USE OF THERMAL GRADIENT TANKS IN THE DETERMINATION OF TEMPERATURE PREFERENDA OF SELECTED ESTUARINE FISHES

by

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ABSTRACT

The Use of Thermal Gradient Tanks in the Determination of Temperature Preferenda of Selected Estuarine Fishes

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The preferred temperature of juvenile Brevoortia patronus, Micropogon undulatus and Mugil cephalus and adult Menidia beryllina was determined in a 9.75m horizontal gradient tank. Juvenile fishes were used for all species except Menidia, and were acclimated to 20C. Individual fish were placed in a gradient tank with a 20 degree range and allowed to select a preferred temperature.

Preferred temperature was found to be 20-25C for Micropogon undulatus, 21-30C for Mugil cephalus, 17-27C for Brevoortia patronus, and 21-29C for Menidia beryllina.

The data collected indicates that many estuarine fishes may adapt efficiently to a wide temperature range. The comparison of field distribution data to experimentally determined temperature preference data shows a good correlation. However, significant field abundance of these fishes at temperatures below those found to be preferred indicates factors other than temperature influence fish distribution.

ACKNOWLEDGEMENTS

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INTRODUCTION

Distribution of fishes may be influenced by food availability, light, currents, and chemical content of the water (Lagler et al., 1962). Fishes are poikilothermic organisms whose body temperature depends upon the temperature of the surrounding water mass. Temperature, therefore, is another important factor influencing fish distribution (Lagler et al., 1962).

Fishes, when given a range of temperatures from which to choose, will seek the temperature optimum for their immediate needs (Lagler et al., 1962). This preferred temperature range, defined as the range of temperatures at which organisms tend to congregate or spend most of their time in the gradient or free-choice situation (Reynolds, 1977), is a valuable tool in evaluating fish distribution. Areas characterized by temperatures outside a preferred temperature range might be eliminated as fish habitats (Wallace, 1977). Ferguson (1958) interpreted laboratory temperature preference results and found that temperature alone can control the distribution of fishes.

Although generally constant within a species, the temperature selected by an organism is subject to considerable modification as the physiological state of the organism changes (Sullivan and Fisher, 1953). This selection may be due to the different physiological processes, each of which may have an optimum temperature. These differences may result in changes in preferred temperature, but in general the fish tends to seek a zone of efficient operation rather than a peak level (Cranshaw, 1977).

Despite the fact that temperature significantly affects distribution of estuarine fishes on the Texas coast (Gunter, 1945), very little temperature preference experimentation has been conducted on the fishes of this area. DeVlaming (1971) stated that preferred temperature data

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Format and style follow that of the Journal of the Fisheries Research Board of Canada were of little value unless the fishes in question have a range of temperatures available to them in their natural habitat. He further noted that estuaries are one area where such a temperature range is available.

Gunter (1945) listed the Atlantic croaker, *Micropogon undulatus* (Linneaus) and the tidewater silver side, *Menidia beryllina* (Cope) as two of the three most abundant species on the Texas coast. He further states that the Gulf menhaden, *Brevoortia patronus* Goode, the striped mullet, *Mugil cephalus* Linneaus and the Atlantic croaker are three of the four species comprising the greatest biomass in Texas coastal waters. The objective of this experimentation is to find the preferred temperature range for these four important species of estuarine fishes. These preferred temperature data are compared with existing field data for each species and the relation of the preferred temperature to the distribution of the fishes is evaluated.

LITERATURE REVIEW

Extensive literature reviews on thermal influences and temperature preference have been compiled by Coutant (1970, 1977). McCauley (1977) reviewed methods for thermal preference determination. Other literature on teleost thermal preferenda has been reviewed by Ferguson (1958) and Fry (1964).

Numerous laboratory studies of thermal preference of freshwater species have been conducted by such authors as Doudoroff (1938), Fisher and Elson (1950), Sullivan and Fisher (1953), Ferguson (1958), Garside and Tait (1958), Jones and Irwin (1962), Ogilvie and Anderson (1965), McCauley and Tait (1970), Otto et al. (1976), and Otto and Rice (1977). These works are not particularly pertinent to the present estuarine study except in methodology and no attempt will be made to review this freshwater literature.

Few data have been published on thermal preference of estuarine fishes. DeVlaming (1971) studied the temperature selection of the Pacific estuarine goby Gillichththys mirabilis. Reynolds and Thompson (1973) tested the effects of gradients of temperature, light, turbulence and oxygen on young Gulf grunion Leuresthes sardina. Wallace (1977) included temperature preference in his study of juvenile yellow-tail snappers, Ocyurus chrysurus.

Sullivan and Fisher (1954) tested effects of light on temperature selection in speckled trout, Salvelinus fontinalis. The effects of temperature and salinity acclimation on temperature preference of Tilapia nilotica was investigated by Beamish (1970). Chung (1977) performed extensive studies of thermal limits and other temperature related parameters of 65 estuarine species occurring on the Texas coast.

The mechanism for temperature selection is located in the central nervous system of fishes, apparently in the hypothalamus, according to Ogilvie and Fryer (1971). Roy and Johansen (1970) found that removal of the pituitary of goldfish did not change the temperature selection response. Fisher and Elson (1950) tested the effects of electrical stimulation on Atlantic salmon (Salmo salar) and speckled trout

(*Salvelinus fontinalis*) in various temperatures and found the highest response in the preferred temperature.

Preferred temperature results were used by Otto et al. (1976) to evaluate effects of a proposed power plant on alewife (*Alosa pseudoharengus*) in Lake Michigan. Gift (1977) reported the value of incorporating behavioral data, such as preferred temperatures into environmental impact assessment for heated effluents. He suggested projecting a thermal plume configuration for various seasons and using isotherms to evaluate preferred areas for each species. Otto and Rice (1977) found preferred temperature data to be valuable for environmental impact assessment and felt that laboratory studies were good indicators for this purpose.

MATERIALS AND METHODS

McCauley (1977) reviewed various methodologies for determining preferred temperature of fishes. He concluded that, although different apparatus and methods do influence preferred temperature values somewhat, variation due to age, size, season, physiological condition, and social factors is likely greater than experimental artifacts. Methodology used in this experimentation was based upon the work of various authors in an attempt to utilize the more effective aspects of each study and to allow possible comparison to other works.

Fishes used in the gradient studies were captured in February and March 1978 from estuarine tidal areas near Galveston, Texas. An attempt was made to seine areas where salinity was 20 ± 2‰ so that no salinity acclimation would be necessary. Fishes were taken in a 6.1-m bag seine and care was taken to minimize physical damage to the specimens. All organisms were placed in ice chests, taken to the lab, and gradually acclimated to the 20C temperature of the holding tanks.

Holding tanks were made of plywood coated with epoxy paint and measured 108cm x 70cm x 36cm. The tanks were heated to 20C with immersion heaters attached to relays controlled by Brooklyn adjustable contact thermometers. The 20C temperature was also used by Roy and Johansen (1970) and Ogilvie and Fryer (1971). Gift and Westman (1971) noted that this temperature showed a low rate of fungal diseases in fish and would also allow comparison with numerous other studies using 20C acclimation.

Salinity was maintained at 20‰, and a photo period of 12 hours was established using a Tork time control attached to a 30W fluorescent light above each tank.

The gradient chamber was a 9.75m x 48cm x 38cm plywood tank with a plexiglass front panel to allow observation of fishes in the chamber (Fig. 1). The observation area was covered with black plastic to avoid observer movements influencing fish behavior.

Each end of the tank was screened off to prevent fish entry. One end of the tank was heated by two large immersion heaters while the other end received cooled seawater from refrigeration tanks. Except

