A COMPARISON OF *TILAPIA MOSSAMBICA* (PETERS) AND *TILAPIA AUREA* (STEINDACHNER) AS PONDFISHES IN EL SALVADOR, CENTRAL AMERICA

By

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PREFACE

This study was part of a cooperative fish culture development project. Cooperators were the Dirección General de Recursos Natuales Renovables, Ministerio de Agricultura y Granderia, El Salvador, America Central; United States Agency for International Development; United States Peace Corps/El Salvador, and Oklahoma Cooperative Fishery Research Unit.

I wish to acknowledge the advice and direction given by Dr. Robert C. Summerfelt during the design and execution of the research. I would like to thank Dr. Michael D. Clady, Dr. O. Eugene Maughan, and Dr. Troy C. Dorris for their suggestions and patience while I was writing this thesis and for serving on my committee.

Thanks age given to Dr. A. Kent Andrews and family for their support throughout my graduate program.

Special gratitude is given Sr. Jesús Galileo Palacios Delegado and personnel of the National Fishculture Station of El Salvador who are most responsible for the completion of the research.

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CHAPTER I

INTRODUCTION

Cichlid fishes of the genus *Tilapia*, especially *Tilapia mossambica* (Peters) and *Tilapia aurea* (Steindachner), and its synonym *Tilapia nilotica* Linneaus, are second in importance only to cyprinid carps in worldwide fish culture (Swingle 1960; Bardach et al. 1972). High fecundity and ease of reproduction, low trophic requirements, and high yields are characteristics of tilapia which contribute to their popularity in extensive fish culture.

Biology of Tilapia

Female *T. mossambica* begin spawning at two or three months of age (80 to 90 mm) and continue spawning at intervals of three to nine weeks for as long as water temperature remains above 20^{o}C (Chimits 1955). The initial spawn contains approximately 80 eggs; and 150 mm females produce between 800 and 1,000 eggs. In Israel, *T. aurea* females spawned every four to nine weeks followed by buccal incubation of eight to ten days at 29^{o}C. The mean number of eggs spawned in one season by 17 females was 719 (Dadzie 1970). McBay (1961) found the mean seasonal fecundity of 127, 152, and 178 mm *T. aurea* females to be 160, 261, and 462 eggs, respectively. Spawning began when females reached approximately 90 mm and water temperature reached 24^{o}C.

Tilapia mossambica and *T. aurea* feed upon phytoplankton, detritus, microcrustaceans, non-benthic insects, benthic macroinvertebrates, filamentous algae, terrestrial grasses, and pelleted feed (Dendy et al. 1968; Chimits 1957; Hickling 1961; McBay 1961) and have digestive systems typical of fishes with low trophic level food requirements. These adaptations include a bulbous enlargement at the anterior end of the digestive tract, a long, much coiled and very thin intestine, and relatively large pharyngeal pads. These pads are arranged to provide 360^{o} surface contact between food items and the small, hard and densely packed teeth.

Tilapia as Pond Fishes

Tilapia efficiently convert fish food resources to fish flesh. Kelly (1957) showed T. mossambica to be more productive than Lepomis macrochirus whereas both T. mossambica and T. aurea were equally productive as Ictalurus punctatus and more productive than Cyprinus carpio and Ictalurus nebulosus marmoratus (Swingle 1960).

Large amounts of tilapia can be produced in limited areas. Chimits (1957) reported production of T. mossambica was 4,930 kg/ha in sewage ponds in Indonesia. T. aurea produced 6,872 kg/ha/yr (Swingle 1960) when fed pelleted fish food in Alabama ponds.

Problem of Over-Reproduction by Tilapia

High total yield, however, does not signify unqualified success for tilapia in fish culture. For example, of 6,872 kg/ha/yr of T. aurea reported by Swingle (1960), only 21.6% of the quantity removed was of harvestable, or usable, size (150 mm or larger). Likewise, Pongsuwana (1956) reported a yield of 10,965 kg tilapia per hectare per year in a Thai pond receiving very heavy feeding and fertilization, but only 30.3% of the fish were of harvestable size.

Several methods of controlling tilapia reproduction and thereby increasing the number of harvestable-size fish have been devised (Bardach et al. 1972). The use of piscivorous fishes appears to be the most successful means of controlling tilapia reproduction, especially where technology and facilities necessary for proper implementation of complex control methods do not exist. Various predaceous species are commonly used. In Uganda *Lates niloticus* controlled tilapia numbers when stocked at a ratio of 1:30; unfortunately, the piscivore did not reproduce (Semakula and Makoro 1968). In other countries other predatory species have been used in: the Cameroons and Congro *Hemichromis fasciatus*, in Nigeria *Lates niloticus*, and in Madagascar *Micropterus salmoides*. Unfortunately, these species were not always satisfactory as a predator (Meschat 1968; Lemasson and Bard 1968; Huet 1968). However, in Ghana *Lates niloticus* and *Hydrocyon brevis* and *Hydrocyon forskali* stocked in tilapia ponds were very useful in population control of tilapia (Denyoh 1968). In Asia, *Ophicephalus* spp. and *Clarias* spp. reduced the number of tilapia young and allowed brood tilapia to grow to harvestable sizes (Chimits 1957). In El Salvador, three hundred *Cichlasoma managüense* stocked into a 0.1060 ha pond and averaging 165 mm and 95 g also controlled reproduction of 100 *T. mossambica* averaging 120 mm and 35 g (Hines 1970).

Origin of the Present Study

The government of El Salvador, Central America, implemented a national fish culture development program in October, 1970 to increase consumption of fish and reduce protein imports. The research described here was part of an experimental project designed to provide the technical basis for fish culture extension. Objectives of the experimentation were: 1) production of individual tilapia of harvestable size, 140 mm and larger; 2) maximization of yields of harvestable tilapia in fertilized ponds; and 3) determination of whether *Tilapia aurea* of *Tilapia mossambica* consistently produces the higher yields of consistently produces the higher yields of harvestable fish in El Salvador.

CHAPTER II

METHODS AND MATERIALS

Ponds for the study were provided by the National Fish Culture Station of El Salvador. These ponds were built in 1957-58 by the Ministry of Agriculture under the supervision of FAO/UN expert S. Y. Lin. The station consisted of 15 earthen ponds ranging in size from 0.1060 ha to 1.5 ha (Fig. 1).

Preparation of Ponds

Prior to implementation of the research program, all ponds were excavated by bulldozer to original drain depth, approximately 1.5 m, and surveyed to determine exact surface area when filled to maximum depth. Before stocking the pond was drained, allowed to dry, and prepared by leveling the bottom to eliminate depressions. Soil which had slipped from pond banks and soil accumulated on the bottom by settling from topping-up water and from fertilizing with chicken manure was removed and either packed into eroded parts of the bank or put on the pond crown. Immediately before filling the pond 60 kg NH_4SO_4/ha was applied to the bottom.

Pond Water Supply

The pond water supply was taken from an earthen canal originating approximately three kilometers from the Fish Culture Station at Rio San

Antonio. The canal was designed for flood irrigation and local women used the canal for laundry and other domestic purposes. The drainage basin of Rio San Antonio is agricultural land planted to corn, beans, cotton, sugar cane, and at the headwaters, coffee. Several small villages are interspersed among the crop fields and domestic wastes are washed into the river during seasonal heavy rains. During wet months (June through October) the river is subject to high flows and carries a heavy sediment load. The canal water probably contained relatively high concentrations of nutrients, especially nitrogen, because of these uses.

Applications of Fertilizer

No commercial fish feed was available in El Salvador but two types of fertilizers, chemical formulations and various organic materials, were available. Broiler chicken house cleanings (CM), consisting mostly of chicken manure with some grain husks and dirt, were readily available and had been previously used at the Fish Culture Station. Also, two one-hundred-kilogram bags of triple superphosphate (TSP), 0-46-0 (N-P-K), were donated by a large agricultural supply company.

The fertilizers were applied in the following manner: chicken manure was weighed to the nearest 50 gm and applied by broadcasting the fertilizer across the pond surface. Triple superphosphate was weighed to the nearest gram, placed in a bag made from plastic mosquito screen, and suspended at the surface in the center of the pond. Wave action slowly dissolved and mixed the fertilizer.

