TEMPERATURE BEHAVIORAL RESPONSES OF THE AMERICAN EEL, ANGUILLA ROSTRATA (LESUEUR), FROM MARYLAND

Theresa Y. BARILA & Jay R. STAUFFER, Jr.

Appalachian Environmental Laboratory, University of Maryland, Center for Environmental and Estuarine Studies, Frostburg State College Campus, Gunter Hall, Frostburg, Maryland 21532

Received August 8, 1979

Keywords: *Anguilla rostrata,* American cell, temperature preference, behavorial response, influence of acclimation temperature

Abstract

Acute temperature preference tests were conducted with American eels, *Anguilla rostrata,* collected from Maryland's eastern shore. Eels were acclimated to temperatures of 6, 12, 18, 24 and 30°C. Final temperature preferendum was 16.7°C. Data differ from the temperature responses of the majority of fishes tested to date in that acclimation temperature did not influence selected temperatures. Similar results were obtained for various other fishes *(Oncorhynchus, Salmo, Salvelinus)* by other investigators. Behavioral responses at various acclimation temperatures were observed.

Introduction

The investigation of thermal behavioral modifications of aquatic organisms is a fundamental requirement for the establishment of temperature standards (Stauffer *et al.,* 1976; Gift, 1977). Discharges associated with waste heat and power production technology may cause significant behavioral modification of fishes (Hall *et al.,* 1978). Much attention has been focused on establishing thermal preference of important game and commercial species, but temperature requirements of forage species have been largely ignored (Gift, 1977).

The American eel, *Anguilla rostrata* (Lesueur), is an important forage species which contributes to the diet of larger fishes (Scott & Crossman, 1973); a predator species on commercially important invertebrates (Wenner & Musick, 1975); and a commercial species in Japan, Canada and parts of the United States (Fahay, 1978). Eels are responsible for a considerable loss to the nutrient cycles of lakes and streams due to their large organic intake, large numbers, lengthy stay in freshwater and subsequent seaward migration (Smith & Saunders, 1955).

The objective of this paper is to report on temperature preference tests and behavior responses of the American eel collected from Maryland's eastern shore.

Materials and methods

Anguilla rostrata were collected in December, 1978, in Mason's Branch of Tuckahoe Creek, tributary to Choptank River, Maryland, using a 220 DC electroshocker. Eels were held in 38 liter glass aquaria in refrigerated units. Photoperiod control was regulated by electric timers using Vita-lites (fluorescent lights emitting wavelengths equal to solar radiation on a clear day). Constant aeration was supplied by an electric air compressor. Aquaria were constantly filtered with air-filtration corner units and water temperatures were maintained with individual thermostatic heaters.

Fish were acclimated to temperatures of 6, 12, 18, 24 and 30°C at a rate of 1°C per day (Brett, 1944) and behavioral responses were observed. After the desired acclimation temperature was reached, the eels were held at that temperature for five days. Water in aquaria at temperatures exceeding 18°C was changed on alternate days to prevent adverse effects caused by synergistic effects of elevated temperatures and metabolic waste.

Temperature preference trials were conducted in an aluminum trough (3.6 x .203 x .254 m) coated with a non-toxic epoxy paint patterned after Meldrim & Gift (1971). Twelve heat lamps located under the trough and set at progressively higher intensities with rheostats, from one end of the trough to the other, established a temperature gradient in the trough. Twenty-two thermistors equally distributed along the trough were connected to a multichannel telethermometer which recorded the temperature gradient. Cold water introduced from a circulating water bath at one end of the trough increased the temperature range of the horizontal gradient. Water was not recycled to avoid a behavioral response due to water conditioned by previous test specimens. Water depth was approximately 2 cm. Overhead Vita-lites illuminated the test apparatus.

Hydrobiologia 74, 49-51 (1980). 0018-8158/80/0741-0049$00.60.

Eight eels at each of the following acclimation temperatures were tested individually: 6, 12, 18, and 24°C. Two eels were tested individually at 30°C. Each test specimen was introduced to the gradient at a point corresponding with its acclimation temperature. A 40-minute orientation period preceded each test. The temperature and position of each fish relative to the twenty-two thermistors were recorded at ten-second intervals for twenty minutes via overhead morrors. All specimens were weighed and measured after testing.

In an attempt to determine preference temperatures at each acclimation temperature, measurement of central tendency of the data was examined by looking at the mean, mode and median. Data were analyzed with exponential, linear and quadratic models. The coefficient of multiple determination, R^2, was used to indicate that proportion of the total variation in the data explained by the fitted regression model (Walpole & Myers, 1972).

Results and discussion

Temperature preference response

Temperature preference responses of all fish tested are depicted in Fig. 1. The mean of the 120 observations per test was determined to be the preferred temperature for that particular response.

