Density and Temperature Effects on Overwintered *Tilapia aurea*

by

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ABSTRACT

Tilapia are currently being evaluated as a potential aquaculture organism. Tilapia culture is restricted by the organism's limited low temperature tolerance and its tendency toward overpopulation resulting in a reduction in growth rates. The present research was conducted to determine growth rates of tilapia held overwinter in flow-through tanks stocked at various densities. Results indicate that tested densities did not limit growth of tilapia. This was attributed to unanticipated slow growth in both ambient and heated water. Economically, the flow-through design did not appear to be feasible for overwintering fish at elevated temperatures, because of its inefficient use of heated water.

INTRODUCTION

Fish belonging to the genus Tilapia (Family Cichlidae) are of major importance to the fisheries of the Near East and Africa (Bardach et al. 1971) and are rapidly being introduced throughout the world. They are especially important to subsistance farmers and small-scale operations of parts of Jamaica, Indonesia, and Taiwan (Bardach et al. 1971).

The citations follow the format and style of *The Transactions of the American Fisheries Society*.

Tilapia are cultured for a number of uses other than providing a quality source of protein. These include weed control (Hickling 1971, Habel 1975) and use as a source of fish meal.

Tilapia are an especially successful aquaculture species because of their high productivity, tolerance of degraded water conditions, and relatively low feeding expense. Many species of tilapia are mouth brooders. The female collects and holds the fry in her mouth in the event of any danger. This greatly increases survival of the young, which in addition to an already high fecundity, accounts for high levels of production. Tilapia are known to inhabit bodies of water, the quality of which would prove fatal to many other species of fish. Because of their wide salinity tolerance, they lend themselves to both freshwater and marine culture. These cichlids are primarily herbivorous, feeding on phytoplankton and higher plants, and need little or no supplemental feed.

One factor restricting the expansion of tilapia culture is related to the limited low-temperature tolerance of this genus. Long-term exposure to temperatures below 13 C proves fatal to the blue tilapia (*Tilapia aurea*), although some individuals are able to withstand temperatures as low as 4 C for a short time (McBay 1961, Gleastine 1974). For this reason, it is necessary to develop methods for overwintering tilapia in temperate climates. In the absence of abundant heated water, such as the thermal effluent of a power plant, overwintering problems can be solved by holding limited numbers of fish indoors in flow-through tanks or raceways.

One problem inherent in rearing tilapia in restricted space involves their tendency toward overproduction which leads to increased degradation of water quality, greater competition for food, and a resulting reduction in growth rates. Overpopulation can be checked by such practices as monosex culture of hybrids (Bardach et al. 1971), hormonal sex changes (Guerrero 1975), and cage culture, in which eggs fall through the cage and are no longer protected by the adults (Guerrero 1975). However, controlling overproduction can not be effective if initial stocking densities are not suitable for a particular body of water. With this fact in mind, the present research was conducted with the following objectives:

(1) To determine the growth and survival of blue tilapia stocked at various densities in flow-through tanks.

(2) To determine the difference in growth rates of tilapia cultured in heated and unheated water.

MATERIALS AND METHODS

Twenty-four wooden flow-through tanks, each containing approximately 44 l of water were utilized to culture tilapia at various stocking rates to evaluate the effects of density on growth and survival (Figure 1). Initially the tanks received filtered water from ponds. However, due to limiting low temperatures, well water was later used as a water source. Flow regulators were utilized to maintain a flow rate of six exchanges per day. These devices, in addition to single airstones placed in each tank, aided in preventing the depletion of dissolved oxygen.

Dissolved oxygen and temperature were monitored periodically using a YSI Model 51 BP oxygen meter. Ammonia was measured intermittently by direct Nesslerization (APHA 1971). One measurement of pH was recorded every month when pond water was used, however, pH was not measured when well water was in use.

Two consecutive experiments were conducted under different temperature regimes. In both studies, fish ranging from 2 to 20 g were stocked at rates which were calculated to yield densities of 6, 11, 17, 34, 62, 96, 130, and 163 g/l when the fish reached weights of 250 g. This weight was reported to be most efficient for culture of *Tilapia mossambica* (Hickling 1971). Individual weights were recorded upon stocking. The tilapia were initially fed a commercial trout diet once daily at rates of 10% body weight. The feeding rate was later reduced to 5% daily. At two week intervals, the biomass of each tank was determined to assess new feeding levels.

