CAGE CULTURE OF *TILAPIA MOSSAMBICA*

IN A HIGHLAND LAKE OF GUATEMALA

By

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CAGE CULTURE OF TILAPIA MOSSAMBICA

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PREFACE

Objectives of this study were to determine the effect of different feed types, daily feeding rates and stocking densities, as they affect survival, growth, feed conversion and production of fish in cages. Analyses of these findings provide the basis for an economic evaluation of the cage culture of _T. mossambica_ as a subsistence or commercial means for fish production.

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CHAPTER I

INTRODUCTION

In Guatemala, as in much of the developing world, increasing population and a growing demand for a better standard of living are causing public officials much concern. Severe nutritional deficiencies already affect Guatemala which is aggravated by an annual population increase of 3.5% (Table 1) and a decreasing area of arable land per person (Busto Brul 1971). Sixty-five percent of Guatemala's economically active population works in subsistence agriculture and 87% of the number of land-holdings are "micro-farms" of 10 manzanas (6.9 ha) or less (de Leon Schlotter 1970).

In spite of the small size of land-holdings food production has increased in recent years (Table 1), reflecting increases primarily in non-meat products. In Central America, meat supplies have not kept pace with growth and demand of the population. As a result, annual consumption of meat decreased from 18.0 kg/person in 1960 to 16.5 kg/person in 1965 (Vasconcelos 1968), well below the 33 kg/person per year established by Instituto Nutricional de Centro America y Panama (INCAP) as the minimal intake of animal protein. Fish production for domestic consumption is low and reaches only the principal cities (Gonzalez Lopez 1968). While annual fresh fish production in Guatemala increased by 333% from 1966 to 1970, less than 0.5 kg/person was available for consumption (Table 1).

Table 1. Demographic, nutritional and fishery commodity data for Guatemala

Area of country (km^2) (Amaro 1970)	108,889
Population (1972) (UN 1973)	5,410,000
Population density (habitants/km^2) (UN 1973)	49.7
Annual rate of population increase (%) (1960-1972) (UN 1973)	3.5
Surface area of country in farms (%) (de Leon Schlotter 1970)	32.6
Population involved in agriculture (%) (de Leon Schlotter 1970)	65.7
Farms less than 0.69 ha (%) (de Leon Schlotter 1970)	20.4
Farms 6.9 ha or less (%) (de Leon Schlotter 1970)	87.4
Food production indices, per capita (1960-1969) (FAO 1971a. Based on indices average for 1952-56 = 100)	97/116
Net change (1960-1969)	+19
Nutritional deficits (%) (Gonzalez Lopez 1968)	
Calories	20
Fats	51
Protein (crude)	15
Protein (animal origin)	60
Fishery commodities (excluding fish meal, oil, etc.) (FAO 1971b)	
Production of marketed fresh (10^3 kg) (1970)	2.4
% increase since 1966	333
Freezing (mainly shrimp) (10^3 kg) (1970)	2.6
Imported fishery products (10^3 kg) (1970)	0.6

In an effort to resolve the disparity between food supply and food demand of an increasing population, the government of Guatemala initiated a pond-fish culture development and extension program in 1954. This program concentrated mainly on the tiger guapote (Cichlasoma managuense), carp (Cyprinus carpio) and Mozambique mouthbrooder (Tilapia mossambica) (Saavedra P., personal communication)[1]. In 1970 an ambitious government fish culture program was initiated at Zacapa Department (FAO 1970), with an eventual goal to obtain 400 ha of fish ponds in seven departments (Gonzalez Lopez 1968). Expected yield from this program will vary as management schemes, level of managerial expertise and availability of resources change.

Typical world fish yields for static water ponds are reported as follows (White House Report 1967):

	kg/ha per year
Ponds unfertilized	56 - 112
Ponds fertilized	168 - 1,680
Ponds fertilized and waste feed added	2,464 - 5,600
Ponds fertilized and prepared feed added	1,120 - 18,440

Guatemala's 400 ha of ponds might provide an annual net production of 22,400 kg under a management plan without use of supplemental feed or fertilizer, to 7,376,000 kg annual net production under an intensive management program using feed and fertilizer. This projection of production represents a potential increase of 10% to over 300% above 1970's production of marketed fresh fish, a substantial step to make

[1]Mario A. Saavedra P., Chief of Fish Culture Division, General Direction of Natural Renewable Resources, Ministry of Agriculture, Guatemala, C.A.

additional fish available to the people for consumption. Guatemala has already attained a 4,000 kg/ha per year production of carp in experimental ponds with feed and fertilizer (Bardach et al. 1972).

The upper level of production in static water systems using feed and fertilizer is reached when toxic waste metabolites and a large biological oxygen demand commence to inhibit growth and survival. Where there is abundant water, as with large bodies of standing or running water, properly designed raceway and cage culture systems, with high rates of water exchange, can support far greater standing crops than well managed static water pond systems. For example, fish yields in intensive culture systems for trout (Salmo gairdneri) have reached 11,200 - 78,400 kg/ha per year, and carp (Cyprinus carpio) and catfish (Pangasius sp.) up to 1,120,000 kg/ha per year (White House Report 1967). Guatemala abounds in surface water (139,755 ha, total) with eleven natural lakes of over 100 ha each (Lin 1957), numerous smaller lakes, thousands of hectares of estuaries, and many streams and rivers. Such areas offer a potential for expansion of aquaculture in a country where lands suitable for conventional pond-culture are limited because of soil type, terrain and competition with crops and livestock.

This study was designed to determine the biological and economical feasibility of cage-culturing Tilapia mossambica Peters in Lake Atitlán, located in a tropical savanna climate of highland Guatemala, Central America. The overall objective was to provide a supplement to a national aquaculture program which is attempting to augment the protein resources of Guatemala. In a series of experiments lasting 13 months the production of T. mossambica in cages was studied where the variables were daily feeding rates, feed types and stocking densities of different fish sizes.

T. mossambica was selected because it was previously introduced into Lake Atitlán where it has maintained a self-reproducing population, and is in great demand as a food fish in Guatemala. It was introduced to Guatemala from Israel in 1960, and to Lake Atitlán in 1961 (Lin 1963). The species is a native of East Africa and is generally considered as omnivorous (consuming mainly algae and detritus) in its food habits. It grows rapidly, converts food to flesh very efficiently and is resistant to disease (Chimits 1955).

The cage system of culturing fish dates back to the 1800's when this method was used with carp in Asia (Hickling 1962). Cage culture is essentially the raising of fish from fingerlings to marketable size in a container (= cage) whose porous walls allow free circulation of water (Schmittou 1970). The system is more adaptable to diverse levels of a country's economy, because of flexibility in scale of operation and capital investment, than pond or raceway systems. Cage culture is suitable as a segment of a multiple-use program for public lakes and reservoirs, particularly where placement of cages would not conflict with other uses. In recent times cage culture has been practiced in Asia with carp (Hickling 1962, Kuronoma 1968, Shiloh and Shlomoh 1973) and the catfishes Pangasius sutchi and P. lernaudii (Hickling 1962); in Europe with carp (Gribanov et al. 1968); in Central America with the Mozambique mouthbrooder (Tilapia mossambica) (Brown 1972a); and in North America with the channel catfish (Ictalurus punctatus) (Lewis 1969, Schmittou 1970, Collins 1970, Lovell 1973), salmonids (Mahnken et al. 1970, Swingle 1973, Tatum 1973a), striped mullet (Mugil cephalus) (Swingle 1973), pompano (Trachinotus carolinus) (Swingle 1973, Tatum 1973b), bluegill (Lepomis macrochirus) (Heidinger 1971), blue tilapia (Tilapia aurea) (Pagan-Font 1970, Armbrester 1971) and striped bass (Morone saxatilis) (Powell 1973).

CHAPTER II

STUDY AREA

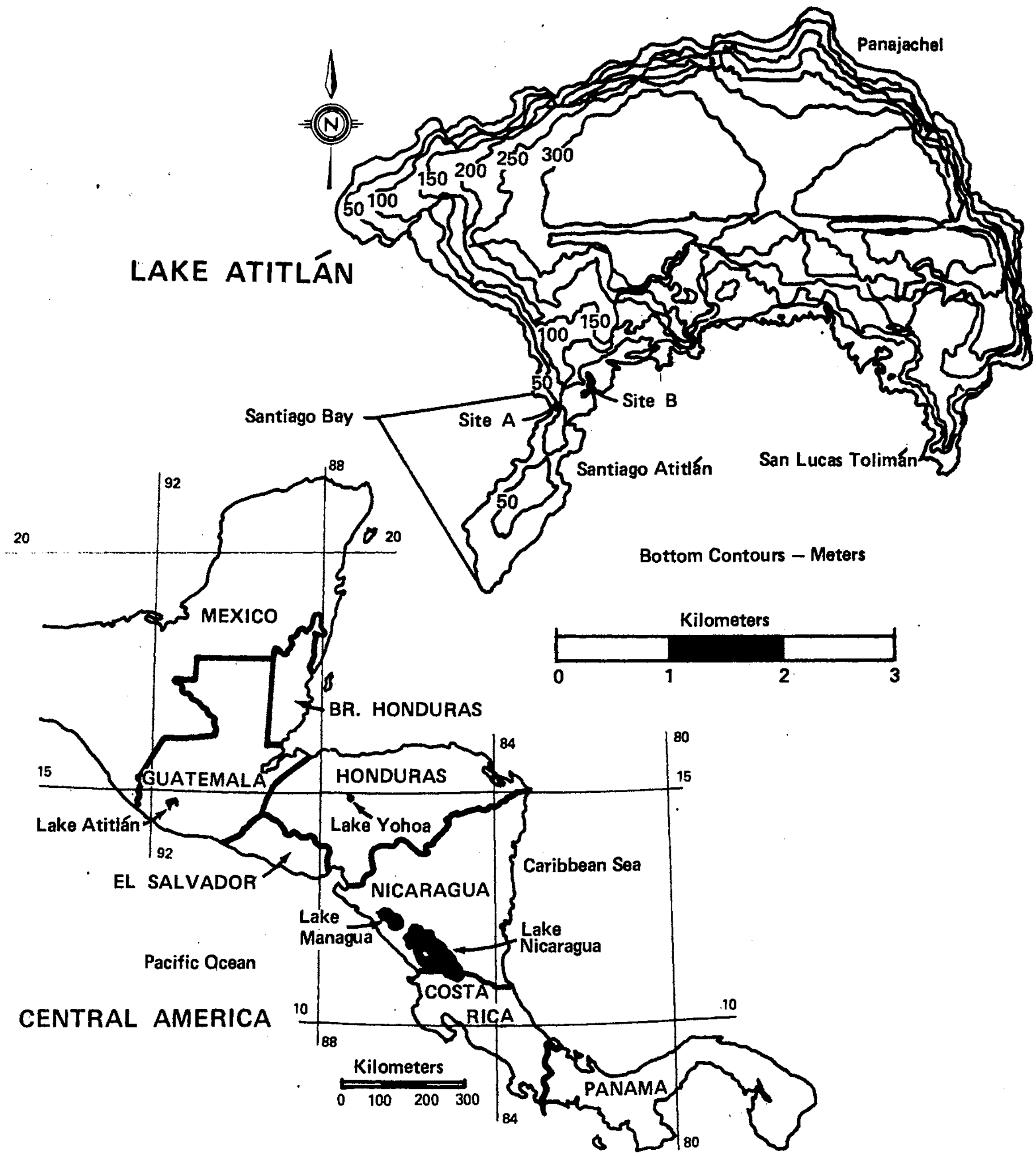
Lake

Cage culture experiments were conducted in Santiago Bay of Lake Atitlán, near the municipality of Santiago Atitlan (Figure 1). The lake basin was formed by a collapse of a highland plateau due to withdrawal of magma by four surrounding volcanos (Atwood 1933). The lake surface has an average altitude of 1,555 m (Williams 1960), surface area 130 km^2, maximum depth 341 m, and average depth 188 m (Weiss 1971).

