THE EFFECT OF STOCKING DENSITY ON PRODUCTION, GROWTH AND MORTALITY OF AFRICAN CATFISH (*Clarias gariepinus* Burchell 1822) CULTURED IN CAGES.

BY

KHWUANJAI HENGSAWAT

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for the Degree of

MASTER OF SCIENCE

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A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ABSTRACT

African catfish (*Clarias gariepinus* Burchell 1822) were cultured at four different densities based on fish biomass per cubic metre in cages suspended in a dugout pond during the summers of 1990 and 1991. In 1990, fish were stocked at an average weight of 1.8 g. After 56 days of rearing, weekly instantaneous growth rates (0.547 - 0.562) were not significantly different among densities. Mortality rates, ranging from 0.036 to 0.101, while high, were not related to stocking densities. The mean fish weight at harvest ranged from 95.7 to 142.8 g per individual. Fish production was 6.52, 11.75, 9.47 and 12.45 kg per cage at stocking densities of 0.14, 0.20, 0.24 and 0.35 kg per cage respectively. In 1991, larger catfish (32 g) were stocked at densities of 1.66, 3.44, 4.65 and 6.40 kg/cage or 50, 100, 150 and 200 fish/cage respectively. At the end of 8 weeks, mean fish weight was highest at the lowest density and was significantly different from the other three higher stocking densities. The biweekly instantaneous growth rates ranged from 0.286 to 0.300. Instantaneous mortality rates were low, from 0.006 to 0.011. Production, therefore, increased with increasing stocking density. Production values were 16.30, 31.19, 48.81 and 60.31 kg/cage from the lowest to the highest stocking density respectively. I conclude that growth and mortality of African catfish cultured in cages at these stocking densities were not affected by initial density. On the other hand, fish production was directly related to stocking density.

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INTRODUCTION

The African catfish or sharptooth catfish, *Clarias gariepinus* Burchell 1822, is also known under its junior synonyms *C. lazera* Valenciennes and *C. mossambicus* Peters (Teugels, 1984), *C. senegalensis* (Viveen et al., 1984). It is tolerant of a wide range of temperatures, low oxygen and high salinities levels (Bovendeur et al., 1987). The precise date when the African catfish was first introduced to Thailand is unknown (Tangtrongpiros et al., 1988); however, because of its fast growth, *C. gariepinus* was introduced in 1987 to Thailand from Laos. During the last few years, this species has been widely cultured by commercial fish farms, by local government fisheries stations and also, for research purposes, at Khon Kaen University.

Cage culture began in Southeast Asia, and has been practised since the end of last century (Ling, 1977). According to Pantulu (1979), the oldest records of cage culture come from Kampuchea where fisherman in and around the Great Lake region kept *Clarias* spp. catfishes and other commercial fishes in captivity. The fish were fed kitchen scraps and were found to grow rapidly (Beveridge, 1984). A similar type of cage culture has been used in Mundung Lake, Jambi, Indonesia, since 1922 (Reksalegora, 1979). Cages can be used for growing fish to market size, breeding, controlling reproduction and producing fish fry (Pangan-Font, 1975; Rifai, 1980; Guerreo, 1979; Beveridge, 1984). Cages may be placed in both lentic and lotic environments. The cage method can provide a good alternative to other intensive culture procedures. Fish in cages are contained in a known, relatively small volume of water. Feeding, harvesting, and disease treatment are facilitated and management of the culture system is simplified.

Cage culture is useful for people who live near reservoirs or lakes. In addition, people can grow fish in cages placed within dugout ponds. Cage culture is one of the major priorities of the Department of Fisheries, Royal Thai Government, especially in the northeastern region where there are many reservoirs.

The stocking density, the volume of water available to a single fish, can constitute a significant productivity factor. With increasing stocking density the excitation level of the fish increases, resulting in a stress situation (Leatherland and Cho, 1985). This high-level physiological impact leads to an enhanced energy requirement, with accordingly reduced growth and food utilization; therefore, a negative effect may be expected from high stocking densities.

The number of fish stocked in cages depends upon the species cultured, the initial size of the fish, cage site and the preferences of the owner. Total production increases with increases in the initial biomass up to an optimum density (Coche, 1979).

The major objective of this study is to determine the relationship between stocking density and production. Other related objective are to determine: the effect of stocking density on the growth of the fish, on mortality, and finally the feasibility of African catfish as a species suitable for cage culture in northeastern Thailand. This information is presently unavailable.

The primary design of the study was to vary the initial stocking density of African catfish per cage based on the biomass (kg) and/or the number of fish per cubic meter while maintaining food levels constant relative to the biomass of fish in each cage.

LITERATURE REVIEW

African catfish (*Clarias gariepinus* Burchell 1822)

The African catfish is widely distributed from the Orange River in southern Africa, throughout Africa and into eastern Turkey (Teugels, 1984), although it is known by different names in different regions (Viveen et al., 1984) (Fig.1). During the last five years it was introduced into Thailand. The maximum recorded length of this fish is 200 cm. Hecht and Appelbaum (1987) have quoted Teugels (1982) as saying this fish is an important source of food in rural areas throughout its range. *Clarias gariepinus* is a hardy species. Because of its ability to practise both efficient aquatic and aerial respiration, it can survive at very low oxygen concentrations (Bovendeur et al., 1987).

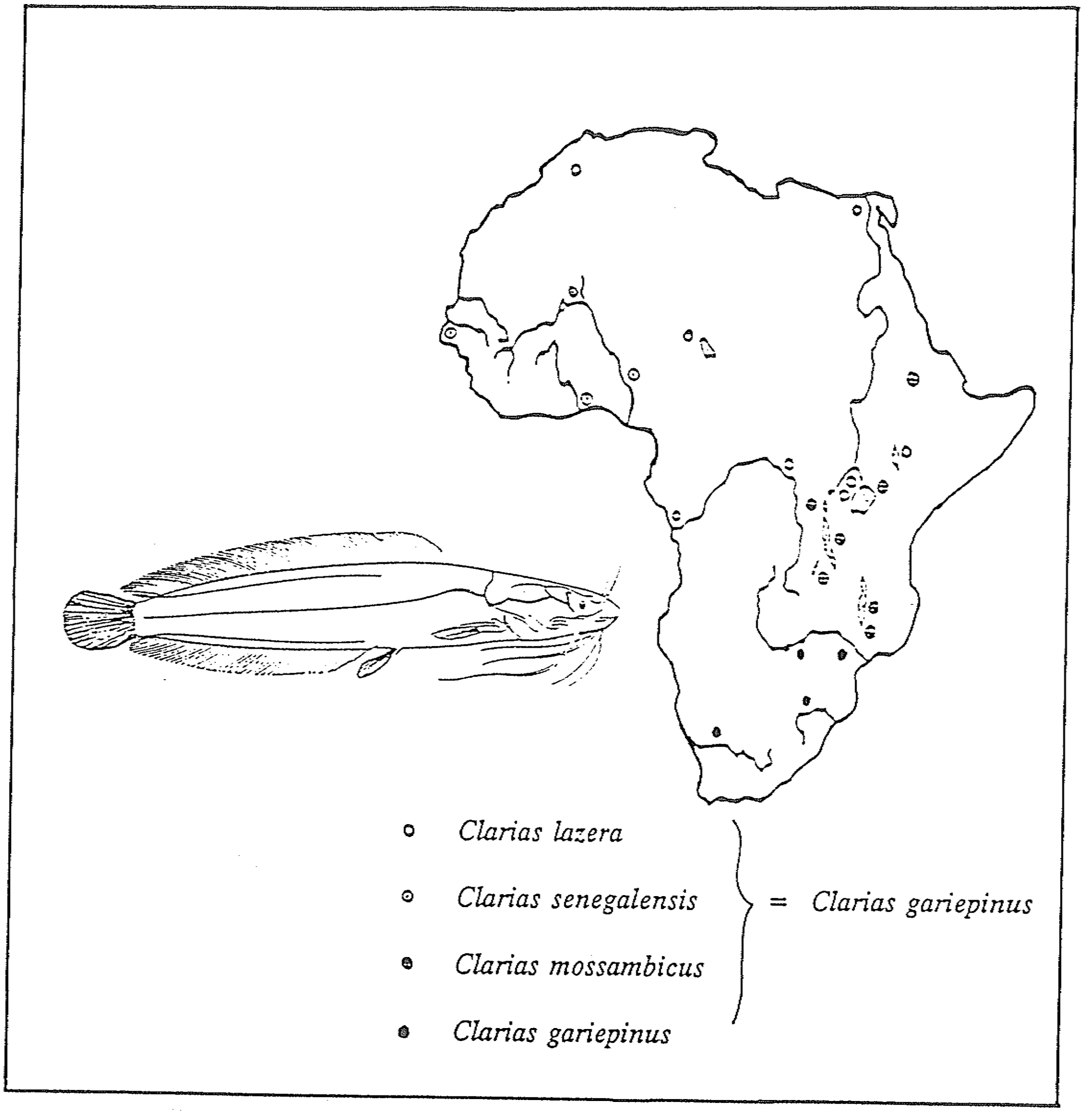
Potential

Because African catfish are omnivores, they are suitable for aquaculture based on a supply of low grade food, commercial food and also agricultural byproducts. The potential of this catfish for aquaculture has been demonstrated for ponds as well as for intensive culture in tanks under controlled indoor conditions. Hogendoorn (1979) and Huisman and Richter (1987) reared fry in ponds with 10-15 individuals/m^3, of 1-5 g size. They recommended a rearing period of from 5 to 10 weeks duration.

During the last decade there has been an increasing interest in the intensive culture of *C. gariepinus*. Most growth experiments were carried out in flow-through systems in the Netherlands using commercial trout feeds (Hogendoorn, 1983; Hogendoorn et al.,1983). These studies were concerned with the effects of body weight, temperature and feeding level on growth.

Clarias gariepinus proved to be a very suitable species for high density culture. It uses up to 80 % of the energy metabolized from the diet. This utilization compares favourably with common carp fed with the same diet (Huisman and Richter, 1987). Reduction of the oxygen content of the water in tank culture results in the fish frequenting the surface to breath and, thereby, meet its oxygen requirements. The air contains about 30 times more oxygen per unit of volume than the water, and this

Figure 1. African catfish (*C. gariepinus* Burchell 1822) and its geographical distribution in Africa.


Clarias lazera
Clarias senegalensis
Clarias mossambicus
Clarias gariepinus
= Clarias gariepinus

explains why the species can tolerate extremely high densities per unit of water volume and low levels of water exchange. The African catfish, raised under optimal husbandry conditions, exhibits a rather lethargic behaviour, which results in low maintenance requirements. The previously mentioned high growth rate and efficient food utilization of the species are the reasons for the remarkably high production in culture conditions.

According to Teugels (1984), the African catfish (*C. gariepinus*) ranks high on the consumer preference list in quite a number of African countries. The following information showed the potential of *C. gariepinus* for intensive flow-through tank culture in the hatchery at the Department of Fish Culture and Fisheries in Wageningen, The Netherlands. The tank volume was 900 L and the area was 2.5 m^2. The water flow was 30 L min^{-1}. The rearing period was 61 days:[1]

	Stocking	Harvesting
Biomass (kg)	180.7	360.0
Individual wt. (g)	105.1	237.3
Weight Ratio fish/water	1:4	1:1.5
Food Conversion Ratio		0.98

This species seems to be a suitable candidate for cage culture development especially in Upper Egypt where market conditions are good. The preliminary results indicated that the weight increment of the fish was about 3.5 g/fish/day when stocked at a density of 200 fish/m^3 and fed a pelleted feed containing 25 % crude protein (Ishak, 1987).

Food

Under natural conditions, planktonic crustaceans are the most important food items of *C. gariepinus* larvae (<20 mm TL) (Hecht and Appelbaum, 1987). More

[1] Source: Huisman and Richter, 1987.

recently, successful attempts have been made to develop an artificial dry food for rearing larvae and juveniles (Uys and Hecht, 1985). Dried and decapsulated *Artemia* eggs have a high floating capacity, sinking slowly to the bottom of culture vessels. All the artemia cysts have a balanced nutritional composition and the nutritional value is not lost by leaching. Decapsulated eggs also gave a high growth rate and seemed to be a diet which results in a considerable storage of glycogen (Huisman and Richter, 1987).

Clarias gariepinus is able to convert food nutrients very efficiency into fish biomass (Machiels, 1987). It can also utilize vegetable proteins (Clay, 1981; Christensen, 1981; Hecht and Appelbaum, 1987). In many experiments in The Netherlands and Africa, a trout diet was used for *C. gariepinus*. In Thailand, Asian catfish food pellets and waste food from kitchens are used for rearing African catfish in commercial fish farms and local ponds respectively.

Reproduction

In nature, catfish mature after 2 to 3 years, but in only 7-10 months under pond conditions (Viveen et al., 1984). African catfish females reproduce successfully during the entire year. One female can provide eggs repeatedly throughout the year, thus enabling efficient brood stock maintenance (Hogendoorn and Vismans, 1980). Injection of hormone or/and its analogues to induced spawning in captivity has been commonly employed in all areas.

Health Control

The African catfish seems to be a resistant fish; however, some minor health problems have been encountered. Common protozoan and metazoan infections caused by organisms such as *Costia sp, Chilodonella sp, Dactylogyrus sp* etc. occur quite often, especially when the fish are raised in ponds in the tropics. Parasites can be easily controlled with organic phosphate esters (Bromix, Diptrex, Mosaten).