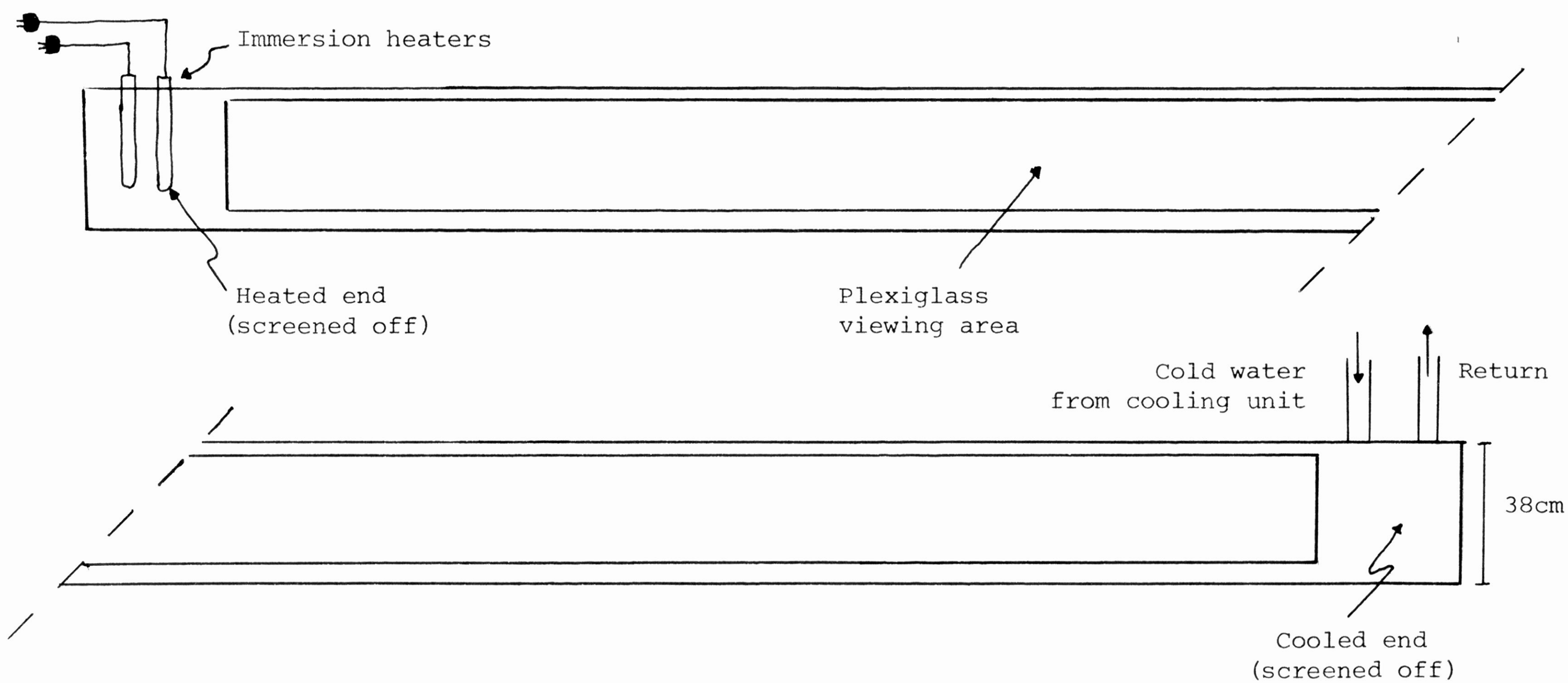

Fig. 1. Diagram of 9.75-m gradient chamber

for the addition of epoxy-painted cooling coils, refrigeration tanks were of the same size and construction as holding tanks. A 1-hp Copeland compressor provided cooling for the refrigeration coils. This cooled seawater was then pumped by a Teel submersible pump to the gradient tank. Another Teel pump took water from the cool end (slightly warmer than the refrigerated water) back to the refrigeration tanks. These pumps were controlled by relays and control thermometers similar to those used to maintain acclimation temperatures. Lighting for the tank was provided by a double row of fluorescent bulbs suspended 1m above the top of the tank. Plexiglass covers also were placed over the tank to retard evaporation, diffuse the lighting and prohibit fish from jumping out of the tank.

Vertical temperature lamination in the gradient chamber was alleviated by a row of air stones running the length of the tank. Silent giant pumps provided air to airstones placed 0.3m apart. Thirty airstones were used in the gradient chamber with three additional airstones placed in heated and cooled ends of the tank to mix these areas. Crushed oyster shell substrate was used to hide airstones and hoses.

Thermal preference was determined from ten replicate tests per species, with one fish in the gradient chamber per replicate. This allowed ease of observation and eliminated bias due to schooling (Jones and Irwin, 1962). No fish was tested more than once. Fishes were carefully transferred from the holding tanks to the 20C area of the gradient chamber. The tank was marked off into 20 sections representing the 20 degrees of temperature difference. Observation of the fish was begun after a 1-hour interval which allowed experimental organisms to explore the tank and select a preferred temperature (Doudoroff 1938; Fisher and Elson 1950; Garside and Tait 1958; Ogilvie and Anderson 1965; McCauley and Tait 1970; Roy and Johansen 1970; Wallace 1977). After this 1-hour interval, the temperature that the fish occupied was recorded every 20 sec for 10 min. The animal then was removed and its standard length recorded in millimeters.

Control experiments were run with three specimens from each species. The same test procedure was followed as described above, except that the gradient tank was maintained at 20C. The tank was marked off into 20 equal sections and the percentage of time spent in each section was noted to assure no preference for a particular section of the tank.

Data for all four species were combined in analysis of control experiments. Individual fishes deviated from a random distribution, but the combination of all control fishes show a more random distribution (Beamish, 1970). The overall frequency of occurrence at each temperature for each species was determined by combining data from the ten replicates per species. A fish was determined to have a preference for a particular temperature if it showed a frequency of occurrence of more than 5%. This 5% level would be the expected frequency in a random distribution with twenty sections. Individual temperature mean, standard deviation and range also was graphed to show variation within a species. Finally, thermal preference data generated during this study were compared to those from field studies conducted along the Texas coast.

RESULTS AND DISCUSSION

Test species subjected to control conditions exhibited no apparent preference for any section of the gradient chamber. Highest frequency of occurrence of control fishes in a particular tank section was noted for sections 1 and 12 (Fig. 2). Section 1 was at an end of the tank while section 12 was near the middle. Numerous authors have reported an "end of tank" bias (Doudoroff 1938; Badenhuizen 1967; Roy and Johansen 1970). Jones and Irwin (1962) felt that the distance the fish traveled to enter and leave the end chambers caused this bias, and that the ends also might afford a false sense of security for fishes. Ogilvie and Anderson (1965) stated that the end peaks were probably due to a response of fish to the corners and end surfaces. DeVlamming (1971) found this tendency to be so pronounced that he gave even more weight to his temperature preference data, as this tendency had been overcome by a temperature response.

The high frequency of occurrence of test fishes in section 12 was due to a 14mm SL croaker which exhibited very little movement in the tank. This individual may have been damaged or may not have been strong enough to swim to other sections of the tank. Had a larger number of control organisms been tested, there may have been a random selection of tank sections by fishes.

Juvenile Atlantic croaker was a relatively slow-swimming species which exhibited a very definite preferred temperature range. Frequency of occurrence peaked between 20 and 25C (Fig. 3).

Individual variation within Atlantic croaker is shown in figure 4. This species was very specific in its temperature selected, and the narrow ranges for these individuals indicate a tendency to stay within a definite temperature range.

Atlantic croaker exhibited a marked tendency to avoid temperatures below 15C and above 28C (Fig. 3).

Juvenile striped mullet exhibited a wider temperature range than that of Atlantic croaker (Fig. 5). Mullet tended to avoid temperatures above 32C (Fig. 5).