Climate is characterized as tropical savanna with alternating wet and dry seasons. The wet season begins in April or May and ends in October, with reduced rainfall and frequent cloudiness in July and August. The dry season extends from November to March or April. A typical daily wind cycle begins with a prevailing south-westerly coastal wind called the "Xocomil" by the Indians, blowing strongly from about 0900-1000 until late afternoon, followed by a shift of winds from the north and lasting until early morning (McBryde 1942).

An annual temperature variation of 6.7°C (range, 17.4 - 24.1) was observed (Figure 2). The coolest air temperatures occur in December and January, the warmest in May. Weiss (1971) found the lowest surface water temperature (20.5°C) in Santiago Bay in the period December-March 1969, the highest (23.5°C) in June and July. The lake

Figure 1. Hydrographic map of Lake Atitlán, Guatemala, and geographic and political relationships in Central America. The former (adopted from Weiss 1971) shows bottom contours and cage culture locations (SITE A - Cerro Chutinamit, SITE B - Isla Teachuc)



LAKE ATITLÁN
N
Panajachel
50
100
150
200
250
300
100
150
50
Site B
Site A
Santiago Bay
Santiago Atitlán
San Lucas Tolimán
50
Bottom Contours — Meters
Kilometers
0
1
2
3
CENTRAL AMERICA
MEXICO
BR. HONDURAS
GUATEMALA
HONDURAS
Lake Atitlán
Lake Yohoa
EL SALVADOR
NICARAGUA
Caribbean Sea
Lake Managua
Lake Nicaragua
Pacific Ocean
COSTA RICA
PANAMA
Kilometers
0 100 200 300
92
88
84
80
20
15
10

is well-known for its exceptionally clear water. In February 1969 a Secchi disk measurement taken 2 km north of the entrance to Santiago Bay was 22 m; in Santiago Bay, midway between the experimental culture sites, measurements were 18 m during the dry season in April 1969 and 5 m during the wet season in September 1969. Stratification develops by late March and lasts into December, with a well-defined metalimnion at a depth of 60-120 m (Weiss 1971). Algal photosynthesis occurs to a depth of 70-80 m. Primary production in the hypolimnion was 0.7 g O_2/m^2 per day during 1970-71 (Dorris, personal communication)[2].

People

Santiago Atitlán, like the other twelve towns and villages that border the lake, is classified as a "town nucleus type", where the people live in a reduced part of the municipality, near the public buildings, and go out to their land to work (Tax 1968). According to the 1964 census (Douglas 1968) 95.7% of the inhabitants were Tzutujil Indians, descendants of the Maya civilization, the remaining 4.3% Ladinos of a Spanish and Spanish-Indian heritage. The population has increased from 6749 in 1940 to 9393 in 1964, but still occupying the same municipal area as it did 30 years ago (Douglas 1968). The primary language of the Atitecos (people of Santiago Atitlán) is Tzutujil, spoken by all of the Indians and most of the Ladinos; Spanish is spoken by about 50% of the Tzutujil men, 10% of the women, and by all the Ladinos. The Atitecos are principally vegetarians, as are most of the highland Guatemala Indians, with corn comprising 80% of their diet

[2]Troy C. Dorris, Director, Reservoir Research Center, Oklahoma State University, Stillwater.

(McBryde 1969). The economy is agricultural-commercial, with some artisanal textile production and fishing. Major crops in order of importance are corn, beans, coffee, vegetables and fruits, with some of the products sold to supplement income. Economic pressures within the home permit very few children to obtain an education beyond the sixth grade. Approximately 10% of the town's school-age population was enrolled in the local elementary school in 1964-65 (Douglas 1968). Increasing numbers of Atitecos migrate to the Pacific Coast for seasonal crop plantings. Because of the bilateral patrimony that leads to the continuous subdivision of already small plots of land, the static level of crop production and the rise in cost of living, the Atiteco finds it extremely difficult to maintain an equilibrium between his subsistence needs and his agricultural production, hence, the need for migration. Early (1971) compared the annual death rate of children 0-4 years of age in Santiago Atitlán with those of the same age in 35 rural villages and small towns of Guatemala. One-hundred seventy-two deaths per 1000 inhabitants occurred in Santiago Atitlán for the period 1960-68 as compared to 128 per 1000 inhabitants for the rural villages and small towns in the years 1958-64. Early associated this high death rate in Santiago Atitlán with malnutrition and infectious diseases, which are aspects of a community suffering the first phase of a demographic transition.

Fishery of Lake Atitlán

A thriving food fishery based on the capture by traps or seines of four small native fishes, the pescadito (*Molliensa sphenops*), the pepesca (*Astyanax fasciatus aenus*), the ulumina (*Profundulus punctatus*) and the serica (= convict cichlid) (Cichlasoma nigrofasciatum), and the lake crab (Potamocarcinus guatemalensis) caught on trot-lines, existed in Lake Atitlán until 1958 (Lin 1963). The fishery contributed greatly to the economy of 100-125 fishermen families and the fish constituted an important supplement to the diet of the lake inhabitants (McBryde 1969). The development of a sport fishery and improvement of the food fishery were recommended by Holloway (1950), a fishery investigator. In 1958 and subsequent years the predator fishes tiger guapote, largemouth bass (Micropterus salmoides) and smallmouth bass (Micropterus dolomieui) were introduced, as well as the black crappie (Pomoxis nigromaculatus), bluegill and Mozambique mouthbrooder, for forage food of the predators. Lin (1963) and Douglas (1968) described aspects of largemouth bass growth and effects on the native fish and fishery. By 1960 bass weighing 500 g were plentiful along the shallow marginal zone of the lake. The growth rate was so extraordinary due to a 12-month growing season and a bountiful supply of native forage fishes that in 1960, 27 months after its introduction, bass specimens over 3 kg in size were often caught. In the U.S.A. bass take 7-11 years to reach a weight of 3 kg (Carlander 1953). The small native fishes, serving as the preferred food of the bass, declined in number so that by 1962-63 they were nearly extinct. After diminution of the food supply, the attractive bass sport fishery also declined because fish over 500 g were less abundant. The seine and trap fisheries were abandoned and a reduced trot-line fishery for the crab shifted to deeper waters where bass predation was less pronounced. The decline of the native fishery seriously affected the economy and diet in lake towns dependent on the fishery as their major source of income, and other lake towns, such as Santiago Atitlán, for which the fishery provided a source of supplementary income and food.

The black crappie and bluegill have since established themselves along the lake margin and in bays and have supplanted the native fishes as forage of the largemouth bass (personal observations in 1970-71). The food fishery has also improved as fishermen have adopted the use of hook-and-line and gillnets as new methods for the capture of these introduced fishes.

CHAPTER III

PROCEDURES

Experimental Sites

The cages were located at Cerro Chutinamit in Santiago Bay April-November 1970 and February-May 1971. Because of heavy north winds, the cages were moved to the south side of Isla Teachuc in Santiago Bay (Figure 1) November 1970 to February 1971.

At the Cerro Chutinamit site a single line of cages were oriented in a north-south direction in a small cove. Rock outcroppings to the north and south protected the cages from the daily winds yet allowed the cages to receive exposure to considerable wave action. The bottom of the cages floated 3-4 m above a flat, soft-sediment substrate which was covered by a heavy mat of stonewort (Chara sp.) and patches of pondweed (Potamogeton sp.), and 6-8 m from a bed of emergent bulrush (Scirpus sp.).

The Isla Teachuc site was located in a 100-m wide channel separating two islands. The cages were oriented in a single east-west line, and received strong flushing action by water currents created by either the north or south wind. The cages floated 3 m above a flat, soft-sediment substrate which was covered exclusively by stonewort and 10 m from a bed of bulrush.

Cages

The cage framing, side and bottom screening and cover were made of aluminum. The inside dimensions of the cage[3] were 1.21 x 0.91 x 0.71 m; the submerged volume was 0.78 m^3. Woven meshing, 64 mm square, covered the sides and bottom; an additional layer of fine-mesh plastic screen was placed over the inside of the bottom of the cage to hold sinking pellets. The cage cover was opaque except for a rectangular opening for adding feed. The frame of the opening extended into the cage 150 cm to contain the floating pellets. Six external plastic floats on each end of the cage provided floatation. The cages, separated by 1 m distance, were tethered to cables extending from the shore.

Fish Stock

Young-of-year (YOY) fish were supplied by the Guatemala Ministry of Agriculture, Division of Fauna, from the fish culture stations at Barcenas and Amatitlan. The fish were transported from the fish culture stations to Santiago Bay in oxygenated double plastic bags at 450 g of fingerling fish to 4 liters of water. Time for shipment from the culture station to Santiago Bay varied from four to six hours. Heavy mortalities were incurred in the first two fish shipments. The remainder of the fish were shipped in water containing the antibiotic, oxytetracycline hydrochloride, at the rate of 50 mg active ingredient per liter of water. The treatment effectively reduced mortality. Upon arrival at the cage culture site, the fish were quarantined for

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[3]Manufactured by Triton Industries, Inc., Tuscaloosa, Alabama.