Experiment I, culture in unheated water, was initiated in September 1977. Due to ambient temperature drops in early October, all tanks were covered and surrounded by styrofoam insulation. However, mortality and extremely variable environmental conditions made it necessary to terminate the study and restock the tanks. Individual weights were not recorded at this time, so statistical analyses were not possible for this study.

Experiment II, culture in heated water, began in mid-December 1977. During this portion of the research, an electric water heater was utilized to maintain temperatures 5-10 degrees above those of the previous test. Individual weights were recorded at the beginning and termination of the study, and a one-way analysis of variance was used to compare the mean weight gains among treatments to determine if any significant differences in growth or survival existed as a function of density.

A second experiment conducted during this period consisted of an attempt to delineate the importance of photoperiod to growth and/or survival. The tops were removed from two rows of tanks, while the other two rows remained covered. Records were kept for a period of one month on any noticable growth of algae or other differences such as dissolved oxygen content with respect to the two photoperiods.

RESULTS AND DISCUSSION

Hydrological

Water chemistry was monitored regularly throughout the first period and much less consistantly during the second as conditions began to stabilize with the use of flow-regulators, a heater, and well water. Installation of the heater allowed for better control of temperature, and the well provided a source of water relatively unaffected by the environment. Flow regulators functioned not only to maintain a constant flow at a less variable temperature, but also aided in maintaining a constant dissolved oxygen content of the water as it was jetted through the device (Figure 2). This jetting action also maintained the circulation throughout the tank needed for proper functioning of the Venturi drains.

Hydrological parameters during the first and second experiments varied primarily as a function of ambient conditions and equipment failure, respectively. Temperature appeared to fluctuate the most, especially during the first study. From September to December, unheated water averaged 18.4 C and ranged from 14 C to 21 C. Both pond water, and to a lesser degree, well water, were affected by ambient temperatures. The well water reportedly exited the well at a reasonably warm temperature (ca. 25 C), but travelled through a pipeline system and a filter before entering the tanks. During this time, the water equilibrated to low ambient temperatures. In the latter parts of the study, water in the tanks ranged from 14 C to 16 C.

From December to March, ambient water mixed with water from an electric heater maintained temperatures from 17 C to 26 C (averaging 21.7 C), thereby providing a much more suitable environment for the fish. However, this method of providing heated water was impractical. In order to heat enough water for six exchanges per day, it was necessary to operate the heater continuously, whereupon electricity costs became restrictive.

Dissolved oxygen content was another widely-changing variable in this study. Although typically low in well water, oxygen levels were maintained above lethal levels by airstones and flow regulators. Mean oxygen levels ranged from 4.8 to 7.8 mg/l in the first study, and from 5.9 to 7.1 mg/l in the second. On occasion, oxygen content reached low levels and became a problem. Unusually low dissolved oxygen content was observed in tanks in which drains had become clogged with fecal wastes, excess food, and bacterial growth. Water flow through the drains was retarded, causing water levels to rise above the opening of the flow regulator (Figure 3). This eliminated aeration by the flow regulators, and to some extent, by the airstones, as they too became clogged. Low oxygen was less of a problem during the initial experiment because the colder water had a greater capacity for gases than did the warm water, and fish held in cold water had a lower metabolic demand for oxygen.

Ammonia and pH were never found to be limiting factors. Ammonia levels in the pond water were characteristically below 1.0 mg/l, while values measured from well water consistantly rose above 2.0 mg/l. While such a change may prove harmful to many species of fish, tilapia have been reported to tolerate levels of 20 mg/l (Stickney et al. 1977).

Biological

Many of the biological aspects in both studies appear to be related to temperature. During the first experiment, fish were highly inactive and exhibited low feeding rates in contrast to the second experiment in which fish fed aggressively. The initial increase in temperature to 26 C was also sufficient to induce spawning in at least one tank. However, as temperatures were reduced to 24 C, no further evidence of spawning was observed.