Clarias gariepinus, raised under controlled hatchery conditions, is rather sensitive to myxobacterial infections. Antibiotic curative agents such as chloramphenicol or oxytetracycline are applied as additives to the food. Infections are mainly associated with environmental changes (temperature, water quality, handling of fish, etc.) and can cause great losses in high density fingerling culture. Furatedone, dissolved in water, can be given as a prophylactic or therapeutic treatment (Huisman and Richter, 1987).

When the fish are reared in recirculation systems, gas bubble disease always occurs (Boon et al., 1987). Two syndromes are found in African catfish. The first one occurs mostly during the fingerling stage and involves a rupture in the caudal part of the intestinal tract. The second syndrome, taking place in catfish larger than 10 cm, causes destruction of the arborescent (atmospheric) organs of the fish and leads to an inflammation of the skull resulting in a lateral skull-break, parallel to the skull plate joints. A similar condition of fish, known as the "crack head syndrome", is found in Asian catfish (*C. batrachus* and *C. macrocephalus*) and has been attributed to Vitamin C deficiency (Viveen et al., 1984; Huisman and Richter, 1987).

Catfish Culture in Thailand

The culture of *Clarias spp* in Thailand, originally in the Bangkok area, began in the late 1950's (Areerat, 1987). Seven species are found in Thailand; however, only two species were commonly used for aquaculture before the African catfish was introduced from Laos in 1987. They are *Clarias batrachus* and *Clarias macrocephalus*.

Preliminary studies on African catfish have been carried out at the National Inland Fisheries Institute, Department of Fisheries, Royal Thai Goverment, since May 1988 and some observations from commercial fish farms, showed that the *C. gariepinus* grows very quickly in earthen ponds and can be spawned by hormone injection (Tangtrongpiros et al., 1988).

During the last four years, *C. gariepinus* has been widely cultured by commercial fish farms, by local government fisheries station and also at the Khon Kaen University. *Clarias gariepinus* culture is desirable because it gives a higher annual income than can be obtained from other species because it grows rapidly and reaches market size in a short time. Consequently there can be two to four crops per year.

The African catfish has been successfully reared in ponds as well as cultured intensively in concrete tanks. In commercial fish farms, fingerlings are stocked at 2.5 cm long and at densities between 2,700 and 50,000 fingerlings/Rai (1 Hectare = 6.25 Rai or 1 Rai = 1,600 m^2) in earthen ponds and in concrete tanks (1.2 m diameter) with water 40-50 cm deep. If the fish are 2-3 month, old about 250 individuals can be stocked or if the fish are 7-8 month old, 50 individuals can be stocked. If tank size is increased (3 x 5 x 1 m) they can be stocked at a density of 130 individuals. Tantrongpiros et al. (1988) studied growth of *C. gariepinus* and *C. macrocephalus* in an earthen pond at a stocking density of 22,000 fish/Rai or about 14 fish/m^3. He also stocked hybrid crosses between male *C. gariepinus* and female *C. macrocephalus* in an concrete-earthen bottom pond at a density of 22 fish/m^3.

Catfish Culture in Cages

Cage culture has received a great deal of world-wide attention in recent years and has been used in the culture of channel catfish (*Ictalurus punctatus*) in the United States for about 15 years (Collins, 1970; Stickney and Moy, 1985). Cages used for catfish experiments in the USA, are usually quite small, about 1 m^3. Stocking densities have been reported to range from 100 to 600 fish/m^3. Use of cages by fish farmers is limited, but commercial producers have employed this technique in special circumstances.

Problems with cage culture include difficulty in treating for diseases, loss of fish in the event of cage damage, and the need to provide continuous security to prevent poaching (Stickney, 1986). Various authors have attempted to determine optimum stocking densities for channel catfish in cages. The consensus is that about 600 fish/m*3* is appropriate (Pennington and Strawn, 1978). Stickney and Moy (1985) studied the culture of channel catfish in cages in Southern Illinois. Their results indicated that channel catfish fingerlings in the 20.4 to 25.4 cm size range at stocking densities of 600 fish/m^3, can be reared in cages to market size during an 18 week summer period.

Cage Culture in Thailand

Cage culture was initiated in Thailand in the early 1950's. Initially, the fish were raised in bamboo cages. The number of fishermen rearing fish in cages has experienced yearly increases. Cages are now usually made with wooden plank frames, covered with galvanized wire mesh. This type of cage is easier to make and handle. Many species are used for culture, for example; catfish (*Pangasius sutchi, Clarias macrocephalus*), sand goby (*Oxyeleotris marmoratus*), common carp (*Cyprinus carpio*), local carp (*Puntius gonionotus*), nile tilapia (*Oreochromis niloticus*), and serpent head (*Ophiocephulus striatus*). The most popular freshwater species for commercial culture are *Pangasius sutchi* and *Oxyeleotris marmoratus*.

Stocking densities used for *Pangasius sutchi* in cages range from 50 to 100 fish/m^3 and 100 fish/m^3 for the sand goby (Tangtrongpiros, 1979). Net cages have been used for the culture of sea bass (*Lates calearifer* Bloch) for the last decade. Most culture activities were conducted in Songkla Lake, the largest brackish and fresh water lake in Thailand. Several experiments on food and feeding, high density culture and economic benefits were carried out and it was shown that sea bass could be successfully cultured in net cages (Dhebtaranon et al., 1979).

MATERIALS AND METHODS

Experimental and Cage Design

Studies in both years, 1990 and 1991, were carried out in one dugout pond (6400 m^2) which has a mean water depth of 1.5 m. This pond is in the Fisheries Division, Department of Fisheries, Faculty of Agriculture, Khon Kaen University, Thailand (16.26 N, 102.50 E), 391 km northeast from Bangkok (Fig.2).

The rectangular cages measured 1 x 1 x 1.5 m and were made of black polyethylene netting of 5 mm mesh size, square measure. The submerged volume of each cage was 1 m^3. Cage frames were made of split bamboo. The cages were suspended from a bamboo structure fixed by cotton-nylon cords to a pathway from shore. Plastic bottles, attached along the four sides of each cage, were used as floats.

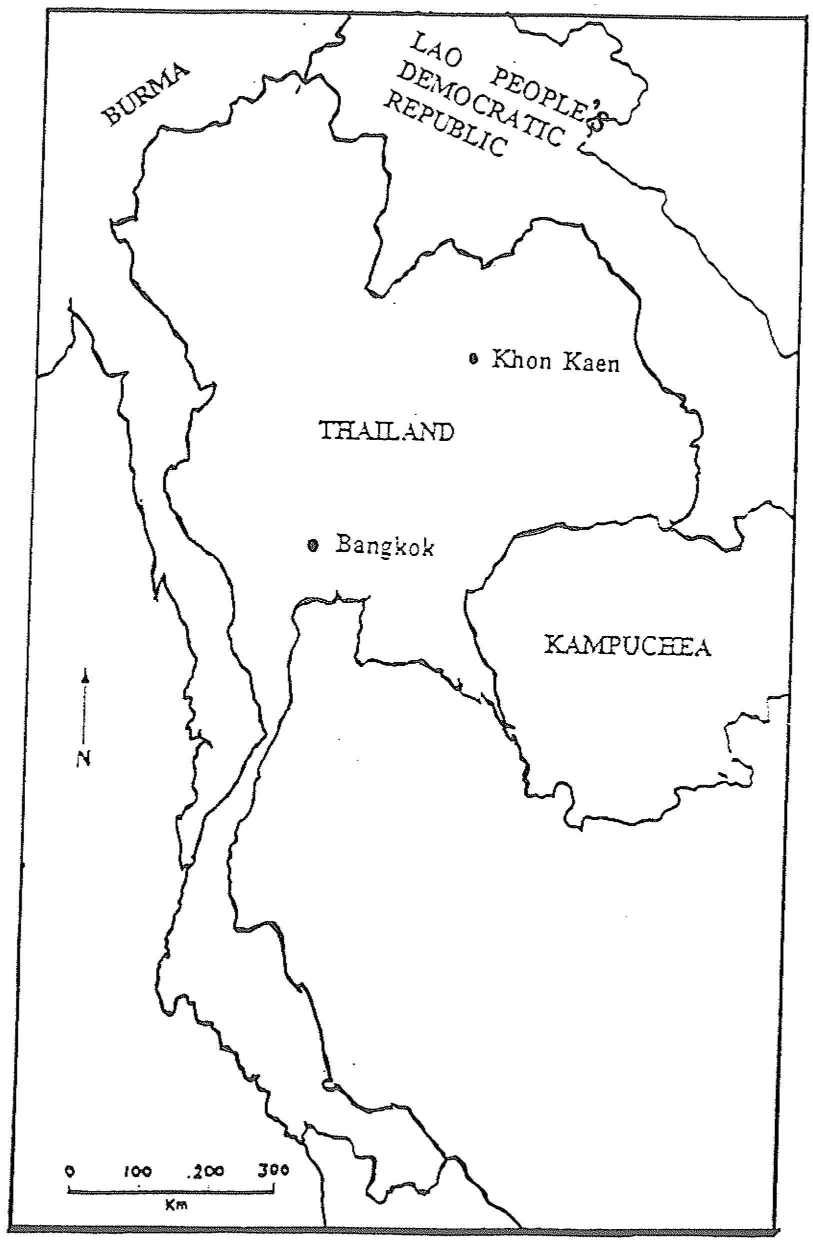
The experiment was set up as a Completely Randomized Design (CRD). There were four treatments each year using four stocking densities and there were three replicates of each treatment. Twelve cages were used in the experiment (Fig.3).

Fish Used In Experiments

In 1990, African catfish fingerlings were bought from the Pungkone Karnkaset Farm in Sakhon Nakorn Province. They were kept for two weeks in concrete tanks to acclimate them to the food pellets. Fish were put in cages for another week, the adaptation period, before being stocked into the experiment cages.

Treatments were randomly assigned to the twelve cages in the dugout pond (Appendix II). A total of 1,575 African catfish, average weight 1.8 g per individual, were allotted to twelve cages at four different densities (0.14, 0.20, 0.24 and 0.35 kg/m^3 or 75, 100, 150 and 200 $fish/m^3$) (Table 1). Fish were stocked on July 5 and harvested on September 6, 1990, a 56 day rearing period. Because of severe initial mortalities during the first two weeks, fish of appropriate size were added to each cage to maintain numbers constant.

Figure 2. Map of Thailand showing the location of the experiments.


BURMA
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Khon Kaen
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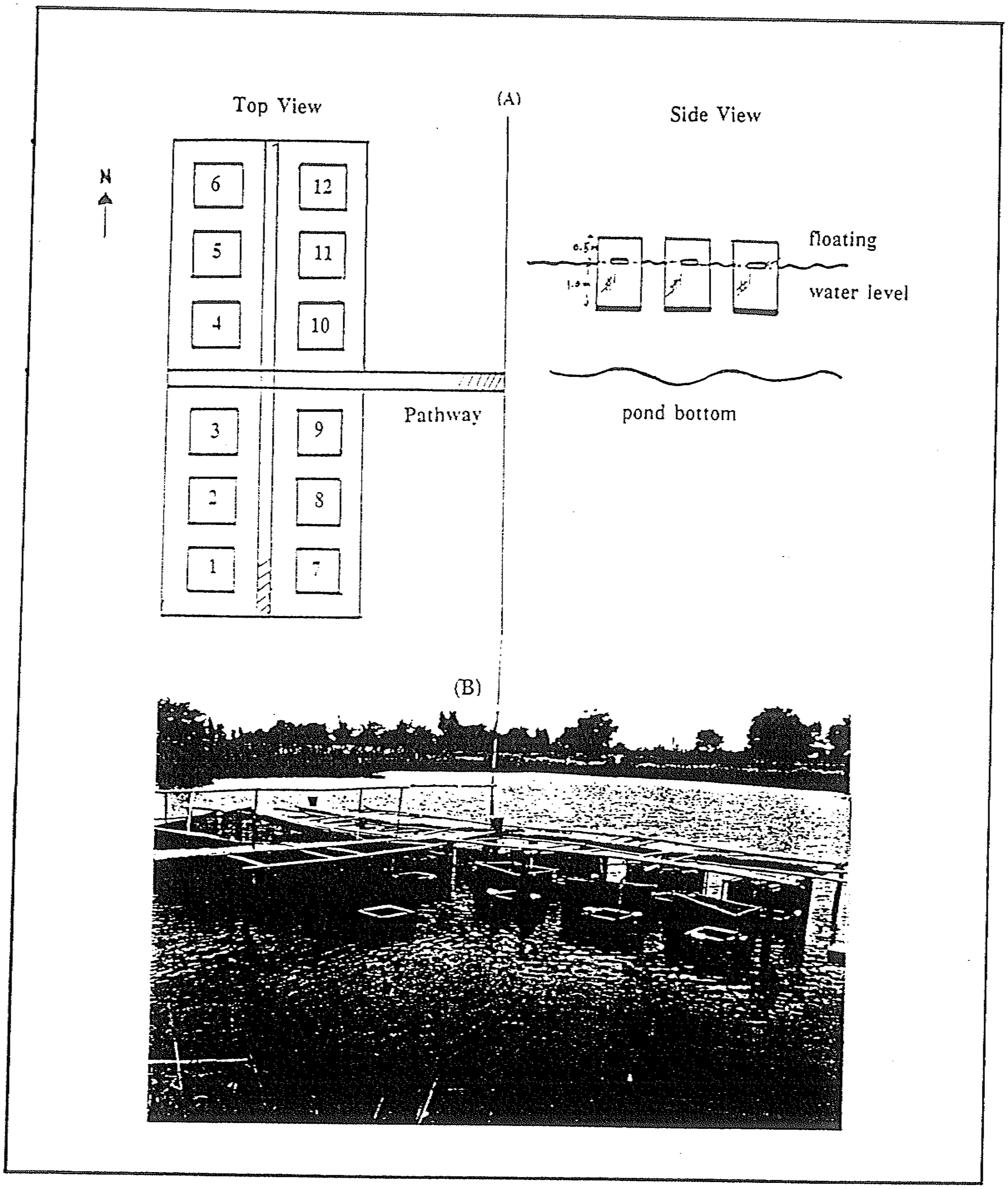
Figure 3. (A) Experimental Design (Completely Randomized Design, top and side views of the experimental site), (B) Experimental cages suspended within a dugout pond.