7-10 days before grading and transfer to their respective cages. Mortality during the first seven days of the experiment was attributed to handling and the fish that died during this time period were replaced with healthy fish of the same size.

Feeding

Two types of feed were used: a nutritionally complete trout ration used extensively in the culture of trout in raceways and fish in cages in the USA; the other, a supplementary ration used in the USA in the pond culture of catfish. Compositional analysis of the feed was supplied by the manufacturer (Table 2). The particular feed type and feeding rate employed are indicated in the procedure section of each experiment. The trout ration was an expanded (floating) pellet, with 40% crude protein content. Both catfish rations were sinking pellets; the "grower" formula contained 30% crude protein and the "developer" formula contained 26% crude protein. Feed costs used to calculate the cost per kg of fish gain were based on the purchase price of the feed where it was manufactured. Cost of the bagged trout ration was $0.265/kg at Jackson City, Mississippi. Bagged catfish grower formula cost $0.340/kg, the catfish developer formula cost $0.315/kg in Guatemala City, Guatemala.

Feed was dispensed manually twice daily, at 0800 and 1700. When the fish did not feed, or when feed was left over from the previous feeding, no feed was dispensed until the next feeding time. The uneaten feed was removed by a hand net. If after two consecutive feedings feed was still uneaten the ration was reduced to one-half until feeding reaction was positive and no uneaten feed was found.

Table 2. Percentage composition and ingredients in experimental rations as supplied by the manufacturers

	Trout Developer[a]	Catfish Grower[b]	Catfish Developer[b]
Crude protein, min.	40.0	30.0	26.0
Crude fat, min.	2.5	2.5	2.5
Crude fiber, min.	5.5	7.0	7.0
Ash, max.	13.0	-	-
Added minerals, max.	3.0	-	-

List of ingredients

Trout Developer: fish meal, soybean meal, ground wheat, brewers' dried yeast, ground yellow corn, wheat middlings, dried whey, dicalcium phosphate, iodized salt, vitamin A supplement, ascorbic acid, D-activated animal sterol, menadione sodium bisulfite (source of vitamin K activity), vitamin E supplement, vitamin B_{12} supplement, biotin, choline chloride, folic acid, pyridoxine hydrochloride, thiamine hydrochloride, niacin, calcium pantothenate, riboflavin supplement, copper sulfate, manganous oxide and zinc oxide.

Catfish Grower: fish meal, soybean meal, ground wheat, hulled wheat, meat and bone meal, vitamin K, vitamin B_{12} supplement, riboflavin supplement, methionine, calcium pantothenate, niacin, vitamin E supplement, vitamin A palmitate, D-activated animal sterol, vitamin D_3, salt, traces of manganous oxide, calcium iodate, iron carbonate, copper oxide and zinc oxide.

Catfish Developer: plant protein products, animal protein products, forage products, processed grain by-products, vitamin E supplement, vitamin A palmitate, D-activated animal sterol, riboflavin supplement, calcium pantothenate, menadione sodium bisulfite, vitamin B_{12} supplement, choline chloride, niacin, ground limestone, deflorinated phosphate, salt, traces of manganous oxide, magnesium oxide, iron sulfate, calcium iodate, iron carbonate, copper oxide and zinc oxide.

[a]Trout Chow Developer made by Ralston Purina Co., Jackson, Miss.

[b]Catfish Grower and Catfish Developer, made by Central Soya de Guatemala, Guatemala City, Guat.

The amount of feed given to the fish was either _ad libitum_, in which they were allowed to consume to satiety, or they were fed an amount not to exceed a fixed percentage of the fish biomass in each cage. The fixed percentage was fed unless feeding reaction was poor or non-existent, at which time the feeding rate was reduced as described above. When feeding on the basis of a percentage of their body weight, feed calculations were adjusted weekly, based on bi-weekly weight samples, or on alternate weeks based on a projection of weight gains from the previous two samplings.

Experimental Design

Data Collection and Statistical Analysis

All fish were counted and weighed en masse at the beginning and end of each experiment. Calculations of daily rations were based on bi-weekly counts and measurements en masse of at least 10% of each cage population. Monthly, at least 10% of each cage population was individually measured and weighed to determine average lengths and weights, health and occurrence of parasitism. Feed consumption, feeding reaction, mortality and maximum-minimum water temperatures (at 1 m depth) were recorded daily. Two types of fish mortality were recorded during the experiments: natural, referring to deaths caused by bacterial and parasitic infections, and handling injuries; and poaching and escapement, referring to fish missing at the end of the experiment and known to or assumed to have been lost due to illegal poaching activities or escapement from the cage. Average water temperature during a culture period was determined by averaging the daily temperatures (the mean of the maximum and minimum temperatures). When sampled for lengths and weights, the oral cavity of the fish was examined for the occurrence of eggs or fry.

Water samples were collected from near the cage bottom at the Isla Teachuc and Cerro Chutinamit sites. The following parameters were analyzed: temperature, dissolved oxygen, pH, phenolphthalein and methyl orange alkalinity (both expressed as ppm calcium carbonate), turbidity (expressed as Jackson Turbidity Units, JTU), conductivity, nitrate-N, nitrite-N and total solids. Nineteen additional dissolved oxygen measurements were taken 25 m offshore from the Cerro Chutinamit site during the period 2/5/73 - 5/25/73 (provided by Richard Beatty, Oklahoma State University) (see Appendix A, Table A).

Analysis of variance (AOV) was used to determine equality of beginning-of-experiment variance of the weights and mean weights between treatments. AOV procedure was also used to test difference among treatments for weight gain, net production, food conversion efficiency, cost per kg of weight gain and per cent natural mortality (Snedecor and Cochran 1967:267). Food conversion efficiency was calculated using Swingle's (1959) S conversion value, where

$$S = \frac{\text{kg of feed added}}{\text{kg of fish gain}}$$

A linear regression equation of body weight (g) on total body length (mm) was computed from 512 fish to provide estimates of body weight from total length, using the model: (see Appendix A, Table B)

$\text{Log } \hat{Y} = \text{Log } \hat{\alpha} + \hat{\beta}\text{Log } X$ where:

$\hat{Y}$ = body weight

X = body length

$\hat{\alpha}$ = the Y axis intercept

$\hat{\beta}$ = the regression coefficient

Experiment I - Preliminary Trial

Young-of-year (YOY) fish weighing 7-9 g were stocked in two cages at densities of 442 (567/m^3) and 885 fish (1,135/m^3) per cage (Table 3). There were no replicates. They were fed nutritionally complete trout developer ration during the 88-day culture period from 4-22-70 to 7-18-70.

Experiment II - Daily Feeding Rates

At the end of Experiment I, 300 of the 70-90 g size YOY fish were stocked in each of four cages (Table 5). Two replicate cages were fed at a daily rate of 4% of the cage biomass, and two were fed ad libitum. All fish were fed the trout developer ration. The 89-day experiment lasted from 7-26-70 to 10-22-70.

Experiment III - Feed Types

Experiment III was conducted at the same time as Experiment II, but using fish newly acquired from Guatemala's Ministry of Agriculture. Six cages were each stocked with three hundred 14-20 g YOY fish (Table 7). Two replicate cages were fed the nutritionally complete trout developer ration, two were fed the supplementary catfish grower ration, and two were fed a mixture of 50% trout developer and 50% catfish grower rations. The daily feeding rate was 4% of the biomass of each cage. The experiment lasted 90 days, from 7-30-70 to 10-27-70.

Experiment IV - Density Trial Number 1

Eleven cages were stocked with the following number and size-classes of fish: two cages with 600 large (L) fish each (769/m^3), one cage with 400 L fish (513/m^3), two cages with 600 medium (M) fish each, two cages with 900 small (S) fish each (115/m^3), two cages with 1100 S fish each (1410/m^3) and two cages with 1300 S fish each (1667/m^3) (Table 9). The three size strata of fish used were L fish greater than 200 mm total length, M fish 100-199 mm total length and S fish less than 100 mm total length. The L and M fish were taken from the survivors of Experiments II and III; the S fish were supplied by Guatemala's Ministry of Agriculture. All fish were fed daily on an ad libitum basis. The L fish were fed the catfish developer ration and the M and S fish the catfish grower ration. The L and M fish and the 900 and 1100 S fish were fed for 91 days (11-11-70 to 2-9-71), and the 1300 S fish were fed for 92 days (11-11-70 to 2-10-71).

Experiment V - Density Trial Number 2

The final experiment consisted of six cages stocked with M fish, the survivors of density trial no. 1. Two cages were stocked with 550 fish each (705/m^3), two cages with 1100 fish each (1410/m^3) and two cages with 1650 fish each (2115/m^3) (Table 11). Fish were fed catfish grower daily, on an ad libitum basis. Fish at densities of 1100 and 1650 fish were fed for 62 days (3-19-71 to 5-19-71); the fish at densities of 550 fish were fed for 61 days (3-19-71 to 5-18-71).

CHAPTER IV

RESULTS AND DISCUSSION

Experiment I - Preliminary Trial

When these experiments were being planned no literature on the cage culture of Tilapia species was known to exist. The first experiment of this study was designed to establish baseline data on growth, food conversion, net production and natural mortality of YOY T. mossambica (Table)

Initially, mean weights and variance of the weights between treatments were not significantly different (P>.05). At the conclusion of the experiment fish at the lower density had larger average weights (.02>P>.01). Weight gain (g/fish per day) was slightly greater but food conversion slightly poorer at the lower stocking density (Table 4). At the higher density net production was 1.6 times that in the lower density but not as high as would be expected with twice the stocking density. Costs to produce the fish were similar at $0.276 and $0.244 per kg gain, respectively, for the lower and higher densities. Water temperatures in this period averaged 22.6°C (range, 21.6 to 23.6). All mortality was attributed to natural causes and very low (1.5% or less) at both densities (Table 3).