Avault and Shell (1968) reported tilapia to be feeding well at 15.5 C; however, in this study, fish required temperatures above 17 C to feed actively. The effects of temperature on feeding, and consequently on growth rates, can be clearly seen in figure 4. The fish did grow in the early parts of the cold water study, but when temperatures dropped, growth rates slowed and in some cases became negative. Mean weight gain in the second experiment was more than double that of the first (Table 1).

Although growth was accelerated with elevated temperatures, the fish did not grow large enough at any density to be growth limited. Growth rates in this study were slightly lower than those achieved in a study comparing growth of tilapia in fertilized and unfertilized ponds during the wet and dry seasons in El Salvador (Ledgerwood et al. 1977). Weight gains of .89 g/day were reached in fertilized ponds whereas only .16 g/day were realized in the control ponds. Fish harvested were 91 g and 20 g, respectively. Stickney et al. (1977) reported growth rates of 1.4 g/day in ponds fertilized with swine and poultry wastes.

In this study, a maximum of .22 g/day was observed in one tank containing 11 fish. Average weight gains of fish in unheated and heated water were .045 g/day and .118 g/day, respectively, with the final weights ranging from less than 10 g to 55 g. Since the fish did not reach their predicted weight, we were not able to accurately delineate the effects of the tested stocking rates. Figure 4 indicates moderately better growth rates in tanks containing 6 and 11 fish, and slower rates in densities of 17, 23, and 29 fish. However, a one-way analysis of variance computed on mean weight gains of both periods shows no significant difference among the densities tested.

Several hypotheses might explain the slow growth rates, with the most apparent of these being low temperature. The importance of photoperiod was also considered. During the greater part of the study, all the tanks were covered with insulation, permitting light to enter only when the fish were fed and weighed. To determine the significance of photoperiod, we removed the covers from two rows of tanks. It was thought that increased light might have some direct beneficial results, and that subsequent growth of algae would provide extra food which would enhance growth rates. However, the experiment was ended after one month, with no apparent differences in growth observed.

Mortality rates were fairly high in both studies. Early in the unheated culture study several fish, both dead and alive, exhibited signs of exopthalmia. Gas bubble disease and bacterial infection were considered as possible causes. Gas bubble disease, a malady which has been associated with water which is heated without release of gas, probably did not occur in this case, because the heater was not in operation. It is possible that a leak in the pump could have resulted in supersaturated water, but no measurements of dissolved gas pressure were made. Several fish were examined for bacterial growth, but the condition disappeared before any causative effects could be found.

It was initially felt that temperature and dissolved oxygen content could have caused many of the deaths. However, close examination of the conditions surrounding the mortalities which were recorded revealed that only in a few cases were these two parameters at levels which might have been lethal (Table 2). In addition, *Tilapia aurea* have a high tolerance for low dissolved oxygen and are efficient in utilizing atmospheric oxygen from the air-water interface (Uchida and King 1962).

It is difficult to statistically correlate mortality with poor water quality in the absense of more complete water chemistry data. One must remember that the values recorded when deaths were observed, were not recorded at the actual time of death, and might indicate a much less harsh environment than actually existed. In any case, no other reasonable explanation could be found for the excessive mortality problem.

CONCLUSIONS

The results of this study indicate that culture of tilapia in flow-through tanks to achieve optimum growth during the winter months is uneconomical and inefficient. However, this system might be feasible for holding the fish overwinter with no attempt to maintain growth rates. In such a program, feeding and heating costs would be greatly reduced.

Should one desire to raise tilapia indoors, several alterations might be made in the experimental design. An alternative method of supplying heated water is almost essential. Perhaps a modified recirculating system requiring proportionately less heated water could be designed. Further investigation into the disadvantages of recirculating systems would be needed to determine its practicality. Other malfunctions such as plugged drains and airstones could be corrected by regular cleaning of the tanks, and feeding the fish twice daily to reduce deposition of excess food.