Criteria for Comparison of *T. aurea* and *T. mossambica*

Growth of tilapia was monitored at monthly intervals. Time required to reach harvestable size, i.e., 140 mm, was used to determine the length of the growing season for Salvadoreño fish culture operations. Maximization of yields of harvestable tilapia was accomplished by controlling tilapia reproduction. *Tilapia mossambica* and *Tilapia aurea* were compared on the bases of: 1) net yield of fish per hectare, i.e., kilograms harvested less kilograms stocked; 2) yield of harvestable fish per hectare, and 3) mean individual weight of harvestable fish. Net yield of fish/ha and yield of harvestable fish/ha were extrapolated to an annual basis, i.e., kg/ha/yr.

Experimental Design

Five experiments were designed and conducted to provide data used in meeting research objectives (Table 1). Treatments by species were: 1) ponds stocked and fertilized with CM at a standard density and rate (Experiment 1); 2) ponds stocked and fertilized with TSP at a standard density and rate (Experiment 2); 3) ponds stocked at the standard density and unfertilized (the control Experiment 5); and 4) ponds stocked at a non-standard density with equal numbers of tilapia and *Cichlasoma managüense* and fertilized with CM at a non-standard rate (Experiment 4). A fifth treatment (Experiment 3) consisted of both tilapias together, each at one-half the standard density, in ponds fertilized with TSP at the standard rate.

Table 1. Types and rates of fertilizer application and stocking density per species, listed by experiment.

Experiment number	Replicates per *Tilapia* species	Species	Fertilizer and rate applied	Stocking density fish/ha
1	3	*T. mossambica*	Chicken manure @ 9.35 kg/ha/da x	2,062
		T. aurea	90 days + 18.7 kg/ha/da x remainder	2,062
2	3	*T. mossambica*	Triple superphosphate	2,062
		T. aurea	@ 12 kg/ha/30 da x 4	2,062
3	3	*T. mossambica* + *T. aurea*	Triple superphosphate @ 12 kg/ha/30 day x 4	1,031 + 1,031
4	3	*T. mossambica* + *C. managuense*	Chicken manure @ 192.3 kg/ha/we x 13 + 384.6 kg/ha/wk x 4	6,115 + 6,115
		T. aurea + *C. managuense*	Same	6,115 + 6,115
5	3	*T. mossambica* *T. aurea*	None	2,062 + 2,062

Description of Experiments

Experiment 1: *Tilapia aurea* averaging 99 mm and 13 g and *T. mossambica* averaging 81 mm and 15 g were stocked by species in three ponds per species at a density of 2,062 fish/ha. Chicken manure was applied at the rate of 9.35 kg/ha/da for the first 90 days and 18.7 kg/ha/da for the remainder of the experiment.

Experiment 2: *Tilapia aurea* averaging 91 mm and 13 g and *T. mossambica* averaging 76 mm and 9 g were stocked in three ponds per species at a density of 2,062 fish/ha. Triple superphosphate was applied at twelve kg phosphorous per ha per 30-day interval on days 1, 30, 60, and 90.

Experiment 3: *Tilapia aurea* averaging 89 mm and 15 g and *T. mossambica* averaging 102 mm and 16 g were stocked together and in equal numbers in three ponds fertilized with TSP. The stocking density of each species was 1,031 fish/ha. Twelve kg P/ha/30 days was applied on days 1, 30, 60, and 90.

Experiment 4: Equal numbers of *T. aurea* averaging 96 mm and 16 g and *Cichlasoma managüense* averaging 111 mm and 24 g were stocked in three ponds. Chicken manure was applied at the rate of 192.3 kg/ha/wk of weeks 1 through 13 and 384.6 kg/ha/wk each of the remaining 4 weeks. Each species was stocked at the density of 6,115 fish/ha.

Experiment 5: *T. aurea* averaging 86 mm and 13 g and *T. mossambica* averaging 95 mm and 16 g were each stocked in three ponds receiving no fertilization. Stocking density of each species was 2,062 fish/ha.

Replicates of Experiments 3, 4, and 5 were conducted for approximately 120 days. Four replicates of Experiment 1 were of approximately

180 days duration, one replicate of approximately 150 days, and one replicate for approximately 120 days (Table 2).

Sampling and Harvesting

Ten percent of all fingerlings stocked were individually weighed to the nearest gram on a Hanson Model 1440 Dietic Scale and total length (TL) measured to the nearest 5 mm increment. The remainder of fish stocked were weighed *en masse*. At thirty-day intervals after stocking, ponds were seined and what were assumed to be originally stocked fish were individually weighed and measured. The assumption as to whether or not a fish was original stock was based upon the experience of Station personnel, and no fish smaller than the smallest fish of the previous month's sample was measured. Minimum sample size was ten percent of the number stocked.

Ponds were harvested by simultaneously lowering the water level and passing a 6.35 mm mesh, 1.83 m x 45.73 m bag seine through the pond until it was completely drained and all fish removed. From each seine-haul 25 fish were randomly removed and individually weighed and measured (TL). Additionally, all fish 140 mm and larger were individually weighed and measured (TL). The remainder of fish smaller than 140 mm in each seine-haul was weighed *en masse*.

Student's *t*, calculated according to the procedure of Steel and Torrie (1960), was used to test for significance of differences of individual length and weight and yields between species.

The first two replicates of Experiment 1 in Ponds 2 and 3 were initiated while all other ponds were undergoing complete renovation. In addition to establishing the growing period to be used in future

Table 2. Species of tilapia stocked, surface areas of ponds, and duration of replicates, listed by experiment.

Experiment number	Replicate number	Species	Pond Number	Pond Surface area ha	Date Stocked	Date Harvested	Duration days
1	1	*T. aurea*	2	0.2573	12- 3-70	6- 4-71	182
	2	*T. aurea*	3	0.2423	12- 3-70	6- 3-71	181
	3	*T. mossambica*	5	0.1080	3- 1-72	8-28-72	179
	4	*T. mossambica*	12	0.1750	3-25-72	9-22-72	180
	5	*T. aurea*	2	0.2573	7-15-72	11-13-72	120
	6	*T. mossambica*	13	0.1650	8-12-72	1- 8-73	149
2	1	*T. aurea*	6	0.1515	11- 8-71	3- 7-72	118
	2	*T. aurea*	11	0.1620	11- 4-71	3- 3-72	118
	3	*T. aurea*	13	0.1650	11-17-71	3-16-72	118
	4	*T. mossambica*	13	0.1650	3-25-72	7-28-72	124
	5	*T. mossambica*	11	0.1620	3-25-72	7-24-72	120
	6	*T. mossambica*	6	0.1616	3-27-72	7-26-72	120
3	1	*T. aurea* + *T. mossambica*	10	0.1060	11- 1-71	3- 1-72	119
	2	*T. aurea* + *T. mossambica*	12	0.1750	11- 9-71	3- 8-72	118
	3	*T. aurea* + *T. mossambica*	14	0.2113	12- 7-71	4- 5-72	118

Table 2. Continued.

Experiment number	Replicate number	Species	Pond Number	Pond Surface area ha	Date Stocked	Date Harvested	Duration days
4	1	+ *T. mossambica* *C. managüense*	11	0.1620	6-21-71	10-20-71	121
	2	+ *T. aurea* *C. managüense*	12	0.1750	6-25-71	10-22-71	118
	3	+ *T. aurea* *C. managüense*	13	0.1650	6-30-71	10-28-71	119
	4	+ *T. mossambica* *C. managüense*	14	0.2113	7-23-71	11-20-71	119
	5	+ *T. aurea* *C. managüense*	14	0.2113	4-18-72	8-23-72	125
	6	+ *T. mossambica* *C. managüense*	11	0.1620	8-16-72	12-14-72	119
5	1	*T. aurea*	4	0.2415	12-21-71	4-17-72	117
	2	*T. mossambica*	15	0.2323	1-19-72	5-18-72	118
	3	*T. mossambica*	2	0.2573	3- 3-72	7- 6-72	123
	4	*T. aurea*	3	0.2423	3- 4-72	7- 3-72	120
	5	*T. mossambica*	4	0.2415	5- 3-72	9- 1-72	120
	6	*T. aurea*	15	0.2323	5-30-72	9-28-72	119

experiments, those two replicates demonstrated to the Ministry of Agriculture that fish could be produced in quantities comparable to other livestock, established my credentials as a fish culturist, trained Station personnel (and myself) in methods and techniques to be used in all research-related activities, and provided fish culture extensionists with rudimentary information on stocking, fertilizing, and harvesting Salvadoreño tilapia ponds.