Shell (1968) obtained food conversion values of 4.1 and 5.6 for T. mossambica in running water tanks fed at the rates of 1% and 4% of

Table 3. Experiment I, an 88-day (4/22/70 - 7/18/70) preliminary culture trial using two stocking densities, and fed trout developer (40% protein) at a rate of 2.2% of cage biomass. Water temperatures averaged 22.6°C (range, 21.6 - 23.6)

Stocking			Harvesting			
Number of fish	Total weight (kg)	Average weight (g)	Number of fish	Total weight (kg)	Average weight (g)	Total mortality (%)
442	3.72	8.4	436	27.33	62.5	1.4
885	6.79	7.7	872	44.83	51.4	1.5

Table 4. Production performance for two stocking densities, 442 and 885 fish per cage

Stocking density (no/cage)	Weight gain		Food conversion	Net production (kg)	Cost per kg gain ($)	Natural mortality (%)
	Average (g)	Daily (g)				
442	54.1	0.61	1.04	23.61	0.276	1.4
885	43.7	0.50	0.92	38.04	0.244	1.5

fish biomass, respectively. He observed a food conversion of 2.5 and a growth rate superior to the other feeding rates when feeding at 2%, indicating that maximum growth and feeding efficiency were reached at a feeding rate slightly above 2%. The 2.2% feeding rate used in this experiment yielded excellent food conversions and growth rates for small T. mossambica, but since Shell's study was not published prior to planning this experiment the choice of a 2.2% feeding rate was fortuitous. The food conversion values of this experiment compare favorably with values of 1.0 average (range, 0.7 to 1.2) reported by Swingle (1968) for 24-120 mm size T. mossambica, T. nilotica, T. aurea and T. melanopleura pond-reared at temperatures above 22°C. Swingle fed a 46% protein feed at the rate of 5% of body weight each day. Kelly (1956) found in Alabama that with 8 g T. mossambica fed a standard trout food at 6% of body weight every other day weight gain averaged 0.66 g/day. Growth of T. mossambica in Experiment I was nearly the same under conditions very similar to Kelly's experiment in which feed, feeding rate and size of fish were similar. Water temperatures in Alabama during Kelly's culture period, however, often range 4-5°C higher than the maximum recorded in Experiment I. This experiment demonstrated that YOY T. mossambica, when stocked at 442 and 885 fish per cage, performed very favorably in feeding efficiency, growth and survival rate, indicating the adaptability of this species to intensive cage culture.

Experiment II - Daily Feeding Rates

The objective of this experiment was to determine production of fingerling T. mossambica in cages when fed a nutritionally complete ration at a fixed (4% of the cage biomass) vs an *ad libitum* feeding rate (Table 5).

At the beginning of the experiment, mean fish weights and variance of the weights between treatments were not significantly different ($P>.05$). Weight gain and net production were not significantly different ($P>.05$) between the two feeding rates. The food conversion was 3.10 for the 4% feeding rate which was significantly higher ($.005>P>.001$) than the food conversion of 1.38 for the *ad libitum* rate (Table 6). Water temperatures averaged 23.1°C, the highest of the series of experiments, and ranged from 21.2 to 24.1°C. Cost per kg of fish gain for the 4% feeding rate was more than double the cost at the ad libitum rate and the difference was highly significant ($.005>P>.001$). Natural mortality was the same and low in both cages. If water temperatures were similar year around, an extrapolation of net production at the *ad libitum* feeding rate shows a yearly production potential of 206.6 kg/m^3.

Cage fish fed nutritionally complete diets at different daily feeding rates generally convert food more efficiently at a lower feeding rate, although growth and production may be adversely affected. In this experiment no loss in weight gain or net production occurred at the lower feeding rate and, as to be expected, food conversion and cost per kg weight gain were much lower than in the 4% feeding rate. Schmittou (1970) found a lower food conversion value of 1.12 when cage-reared channel catfish were fed 2.5% of their body weight daily, and 1.39 when fed at 3.0%; growth was only slightly greater at the higher feeding rate. Armbrester (1972) observed that caged *Tilapia aurea* fed a nutritionally incomplete feed performed poorer in production and

Table 5. Experiment II, an 89-day feeding trail (7/26/70 - 10/22/70), where the fish were fed trout developer (40% protein) at feeding rates of 4% of cage biomass or *ad libitum*. Water temperatures averaged $23.1^{\circ}C$ (range, 21.2 - 24.1)

Feeding rate	Stocking			Harvesting			Mortality (%)	
	Number of fish	Total weight (kg)	Average weight (g)	Number of fish	Total weight (kg)	Average weight (g)	Natural	Poaching and escapement
4%	300	24.48	73.2	292	60.27	206.0	1.0	1.5
ad lib.	300	23.76	79.2	292	63.06	215.8	1.0	0.8

Table 6. Production performance at two daily feeding rates, 4% of cage biomass and *ad libitum*

Feeding rate	Weight gain Average (g)	Weight gain Daily (g)	Food conversion	Net production (kg)	Cost per kg gain ($)	Natural mortality (%)
4%	132.8	1.50	3.10	39.28	0.822	1.0
ad lib.	136.6	1.54	1.38	39.30	0.366	1.0
Analysis of Variance						
F Value	2.068	-	361.997	0.289	360.8	-
Probability	P>.05	-	.005>P>.001	P>.05	.005>P>.001	-
df	1,2	-	1,2	1,2	1,2	-

growth but better in food conversion at 1.5% than at 3% feeding rate. Armbrester reported that production was 151.5 kg/m^3, growth 0.72 g/fish per day, and food donversion at a daily feeding rate of 3.0% per day was 4.47 to 5.17, whereas at 1.5% daily feeding rate production was 142.1 kg/m^3, growth was 0.67 g/fish per day, and the food conversion varied from 2.45 to 4.68. Growth of T. mossambica was 1.54 g/fish per day in the present study. Although this type of growth measurement is difficult to compare because its magnitude will vary with the size of the fish, the observed growth in the present study was for relatively small fish, yet the growth rate was equal to or better than observed by Gomez (1971) for caged T. mossambica, and caged T. aurea by Pagan-Font (1970) and Armbrester (1972). Extrapolated net production for T. Mossambica in the study is far superior to extrapolated net production of Tilapia cultured in cages by Gomez (1971) and Pagan-Font (1970).

It was concluded from this experiment that a daily feeding rate of 4% of the fish biomass was in excess of the metabolic requirements of 72-83 g size T. mossambica when fed a nutritionally complete food. The fish fed at the ad libitum rate consumed an amount of food equivalent to a 2% daily feeding rate, approximately the same feeding rate as in Experiment I where growth and food conversion were excellent. The production results again confirm the adaptability of T. mossambica to the cage system of culturing fish.

Experiment III - Feed Types

This experiment was designed to determine production of fingerling T. mossambica in cages when fed a nutritionally complete trout ration, a supplementary catfish ration or a mixture of the trout and catfish rations (Table 7).

Mean fish weights among treatments were not significantly different ($P>.05$) at the beginning of the experiment. After 90 days, there were no significant differences in weight gains or net production among cages receiving the three feed types (Table 8). Significant differences among the feed types occurred for food conversion ($.05>P>.025$) showing a greater feeding efficiency, and cost per kg of weight gain ($.01>P>.05$), showing a lower cost as the nutritional level of feed was increased. A bacterial disease caused 26.7% mortality in one of the 100% trout ration replicates, resulting in a substantial reduction in mean net production for that treatment. If an adjustment is made for mortality for the trout ration cages, net production increases as the quality of feed increases. Water temperatures were the same as observed in Experiment II since both experiments were conducted at the same time.

Although this experiment indicated that the lowest cost per kg gain in weight occurred for fish fed the trout ration, it is important to consider the substantial difference in costs of identical feed types in Guatemala and the U.S.A. At the time of this study the nutritionally complete trout developer sold in the U.S.A. for considerably less than the nutritionally incomplete catfish rations in Guatemala. In the U.S.A., the same catfish rations were selling for less than the trout ration. This price differential probably resulted from lower costs of feedstuffs and a more competitive, established and high-volume market in the U.S.A. To realistically compare the cost of weight gain among the three feed types in this experiment the cost of

Table 7. Experiment III, a 90-day feeding trial (7/30/70 - 10/27/70), where the fish were fed 100% trout developer (TD) (40% protein), 100% catfish grower (CG) (30% protein) or a mixture of 50% trout developer and 50% catfish grower at a feeding rate of 4% of cage biomass. Water temperatures averaged 23.1°C (range, 21.2 - 24.1)

	Stocking			Harvesting			Mortality (%)	
Feed types	Number of fish	Total weight (kg)	Average weight (g)	Number of fish	Total weight (kg)	Average weight (g)	Natural	Poaching and escapement
100% TD	300	3.52	11.7	250	15.20	60.2	13.4	3.1
50% TD + 50% CG	300	4.42	14.8	276	16.55	59.8	0.2	8.0
100% CG	300	4.81	16.0	294	15.84	53.8	0	1.8

Table 8. Production performance for three feed types, 100% trout developer (TD), 100% catfish grower (CG) and a mixture of 50% trout developer and 50% catfish grower

Treatment	Weight gain Average (g)	Weight gain Daily (g)	Food conversion	Net production	Cost per kg gain ($)	Natural mortality (%)
100% TD	48.4	0.54	2.40	11.68	0.636	13.4
50% TD + 50% CG	45.0	0.50	2.72	12.12	0.823	0.2
100% CG	37.8	0.42	3.63	11.03	1.234	0
<u>Analysis of variance</u>						
F Value	4.62	-	12.86	.046	35.472	0.989
Probability	P>.05	-	.05>P>.025	P>.05	.01>P>.005	P>.05
df	2,3	-	2,3	2,3	2,3	2,3

trout developer was adjusted from $0.265/kg to $0.400/kg, a level which approximates the expected price differential between trout and catfish feeds produced in Guatemala.

After adjustment of the cost of the trout feed, there was no longer a significant advantage in cost of weight gain for the trout feed when compared with the catfish feed ($P>.05$; $F=5.511$; $df=2,3$). The adjusted costs were $1.020, $1.006 and $1.234 per kg gain, respectively, for the 100% trout developer, the 50% trout developer + 50% catfish grower and the 100% catfish grower rations.

Growth rates of fish in Experiments I and III were similar. Fish size was nearly the same in both experiments and average water temperature differed by only 0.5°C. Food conversion and cost of fish gain were much higher in Experiment III, evidently because of the excessive use of feed.

A wide variety of feed types have been used in commercial and experimental catfish culture. Hickling (1962) reported that Pangasius spp. reached a gross production of 164.5 kg/m^3 in Cambodian rivers, utilizing as food sources food scraps, water plants and drift organisms. In Russia, two-year-old carp fed a diet devoid of animal protein gained 750 g in live weight in six months (Gribanov et al. 1968). Lovell (1973) found after feeding different levels of protein to caged channel catfish that a maximum of 35% protein could be recommended if good dietary protein and energy are used. He reported a growth of 3.2 g/fish per day, a food conversion of 1.26 and a cost of $0.141 per kg of fish gain when 35% protein was used. He observed that fishmeal replaced in part by amino acids and plant protein was ineffective when compared to the same level of protein of which 38%

was fishmeal.