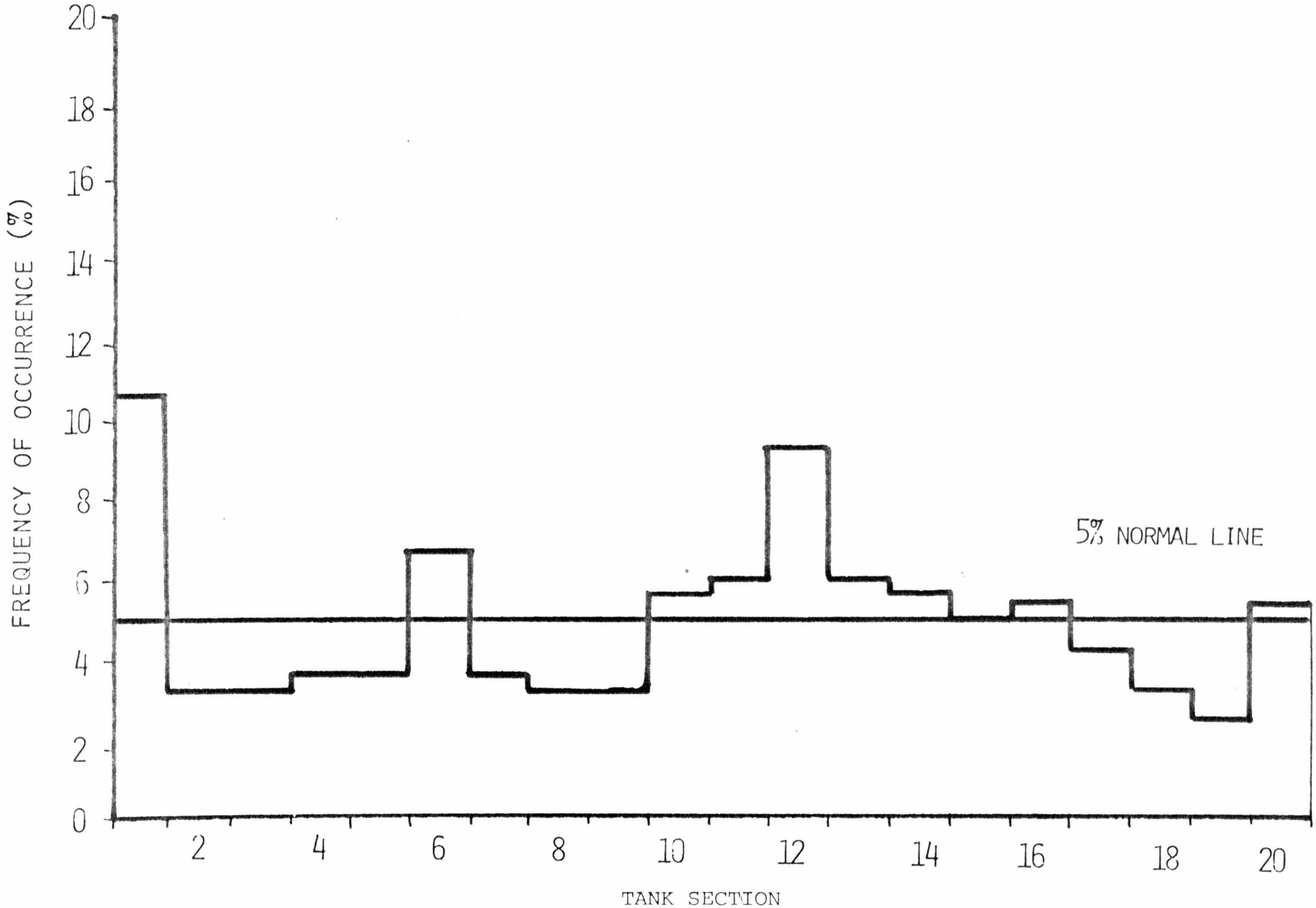

Fig. 2. Frequency of occurrence of control fishes (all species combined) in sections of a gradient chamber with constant 20C temperature.

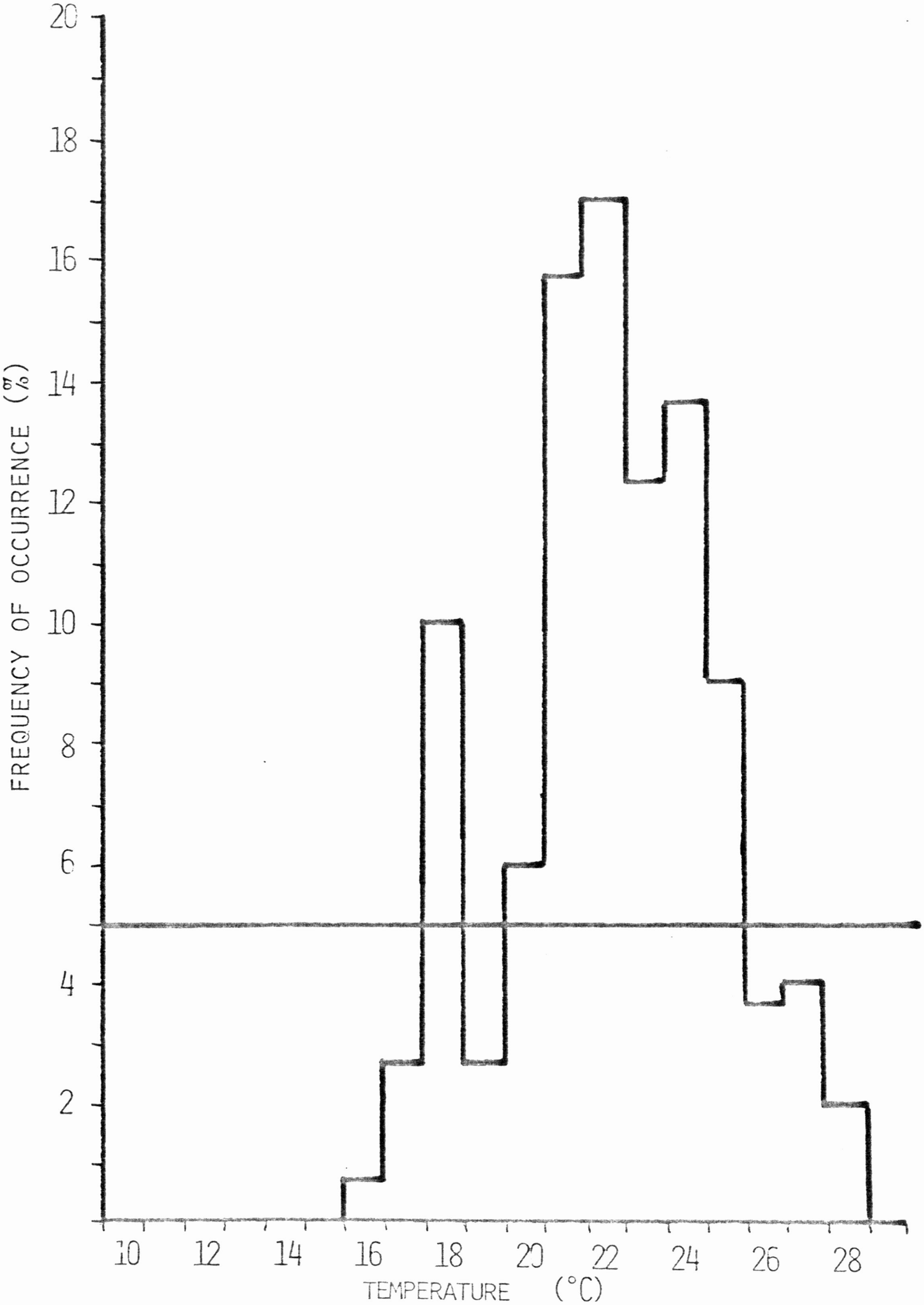

Fig. 3. Frequency of occurrence of juvenile *Micropogon undulatus* in a 10-30C thermal gradient chamber

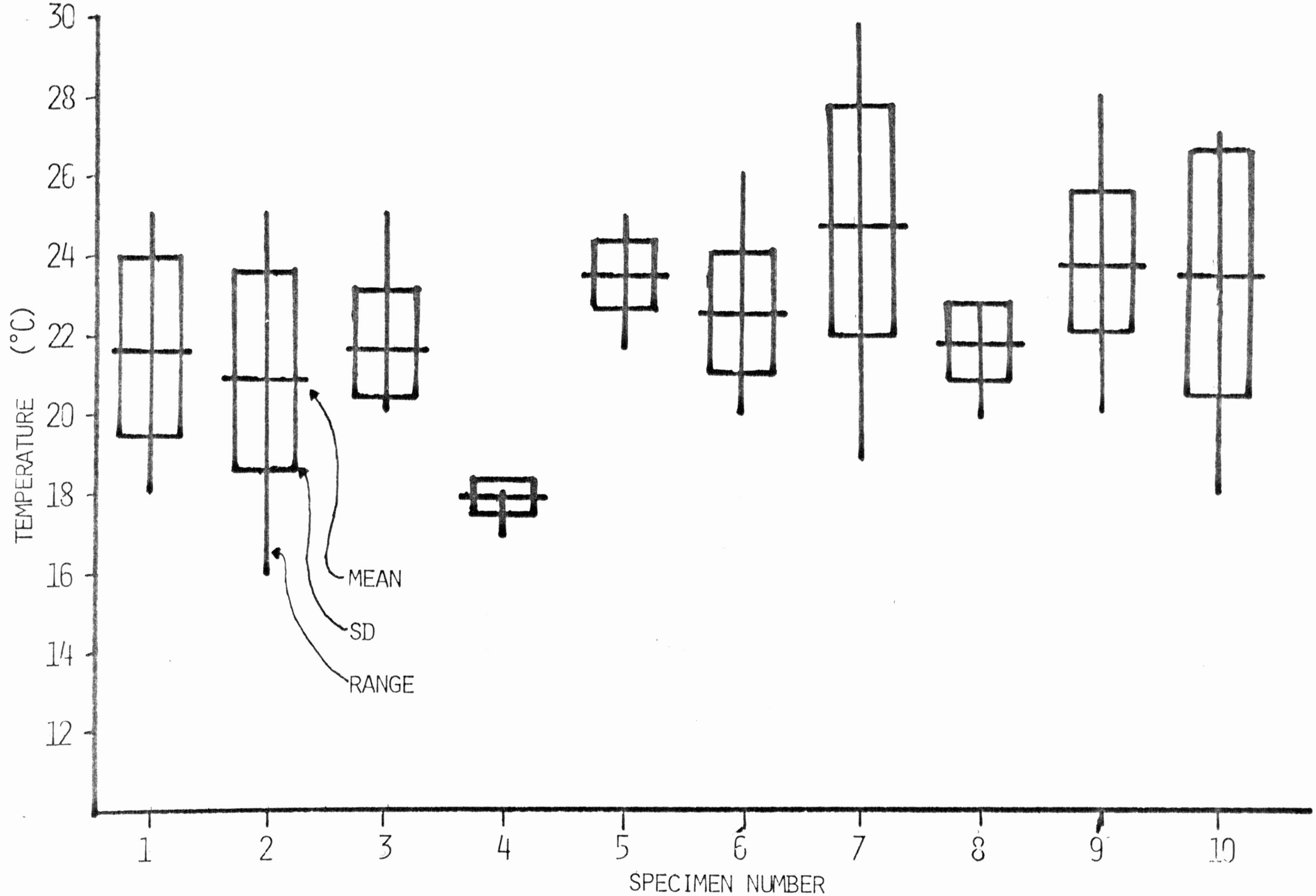

Fig. 4. Mean temperature, standard deviation (SD); and temperature range for individual juvenile *Micropogon undulatus* in a 10-30C thermal gradient chamber