In this study, the best fit was determined to be $\ln P = .03A + 2.27$, which explained only 32.9% of the raw data (mean sum of squares: 197.9; residual sum of squares: 403.4). Based on the low value of the R^2 term and an examination of the histogram, it was determined that acclimation temperature did not influence preferred temperature for the American eel. Fry (1947) defined the final temperature preference as that point where the preferred temperature equals the acclimation temperature, and where an animal will finally select regardless of its acclimation temperature, given sufficient time and an expanded temperature gradient. However, McCauley (1977a) suggested that when no relationship between preferred temperature and acclimation temperature can be discerned for acute preference data, that the overall mean of the data should be used to estimate the final temperature preferendum. Using this technique, the final temperature preferendum for *Anguilla rostrata* was 16.7°C. It should be noted that other investigators have shown that acclimation temperature does not influence preferred temperature for certain salmonids (McCauley & Tait, 1970; Garside & Tait, 1958).

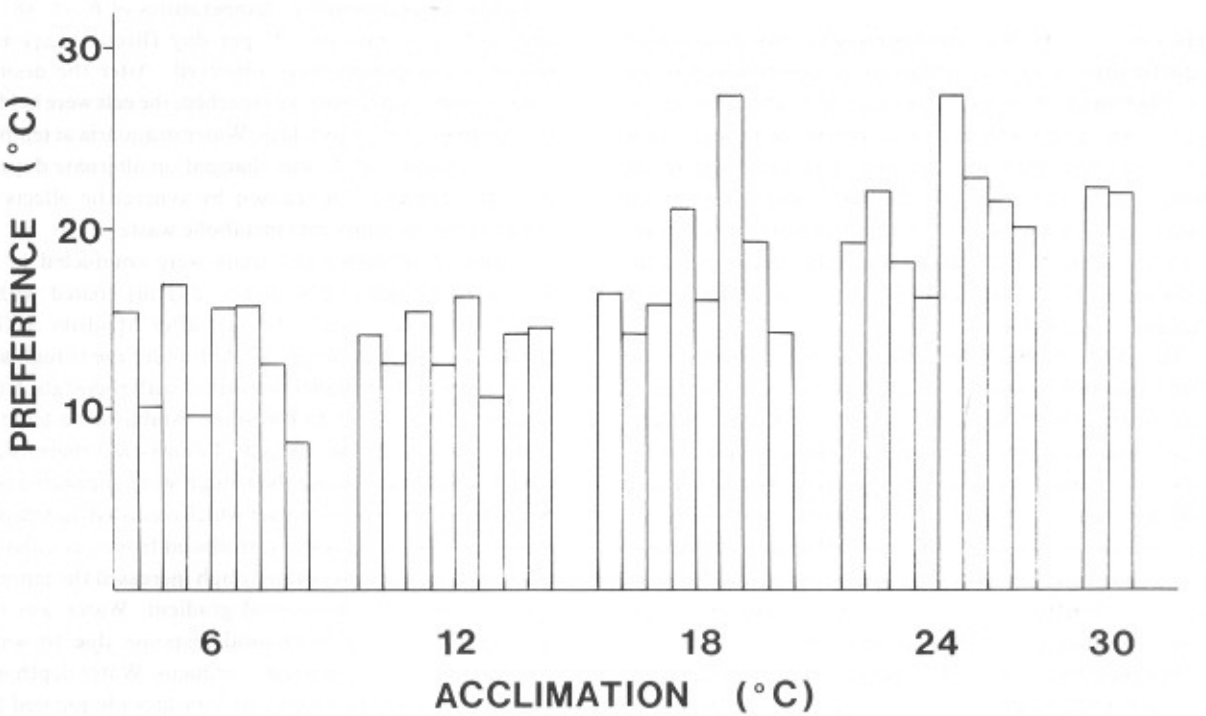

Fig. 1. Mean preferred temperatures of individual eels at each acclimation temperature.

Behavioral observations

Behavioral data on *Anguilla rostrata* are limited. During the time eels were held in our laboratory, three behavioral responses were observed. At temperatures below 18°C, congregations of eels into clumps in corners of the aquaria occurred. Crowding of eels has been previously reported by Smitt (1895 in: Nyman, 1972) and Nyman (1972), and may be assumed to be an adaptation to cold, since relatively less heat is emitted by a larger heat-radiating body (Nyman, 1972).

A second behavioral response noted was aggressive display. Larsen (1970 in: Nyman, 1972) attributed this to territorial defense. Nyman (1972) reported similar findings of direct aggression at temperatures above 17°C. Aggressive behavior was observed in this study at temperatures above 18°C. Biting and gripping of tail and head by an aggressor resulted in wounds which became infected at temperatures above 24°C and resulted in the loss of several test specimens.