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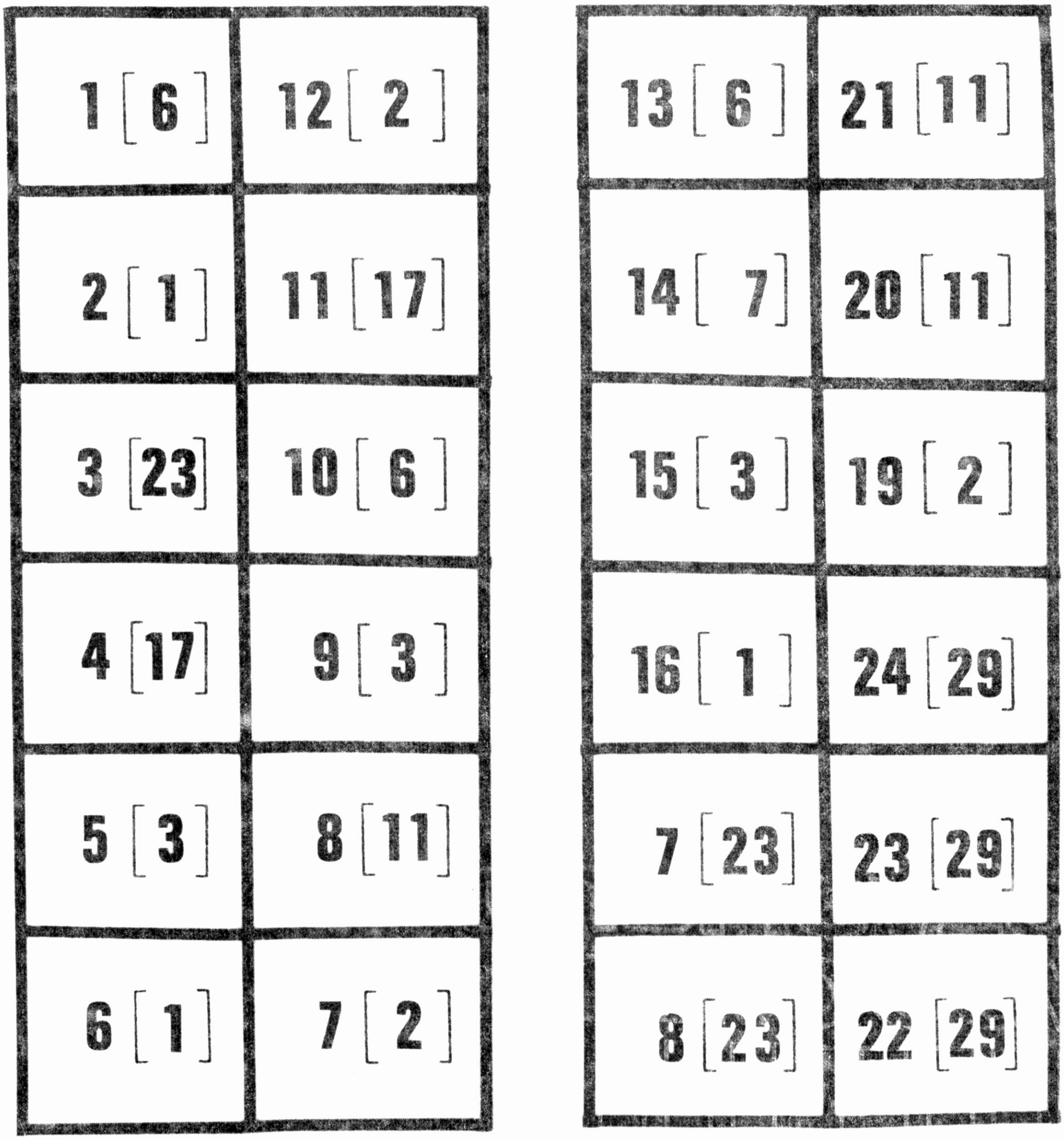

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4 [17]	9 [3]	16 [1]	24 [29]
5 [3]	8 [11]	7 [23]	23 [29]
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Figure 1. Arrangement of tilapia culture tanks with the number of fish per tank in parentheses.