Top View
(A)
Side View
N
6
5
4
12
11
10
floating
water level
Pathway
pond bottom
3
2
1
9
8
7
(B)

For the 1991 experiment, five female catfish (brood stock survivors from 1990 experiment) were spawned at the Fisheries Division, Department of Fisheries, Khon Kaen University on April 28, 1991. Catfish larvae were held in a circular concrete pond for 33 days. The fish were fed zooplankton (*Moina spp.* and *Artemia salina*) during the first two weeks, then they were fed pellets. Fingerlings were kept in cages for an adaptation period of three weeks before being allotted to the experiment. African catfish were treated with a solution of formalin (200 ppm) for 3 to 5 minutes before being placed in the same cages and the same experimental site used in 1990. A total of 1,500 fish were stocked on June 23, 1991 at 32.9 g average weight per individual fish at four different densities (1.66, 3.44, 4.65 and 6.40 kg/m^3 or 50, 100, 150 and 200 fish/m^3 (Table 1) and harvested 56 days later on August 18, 1991.

Food and Feeding

In 1990, a commercial catfish food (9912) of known nutrient content (Appendix II) manufactured by Chareon Pokpand Ltd was used. Catfish were hand fed initially at 23% of body weight (BDW) 4 times daily. The food quantity was decreased to 20%, 15% BDW at the 2^{nd} and 6^{th} week respectively. Rations were kept constant at 15 % BDW after the sixth week until the end of the experiment. Some problems were caused by unsuitable food: crude protein (CP) level was low for fish fry. The pellet particle size was too large and the amount of food given each meal was equal which is not the correct method because catfish prefer to feed at night; therefore, the larger meal should be given at night.

For the 1991 experiment, catfish food was supplied by the same company but two particle sizes were used. Fish were hand fed initially with 9910 (small particle size and high Crude Protein) at 10 % BDW 4 times per day (07:00, 12:00 a.m., 05:00 and 11:00 p.m.) at the amounts of 25, 20, 25 and 30% of the daily ration. The highest amount was given at night and the lowest at midday. Satiation feeding was employed in the first day of each sampling period for adjusting the amount of food offered to per cent of body weight per day. Following sampling and the replacement of fish, food of the first meal was mixed with an antibiotic, oxytetracycline, at 50 mg/kg of food.

Table 1. Stocking and harvesting data (means, n=3) for African catfish reared in cages for 56 days at different densities in 1990 and 1991. The 95% Confidence Intervals are shown in parentheses.

Treatments	Stocking			No. of fish harvested
	Mean Wt. (g)	No.of Fish Per m^3	Biomass kg/m^3	
1990				
1	1.84(±0.09)	75	0.14(±0.01)	47.33(±10.02)
2	2.00(±0.00)	100	0.20(±0.00)	78.00(±19.36)
3	1.57(±0.06)	150	0.24(±0.00)	94.33(±28.94)
4	1.75(±0.00)	200	0.35(±0.00)	105.67(±14.53)
1991				
1	33.13(±7.67)	50	1.66(±0.38)	43.00(± 6.55)
2	34.42(±6.27)	100	3.44(±0.63)	89.67(±13.65)
3	31.02(±5.35)	150	4.65(±0.80)	143.33(±13.65)
4	32.90(±6.38)	200	6.40(±1.04)	183.00(± 6.56)

This antibiotic was used as a curative agent for stress-induced myxobacterial infections caused by sampling and handling.

The total biomass of fish in each cage was used to readjust the food quantity downwards from 10 to 7 and 5 % BDW for the 2nd and the 4th week respectively according to the calculated fish biomass. After the fourth week the food was changed to the 9912 formula (bigger particle size and lower CP). Subsequently, the amount was kept constant at 5 % BDW until the 7th week of the experiment. During the last week (8th) of the experiment, fish were fed at 7% of the total biomass.

Sampling

African catfish were randomly sampled each week for the 1990 experiment but at two week intervals in 1991. Twenty percent of the fish in each cage were weighed in grams using a 1 kg spring balance manufactured by TANICA Co. Ltd. The scale was calibrated in 5 g gradations. The total length in cm of each weighed fish was also measured, using a measuring board made of glass and with graph paper showing the gradations. All fish in each cage were weighed to find the actual total biomass each week for 1990 and at two weeks intervals in 1991, using a 7 kg spring balance. Mean fish weight at each time period was calculated by dividing the total biomass by number of fish in each cage. The number of fish in each cage was also recorded to provide an estimate of mortality.

Data Analyses

Data collected in both years were analyzed for the following;

(1) final biomass: the final biomass in each cage harvested after 56 days;

(2) average mean fish weight: the average weight of individual fish in each cage at each sampling date, estimated by dividing the total biomass by the number of survivors;

(3) total weight gains per cage in kilograms for both experiments, estimated by comparing total final biomasses with initial biomasses for surviving fish in each cage:

$$\Delta B_t = B_t - B_0 \qquad \text{where}$$

B_t = total final biomass (kg);

B_0 = total initial biomass (kg);

(4) average weight increment, per fish in each cage, per day estimated by the difference between initial and final weight after 56 days:

$$\Delta w_t = W_t - W_0/t \quad \text{where}$$

W_t = final mean fish weight (g);

W_0 = initial mean fish weight (g);

t = times (days)

(5) the average relative growth rates per day for all cages for both experiments where determined as follows (Ricker, 1975):

$$kw = (W_t - W_0)/W_t/t \quad \text{where;}$$

kw = relative daily growth rate;

(6) average daily instantaneous growth rates for fish in each cage estimated by using the following procedure (Ricker, 1975):

$$Gw = \frac{\ln W_t - \ln W_o}{t} \quad \text{where}$$

Gw = the instantaneous daily growth rate in weight;

(7) instantaneous growth rates determined from the regression of the natural logarithms of mean fish weight of each treatment on time (one week in 1990 and two week intervals in 1991), using the equation below (Ricker, 1975):

$$W_t = W_0 \, e^{Gw}{}_t \quad \text{where}$$

W_t = Weight at time t

W_0 = initial weight

Gw = growth coefficient

(8) daily relative mortality rates:

$$M = (N_0 - N_t)/N_0/t \quad \text{where}$$

M = Total mortality

N_t = total final number of survivors per cage at the end of the experiment;

N_0 = total initial number of fish per cage

(9) daily instantaneous mortality rate:

$$Z = -(\ln N_t - \ln N_0)/t \quad \text{where}$$

(10) weekly and biweekly instantaneous mortality rates:

$$N_t = N_0 e^{-Z}{}_t \quad \text{(Ricker, 1975) where}$$

-Z = Instantaneous mortality rate;

(11) production (P), measured in kilogram in each cage was estimated using the equation below:

$$P = Gw \bar{B} \quad \text{(Chapman, 1968) where}$$

$\bar{B}$ = Average biomass in kilograms (the mean of two adjacent biomasses 1 week for 1990 and 2 weeks for 1991);

(12) Food conversion ratio (FCR) or food quotient (FQ):

$$\text{Food Conversion Ratio} = \frac{\text{food consumed (kg)}}{\text{increase in fish weight(kg)}} \quad \text{(Steffens, 1989)}$$

(13) The economic data of this study were evaluated to provide an estimates of the differences in costs and income of catfish reared in cages at different stocking densities in both 1990 and 1991. Costs were estimated for the purchasing fingerlings and food. Net income was determined by the difference between the sale price of the fish and the total costs.

(14) For the 1990 experiment, only water temperature and pH were observed. In 1991, dissolved oxygen and temperature (using the Orion 820 Dissolved Oxygen Meter) were measured every two weeks at 2:00 p.m. The pH of the water was also measured at the same time by using a Corning pocket pH meter (Appendix II).

Analyses of variance (ANOVA) using SAS programs (SAS, 1988) were employed to test the effect of stocking density on various growth parameters. Regression procedure was used to estimate instantaneous growth and mortality rates (SAS, 1988).

Tukey's Studentized Range (HSD) test ($p \leq 0.05$) was employed to compare the significance of differences between the means of the various growth parameters at the four stocking densities (SAS, 1988). The 95% confidence interval of means at each density was calculated for all parameters.

RESULTS

Final Biomass

The final biomasses in experiment 1 (1990) after 56 days, using stocking densities of 0.14, 0.20, 0.24 and 0.35 kg/m^3 were 5.87, 10.94, 8.89 and 10.72 kg respectively (Table 2). There were significant differences in final biomasses between the two higher densities (0.20 and 0.35 kg/cage) and the lowest density (0.14 kg/cage) (F=8.43, Pr>F = 0.0074, R^2 =0.7596, α = 0.05). The second lowest stocking density (0.20 kg/cage) gave the highest biomass rather than the highest stocking density (0.35 kg/cage).

In 1991, biomass per cage increased steadily with increasing stocking density. Biomasses from stocking densities of 1.66, 3.44, 4.65 and 6.40 kg/cage were 16.58, 32.73, 51.19 and 63.47 kg/m^3 respectively (Table 2). The increase in biomass was statistically significant (F = 466.110, Pr>F = 0.0001, R^2 = 0.9943, α = 0.05) at every stocking density. The increase in biomass at a stocking density of 6.40 kg/cage was 382.90, 193.91 and 123.98% over that of 1.66, 3.44 and 4.65 kg/cage respectively.

Final Mean Fish Weight

The average weight of fish after the 56 day period, in 1990, was not statistically different at most densities (F = 2.220, Pr>F = 0.1636, R^2 = 0.454, α = 0.05). The highest average weight (142.83 g) was found in the second lowest density (0.20 kg/cage) and the average weight of 0.14, 0.24 and 0.35 kg/cage were 124.21, 95.74 and 102.25 g/fish respectively (Table 2).

For the 1991 experiment, mean fish weights decreased with increasing stocking density. The highest weight (385.75 g) occurred at the lowest density (1.66 kg/cage). At the end of the experiment, mean weights of fish were 364.93, 357.13 and 346.81 g for densities of 3.44, 4.65 and 6.40 kg/cage (Table 2). There were significant differences in mean fish weight between densities of 1.66 kg/cage (lowest) and the other three higher densities. There were also significant differences between the densities of 3.44 and 6.40 kg/cage, but not between densities of 3.44 and 4.65 kg/cage. There was no difference in final mean fish weight between the second highest (4.65

Table 2. Final biomass, mean weight and weight gain per cage (means, n=3) for African catfish cultured in cages at different densities in 1990 and 1991. The 95% Confidence Intervals are shown in parentheses.

Treatments	Biomass (kg)	Mean Wt. (g)	Wt. gain/cage (kg)
1990			
1 0.14 [1]	5.87(±1.00)[a]	124.21(±18.29)[a]	5.73(±1.00)[a] [2]
2 0.20	10.94(±4.33)[b]	142.83(±95.83)[a]	10.74(±4.33)[b]
3 0.24	8.89(±1.78)[ab]	95.74(±46.98)[a]	8.65(±1.77)[ab]
4 0.35	10.72(±5.02)[b]	102.25(±60.31)[a]	10.37(±5.02)[b]
1991			
1 1.66	16.58(±1.92)[a]	385.75(±25.39)[a]	14.92(±2.27)[a]
2 3.44	32.73(±5.52)[b]	364.93(±11.47)[b]	29.29(±5.36)[b]
3 4.65	51.19(±5.35)[c]	357.13(±10.81)[bc]	46.54(±4.94)[c]
4 6.40	63.47(±2.09)[d]	346.81(± 1.33)[c]	57.06(±1.43)[d]

[1] These values represent the stocking densities (kg/cage)

[2] Values with the same letter are not significantly different ($\alpha \leq 0.05$)

kg/cage) and the highest (6.40 kg/cage) densities (F = 22.41, Pr>F = 0.0003, R^2= 0.894, α= 0.05, Table 2).

Growth

Average Weight Gain Per Cage

Weight gain per cage of catfish at the density of 0.14 kg/cage (lowest density), at the termination of the 1990 experiment, was significantly different from the densities of 0.20 and 0.35 kg/cage but not from the density of 0.24 kg/cage (F = 8.000, Pr>F = 0.009, R^2 = 0.7501, α = 0.05). The highest weight gain per cage was 10.74 kg at the second lowest density cages (0.20 kg/cage). Stocking densities of 0.14, 0.24 and 0.35 kg/cage gave weight gains per cage of 5.73, 8.65 and 10.37 kg respectively (Table 2). On the other hand, weight gain per cage for catfish in 1991 increased from the lowest to the highest density for the term of the experiment. There were significant differences between all four densities (F = 426.500, Pr>F = 0.0001, R^2= 0.9938, α = 0.05) in weight gains per cage for this year. Weight gains per cage were 14.92, 29.29, 46.54 and 57.06 kg/cage for the lowest to the highest densities respectively (Table 2).

