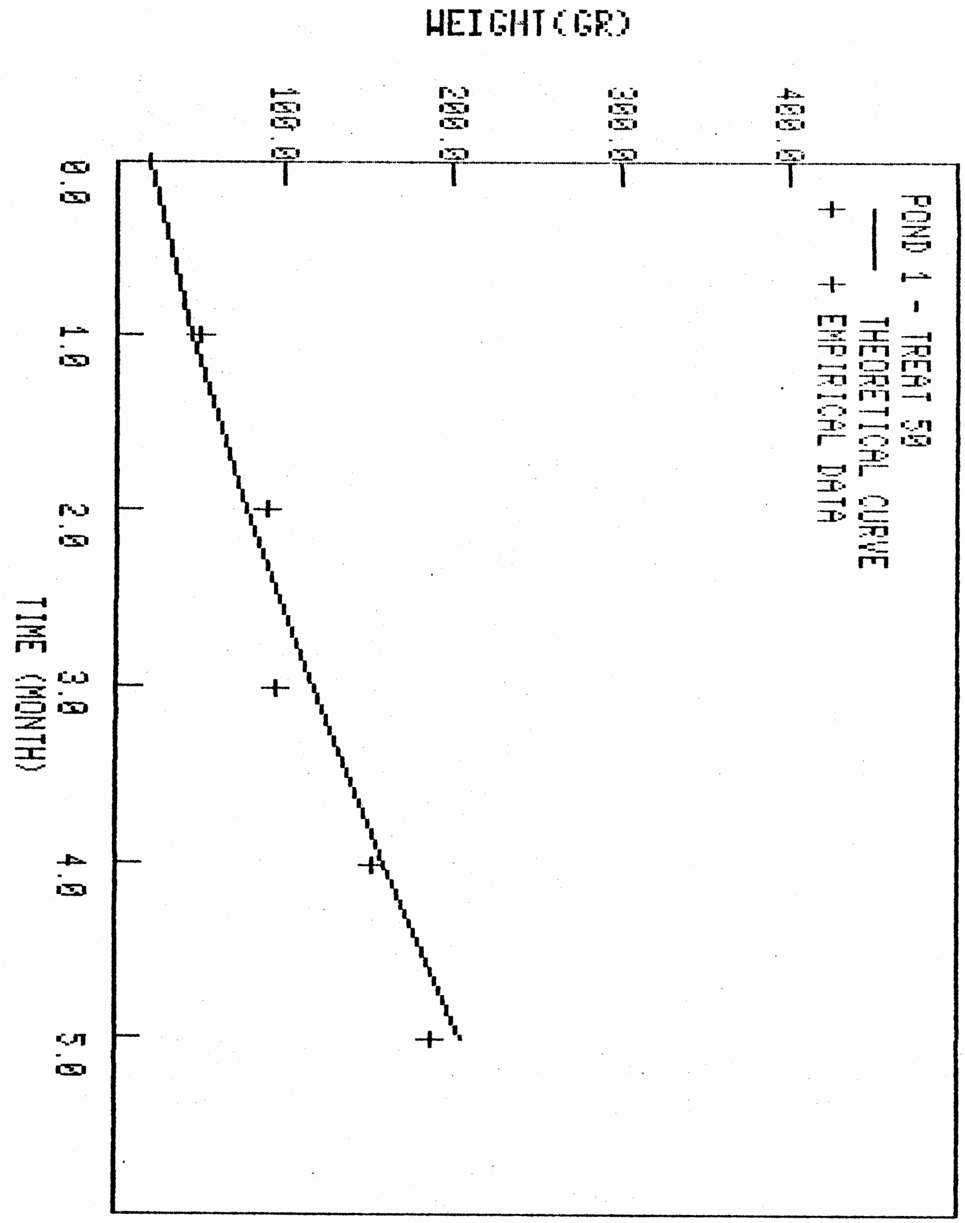

WEIGHT(GR)
100.0
200.0
300.0
400.0
POND 1 - TREAT 50
THEORETICAL CURVE
+ EMPIRICAL DATA
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 58. Growth curve in weight for channel catfish in treatment 75 (number of tilapia) at pond 1.

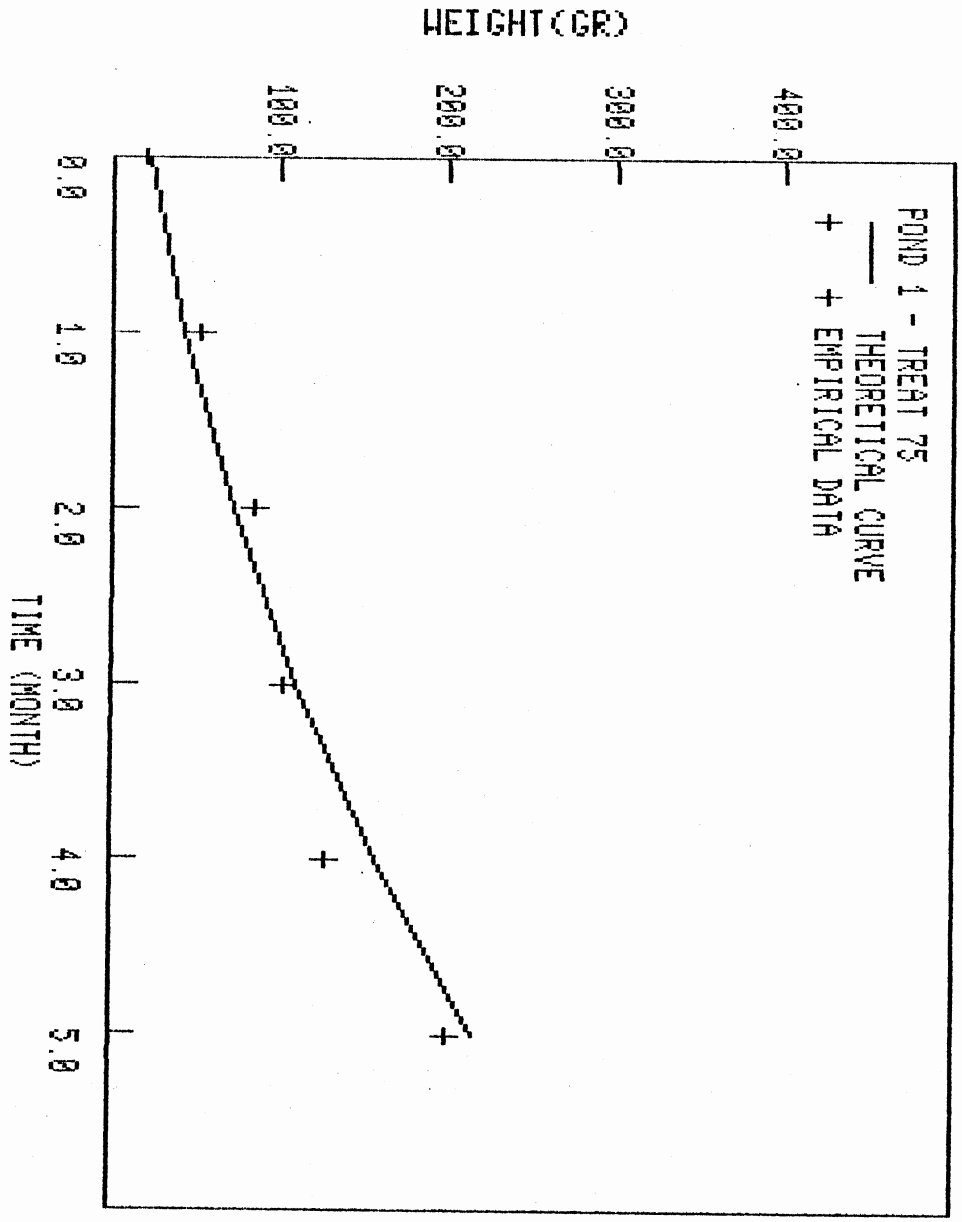
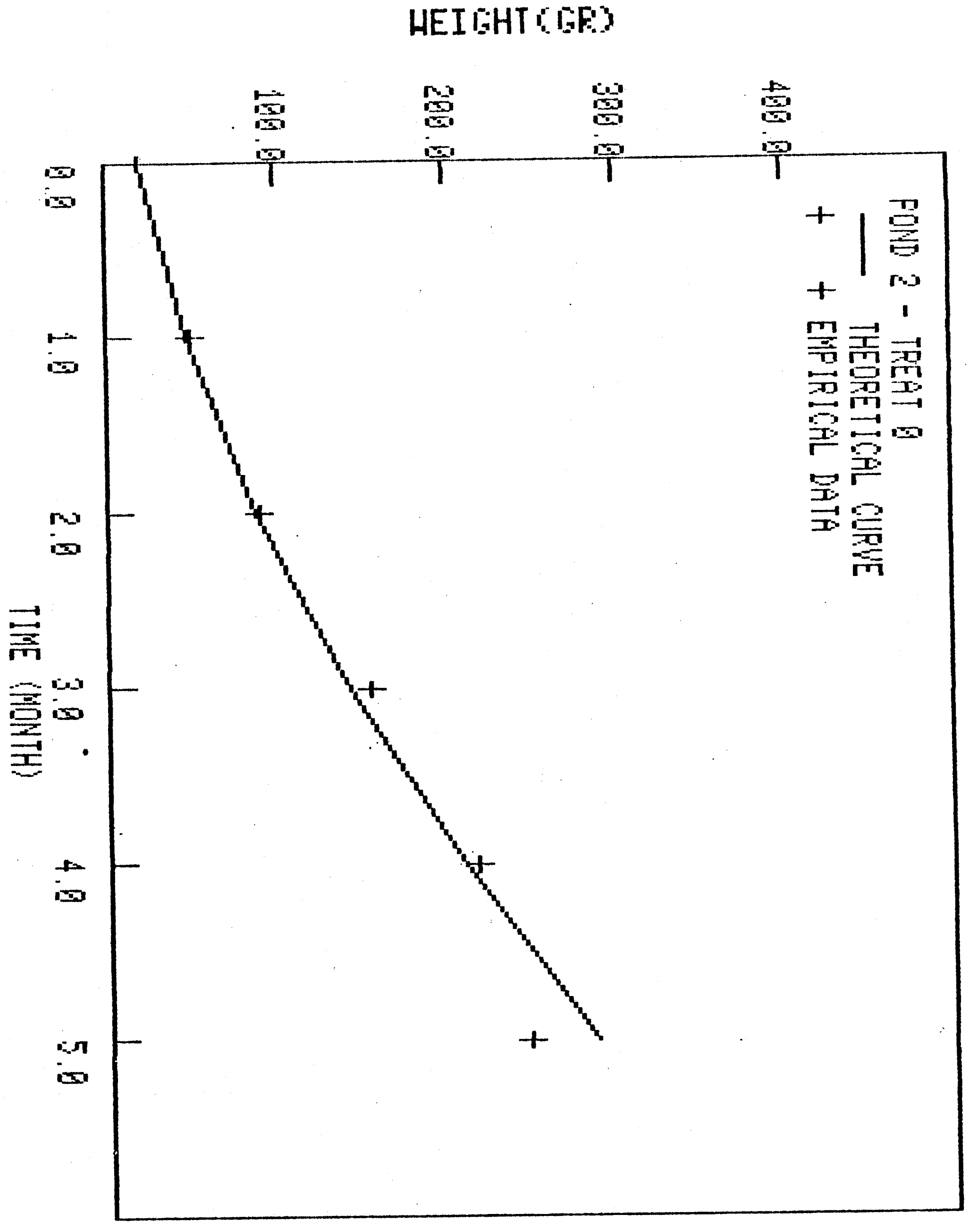

WEIGHT(GR)
400.0
300.0
200.0
100.0
POND 1 - TREAT 75
THEORETICAL CURVE
+ + EMPIRICAL DATA
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 59. Growth curve in weight for channel catfish in treatment 0 (number of tilapia) at pond 2.



WEIGHT(GR)
100.0
200.0
300.0
400.0
FOND 2 - TREAT 0
THEORETICAL CURVE
+ EMPIRICAL DATA
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 60. Growth curve in weight for channel catfish in treatment 25 (number of tilapia) at pond 2.

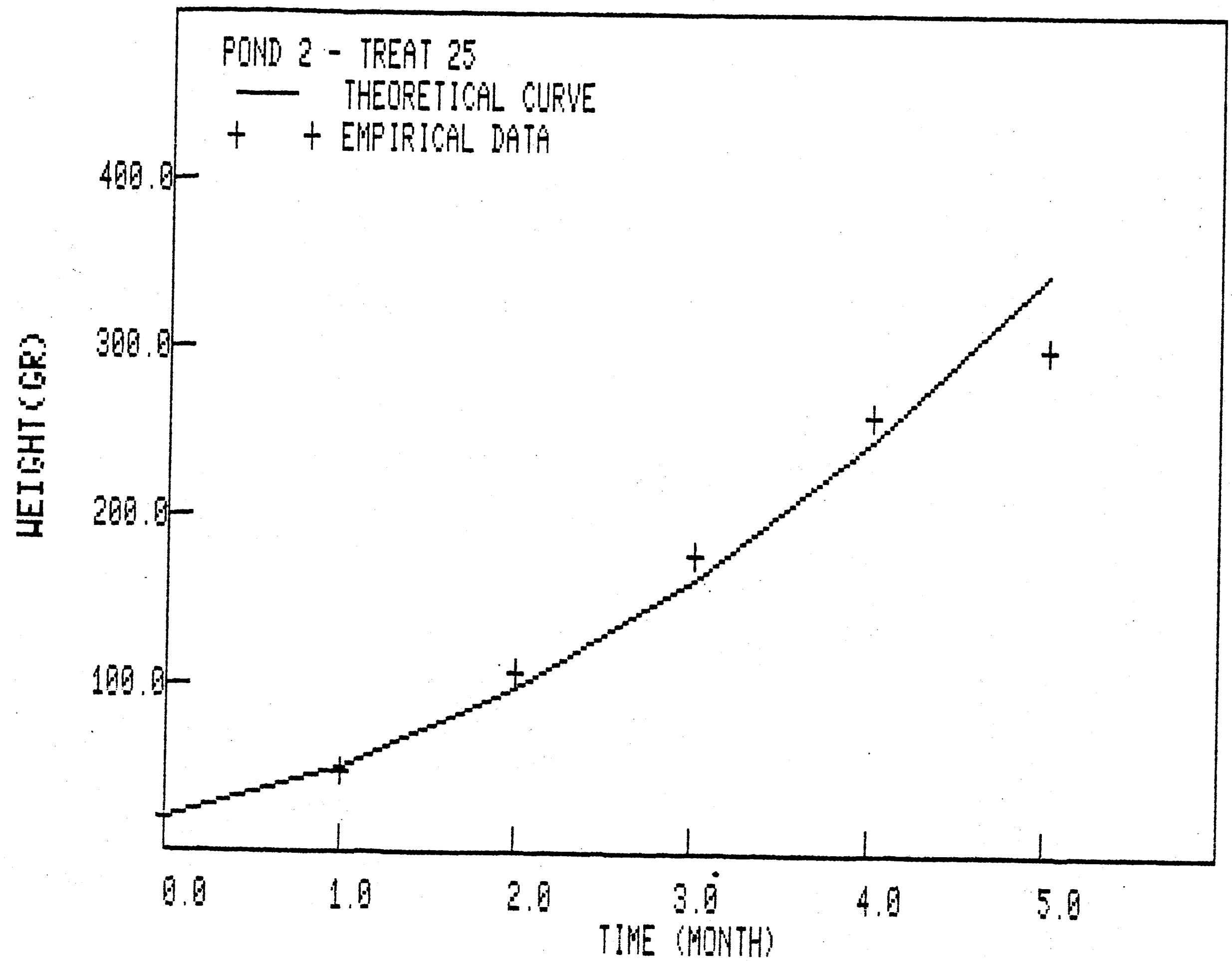

POND 2 - TREAT 25
THEORETICAL CURVE
EMPIRICAL DATA
WEIGHT(GR)
400.0
300.0
200.0
100.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 61. Growth curve in weight for channel catfish in treatment 50 (number of tilapia) at pond 2.