The degrees of success and failure associated with the various objectives of those first two replicates influenced all subsequent research. For example, the failure of tilapia fingerlings to retain clips on the soft-rayed portion of their dorsal fin for a month precluded positive identification of originally stocked fish. The successful grasping of the concept of a random sample (as I conceived it) by the Station personnel also made subsequent monthly and harvest samples consistent and representative.

Two forms of bias impinge upon all experiments. Even though Ponds 2, 3, 4, and 14 and 15 supposedly were constructed with equal surface areas, surveying disclosed no two ponds were of equal area. Because of the immediate need for information by extensionists and the limited number of ponds, preliminary information was obtained by initially stocking less than three replicates simultaneously. As ponds became available replicates required to complete the standard three tests per species per experiment were stocked. Data from all replicates per experiment were pooled by species in an effort to reduce effects of these two forms of bias.

A routine practice during these experiments was to note any details relating to condition or appearance of the fish. For example, physical deformation such as a curved spinal column, atrophied fins, blindness or occurrence of eggs or fry in the mouth of a female were recorded during sampling and harvest.

CHAPTER III

RESULTS

Growth

With the exceptions of Experiments 1 and 4 growth of originally stocked fish stopped during the last month of each experiment (Figures 2-5) (Table 3). *Tilapia aurea* in Experiment 1 continued to grow at an average daily rate of 1.02 g/da until the end of the experiment; *T. mossambica* grew at an average daily rate of 0.58 g/da during the first 150 days and at -0.58 g/da during the final 30-day interval. In Experiment 2 *T. aurea* grew at 1.31 g/da for 90 days and -0.25 g/da the remaining 28 days; *T. mossambica* grew at 0.72 g/da until the end of the experiment. *T. aurea* grew an average of 0.91 g/da during the first 90 days of Experiment 3 and -0.17 g/da the last 28 days; *T. mossambica* grew at 0.46 g/da for 90 days, but then its growth declined to -0.33 g/da the last 28 days. In Experiment 4 *T. aurea* grew an average of 0.76 g/da and *T. mossambica* grew 0.75 g/da until the end of the experiment. *T. aurea* in Experiment 5 grew at 0.95 g/da until the 90th day, then growth dropped to -0.30 g/da during the remaining 29 days. *T. mossambica* grew 0.77 g/da the first 90 days, then its growth also fell to -0.30 g/da during the last 30 days.

Figure 1. Fishponds of the National Fishculture Station of El Salvador, Central America.

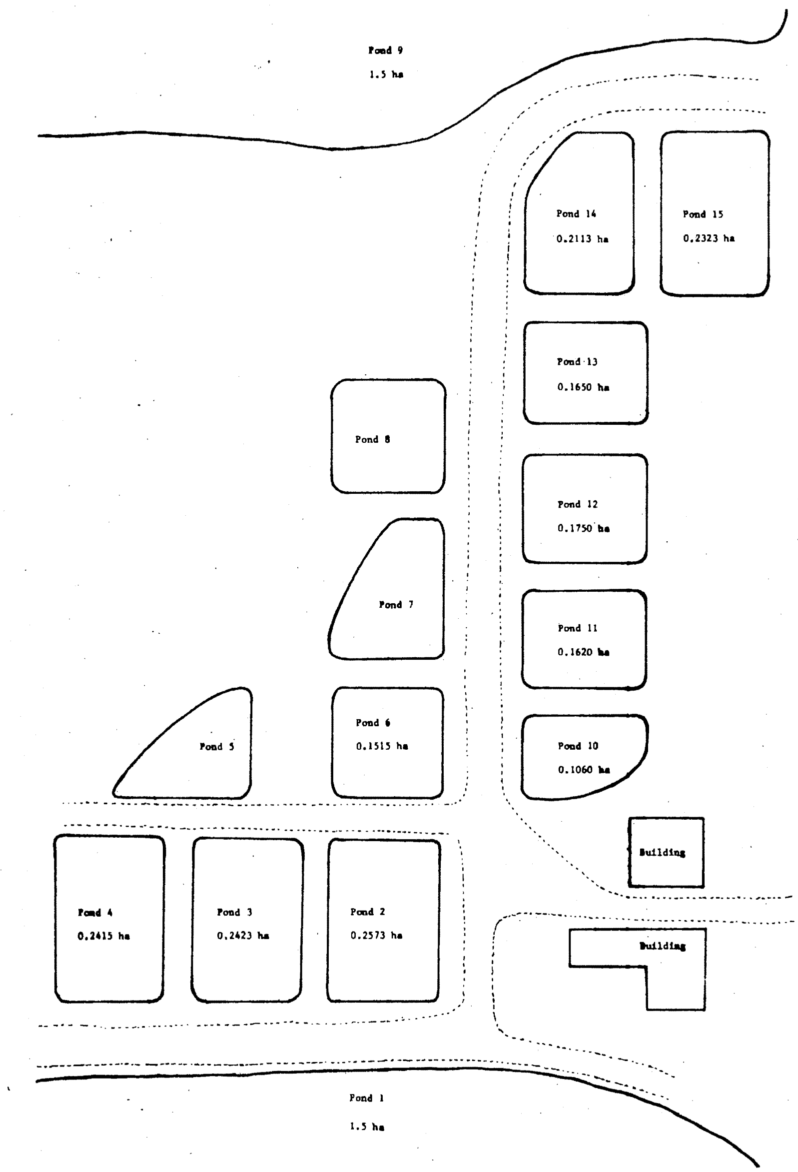

Pond 9
1.5 ha
Pond 14
0.2113 ha
Pond 15
0.2323 ha
Pond 13
0.1650 ha
Pond 8
Pond 12
0.1750 ha
Pond 7
Pond 11
0.1620 ha
Pond 5
Pond 6
0.1515 ha
Pond 10
0.1060 ha
Building
Pond 4
0.2415 ha
Pond 3
0.2423 ha
Pond 2
0.2573 ha
Building
Pond 1
1.5 ha

Figure 2. Growth of tilapia stocked in ponds fertilized with chicken manure.