Daily Weight Increments, Relative and Instantaneous Growth Rates

There were no significant differences in daily weight increments per fish (Δwt), relative (kw) and instantaneous (Gw) growth rates among the four different densities in 1990 (Table 3). The F-values for daily weight increments, relative and instantaneous growth rates were 2.18, 0.60 and 0.63, and the Pr>F-values were 0.1678, 0.6326 and 0.6149 respectively.

The pattern of daily increments in weight (Δwt) per fish was different in the second experiment. The lowest density was significantly different from the other three densities. There were also differences between the second lowest density and the highest density but there was no difference between density2 and density3 and also between density3 and the higest density (F = 25.58, Pr>F = 0.0002, R^2 = 0.9056, α = 0.05). In contrast, the average daily relative growth rates (kw) were not different

Table 3. Daily mean (n=3) weight increments per fish, relative and instantaneous growth rates in weight of African catfish in 1990 and 1991. The 95% Confidence Intervals are shown in parentheses.

Treatments	Wt.Incre.(g) (Δwt)	Rel. Growth (kw)	Inst. Growth (Gw)
1990			
1 0.14 [1]	2.185(±0.33)	1.189(±0.23)	0.075(±0.00)
2 0.20	2.515(±1.71)	1.257(±0.86)	0.076(±0.00)
3 0.24	1.682(±0.84)	1.067(±0.50)	0.073(±0.01)
4 0.35	1.795(±1.08)	1.025(±0.62)	0.072(±0.01)
1991			
1 1.66	6.297(±0.36)[a2]	0.191(±0.04)[a]	0.044(±0.00)[a]
2 3.44	5.902(±0.29)[b]	0.172(±0.04)[a]	0.042(±0.00)[a]
3 4.65	5.823(±0.10)[bc]	0.188(±0.03)[a]	0.044(±0.00)[a]
4 6.40	5.605(±0.13)[c]	0.171(±0.04)[a]	0.042(±0.00)[a]

[1] These values represent the stocking density

[2] Values with the same letter are not significantly different ($\alpha \leq 0.05$)

among these four densities (F = 1.43, Pr>F = 0.3031, R^2 = 0.3497, α = 0.05). For daily instantaneous growth rates (Gw) in this year, there was also no significant differences with varying the stocking densities (F = 1.42, Pr>F = 0.3054, R^2 = 0.3483, α = 0.05).

Weekly and Biweekly Instantaneous Growth Rates

The growth patterns of fish at every stocking density in 1990 (Fig.4) showed that weekly instantaneous growth rates were high during the first two weeks, decreased during the third week, increased again during the fourth week and then decreased to the sixth week. They increased slightly during the last week. Variations among treatments were quite high as indicated by the wide confidence intervals. The relationship between stocking density and average weekly instantaneous growth rate in the 1990 data indicated that there were no significant differences among the four densities (Table 4). The statistical values for the relationship between the natural logarithms of weight and time for each treatment were very high.

The growth pattern in 1991 was different (Fig.5). The high growth rates occurred in all four treatments during the first 2 weeks and decreased consistently after that; however in three of four treatments, growth was low between week 2 and 4. There was no significant difference among four densities (F = 2.52, Pr>F = 0.1315, R^2 = 0.4860, α = 0.05). There were also highly significant relationships between the natural logarithms of weight and time for each treatment (Table 4).

Figure 4. The relationship between weekly instantaneous growth rates (Gw) and time for all four stocking densities in 1990.

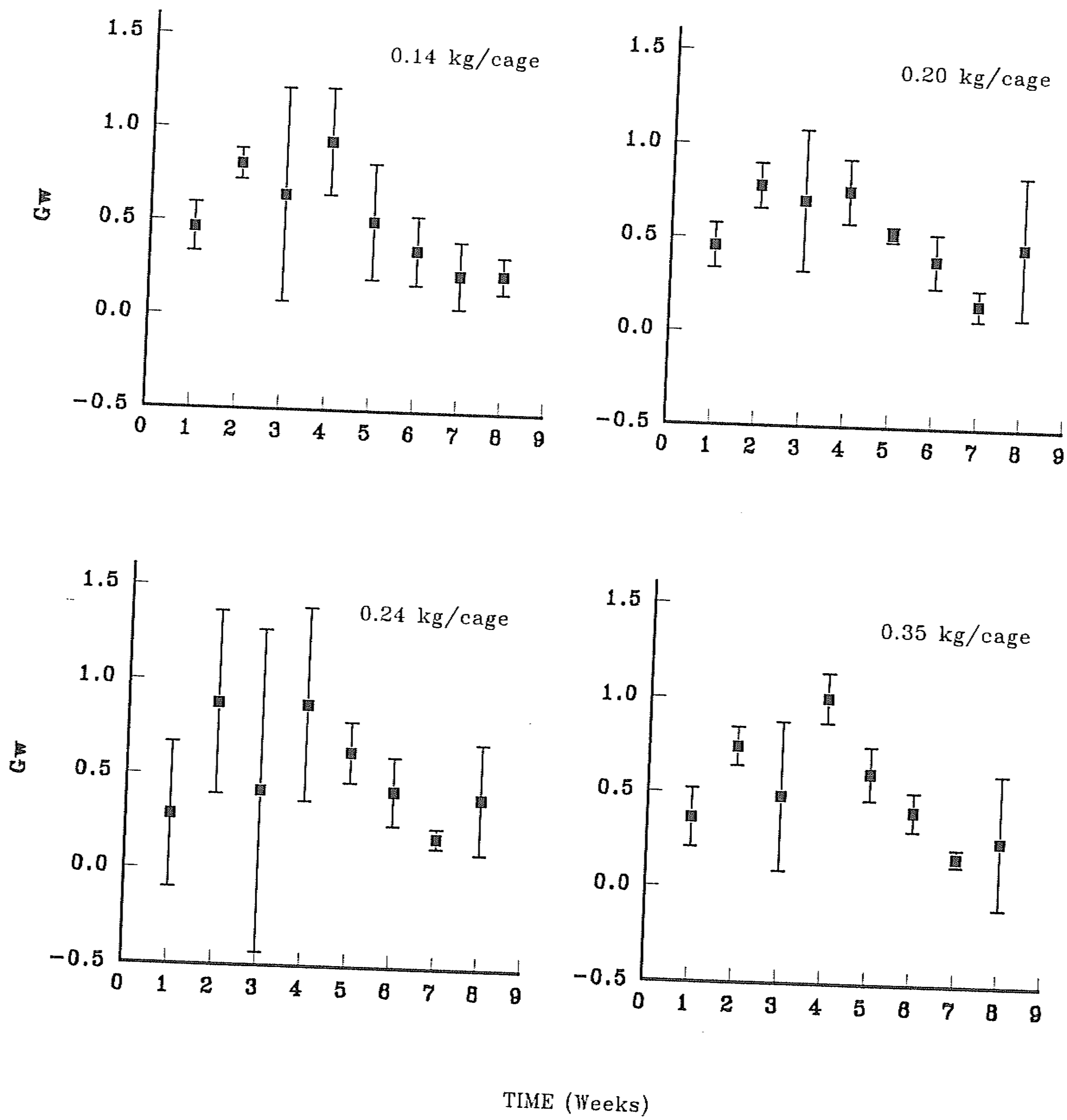
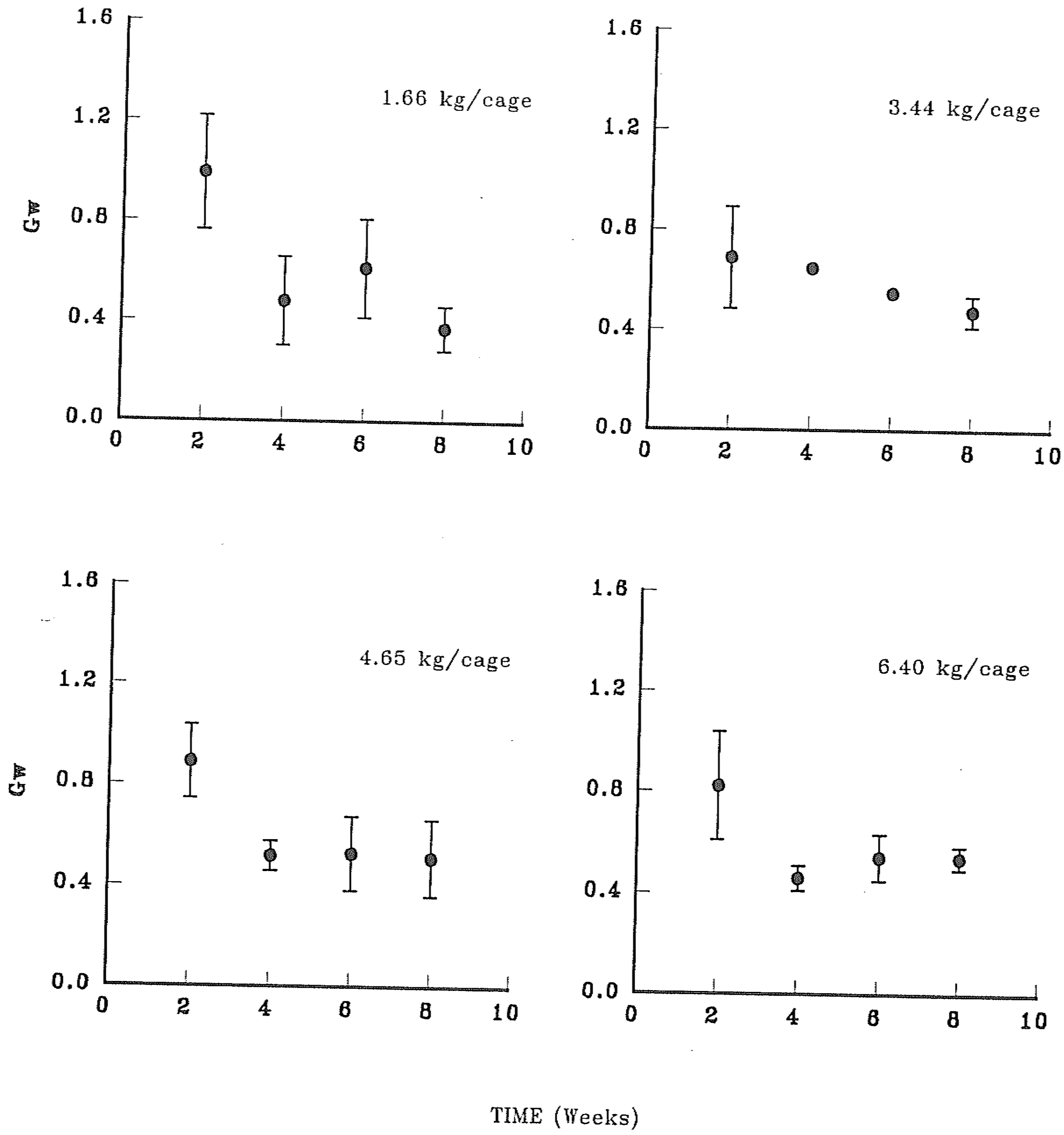

0.14 kg/cage
0.20 kg/cage
0.24 kg/cage
0.35 kg/cage
Gw
1.5
1.0
0.5
0.0
−0.5
0 1 2 3 4 5 6 7 8 9
TIME (Weeks)

Table 4. Average weekly and biweekly Instantaneous growth rates in weight (Gw) according to stocking density during the 1990 (n=27) and 1991 (n=15) experiments and statistical values. The 95% Confidence Intervals (n=3) are shown in parentheses.

Treatment	Density (kg/cage)	Gw	F	Pr>F	R-square
1990					
1	0.14	0.562(±0.03)	632.26	0.0001	0.9620
2	0.20	0.550(±0.07)	785.63	0.0001	0.9692
3	0.24	0.547(±0.03)	704.24	0.0001	0.9657
4	0.35	0.552(±0.05)	653.16	0.0001	0.9631
1991					
1	1.66	0.300(±0.02)	386.77	0.0001	0.9675
2	3.44	0.296(±0.02)	1767.66	0.0001	0.9927
3	4.65	0.297(±0.01)	736.42	0.0001	0.9827
4	6.40	0.286(±0.02)	1030.65	0.0001	0.9875

Figure 5. The relationship between biweekly instantaneous growth rates (Gw) and time for all four stocking densities in 1991.



1.66 kg/cage
3.44 kg/cage
4.65 kg/cage
6.40 kg/cage
Gw
1.6
1.2
0.8
0.4
0.0
0
2
4
6
8
10
TIME (Weeks)

Mortality Rates

Average Daily Mortality

The daily instantaneous mortality rate data for 1990 (Table 5) showed that the rate for treatment4 which was at the highest density was highest and significantly different to the value for treatment2 which showed the lowest mortality rate. There was no significant difference between treatments 1 and 2 and treatment 3 (F = 8.31, Pr>F = 0.0077, R^2 = 0.7571, α = 0.05). The significance of daily relative mortality rate data gave the same results as the instantaneous mortality rate data (F = 8.10, Pr>F = 0.0083, R^2 = 0.7524, α = 0.05). In 1991, daily instantaneous and relative mortality rates were very low and were not affected by stocking density. There were no significant differences between the four treatments (Table 5).

Weekly and Biweekly Instantaneous Mortality Rates

For experiment1 (1990), analyses based on the regression analysis of the logarithms of number of fish on time (Table 6) indicated that there were no significant differences in instantaneous mortality rates between treatments 1, 3 and 4 (Table 6); however, treatment2 (0.20 kg/cage) had the lowest mortality and was significantly different from mortality rates at the lowest and the highest densities (F = 9.03, Pr>F = 0.0060, R^2 = 0.7720, α = 0.05).