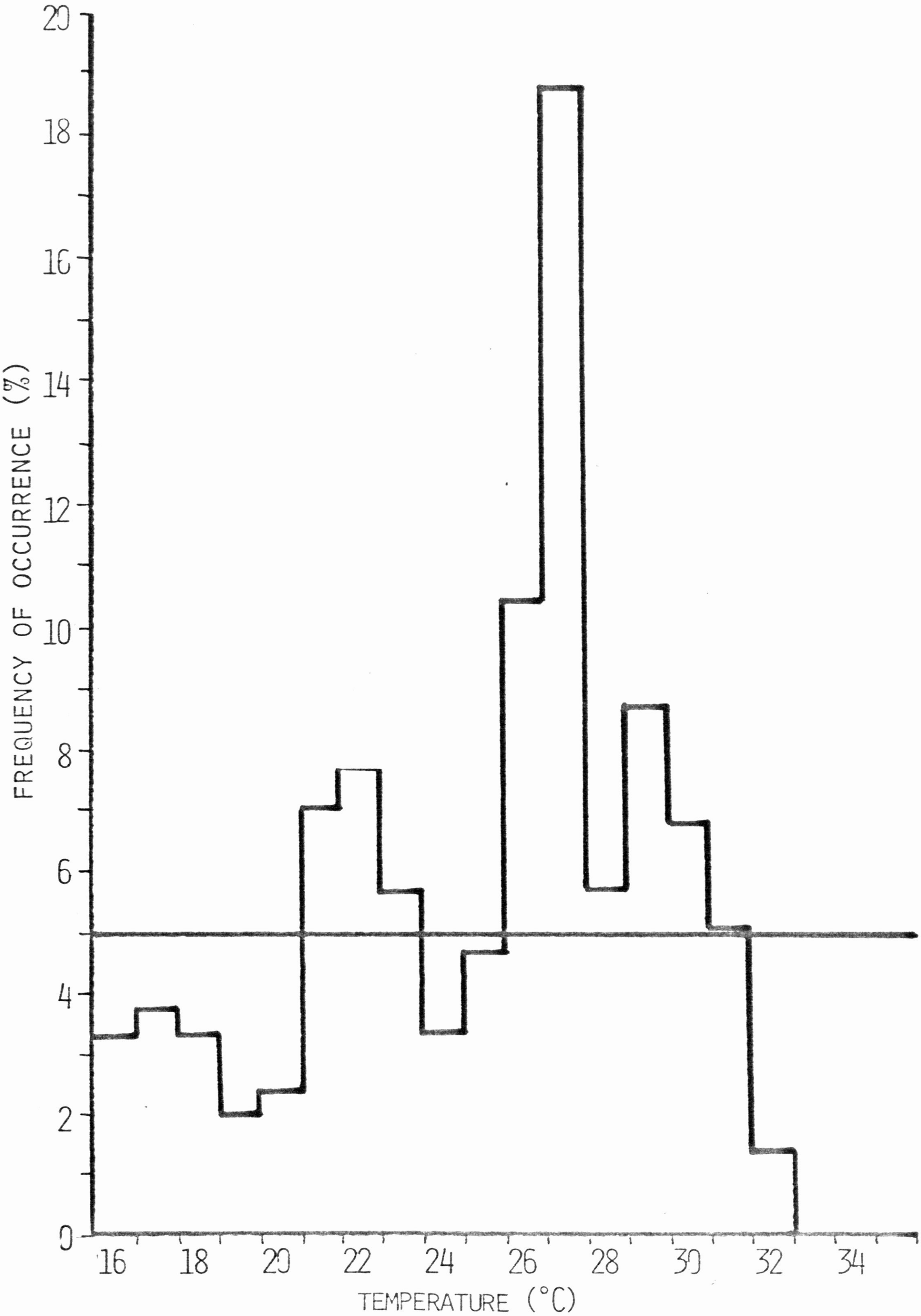

Fig. 5. Frequency of occurrence of juvenile *Mugil cephalus* in a 16-35C thermal gradient chamber

Although a lower avoidance temperature for this species was not determined, there was a definite preferred temperature range between 21 and 30C. Highest frequency of occurrence was noted at 27C.

Figure 6 shows the variation within the species for striped mullet. This species seems to contain some individuals which prefer a notably cooler temperature than that of the majority of the species. Most of the individuals do show a preferred temperature within the previously stated 20-30C range.

Tidewater silverside also showed a very wide temperature range in this experimentation with an upper avoidance level at 35C (Fig. 7). The species seems to prefer temperatures between 21 and 29C with no notable peaks within this range.

Silversides were much stronger swimmers than other species tested and tended to cover a wide area of the tank faster. The wide temperature ranges depicted in Figure 8 are indicative of this superior swimming ability and the rapid adaptibility of this species to temperature variation. Nevertheless, individuals tended to stay within the 21-29C preferred range.

Juvenile Gulf menhaden exhibited upper and lower avoidance temperatures of 29 and 11C, respectively (Fig. 9). There was a definite preference for temperatures between 17 and 27C with peak frequency of occurrence noted at 23C.

Menhaden usually showed higher frequency in temperatures within the stated preferred temperature range (Fig. 10). This fish was not a strong swimmer and generally did not have a wide range within the tank.

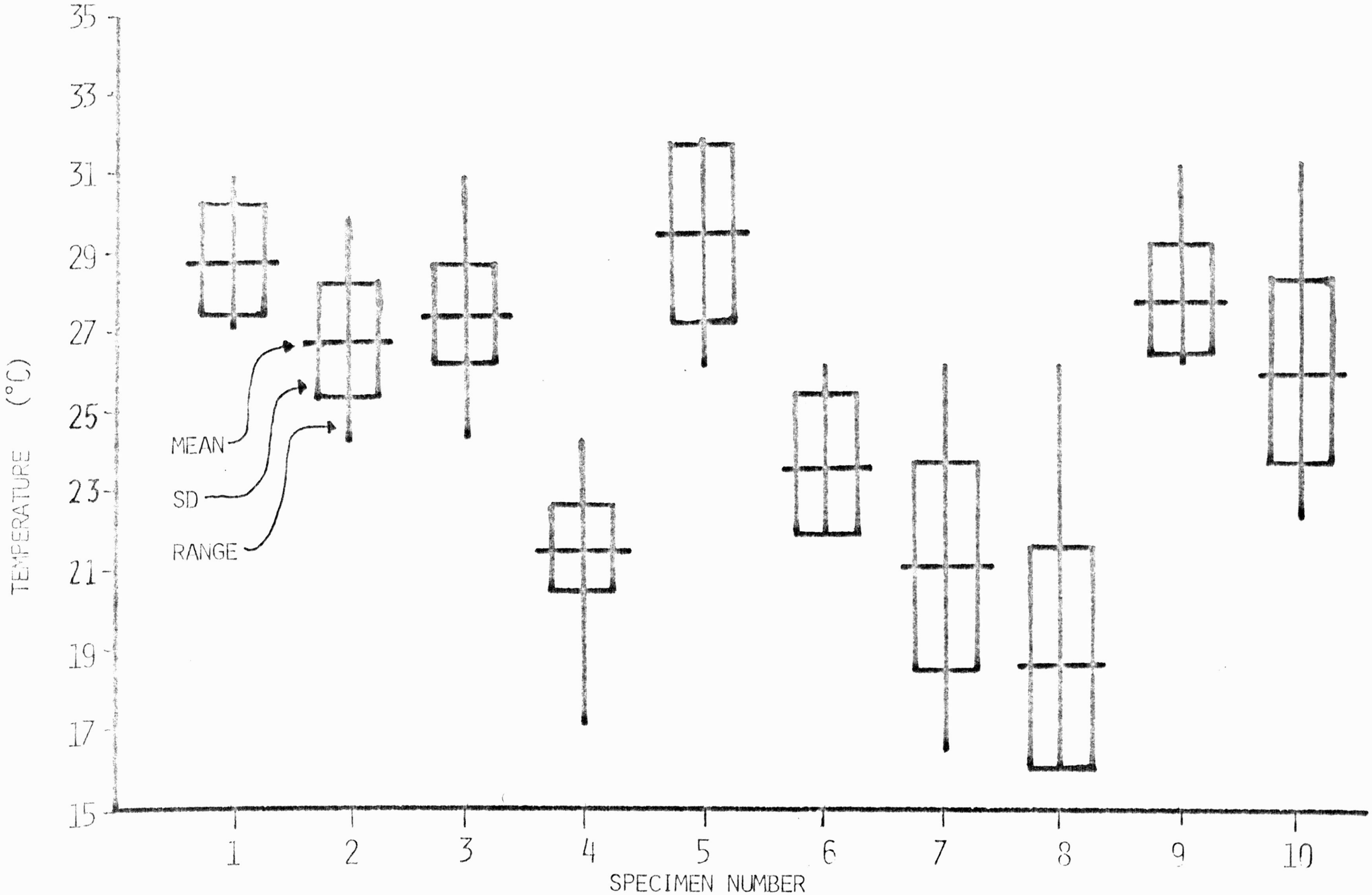

Fig. 6. Mean temperature, standard deviation (SD), and temperature range for individual Mugil cephalus in a 16-35C thermal gradient chamber

