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# EFFECTS OF SALINITY ON PREFERRED AND LETHAL TEMPERATURES OF THE MOZAMBIQUE TILAPIA, OREOCHROMIS MOSSAMBICUS (PETERS)[1]

*Jay R. Stauffer, Jr.*[2]

ABSTRACT: The final preferred temperature of *Oreochromis mossambicus* acclimated to freshwater was 32.2 C, which was significantly ($P \leqslant 0.05$) lower than final preferred temperatures of fish acclimated at 15 o/oo and 30 o/oo salinity. The thermal tolerance zone of *Oreochromis mossambicus* ranged between 15-37 C and was not affected by acclimation to different salinity levels.
(KEY TERMS: exotic species; salinity; temperature preference; lethal temperatures.)

## INTRODUCTION

Studies on effects of temperature as both directive and lethal factors (e.g., Fry, 1947) on aquatic poikilotherms were reviewed by Stauffer (1980). In essence, fishes in complex thermal environments can often maintain body temperatures which fluctuate less than ambient water temperatures through the selection of thermal regimes which optimize physiological processes (Brett, 1944; Beitinger, 1977; Hokanson, 1977; Reynolds, 1977). In addition to its effects as a directive factor, lethal temperatures may limit the dispersal and distribution of fishes. Death may result from exposure to either high or low extremes (e.g., Umminger, 1969; Prosser, *et al.*, 1970; Stauffer, 1980). The interaction of temperature and salinity may be the most important parameter which affects marine and estaurine teleosts (Kinne, 1963, 1964; Morgan, *et al.*, 1981).

The purposes of this study were to determine: (1) if acclimation to different salinities affected the preferred and lethal temperature responses of the exotic Mozambique tilapia, *Oreochromis mossambicus* (Peters); and (2) the upper and lower incipient lethal temperature of this species when acclimated to freshwater.

*O. mossambicus* is native to southeastern Africa. In North America it has established reproducing populations in Florida, California, Arizona, Texas, and North Carolina (Hensley and Courtenay, 1980).

## METHODS AND MATERIALS

Juvenile *O. mossambicus* used in these studies were raised in fresh water at 27 C from brood stock collected in Florida. Fish were held on a 14:10/L:D photoperiod with Vita-lites, which provided light of similar spectral quality as sunlight. Dissolved oxygen levels were maintained between 95-100 percent saturation, and pH ranged between 7.0-7.3.

### *Preference Tests*

Fish for the temperature preference trials were acclimated to 25 C at 0 o/oo salinity. After initial temperature acclimation, one-third of the specimens were acclimated to 15 o/oo salinity and one-third to 30 o/oo salinity at a rate of 2 o/oo salinity per day, and held at that salinity for 10 days. Fish at all three salinities were acclimated to 15, 20, 25, 30, and 35 C at a rate which did not exceed $1^{o}$C/day. Fish were held at their respective temperature and salinity acclimation combination for a minimum of 10 days prior to testing.

Temperature preference trials were conducted in a horizontal trough, 3.6 m x 0.203 m x 0.254 m (Meldrim and Gift, 1971). Testing procedures were similar to those described in Stauffer, *et al.* (1984). Temperature preference was regressed against acclimation temperature to generate a temperature response curve for all acclimation temperatures at each salinity. A two-way ANOVA was used to determine the influence of acclimation temperature and salinity on preferred temperature.

### *Tolerance Tests*

All holding and acclimation procedures followed those previously described. Upper and lower lethal temperatures were determined for all three species acclimated to 25 C at 0, 15, and 30 o/oo salinity.

Once acclimation was completed, 10 fish were immediately exposed to each of the following temperatures: 9, 11, 13, 15,

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[2] Associate Professor, Fishery Science, The Pennsylvania State University, 8B Ferguson Bldg., University Park, Pennsylvania 16802.

17, 19, 21, 23, 25*, 27, 29, 31, 33, 35, 37, 39, and 41 C (* = control temperature). Fish acclimated to freshwater were tested in freshwater; those acclimated to 15 o/oo salinity were tested at 15 o/oo salinity; and those at 30 o/oo were tested at 30 o/oo salinity. Responses of fishes exposed to temperature changes were monitored for 10,000 minutes. The number of dead fish in each test was recorded at various time intervals. Fish were considered dead when there was complete cessation of opercular movement and no response to mechanical stimuli.

In addition, lower lethal temperatures were determined for *O. mossambicus* acclimated to 15 C and upper lethal temperatures for specimens acclimated to 35 and 37 C at 0 o/oo salinity. Resistance times were recorded in these experiments.