The third observation involved initiation of feeding while held in aquaria. Bruun (1963) reported feeding did not occur until temperatures of at least 10°C were reached. Nyman (1972) reported 14°C as the minimun temperature for active searching for food. Nyman (1972) considered non-feeding may be due to short acclimatization time. In this investigation food was presented daily, but feeding did not occur at temperatures lower than 14°C.

Summary

Information on the responses of fishes to natural temperature gradients can be obtained by studying responses to laboratory gradients where factors can be rigidly controlled (McCauley, 1977b). Growing recognition of the importance of behavioral studies in thermal discharge impact evaluations can be seen by increasing federal requirements for controlling thermal effluents (Gift, 1977). Behavioral data and the ability of fish to perceive and respond to temperature gradients provide important information (Gift, 1977).

Anguilla rostrata collected from Maryland's eastern shore did not show an influence of acclimation temperature to preferred temperature. The overall mean of the preferred temperature of all the individual fish tested, as suggested by McCauley (1977a), was used in estimating the final temperature preferendum of 16.7°C. Three behavioral responses were observed: clumping at temperatures below 18°C, aggressive display at temperatures above 18°C and initiation of feeding at 14°C.

References

Brett, J. R. 1944 . Some lethal temperature relations of Algonquin Park fishes. Univ. Toronto Stud. Biol. Ser. 52. Publ. Ont. Fish. Res. Lab. 63: 1-49.

Bruun, A. F. 1963. The breeding of North Atlantic freshwater eels. Adv. Mar. Biol. 1: 137-169.

Coutant, C. C. & Cox, D. K. 1975. Growth rates of subadult largemouth bass at 24 to 35.5°C. Pg. 118-120 in: B. W. Esch & R. W. McFarlane, eds. Ther, Ecol. II. Conf. 750425 Natl. Tech. Info. Serv., Springfield, Va.

Fahay, M. P. 1978. Biological and fisheries data on American eel, Anguilla rostrata (LeSueur). NE Fish. Ctr., Natl. Mar. Fish Serv. NOAA Tech. Ser. Rep. No. 17.

Fry, F. E. J. 1947. Effects of the environment on animal activity. Univ. of Toronto Stud. Biol. Series No. 55. Ont. Fish. Res. Lab. No. 68: 1-62.

Garside, E. T. & Tait, J. S. 1958. Preferred temperature of rainbow trout (Salmo gairdneri Richardson) and its unusual relationship to acclimation temperature. Can. J. Zool. 36: 563-567.

Gift, J. J. 1977. Application of temperature preference studies to environmental impact assessment. J. Fish. Res. Bd. Can. 34: 746-749.

Hall, L. W., Jr., Cincotta, D. A., Stauffer, Jr., J. R. & Hocutt, C. H. 1978. Temperature preference of the crayfish Orconectes obscurus. Arch. Environm. Toxicol. 7: 379-383.

McCauley, R. W. 1977a. Influence of acclimation temperature on preferred temperature in rainbow trout, Salmo gairdneri. Trans. Am. Fish. Soc. 106 (4): 362-365.

McCauley, R. W. 1977b. Laboratory methods for determining temperature preference. J. Fish. Res. Bd. Can. 34 (5): 749-752.

McCauley, R. W. & Tait, J. S. 1970. Preferred temperature of yearling lake trout, Salvelinus namaycush. J. Fish. Res. Bd. Can. 27 (10): 1729-1733.

Meldrim, J. W. & Gift, J. J. 1971. Temperature preference, avoidance and shock experiments with estuarine fishes. Ichthyol. Assoc. Bull. 7: 75 pp.

Nyman, L. 1972. Some effects of temperature on eel (Anguilla) behavior. Inst. of FW Res. Rep. No. 52: 90-102.

Scott, W. B. & Crossman, E. J. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184: 966 pp.

Smith, M. W. & Saunders, J. W. 1955. The American eel in certain fresh waters of the Maritime Provinces of Canada. J. Fish. Res. Bd. Can. 12 (2): 238-269.

Stauffer, J. R., Jr., Dickson, K. K., Cairns, Jr., J. & Cherry, D. S. 1976. The potential and realized influences of temperature on the distribution of fishes in the New River, Glen Lyn, Va. Wildl. Monogr. 50: 1-40.

Walpole, R. E. & Myers, R. H. 1972. Probability and statistics for engineers and scientists. MacMillan Publ. Co., Inc., NY. 506 pp.

Wenner, C. A. & Musick, J. A. 1975. Food habits and seasonal abundance of the American eel, Anguilla rostrata, from the lower Chesapeake Bay. Ches. Sci. 16 (1): 62-66.