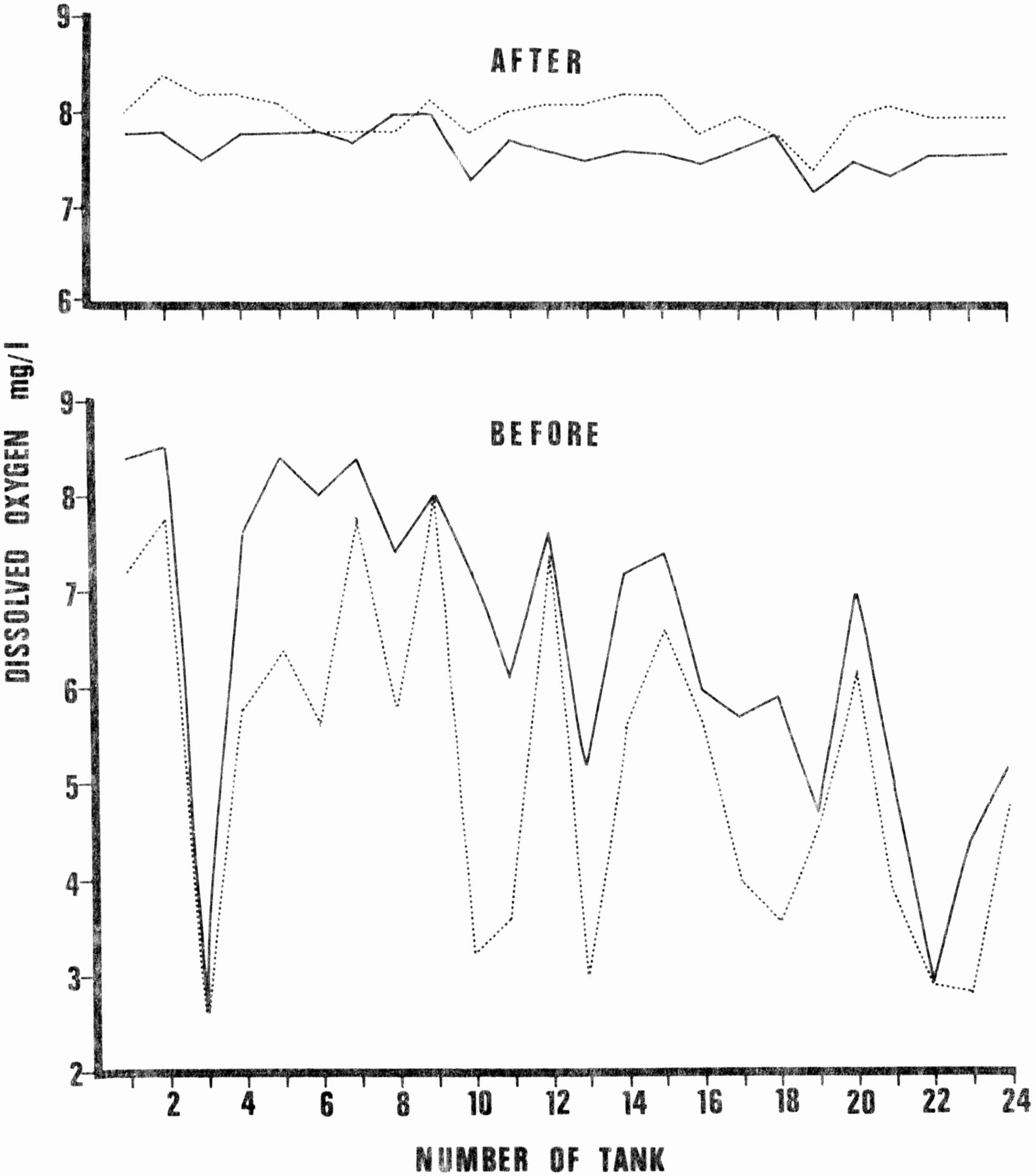

Figure 2. Comparison of dissolved oxygen levels in representative tanks before and after installation of the flow regulators.