## RESULTS

### *Temperature Preference*

The mean preferred temperatures ranged between 27.5 C and 37.8 C with an overall mean of 33.4 C (Table 1). However, no suitable regression model could be found which adequately explained the relationship between preferred temperature and acclimation temperature at the different salinity levels. This phenomenon has been reported with other stenothermal species (Stauffer, *et al.,* 1984; Stauffer, *et al.,* 1985); thus, the overall mean was used as an estimate for the final preferred temperature for each salinity level (McCauley, *et al.,* 1977). Fish acclimated to freshwater had a final preferred temperature of 32.2 C, those acclimated to 15 o/oo salinity had a final preferred temperature of 34.1 C and those acclimated to 30 o/oo had a final preferred temperature of 33.9 C.

A two-way ANOVA was used to determine the effect of salinity and acclimation temperature on preferred temperature (Table 2). Both acclimation temperature and salinity level significantly ($P \leq 0.05$) affected selected temperatures. A Duncan's multiple range test ($P \leq 0.05$) indicated that fish acclimated to 15 C selected a significantly lower overall mean temperature (x = 29.1 C) than those acclimated to 20 (x = 33.6 C), 25 (x = 33.4 C) and 30 C (x = 34.4 C). Moreover, those acclimated to 35 C selected an overall mean preferred temperature of 36.4 C, which was significantly ($P \leq 0.05$) higher than those selected by fish acclimated to lower temperatures. Furthermore, it was determined that preferred temperatures of fishes acclimated to freshwater was significantly ($P \leq 0.05$) lower than when acclimated to 15 and 30 o/oo salinity. Conclusions about the mean effects, however, are confounded by the significant interaction term.

TABLE 2. Two-Way ANOVA on Preferred Temperature, with Acclimation Temperature (A) and Salinity Levels (S) as Classes.

| Source of Variation | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| A | 676.9 | 4 | 169.2 | * |
| S | 88.9 | 2 | 44.4 | * |
| A x S | 375.9 | 8 | 47.0 | * |
| Error | 795.1 | 105 | 7.6 | |

*Significant at $P \leq 0.05$.

### *Lethal Temperatures*

The thermal zone of tolerance ranged between 15 and 37 C and apparently was not affected by salinity (Table 3).

TABLE 3. Percent Survival for Fish Acclimated to 25 C and 0, 15, and 30 o/oo Salinity; and Exposed to Various Test Temperatures for 10,000 Minutes.

| Test Temperature (C) | Salinity (o/oo) 0 | 15 | 30 |
|---|---|---|---|
| 9 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 |
| 15 | 90 | 90 | 20 |
| 17-35* | 100 | 100 | 100 |
| 37 | 80 | 100 | 100 |
| 39 | 0 | 20 | 10 |
| 41 | 0 | 0 | 0 |

*Test temperatures were at 2°C intervals and included control at 25 C.

TABLE 1. Mean Preferred Temperature and Standard Deviations for Each Acclimation Temperature and Salinity.

| Acclimation Temperature (C) | Salinity 0 N | 0 $\bar{x}$ | 0 S.D. | 15 N | 15 $\bar{x}$ | 15 S.D. | 30 N | 30 $\bar{x}$ | 30 S.D. | Means for Each Acclimation Temperature N | $\bar{x}$ | S.D. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 8 | 28.9 | 3.9 | 8 | 27.5 | 5.5 | 8 | 31.0 | 2.9 | 24 | 29.1 | 4.3 |
| 20 | 8 | 34.8 | 2.5 | 8 | 32.9 | 4.0 | 8 | 33.2 | 1.5 | 24 | 33.6 | 2.9 |
| 25 | 8 | 28.2 | 2.7 | 8 | 36.1 | 1.9 | 8 | 35.7 | 1.9 | 24 | 33.4 | 4.3 |
| 30 | 8 | 32.6 | 2.4 | 8 | 36.0 | 2.3 | 8 | 34.7 | 2.1 | 24 | 34.4 | 2.3 |
| 35 | 8 | 36.23 | 2.0 | 8 | 37.8 | 1.0 | 8 | 35.0 | 2.0 | 24 | 36.4 | 2.0 |
| Means for Each Salinity | 40 | 32.2 | 4.2 | 40 | 34.1 | 4.8 | 40 | 33.9 | 2.6 | 120 | 33.4 | 4.0 |

*O. mossambicus* could tolerate temperatures outside of its zone of tolerance for short time periods (Table 4). Ninety percent of fish acclimated to 25 C and exposed to 13 C survived for 2,000 minutes (1.4 days), 70 percent survived for 4,000 minutes (2.8 days), and 50 percent for 5,000 minutes (3.5 days). Moreover, 100 percent of fish acclimated to 15 C and exposed to 11 and 9 C had resistance times of 2,000 and 1,000 minutes, respectively.