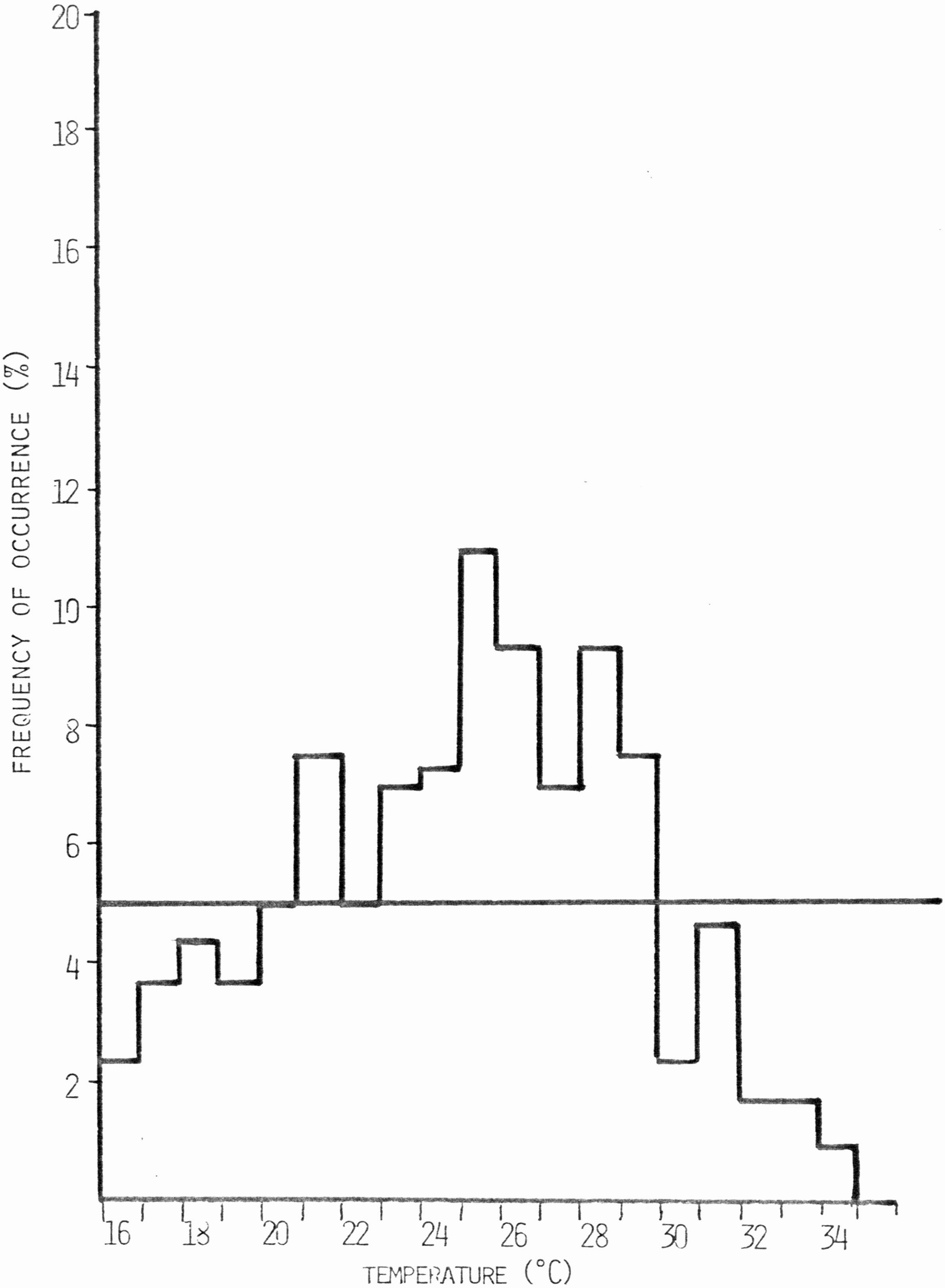

Fig. 7. Frequency of occurrence of juvenile <u>Menidia beryllina</u> in a 16-35C thermal gradient chamber

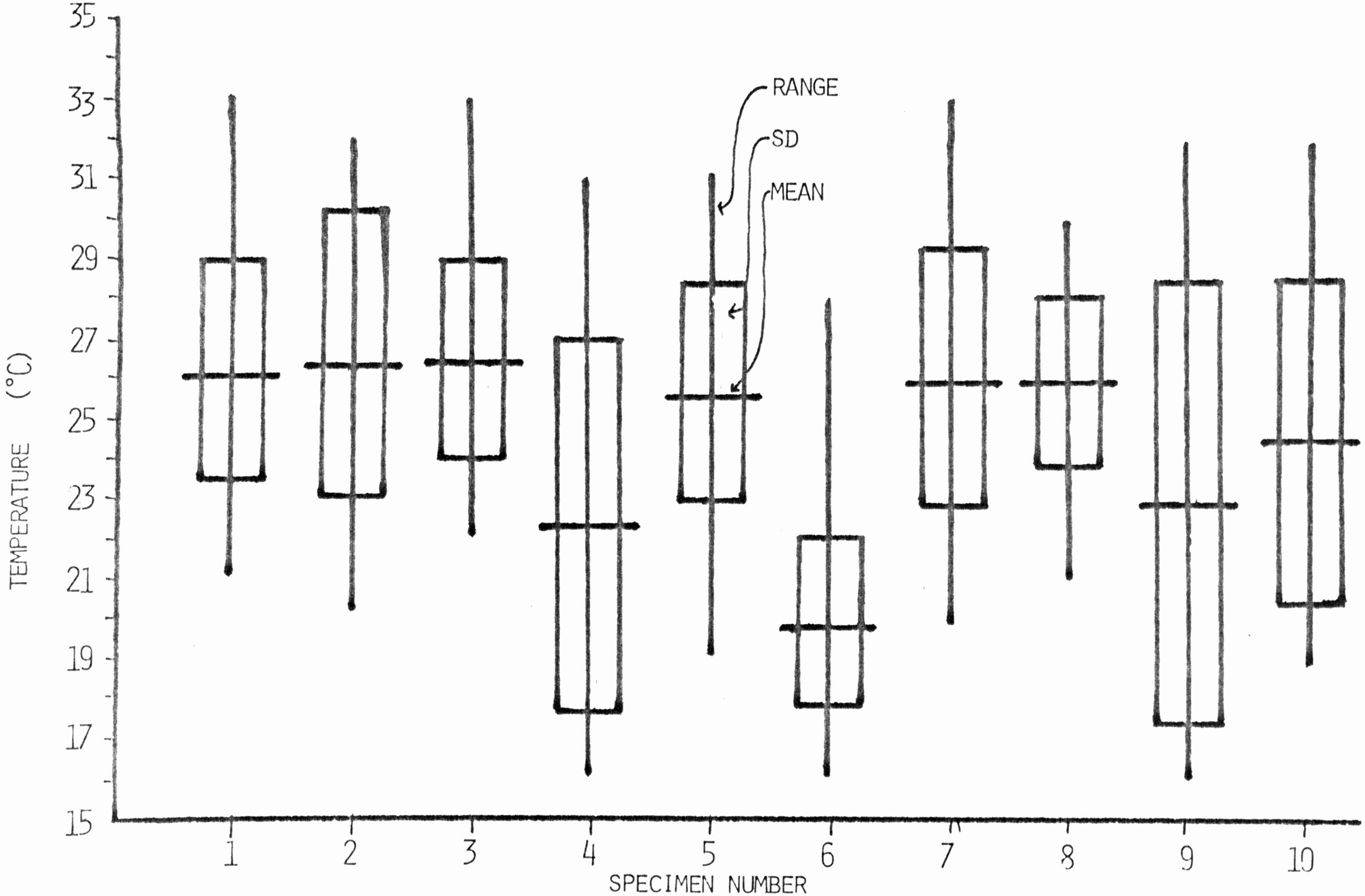

Fig. 8. Mean temperature, standard deviation (SD), and temperature range for individual *Menidia beryllina* in a 16-35C thermal chamber

