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TEMPERATURE SELECTION AND HEAT RESISTANCE OF THE MOSQUITO FISH, *Gambusia affinis*[1]

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ABSTRACT

The average selected temperature of a sample of *Gambusia affinis* previously acclimated to 20°C decreased from 28-29°C to about 27°C after the fish had lived in a temperature-gradient tank for one month. The final thermal distribution of the fish varied with sex and developmental stage. Males selected lower temperatures than did adult females. The young fish, although more scattered than the adults, occurred mostly at temperatures higher than those selected by the adults. These results may indicate temperature separation of young and adult fish in nature which would reduce intraspecific predation and competition. Heat resistance of adult females taken from the 26.2°C-compartment of the temperature-gradient tank was higher than the resistance of 28.0°C acclimated fish. The temperature-gradient females either had attained a high acclimation level by temporarily venturing above 28.0°C or had accumulated high resistance by living at varying temperatures below 28.0°C.

INTRODUCTION

The mosquito fish, *Gambusia affinis* (Baird and Girard), is native of many lowland ponds, lakes, and streams in southeastern areas of the United States. It has been widely introduced in other areas of the world as a mosquito control agent. Hart (1952) reported that this species has high heat tolerance in conformity with the high summer temperatures of its habitat — the surface regions of shallow, marshy waters. Adult females are more heat resistant than adult males; fry are more resistant than the adults of either sex (Hagen, 1964). He suggested that the observed differences may have adaptive value. The high heat tolerance of females allows them to withstand high temperatures when gravid, thereby ensuring survival of the population during hot summers. High heat tolerance of the fry permits them to live in very shallow, warm water in which predation and intraspecific competition would be reduced. Both Hart (1952) and Hagen (1964) worked with fish acclimated to constant temperatures; however, the temperature-gradient is comparable to the natural environment of the species.

Objectives of the present study were to investigate temperature selection in *G. affinis* and to evaluate heat tolerance of the fish living in a thermal gradient.

MATERIALS AND METHODS

Gambusia affinis were collected late in the winter of 1965-1966 from Little Wildcat Creek, a spring-fed tributary of the Illinois River about five miles northwest of Fayetteville, Arkansas. The fish were held in

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a shallow pond in Fayetteville until September, 1966 when a sample was seined and brought to the laboratory. After four months at room temperature (18-22°C), the fish were acclimated to 20.0 ± 0.1°C for two months. On March 25, 1967, a sample of adult fish was transferred from the acclimation tank to the 20°C-compartment of a temperature selection tank. This tank (455 x 66 x 35 cm) was divided by plexiglas partitions into 16 compartments each about 28cm wide. Each partition was drilled with four 3 cm holes to allow fish movement and water circulation. A fairly stable and linear temperature gradient was maintained by thermostatically heating and refrigerating opposite ends of the tank and by aerating the water of each compartment. The temperature gradient ranged from 35°C to 20°C. At 1-3-day intervals the numbers of adult and larger immature fish per compartment were estimated, and compartmental temperatures were recorded. The fish seemed to prosper in the gradient tank, and many young were produced. On May 9, 1967, a secondary partition was placed against each primary partition so that the holes of the two partitions matched. The secondary partitions were 5 cm shorter than the primary ones to which they were tightly clamped. On May 17, 1967, the secondary partitions were shifted against the main ones so that the holes no longer matched; the fish were then confined to the compartments they occupied before the shift. The shifting of the secondary partitions was accomplished as rapidly as possible to prevent fish movement; the entire process required about 15 seconds. Within 40 minutes, adult fish were removed from their respective compartments and placed in lethal temperature baths at 38.0 ± 0.05°C. Each lethal bath consisted of a two-gallon goldfish drum equipped with aeration and a thermostatically-controlled heater. Time until death was recorded for each fish.

Other fish of the same original stock were acclimated at 28.0 ± 0.1°C for 25 days and subjected to lethal resistance tests at 38.0 ± 0.05°C for comparison with fish from the temperature gradient.

Aged Fayetteville tap water was used in the acclimation, selection, and test tanks. The entire experiment was conducted under continuous, cool-white fluorescent light. The fish were fed Arapaho Trout Food at 1-2-day intervals; the last feeding was 24 hours before lethal tests.