Shiloh and Shlomoh (1973) concluded from studies of caged carp that the lowest protein level used (25.7%) was above the critical level where protein becomes limiting, and that weight gain showed a high positive correlation with energy level. They observed that maximum growth (3.9 g/fish per day) occurred at the energy:protein ratio of 118:1 when 325 g carp were fed for 39 days. In Costa Rica, Gomez (1971) reported growth of 1.3 g/fish per day over 250 days for 5 g T. mossambica which were cage-reared in ponds and fed the 30% catfish feed (30% protein) used in this study. Water temperatures in that area of Costa Rica generally range from 23 to 32°C (Brown 1972), considerably higher than temperatures encountered in Lake Atitlán. Armbrester (1972) observed unsatisfactory food conversion ratios (2.45-6.27) for caged T. aurea when using a supplementary pond feed which he described as an incomplete feed, and low food conversions (1.05 and 1.51) when using a trout raceway ration. He observed that caged fish reared in fertilized ponds and not fed artificial feed produced nearly as well as fish fed the incomplete ration, but less than fish fed the trout ration.

When using trout feed with costs adjusted to Guatemala feed prices the results of this experiment show that growth and production costs for caged T. mossambica are comparable to results obtained when a supplementary catfish ration is fed.

Experiment IV - Density Trial Number 1

The objective of this experiment was to determine production of T. mossambica in cages when stocked with small (S), medium (M) and large (L) size fish at different densities. S and M fish were fed the 30% protein ration, and the L fish the 26% catfish ration (Table 9).

Initial mean fish weights within treatments (L=154.4-163.2 g; S=14.5-15.7 g) were not significantly different (P>.05). There was only one cage of M fish. Nonstatistical analyses of L and M treatments were made due to the lack of sufficient fish for two replicates of each treatment.

Weight gain, food conversion, cost per weight gain and mortality were similar between the L-600 and L-400 treatments. Weight gain was 0.46 g/fish per day for both densities; food conversion and cost per kg gain were slightly higher for the lower stocking density (Table 10).

Net production in the higher density L-600 cages was more than double net production of the lower density L-400 treatment. Interpretation of the results are complicated by two interacting factors: 1) L-600 fish were slightly larger (8.8 g) than the L-400 fish at the beginning of the experiment, and 2) 6% mortality attributed to poaching and escapement reduced net production in the L-400 cage to a level lower than would be expected. Food conversion and cost per kg gain were higher in the M cage as a result of the poorer food conversion obtained for the smaller M fish and possibly because of the higher cost of the feed given to M fish. One L-600 cage yielded a standing crop of 127.86 kg (= 163.9 kg/m^3), a net production of 26.51 kg (= 33.99 kg/m^3) during the culture period. Assuming similar water temperatures, extrapolation of net production to a year around basis shows a net production potential of 136.3 kg/m^3 per year.

There were no significant differences among the three densities of S fish for weight gain, food conversion, cost per kg gain or natural

Table 9. Experiment IV, density trial number 1, a 92-day (11/11/70 - 2/10/71) growth comparison of small (S), medium (M) and large (L) fish at different stocking densities. The L fish were fed catfish developer (26% protein) and M and S fish were fed catfish grower (30% protein) at <u>ad libitum</u> feeding rates. Water temperatures averaged 21.1^{o}C (range, 18.6 - 22.5)

	Stocking			Harvesting			Mortality (%)	
Size group	Number of fish	Total weight (kg)	Average weight (g)	Number of fish	Total weight (kg)	Average weight (g)	Natural	Poaching and escapement
L	600	97.90	163.2	598	123.08	206.0	0.4	0
L	400	61.76	154.4	375	73.77	196.7	0.2	6.0
M	600	25.08	41.8	586	38.50	65.7	1.4	1.0
S	900	14.13	15.7	795	27.26	34.2	10.0	0.7
S	1100	15.97	14.5	916	30.08	32.9	5.6	11.1
S	1300	18.98	14.6	1250	41.23	33.0	1.3	2.6

Table 10. Production performance of small (S), medium (M) and large (L) fish at different stocking densities. The AOV is for the difference in performance of the three groups of small fish

Size group-stocking density	Weight gain Average (g)	Daily (g)	Food conversion	Net production (kg)	Cost per kg gain ($)	Natural mortality (%)
L-600	42.8	0.46	4.52	25.18	1.424	0.4
L-400	42.3	0.46	4.66	12.01	1.468	0.2
M-600	23.9	0.26	4.87	13.42	1.656	1.4
S-900	18.5	0.20	7.70	13.02	2.618	10.0
S-1100	18.4	0.20	7.22	14.12	2.455	5.6
S-1300	18.4	0.20	7.20	22.25	2.448	1.3
Analysis of Variance						
F Value	0.039	-	0.705	5.522	.705	1.574
Probability	P>.05	-	P>.05	P>.05	P>.05	P>.05
df	2,3	-	2,3	2,3	2,3	2,3

mortality. The fact that net production in each of the S densities (Table 10) differed only slightly (.10>P>.05) was probably due to high variation in mortality from disease in the S-900 and S-1100 cages, and poaching-escapement in the S-1100 and S-1300 cages. An adjustment of net production values to compensate for these mortalities produces a positive, linear correlation between net production and increasing stocking density.

To produce the maximum economic return from cage culture, an optimum stocking density that produces the largest number of marketable fish must be employed in the most efficient manner (Schmittou 1970). Production efficiency is measured not by maximum weight produced (= maximum standing crop), but rather by the maximum economic return. The latter is a function of the optimum growth rate, food conversion, survival rate, net production per unit of time, feed cost, market demand, and any premium value for specific fish sizes.

Many of the above factors may be affected by stocking density which must then be worked out for each local condition. Under- and over-stocking are detrimental to growth. Under-stocking promotes hierarchy formation and fighting (Lewis 1969), while over-stocking can produce physical interference among fish (Hickling 1962), or a deterioration in water quality, including excretion of growth-inhibiting levels of waste products (Yashouv 1958) and reduction of oxygen to a level that inhibits feeding (Hickling 1962). The negative effects of over-stocking in cages tend to be reduced by the flushing action of natural and fish-induced water currents.

A wide range of stocking density has been reported in the literature for a number of fish species. <u>Pangasius</u> spp. are cultured in cages floating on rivers at stocking rates equivalent to 89-267 fingerlings/m^3 (Hickling 1962), with growth rates of 1.0-1.2 kg in 8-10 months. Vaas and Sachlan (1957) reported that 50-75 kg of *Pangasius* spp. were produced in 2-3 months when stocked at a density of 127-247 fish/m^3 in Cambodian rivers. A stocking density of 55 fish/m^3 is advised for maximum production for carp commercially cultured in cages in large lakes of Japan (Brown 1969). Mean production at this density reaches only 21.1 kg/m^3 per year. Gribanov et al. (1968) reported growth of 4.0 g/fish per day for 40 g carp stocked at 100/m^3 but less (3.2 g/fish per day) for fish stocked at 200 and 250 fish/m^3. Schmittou (1970) studied three stocking densities of caged channel catfish in ponds and found the most efficient food conversion (1.26) at 300 fish/m^3, fastest growth (4.7 g/fish per day) at 400 fish/m^3, and highest production (89.62 kg/m^3) when fish were stocked at 500/m^3, a level at which maximum carrying capacity was apparently not reached. Collins (1971) found that dissolved oxygen in cages located on a large reservoir remained near saturation at all times when stocked with 342 channel catfish/m^3.

Pagan-Font (1970) reported a fairly linear decrease in growth and increase in food conversion efficiency as stocking density of caged *T. aurea* was increased. At the lowest density of 282 fish/m^3 growth was 1.5 g/fish per day and food conversion was 1.2; at the highest density of 847 fish/m^3 growth decreased to 1.0 g/fish per day, and food conversion increased to 1.8. When stocking density was increased by 300%, from 282 to 847 fish/m^3, net production increased by only 200%, from 47.6 to 96.4 kg/m^3, respectively. Gomez (1971) observed that caged *T. mossambica* reared in ponds grew from 5 g to

323 g in 250 days (1.27 g/fish per day) when stocked at 250 fish/m^3.

Growth was very low for all size classes used in Experiment IV and did not compare favorably with growth reported by researchers for caged Tilapia and other cage cultured species, or with the findings of the previous experiments in this study. The range in water temperatures in the present study (18.6-22.5°C) was lower than optimum water temperatures (20-35°C) for growth of T. mossambica (Chimits 1955). The inventory method used in the present study caused an overestimation of the cage populations and feeding rates far in excess of fish demands. Therefore, food conversion values were very high for all treatments, probably because of both low water temperatures and excessive feeding.

An increase in stocking density of L fish from 400 to 600 per cage and S fish from 900 to 1300 per cage caused no reduction in weight gain. Net production showed a positive, linear relationship with stocking density for both L and S fish, indicating that at densities of up to 600 L fish per cage (= 769 fish/m^3) and up to 1650 S fish per cage (= 2115 fish/m^3) carrying capacity of T. mossambica was not exceeded in the present study (Figure 2).