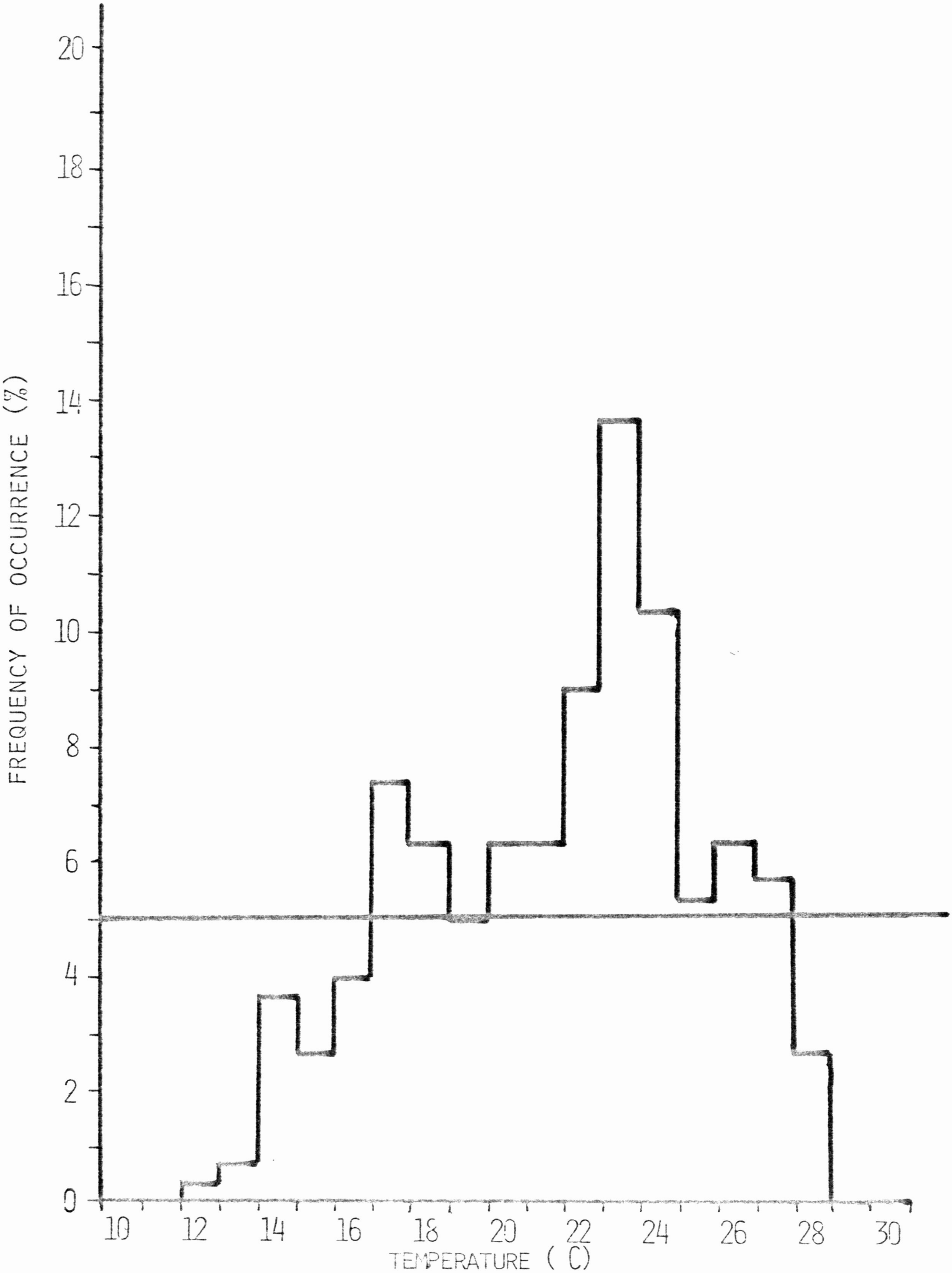

Fig. 9. Frequency of occurrence of juvenile Brevoortia patronus in a 10-30C thermal gradient chamber

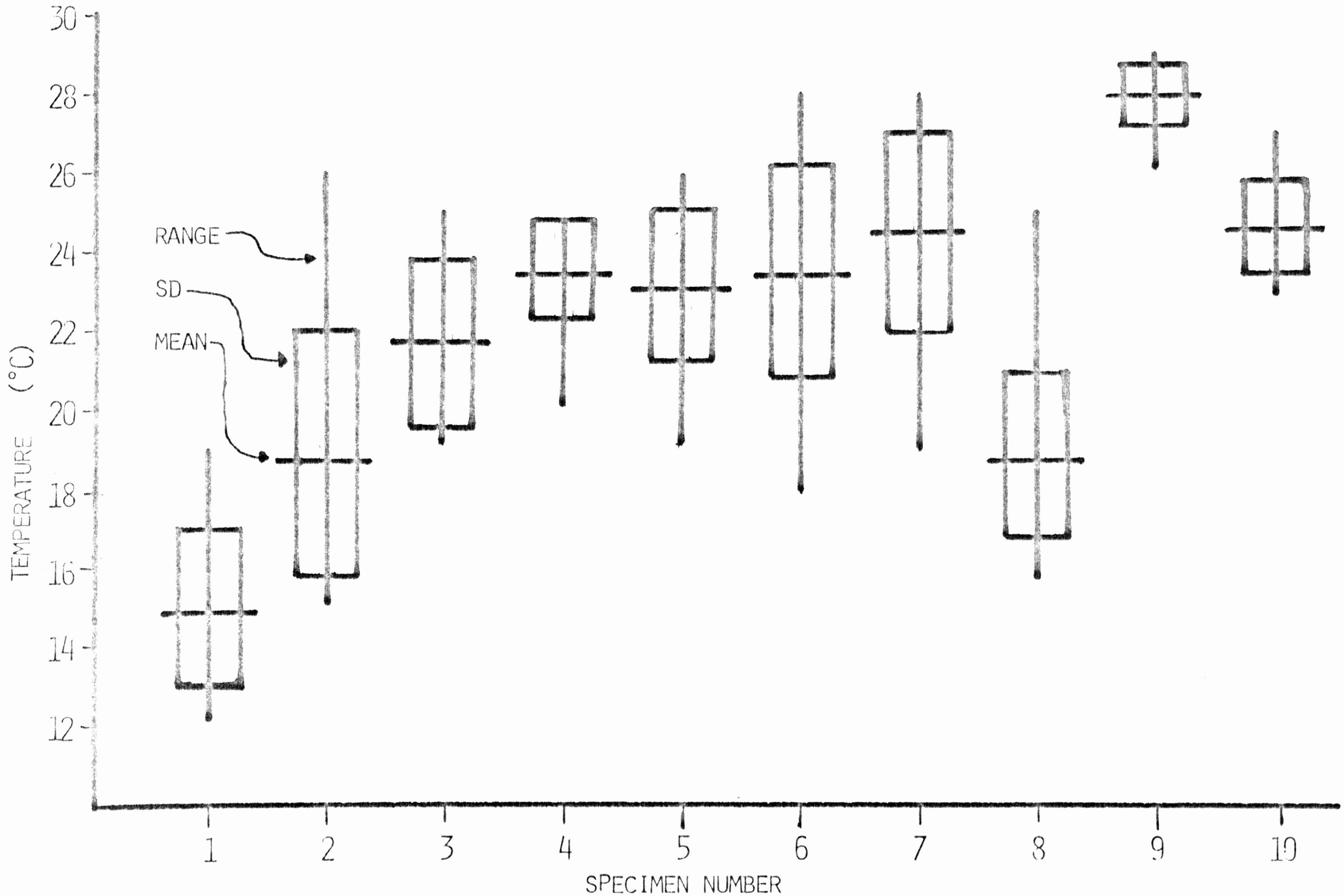

Fig. 10. Mean temperature, standard deviation (SD), and temperature range for juvenile Brevoortia patronus in a 10-30C thermal gradient chamber

CONCLUSIONS

Fishes of the four species tested would be expected to be found in their preferred temperature if presented with a temperature range in the field. Such a temperature range might be found in an estuary or power plant thermal effluent. Experimental data indicate that there are other factors which influence distribution of the four species tested to a greater degree than does temperature. This conclusion is drawn from the fact that these fishes are sometimes common in temperatures which experimental data indicate they do not prefer.

Field studies of Micropogon undulatus (Fig. 11) indicate that the ranges in which this species is taken in trawl and seine samples usually include preferred temperatures determined in this study. The data presented by Parker (1971) included many juvenile croaker, yet the field preference is significantly lower than the laboratory temperature perference. This may indicate that the migrations of young croaker are not dominated by temperature. Many of the fishes in the other studies were older fishes whose preferred temperature range seemed to coincide very well with data recorded for juveniles in the present study. This fact tends to indicate that juvenile croaker may be heavily influenced in their migrations by factors other than temperature.