RESULTS AND DISCUSSION

The estimates of average selected temperatures were calculated from the composite distributions of male, female and larger immature fish. The average selected temperature fluctuated considerably during the study period (Figure 1). This fluctuation was caused by actual day-to-day variation in the temperatures selected by the fish and by random errors in estimating the numbers of fish in the compartments. In spite of fluctuation, a general trend was apparent. Mean selected temperature decreased from 28-29°C to about 27°C after the fish had been in the tank approximately one month. The average selected temperature fluctuated around 27°C for the duration of the experiment. This temperature, 27°C, apparently would correspond to Fry's (1947) theoretical value, the final temperature preferendum. The thermal distributions of adults of each sex and of the young fish were determined on the last day of the experiment when the compartments were closed. Adult fish were less scattered in the gradient than were the younger fish (Figure 2). A one-tailed Mann Whitney U Test (Siegel, 1956) indicated that males selected significantly ($p = 0.05$) lower temperatures than did the adult females. Unsexed fish, 15-19mm in standard length, selected the same or slightly higher temperatures than did the adult females. Immature fish, less than 15mm in standard length, appeared bimodal in their thermal distribution; most of these occurred at temperatures higher and some at temperatures lower than those selected by the other three groups. Our observations led us to believe that gravid females generally moved to the extreme temperatures of the gradient to spawn; the young appeared, therefore, to be not only very tolerant of high temperatures as Hagen (1964) noted, but also tolerant of low temperatures as well. The young fish, because of their greater temperature tolerance, were able to avoid predation by the adults. As they grew larger, they were observed in the compartments with the adults. Very

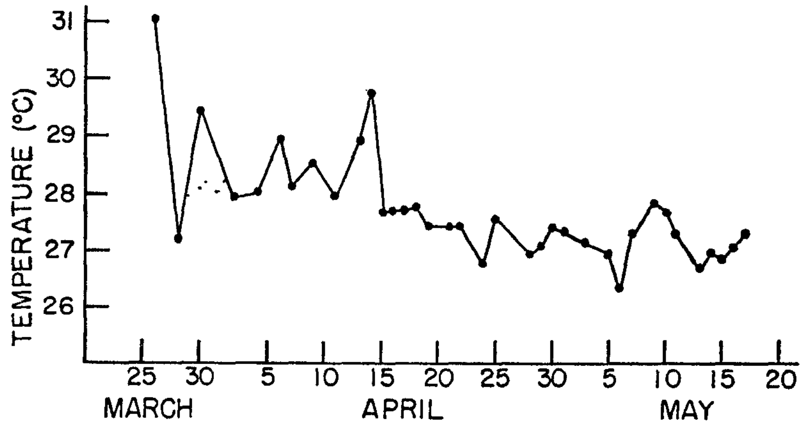

Figure 1. Estimated mean selected temperatures of *Gambusia affinis* from March 25 to May 17, 1967.

few young survived in the group of fish maintained in the constant temperature tank even though recently-spawned young fish were observed on several occasions. Probably some spawning occurred in compartments of the temperature gradient within the selection range of the adults; cannibalism undoubtedly accounted for most of these fry.

Although little heat resistance data were obtained for males and young fish from the thermal gradient, the relationships were essentially the same as those Hagen (1964) found for fish acclimated to constant temperatures in that males were less resistant than females, and young fish were more heat resistant than adults of either sex.

Among female fish (20mm or greater in standard length) from the temperature selection tank, little relationship between selected temperature and heat resistance was evident (Figure 3); the resistance of female fish from the 26.2°C-compartment was not considerably different from the resistance of fish taken from the 29.0°C-compartment. Apparently, in this range of temperatures, the fish moved freely from compartment to compartment so that the average acclimation level of the fish in one compartment at any instant was similar to the average level of fish in nearby compartments.