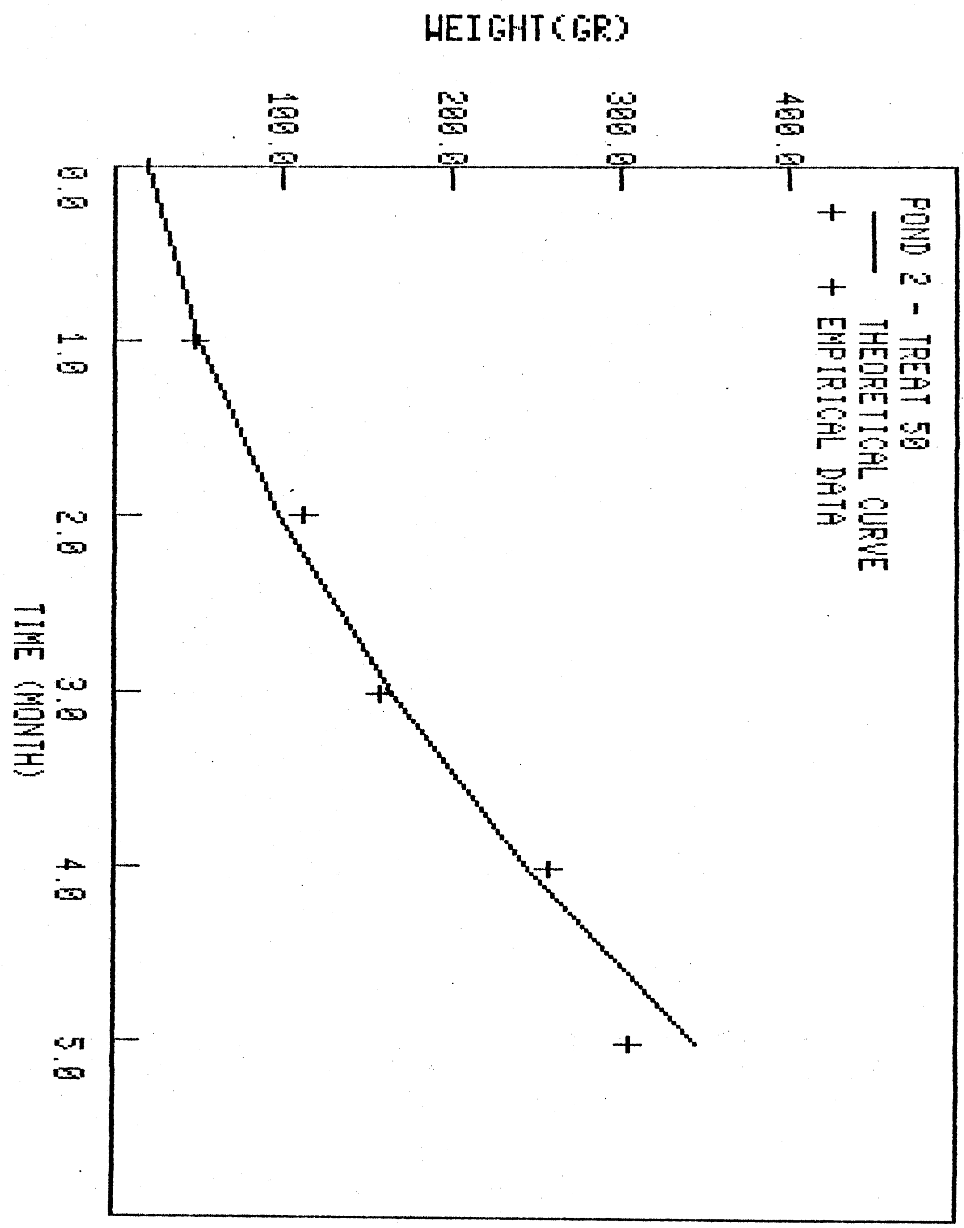

POND 2 - TREAT 50
THEORETICAL CURVE
+ + EMPIRICAL DATA
WEIGHT(GR)
100.0
200.0
300.0
400.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 62. Growth curve in weight for channel catfish in treatment 75 (number of tilapia) at pond 2.

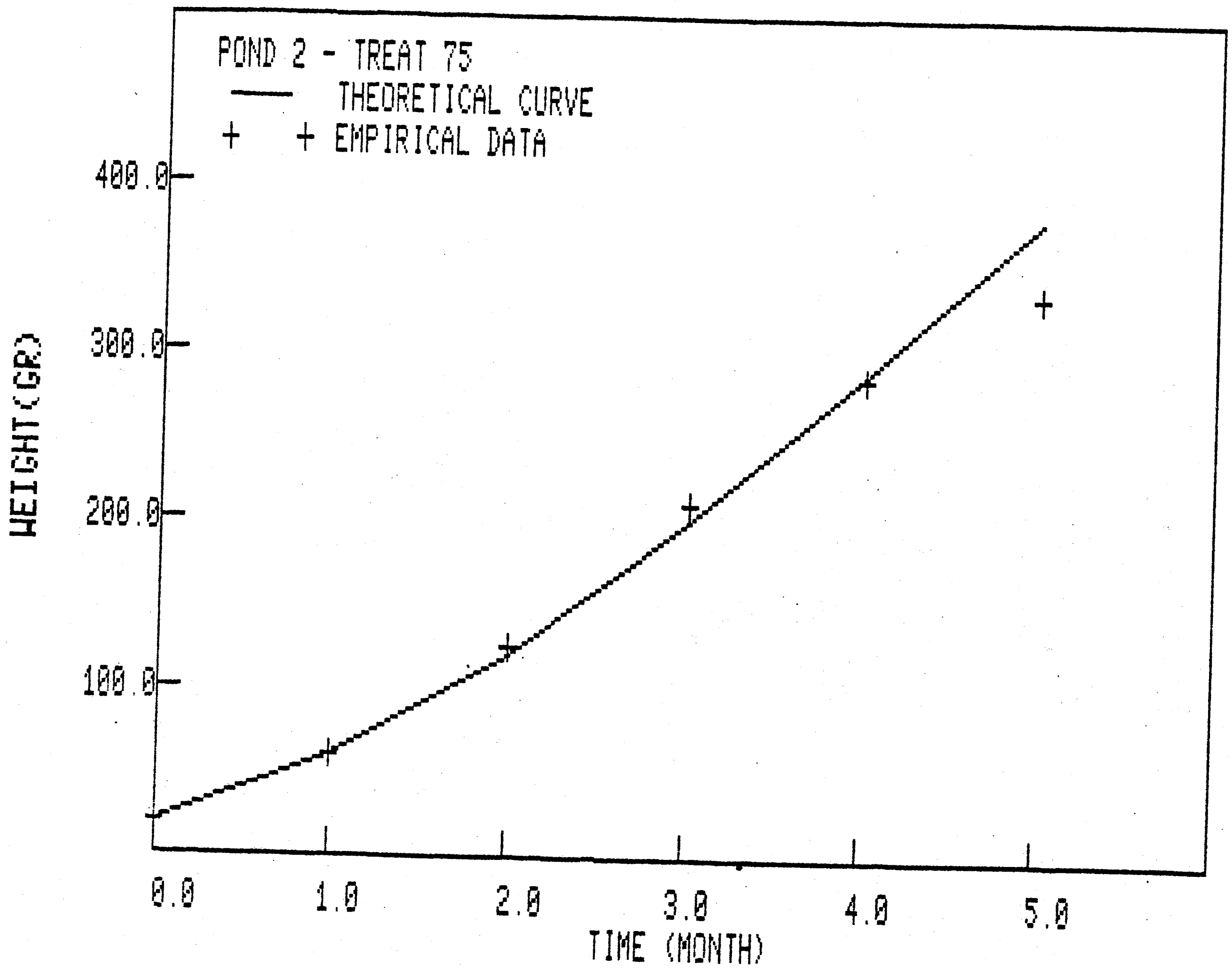

POND 2 - TREAT 75
THEORETICAL CURVE
+ + EMPIRICAL DATA
400.0
300.0
200.0
100.0
WEIGHT(GR)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 63. Growth curve in weight for channel catfish in treatment 0 (number of tilapia) at pond 3.

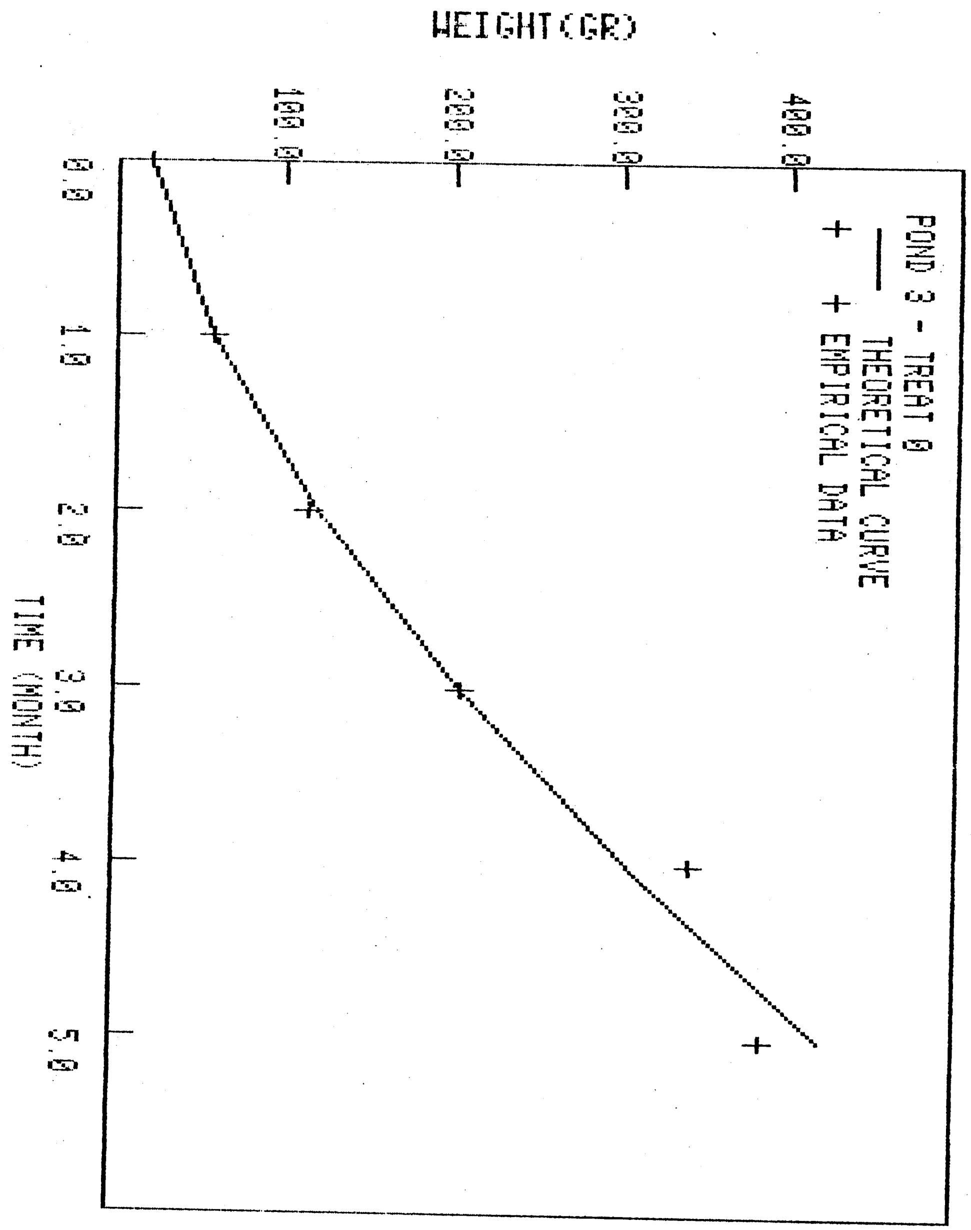

WEIGHT(GR)
100.0
200.0
300.0
400.0
POND 3 - TREAT 0
THEORETICAL CURVE
+ + EMPIRICAL DATA
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 64. Growth curve in weight for channel catfish in treatment 25 (number of tilapia) at pond 3.

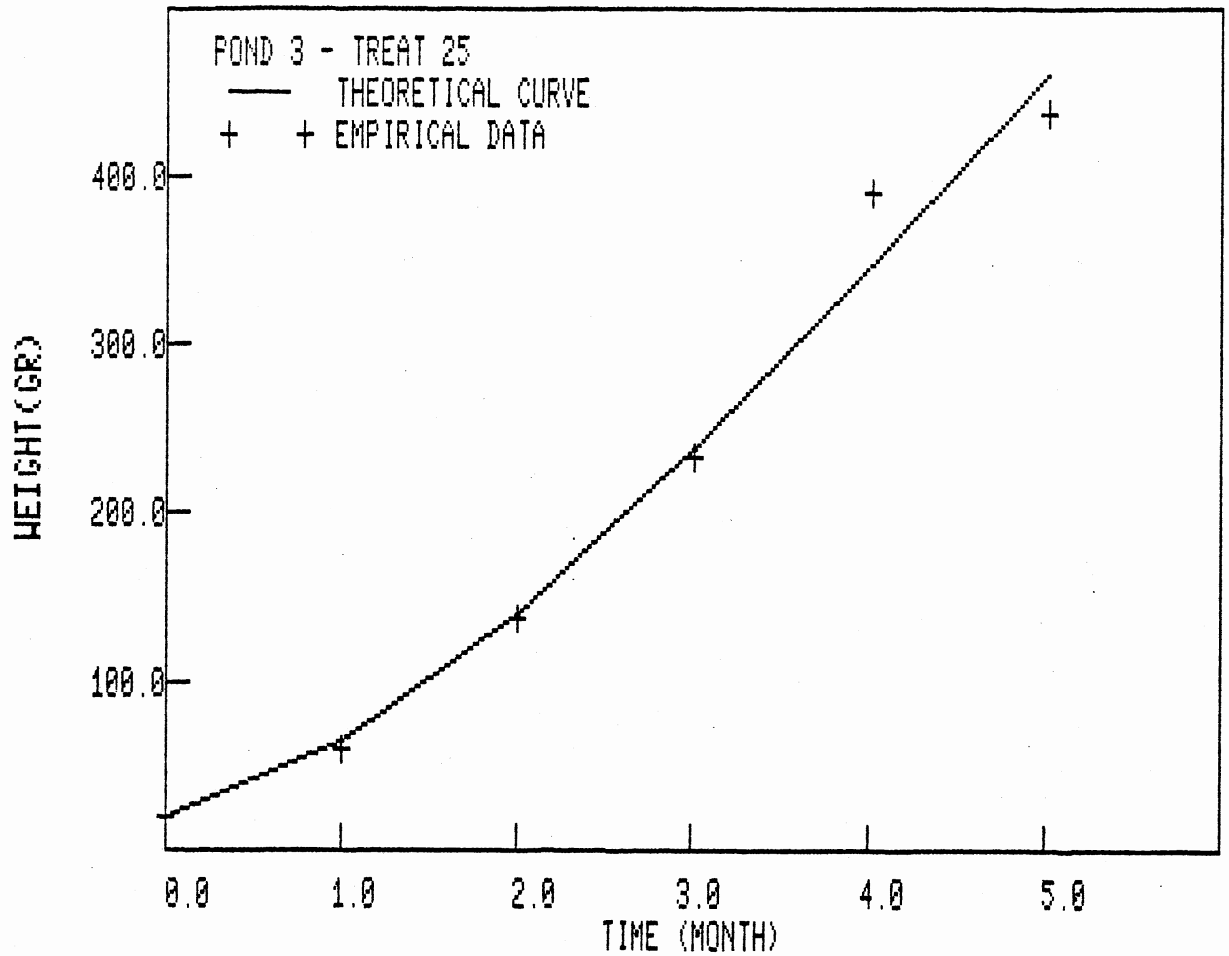

POND 3 - TREAT 25
THEORETICAL CURVE
EMPIRICAL DATA
400.0
300.0
200.0
100.0
WEIGHT(GR)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 65. Growth curve in weight for channel catfish in treatment 50 (number of tilapia) at pond 3.