Field temperature data for Mugil cephalus are indicated in Fig. 12. The 20-30C preferred temperature range established during the present study falls within the temperature range noted in field studies.

Very few studies on the Texas coast include a temperature range for tidewater silverside. This is primarily due to the fact that this species is a nearshore inhabitant which is seldom taken in trawl studies. A few studies which include seine data provide temperature ranges (Fig. 13) but these do not coincide well with the preferred temperature range established during the present study. These differences appear to indicate that this species is not as significantly influenced by temperature as by other environmental factors. In addition, it can be seen from field data that silverside do venture outside their preferred temperature. Most studies incorporating this

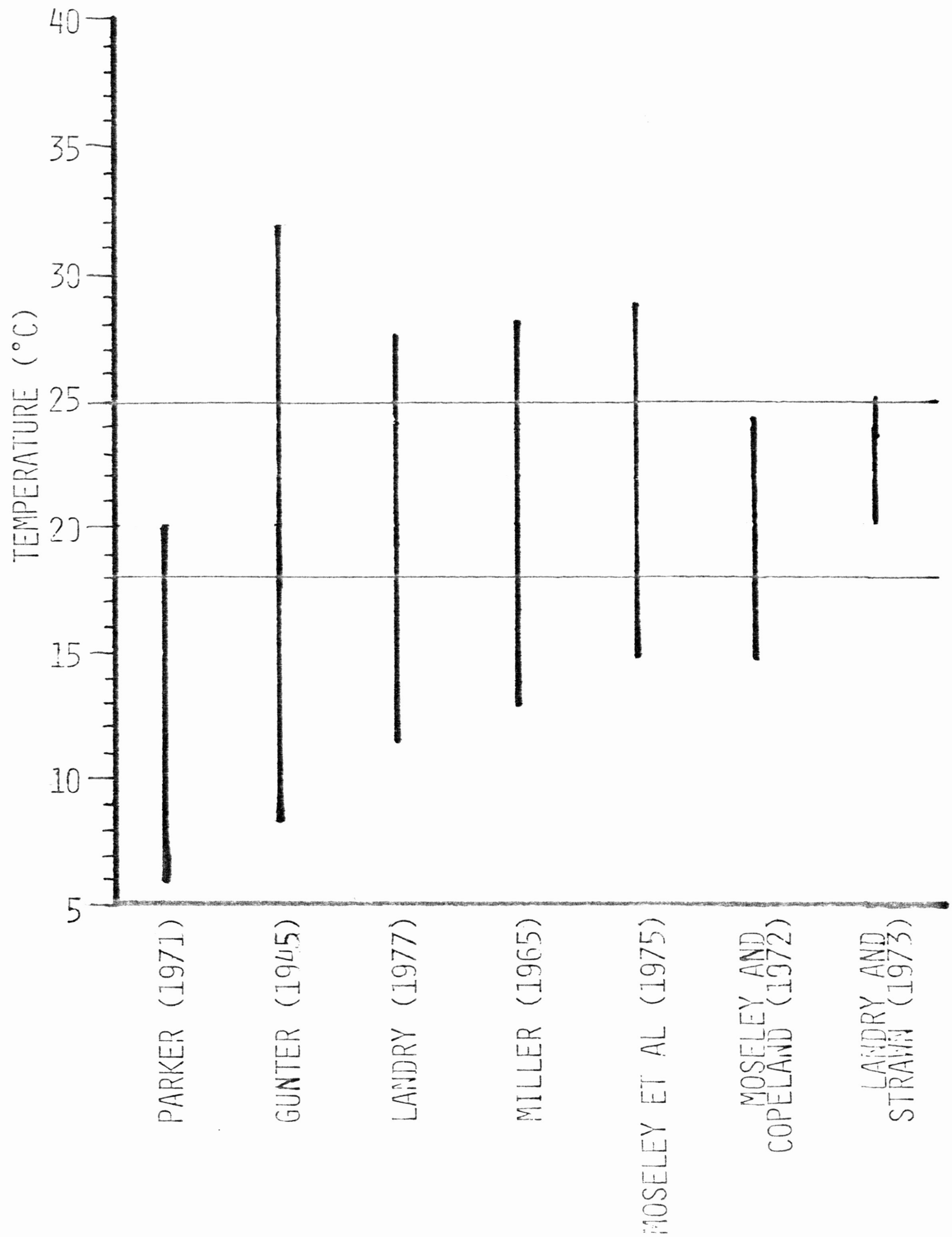

Fig. 11. Comparison of *Micropogon undulatus* field (vertical lines) and gradient chamber (horizontal lines) preferred temperature ranges.

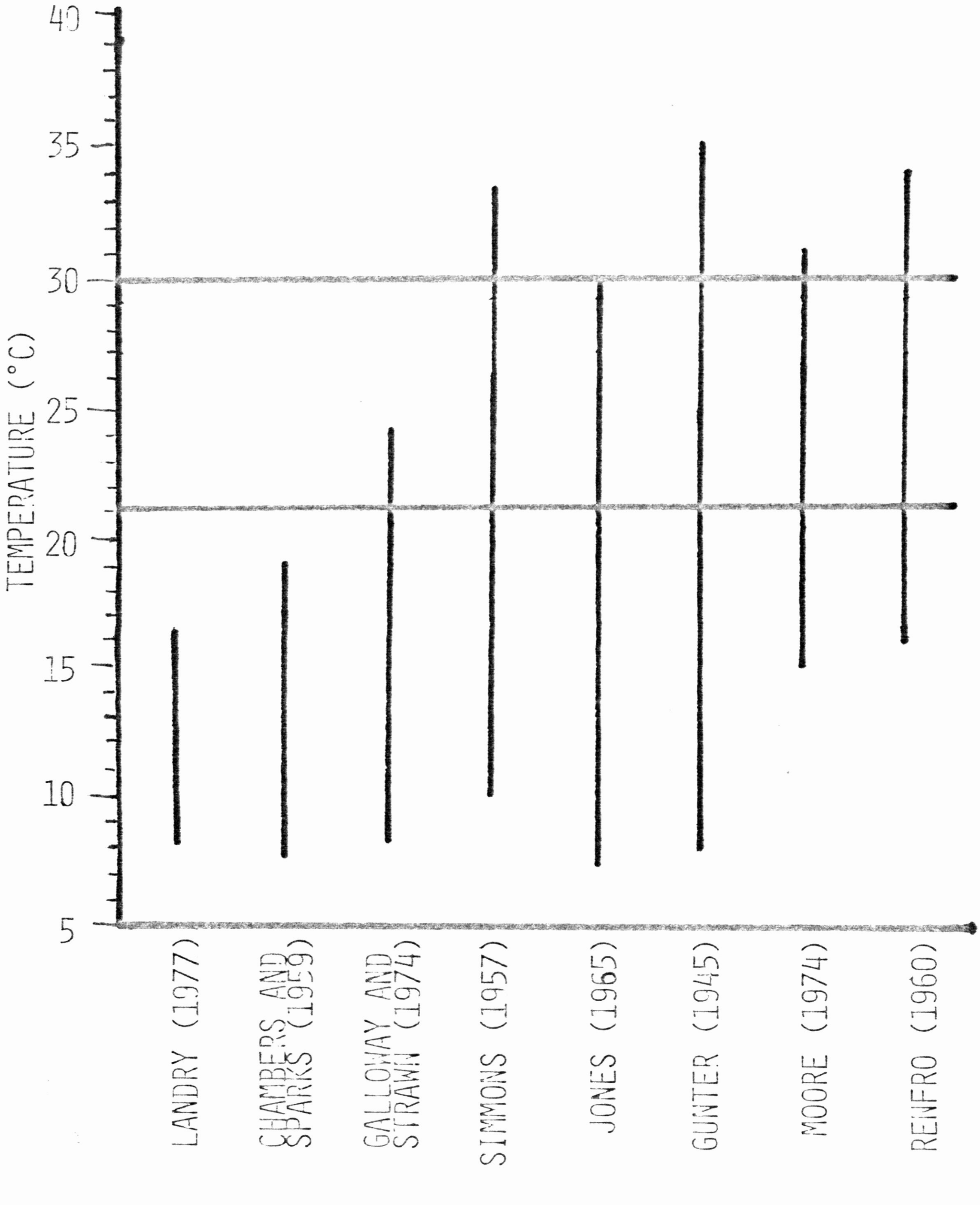

Fig. 12. Comparison of Mugil cephalus field (vertical lines) and gradient chamber (horizontal lines) preferred temperature ranges