Adult female fish acclimated to 28.0°C were generally less heat resistant than female fish taken from the 26.2-, 27.3-, 28.3-, and 29.0°C-compartments of the temperature selection tank (Figure 3). Fish from the 26.2- and 27.3- compartments were apparently acclimated to temperatures higher than those of the compartments from which they were taken. Two possible hypotheses could account for the higher resistance of fish from the gradient. The fish may have spent enough time at temperatures higher than 28°C to have attained average acclimation levels higher than 28.0°C. Secondly, living in a temperature gradient at temperatures lower than 28.0°C, the fish may have accumulated heat resistance (by virtue of moving through water of varying temperatures) so that their apparent acclimation level was higher than that of fish acclimated to a constant temperature of 28.0°C. Brett (1944) found that brown bullheads, *Ictalurus nebulosus*, taken directly from a shallow Ontario lake in mid-summer, 1941, had heat resistance that indicated acclimation levels above the maximum lake temperatures recorded. Additional experiments are in progress to determine the value of the two hypotheses.

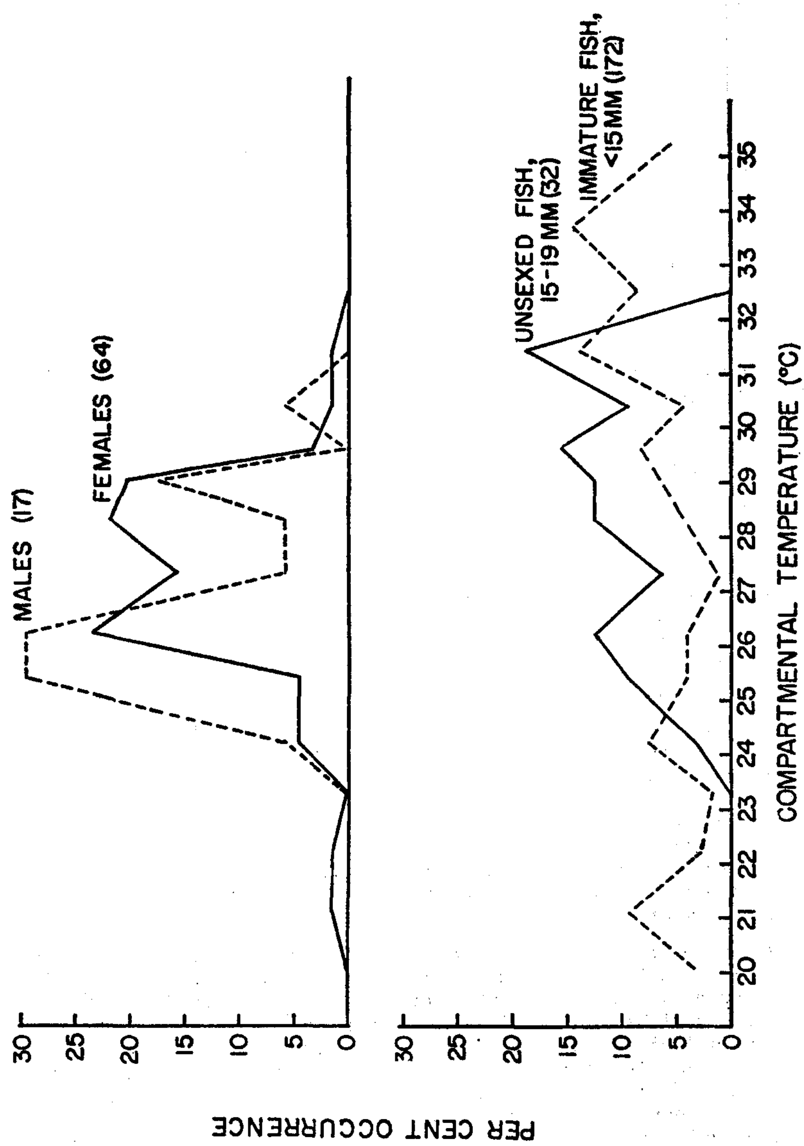

Figure 2. Frequency distributions of *Gambusia affinis* in the temperature-gradient tank at the end of the study period (May 17, 1967). Number of individuals in each category is given in parentheses.