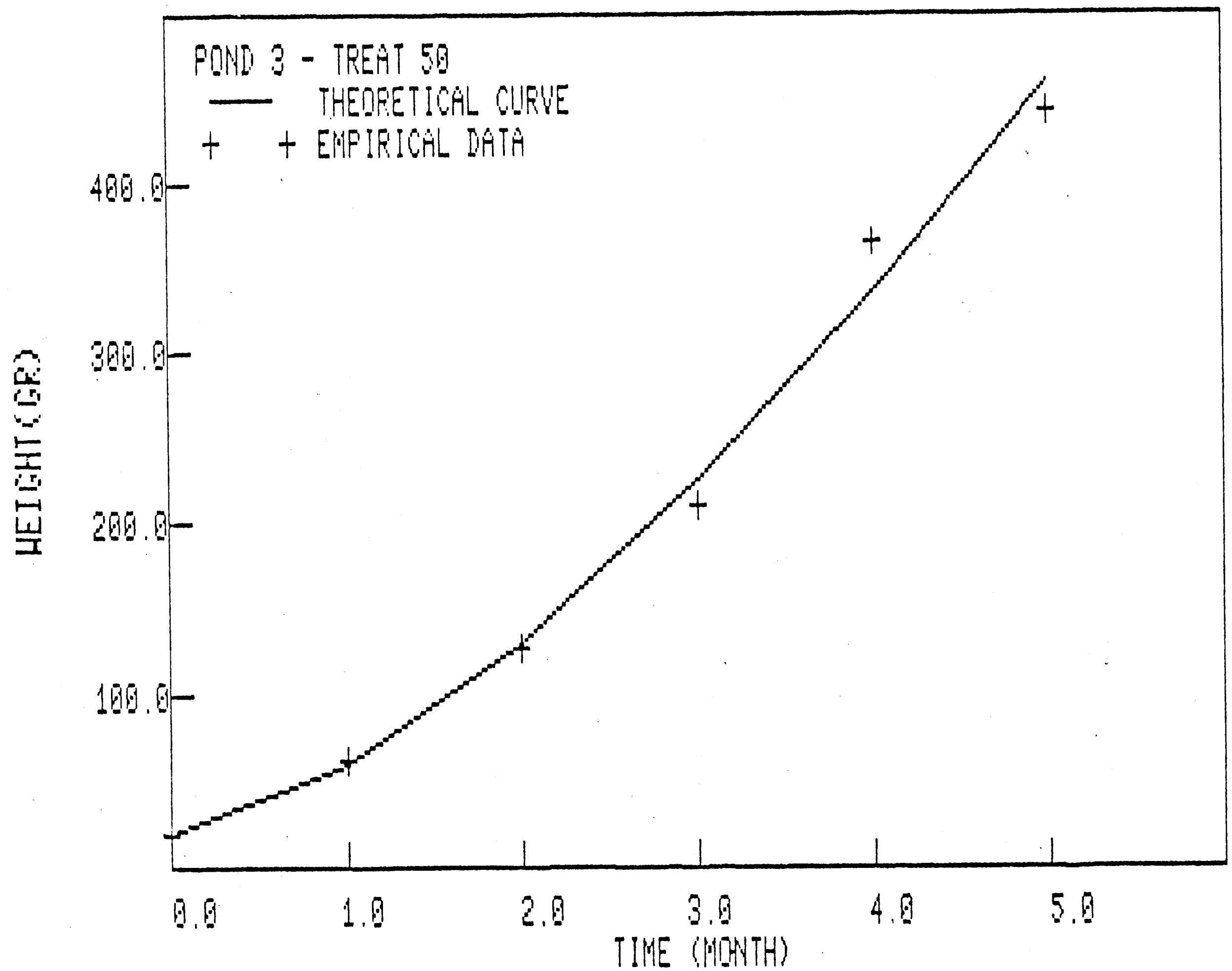
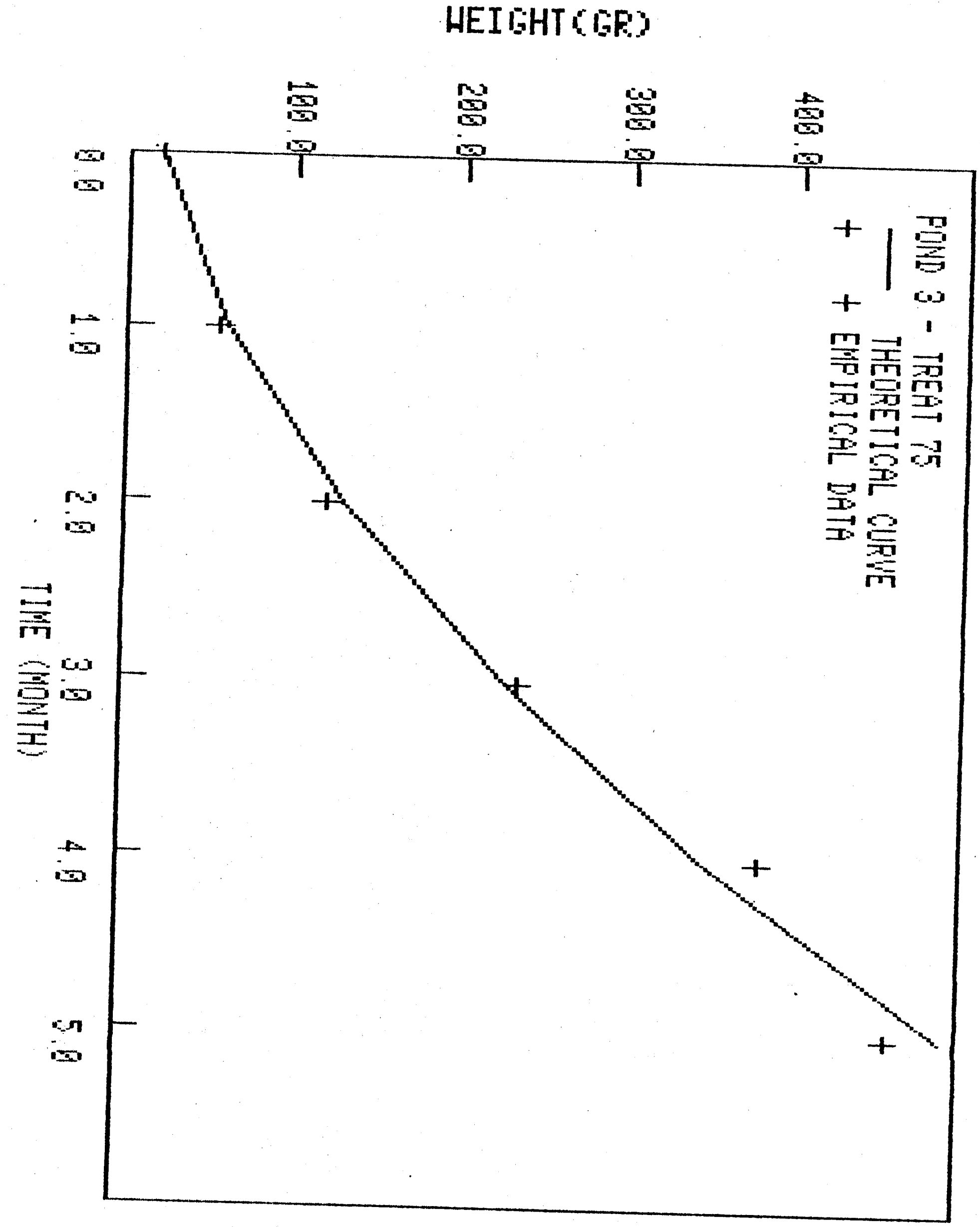

POND 3 - TREAT 50
THEORETICAL CURVE
EMPIRICAL DATA
400.0
300.0
200.0
100.0
WEIGHT(GR)
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 66. Growth curve in weight for channel catfish in treatment 75 (number of tilapia) at pond 3.


POND 3 - TREAT 75
THEORETICAL CURVE
+ + EMPIRICAL DATA
WEIGHT(GR)
100.0
200.0
300.0
400.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

APPENDIX D

YIELD CURVE FOR CHANNEL CATFISH

Figure 67. Yield curve for channel catfish in treatment 0 (number of tilapia) at pond 1.

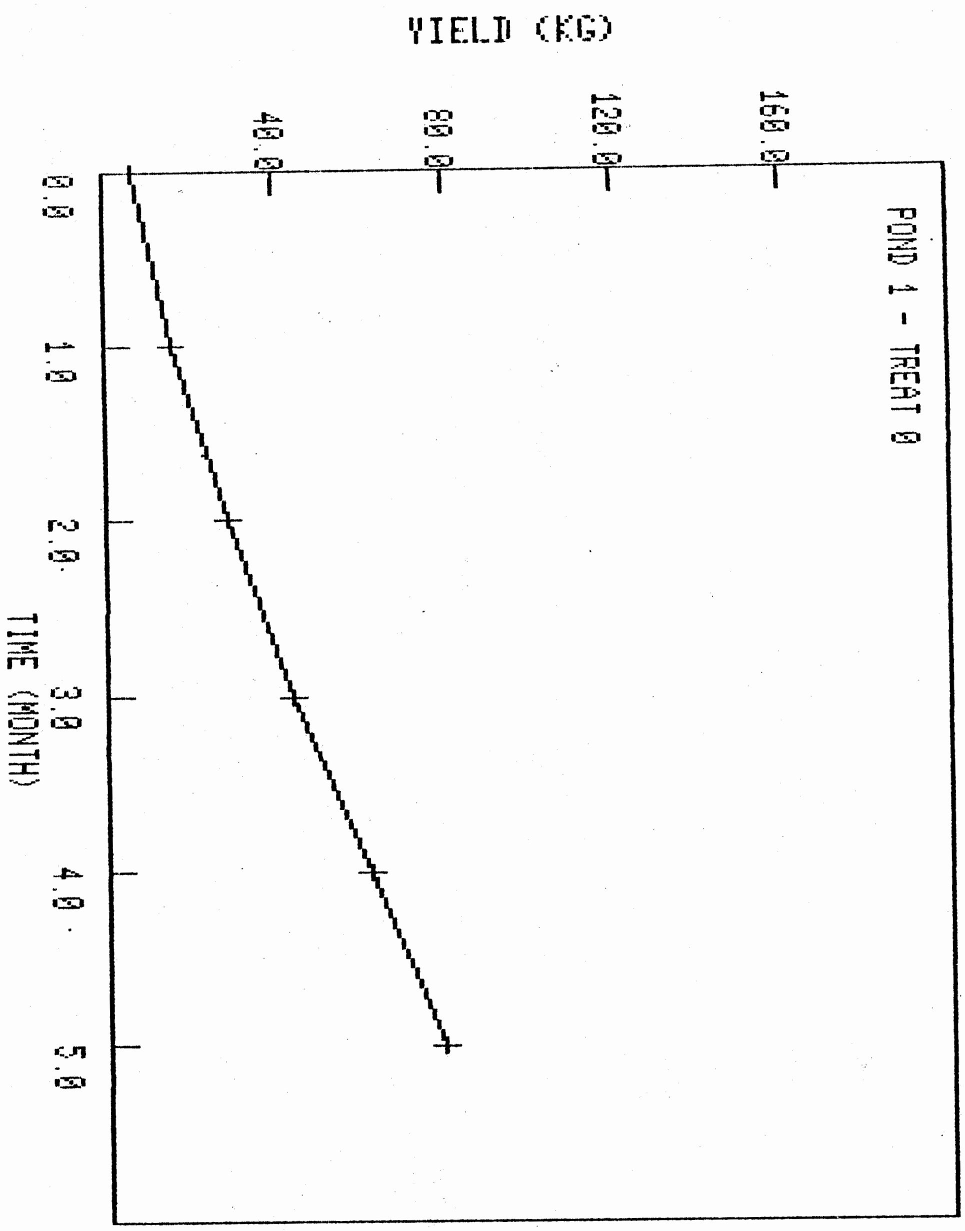

YIELD (KG)
POND 1 - TREAT 0
160.0
120.0
80.0
40.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 68. Yield curve for channel catfish in treatment 25 (number of tilapia) at pond 1.

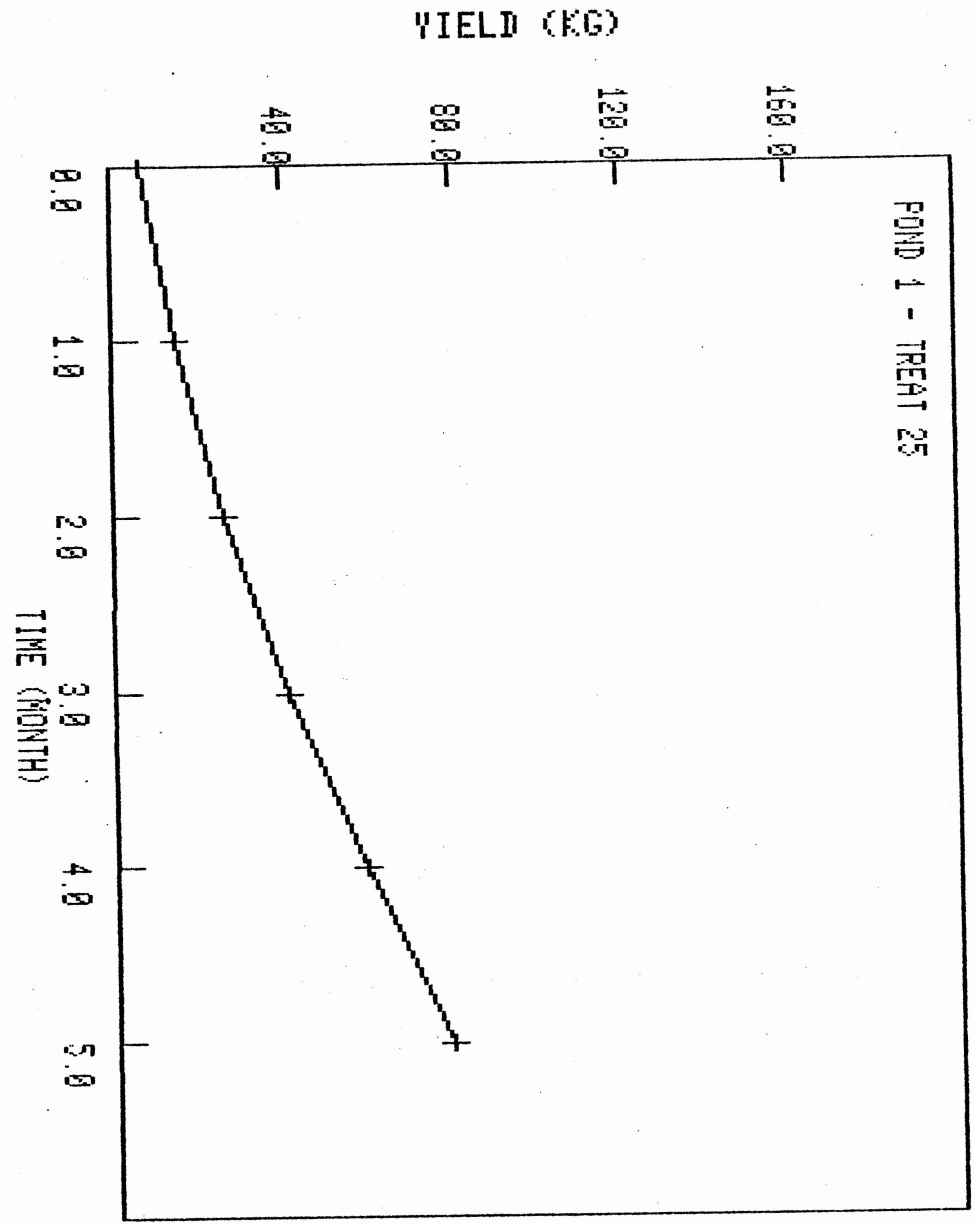

POND 1 - TREAT 25
YIELD (KG)
160.0
120.0
80.0
40.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 69. Yield curve for channel catfish in treatment 25 (number of tilapia) at pond 1.

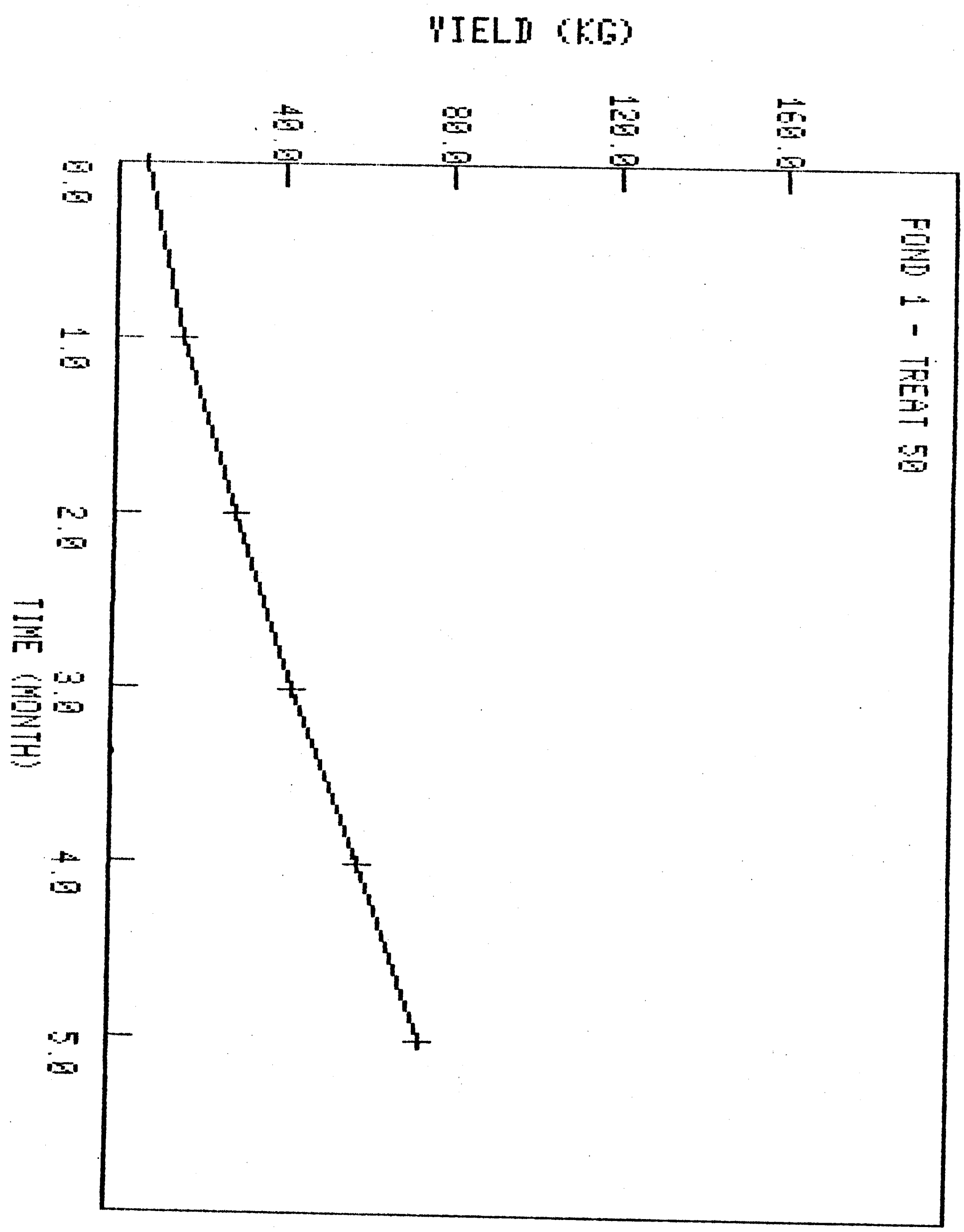

YIELD (KG)
160.0
120.0
80.0
40.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)
POND 1 - TREAT 50

Figure 70. Yield curve for channel catfish in treatment 75 (number of tilapia) at pond 1.