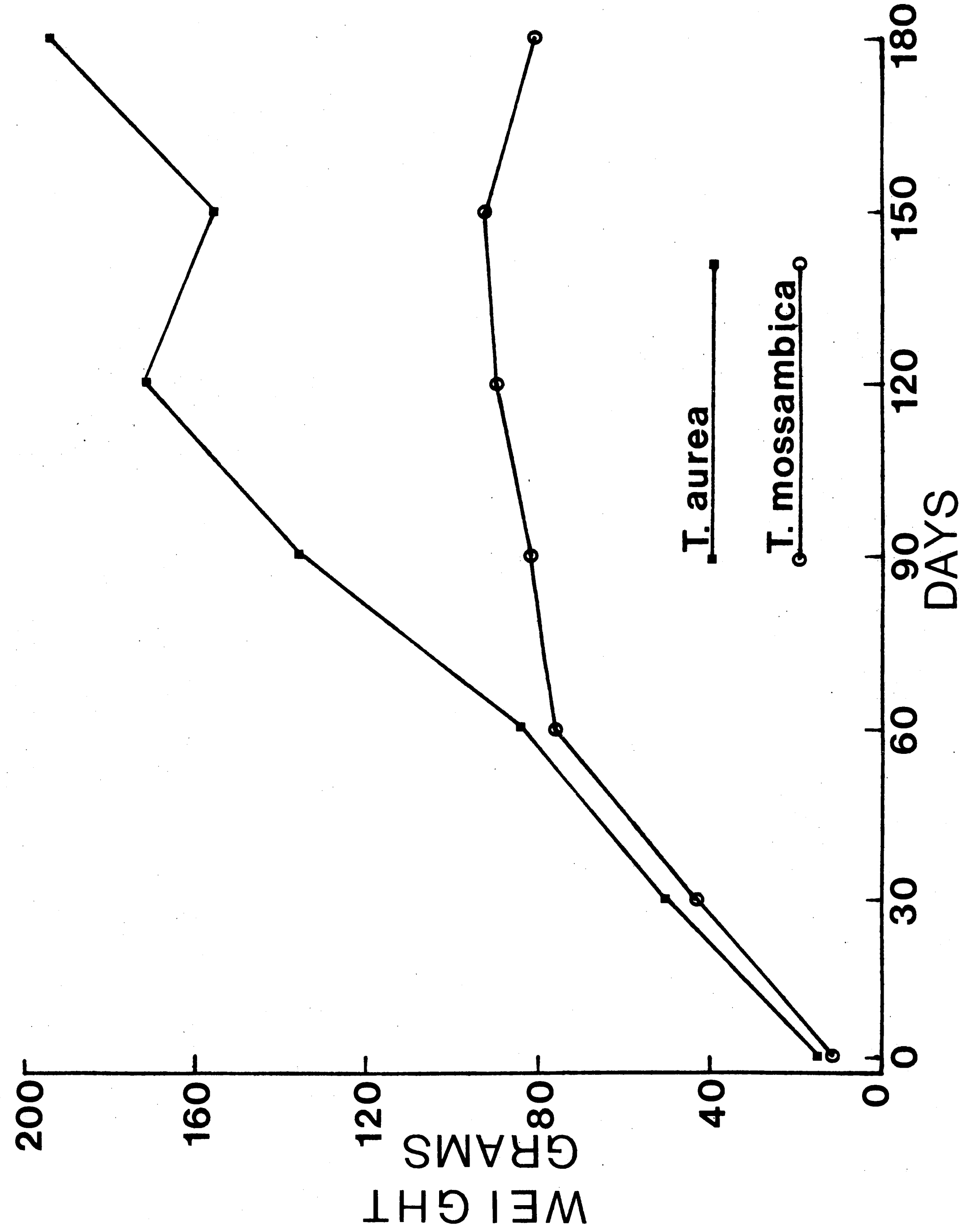

WEIGHT
GRAMS
200
160
120
80
40
0
0
30
60
90
120
150
180
DAYS
T. aurea
T. mossambica

Figure 3. Growth of tilapia stocked in ponds fertilized with triple superphosphate (0-46-0).

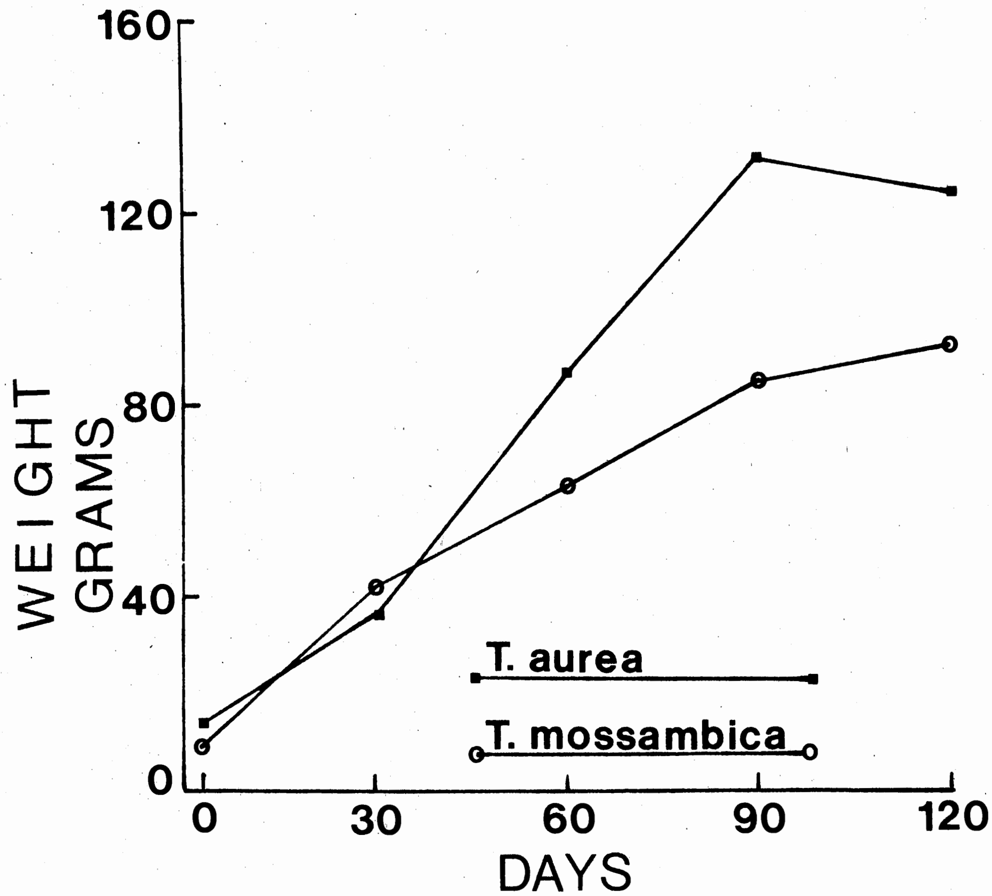

160
120
80
40
0
WEIGHT GRAMS
T. aurea
T. mossambica
0
30
60
90
120
DAYS

Figure 4. Growth of tilapia stocked together in ponds fertilized with triple superphosphate (0-46-0).

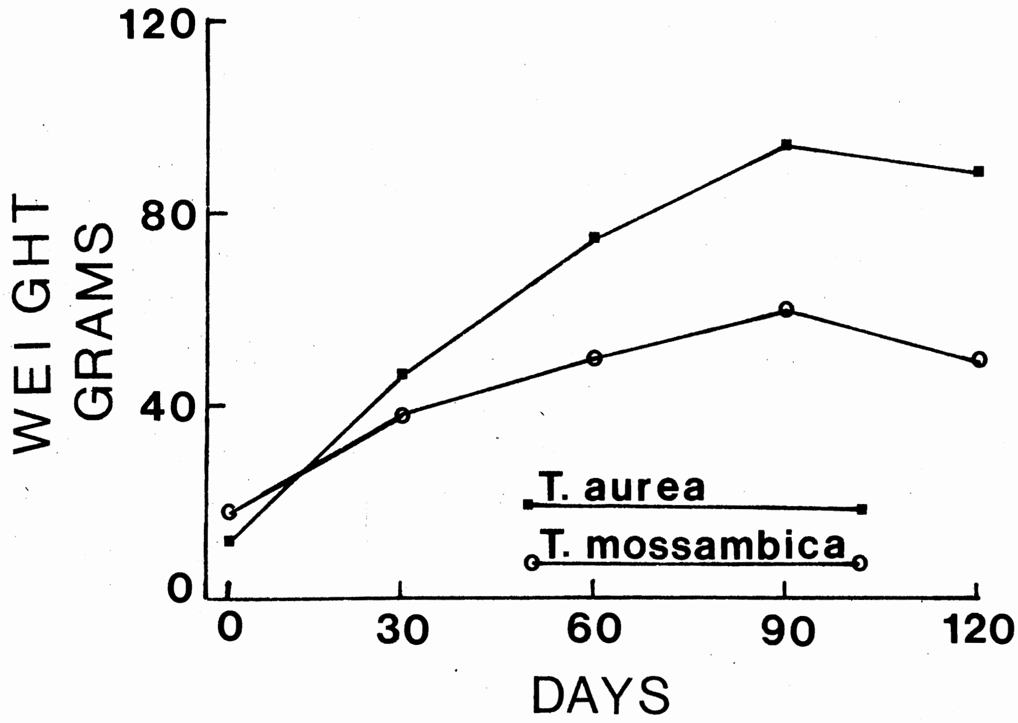
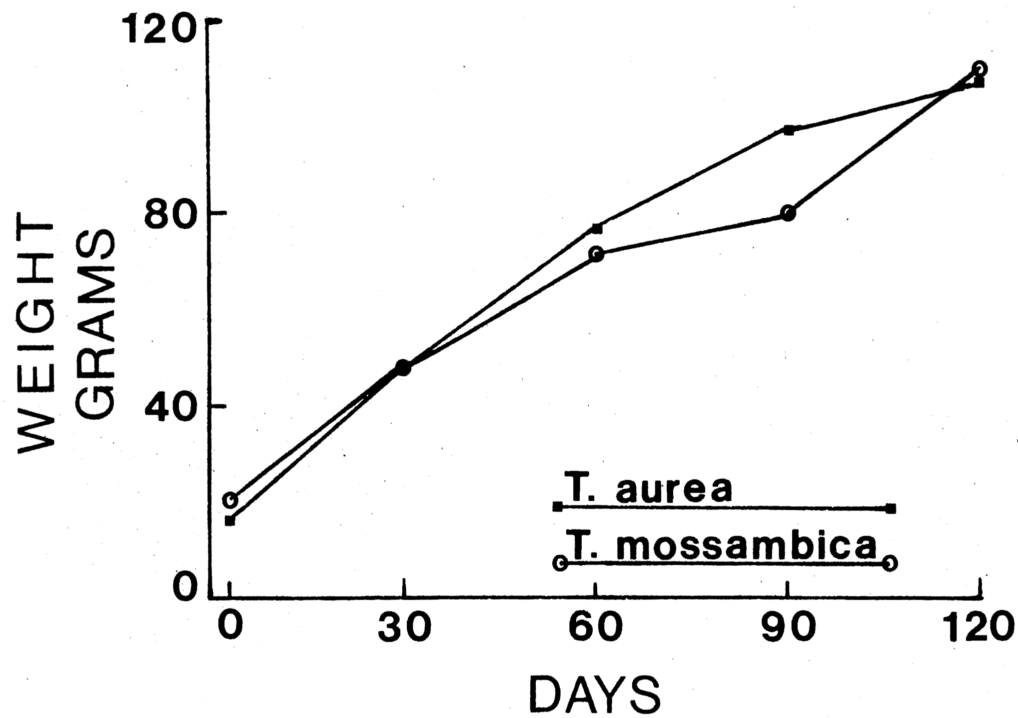

120
80
40
0
WEIGHT
GRAMS
T. aurea
T. mossambica
0
30
60
90
120
DAYS

Figure 5. Growth of *T. aurea* and *T. mossambica* stocked with *C. managüense* in ponds fertilized with chicken manure.