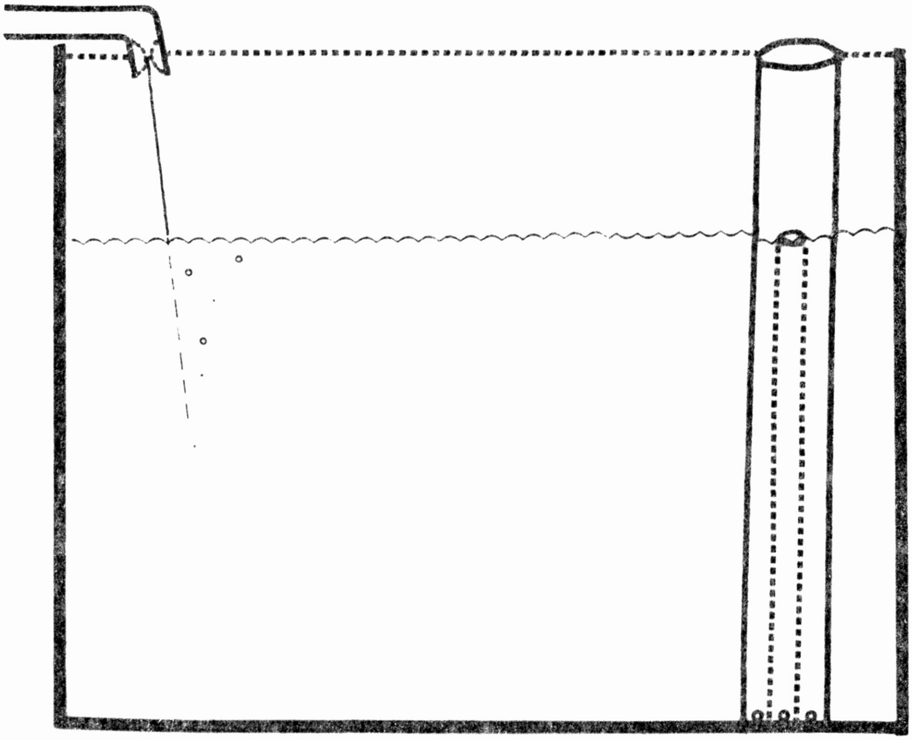

Figure 3. Cross-sectional diagram of a culture tank. The uppermost line represents the water level when the drain was clogged.