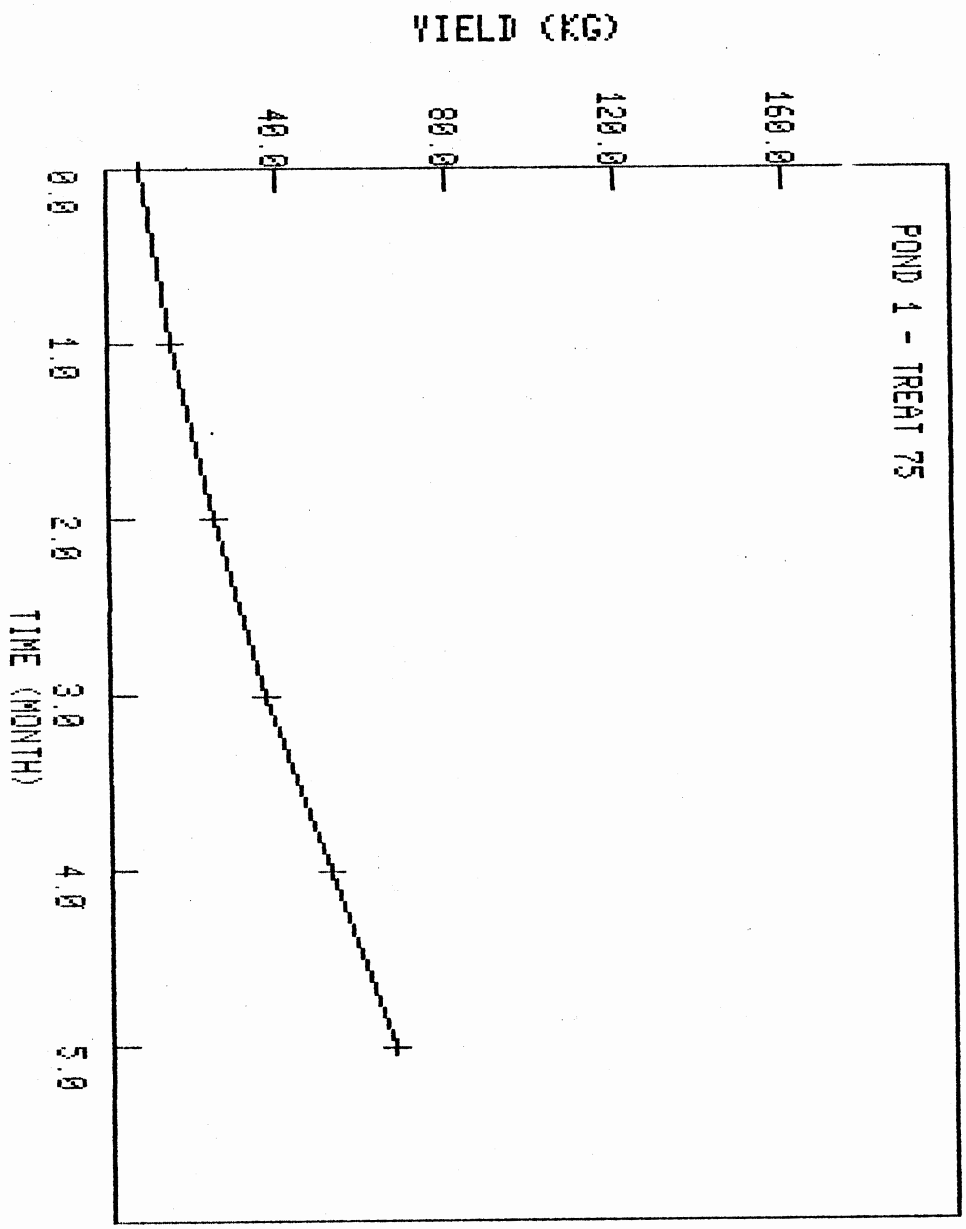

POND 1 - TREAT 75
YIELD (KG)
40.0
80.0
120.0
160.0
TIME (MONTH)
0.0
1.0
2.0
3.0
4.0
5.0

Figure 71. Yield curve for channel catfish in treatment 0 (number of tilapia) at pond 2.

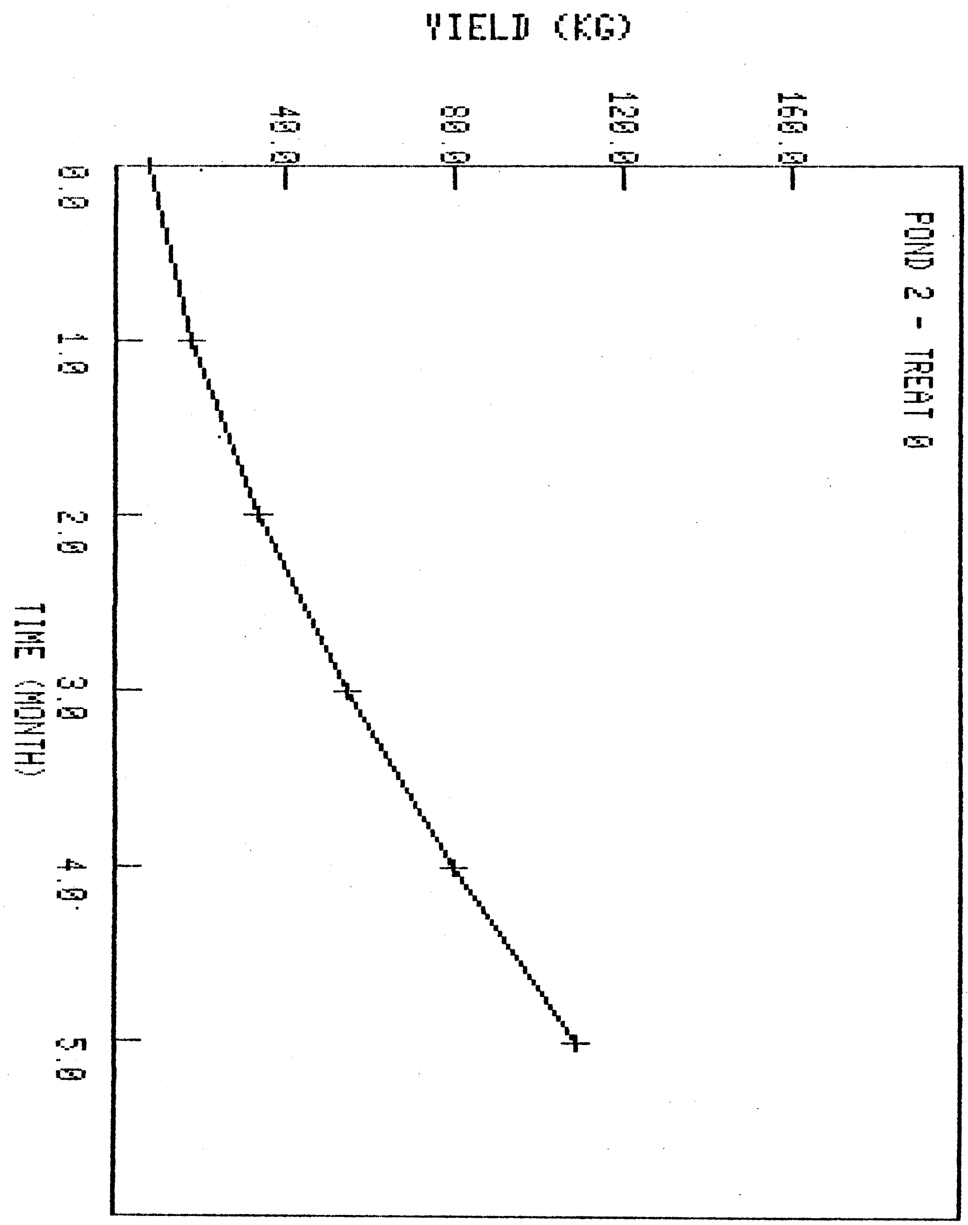

POND 2 - TREAT 0
YIELD (KG)
40.0
80.0
120.0
160.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 72. Yield curve for channel catfish in treatment 25 (number of tilapia) at pond 2.

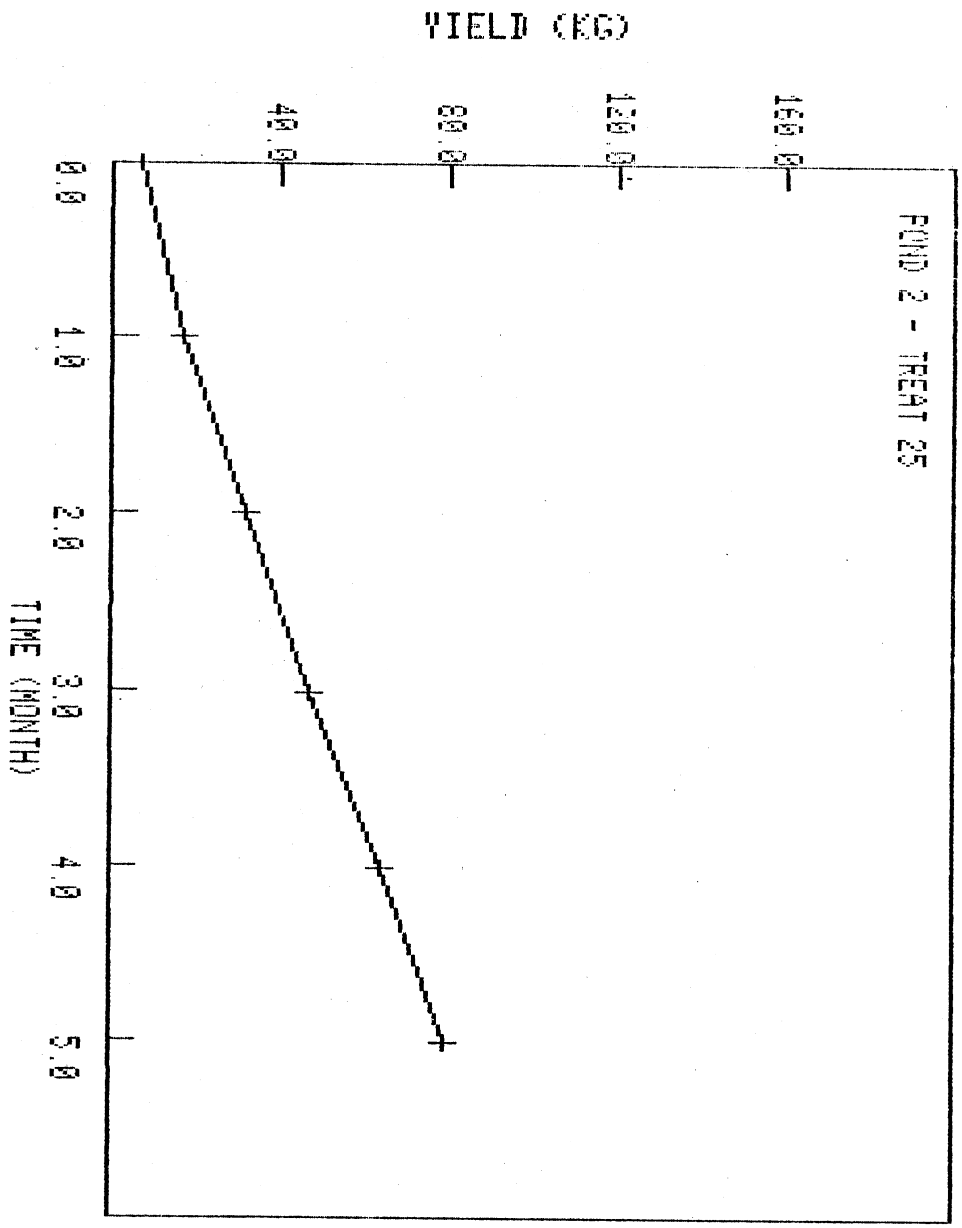

POND 2 - TREAT 25
YIELD (KG)
40.0
80.0
120.0
160.0
TIME (MONTH)
0.0
1.0
2.0
3.0
4.0
5.0

Figure 73. Yield curve for channel catfish in treatment 50 (number of tilapia) at pond 2.

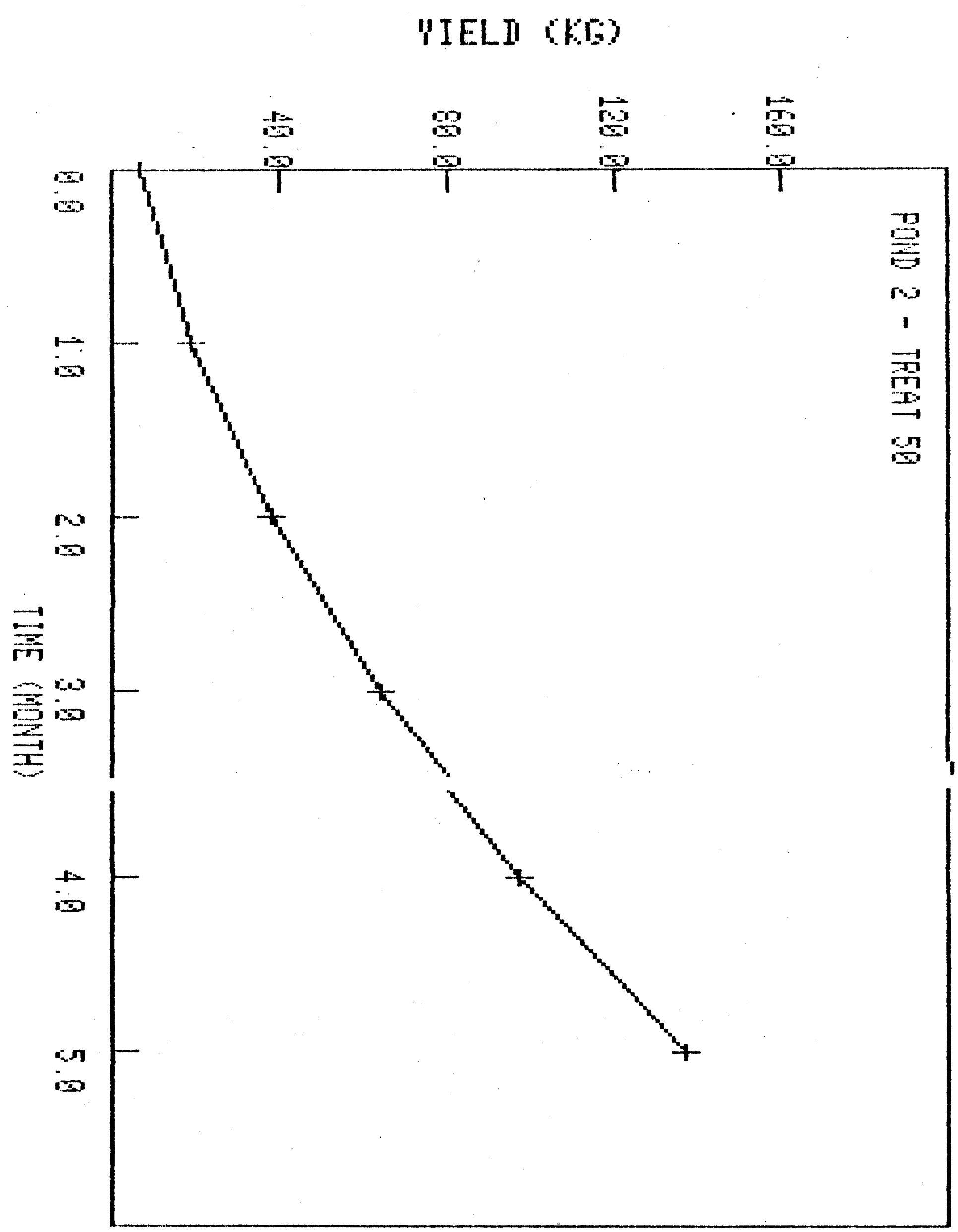

YIELD (KG)
40.0
80.0
120.0
160.0
POND 2 - TREAT 50
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 74. Yield curve for channel catfish in treatment 75 (number of tilapia) at pond 2.