In the second experiment (1991), there were no significant differences between biweekly instantaneous mortality rates for most densities (F = 2.26, Pr>F = 0.1584, R^2 = 0.4589, α = 0.05), based on the regression of the natural logarithms of number of fish on time (Table 6).

Table 5. Mean daily relative and instantaneous mortality rates (in number of African catfish) at four different densities in both 1990 and 1991. The 95% Confidence Intervals (n=3) are shown in parentheses.

Treatments		Rel. Mort (M)	Inst. Mort (Z)
1990			
1	0.14 [1]	0.007(±0.00)[ab2]	0.008(±0.00)[ab]
2	0.20	0.004(±0.00)[a]	0.004(±0.00)[a]
3	0.24	0.007(±0.00)[ab]	0.008(±0.01)[ab]
4	0.35	0.008(±0.00)[b]	0.011(±0.00)[b]
1991			
1	1.66	0.003(±0.00)[a]	0.003(±0.00)[a]
2	3.44	0.002(±0.00)[a]	0.002(±0.00)[a]
3	4.65	0.001(±0.00)[a]	0.001(±0.00)[a]
4	6.40	0.002(±0.00)[a]	0.002(±0.00)[a]

[1] These values represent the stocking density

[2] Values with the same letter are not significantly different ($\alpha \leq 0.05$)

Table 6. Weekly and biweekly instantaneous mortality rates (Z) and their statistical significance at different densities in the 1990 (n=27) and 1991 (n=15) experiments. The 95% Confidence Intervals (n=3) are shown in parentheses.

Treatment	Density (kg/cage)	Z	F	Pr>F	R-square
1990					
1	0.14	0.077(±0.05)[a] [1]	107.47	0.0001	0.8113
2	0.20	0.036(±0.03)[b]	54.02	0.0001	0.6836
3	0.24	0.074(±0.05)[ab]	104.44	0.0001	0.8069
4	0.35	0.101(±0.02)[a]	166.96	0.0001	0.8698
1991					
1	1.66	0.020(±0.02)	15.88	0.0016	0.5499
2	3.44	0.013(±0.02)	14.77	0.0020	0.5318
3	4.65	0.006(±0.01)	7.18	0.0189	0.3559
4	6.40	0.011(±0.01)	24.68	0.0003	0.6550

[1] Values with the same letter are not significantly different ($\alpha \leq 0.05$)

Production

Estimates of production using biomass and instantaneous growth rate data indicated that, in 1990, treatment4 which was the highest density test (0.35 kg/cage) showed the highest total production. The lowest density provided the lowest total production (Table 7); however, only treatment1 (lowest density) had a significantly lower production value than treatment2 and 4 but it was not significantly different from treatment 3 ($F = 7.28$, $Pr>F = 0.0113$, $R^2 = 0.7319$, $\alpha = 0.05$). The weekly production pattern (Fig.6) showed that production estimates at all densities were high from the 4th to the 6th weeks. During the 7th week production decreased but increased again for the last week of the experiment. Confidence Intervals about the means were high and variable.

In 1991, the mean total production values were directly affected by stocking density (Table 7). Total production increased significantly with increasing densities ($F = 712.65$, $Pr>F = 0.0001$, $R^2 = 0.9963$, $\alpha = 0.05$). The biweekly production pattern (Fig.7) indicated that production at each density increased as the fish grew especially after the 4th week. During the final weeks of the experiment, production increased steadily. These increases during the latter half of the experimental period were particularly apparent at the three highest densities.

Food Conversion Ratio

The results of analysis of variance conducted at the end of experiment1 (1990) using the feeding data, indicated that there was no significant difference ($F = 2.47$, $Pr>F = 0.1367$, $R^2 = 0.4804$, $\alpha = 0.05$) between food conversion ratios (FCR) at various densities of African catfish cultured in the cages. The FCR were high in the first week but they decreased as fish grew. The food conversion ratios at densities of 0.14, 0.20, 0.24 and 0.35 kg/cage were 2.93, 2.33, 2.45 and 2.78 respectively. In 1991, food conversion ratio was lowest (1.21) in treatment3 and highest (1.39) in treatment1. For densities of 3.44 and 6.40 kg/cage, they were 1.27 and 1.24 respectively. There was only one significant difference, that between the lowest density (1.66 kg/cage) and the other higher three densities ($F = 12.14$, $Pr>F = 0.0024$, $R^2 = 0.8199$, $\alpha = 0.05$).

Table 7. Mean (n=3) total production (kg) for varying stocking densities of African catfish in 1990 and 1991.

Treatments	Densities (kg/cage)	Production (kg/cage)	CI (95%)
1990			
1	0.14	6.52 [a] [1]	1.2752
2	0.20	11.75 [b]	5.4840
3	0.24	9.47 [ab]	2.1986
4	0.35	12.45 [b]	5.9857
1991			
1	1.66	16.30 [a]	2.0868
2	3.44	31.19 [b]	3.5934
3	4.65	48.81 [c]	3.7352
4	6.40	60.31 [d]	2.7619

[1] Values with the same letter are not significantly different ($\alpha \leq 0.05$)

Figure 6. Weekly production (kg) of African catfish reared at four densities in 1990. Symbols are as follows: ● — ● treatment1, ○ — ○ treatment2, ■ — ■ treatment3, □ — □ treatment4.

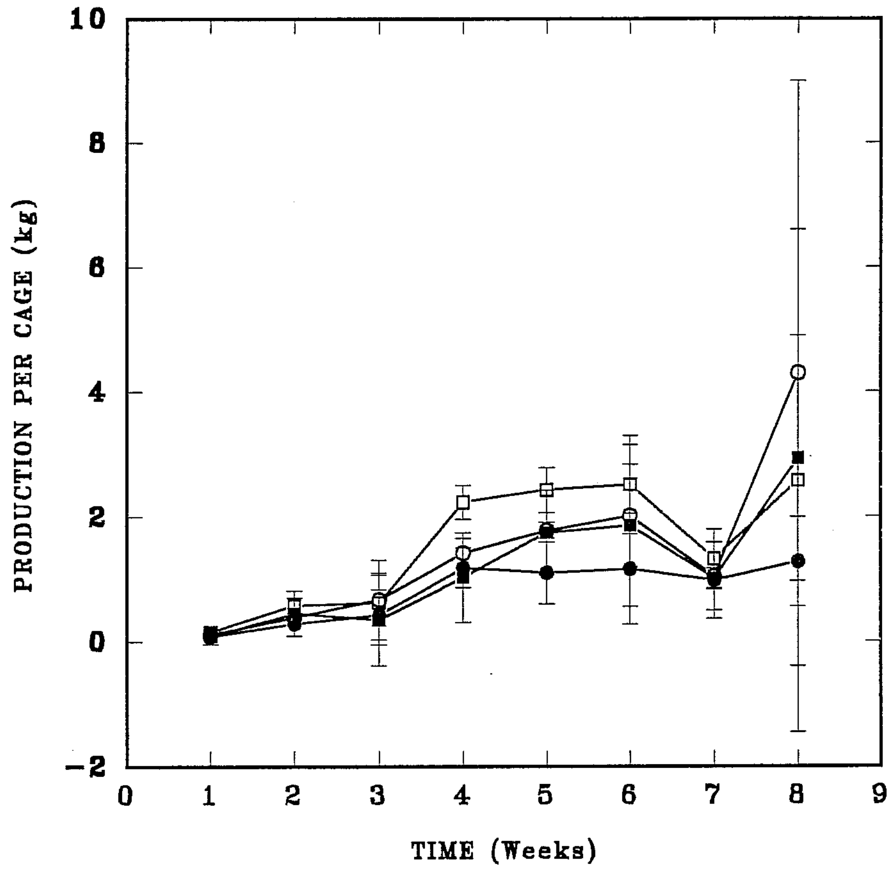
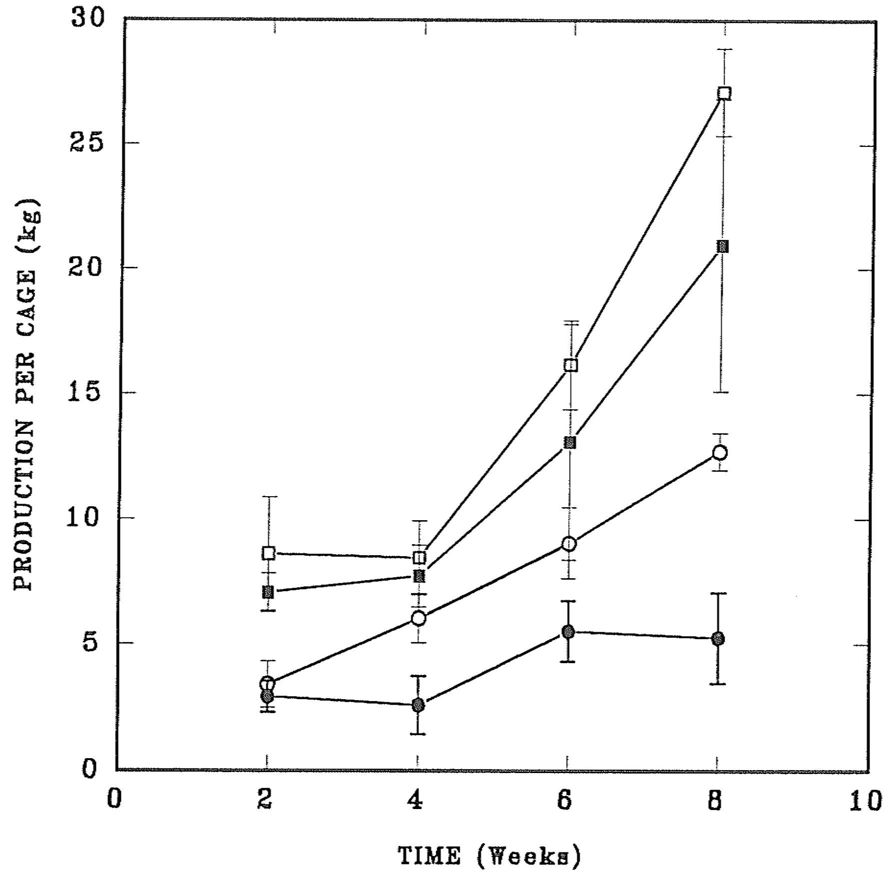

PRODUCTION PER CAGE (kg)
TIME (Weeks)
10
8
6
4
2
0
-2
0
1
2
3
4
5
6
7
8
9

Figure 7. Biweekly production of African catfish reared at four densities in 1991. Symbols are as follow: ● — ● treatment1, ○ — ○ treatment2, ■ — ■ treatment3, □ — □ treatment4.



PRODUCTION PER CAGE (kg)
TIME (Weeks)
0
5
10
15
20
25
30
0
2
4
6
8
10

Economics

In the 1990 experiment catfish were stocked at a smaller size and the cost per fingerling was 1 B$ lower than for the bigger fish used in 1991. Because of the high initial mortality rate in 1990, cage culture failed in terms of its economic value (Table 8). It was found that the second density (0.20 kg/cage) had the lowest mortality and provided the best income. In the absence of the mortality problems which occurred in 1990, the economic result in the 1991 experiment was directly related to stocking density. The highest density provided the highest profit per cage; although the cost of fingerlings was also high (Table 9).

Table 8. Economic information based on total final biomasses at the end of experiment and calculated production on African catfish cultured in cages in 1990 at four different stocking densities using data collected after the second week (without replacement of dead fish, 42 days period) .

	Treatments			
	1	2	3	4
Cost				
Density (Fish/cage)	75	100	150	200
Fingerling Cost				
(1.50 B$[1]/fish)	112.50	150.00	225.00	300.00
Food amount (kg)	14.96	23.38	20.22	26.98
Food Cost (12.5 B$/kg)	187.00	292.25	252.75	337.25
Total Cost	299.50	442.25	477.75	637.25
Income				
Final Biomass (kg)	5.87	10.94	8.89	10.72
Production (kg)	6.15	11.33	9.26	11.73
Fish Value (35 B$/kg)				
Based on Biomass	205.45	382.90	311.15	375.20
Based on Production	215.25	396.55	324.10	410.55
Net Profit				
Based on Biomass	-94.05	-59.35	-166.60	-262.05
Based on Production	-84.25	-45.70	-153.65	-226.70

[1] B$ is a Thai currency unit, ≈ 20 B$ = 1 Can.$

Table 9. Economic information based on both final biomasses and production on African catfish cultured in cages in 1991 at four different stocking densities (56 days).

	Treatments			
	1	2	3	4
Cost				
Density (fish/cage)	50	100	150	200
Fingerling Cost				
(2.50 B$/fish)	125.00	250.00	375.00	500.00
Food amount (kg)	20.75	37.25	56.49	70.62
Food Cost(12.5 B$/kg)	259.36	465.59	706.08	882.76
Total Cost	384.36	715.59	1081.08	1382.76
Income				
Final Biomass (kg)	16.58	32.73	51.20	63.47
Production (kg)	16.30	31.19	48.81	60.31
Fish Value (30 B$/kg)				
Based on Biomass	497.40	981.90	1535.73	1903.98
Based on Production	489.00	935.70	1464.30	1809.30
Net Profit				
Based on Biomass	113.04	203.31	454.65	521.22
Based on Production	104.64	220.11	383.22	426.54

DISCUSSION

There was evidence from the second experiment (1991) that the highest fish biomass of African catfish was found at the highest stocking density (6.40 kg/m^3) during the culture period of 56 days when severe mortality unrelated to experimental conditions did not occur. In 1990, the biomass were also high at the high stocking density up to the 7th week; however, during the last week, biomass in treatment 2 (0.20 kg/cage) increased greatly and resulted in the highest biomass at harvest. For treatment 3 (0.24 kg/cage), the increase in biomass was very low caused by high mortality to weak fish. After the 2nd week of rearing, the biomass in this treatment was lower than in treatment 2 (0.20 kg/cage) and remained lower until the end of the experiment. The general cause of these results in the 1990 experiment was that the condition of the fish at stocking was poor, resulting in mortalities which were unrelated to stocking density. Reasons for the relatively high biomass from treatment 2 in 1990 is not apparent.