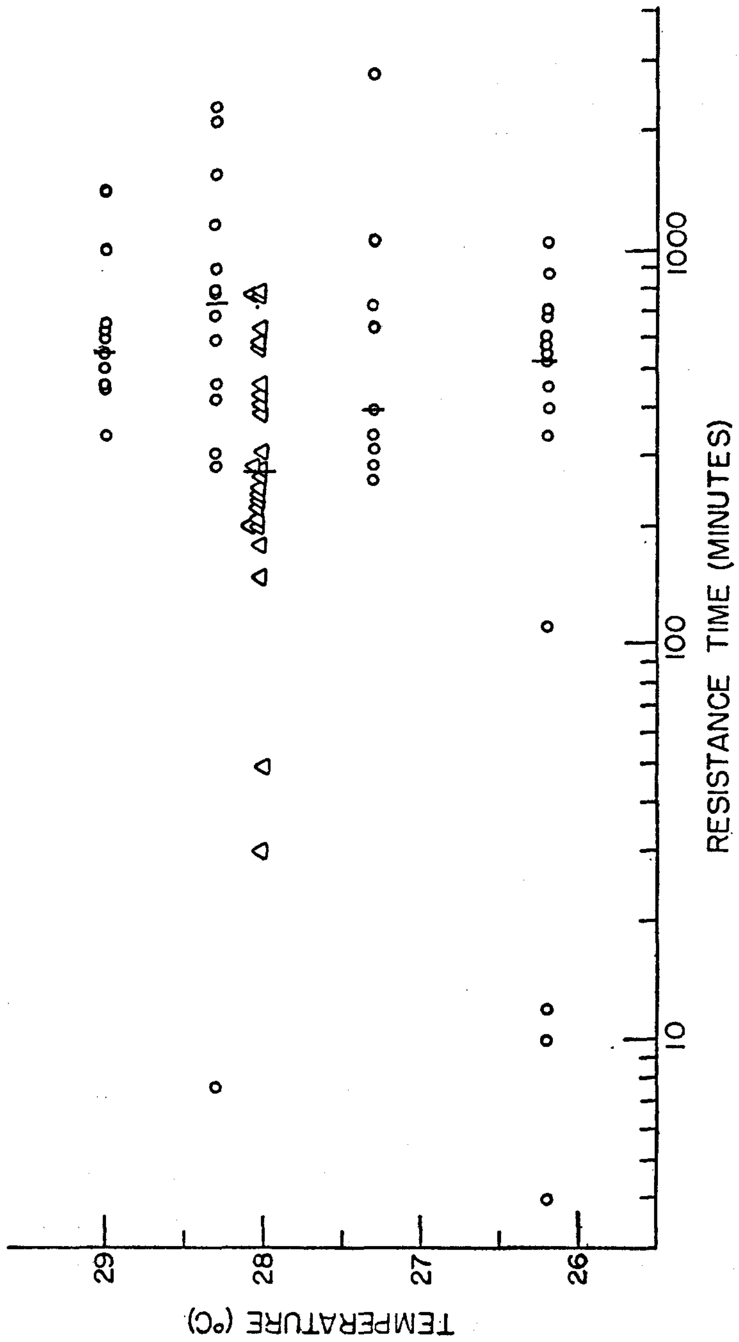

Figure 3. Resistance times of individual adult females (20mm or greater in standard length) acclimated to 28.0°C (Δ) and from the temperature gradient (o). Vertical bars show sample median resistance times.

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RATES OF RESPIRATION OF ESTUARINE FISH [1]

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ABSTRACT

A flowing-water respirometer was used to measure oxygen consumption of five species of estuarine fish: pinfish, *Lagodon rhomboides*; black sea bass, *Centropristes striatus*; Atlantic croaker, *Micropogon undulatus*; oyster toadfish, *Opsanus tau*; and mummichog, *Fundulus heteroclitus*. The relation between the amount of oxygen consumed and body size, in general, may be expressed by the formula $Q = a\ \text{Weight}^k$, where a and k are constants derived from experimental data for a species. Some investigators have stated that k values do not vary significantly among species of fish. In my investigations the value of k did vary significantly between certain species. The values obtained for k are given and the methods used to measure respiration rates are discussed.

INTRODUCTION

The rates of respiration of fish and the relation between these rates and the weight of the fish have been used to calculate energy requirements of populations of fish. Respiration is generally related to body weight by the equation $Q = aW^k$ where Q is the respiration rate or routine metabolism (Beamish and Mookherjii, 1964), a and k are constants for the species, and W is the weight of the fish. Some question concerning this relation exists, however. Winberg (1956) implied that respiration rate and weight are linearly related throughout life but Hickman (1959) believed that the relation changes with the development of the fish.

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