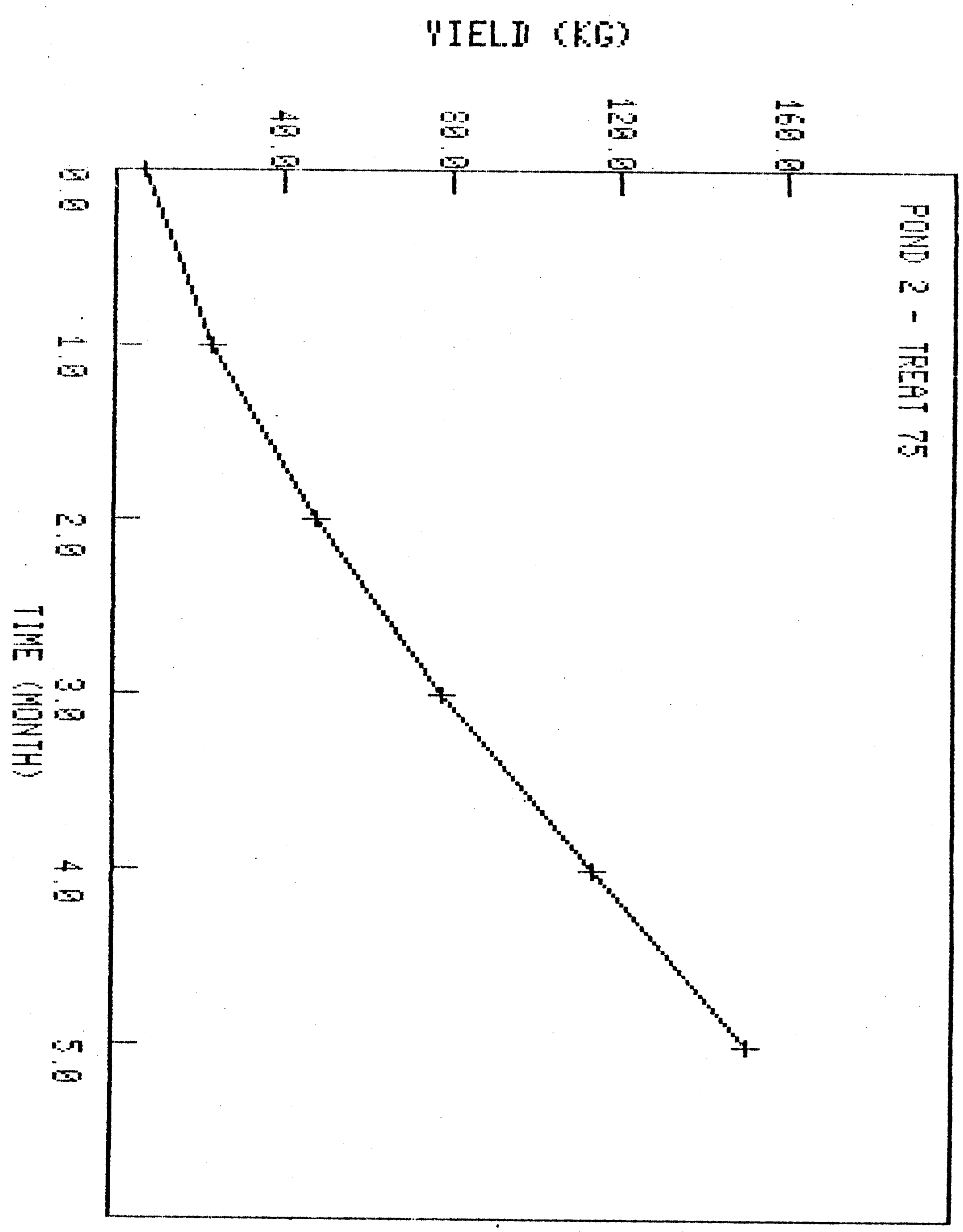

POND 2 - TREAT 75
YIELD (KG)
40.0
80.0
120.0
160.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 75. Yield curve for channel catfish in treatment 0 (number of tilapia) at pond 3.

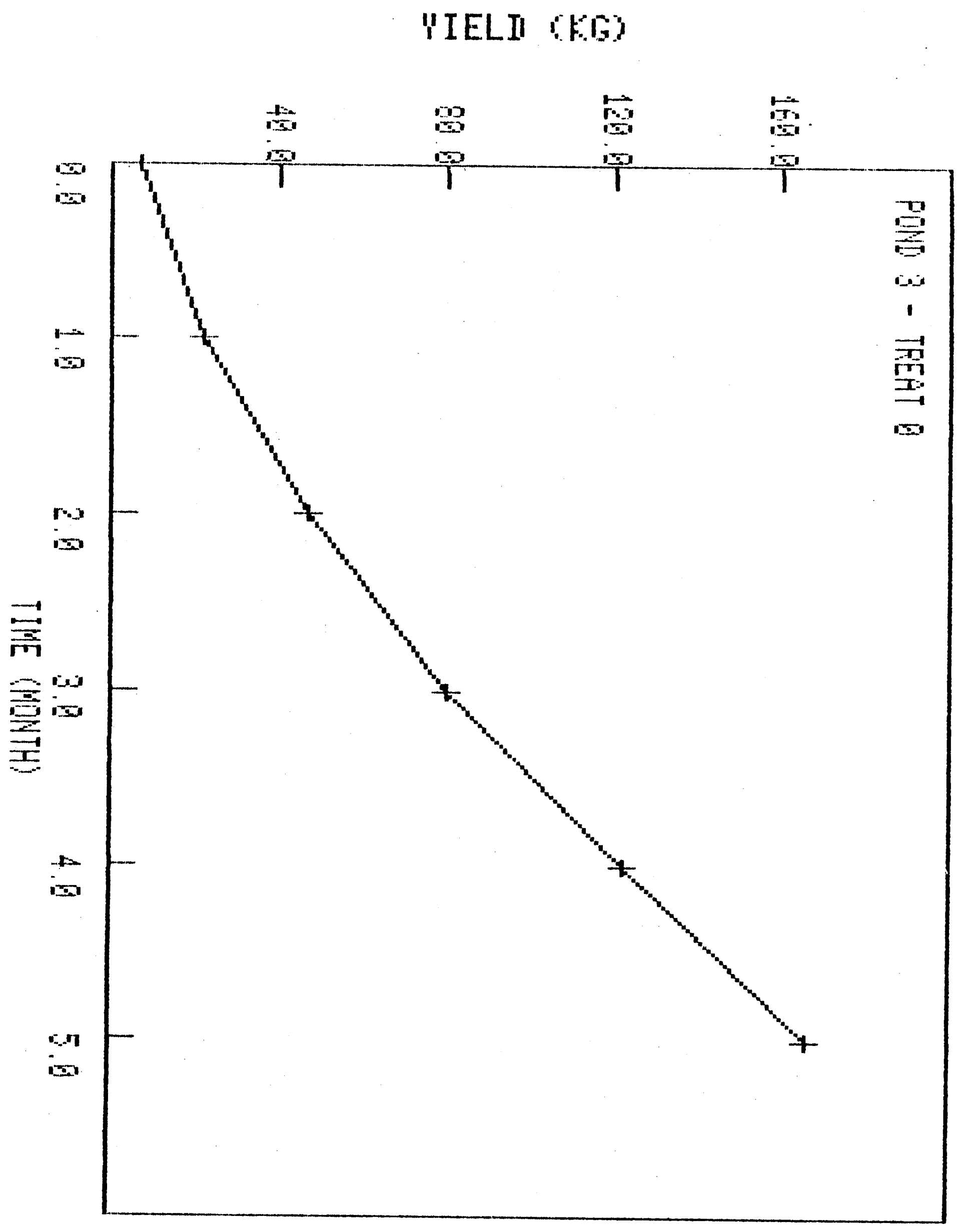

POND 3 - TREAT 0
YIELD (KG)
40.0
80.0
120.0
160.0
TIME (MONTH)
0.0
1.0
2.0
3.0
4.0
5.0

Figure 76. Yield curve for channel catfish in treatment 25 (number of tilapia) at pond 3.

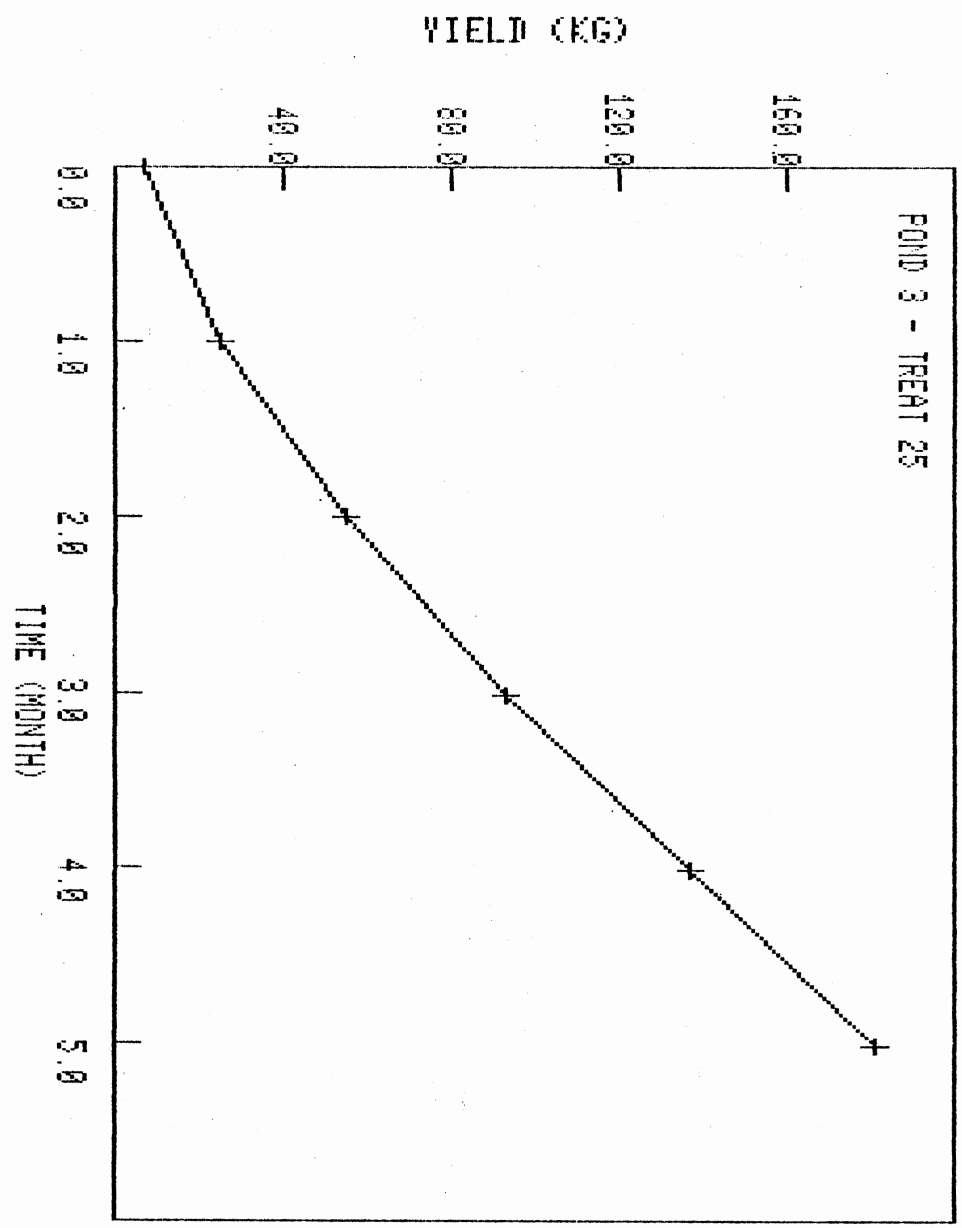

POND 3 - TREAT 25
YIELD (KG)
40.0
80.0
120.0
160.0
TIME (MONTH)
0.0
1.0
2.0
3.0
4.0
5.0

Figure 77. Yield curve for channel catfish in treatment 50 (number of tilapia) at pond 3.

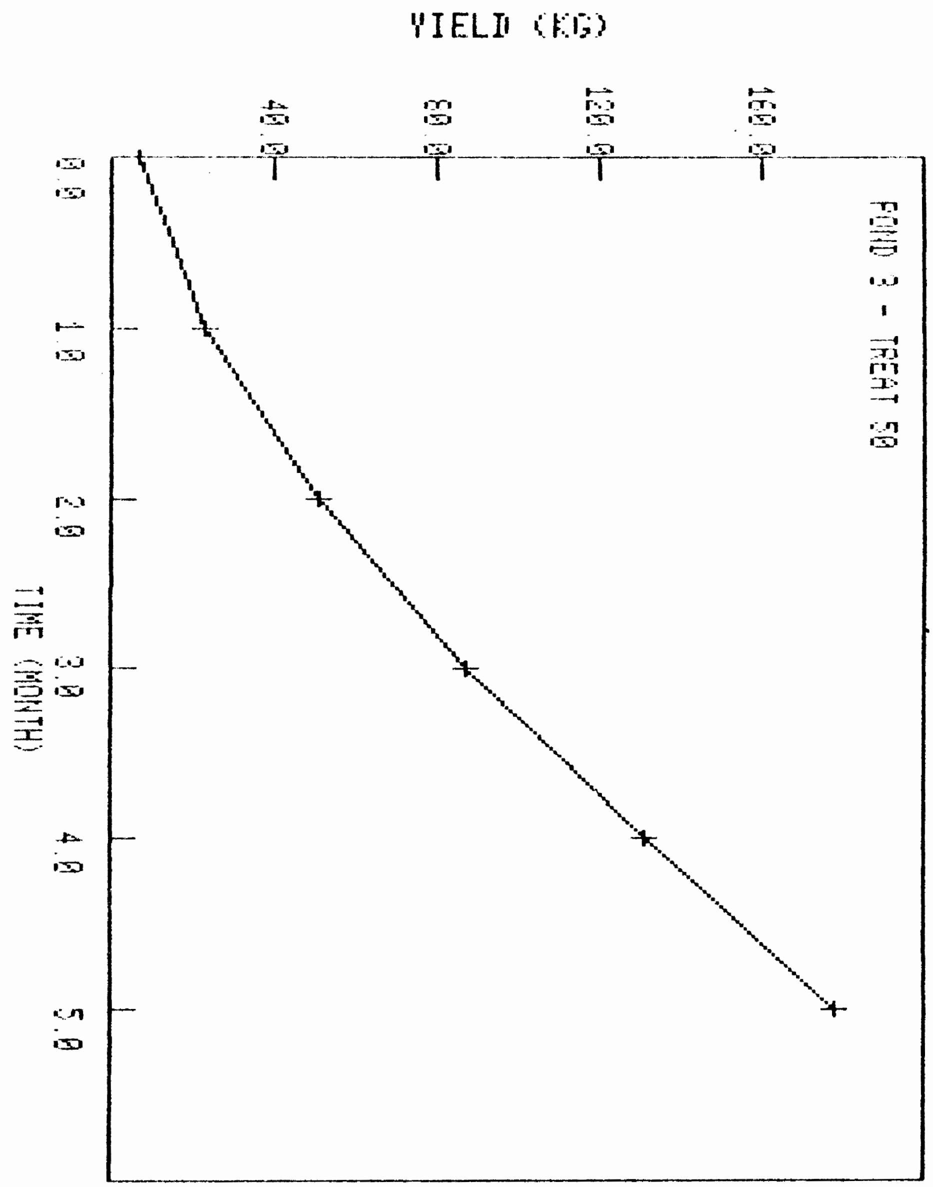
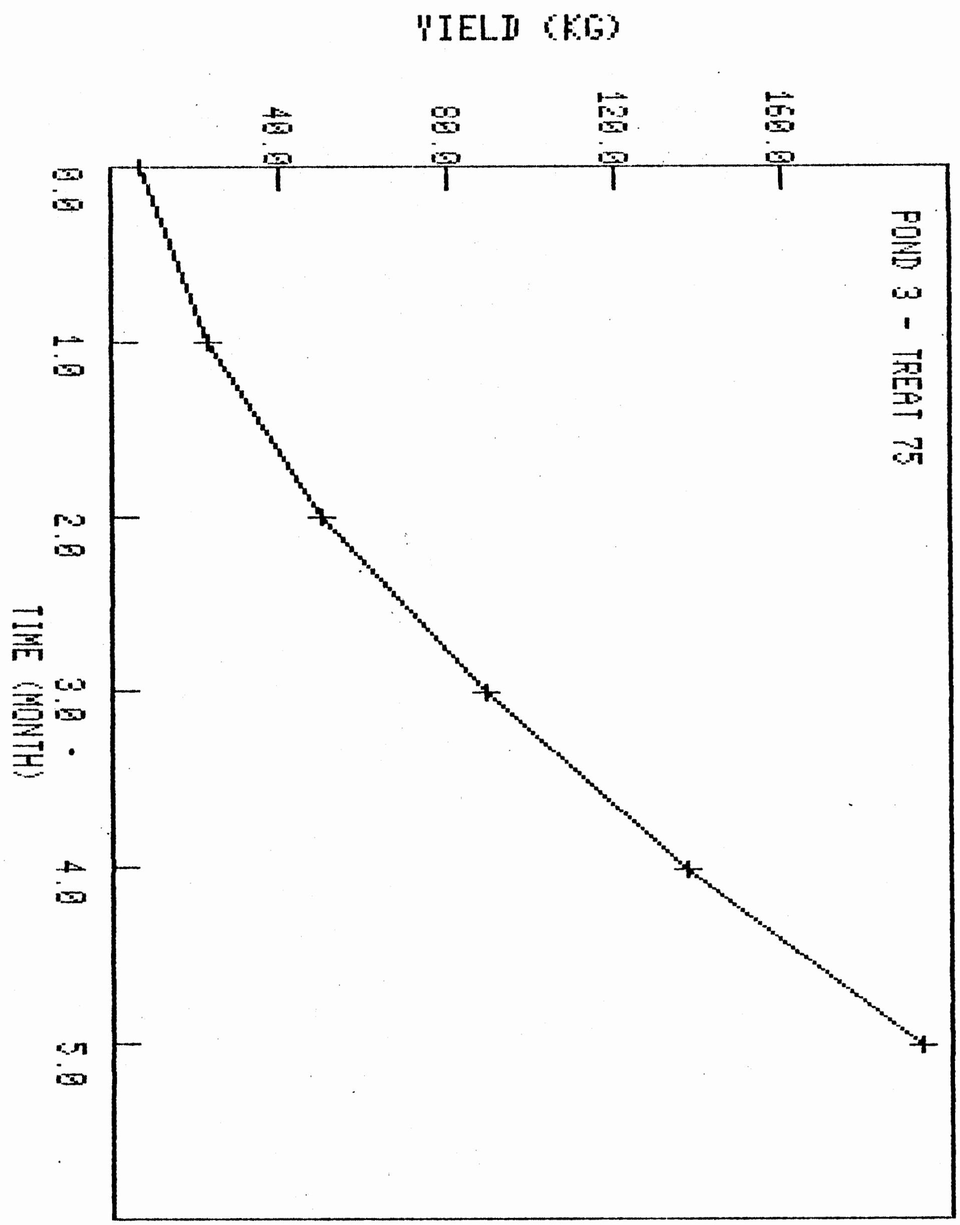

YIELD (KG)
160.0
120.0
80.0
40.0
POND 3 - TREAT 50
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

Figure 78. Yield curve for channel catfish in treatment 75

(number of tilapia) at pond 3.