120
80
40
0
WEIGHT
GRAMS
T. aurea
T. mossambica
0
30
60
90
120
DAYS

Table 3. Weight (g) of Tilapia mossambica, T. aurea, and Cichlasoma managüense at 30-day intervals after stocking, listed by replicate.

Experiment number	Replicate number	Species	Time (days) after stocking 0	30	60	90	120	150	180
1	1	T. aurea	14	55	112	150	172	194	189
	2	T. aurea	16	41	79	166	238	160	200
	3	T. mossambica	9	62	103	98	85	90	76
	4	T. mossambica	9	36	55	64	95	93	86
	5	T. aurea	8	30	72	83	88		
	6	T. mossambica	15	55	64	90	109	111	
	Mean	T. mossambica	11	51	74	84	96	98	81
	Mean	T. aurea	13	42	88	133	166	177	194
2	1	T. aurea	14	36	78	135	135		
	2	T. aurea	13	39	99	159	148		
	3	T. aurea	12	36	86	98	90		
	4	T. mossambica	10	43	62	72	91		
	5	T. mossambica	10	36	59	90	94		
	6	T. mossambica	8	47	67	92	92		
	Mean	T. mossambica	9	42	63	84	92		
	Mean	T. aurea	13	37	87	131	124		
3	1 +	T. mossambica	17	39	54	56	49		
		T. aurea	12	42	68	78	81		
	2 +	T. mossambica	15	35	45	63	50		
		T. aurea	15	45	76	109	95		
	3 +	T. mossambica	23	39	52	62	50		
		T. aurea	10	53	80	97	91		
	Mean	T. mossambica	18	38	50	60	60		
	Mean	T. aurea	12	47	75	94	89		
4	1 +	T. mossambica	18	46	65	81	99		
		C. managüense	16	26	42	36	54		
	2 +	T. aurea	19	50	81	102	111		
		C. managüense	20	26	26	28	47		
	3 +	T. aurea	12	44	79	97	103		
		C. managüense	16	20	29	31	60		
	4 +	T. mossambica	25	50	70	80	97		
		C. managüense	16	34	33	35	56		
	5 +	T. mossambica	18		78		133		
		C. managüense	20		27	28	47		

Table 3. Continued.

Experiment number	Replicate number	Species	0	30	60	90	120	150	180
			Time (days) after stocking						
	6 +	T. aurea	17		70	91	109		
		C. managüense	37		38	38	54		
	Mean	T. mossambica	20	48	71	80	110		
	Mean	C. managüense	17	30	34	33	52		
	Mean	T. aurea	16	47	77	97	107		
	Mean	C. managüense	24	23	31	32	53		
5	1	T. aurea	17	41	81	104	101		
	2	T. mossambica	22	33	46	61	57		
	3	T. mossambica	13	48	93	93	83		
	4	T. aurea	10	61	90	110	95		
	5	T. mossambica	16	75	101	103	91		
	6	T. aurea	12		70	76	64		
	Mean	T. mossambica	17	51	80	86	77		
	Mean	T. aurea	12	51	80	97	87		

Net Yield

The largest net yield of each species when stocked separately was obtained in Experiment 1 (CM) (Table 4). Tilapia mossambica yielded the equivalent of 2,676 kg fish/ha/yr, and T. aurea yielded 2,540 kg/ha/yr. There was no difference ($0.1 < P < 0.2$) (136 kg/ha/yr) between net yields of the two species. The largest net yield irrespective of species--2,708 kg/ha/yr--was attained in Experiment 3 in which both species were stocked together (Table 4); the difference (672 kg/ha/yr) in net yield between species within Experiment 3 was significant ($P<0.001$), and was the only experiment in which the difference in net yield between species was significant. The net yield of T. aurea was 60% that of T. mossambica. No difference ($0.4<P<0.5$) occurred between the net yield of combined species in Experiment 3 and with either tilapia stocked separately in Experiments 1 and 2.

Yield of Harvestable-Sized Tilapia

Of the four experiments in which tilapia reproduction was uncontrolled T. aurea in Experiment 2 demonstrated the highest yield of harvestable fish, 864 kg/ha/yr, compared to the low of 242 kg/ha/yr of T. mossambica in Experiment 1 and the next highest of 540 kg/ha/yr in Experiment 5. In every experiment T. aurea produced a larger yield of harvestable fish than T. mossambica. The percentages of the yield of T. mossambica represented by the yield of T. aurea was: 194%, Experiment 1; 217%, Experiment 2; 235%, Experiment 3; 117%, Experiment 4; 188%, Experiment 5. The difference in harvestable yield between species was significant ($P \leq 0.05$) in Experiments 1 (228 kg/ha/yr), 2 (465 kg/ha/yr), 3 (124 kg/ha/yr), and 5 (252 kg/ha/yr) (Table 4).

Table 4. Total annual net yield (kg/ha/yr) and yield and individual weight of harvestable *Tilapia*.

Experiment number	Replicates per *Tilapia* species	Species	Average net yield kg/ha/yr	Average yield of harvestable fish kg/ha/yr	Average of harvestable fish g	Harvestable yield / net yield %
1	3	*T. aurea*	2,540	470	159	18.5
		T. mossambica	2,676	242	91	9.0
2	3	*T. aurea*	2,441	863	125	35.3
		T. mossambica	2,650	398	92	15.0
3	3 +	*T. aurea*	1,018	216	90	21.3
		T. mossambica	1,690	92	54	5.5
	Total		2,708	308		11.4
4	3 +	*T. aurea*	1,724	1,786	115	103.6
		C. managüense	234	104	55	44.4
	Total		1,958	1,890		
	+	*T. mossambica*	1,321	1,523	108	115.3
		C. managüense	366	260	53	71.1
	Total		1,687	1,783		
5	3	*T. aurea*	2,105	540	86	25.6
		T. mossambica	2,140	288	78	13.5

Survival to and Size at Harvest

As few as fifty-one percent of originally stocked fish of both species stocked together (Experiment 3) and as many as 106% of *T. aurea* in Experiments 2 and 5 reached harvestable size within 120 days after stocking. Ninety-nine percent of *T. aurea* and 96.7% of *T. mossambica* harvested in Experiment 4 were of harvestable size (Table 5). The average individual size of harvestable *T. aurea* in Experiment 4 was 187 mm and 115 g; harvestable *T. mossambica* averaged 180 mm and 108 g. In all five experiments *T. aurea* of harvestable size were significantly larger ($P \leq 0.01$) in length and weight than harvestable *T. mossambica*.

The fish harvested in Experiments 3 and 5 contained enough brooding females of both species to permit statistical comparisons of length and weight between harvestable females of both species. Females of *T. aurea* were larger ($P<0.001$) than females of *T. mossambica* in both Experiments 3 and 5. In Experiment 3 *T. aurea* females averaged 155 mm and 69 g and *T. mossambica* females averaged 146 mm and 52 g. In Experiment 5 *T. aurea* females averaged 160 mm and 69 g, but *T. mossambica* females averaged 144 mm and 46 g. In every experiment a higher percentage of originally stocked *T. aurea* reached harvestable size than did *T. mossambica*. Of all *T. aurea* stocked in Experiment 4, 100.8% survived to harvest, indicating a few offspring as well as most originals survived predation from *C. managüense*. Survival to harvest of *T. mossambica* was 96.5% (Table 6).

Table 5. Number and size of tilapia stocked and harvested, listed by species and replicate.