Experiment V - Density Trial Number 2

This experiment was designed to determine production of T. mossambica when stocking medium size fish at different densities (Table 11)

Mean fish weights among treatments at the beginning of the experiment were not significantly different (P>.05). No significant differences (P>.05) among treatments were found in weight gain, food conversion, cost per kg gain and net production (Table 12). Weight

Figure 2. Growth rates (g/fish per day) of small (S), medium (M), and large (L) size classes of *T. mossambica* and average daily water temperatures (°C) during cage culture Experiments I-V (period of 4-22-70 to 5-19-71)

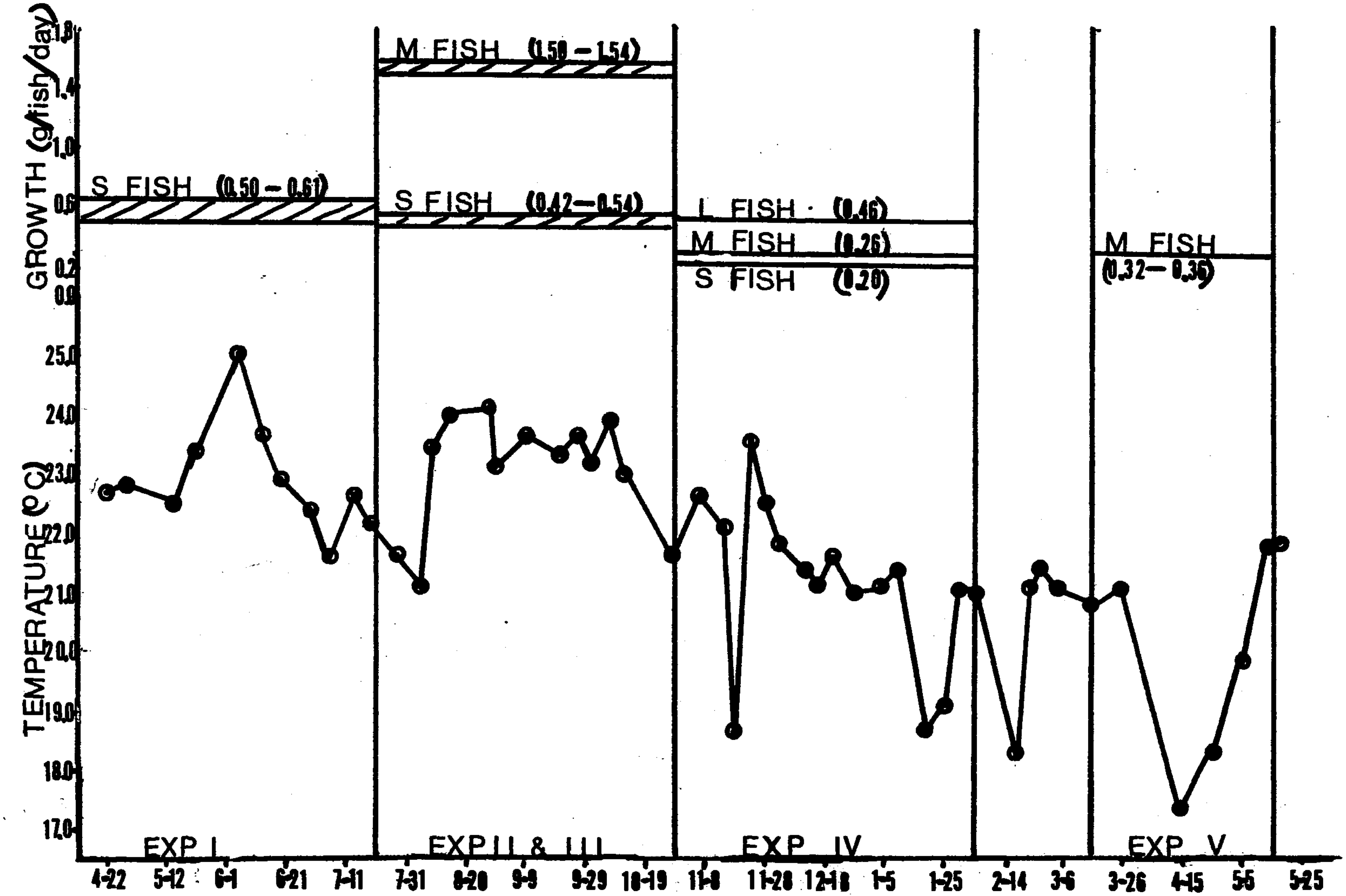
GROWTH (g/fish/day)
TEMPERATURE (°C)
1.8
1.4
1.0
0.6
0.2
0.0
25.0
24.0
23.0
22.0
21.0
20.0
19.0
18.0
17.0
S FISH (0.50 – 0.61)
M FISH (1.50 – 1.54)
S FISH (0.42 – 0.54)
L FISH (0.46)
M FISH (0.26)
S FISH (0.20)
M FISH (0.32 – 0.36)
EXP I
EXP II & III
EXP IV
EXP V
4-22
5-12
6-1
6-21
7-11
7-31
8-20
9-9
9-29
10-19
11-8
11-28
12-18
1-5
1-25
2-14
3-6
3-26
4-15
5-5
5-25

Table 11. Experiment V, density trial number 2, a 62-day growth interval (3/19/71 - 5/19/71), where medium-size fish were stocked at three different densities and fed catfish grower (30% protein) at an *ad libitum* feeding rate. Water temperatures averaged 20.3°C (range, 17.4 - 21.8)

Stocking			Harvesting			Mortality (%)	
Number of fish	Total weight (kg)	Average weight (g)	Number of fish	Total weight (kg)	Average weight (g)	Natural	Poaching and escapement
550	24.76	45.0	479	30.83	64.2	0.6	12.2
1100	41.78	38.0	818	50.10	61.0	0.6	25.0
1650	71.02	43.0	1202	77.70	65.3	4.2	23.0

Table 12. Production performance of M size fish stocked at densities of 550, 1100 and 1650 fish per cage

Stocking density	Weight gain Average (g)	Weight gain Daily (g)	Food conversion	Net production (kg)	Cost per kg gain ($)	Natural mortality (%)
550	19.2	0.32	17.40	6.06	5.916	0.6
1100	23.0	0.38	9.06	8.32	3.080	0.6
1650	22.5	0.36	8.28	6.68	2.815	4.2
<u>Analysis of variance</u>						
F value	0.132	-	3.974	0.040	3.974	14.535
Probability	P>.05	-	P>.05	P>.05	P>.05	.05>P>.025
df	2,3	-	2,3	2,3	2,3	2,3

gains ranged from 0.32 to 0.38 g/fish per day. Poaching losses were serious in all treatments (two replicate cages each), ranging from 12.2 to 23.0%. One of the 1100 cages lost 35.0% and one of the 1650 cages lost 38.1% of their respective populations. Natural mortalities accounted for a 4% loss in both of the 1650 cages and less than 1% loss in each of the lower stocking densities. The high total losses (poaching and natural mortalities) caused low mean net production for all treatments. Comparison of the effects of stocking density on production, after adjustment for weight losses due to mortality, revealed no significant differences. Unusually high food conversions and cost per kg gain for all treatments are probably due to lack of knowledge of poaching losses of individual cage populations and resultant over-feeding. Water temperatures may have influenced growth and food conversion since average temperatures were lower (20.3°C) than in all previous experiments. However, growth of the medium size fish was about 0.1 g/fish per day greater than in Experiment IV, where fish of the same size were cultured in water averaging 0.8°C higher. In contrast, growth in Experiment V was about one-fifth of growth in Experiment II, in which fish of the same size was used and average water temperature was nearly 3°C higher. The difference may have been due to differences in feed quality.

Fish in the 1650 density cages were severely afflicted with a bacterial disease evidently related to social behavior, stocking density and cage construction. Fish in all three stocking densities were observed swimming in a counter-clockwise direction. Fish in the 1650 density cages swam noticeably closer to the cage wall than fish at lower densities. Numerous individuals in the 1650 density had lesions 10-20 mm in diameter on the right anterior portion of the trunk. The lesions, barren of scales and epidermal tissue, appeared to have been caused by the fish scraping the mesh of the cage wall. The majority of dead fish observed in these cages had lesions, and death was probably due to bacterial infections which gained entry into the fish through the lesion.

It can be concluded from Experiment V that stocking cages with 37-49 g size T. mossambica up to a density of 1650 per cage (= 2115 fish/m^3) does not reduce growth. The comparatively reduced rate of growth at all stocking densities, when compared to the same size fish in Experiments III and IV, appears to be related to water temperature which averaged less than 21°C during the culture period. At the stocking density of 2115 fish/m^3 the increased incidence of disease reduced net production in comparison with the other stocking densities used in Experiment V.

CHAPTER V

OBSERVATIONS

Control of Reproduction in Cages

Pagan-Font (1970) stated that the culture of *T. aurea* in cages prevented the reproduction of fry, while with *T. aurea* free-swimming in adjacent waters, up to 448,146 fry per ha were produced. In this set of experiments fry and eggs were found in the mouths of fish from October 1970 to the experiment end in May 1971. Temperatures ranged from 18.6 to 24.1°C. The frequency of occurrence of eggs or fry was 13 out of approximately 45,000 fish examined (0.03%). No fry or eggs were found during Experiments I and II, periods of warmer water, during which fish were 100 g or less in size. No free-swimming offspring were observed in the cage nor were any removed when the cage was harvested. Population increase was apparently controlled within the cage, although there is no certainty that offspring were not produced within the cage and escaped.

Water Quality

Data from water analyses indicate a quality highly suitable for fish culture. Dissolved oxygen levels were very high, ranging upward from a low of 7.3 ppm (83% of saturation). Average oxygen saturation for day and night values was 101.6% (range, 92.0 - 116.2) (Table 13).

Exchange rates of water in the cage were determined at no-wind and

Table 13. Water quality analyses of two cage culture sites.

Parameter	Isla Teachuc 12-13-70	Cerro Chutinamit[a] 5-28-71
Time	1200	1000
Temperature (°C)	22.7	22.3
Dissolved oxygen (ppm)	7.30	-
Oxygen saturation (%)	83	-
pH	8.42	8.42
Alkalinity		
methyl orange (ppm)	12	9
phenolphthalein (ppm)	149	149
Turbidity (JTU)	18	6
Conductivity (umho)	-	528
Nitrate-N (ppm)	0.0	0.03
Nitrite-N (ppm)	0.0	0.003
Solids, total (ppm)	299	-

[a]Nineteen measurements of temperature and dissolved oxygen were made between 2-5-73 and 5-25-73. Temperatures averaged 20.9°C and dissolved oxygen averaged 7.5, oxygen saturation averaged 101.6% (range, 92.0 - 116.2).

moderate-wind conditions. The no-wind determinations were conducted at night, the moderate-wind at mid-morning, when the Xocomil had been blowing for one hour. Exchange rates under no-wind and moderate-wind conditions were equivalent to 0.78 m^3 and 2.34 m^3 of water flow per minute, respectively. Water supplied to cages at such a high turnover rate with near-saturation levels of dissolved oxygen undoubtedly provide optimum conditions for intensive culture of fish. A growth of colonial bryozoans on the cage walls tended to restrict the rate of water exchange if left attached. Weekly brushings of the growth quickly and effectively eliminated this potential problem.

Relationship of Total Length to Weight

The linear regression equation expressing the relationship between total length (mm) and weight (g) for 512 individual fish randomly selected throughout the experiment was:

$$\text{Log } Y = -4.82783 + 3.03109 \text{ Log } X \quad (r = 0.982).$$

From this expression Table 14 was constructed for the prediction of body weight when only total lengths are known.