POND 3 - TREAT 75
YIELD (KG)
40.0
80.0
120.0
160.0
0.0
1.0
2.0
3.0
4.0
5.0
TIME (MONTH)

APPENDIX E

VARIATIONS OF K AND LMAX FOR CHANNEL CATFISH

Figure 79. Variations of K and LMAX for channel catfish in treatments 0, 25, 50, and 75 (number of tilapia) at pond 1.

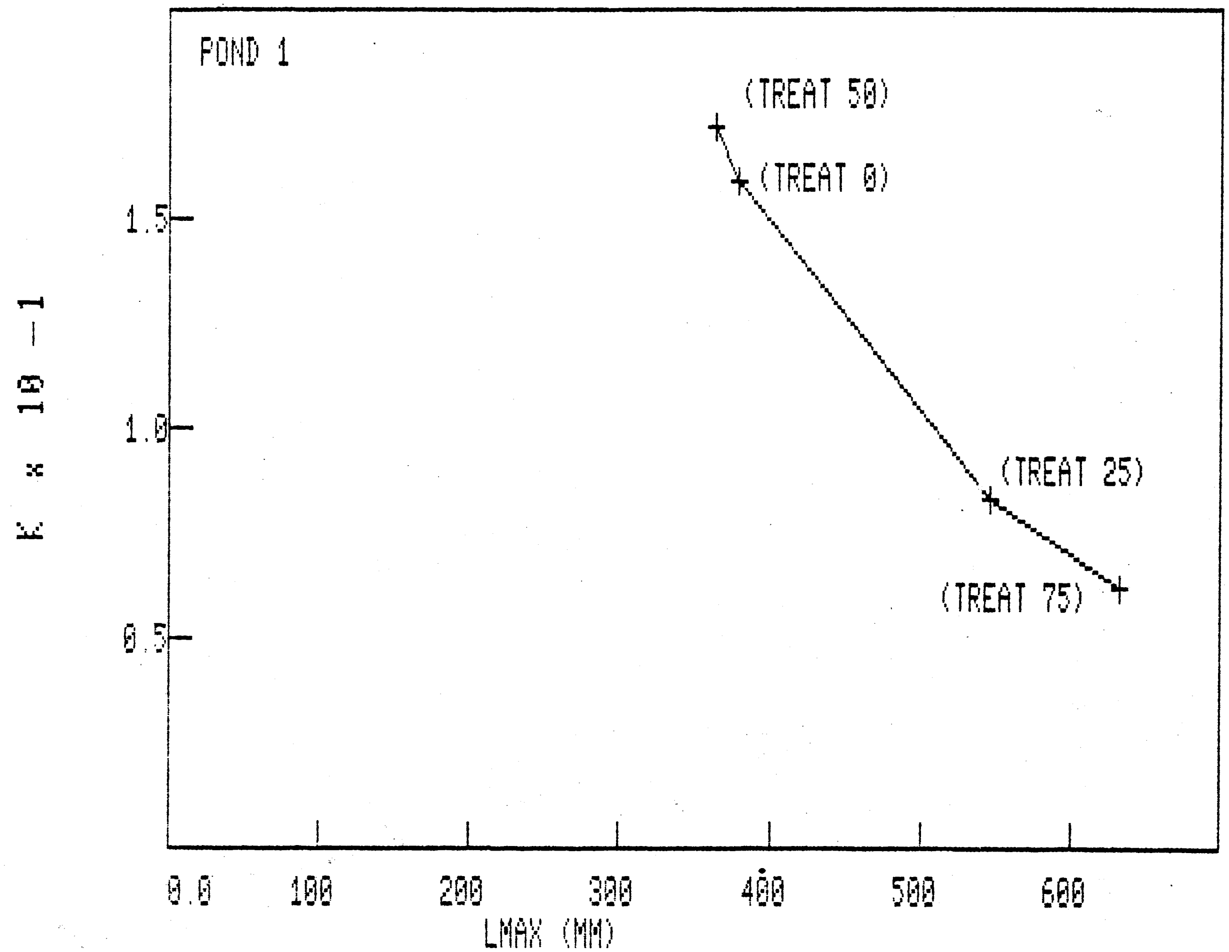

POND 1
(TREAT 50)
(TREAT 0)
(TREAT 25)
(TREAT 75)
1.5
1.0
0.5
K x 10 -1
0.0
100
200
300
400
500
600
LMAX (MM)

Figure 80. Variations of K and LMAX for channel catfish in treatments 0, 25, 50, and 75 (number of tilapia) at pond 2.

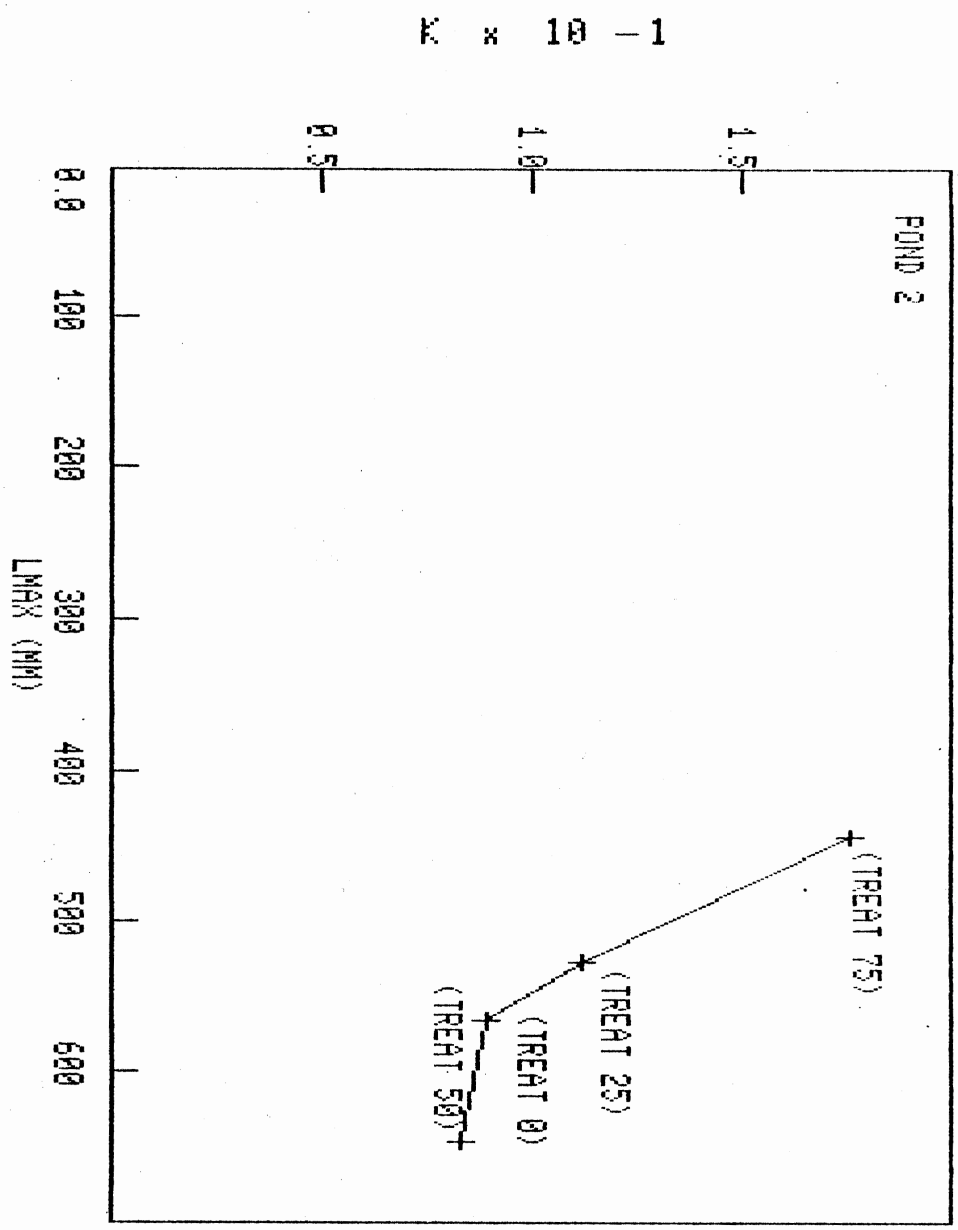
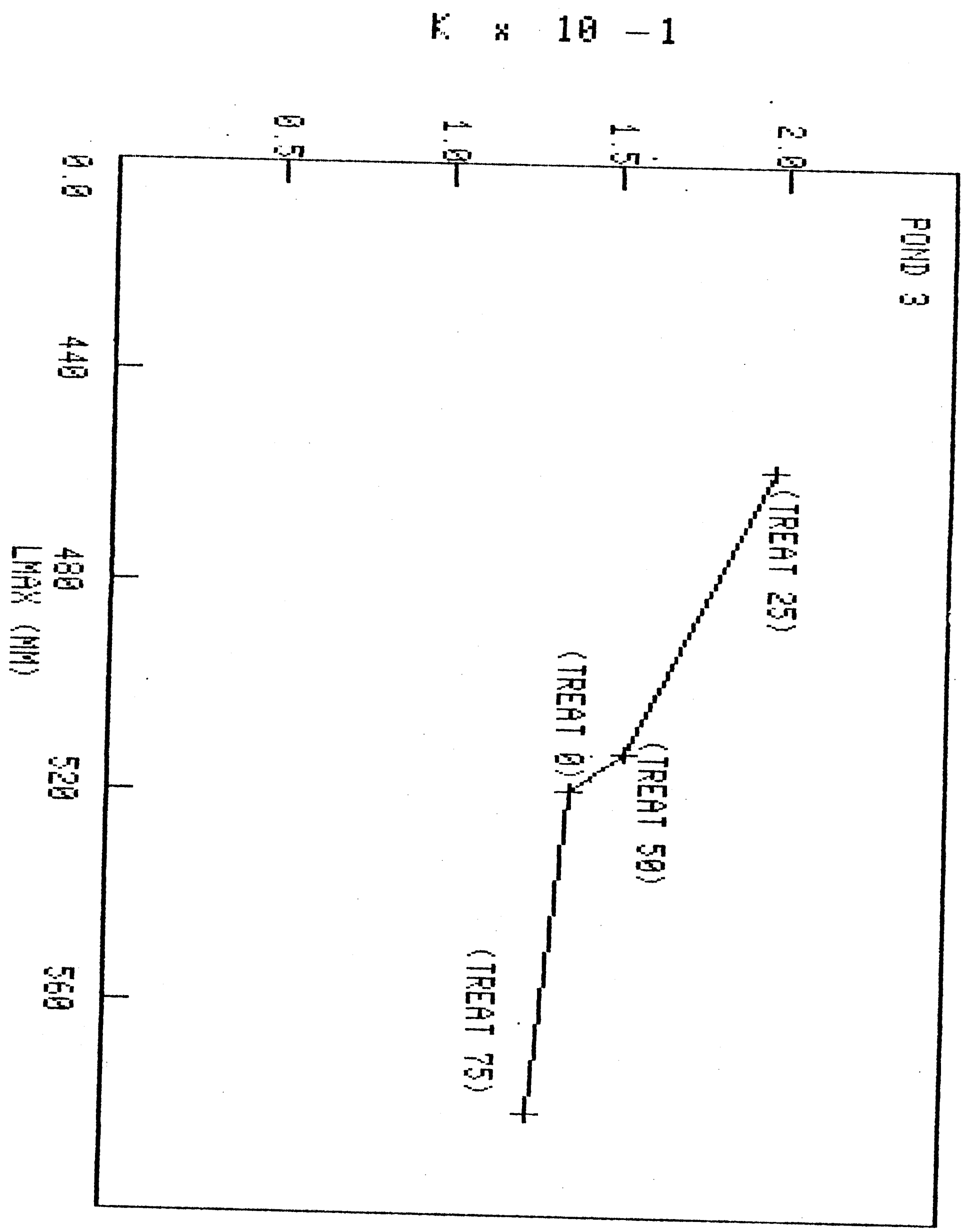

K x 10 −1
0.5
1.0
1.5
POND 2
0.0
100
200
300
400
500
600
LMAX (MM)
(TREAT 75)
(TREAT 25)
(TREAT 0)
(TREAT 50)

Figure 81. Variations of K and LMAX for channel catfish in treatments 0, 25, 50, and 75 (number of tilapia) at pond 3.

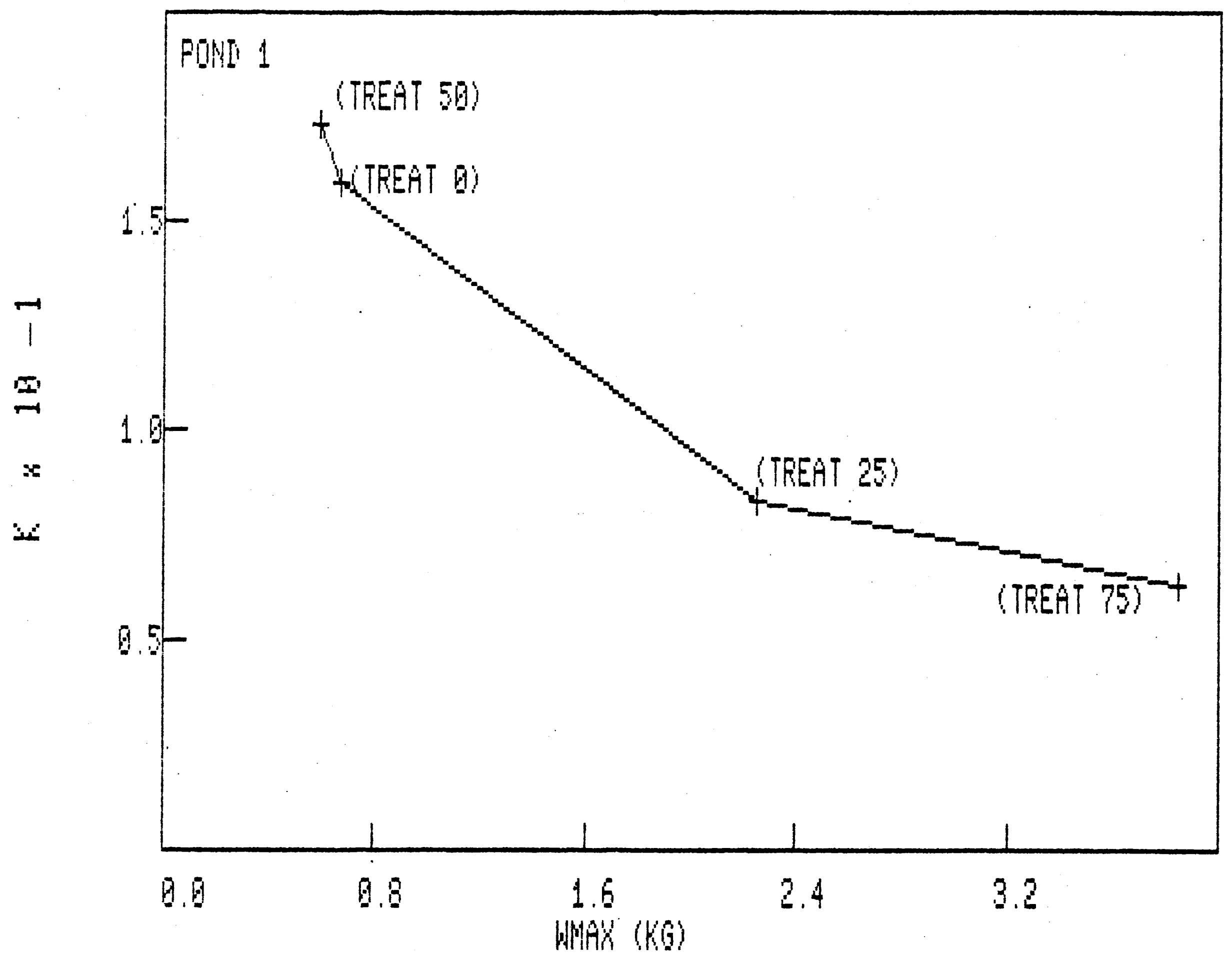

K x 10 -1
0.0
0.5
1.0
1.5
2.0
POND 3
440
480
520
560
LMAX (MM)
(TREAT 25)
(TREAT 50)
(TREAT 0)
(TREAT 75)