Experiment number	Replicate number	Type of fertilizer	Species	Net yield kg/ha/yr	Harvestable yield kg/ha/yr	Number and average individual size of harvestable fish No.	mm	g	Number and average individual size of fish stocked No.	mm	g
1	1	*CM	T. aurea	3,015	462	314	226	188	451	101	14
	2	"	"	2,583	546	333	224	200	470	98	16
	3	"	T. mossambica	2,864	240	171	168	76	223	89	13
	4	"	"	3,197	240	244	177	86	361	76	9
	5	"	T. aurea	2,021	403	392	171	88	451	72	8
	6	CM	T. mossambica	1,966	244	152	188	111	340	98	19
		mean	T. mossambica	2,676	241		178	91		81	14
		mean	T. aurea	2,540	470		207	159		99	13
2	1	**TSP	T. aurea	2,205	979	361	193	138	312	93	14
	2	"	"	2,767	1,012	368	194	148	334	92	13
	3	"	"	2,358	601	326	171	98	340	87	12
	4	"	T. mossambica	2,649	369	225	174	91	340	78	10
	5	"	"	3,337	511	292	176	94	334	77	10
	6	TSP	T. mossambica	1,962	313	173	176	91	312	73	8
		mean	T. mossambica	2,649	864		175	92		76	9
		mean	T. aurea	2,443	398		186	128		91	13
3	1	TSP +	T. aurea	900	192	78	166	99	110	88	12
			T. mossambica	2,188	37	23	150	57	109	96	18
		Total		3,088	229						
	2	" +	T. aurea	1,318	204	122	172	97	181	92	15
			T. mossambica	1,703	155	129	149	54	180	94	15
				3,021	359						
	3	TSP	T. aurea	837	253	179	171	95	218	86	11
			T. mossambica	1,178	86	111	148	64	218	100	23
		Total		2,015	339						
		mean	T. mossambica	1,690	93		149	58		102	16
		mean	T. aurea	1,018	216		170	97		89	15

Table 5. Continued.

Experiment number	Replicate number	Type of fertilizer	Species	Net yield kg/ha/yr	Harvestable yield kg/ha/yr	Number and average individual size of harvestable fish No.	mm	g	Number and average individual size of fish stocked No.	mm	g
4	1	CM	*T. mossambica* +	1,326	1,695	955	172	96	990	106	18
			C. managüense	403	282				990	102	16
	2	"	*T. aurea* +	1,293	1,506	1,066	183	111	1,070	105	19
			C. managüense	133	40				1,070	106	20
	3	"	*T. aurea* +	1,846	1,829	973	184	113	1,009	91	12
			C. managüense	284	146				1,009	97	16
	4	"	*T. mossambica* +	1,132	1,104	1,127	174	95	1,292	112	25
			C. managüense	444	268				1,292	91	16
	5	"	*T. aurea* +	2,033	2,024	1,303	190	122	1,292	94	17
			C. managüense	284	172				1,292	130	37
	6	CM	*T. mossambica* +	1,503	1,769	711	193	134	990	97	18
			C. managüense	251	231				990	104	20
		mean	*T. mossambica*	1,320	1,523		180	108		105	21
		mean	*T. aurea*	1,724	1,786		187	115		96	16
5	1	None	*T. aurea*	2,249	577	459	180	102	498	100	17
	2	"	*T. mossambica*	2,212	128	171	154	58	479	106	21
	3	"	"	1,615	338	348	173	84	530	87	13
	4	"	*T. aurea*	2,055	426	376	172	98	500	77	10
	5	"	*T. mossambica*	2,593	399	353	179	91	498	93	16
	6	None	*T. aurea*	2,010	617	738	158	64	479	82	12
		mean	*T. mossambica*	2,140	288		169	78		95	16
		mean	*T. aurea*	2,105	540		170	88		86	13

*Chicken manure

**Triple superphosphate

Table 6. Number and size of fish harvested in Experiment 4, in which *Tilapia* were stocked with the piscine predator *Cichlasoma managüense* at a ratio of 1:1.

Replicate number	Stocked number	Harvested number	Survival %	Harvestable number	No. harvestable / No. harvested %	Average weight g
			Tilapia mossambica			
1	990	1,006	101.6	955	94.9	96
6	990	718	72.5	711	99.0	134
4	1,292	1,178	91.2	1,127	95.7	95
Means			88.4		96.5	108
			Tilapia aurea			
3	1,009	1,007	99.8	973	96.6	113
2	1,070	1,073	100.3	1,066	99.3	109
5	1,292	1,323	102.4	1,303	98.5	122
Means			100.8		98.1	115

CHAPTER IV

DISCUSSION

Factors Influencing Growth

Effects of Fertilization

Yashouv (1955) credits Swingle with first recognizing the usefulness of inorganic fertilizers for increasing the abundance of plankton. Hepher (1962) demonstrated a four-to-five-fold increase in primary productivity in Israeli fishponds receiving inorganic fertilizer over unfertilized ponds. The important factor appears to be phosphate. The addition of phosphate-only fertilizer to 7.3 m^2 plastic pools in Alabama increased production of Pimephales promelas by a factor of five over unfertilized pools (Greene 1968). Cottonseed meal, which served as food for the minnows as well as an organic fertilizer, increased production by nine times over unfertilized ponds. Prowse (1968) reported a definite correlation between the crop of fish and the quantity of phosphate added to Malaysian ponds although departure from linearity occurred at 71.2 kg P_2O_5/ha. Swingle, et al. (1963) showed phosphate alone increased bluegill (Lepomis marochirus) production by 48%; sodium nitrate alone slightly reduced production, while nitrate added to phosphate increased production an additional 24%. Production of benthos also increases when fertilizer is applied (McIntire and Bond 1962). Howell (1941) reported the use of cottonseed meal as an organic fertilizer greatly increased abundance of bottom organisms, and production of *Micropterus salmoides* and *Lepomis macrochirus* increased as abundance of bottom organisms increased.

Prowse (1961) reported that superphosphate produced relatively larger quantities of algal forms more digestible by fish than did manure. In this study there was an obvious difference in the quality of plankton that developed in ponds fertilized with CM and those fertilized with TSP. Ponds fertilized with CM developed zooplankton shortly after filling, followed by dense blooms of *Euglena* sp. and *Anabaena spiroides*. *Anabaena spiroides* was easily the most abundant and flourished until the ponds were harvested. Prowse (1961) reported *Anabaena* spp. are indigestible by fish, but Dendy et al. (1968) reported *Anabaena* was well digested by *T. mossambica*. Ponds fertilized with TSP contained predominantly diatoms, although *Anabaena* was abundant. Unlike CM ponds in which zooplankton developed only shortly after filling and disappeared, zooplankton bloomed sporadically throughout the course of TSP replicates.

Even though a comparison between Experiment 1 and Experiments 2 and 3 is not statistically valid because different types and rates of fertilizers were used, it is interesting to note that 12 kg TSP/ha/mo (Experiments 2 and 3) produced the same ($0.4 < P < 0.5$) yield as 280.5 kg CM/ha/mo (Experiment 1). Both Prowse (1961) in Malysia and Sarig (1955) in Israel found inorganic fertilizers economically preferable to manures. However, one advantage of some organic fertilizers offer over chemical fertilizer is that the organic material may be utilized as food by fishes such as carps and tilapia.

Effects of *Pithophora*

Growth of *T. aurea* in Experiment 1 did not stop at any time during any replicate (Table 3). In replicates one and two (180 days), both ponds developed dense growths of *Pithophora* sp. (Chlorophyceae) that blanketed the pond bottom and formed floating mats that covered approximately one-quarter of the pond's surface. This growth of *Pithophora* become apparent during the third week after stocking and persisted until approximately the tenth week. Tilapia were continually observed ingesting *Pithophora*. Examination of stomach contents of fish removed from ponds containing *Pithophora* showed the algæ only slightly digested; however, when the partially digested algae was compared with algae from the pond it was obvious that passage through the gut cleaned the algae of abundant protozoa, periphyton, and detritus which were well digested. Apparently *Pithophora*, although not itself a high quality food, served as a substrate for other food items from which *T. aurea* derived nourishment. The *Pithophora* eventually disappeared as a result of changing water quality or adverse effects of repeated passage through tilapia alimentary canals, or both.

Planktonic algae, especially *Anabaena spiroides* (Cyanophyta), succeeded filamentous *Pithophora* and formed thick scums on windward portions of the ponds' surface. These planktonic algae persisted in recurrent dense blooms until ponds were harvested.