Table 14. Calculated weights ($\hat{Y}$) from length-weight regression (Log $\hat{Y}$ = -4.82783 + 3.03109 Log X) for 5-mm total length size classes of *Tilapia mossambica*. The regression was based on length (mm) and weight (g) measurements during the cage experiments of 512 fish

Total length	Body weight	Total length	Body weight
75	7.2	180	101.9
80	8.7	185	110.7
85	10.5	190	120.0
90	12.5	195	129.9
95	14.7	200	140.2
100	17.2	205	151.1
105	19.9	210	162.6
110	22.9	215	174.6
115	26.2	220	187.2
120	29.8	225	200.4
125	33.7	230	214.2
130	38.0	235	228.6
135	42.6	240	243.7
140	47.6	245	259.4
145	52.9	250	275.8
150	58.6	255	292.8
155	64.8	260	310.6
160	71.3	265	329.0
165	78.3	270	348.2
170	85.7	275	368.1
175	93.6	-	-

CHAPTER VI

ECONOMIC EVALUATION OF CAGE CULTURING *TILAPIA MOSSAMBICA* IN LAKE ATITLÁN

An evaluation of the economic viability for local commercialization of cage culture of *Tilapia mossambica* in Lake Atitlán was made based on observed growth, feed conversion efficiency and mortality of fish reared under experimental conditions in L. Atitlán, and the use of actual feed and fingerling costs and market value of harvested fish at the time of the study compared with projected costs for feed and fingerlings for the model culture systems. A profit and loss analysis was developed for a farmer-owned, farmer-operated production unit. The economic evaluation is based upon a concept where each farmer would build and operate a 10-cage system that would be financed by a loan at an annual interest rate of 10% to be paid in full at the end of 6 months. Initially, it is assumed that each farmer will harvest and market his own fish locally with no costs calculated for sales or marketing. Large fish markets occur daily at the lake towns of Santiago Atitlán, San Lucas Toliman and Panajachel, and fish wholesalers transport fish daily from these towns to Guatemala City. Yield of each cage is based on observed growth rate and natural mortality of YOY fish cultured in Experiments I and II from April to October 1970, when the highest average water temperatures were observed (Fig. 2). The fish surviving Experiment I were used in Experiment II, hence growth of the same fish was observed over an unbroken 183-day, or 6-month test period. The fish grew from about 10 g at the initial stocking of Experiment I to about 200 g at the end of Experiment II, a net increase of 190 g.

Cage costs are based on actual costs to construct five cages using local wood and galvanized steel wire mesh. Equipment consists of plastic basins, hand-nets, plastic pails and scales. The boat cost consists of a dugout canoe and paddle, both constructed locally. Disease prevention and control are accomplished with acetic acid and salt. All equipment and supply items are made in Guatemala except for the galvanized steel mesh. A mortality of 5% was projected to adequately compensate for disease and handling losses. Fish market prices are based on a market survey conducted by the author in 1971 of selected hotels and seafood restaurants in Panajachel, a tourist center on the north shore of L. Atitlán, and in Guatemala City. *T. mossambica* was regarded by all owners as a choice food fish whose demand was not being filled by any regular supplier in the country. They indicated that a price to the producer of $0.88 - 1.10/kg of whole fish was reasonable.

Three production models are analyzed: model A typifies feed and fingerling prices existent in Guatemala during 1970-71, when this study was conducted; model B employs the same fixed and variable costs except it uses a 50% lower feed cost; model C reduces costs of both feed and fingerlings. Model A illustrates the cost of a system which uses commercially purchased pelleted feed ($0.35/kg) and YOY *T. mossambica* purchased from the Guatemala government ($0.05 each). Model B feed costs are reduced 50% of the cost of feed in model A by assuming that feeds can be mixed locally from low-cost feedstuffs. The fact that T. mossambica will eat a wide variety of feedstuffs, including agricultural by-products, household scraps and aquatic weeds, presents the interesting culture possibility of utilizing low-cost and no-cost feed to nourish the fish in cages. In El Salvador, T. aurea has been successfully cultured in pens and ponds, using a ration containing 30% coffee pulp, and both T. aurea and T. mossambica have grown well in ponds with chicken manure as the only supplementary food (David Bowman, personal communication).[3] To account for the lower nutritive value of this ration and the increased weight of the material if composted, the calculated weight of the feed consumed and the feed conversion values are both double those of model A. Ration cost in model B should easily be reduced to 25%, or $0.088/kg, of ration cost in model A when local materials and preparation are employed.

In model C feed costs are the same as in model B, 50% lower than the feed costs for model A. In addition, the cost of fingerlings in model C is reduced to $0.01 each. Cost of fingerlings in models A and B, $0.05 each, was the Guatemalan government price charged to fish farmers in 1971. Costa Rica and El Salvador had a program providing fingerlings to the fish farmers at no cost. A free fingerling distribution program would obviously reduce costs but the cost for fingerlings may be reduced to about $0.01 each by entry of private enterprise into fish culture. For example, small ponds located in the lower, warmer altitudes between the Pacific Coast and L. Atitlán could pro-

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[3] David Bowman, Fish Culturist, Fish Culture Station, Santa Cruz Porrillo, El Salvador

duce an adequate supply of fingerlings year-around, at virtually no cost for feeding if pond fertilization was used. Another system of fingerling production could be located in L. Atitlán itself. In a preliminary trial in 1971, the author stocked adult T. mossambica in pens in a shallow, protected cove near the Isla Teachuc cage culture site, at the rate of one male and three females per 2.23 m^2 of surface area. Water temperatures were 23.0°C or greater during the trial. Within one week after stocking the males began constructing nests and shortly thereafter eggs were layed, fertilized and fry were observed swimming outside the female's mouth. Cost for construction of the pens was low and cost for feeding the broodfish was insignificant. Normally, several hundred fry can be expected to survive from an adult female. To produce the 5250 fingerlings required to stock the 10-cage rearing system, no more than 22 females and 8 males should be needed as broodfish.

The profit and loss analysis of model A indicates that that type of cage culture system would not have been economically feasible based on purchasing commercially pelleted feed and fingerling rearing stock at prices current in 1970-71. The largest cost items in model A which made it uneconomical are feed and fingerlings. In models B and C, feed and fingerling costs are adjusted to reflect potential modifications which provide a return on investment (23.87% and 79.61%, respectively) of sufficient magnitude to appear attractive as a commercial operation. Models B and C require the local availability of low-cost feed materials of nutritive value to T. mossambica. This feed need not be pelletized nor ground and dried. Some of the feedstuffs, such as coffee pulp, animal manures, paunch manure, aquatic plants, and banana leaves and peels, may be composted and fed in a high-moisture state. Composting, in addition to providing a method of preservation of the materials during storage, increases the nutritional quality and palatability of the original materials. Low-cost materials purchased in a dry form, such as rice polishings, wheat chaff and cottonseed cake, may be moistened just prior to feeding and fed in compact balls. Minerals and vitamins lacking in the rations may be added to the compost or dried feeds as pre-mixes.

The impact of a fish culture enterprise represented in models B and C on the earning capacity of a resident of L. Atitlán would be profound. The substantial profit of $169.56 and $390.06 shown for models B and C (Table 15), respectively, may be derived from an operation that requires the attention of the farmer for less than an average of one hour per day for 6 months each year. This level of income is highly significant in an area like L. Atitlán where wages are often less than $1.00/man-day. Based on the production criteria described in models B and C the intensive culture of T. mossambica provides an attractive method of increasing the earning capacity of residents of L. Atitlán, as well as many other water areas of Guatemala, while producing a source of protein for the people of Guatemala.

Table 15. Three commercial food production models for T. mossambica in Lake Atitlán. All models have in common a 10-cage system stocked with 525 ten g fish/cage and a proposed yield of 500 one-half kg fish/cage: in model A the feed is 26% protein catfish ration (Feed Type I) and all fingerlings are purchased at $0.05 each; in model B feed costs are reduced by 50% (Feed Type II) and fingerlings are purchased at $0.05 each; in model C feed costs are the same as in model B (Feed Type II) and fingerlings are purchased at $0.01 each.

	MODEL A	MODEL B	MODEL C
COSTS			
Fixed			
Cages (10 @ $15.00 each), equipment ($25.00) and boat ($50.00) amortized @ 10% for 5 yrs	$ 59.36	$ 59.36	$ 59.36
Variable			
Fingerlings, 5250 @ $0.05 each	262.50	262.50	-
Fingerlings, 5250 @ $0.01 each	-	-	52.50
Feed, Type I, 1900 kg @ $0.35/kg (food conversion = 2.0)	665.00	-	-
Feed, Type II, 3800 kg @ $0.088/kg (food conversion = 4.0)	-	332.50	332.50
Disease therapy chemicals	10.00	10.00	10.00
Labor			
Daily feeding and observation, 11.25 man-days @ $1.00/man-day	11.25	11.25	11.25
Harvesting, 1.0 man-day @ $1.00/man-day	1.00	1.00	1.00
Total production costs	1009.11	676.61	466.61
Interest (5% of total production costs)	50.46	33.83	23.33
Total costs	1059.57	710.44	489.94
GROSS INCOME			
Total fish sales, 1000 kg @ $0.88/kg (total weight x unit value)	880.00	880.00	880.00
Less total costs	1059.57	710.44	489.94
NET INCOME (gross income less total costs)	-179.57	169.56	390.06
RETURN ON INVESTMENT (net income as a % of total costs)	-16.95	23.87	79.61

CHAPTER VII

SUMMARY

1. This study evaluated the biological and economic feasibility of producing *Tilapia mossambica* in cages in Lake Atitlán.

2. Daily feeding rates of 4% of cage biomass and *ad libitum* were tested. The *ad libitum* rate showed that the fish chose to feed at a rate of 2%, and that growth rate, net production, feed costs and cost per weight gain were superior to the 4% rate.

3. Three different qualities of feed were tested. No difference in weight gain and net production occurred among the three types. After an adjustment for feed cost differential was made on the trout feed, feed conversion and cost per weight gain were not different among the feed types. *T. mossambica* appears capable of utilizing economically a low-quality and low-cost feed ration.

4. Stocking densities ranged from 300 to 1650 fish per cage (384-2115 fish/m^3). The maximum carrying capacity was not exceeded at densities of 163.9 kg/m^3 at a stocking density of 769 large fish per m^3. Increase in stocking densities of small size fish to a maximum of 1667 fish/m^3 caused no adverse effects on growth, food conversion or cost per gain. Net production increased proportionally as stocking density increased at this density. Extrapo-

lation of net production for 769 large fish/m^3 shows a production potential of 136.3 kg/m^3 per year.

5. Maximum growth of 1.50 g/fish per day occurred with 7-9 g fish stocked and fed a complete trout developer ration at 2.2% daily of the cage biomass. Average water temperature during this period averaged 22.6°C.