The highest stocking density in the 1991 experiment resulted in the highest biomass at harvesting although the mean weight of the fish was reduced. Over stocking may reduce growth and production of fish as a result of competition for food and space (Weatherley, 1972); however, in this experiment, food was given at an amount related to fish biomass. The food given in the high density trial was definitely greater than at the lower densities. This procedure was intended to avoid competition for food.

Studies by Hogendoorn and Koops (1983) on the same catfish in pond culture also found that the highest biomass was achieved from the highest stocking density. Culture of *O. niloticus* in cages showed that the highest stocking density (100 fish/m^3) achieved the highest biomass after five and a half months (Daungsawasdi et al., 1986).

The mean weight of the catfish, in the 1990 experiment, after 56 days was not statistically different at most densities. Reasons for this variability in the data were, again, related to high, variable, mortality rates associated with the initial poor condition and small size of the fish used to stock the cages. The results from the 1991 trial showed that the individual weight increase was inversely proportional to stocking density, which was particularly evident when average weight of fish held at the lowest and highest densities were compared; however, only the average weight of fish reared at the lowest stocking density was significantly different from weights of fish reared at the other densities. Jarimopas et al. (1992) found that stocking density had an influence on the growth of *C. macrocephalus* x *C. gariepinus* hybrids cultured in concrete ponds at three different densities. After 4 months, the mean fish weights were 180.60, 180.46 and 150.32 g for densities of 25, 50 and 75 fish/m^3 respectively. Average weights were much lower when fish were stocked at 75 fish/m^3 than at 50 fish/m^3.

This study indicated that these African catfish grew rapidly in cages. They reached a maximum mean weight of 142.8 g after 56 days when stocked at 0.2 kg/cage (2.0 g per fish) in 1990. In the second study, cages stocked with 32 g fish, showed even better results. The highest mean fish weight was achieved at the lowest density (1.66 kg/cage), 385.7 g per fish after 56 days. Tangtrongpiros et al (1988) found that, after catfish were fed with pellets for 141 days, the average weight of *C. gariepinus* was 493.3 g, while of *C. macrocephalus* was 189.64 g when these fish were reared at equal stocking numbers (14 fish/m^2) in a 1600 m^2 earthen ponds. In addition, the maximum weight of *C. gariepinus* and *C. macrocephalus* were 1,500 g and 265 g respectively. From these results, it is evident that *C. gariepinus* gave a six fold faster growth rate than *C. macrocephalus* in pond culture. This present study, showed that catfish cultured intensively in cages grew much faster than in pond culture; however, Bureau (1992) found that the use of crop residues incorporated with food affected the growth of African catfish. Catfish were stocked in cages at 5.9 to 6.6 g per fish. After 10 weeks of rearing, catfish only reached mean weights ranging from 57 to 82 g.

Various studies on African catfish report differences according to the type of culture. Viveen et al. (1984) reported that growing catfish in tanks required 24-28 weeks to reach a size of 300-500 g. In ponds in which the fish were fed, using the same period of time, catfish grew to a weight of 200 g; however, Hogendoorn and

Koops (1983) found that the fish, under field conditions, reached 300 g in only 22 weeks. During the same period, but in fertilized ponds and without supplemental food, catfish reached a maximum weight of 135 g (Bok and Jongbloed, 1984). Results from present study, showed that catfish reached weights between 95 and 142 g in only 8 weeks when stocked as small fish (1.8 g). Furthermore, during the same period, catfish reached weights ranging from 346 to 385 g when stocked as larger fish (32 g).

In both the 1990 and 1991 studies, weight gain per fish was not affected by stocking density. Consequently, weight gain per cage increased with increasing density; therefore the fish could be stocked at a higher density than 200 fish or 6.40 kg/m^3. Stocking density, also, did not have any influence on live weight gains in *O. niloticus*. Results obtained by Wannigama et al. (1985) indicated that fish can be stocked in cages up to 800 $fish/m^3$, but Steffens (1989), based on a study with carp, found that density affected weight gain per fish and, also, the Food Conversion Ratio. The highest density (600 $fish/m^3$) had the lowest weight gain per fish and the highest FCR compared to the lower densities of 200 and 400 $fish/m^3$.

Growth rates determined from the 1990 experiment were variable for reasons given previously; however, in 1991, growth rates, both instantaneous and relative, were unrelated to stocking density. Growth rates were high even at the highest density. These results agree with those reported by Machiels and Van Dam (1987) for this catfish cultured in aquaria, Woiwode and Adelman (1989) for channel catfish (*Ictalurus punctatus*) in raceways, Soderberg and Krise (1986) for lake trout (*Salvelinus namaycush*) in cage culture, and Daungsawasdi et al. (1986) and Wannigama and Weerakoon (1982) for Nile tilapia (*O. niloticus*) in cages. In contrast, Steffens (1989) found that growth rates in rainbow trout were inversely related to stocking density. Differences between my results and Steffens's were probably caused by differences in the biology and environmental requirements of the different species.

Average instantaneous growth rates achieved during the 1990 experiment may have been affected by the condition of the fish at stocking and by the resulting high mortalities; therefore, the growth rates may not have been completely controlled by stocking density. The reason for the high rates at all treatments may have been caused by the small size of the fish used in 1990 in comparison with fish used in 1991. Small fish generally have higher growth rates than larger fish (Ricker, 1975). The relationships between instantaneous growth rates (Gw) and time in the 1991 experiment were similar for all treatments. The decrease in Gw's after week 4 was caused by a failure to provide sufficient food.

High mortality in the 1990 study was high caused by unsuitable food particle size, feeding regime, handling and the condition of fish used to stock the cages; therefore, mortality rates were probably not entirely determined by the treatments (density differences). Results from the 1991 experiment, indicated that mortality rates observed in the treatment groups were not related to stocking density as might be expected. Hogendoorn and Koops (1983) also reported that the survival rate of African catfish in ponds was not clearly influenced by stocking density. The mortality of *O. niloticus* in cages, also was not dependent upon by stocking density (Daungsawasdi et al., 1986). The same result was found in the culture of channel catfish in raceways (Woiwode and Adelman, 1989); however, a contrasting result was found in rainbow trout. The highest mortality rate occurred at the highest stocking density (Trzebiatowski et al., 1981). It is generally recommended that stocking densities should be below the maximum carrying capacity of the system because pathological and nutrition diseases increase as maximum capacity is approached (Cruz and Ridha, 1991). As mentioned previously, the 1990 experiment was compromised because the fish which were stocked were too small and in poor condition. Furthermore, sampling was too frequent and the fish were fed with inappropriately sized pellets. These conditions and procedures resulted in severe mortalities at all densities. The mouth of African catfish has a circumference of 1/4 of their total length. Catfish can swallow whole fish (Viveen et al., 1985). This adaptation of a large gape permits them to feed on and control the population of tilapia in polyculture situation. In the 1990 experiment, another source of error was cannibalism which was caused by the previously discussed problem of using improperly sized food pellets. They were too large and the result was an inadequate ration. This problem has occurred in other species, for example; walleye, *Stizostedion vitreum*, (Chevalier, 1973; Li and Mathias, 1982; Loadman et al., 1986, 1989; McIntyre et al., 1987), pike, *Esox lucius* (Giles et al., 1986), and cod, *Gadus morhua* L. (Folkvord, 1991). The results from the 1991 experiment showed that stocking larger fingerlings and adjusting food pellets size resulted in low and consistent mortality rates.

Production, biomass corrected for growth and mortality, estimated from the 1990 results was highly variable and unrelated to stocking densities. I believe that these high variabilities were caused by the previously discussed problems dissociated with fish size at stocking, food particle size and stress caused by too frequent sampling. Therefore, the results of the 1990 study do not indicate the effect of stocking density on production. In contrast, the production data for the 1991 experiment clearly indicate the importance of the factors of fish size, food size and handling on the succesful culture of African catfish.

From this study, the larger fry (32 g) stocked in 1991 which were at the appropriate recommended stocking size, had a lower mortality rate than the smaller fish (1.8 g) used in 1990. Krummich and Heidinger (1973) showed that mortality can be reduced by stocking the larger fish; however, the cost of rearing fish fry increases with fish size. The minimum size of Channel catfish recommended for stocking in a small impoundment in the USA is 200 mm total length (Storck and Newman, 1988).

The frequency of sampling affected growth, mortality and also FCR in the 1990 experiment. For example, one day after being sampled, the fish were still stressed. Stress can be detected because catfish show a mosaic-like pattern of dark and light spots in this condition (Viveen et al., 1984). In addition, they were still weak from handling during sampling. Finally swimming speed was reduced and the direction of swimming was also changed. In summary, stress resulted in low food consumption and high mortality.

Although differences between production at all stocking densities in 1990 were not significantly different there was a strong trend for production to increase with increasing stocking density in 1991. These 1991 results agree with those of Cruz and Ridha (1989) working on *Oreochromis spilurus* Gunther in small nets cages (1 m^3).

They found that production was maximized at 300 fish per cage; however, there were no significant differences between 200 and 300 fish/m^3 when using larger nets cages (12.5 m^3) (Cruz and Ridha, 1991). My results also agree with those of Teng and Chua (1979) and confirm that stocking density is important in maximizing production.

Production estimates which are based on biomass estimates adjusted for mortality and corrected for growth rate (Chapman, 1968; Kelso and Ward, 1972), are the basis for estimating the economic yield from both fish culture operations and from natural fish populations. The results from the 1991 experiment indicate how dependent production values are on good fish culture practices.

While production was directly related to stocking density in the 1991 experiment, there must be some density at which mortality from a variety of causes reduces both average biomasses and growth rates to the point where production is reduced. This critical level was not reached although the stocking density at treatment 4 was high (6.40 kg/cage). One reason for the ability of African catfish to maintain high production levels when cultured at high densities, but provided with sufficient food, may be their adaptation for aerial respiration. I observed that frequency of aerial breathing increased at the higher stocking densities.

High stocking density generally causes higher food conversion ratios. When stocking fish at a high density, freedom of movement and ability to find food is limited even if food is offered in excess of requirements thus causing higher FCRs (Wedemeyer, 1976). Stocking densities used in my experiments caused a reversal in the expected FCR-density relationship. The FCRs decreased slightly with increasing density. Fish in high density cages seemed to be more active in feeding than fish held at lower densities. Consequently, feeding activity was more intense; however, only fish held at the lowest density in the 1991 experiment showed a significantly higher difference in FCR values from the other three treatments. Similar results, a high FCR at low density, were reported in the culture of rainbow trout by Trzebiatowski et al. (1981).

The FCRs in this experiment cannot be compared to other feeding experiments because the amount of food given was assumed to be the amount eaten by the fish;

however, differences in FCRs between the four different densities, while the food was given at the same regime and also the same level relative to their body weight, was observed.

It is difficult to compare the economics of different methods of aquaculture because of the variability of fish species, environments and, also, economic and cultural differences between countries and locations (Collins and Demeldo, 1979); however it is possible to compare the economic data obtained from the two experiments.

Fish value per kilogram in the 1991 experiment was lower than in 1990 because of the average weight of the fish was greater than the preferred market size. In northeastern Thailand, catfish are sold as whole fish, generally at a weight of 200 to 250 g or 4-5 fish per kilograms. Larger fish can only be sold to big restaurants; however the demand by this market is small. In the 1991 experiment, catfish were stocked at a weight of about 32 g per fish. At this stocking size, the fish should have been harvested soon after the sixth week at an average weight between 200 to 265 g to increase value per kilograms. Furthermore, additional crops per year can be reared.

When my production data are converted to monetary ones, it is evident that the problems encountered in the 1990 experiment caused an economic deficit at all densities. Again this result emphasizes the importance of good cultural practices.

The 1991 data also clearly indicate the economic advantage of culturing fish for the specific requirements of the market in northeastern Thailand. Smaller fish are preferred over the larger size harvested from the 1991 experiment. The highest economic yield may be determined not by maximum production but by preferred market size and price (Zonneveld and Fadholi, 1991)

In conclusion, the two rearing experiments, while providing useful information of both positive and negative kinds, had limitations. The 1990 results were affected by problems associated with fish size at stocking and design of the experiment. Results in 1991 were in general positive but did not indicate the upper limit of stocking densities for African catfish cultured in the system used. Additional experiments could be conducted to determine optimal stocking density of catfish in small cages and also densities which would produce the maximum number of fish of the desired size. Other experiments could be carried out to determine optimum food levels at various densities.