Two points are important in relation to these two replicates of Experiment 1: Pond 2 (replicate 1) and Pond 3 (replicate 2) had lain fallow for more than a year before being stocked. *Pithophora* developed only in these two replicates. The exceptional fertility and resultant extended abundance of food, e.g., filamentous algae, protozoa, periphyton, plankton algae, and chicken manure, permitted continuous growth of both originally stocked fish and offspring of the originally stocked fish until the ponds were harvested and drained.

Importance of Carrying Capacity

Cichlasoma managüense was stocked at a ratio of one *C. managüense* per one tilapia in Experiment 4 to assure that no portion of tilapia young would survive and tilapia numbers would remain as stocked (6,115/ha). The density of 6,115/ha was based upon an expected average individual weight of 253 g and net yield of 1,547 kg/ha/6 mos., i.e., 1,547 kg/ha/6 mos. ÷ 0.253 kg/fish = 6,115 fish/ha. Actual average yield of harvestable *T. mossambica* was 1,523 kg/ha/yr in Experiment 4. Had the actual yield of *T. mossambica* from Experiment 4 (1,523 kg/ha/yr) and average individual size (105.6 g) been known in advance, a more realistic stocking density could have been calculated, i.e., 1,523 kg/ha/yr x 1,000 g/kg ÷ 105.6 g/fish ÷ 3 growing periods/yr = 4,807 fish/ha/growing period. This procedure is further illustrated by comparing the quantities used in the first calculation above and in Experiment 4. The estimate of 1,547 kg/ha/6 mos. was based upon the average yield of replicates 1 and 2 of Experiment 1, inclusive of all size classes. The expected averaged individual size of 253 g was representative of the larger individuals sampled at 120 days in replicate 2, Experiment 1. The average yield of *T. aurea* in Experiment 4, 862 kg/ha/6 mos. of 115 g individuals, were approximately half those upon which they were based, i.e., replicates 1 and 2, Experiment 1. The results taken from Experiment 1 represented food available to all sizes of fish, whereas yield of *T. aurea* in

Experiment 4 represented the availability of food needed by originally stocked fish to reach adult size and grow to an average of 115 g within 120 days. In other words, the average total carrying capacity of replicates 1 and 2 of Experiment 1 was greater than the average "adult food" component of carrying capacity in T. aurea replicates of Experiment 4. The average yield of harvestable fish of replicates 1 and 2, Experiment 1, was 252 kg/ha/6 mos., or 3.4 times less than that of T. aurea, Experiment 4. However, the difference in carrying capacity of harvestable fish between the two experiments was not as great as these data indicated. There are no clear demarcations of food habits among size groups of tilapia, and fish smaller than harvestable size compete for food with larger fish. As used above, carrying capacity is actually a sum of the carrying capacities associated with each size class segregated from other classes by food habits. Therefore, the degree of availability of food to originally stocked fish in Experiment 1 in which reproduction was uncontrolled was less than in Experiment 4 in which reproduction was controlled. In Experiment 1 the availability of food of large fish was partially represented by the yield of less-than-harvestable-sized fish, whereas in Experiment 4 the availability of fish food of large T. aurea was represented only by the yield of harvestable tilapia, except for the (unknown) competition from C. managüense.

I conclude that in the case of tilapia, culture should be based upon at least two known and reproducible fundamental statistics from among individual weight at harvest, carrying capacity of the pond or culture system as determined by management procedures (Yashou 1959), and stocking density. Carrying capacity is the most important statistic and should be used when known.

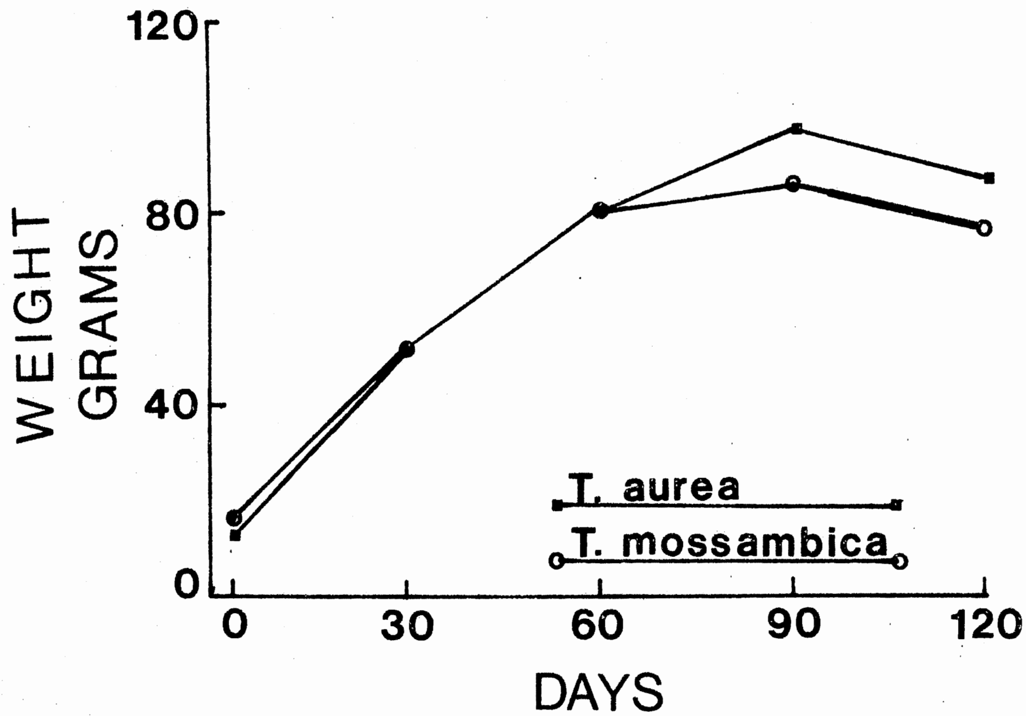
Ability to calculate a reliable estimate of carrying capacity allows extension agents to prescribe exact numbers of fish fingerlings to be stocked into private ponds. The only routine procedure the pond owner, or novice fish culturist, must follow is application of the prescribed fertilization rate, which has been determined for him by the extension agent and a fish culture research facility.

Competition From Offspring

The marked decline in growth of originally stocked fish of both tilapia species in Experiments 2, 3, and 5 can be attributed to competition for food from offspring resulting from high population densities when reproduction was uncontrolled. T. aurea as small as 25 mm compete with larger individuals for some food items (McBay 1961). Kelly (1955) found T. mossambica ranging in size from 113 mm to 169 mm to have similar food habits, and Chimits (1955) reports that both young and adult T. mossambica feed on planktonic algae. The minimum average size of fish stocked was 76 mm (T. mossambica, Experiment 2) and 86 mm for T. aurea (Experiment 5). Each of these sizes is 4 mm less than the minimum spawning size reported for each species (Chimits 1955; McBay 1961). Therefore it is assumed that both species spawned during the first month after stocking, and offspring would begin eating the same food items as adults before the end of the second month. Once the density became great enough that food was limiting competition would develop. Figures 3, 4, and 6 suggest that competition became severe during the third and fourth months after stocking.

Swingle (1960) first used largemouth bass, Micropterus salmoides,

Figure 6. Growth of tilapia stocked in unfertilized ponds.



120
80
40
0
WEIGHT
GRAMS
T. aurea
T. mossambica
0
30
60
90
120
DAYS

to control tilapia reproduction and demonstrated an increase in the percentage of harvestable tilapia over ponds without predators. The most effective control of tilapia reproduction was achieved by stocking 193 bass per acre in August on top of 77 brood tilapia stocked in May. Swingle states,

> At this time many young-of-the-year tilapia were too large to be eaten, but the addition of bass reduced the survival of tilapias which hatched subsequently. The rate of feeding was then doubled, causing many of the larger fingerling tilapias to grow to harvestable size. This procedure resulted in a production of 2,543 pounds of harvestable fish per acre (p. 146).

On an annual basis Swingle's production of 2,543 pounds of fish 152 mm and larger is approximately 4,015 kg/ha/yr, nearly double the single replicate maximum of 2,024 kg/ha/yr of Experiment 4. The method described by Swingle was not directly applicable to fish culture in El Salvador where commercial fish feed was unavailable and no fish culture tradition existed, however.

A search of the literature revealed no reference to the biology of C. managüense, but this study showed that Cichlasoma managüense is a piscivorous cichlid. Cichlasoma managüense stocked with tilapia in Experiment 4 apparently consumed essentially all tilapia offspring. The remaining tilapis grew well from stocking to harvest, and tilapia numbers remained constant.