   The poorest growth of 0.20 g/fish per day occurred with 1 μ - 16 g fish fed 30% protein catfish developer at an _ad libitum_ feeding rate. Average water temperature during this period was low at 21.1°C.

6. Poaching was a major factor in causing low net production in many of the cages. Over-feeding as a result of the lack of knowledge that poaching occurred produced low feed conversion efficiencies and high cost per weight gains.

7. Water analyses demonstrated high quality, ideal for the intensive culture of fish. Dissolved oxygen levels remained near saturation and high water turnover rates caused rapid flushing of metabolic and feed wastes from the cages.

8. Mortality due to disease and handling stress tended to increase as stocking densities increased. The tendency of fish at higher densities to swim in a counter-clockwise direction caused them to lose scales as they scraped the cage walls. Bacterial invasion through these lesions caused eventual death of the affected individuals.

9. Control of reproduction in cages is not complete since a very small occurrence of fry or eggs is found in the brood fish during part of

the year. No offspring were found within the cages during harvest or inspection of cages.

10. The major factor limiting cage culture of T. mossambica in Lake Atitlán appears to be the low water temperatures. Growth in cages on a year around basis is less than in areas where temperatures permitting optimum growth occur. The development of a low-cost, nutritionally adequate diet for T. mossambica in cages would compensate for the feed conversions observed in this study. A cage system culturing T. mossambica to a small, marketable size in the half of the year of warm water temperatures, or a two-species, two-crop system culturing T. mossambica to harvestable size in the warmer half of the year and a cool-water food fish during the cooler half of the year, has promising potential as a means of producing food fish in Lake Atitlán.

LITERATURE CITED

Amaro, N. 1970. Aspectos ecológico-demograficos. Pages 21-43, in N. Amaro (ed.), El reto del desarrollo en Guatemala. Publicaciones IDESAC Diagnósticos, Guatemala.

Armbrester, W., Jr. 1972. The growth of caged *Tilapia aurea* in fertile ponds. Proc. S.E. Assoc. Game and Fish Comm. 25(1971):446-451.

Atwood, W. W. 1933. Lake Atitlán. Bull. Geol. Soc. Amer. 44:661-668.

Bardach, J. E., J. H. Ryther and W. O. McLarney. 1972. Aquaculture. The farming and husbandry of freshwater and marine organisms. Wiley-Interscience, New York. 868 pp.

Brown, E. E. 1969. The fresh water cultured fish industry of Japan. College Agric. Exp. Sta. Res. Rep. No. 41, Univ. of Georgia, Athens. 57 pp.

Brown, R. J. 1972a. Monosex cage culture. A comparison of growth rates of *Tilapia mossambica* males and females. Cantonal Agricultural Center. Turrialba, Costa Rica. 8 pp (mimeo).

__________. 1972b. Temperature profiles from the Zapote pond complex. Cantonal Agricultural Center, Turrialba, Costa Rica. 8 pp (mimeo).

Busto Brul, B. 1971. Project for the establishment of the planning division of the Directorate of Natural Renewable Resources and Natural Resources Development. Pre-feasibility Program 1971-1975. Min. of Agric., Dir. of Nat. Renew. Res., Guatemala City. (mimeo).

Carlander, K. D. 1953. Handbook of freshwater fishery biology with the first supplement. Wm. C. Brown Co., Dubuque, Iowa. 429 pp.

Chimits, P. 1955. Tilapia and its culture. A preliminary bibliography. FAO Fish. Bull. 8(1):1-33.

Collins, R. A. 1970. Culturing catfish in cages. Amer. Fish Farmer 1(3):5-8.

____________. 1971. The effect of cage size upon growth and feed conversion in channel catfish, Ictalurus punctatus (Rafinesque). Paper pres. at 25th Annu. Meet., S.E. Assoc. Game and Fish Comm., Charleston, S. C., Oct. 1971. 7 pp.

de Leon Schlotter, R. 1970. La tenencia de la tierra. Pages 305-336, in N. Amaro (ed.), El reto del desarrollo en Guatemala. Publicaciones IDESAC Diagnósticos, Guatemala.

Douglas, W. G. 1968. Santiago Atitlán. Pages 229-276, in Seminario de Integración Social Guatemalteca (ed.), Los Pueblos del Lago de Atitlán. Tipografía Nacional, Guatemala.

Early, J. D. 1971. Perfil demografico de una comunidad maya. Los atitecos de Santiago Atitlán. Unpublished manuscript, Dep. of Anthropology, Florida Atl. Univ.

FAO. 1970. Guatemala: intensive development of fish production in Zacapa Department. Freedom From Hunger Campaign. 6 pp (mimeo).

___. 1971a. The state of food and agriculture, 1971. FAO of the U.N., Rome. 234 pp.

___. 1971b. Yearbook of fisheries statistics - Vol. 33, fishery commodities, 1971. Dep. Fisheries, FAO of the U.N., New York. 328 pp.

Gómez Torres, E. A. 1971. Informe del experto en piscicultura, Mayo

3-Agosto 3, 1971. Convenio ATN/TF-1005-CR. 15 pp (mimeo).

González López, J. L. 1968. Guatemala. Proyecto de desarrollo de la piscicultura en estanques y estudio de factibilidad económica. Min. of Agric., Div. of Fauna, Guatemala City. 31 pp (mimeo).

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, FAO Fish. Rep. 44(5):218-226.

Heidinger, R. C. 1971. Feeding fish with light. Amer. Fish Farmer 3(1):12-13.

Hickling, C. F. 1962. Fish culture. Faber, London. 292 pp.

Holloway, A. D. 1950. Recommended actions for the development of the fishery resources of Guatemala. Pages 99-140, in U.S. Fish and Wildl. Serv., Spec. Sci. Rep. 5, A Fish and Wildlife Survey of Guatemala.

Kuronuma, K. 1968. New systems and new fishes for culture in the Far East. Proc. World Symposium Warm-water Pond Fish Culture, FAO Fish. Rep. 44(4):123-142.

Lewis, W. M. 1969. Cage culture of channel catfish. Catfish Farmer 1(4):5, 8-9, 35.

Lin, S. Y. 1957. Informe al gobierno de Guatemala sobre el fomento de la pesca continental. Programa Ampliado de Asistencia Técnica. Informe No. 574, FAO, Rome.

________. 1963. Second report to the Government of Guatemala on development of inland fisheries. Based on the work of S. Y. Lin. Rep. FAO/EPTA (1719).

Lovell, R. T. 1973. Protein requirements of cage-cultured channel catfish. Proc. S.E. Assoc. Game and Fish Comm. 26(1972):357-361.

Mahnken, C. V., A. J. Novotny and T. Joiner. 1970. Salmon mariculture potential assessed. Amer. Fish Farmer 2(1):12-15.

McBryde, F. W. 1942. Studies in Guatemalan meteorology. Weather types in southwest Guatemala. Bull. Amer. Met. Soc. 23:400-406.

____________. 1969. Geografía cultural e histórica del suroeste de Guatemala. Tomo I. Seminario de Integración Social Guatemalteca. Tipografía Nacional, Guatemala. 248 pp.

Pagan-Font, F. A. 1970. Cage culture of the cichlid fish Tilapia aurea (Steindachner). Unpublished Ph.D. Diss., Auburn Univ., Auburn, Ala. 109 pp.

Powell, M. R. 1973. Cage and raceway culture of striped bass in brackish water in Alabama. Proc. S.E. Assoc. Game and Fish Comm. 26(1972):345-356.

Schmittou, H. R. 1970. Developments in the culture of channel catfish, Ictalurus punctatus (Rafinesque), in cages suspended in ponds. Proc. S.E. Assoc. Game and Fish Comm. 23(1969):226-244.

Shell, E. W. 1969. Relationship between rate of feeding, rate of growth and rate of conversion in feeding trials with two species of tilapia, Tilapia mossambica Peters and Tilapia nilotica Linnaeus. Proc. World Symposium Warm-water Pond Fish Culture. FAO Fish. Rep. 44(3):411-417.

Shiloh, S. and V. Shlomoh. 1973. Experiments in the nutrition of carp growing in cages. Bamidgeh 25(1):17-31.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical methods. Iowa State Univ. Press, Ames. 593 pp.

Swingle, H. S. 1959. Experiments on growing fingerling channel catfish to marketable size in ponds. Proc. S.E. Assoc. Game and Fish Comm. 12(1958):63-72.

____________. 1969. Estimation of standing crops and rates of feeding fish in ponds. Proc. World Symposium Warm-water Pond Fish Culture. FAO Fish. Rep. 44(3):416-423.

Swingle, W. E. 1973. Alabama's marine cage culture studies. Proc. World Mariculture Soc. 3(1972):75-81.

Tatum, W. M. 1973a. Brackish water cage culture of rainbow trout (Salmo gairdneri) in South Alabama. Trans. Amer. Fish. Soc. 102(4):826-828.

____________. 1973b. Comparative growth, mortality and efficiency of pompano (Trachinotus carolinus) receiving a diet of ground industrial fish with those receiving a diet of trout chow. Proc. World Mariculture Soc. 3(1972):65-74.

Tax, S. 1968. Descripción sumaria de los pueblos. Pages 17-40, in Seminario de Integración Social Guatemalteca (ed.), Los Pueblos del Lago de Atitlán. Tipografía Nacional, Guatemala.

UN. 1973. Monthly bulletin of statistics, May-August, 1973. Vol. 27, No. 8. United Nations, Dep. Econ. and Social Affairs, Statistical Office, New York. 245 pp.

Vasconcelos, L. L. 1968. Perspectivas para la dinamización del desarrollo pesquero en el istmo centroamericano. UN-FAO Proyecto Regional de Desarrollo Pesquero en Centro América. May. 27 pp (mimeo).

Vass, K. R. and M. Sachlan. 1957. Cultivation of common carp in running water in West Java. Proc. Indo-Pacific Fish. Council, 6th

Session (1956), Sections II and III:187-196.

Weiss, C. M. 1971. Water quality investigations. Guatemala. Lake Atitlán 1968-70. ESE Publ. No. 274. Univ. of N. C., Chapel Hill. 175 pp.

White House Report. 1967. The world food problem. President's Science Advisory Committee, Panel on the World Food Supply Problem. Vol. II. 772 pp.

Williams, H. 1960. Volcanic collapse-basins of Lakes Atitlán and Ayarza, Guatemala. Int. Geol. Cong. Copenhagen, 21st Session. Part 21:110-118.

Yashouv, A. 1958. The excreta of carp as a growth-limiting factor. Bamidgeh 10(4).

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