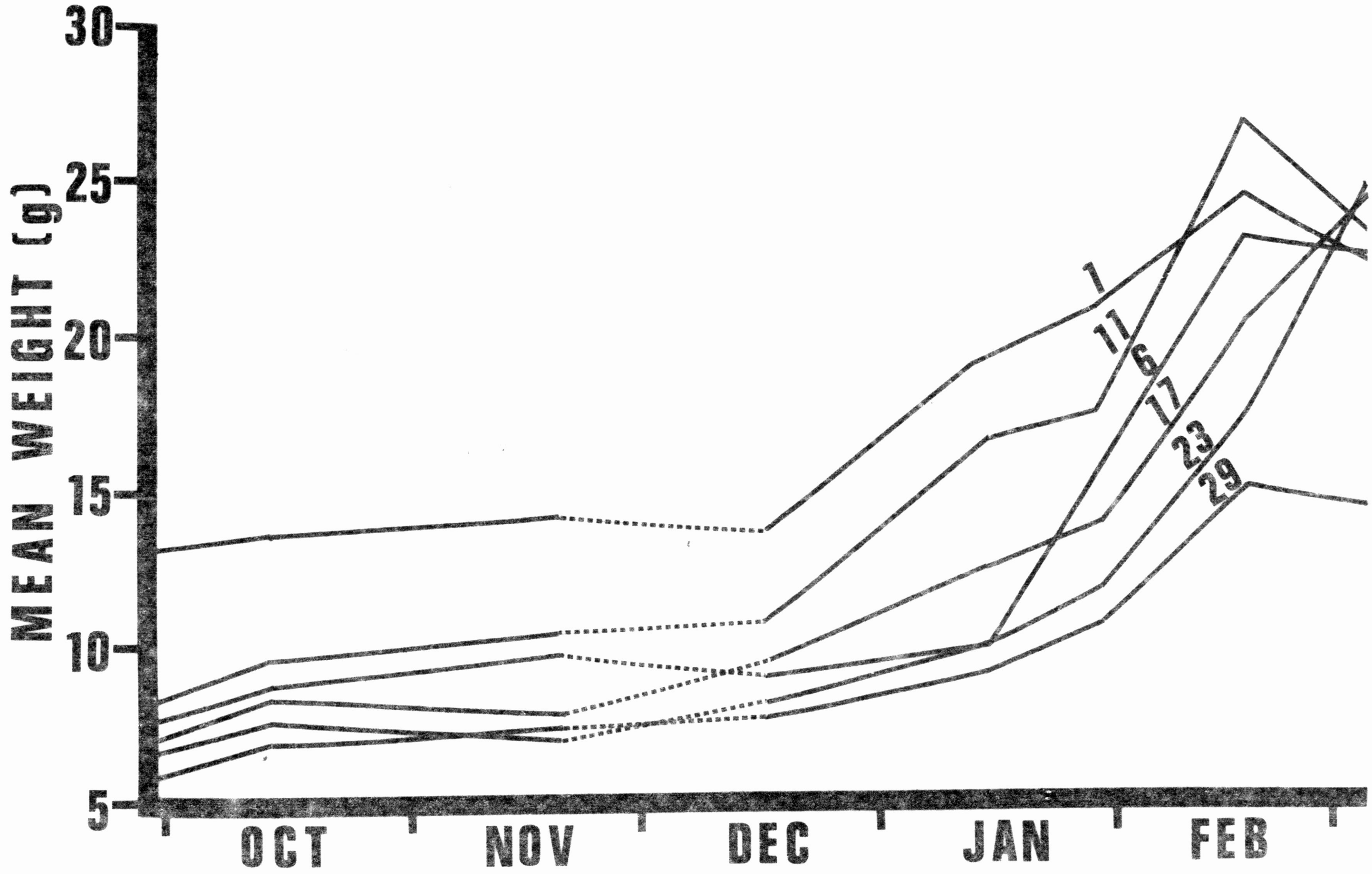

Figure 4. A plot of the mean weight gain of tilapia in tanks containing 1, 6, 11, 17, 23, and 29 fish. Tanks containing 2 and 3 fish were eliminated due to mortality.

Table 1. Initial and final biomass of *Tilapia aurea* stocked at various densities in unheated (Experiment I) and heated (Experiment II) water.

		EXPERIMENT I		EXPERIMENT II	
TANK	STOCKING DENSITY	INITIAL BIOMASS	FINAL BIOMASS	INITIAL BIOMASS	FINAL BIOMASS
1	6	47.05	61.36	54.39	128.26
2	1	10.79	11.50	10.60	98.62
3	23	151.55	215.13	226.32	342.16
4	17	113.32	168.57	156.79	416.81
5	3	16.52	22.24	19.61	51.95
6	1	13.06	14.24	13.92	22.48
7	2	8.85	7.64	15.00	0
8	11	78.60	124.67	121.92	269.72
9	3	17.87	25.22	25.02	0
10	6	49.75	45.49	49.29	0
11	17	122.86	66.09	158.81	252.06
12	2	13.94	17.47	23.54	0
13	6	43.99	57.90	56.50	144.43
14	17	117.68	171.23	174.05	352.90
15	3	16.68	20.77	23.20	0
16	1	5.89	7.61	8.05	0
17	23	163.43	10.00	191.59	573.42
18	23	151.03	264.80	159.03	298.96
19	2	17.45	21.25	11.63	0
20	11	95.96	144.72	145.19	338.65
21	11	64.33	79.48	93.01	189.26
22	29	163.01	178.89	204.87	126.75
23	29	164.77	183.56	193.91	219.35
24	29	165.99	217.35	230.83	418.30

Table 2. Water quality parameters and stocking density which accompanied observed mortality of overwintered *Tilapia aurea*.

TANK	STOCKING DENSITY	NUMBER OF MORTALITIES	DISSOLVED OXYGEN	TEMPERATURE (C)
18	23	1	1.4	19.0
14	17	3	0.8	17.0
11	17	1	7.6	17.0
17*	23	21	4.0	20.0
10*	6	1	3.2	20.0
21*	11	1	3.9	20.0
22*	29	2	2.0	20.0
23	29	2	-	-
23	29	2	1.8	-
11	17	1	2.2	23.5
2	6	2	1.7	17.0

* Signs of exopthalmia observed among many of the dead fish.