Effects on Yields and Average Size of Slower Growth of Females

Disparate growth rates of females is one of the most important differences between the species. Brown (unpublished undated) found females of T. mossambica grow more slowly than males in monosex cage culture in Costa Rica, and Sumawidjaja (1969) found the relative growth rate of males of both *T. aurea* and *T. mossambica* to be greater than that of the females. *T. mossambica* also reached sexual maturity at a smaller size and at an earlier age and reproduced more often than *T. aurea* (Therezien 1966). In Experiments 3 and 5 *T. aurea* females grew faster than *T. mossambica* females.

The literature contains no reference to direct comparisons of the growth rates of males of the two species. Chimits (1955) reports that *T. aurea* reaches a maximum size of 50 cm and 2,500 g, but *T. mossambica* attains only 36 cm and 700 g. If these data were accurate *T. aurea* males could have a faster growth rate than *T. mossambica* males, but I have personally measured a male *T. mossambica* from a privately-owned pond that exceeded 40 cm. Observations made during the course of these experiments suggest there is very little, if any, difference in the relative growth rates of males of the two tilapias. Therefore, under conditions such as Experiment 4 where reproduction is controlled and population density does not cause food to become limiting, differences in size of harvestable fish between species is most probably determined by inherent differences in growth rates of females of *T. aurea* and *T. mossambica*.

Comparison of the Two Tilapias

Which of the two tilapias is better suited to Salvadoreño fish culture? Elements of this question are: 1) which species produces more fish 140 mm or larger? 2) and if both yielded the same quantity of harvestable fish, which species would produce the larger individuals?

Yield of Tilapia Relative to Other Fishes

In this research the maximum net yield was 3,015 kg/ha/yr of T. aurea (replicate 1, Experiment 1) and 3,197 kg/ha/yr of T. mossambica (replicate 4, Experiment 1). This production is superior to the maximum yield of channel catfish (479 kg/ha/yr) stocked at 6,916/ha in ponds fertilized with 89 kg/ha of 0-8-2 (Swingle et al. 1963) but comparable to that of brown bullhead, Ictalurus nebulosus marmoratus, in fertilized ponds (334 kg/ha/yr) and when pelleted feed was given (1,602 kg/ha/yr) and that of common carp in fertilized ponds (601 kg/ha/yr) and when fed (1,736 kg/ha/yr). Swingle (1960) found a maximum yield of channel catfish (3,120 kg/ha/yr) fed pelleted feed in fertilized ponds in Alabama. Only polyculture produces higher yields than tilapia culture. Tang (1970) reported 7,287 kg/ha/yr from a 6.0 ha Taiwan pond containing five species of carps, grey mullet and sea perch and receiving fertilization and supplemental feeding.

Comparison of Net Yields

Tilapia mossambica yielded larger quantities of fish than Tilapia aurea (Experiments 1, 2, 3, and 5) (Table 4), but the margin of difference in net yield was significant ($P<0.001$) only in Experiment 3. Both tilapias were stocked together in equal density/species in Experiment 3. The reason why T. mossambica represented a significantly larger portion of the net yield can be attributed to the significantly ($P<0.001$) larger average size of T. mossambica at stocking, 102 mm, as opposed to 89 mm for T. aurea. T. mossambica at stocking were approximately 20 mm larger than their minimum adult size and could have begun spawning within two weeks. Two weeks was the shortest time between stocking and first appearance of fry observed by Station personnel. *T. aurea* were only just reaching their minimum adult size of 90 mm and could be expected to require longer than *T. mossambica* to begin spawning. The larger size of *T. mossambica* could have represented an advantage in competition for spawning sites. Therefore more *T. mossambica* offspring would have been produced, and those offspring probably constituted the difference in net yields of the two species.

Yields of Harvestable Fish

Tilapia aurea produced larger yields of harvestable fish than *T. mossambica* in every experiment. The yields were significantly larger ($P<0.05$) in Experiments 1, 2, 3, and 5. The larger ($P<0.01$) net yield of harvestable fish in Experiment 1 was apparently due to abundance of *Pithophora* sp. as discussed above.

Sumawidjaja (1969) stocked *T. aurea* and *T. mossambica* together in ratios of 1:1, 2:1, and 1:2, respectively. He obtained the highest net production with *T. mossambica* and *T. aurea* at a ratio of 2:1, respectively. The total weight of harvestable fish increased with the increasing percentage of *T. aurea*; the highest total weight of harvestable fish was obtained in a population in which 91.2% of the adult stock was *T. aurea*. However, the relative growth rates of both tilapias decreased as the percentage of *T. aurea* in the population increased. *T. aurea* of the same size were heavier than *T. mossambica*. These results suggested to Sumawidjaja that interspecific competition was more important in determining the relative growth rate of *T. mossambica*, and intraspecific competition was more important with *T. aurea*.

Sumawidjaja's (1969) hypotheses suggest that among T. aurea and T. mossambica of similar size interspecific overlap of food preference is similar to the intraspecific competition among T. aurea across all sizes. In other words, as the percentage of T. aurea increases the individual sizes of T. mossambica and T. aurea at any given time approach equality, because effects of intraspecific competition among T. aurea approaches the effects of interspecific competition between the tilapias.

Results of Experiment 3 were similar to those of Sumawidjaja in that net yield was greater than in the single-species Experiment 2, but not significantly so ($0.4 < P < 0.5$). Also, the growth rate, yield of harvestable fish, and average size of harvestable fish of both species were lower. In addition to the effects of competition as postulated by Sumawidjaja (1969), the higher net yield of T. mossambica and higher yield of harvestable T. aurea in Experiment 3 is due probably to two other factors: 1) the smaller initial size of T. aurea, and 2) more rapid growth of T. aurea females as opposed to T. mossambica females.

Larger size at stocking would normally be considered conducive to attainment of a larger size at harvest. However, as discussed above the larger stocked size of T. mossambica would be an advantage only in securing spawning sites. Because both tilapias spawn in the same habitat, i.e., water deeper than 0.5 meter and especially where the slope of the bank joins the bottom, the larger T. mossambica males could establish themselves on nests more easily than T. aurea males. Therefore, T. aurea of both sexes would expend less energy in spawning than T. mossambica and fewer T. aurea offspring would be produced to constitute a portion of the harvest.

Sizes of Harvestable Fish

T. mossambica were significantly larger ($P<0.001$) at stocking in Experiments 3, 4, and 5 and *T. aurea* larger ($P<0.001$) in Experiments 1 and 2. Individual *T. aurea* were significantly larger ($P<0.01$) at harvest in length and weight than individual *T. mossambica* in every experiment. Apparently, then, if sex is not considered the average *T. aurea* grows larger than the average *T. mossambica* under similar conditions regardless of which species is larger at stocking. The more rapid growth of *T. aurea* females and higher reproductive rate of *T. mossambica* as discussed above probably are the most significant factors determining the larger average size of *T. aurea*.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Result of Comparison

Both *Tilapia aurea* and *Tilapia mossambica* will grow to harvestable size (140 mm or larger) in 120 days in El Salvador. The average rate of growth of *T. aurea* is faster than *T. mossambica*. *T. aurea* and *T. mossambica* produce equal quantities of harvestable fish when tilapia reproduction is controlled by *C. managüense*, but *T. aurea* produces the larger yield of harvestable fish when reproduction is uncontrolled. Harvestable-sized *T. aurea* are larger than harvestable-sized *T. mossambica*.

T. aurea will be the more desirable species as long as fish culture in El Salvador remains extensive and the yield of harvestable-sized fish is more important than yield of all fish.

Suggestions for Further Research

Research in El Salvador should be conducted to determine the desirability of inorganic vs organic fertilizers, and the optimum application rate of the fertilizer.

The stocking ratio of tilapia to *C. managüense* should be refined to optimize growth of originally stocked *C. managüense* while maintaining control of tilapia reproduction.

Experiments similar to Experiment 3 in which both tilapias were stocked together should be conducted in conjunction with stocking C. managüense. A T. aurea - T. mossambica - C. managüense mixture in the proper ratios would reduce competition between the tilapias to the benefit of T. mossambica and minimize intraspecific competition of T. aurea across size classes, and lowering the density of C. managüense perhaps would allow more rapid growth of originally stocked individuals. Perhaps then total yield of harvestable fish of all species will more nearly approximate the yield of ponds in which tilapia reproduction is not controlled.

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