## DISCUSSION

The ability for fish to select temperatures when exposed to a heterothermal gradient permits them to optimize certain physiological processes (Brett, 1944; Reynolds, 1977). Numerous authors (see Stauffer, 1980) have shown that acclimation temperature influences selected temperatures of aquatic poikilotherms. Beamish (1970) showed that salinity acclimation affected the temperature preference responses of *Tilapia* [=*Oreochromis*] *nilotica. O. mossambicus* preferred a lower preferred temperature when acclimated to freshwater than when acclimated to either 15 or 30 o/oo salinity. Perhaps *O. mossambicus* requires more energy for osmoregulation in freshwater than in saline water. A preference for lower water temperatures could lower the metabolic rate and thus conserve energy. Javaid and Anderson (1967) reported that *Salmo gairdneri* and *Salvelinus fontinalis* selected cooler water during periods of starvation, while *Salmo salar* preferred warmer water. Lillywhite, *et al.* (1973), showed that toads (*Bufo boreas*) selected lower temperatures during a period of starvation. Brett (1971) hypothesized that preference for cooler water and the resultant lower metabolic rate was a response triggered by limited food supplies.

Shafland and Pestrak (1982) reported a lower lethal temperature of 9-10 C for *Tilapia* [=*Oreochromis*] *mossambicus.* They tested fish by lowering the temperature 1°C/day and recording survival. My hypothesis is that the fish were in their "zone of resistance" (see Fry, 1947) below 13 C; but that it took them several days to succumb. During this time the test temperature was being lowered daily, which could have resulted in a low estimate of the lethal temperature. Resistance time data reported herein support this hypothesis. Moreover, the estimate of a lower lethal limit between 13 and 15 C is supported by Smit, *et al.* (1981), who showed that *Sarotherodon* [=*Oreochromis*] *mossambicus* experienced osmoregulatory collapse at 15 C. Stauffer, *et al.* (1984), reported a similar phenomenon for *Sarotherodon melanothenon.*

Based on these results, it is postulated that *O. mossambicus* can expand its existing range throughout the southern portion of North America. It is euryhaline and thus can utilize avenues of dispersal not available to many primary freshwater species. Although *O. mossambicus* is relatively stenothermal (i.e., zone of tolerance = 13-37 C), it is capable of withstanding lower and higher temperatures for short time periods. Furthermore, data presented herein (i.e., differential mortality) show that some members of the population appear to have a wider zone of tolerance that others. This phenomenon is particularly important since all of our test specimens were cultured from a relatively few number of adults; hence, it is speculated that the population at large may exhibit a much wider range of thermal tolerance. The progeny of such specimens would be selected, as *O. mossambicus* expands its range northward. Finally, it should be noted that the presence of industrial thermal outfalls may maintain populations in

TABLE 4. Number of *Oreochromis mossambicus* Surviving at Each Time Interval After Being Acclimated to 15, 25, 35, and 37 C and Subsequently Exposed to Various Test Temperatures in Freshwater. Fish acclimated to 25 C were exposed to all test temperatures; those acclimated to 15 C were exposed only to temperatures at and below the acclimation temperature; and those acclimated to 35 and 37 C were exposed to temperatures at and above the acclimation temperatures. For those test temperatures not reported below (including controls), there was 100 percent survival through 10,000 minutes.

| Time of Observation (min) | Test Temperatures (C) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | | 11 | | 13 | 15 | 37 | 39 | | | 41 | | |
| | Acclimation Temperature (C) | | | | | | | | | | | | |
| | 15 | 25 | 15 | 25 | 25 | 25 | 35 | 25 | 35 | 37 | 25 | 35 | 37 |
| 1-10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 10 | 10 |
| 10-100 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 10 | 10 | 0 | 6 | 9 |
| 100-500 | 10 | 0 | 10 | 10 | 9 | 10 | 10 | 0 | 8 | 8 | | 0 | 2 |
| 1,000 | 10 | | 10 | 10 | 9 | 10 | 10 | | 8 | 7 | | | 0 |
| 2,000 | 2 | | 10 | 2 | 9 | 10 | 10 | | 8 | 7 | | | |
| 3,000 | 0 | | 9 | 0 | 7 | 10 | 9 | | 7 | 7 | | | |
| 4,000 | | | 5 | | 7 | 10 | 8 | | 7 | 7 | | | |
| 5,000 | | | 1 | | 5 | 10 | 8 | | 7 | 2 | | | |
| 6,000 | | | 0 | | 4 | 10 | 8 | | 2 | 0 | | | |
| 7,000 | | | | | 1 | 10 | 8 | | 0 | | | | |
| 8,000 | | | | | 0 | 10 | 8 | | | | | | |
| 9,000 | | | | | | 10 | 8 | | | | | | |
| 10,000 | | | | | | 9 | 8 | | | | | | |

marginal areas during cold weather periods (e.g., Buntz and Manooch, 1969; Nobel, *et al.*, 1976; Skinner, 1984). More data are needed on the effects of temperature, salinity, life history, and other physical and chemical limiting factors of *O. mossambicus* and other exotic species which are currently established in North America.

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