APPENDIX F

VARIATIONS FOR K AND WMAX FOR

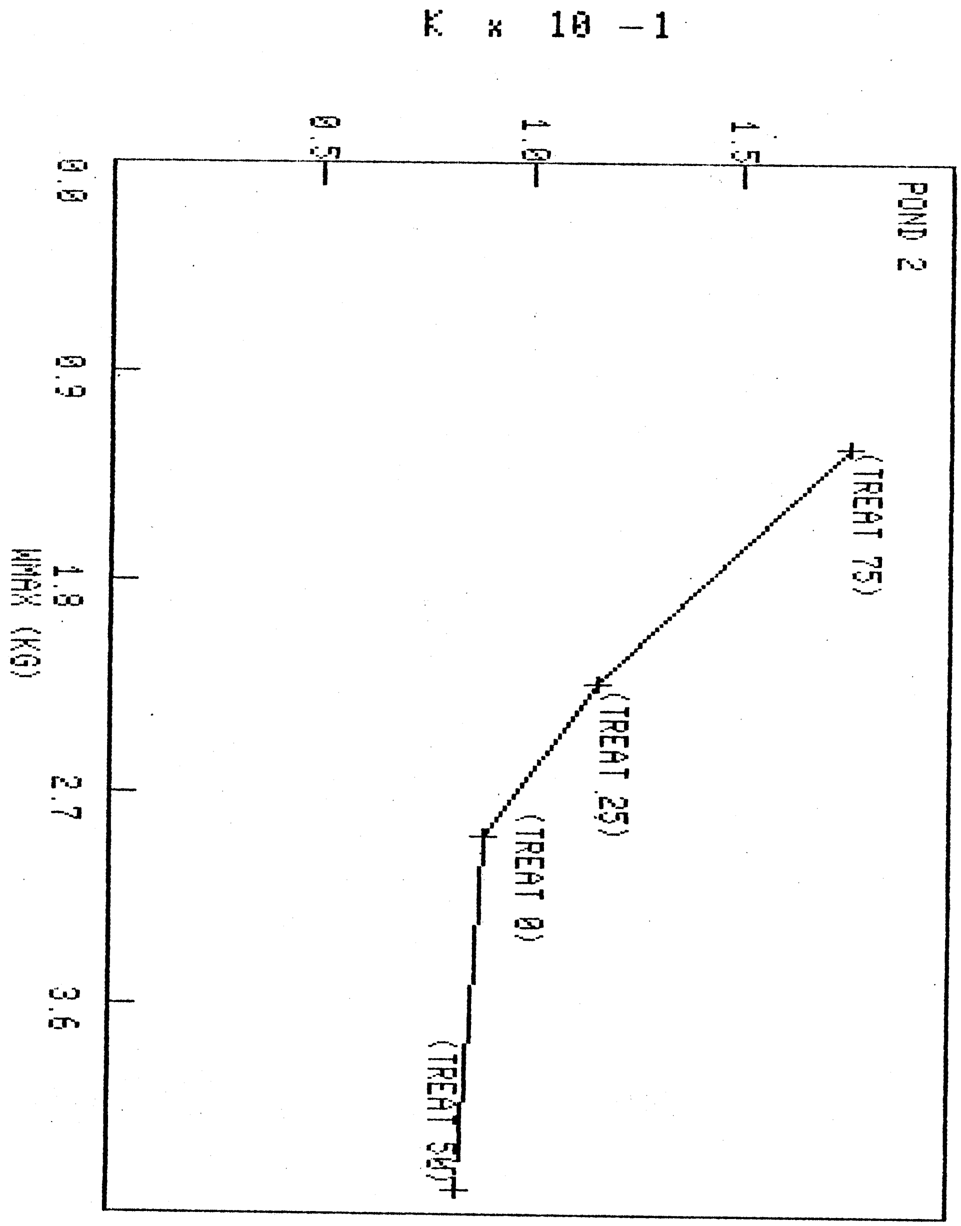
CHANNEL CATFISH

Figure 82. Variation of K and LMAX for channel catfish in treatments 0, 25, 50 and 75 (number of tilapia) at pond 1.



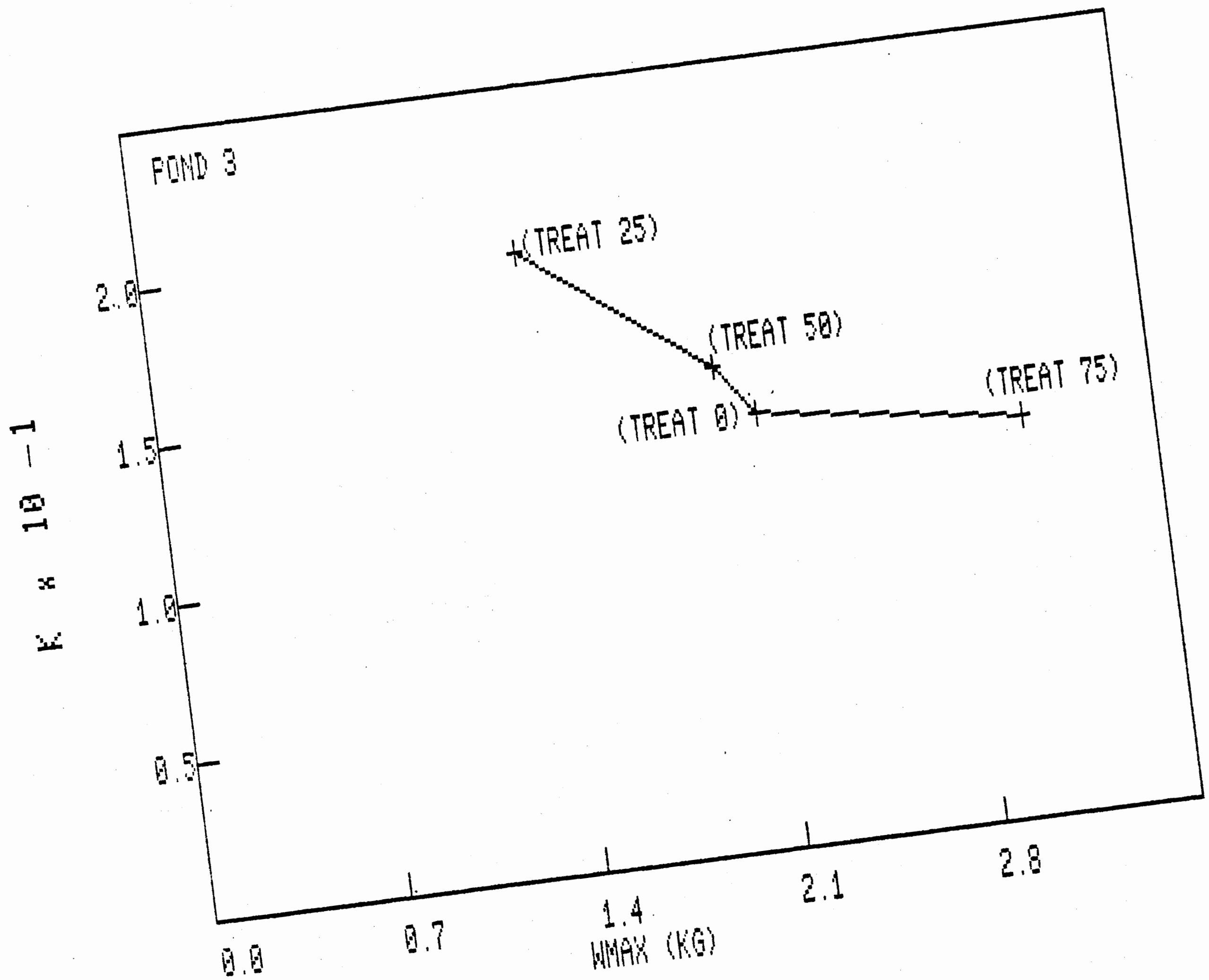
POND 1
(TREAT 50)
(TREAT 0)
(TREAT 25)
(TREAT 75)
K x 10 —1
1.5
1.0
0.5
0.0
0.8
1.6
2.4
3.2
WMAX (KG)

Figure 83. Variation of K and LMAX for channel catfish in treatments 0, 25, 50 and 75 (number of tilapia) at pond 2.



K x 10 -1
0.5
1.0
1.5
POND 2
0.0
0.9
1.8
2.7
3.6
WMAX (KG)
(TREAT 75)
(TREAT 25)
(TREAT 0)
(TREAT 50)

Figure 84. Variation of K and LMAX for channel catfish in treatments 0, 25, 50 and 75 (number of tilapia) at pond 3.


POND 3
(TREAT 25)
(TREAT 50)
(TREAT 0)
(TREAT 75)
K x 10 −1
2.0
1.5
1.0
0.5
0.0
0.7
1.4
2.1
2.8
WMAX (KG)