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APPENDIX I

Weight - Length Relationship

It was found that within any period of a fish's life, weight varies as some power of length. The basic equation is:

$w = al^b$ where

w = weight in grams;

l = length in cm;

a = y-intercept;

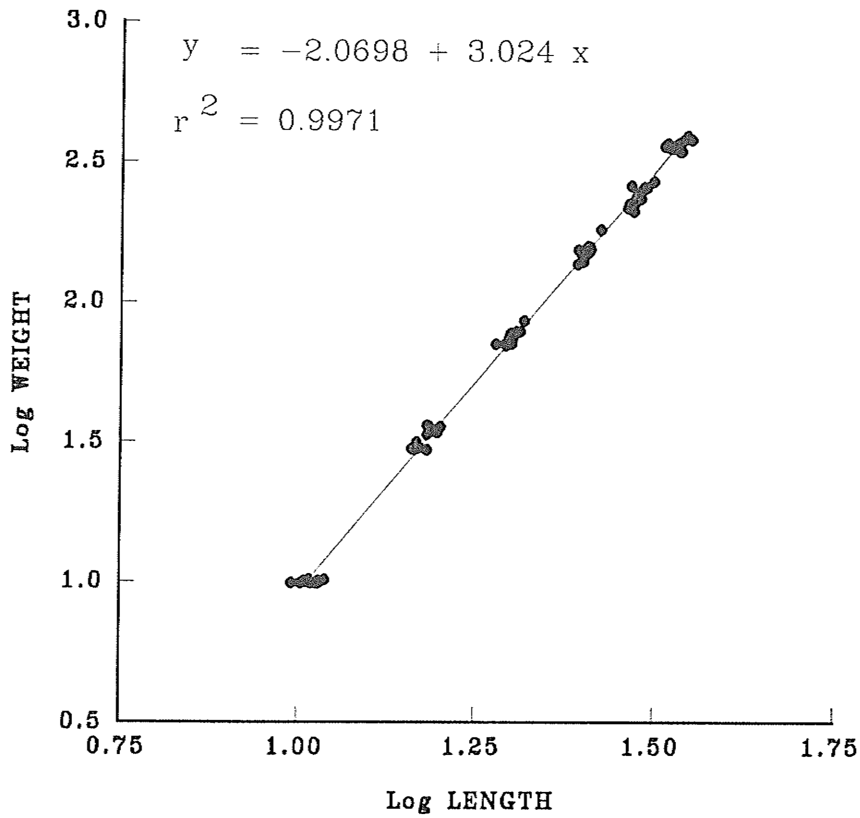
b = slope or exponent.

The weight-length relationship equation was normally transformed to a linear form for regression analysis by plotting the logarithm base10 of weight against logarithm base10 of length (Fig. 1). The transformed equation for African catfish from this study was:

$$\log_{10} w = -2.0698 + 3.024 \log_{10} l$$

The R^2 value was 0.9971. Either fish weights or lengths can be accurately predicted from this equation.

Figure 1. Plot of $\log_{10}$ of weight (g) against $\log_{10}$ of length (cm) of African catfish in 1991 experiment.



y = -2.0698 + 3.024 x
r 2 = 0.9971
3.0
2.5
2.0
1.5
1.0
0.5
Log WEIGHT
0.75
1.00
1.25
1.50
1.75
Log LENGTH

APPENDIX II

Table 1. Randomized arrangement of cages by treatment and replicate.

CAGE NO.	1990	1991
1	T1R1	T2R3
2	T3R2	T1R2
3	T4R2	T1R3
4	T3R1	T4R1
5	T4R1	T2R1
6	T1R2	T2R2
7	T2R1	T3R2
8	T1R3	T3R1
9	T2R2	T4R3
10	T4R3	T3R3
11	T3R3	T4R2
12	T2R3	T1R1

Table 2. Nutrient content of experimental catfish foods (Chareon Pokpand Ltd.).

Nutrient (%)	FOOD	
	No. 9910 (Fine particles)	No. 9912 (Large particles)
Crude Protein	33.1906	27.6674
Fat	1.6350	1.8733
Fiber	2.6100	3.2160
Soluble Ash	11.5666	11.6117
Insoluble Ash	1.6686	2.5895
Energy	4.0922	4.3844
Ca	1.5800	2.0600
P	1.8073	1.5273
Moisture	6.1312	1.5273

* Proximate analysis from Applied Nutrition Laboratory, Department of Animal Science, Faculty of Agriculture, Khon Kaen University, Thailand.

Table 3. Water Quality Regime in 1991 (sample was taken at 2:00 p.m.).

	Stocked				Harvested
Time (wks)	0	2	4	6	8
Date	Jun. 23	Jul. 7	Jul. 21	Aug. 4	Aug. 18
DO(mg L^{-1})	14.7	15.2	16.5	18.0	17.8
pH	8.4	8.4	8.2	8.5	8.4
Temp.(°C)	31.7	31.5	31.8	29.6	32.2

APPENDIX III

Table 1. Mean (n=3) Weekly and biweekly Instantaneous Growth rates (Gw) in weight according to density during the 1990 and 1991 experiments. The 95% Confidence Intervals are shown in parentheses.

Time (wks)	Trt1	Trt2	Trt3	Trt4
1990				
1	0.467(±0.13)	0.457(±0.12)	0.286(±0.38)	0.363(±0.16)
2	0.810(±0.08)	0.779(±0.12)	0.881(±0.48)	0.743(±0.10)
3	0.648(±0.57)	0.702(±0.38)	0.418(±0.85)	0.482(±0.39)
4	0.935(±0.28)	0.754(±0.17)	0.877(±0.51)	1.006(±0.13)
5	0.513(±0.31)	0.531(±0.04)	0.629(±0.16)	0.610(±0.14)
6	0.363(±0.18)	0.393(±0.14)	0.427(±0.18)	0.411(±0.10)
7	0.236(±0.18)	0.161(±0.08)	0.183(±0.05)	0.172(±0.04)
8	0.240(±0.10)	0.469(±0.38)	0.395(±0.29)	0.261(±0.35)
1991				
2	0.992(±0.23)	0.689(±0.20)	0.890(±0.15)	0.822(±0.22)
4	0.480(±0.18)	0.646(±0.01)	0.517(±0.06)	0.458(±0.05)
6	0.613(±0.20)	0.551(±0.02)	0.527(±0.14)	0.540(±0.09)
8	0.373(±0.09)	0.477(±0.06)	0.511(±0.15)	0.537(±0.04)

Table 2. Estimates of production (P) in kilogram of African catfish in each treatments in 1990 (average weight in gram (W), Instantaneous growth rates (Gw), biomass (B), and ($\bar{B}$) is mean biomass).

Age/weeks	W(g)	Ln W	Gw	B(kg)	$\bar{B}$	P(kg)
Treatment 1						
0	1.84	0.6098		0.138		
1	2.94	1.0777	0.4680	0.220	0.179	0.084
2	6.61	1.8884	0.8107	0.496	0.358	0.290
3	12.73	2.5436	0.6551	0.837	0.667	0.437
4	32.14	3.4702	0.9266	1.715	1.276	1.182
5	53.70	3.9834	0.5132	2.617	2.166	1.112
6	77.11	4.3452	0.3618	3.728	3.173	1.148
7	97.81	4.5830	0.2379	4.703	4.216	1.003
8	124.21	4.8219	0.2389	5.867	5.285	1.263
					Total =	6.518
Treatment 2						
0	2.00	0.6931		0.200		
1	3.16	1.1506	0.4574	0.316	0.258	0.118
2	6.88	1.9291	0.7785	0.688	0.502	0.391
3	13.98	2.6378	0.7087	1.242	0.965	0.684
4	29.57	3.3869	0.7491	2.514	1.878	1.407
5	50.28	3.9176	0.5308	4.207	3.361	1.784
6	74.69	4.3133	0.3956	6.037	5.122	2.027
7	87.64	4.4732	0.1599	7.000	6.519	1.042
8	142.83	4.9616	0.4884	10.940	8.970	4.381
					Total =	11.833

(Table 2 Cont.)

Age/weeks	W(g)	Ln W	Gw	B(kg)	$\bar{B}$	P(kg)
Treatment 3						
0	1.57	0.4530		0.237		
1	2.11	0.7481	0.2951	0.317	0.277	0.082
2	5.26	1.6603	0.9122	0.664	0.491	0.447
3	7.72	2.0432	0.3828	1.036	0.850	0.325
4	18.62	2.9244	0.8812	2.025	1.531	1.349
5	34.75	3.5483	0.6239	3.538	2.782	1.735
6	53.67	3.9829	0.4346	5.097	4.318	1.877
7	64.40	4.1651	0.1822	6.050	5.574	1.016
8	95.74	4.5617	0.3965	8.888	7.469	2.962
					Total =	9.792
Treatment 4						
0	1.75	0.5596		0.350		
1	2.52	0.9243	0.3646	0.504	0.427	0.156
2	5.30	1.6677	0.7434	1.060	0.782	0.581
3	8.68	2.1615	0.4938	1.520	1.290	0.637
4	23.60	3.1613	0.9998	2.940	2.230	2.230
5	43.26	3.7672	0.6059	5.047	3.994	2.420
6	65.28	4.1786	0.4114	7.153	6.100	2.509
7	77.63	4.3519	0.1733	8.170	7.662	1.328
8	102.25	4.6274	0.2755	10.723	9.447	2.602
					Total =	12.463

Table 3. Estimates of production (P) in kilogram of African catfish in each treatment in 1991 (average weight in gram (W), Instantaneous growth rates (Gw), biomass (B), and ($\bar{B}$) is mean biomass).

Age (wks)	W(g)	Ln W	Gw	B(kg)	$\bar{B}$	P(kg)
Treatment 1						
0	33.13	3.5005		1.657		
2	89.21	4.4909	0.9904	4.240	2.949	2.920
4	144.02	4.9700	0.4790	6.532	5.386	2.580
6	265.93	5.5832	0.6133	11.577	9.055	5.553
8	385.75	5.9552	0.3720	16.575	14.076	5.236
					Total =	16.289
Treatment 2						
0	34.42	3.5385		3.442		
2	68.46	4.2262	0.6877	6.485	4.964	3.413
4	130.63	4.8723	0.6461	12.197	9.341	6.035
6	226.53	5.4229	0.5505	20.630	16.414	9.036
8	364.93	5.8997	0.4768	32.730	26.680	12.722
					Total =	31.207

(Table 3 Cont.)

Age/weeks	W(g)	Ln W	Gw	B(kg)	$\bar{B}$	P(kg)
Treatment 3						
0	31.02	3.4345		4.653		
2	75.40	4.3228	0.8883	11.233	7.943	7.056
4	126.40	4.8394	0.5166	18.625	14.929	7.712
6	214.50	5.3683	0.5289	30.860	24.743	13.087
8	357.13	5.8781	0.5098	51.191	41.026	20.913
					Total =	48.768
Treatment 4						
0	32.92	3.4941		6.404		
2	74.75	4.3141	0.8200	14.533	10.469	8.584
4	118.23	4.7726	0.4585	22.272	18.403	8.438
6	202.80	5.3122	0.5396	37.583	29.928	16.150
8	346.81	5.8488	0.5366	63.466	50.525	27.109
					Total =	60.281

APPENDIX IV

Table 1. Final biomass (kg) of catfish each cage in 1990

Time	Started								Harvested
	0	1	2	3	4	5	6	7	8
Trt	Jul.5	Jul.12	Jul.19	Jul.26	Aug.2	Aug.9	Aug.16	Aug.23	Aug.30
T1R1	0.140	0.226	0.502	0.870	1.901	2.770	4.250	5.060	6.330
T1R2	0.135	0.225	0.525	0.755	1.592	2.480	3.370	4.620	5.660
T1R3	0.140	0.210	0.460	0.885	1.652	2.600	3.560	4.430	5.610
MEANS	0.138	0.220	0.496	0.837	1.715	2.617	3.728	4.703	5.867
T2R1	0.200	0.300	0.690	1.315	2.547	4.190	6.290	7.160	12.900
T2R2	0.200	0.330	0.710	1.205	2.525	4.200	5.930	7.070	10.380
T2R3	0.200	0.318	0.665	1.205	2.471	4.230	5.890	6.770	9.540
MEANS	0.200	0.316	0.688	1.242	2.514	4.207	6.037	7.000	10.940
T3R1	0.235	0.269	0.612	0.900	1.765	3.020	4.350	5.240	8.720
T3R2	0.235	0.308	0.632	1.110	2.100	3.745	5.250	6.210	8.270
T3R3	0.240	0.375	0.749	1.098	2.210	3.850	5.690	6.700	9.673
MEANS	0.237	0.317	0.664	1.036	2.025	3.538	5.097	6.050	8.888
T4R1	0.350	0.505	1.110	1.450	2.820	4.830	6.880	7.790	8.650
T4R2	0.350	0.472	0.985	1.370	2.750	4.840	7.220	8.060	10.820
T4R3	0.350	0.535	1.085	1.740	3.250	5.470	7.360	8.660	12.700
MEANS	0.350	0.504	1.060	1.520	2.940	5.047	7.153	8.170	10.723

Table 2. Average weight (g) of fish each cage in 1990

Time	Started								Harvested
	0	1	2	3	4	5	6	7	8
Trt	Jul.5	Jul.12	Jul.19	Jul.26	Aug.2	Aug.9	Aug.16	Aug.23	Aug.30
T1R1	1.86	3.01	6.69	13.18	33.35	50.36	78.78	93.70	124.12
T1R2	1.80	3.00	7.00	10.49	30.04	57.67	78.37	107.44	131.63
T1R3	1.86	2.80	6.13	14.51	33.04	53.06	74.17	92.29	116.88
MEANS	1.84	2.94	6.61	12.73	32.14	53.70	77.11	97.81	124.21
T2R1	2.00	3.00	6.90	16.44	32.24	54.42	85.00	98.08	186.96
T2R2	2.00	3.30	7.10	12.55	27.75	46.67	69.77	85.18	126.59
T2R3	2.00	3.18	6.65	12.96	28.73	49.77	69.29	79.65	114.94
MEANS	2.00	3.16	6.88	13.98	29.57	50.28	74.69	87.64	142.83
T3R1	1.56	1.79	4.08	6.62	16.65	31.13	45.49	56.34	94.78
T3R2	1.56	2.05	4.21	8.69	16.67	33.44	49.07	58.04	77.29
T3R3	1.60	2.50	7.49	7.84	22.55	39.69	66.16	78.82	115.16
MEANS	1.57	2.11	5.26	7.72	18.62	34.75	53.67	64.40	95.74
T4R1	1.75	2.53	5.55	8.33	23.50	42.54	61.43	72.13	80.09
T4R2	1.75	2.36	4.93	7.17	20.22	39.67	62.24	73.27	98.36
T4R3	1.75	2.68	5.25	10.55	27.08	47.57	72.16	87.48	128.28
MEANS	1.75	2.52	5.3	8.68	23.60	43.26	65.28	77.63	102.25