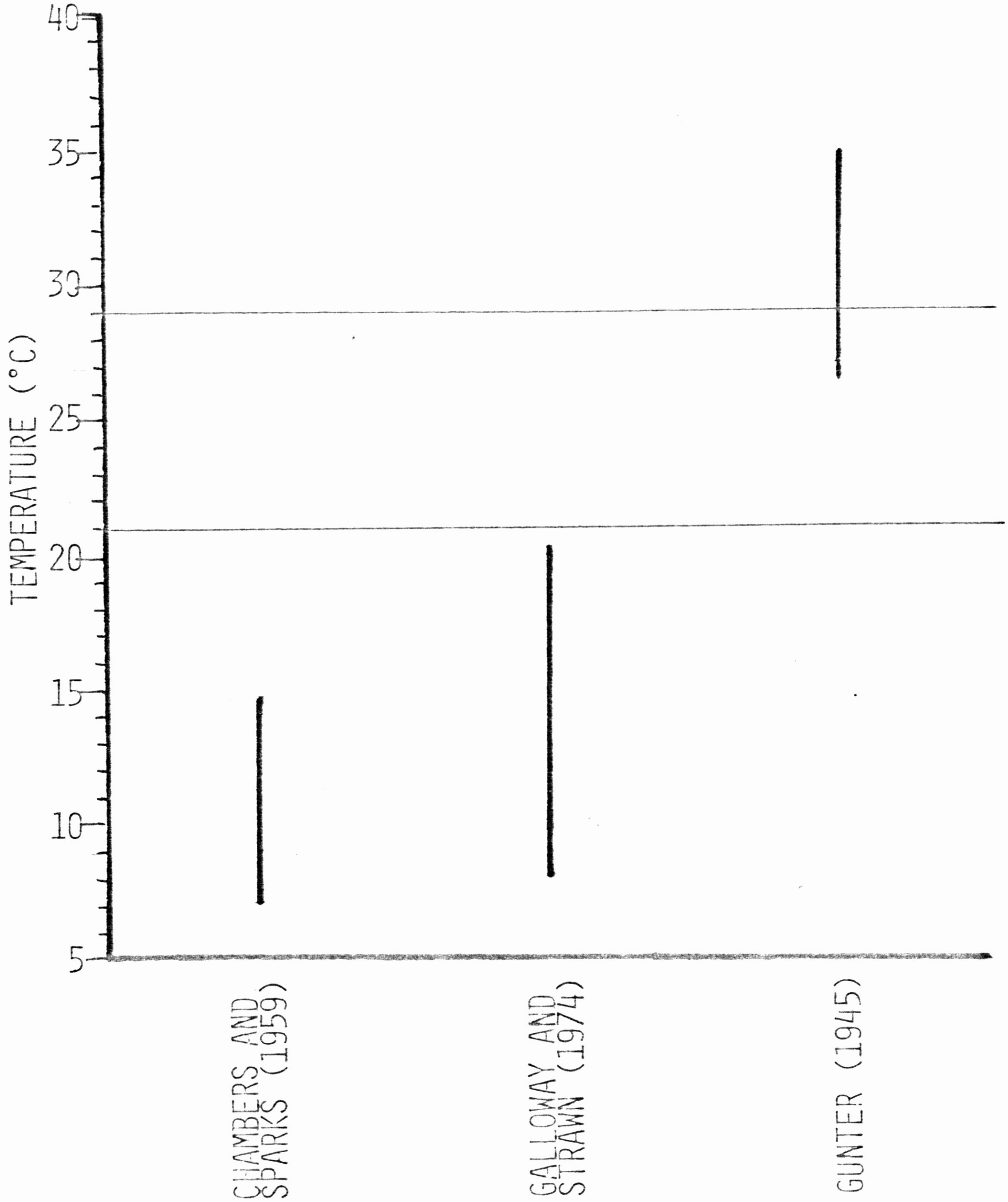

Fig. 13. Comparison of *Menidia beryllina* field (vertical lines) and gradient chamber (horizontal lines) preferred temperature ranges

species reported that it was present at almost all temperatures.

The numerous field studies on *Brevoortia patronus* (Fig. 14) report that the laboratory preferred temperature data coincides well with similar data from the field. Almost all reported ranges of occurrence for this species include the preferred temperature range noted during the present study. The fact that almost all field studies include the 17-27C preferred range found in this study indicates a good correlation between temperature preference data and the known distribution for *Brevoortia patronus*.

Heated effluents from power plants represent areas of warmer than ambient temperature during winter months. Estuarine fishes preferring temperatures warmer than ambient waters will tend to move into its preferred temperature. Because temperature is not the only factor involved, there may be other factors which will cause the fish to move to areas of unfavorable temperature. However, if food, light, and water conditions are equal, the fishes should tend to stay within the heated water.

All fishes tested in this study showed a fairly wide temperature preference range which was indicative of their ability to thrive in the rapidly fluctuating temperatures of Texas estuaries. Although only four species of fishes were tested, these taxa are a major component of the estuarine biomass and their behavior is generally representative of most estuarine ichthyofauna.

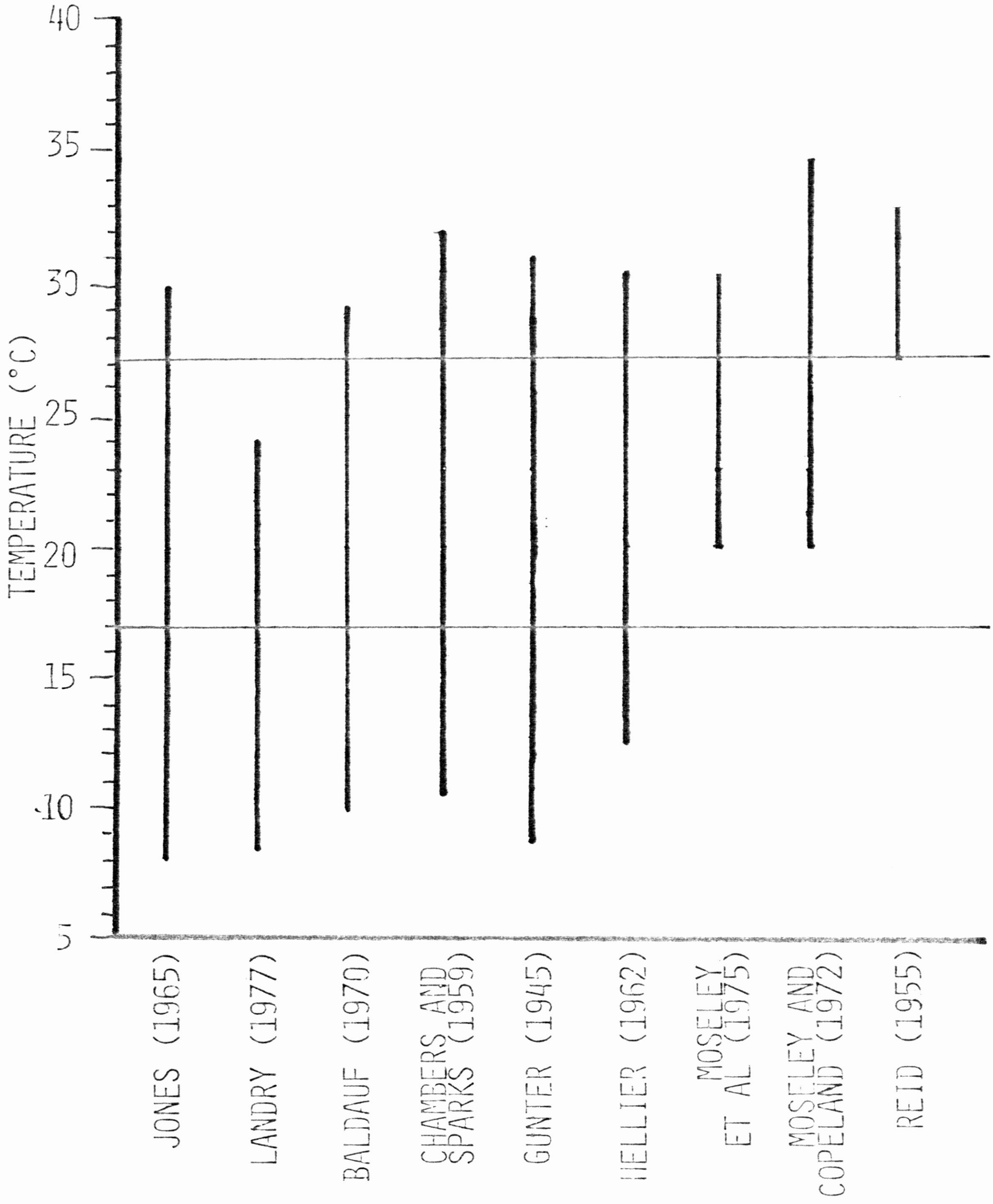

Fig. 14. Comparison of Brevoortia patronus field (vertical lines) and gradient chamber (horizontal lines) preferred temperature ranges

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