APPENDIX G

LISTING OF BASIC COMPUTER PROGRAM

```
0 REM BASIC COMPUTER MODEL FOR INTENSIVE FISH CULTURE WRITTEN BY AECIO MOURA DA
SILVA(COPYRIG(TED-1982).OK.ST.UNI.
1 REM THIS PROGRAM WAS WRITTEN IN ATARI BASIC. IT CAN BE RUN IN ANY ATARI COMPUT
ER, FOR FURTHER INFORMATIONS
2 REM PLEASE SEE THE M.S THESIS "QUANTITATIVE ANALYSIS OF SMALL SCALE CAGED FISH
 OF CHANNEL CATFISH",OSU-1983-OK
3 DIM NM$(25),Z$(2):GOSUB 600:GOSUB 900:?
4 FOR I=0 TO R-1:JE(I,1)=0:JE(I,2)=0:JE(I,4)=0:JE(I,5)=0:NEXT I
6 FOR I=0 TO R-1:? "LENGTH(";I;")";:INPUT L
8 ? "WEIGHT(";I;")";:INPUT W:?
10 JE(I,1)=L:JE(I,2)=W:JE(I,4)=L:JE(I,5)=JE(I+1,1):JE(R-1,4)=0:NEXT I
11 FOR I=0 TO R-1:JE(I,5)=JE(I+1,1):JE(R,1)=0:NEXT I:FOR I=0 TO R-1:? JE(I,1);"
";JE(I,2);" ";JE(I,4);" ";JE(I,5)
12 NEXT I
19 ? CHR$(125):? "PLEASE,WAIT A SECOND,I'M WORKING        HARD  WITH THESE LAZY
FISHES!!OK!"
20 FOR I=0 TO R-1:N=N+1
30 REM **LOGARITHMS TRANSFORMATIONS**
40 T1=T1+LOG(JE(I,1)):T2=T2+LOG(JE(I,2))
42 T3=T3+LOG(JE(I,1))*LOG(JE(I,2))
44 T4=T4+LOG(JE(I,1))^2:T4A=T4A+LOG(JE(I,2))^2
49 REM *INPUT FOR THE GR.CURVE LENG**
50 T5=T5+JE(I,4):T6=T6+JE(I,5):T7=T7+JE(I,4)*JE(I,5)
52 T8=T8+JE(I,4)^2:T8A=T8A+JE(I,5)^2
60 NEXT I
70 GOSUB 1000:PRINT
72 GOSUB 2000:PRINT
75 GOSUB 3000:? "MEAN CONDITION FACTOR =";MCF
78 PRINT :PRINT :GOSUB 4000
80 ? "MAXIMUM LENGTH-LMAX=";:? INT(100*LMAX+0.05)/100;:? " MM"
85 ? "MAXIMUM WEIGHT-WMAX=";:? INT(100*WMAX+0.05)/100;:? " GR"
90 ? "WEI/LEN RELAT.CONST =";INT(1000*B2+5.0E-03)/1000
100 ? "(PRESS ANY KEY TO CONTINUE)":OPEN #2,4,0,"K:":GET #2,X9:CLOSE #2
110 ? CHR$(125)
120 ? " REGRESSION EQUATION OF THE LOGORITHMIC TRANSFORMATION OF THE WEIGHT/LENG
TH RELATIONSHIP"
125 ? "*********************************"
130 PRINT "LOG(WT) =";:? LOG(MCF);:PRINT " + ";:PRINT INT(1000*B2+5E-04)/1000;:P
RINT ".LOG(LT)"
132 ? "DETERMINATION COEFFCIEN.=";D2
134 ? "CORRELATION COEFFICIEN.";SQR(D2):? "STANDARD ERROR OF ESTIMATE=";SQR(C2/(
N-2))
140 PRINT :PRINT "CURVE OF THE MEAN TOTAL WEIGHT/MEAN TOTAL LENGTH RELATIONSHIP"
:? "*******************************"
150 PRINT "WT =";:? MCF;:PRINT ".LT^";:PRINT INT(1000*B2+5.0E-03)/1000
155 ? "(PRESS ANY KEY TO CONTINUE)":OPEN #2,4,0,"K:":GET #2,X9:CLOSE #2:? CHR$(1
25)
160 ? :? "REGRESSION EQUATION  OF THE FORD-WALFORD  TRANSFORMATION":? "*********
*******************"
170 PRINT "L(T+DT) =";:PRINT A1;:PRINT " + ";:PRINT B1;:PRINT ".L(T)"
172 ? "DETERMINATION COEFFICIEN.";D1
174 ? "CORRELATION COEFFICIEN.";SQR(D1):? "STANDARD ERROR OF ESTIMATE=";SQR(C1/(
(N-1)-2)):?
180 ? "    REGRESSION EQUATION OF L*T AND T*":? "   ***************************"
190 ? "L*T =";:? A3;:? " ";:? B3;:? "T*"
192 ? "DETERMINATION COEFFICIEN.";D3
194 ? "CORRELATION COEFFCIEN.=";SQR(D3):? "STANDARD ERROR OF ESTIMATE=";SQR(C3/(
N-2)):? :?
195 PRINT :PRINT "    RELATIVE TIME :TE =";TE
200 PRINT "     GROWTH CONSTANT : K=";K
202 ? "(PRESS ANY KEY TO CONTINUE)":OPEN #2,4,0,"K:":GET #2,X9:CLOSE #2:? CHR$(1
25)
205 ? :? "          GROWTH CURVE IN LENGTH-LT":? "         **************************"
210 ? "LT =";:? LMAX;:? "(1-EXP(-";:? K;:? "(T+";:? TE;:? "))"
215 ? :? "          GROWTH CURVE IN WEIGTH-WT":? "         **************************"
```

```
220 ? "WT =";:? WMAX;:? "(1-EXP(-";:? K;:? "(T+";:? TE;:? "))^";:? B2
225 ? :? "     Y I E L D       C U R V E-YT":? "     ***************************
*"
230 ? "YT =";:? TOT;:? "*(";:? SDT;:? "^T";:? ")*";:? WMAX;:? "(1-EXP(-";:? K;:?
 "(T+";:? TE;:? ")))^";:? B2:?
235 ? "(PRESS ANY KEY TO CONTINUE)":OPEN #2,4,0,"K:":GET #2,X9:CLOSE #2:? CHR$(1
25)
238 ? "MORTALITY INDEX:M =";M
240 ? "MONTHLY SURVIVAL ;SDT =";SDT
250 ? "MAXIMUM YIELD :BM =";:? INT(BM)/1000;:? " KILOS"
260 ? "TIME OF MAXIMUM YIELD:TYM= ";:? INT(10*TBM+0.5)/10;:? " MONTHS"
270 ? "YIELD GAIN INDEX:IB =";INT(IB)/1000;:? " KILOS/MONTHS"
272 ? :? :? "PRESS ANY KEY TO PLOT CURVES,BUT,      PLEASE,PRESS VERY SOFTLY!!!!"
:OPEN #1,4,0,"K":GET #1,X9
274 DIM XY(200,2),N$(5):COLOR 3:GRAPHICS 0
276 GOSUB 5000:GOSUB 5100
280 GRAPHICS 2:? #6;"PLEASE,WHAT CURVE DO YOU WANT TO SEE":? #6;"CHOOSE A NUMBER
 FROM 1 TO 3":MO=0:Y=0
282 ? #6;"********************"
284 ? #6;" 1)- GROWTH CURVE IN LENGTH":? #6;" 2)- GROWTH CURVE IN WEIGTH":? #6;"
 3)- YIELD CURVE"
286 ? "TYPE YOUR CHOICE AND PRESS RETURN"
288 INPUT OP:IF OP(1 OR OP)3 THEN 780
290 GRAPHICS 2:? #6;"PLEASE ENTER THE":? #6;"NUMBER OF MONTHS":? #6;"THAT  YOU
WANT":? #6;"TO SEE PLOTTED"
292 ? #6;"IN THE GRAPHIC":? #6;"(AND PRESS RETURN)":? "HOW MANY MONTHS(PLEASE, T
YPE   AN     EVEN NUMBER";
294 INPUT MO:IF MO(2 THEN ? CHR$(125):? CHR$(253);:? "INVALID INPUT":GOTO 290
310 ON OP GOTO 4500,4600,4700
339 ? "(PRESS  ANY KEY TO SEE THE CURVE)":OPEN #2,4,0,"K:":GET #2,X9:CLOSE #2
340 GOSUB 5200:GOSUB 5300
342 ON OP GOTO 370,380,390
370 ? "  GROWTH CURVE IN LENGTH(MM/MO)"
372 ? "L(0)=";INT(XY(0,2));"---- L(";MO/2;")=";INT(XY((MO/2),2))
374 ? "L(";MO;")=";INT(XY(MO,2));"(PRESS ANY KEY TO CONT)":GOTO 400
380 ? "   GROWTH CURVE IN WEIGHT(KG/MO)"
382 ? "W(O)=";INT(XY(0,2));"----  W(";MO/2;")=";INT(XY((MO/2),2))
384 ? "W(";MO;")=";INT(XY(MO,2));"(PRESS ANY KEY TO CON)":GOTO 400
390 ? "          YIELD CURVE(KG/MO)"
392 ? "YIELD(0)=";INT(XY(0,2))/1000;"-YIELD(";MO/2;")=";INT(XY((MO/2),2))/1000
394 ? "YIELD(";MO;")=";INT(XY(MO,2))/1000;"(PRESS ANY KEY)"
400 OPEN #2,4,0,"K;":GET #2,X9:CLOSE #2
410 ? :? "DO YOU WANT TO SEE  MORE CURVES?":? "(PLEASE, TYPE  Y  OR  N  AND PRES
S    RETURN)"
420 INPUT N$:IF N$="N" THEN 500
430 GOTO 276
500 GRAPHICS 2:? #6;"    ";NM$:? #6;"DO YOU WANT TO":? #6;"RERUN   FISHFARM1":?
#6;"PLEASE, TYPE Y OR N"
520 ? #6;"AND PRESS RETURN"
530 INPUT N$:IF N$="Y" THEN RUN
540 GOTO 920
600 GRAPHICS 2:? #6;"HI!! FRIEND":? #6;"PLEASE, TYPE  YOUR":? #6;"FIRST NAME AND
 PRESSRETURN":INPUT NM$
610 ? #6;" HELLO!!";NM$:? #6;"DO YOU NEED INTRUCTIONS?":? #6;"PLEASE, TYPE Y OR
N AND PRESS RETURN"
612 INPUT Z$:IF Z$="N" THEN 698
615 GOSUB 6000
620 ? "                ";NM$:? :? "MY NAME IS COMPATARI.I'M VERY GLAD TO":? "MET YO
U.FROM NOW ON,WE ARE FRIENDS."
630 ? "THIS PROGRAM IS CALLED FISHFARM1.":? "IT WAS DESIGNED AND DEVELOPED BY"
632 ? "AECIO MOURA DA SILVA(COPYRIGHTED,1983)"
640 ? "I WISH THAT FISHFARM1 WORKS SMOOTHLY":? "WITH YOUR DATA.":? NM$;", IN MAN
Y PARTS OF THIS"
650 ? "PROGRAM,I'M GOING TO ASK YOU TO TYPE":? "LETTERS,PRESS ANY KEY,PRESS RETU
RN.":? "PLEASE,READ THE QUESTION";
660 ? ", FOLLOW":? "MY DIRECTIONS, AND GOOD LUCK.":?
```

```
670 ? "FIRST OF ALL, REMEMBER THAT WHEN":? "RUNNING FISHFARM1, YOU NEED TO":? "I
NPUT THE MEAN MONTHLY LENGTH."
680 ? "AND WEIGHT.":? "(PLEASE, PRESS ANY KEY TO CONTINUE.)":OPEN #1,4,0,"K:":GE
T #1,X9:CLOSE #1
684 ? CHR$(125):? "               ":NM$:? :?
686 ? "THIS PROGRAM WILL GIVE TO YOU AN":? "ANALYSIS OF POPULA. DYNAMICS WHICH"
688 ? "INCLUDES SEVERAL REGRESSION ANALYSES,":? "POPULATION PARAMETERS, GROWTH":
? "CURVES IN LENGTH, IN WEIGHT,"
690 ? " AND A YIELD CURVE.":? :? "BESIDES, FISHFARM1 CAN BE USED TO ACT":? "ANAL
YSIS OF POPULATION DYNAMICS FOR"
692 ? "ANY SPECIES UTILIZED IN INTENSIVE":? "AQUACULTURE THAT FOLLOWS":? "THE VO
N BERTALANFFY'S(1938) GROWTH"
694 ? " EQUATION AND SANTOS(1978) METHOD":? "(PLEASE, PRESS ANY KEY TO CONTINUE)
"
696 OPEN #1,4,0,"K:":GET #1,X9:CLOSE #1
698 GOSUB 6000
700 ? CHR$(125):? "PLEASE TYPE THE NUMBER OF TIMES":? "THAT YOU SAMPLED THE FISH
ES[MINIMUM!! SIX(6),MAXIMUM!";
702 ? "SIXTY(60) SAMPLES]     AND PRESS    RETURN"
710 ? :? :INPUT R:IF R<6 OR R>60 THEN ? CHR$(125);CHR$(253);"INVALID INPUT":R=0:
GOTO 700
720 ? CHR$(125):? "PLEASE TYPE  THE NUMBER OF FINGERLINGS   STOCKED AND PRESS
 RETURN":? :?
730 INPUT TOT:IF TOT<1 THEN ? CHR$(125):? CHR$(253);:? "INVALID INPUT!!":GOTO 72
0
735 DIM JE(R,5)
740 ? CHR$(125):? "PLEASE TYPE THE NUMBER OF FISHES      HARVESTED AND PRESS    R
ETURN"
750 ? :? :INPUT S:IF S>TOT OR S=0 THEN 770
760 RETURN
770 ? "SHOULD BE LESS THAN OR EQUAL TO":? "THE NUMBER  STOCKED":? "(  TRY   AGAI
N  )":GOTO 750
780 ? CHR$(125):? CHR$(253);"INVALID INPUT. ( TRY AGAIN )":GOTO 276
800 ? CHR$(125):? "      ";:? NM$:? "NOW,YOU ARE GOING TO INPUT THE FISH":? "MEAN
 TOTAL LENGTH AND WEIGHT"
805 ? "DURING EACH MONTH THAT YOU"
810 ? "SAMPLED, BEGINNING WITH":? "LENGTH(O) THAT IS THE FISH MEAN TOTAL":? "LEN
GTH AT STOCKING TIME."
815 ? "   (LENGTH IN MILLIMETERS)":? "   (WEIGHT IN GRAMS)"
820 ? "( REMEMBER TO PRESS RETURN AFTER":? "TYPING EACH MEAN )":RETURN
920 GRAPHICS 2+16:POKE 756,226:SETCOLOR 0,3,2:FOR X=0 TO 11:IF X>0 THEN POSITION
 1,X-1:? #6;"                   "
922 POSITION 1,X:? #6;"  Jesus loves you":FOR L=1 TO 150:NEXT L:NEXT X
930 GRAPHICS 2:? #6;"      ";NM$:? #6;"IT  WAS  VERY  NICE":? #6;"TO WORK WITH
YOU":? #6;"COME BACK  SOOONNN."
932 ? #6;"TCHAU!!!HASTA LUEGO":? #6;"BYE.BYE!EU JA VOU INDO"
934 ? #6;"HAVE A NICE DAY."
940 END
990 REM * SUB-ROUTINE TO CALCULATE        CURVE COEFFICIENT OF THE LINEAR
 REGRESSION OF THE FORD-WALFORD
991 REM * TRANSFORMATION, THE             MAXIMUM  LENGTH THAT THE FISH CAN
REACH IN INTENSIVE CULTURE
992 REM * AND REGRESSION ANALYSIS.
1000 B1=((N-1)*T7-T5*T6)/((N-1)*T8-T5*T5)
1025 A1=(T6/(N-1))-(B1*(T5/(N-1)))
1030 LMAX=A1/(1-B1)
1040 C1=(T8A-T6^2/(N-1))-(B1*(T7-T5*T6/(N-1)))
1050 D1=(B1*(T7-T5*T6/(N-1)))/(T8A-T6^2/(N-1))
1060 GOTO 72
1990 REM * SUB-ROUTINE TO CALCULATE       CURVE COEFFICIENT OF THE LINEAR
 REGRESION OF THE LOG TRANFOR
1991 REM * MATION OF THE MEAN TOTAL       WEIGHT/MEAN TOTAL LENGTH RELATIO
 NSHIP, AND THE CONSTANT OF THE
1992 REM WEIGTH/LENGTH RELATIONSHIP,      AND COMPUTE THE REGRESSION
 ANALYSIS.
2000 B2=(N*T3-T1*T2)/(N*T4-T1*T1)
```

```
2020 A2=T2/N-B2*(T1/N)
2030 C2=(T4A-T2^2/N)-(B2*(T3-T1*T2/N))
2040 D2=(B2*(T3-T1*T2/N))/(T4A-T2^2/N)
2050 RETURN
2990 REM * SUB-ROUTINE TO CAL. R1
3000 ? :? "  MONTHLY  CONDITION  FACTOR":? "  ******************************"
3010 FOR I=0 TO R-1
3030 AB=(JE(I,2)/(JE(I,1))^B2):? "MCF";:? I;:? "=";:? AB:T19=T19+AB
3049 REM *CAL,RELATIVE TIME T*
3050 T13=T13+I:T14=T14+LOG((LMAX-JE(I,1))/LMAX):T15=T15+I*(LOG((LMAX-JE(I,1))/LM
AX)):T16=T16+I^2
3052 T16A=T16A+(LOG((LMAX-JE(I,1))/LMAX))^2
3055 NEXT I
3057 REM CURVE COEFFICIENTS OF THE L*T        AND T* REGRESSION ANALYSIS  AND
   CALCULATION OFTHE RELATIVE TIME
3060 B3=(N*T15-(T13*T14))/(N*T16-(T13*T13)):A3=(T14/N)-B3*(T13/N):TE=A3/B3
3062 C3=(T16A-T14^2/N)-(B3*(T15-T13*T14/N))
3064 D3=(B3*(T15-T13*T14/N))/(T16A-T14^2/N)
3080 MCF=T19/N:REM MEAN CONDITION FACTOR
3090 WMAX=(MCF)*(LMAX^B2):REM MAXIMUM WEIGHT
3100 K=-B3:REM WEI/LEN RELAT.CONTANT
3110 RETURN
3990 REM SUB-ROUTINE TO CALCULATE THE       SURVIVING TAX, MORTALITY INDEX,
 MAXIMUM YIELD,INST.OF.MAX.YIELD
4000 SDT=(S/TOT)^(1/(N-1)):M=-LOG(SDT)
4009 REM CALCULATION OF THE MAXIMUM         YIELD
4010 BM=TOT*EXP(M*TE)*WMAX*((M/(M+B2*K))^(M/K))*(((B2*K)/(M+B2*K))^B2)
4019 REM CALCULATION OF THE INSTANT         OF MAXIMUM YIELD-TMY(TBM)
4020 TBM=(-1/K)*LOG(M/(M+B2*K))-TE
4049 REM CALCULATION OF THE YIELD           GAIN INDEX - YGI(IB)
4050 IB=BM/TBM
4060 RETURN
4490 REM SUBROUTINES TO COMPUTE THE         DATA TO BE PLOTTED(SUBROUTINES
 4500,4600,4700)
4500 GRAPHICS 17:? "      DATA TO BE PLOTTED":FOR I=0 TO MO:X=I:XY(I,1)=X:Y=LMAX*
(1-EXP(-K*(I+TE)))
4510 XY(I,2)=Y:GOSUB 5150:? "MONTH #";I;"----LENGTH= ";INT(Y);" MM"
4520 IF INT(LMAX)=INT(Y) THEN ? "MAXIMUN LEMGTH"
4540 NEXT I:GOTO 339
4600 GRAPHICS 17:? "     DATA TO BE PLOTTED":FOR I=0 TO MO:X=I:XY(I,1)=X:Y=WMAX*(
1-EXP(-K*(I+TE)))^B2:XY(I,2)=Y
4610 GOSUB 5150:? "MONTH #";I;"----WEIGHT= ";INT(Y);" GRAMS"
4620 IF INT(WMAX)=INT(Y) THEN ? "MAXIMUM WEIGHT"
4640 NEXT I:GOTO 339
4700 GRAPHICS 17:? "  DATA TO BE PLOTTED":FOR I=0 TO MO:X=I:XY(I,1)=X:Y=TOT*(SDT
^I)*WMAX*(1-EXP(-K*(I+TE)))^B2
4710 XY(I,2)=Y:GOSUB 5150:? "MONTH #";I;"----YIELD= ";INT(Y)/1000;" KILOS"
4720 IF INT(BT)=INT(Y) THEN ? "MAXIMUM YIELD"
4740 NEXT I:GOTO 339
4990 REM INITIALIZE ARRAY
5000 FOR I=0 TO MO:XY(I,1)=0:XY(I,2)=0:NEXT I:YMAX=0:XMAX=0:RETURN
5099 REM SET SCREEN PARAMETERS (80X160      SCREEN FOR GRAPHICS MODE 7)
5100 ROWS=79:COLMS=159:RETURN
5149 REM TEST BOUNDARY DATA VALUES
5150 IF XY(I,1))XMAX THEN XMAX=XY(I,1):IF XY(I,2))YMAX THEN YMAX=XY(I,2):RETURN
5199 REM SET SCALING FACTORS FOR            PLOTTING
5200 YSCALE=YMAX/ROWS:XSCALE=XMAX/COLMS:RETURN
5290 REM ****PLOTTING SUBROUTINE***
5295 REM DRAWING THE X AND Y AXES
5300 GRAPHICS 7:SETCOLOR 2,0,0
5302 COLOR 1:PLOT 0,0:DRAWTO 0,ROWS
5304 DRAWTO COLMS,ROWS:DRAWTO COLMS,0:DRAWTO 0,0
5308 REM DRAWING THE DATA POINTS
5310 COLOR 1
5320 FOR I=0 TO MO:PLOT INT(XY(I,1)/XSCALE),ROWS-INT(XY(I,2)/YSCALE):NEXT I
5323 REM PLOTTING THE TREND LINE
```

```
5325 PLOT 0,ROWS-(INT(XY(0,2)/YSCALE)):REM PLOT Y INTERCEPT
5330 COLOR 2:FOR I=0 TO MO:FOR J=1 TO 20:REM J LOOP CONTROL PLOT SPEED
5334 DRAWTO INT(XY(I,1)/XSCALE),ROWS-INT(XY(I,2)/YSCALE)
5336 NEXT J:NEXT I
5350 RETURN
6000 GRAPHICS 0:SETCOLOR 0,2,8:SETCOLOR 1,15,14:SETCOLOR 2,12,8:SETCOLOR 3,4,6:S
ETCOLOR 4,1,10:RETURN
```

\

VITA

Aecio Moura da Silva

Candidate for the Degree of

Master of Science

Thesis: QUANTITATIVE ANALYSIS OF SMALL SCALE CAGED FISH CULTURE OF CHANNEL CATFISH

Major Field: Zoology

Biographical:

Personal Data: Born in Belo Jardim, Pernambuco, Brazil, January 30, 1951, the son of Francisco Frade da Silva and Clotildes Moura da Silva.

Education: Graduated from Escola Tecnica Federal de Pernambuco, Recife, Pernambuco, December 1970; received the Engenheiro de Pesca degree in December 1974 from Universidade Federal Rural de Pernambuco, Recife, Pernambuco; completed requirements for the Master of Science degree at Oklahoma State University, Stillwater, Oklahoma, in July 1983.

Professional Experience: Extension Agent of Associaçao de Assistencia Tecnica e Extensao Pesqueira de Santa Catarina, 1975; Assistant of Superintendencia do Desenvolvimento da Pesca, from 1976 through 1978; Coordinator of Coordenadoria de Assuntos Pesqueiros, Minister of Agriculture, from 1979 to 1980; Head of the project of Microposto de Piscicultura Acoplado a Biodigestor, Programa de Desenvolvimento de Comunidades Rurais-Prodecor-Minister of Agriculture, Brazil, from 1980.