Table 3. Weight gain (kg) per cage per week in 1990

Time	Started							Harvested
	0	1	2	3	4	5	6	7	8
Trt	Jul.5	Jul.12	Jul.19	Jul.26	Aug.2	Aug.9	Aug.16	Aug.23	Aug.30
T1R1		0.086	0.226	0.368	1.031	0.869	1.484	0.806	1.270
T1R2		0.090	0.280	0.230	0.837	0.888	0.890	1.250	1.040
T1R3		0.070	0.225	0.470	0.785	0.950	0.960	0.870	1.180
MEANS		0.082	0.257	0.356	0.884	0.902	1.111	0.975	1.163
T2R1		0.100	0.375	0.700	1.232	1.613	2.100	0.870	5.740
T2R2		0.130	0.375	0.495	1.365	1.675	1.730	1.140	3.310
T2R3		0.118	0.337	0.540	1.266	1.759	1.660	0.880	2.770
MEANS		0.116	0.362	0.578	1.288	1.682	1.830	0.963	3.940
T3R1		0.034	0.273	0.293	0.865	1.255	1.330	0.890	3.480
T3R2		0.073	0.281	0.528	1.000	1.045	1.505	0.960	2.060
T3R3		0.135	0.361	0.419	1.116	1.640	1.840	1.010	2.973
MEANS		0.081	0.305	0.413	0.994	1.313	1.558	0.953	2.838
T4R1		0.155	0.550	0.340	1.375	2.010	2.050	0.910	0.860
T4R2		0.122	0.433	0.585	1.384	2.086	2.380	0.840	2.760
T4R3		0.184	0.467	0.655	1.510	2.220	1.890	1.300	4.040
MEANS		0.154	0.483	0.527	1.423	2.105	2.107	1.017	2.553

Table 4. Total number of fish each cage in 1990

Time	Started 0	1	2	3	4	5	6	7	Harvested 8
Trt	Jul.5	Jul.12	Jul.19	Jul.26	Aug.2	Aug.9	Aug.16	Aug.23	Aug.30
T1R1	75	75	75	66	57	55	54	54	51
T1R2	75	75	75	72	53	43	43	43	43
T1R3	75	75	75	61	50	49	48	48	48
MEANS	75	75	75	66	53	49	48	48	48
T2R1	100	100	100	80	79	77	74	73	69
T2R2	100	100	100	96	91	90	85	83	82
T2R3	100	100	100	93	86	85	85	85	83
MEANS	100	100	100	90	85	84	81	80	78
T3R1	150	150	150	136	106	97	95	93	92
T3R2	150	150	150	129	126	112	107	107	107
T3R3	150	150	150	140	98	97	86	85	84
MEANS	150	150	150	135	110	102	96	95	94
T4R1	200	200	200	174	120	114	112	108	108
T4R2	200	200	200	191	136	122	116	110	110
T4R3	200	200	200	165	120	115	102	99	99
MEANS	200	200	200	177	125	117	110	106	106

Table 5. Food Intake (kg) per cage in 1990

Time / Trt	Started 0 Jul.5	1 Jul.12	2 Jul.19	3 Jul.26	4 Aug.2	5 Aug.9	6 Aug.16	7 Aug.23	Harvested 8 Aug.30
T1R1		0.239	0.336	0.722	1.270	2.550	2.905	4.599	4.116
T1R2		0.234	0.343	0.750	1.112	2.124	2.604	4.200	3.752
T1R3		0.239	0.329	0.718	1.201	2.230	2.730	4.025	3.171
MEANS		0.237	0.336	0.730	1.194	2.301	2.746	4.275	3.717
T2R1		0.347	0.441	0.878	1.916	3.377	4.396	6.510	6.538
T2R2		0.347	0.469	0.992	1.694	3.365	4.893	6.433	6.846
T2R3		0.342	0.462	0.938	1.757	3.332	4.438	6.160	6.888
MEANS		0.345	0.457	0.936	1.789	3.358	4.576	6.368	6.357
T3R1		0.403	0.476	0.908	1.320	2.339	3.171	4.769	5.684
T3R2		0.403	0.497	0.878	1.615	2.790	3.927	5.649	5.369
T3R3		0.408	0.546	0.995	1.601	2.886	4.309	6.097	6.349
MEANS		0.405	0.506	0.927	1.512	2.672	3.802	5.505	5.800
T4R1		0.600	0.784	1.448	2.113	3.726	5.068	7.084	5.635
T4R2		0.590	0.777	1.328	2.003	3.670	5.028	7.329	6.944
T4R3		0.600	0.846	1.388	2.536	4.320	4.740	7.875	8.715
MEANS		0.597	0.802	1.388	2.217	3.905	4.945	7.429	7.098

Table 6. Cumulative FCR (from the first week) of catfish each cage in 1990

Time	Started								Harvested
	0	1	2	3	4	5	6	7	8
Trt	Jul.5	Jul.12	Jul.19	Jul.26	Aug.2	Aug.9	Aug.16	Aug.23	Aug.30
T1R1		2.708	1.145	1.409	1.350	1.847	2.822	3.295	3.283
T1R2		2.600	1.090	1.757	1.532	1.839	2.216	2.534	2.736
T1R3		3.410	1.230	1.453	1.507	1.814	2.177	2.674	2.777
MEANS		2.930	1.155	1.567	1.463	1.833	2.405	2.834	2.932
T2R1		3.470	1.142	1.267	1.407	1.660	1.865	2.567	1.921
T2R2		2.670	1.149	1.500	1.388	1.635	2.052	2.648	2.460
T2R3		2.900	1.209	1.446	1.416	1.615	1.980	2.683	2.604
MEANS		3.013	1.167	1.404	1.404	1.637	1.966	2.633	2.328
T3R1		11.850	1.436	1.985	1.760	1.803	2.094	2.674	2.247
T3R2		5.520	1.424	1.601	1.616	1.650	2.016	2.637	2.629
T3R3		3.022	1.274	1.757	1.607	1.671	1.922	2.565	2.430
MEANS		6.797	1.378	1.781	1.661	1.708	2.011	2.625	2.436
T4R1		3.870	1.247	1.953	1.754	1.795	2.104	2.798	3.188
T4R2		4.840	1.387	1.967	1.706	1.728	1.950	2.688	2.643
T4R3		3.260	1.333	1.629	1.652	1.771	2.076	2.684	2.512
MEANS		3.990	1.322	1.850	1.704	1.765	2.043	2.723	2.781

APPENDIX V

Table 1. Total biomass (kg) of African catfish in cages 1991

Time (Wk)	Stocked 0	2	4	6	Harvested 8
Trt	June 23	July 7	July 21	August 4	August 18
T1R1	1.700	4.200	6.210	11.220	15.974
T1R2	1.485	4.320	7.130	12.040	17.450
T1R3	1.785	4.200	6.255	11.472	16.300
MEANS	1.657	4.240	6.532	11.577	16.575
T2R1	3.575	6.150	11.700	19.380	30.930
T2R2	3.600	7.000	12.990	22.410	35.220
T2R3	3.150	6.305	11.900	20.100	32.040
MEANS	3.442	6.485	12.197	20.630	32.730
T3R1	4.493	11.270	17.905	29.930	48.750
T3R2	5.025	11.460	19.366	33.170	52.850
T3R3	4.440	10.970	18.605	29.480	51.972
MEANS	4.653	11.233	18.625	30.860	51.191
T4R1	5.992	14.830	22.900	37.600	62.500
T4R2	6.390	14.420	21.250	37.050	64.048
T4R3	6.830	14.350	22.665	38.100	63.850
MEANS	6.404	14.533	22.272	37.583	63.466

Table 2. Average weight (g) per individual fish in cages 1991

Time(Wk)	Stocked				Harvested
	0	2	4	6	8
Trt	June 23	July 7	July 21	August 4	August 18
T1R1	34.400	84.000	141.360	267.143	380.333
T1R2	29.700	88.163	148.540	250.833	379.348
T1R3	35.700	95.455	142.159	279.805	397.561
MEANS	33.133	89.206	144.020	265.927	385.747
T2R1	35.750	66.129	125.800	217.753	359.651
T2R2	36.000	70.707	135.313	233.438	366.875
T2R3	31.500	68.540	130.769	228.409	368.276
MEANS	34.417	68.459	130.627	226.533	364.934
T3R1	29.950	76.667	125.209	218.467	355.839
T3R2	33.500	76.400	129.106	227.192	361.986
T3R3	29.600	73.133	124.870	197.853	353.551
MEANS	31.017	75.400	126.395	214.504	357.125
T4R1	29.960	74.150	119.657	201.069	347.222
T4R2	34.650	72.100	111.842	200.270	346.205
T4R3	34.150	77.989	123.179	207.065	347.011
MEANS	32.920	74.746	118.226	202.801	346.813

Table 3. Weight Gain (kg) per cage per two weeks

Time(Wk)	Stocked 0	2	4	6	Harvested 8
Trt	June 23	July 7	July 21	August 4	August 18
T1R1		2.500	2.010	5.100	4.754
T1R2		2.835	2.810	4.910	5.410
T1R3		2.415	2.055	5.217	4.828
MEANS		2.583	2.292	5.076	4.997
T2R1		2.575	5.550	7.600	11.550
T2R2		3.400	5.990	9.420	12.810
T2R3		3.155	5.595	8.200	11.940
MEANS		3.043	5.712	8.407	12.100
T3R1		6.778	6.635	12.025	18.820
T3R2		6.435	7.906	13.804	19.680
T3R3		6.530	7.635	10.875	22.492
MEANS		6.581	7.392	12.235	20.331
T4R1		8.838	8.087	14.700	24.900
T4R2		7.490	6.830	15.800	26.998
T4R3		7.520	8.315	15.435	25.750
MEANS		7.949	7.744	15.312	25.883

Table 4. Total Number of Fish Each Cage

Time (Wk)	Stocked				Harvested
	0	2	4	6	8
Trt	June 23	July 7	July 21	August 4	August 18
T1R1	50	50	44	42	42
T1R2	50	49	48	48	46
T1R3	50	44	44	41	41
MEANS	50	48	45	44	43
T2R1	100	93	93	89	86
T2R2	100	99	96	96	96
T2R3	100	92	91	88	87
MEANS	100	95	93	91	90
T3R1	150	147	143	137	137
T3R2	150	150	150	146	146
T3R3	150	150	149	149	147
MEANS	150	149	147	144	143
T4R1	200	200	198	187	180
T4R2	200	200	190	185	185
T4R3	200	184	184	184	184
MEANS	200	195	191	185	183

Table 5. Food Intake (kg) per cage per two weeks

Time(Wk)	Stocked				Harvested
	0	2	4	6	8
Trt	June 23	July 7	July 21	August 4	August 18
T1R1	2.380	4.116	4.284	9.424	20.204
T1R2	2.079	4.234	4.991	10.113	21.417
T1R3	2.499	4.116	4.379	9.636	20.630
MEANS	2.319	4.155	4.551	9.724	20.750
T2R1	5.005	6.027	8.190	16.479	35.701
T2R2	5.040	6.860	9.093	18.824	39.817
T2R3	4.830	6.179	8.330	16.884	36.223
MEANS	4.958	6.355	8.538	17.396	37.247
T3R1	6.290	11.045	12.534	25.140	55.008
T3R2	7.035	11.231	13.556	27.859	59.681
T3R3	6.216	10.751	13.024	24.775	54.766
MEANS	6.514	11.009	13.038	25.925	56.485
T4R1	8.389	14.534	16.030	31.584	70.537
T4R2	9.702	14.132	14.875	31.121	69.830
T4R3	9.562	14.063	15.866	32.004	71.495
MEANS	9.218	14.243	15.590	31.570	70.621

Table 6. Cumulative Average Food Conversion Ratio each Time (from start).

Time(Wk)	Stocked				Harvested
	0	2	4	6	8
Trt	June 23	July 7	July 21	August 4	August 18
T1R1		1.280	1.550	1.220	1.460
T1R2		1.240	1.350	1.210	1.420
T1R3		1.230	1.510	1.190	1.440
MEANS		1.250	1.470	1.207	1.440
T2R1		1.650	1.360	1.230	1.300
T2R2		1.540	1.340	1.180	1.290
T2R3		1.531	1.340	1.200	1.280
MEANS		1.574	1.347	1.203	1.290
T3R1		1.170	1.370	1.230	1.270
T3R2		1.210	1.310	1.160	1.260
T3R3		1.240	1.310	1.270	1.190
MEANS		1.207	1.330	1.220	1.240
T4R1		1.260	1.470	1.310	1.300
T4R2		1.260	1.550	1.270	1.220
T4R3		1.510	1.580	1.350	1.300
MEANS		1.343	1.533	1.310	1.273