variation). At stations 4 and 5, the relatively high salinity stations, POC exerted little influence upon ATP; salinity, temperature and pH could account for a large portion of the variability. POC, salinity, pH and temperature as a 4 variable model could account for biomass variations of 71.4% at station 1, 80.9% at station 2, 61.4% at station 3, 62.1% at station 4, but only 36.2% at station 5.

The adenosine triphosphate (ATP) extractable from microorganisms inhabiting aqueous environments has been employed as a parameter for the quantification of total microbial biomass for approximately a decade. The nondiscriminatory nature of the technique is both an advantage in that any organism retained on the filter will be quantified without the need for tedious counting or cultivation and a disadvantage in that the precise class of microorganism, i.e., bacteria or algae, being assayed cannot be determined with certainty. Consequently, the assay simply reflects the total microbial community, and insights into the distribution of microbial biomass in estuarine systems can be gained by examining the chemical-physical conditions associated with the ecosystem.

Both POC and ATP have been measured in similar ecosystems. The values of POC reported by Erkenbrecher and Stevenson (1975) and Odum and de la Cruz (1967) are in general agreement with the values herein reported. Erkenbrecher and Stevenson (1975), working within the North Inlet Estuary, reported ATP values in close agreement with the ATP values obtained in this study. The values reported herein should be considered minimal for the system since all samples were collected at, or close to, slack high tide (Erkenbrecher and Stevenson 1975). These similarities together with the lack of any definitive statistical differences in the mean concentrations of ATP recovered from the various stations and the general lack of a significant negative correlation of salinity and ATP indicate that the influx of fresh water has little effect on the total level of microbial biomass in the creek systems of the North Inlet. Even though the encroachment of fresh water into the marsh environment did not significantly alter the amount of apparent microbial biomass, no inference should be made concerning the type of organisms present.

The interaction of physical, chemical and biological factors tend to make the subtropical salt marsh an extremely complex system. Extensive variations may be expected to occur among experimental components within the same estuarine system and even within a single sampling station. This potential variation was exemplified by our findings for station 5, where only 39.2% of the biomass variation could be accounted for by POC, pH, temperature and salinity, but 80.9% of the variability could be accounted for by the same components at station 2. No single component can adequately explain or describe all of the stations. Exceptional care must be taken when attempting to characterize a large estuarine system on the basis of data collected at specific locations.

LITERATURE CITED

BARR, A. J., J. H. GOODNIGHT, J. P. SALL, AND J. T. HELWIG. 1976. A users guide to SAS 76. Sparks Press, Raleigh, North Carolina.

DAME, R., F. VERNBERG, R. BONNELL, AND W. KITCHENS. 1977. The North Inlet marsh-estuarine ecosystem: A conceptual approach. *Helgol. wiss. Meeresunters.* 30: 343–356.

ERKENBRECHER, C. W., AND L. H. STEVENSON. 1975. The influence of tidal flux on microbial biomass in salt marsh creeks. *Limnol. Oceanogr.* 20:618–625.

———, AND ———. 1978. The transport of microbial biomass and suspended material in a high marsh creek. *Can. J. Microbiol.* 24:839–846.

HOLM-HANSEN, O., AND C. R. BOOTH. 1966. The measurement of adenosine triphosphate in the ocean and its ecological significance. *Limnol. Oceanogr.* 11:510–519.

———. 1973. Determination of total microbial biomass by measurement of adenosine triphosphate, p. 73–89. *In* L. H. Stevenson and R. R. Colwell (eds.), Estuarine microbial ecology. University of South Carolina Press.

KJERFVE, B., M. S. IVESTER, AND D. J. LONSDALE. 1975. Circulation of the North Inlet Estuary. Am. Soc. Limnol. Oceanogr. 38th Meeting (Abstract).

LONSDALE, D. J., AND B. C. COULL. 1977. Composition and seasonality of zooplankton of North Inlet, South Carolina. *Chesapeake Sci.* 18:272–283.

ODUM, E. P., AND A. A. DE LA CRUZ. 1967. Particulate organic detritus in a Georgia salt marsh-estuarine ecosystem, p. 383–388. *In* G. H. Lauff (ed.), Estuaries. Publ. Am. Assoc. Adv. Sci. 83.

STRICKLAND, J. D. H., AND T. R. PARSONS. 1968. A practical handbook of seawater analysis. *Bull. Fish. Res. Board Can.* 167.

R. T. WEILAND, THOMAS H. CHRZANOWSKI,
AND L. HAROLD STEVENSON

Department of Biology
and
The Belle W. Baruch Institute for
Marine Biology and Coastal Research
University of South Carolina
Columbia, South Carolina 29208

Temperature Preference of the White Perch, *Morone americana*, Collected in the Wicomico River, Maryland.

ABSTRACT: Temperature preference tests were conducted on fresh water white perch (*Morone americana*), collected from the Wicomico River, Maryland. Collection temperature was 27 C and acclimation temperatures used in temperature preference tests were 6, 12, 18, 24, 30, and 33 C. The following methods were used to determine the final temperature preference: linear regression, quadratic equation, and "eyeball" plots. Recorded final temperature preference values were 28.9, 29.3 and 30.6 C using each method respectively.

Estuaries Vol. 2, No. 2 June 1979

0160-8347/79/020129-04$01.50/0

Introduction

Behavioral data on fish has become important in recent years due to the Environmental Protection Agency's 1974 request for information on upper lethal temperatures and maximum temperatures for development. These criteria incorporated behavioral data into the 316(a) evaluation and focused on the demand for accurate and reproducible temperature preference and avoidance data (Gift 1977).

White perch (*Morone americana*) are widely distributed along the east coast of the United States (Goode 1903) with dense populations found in the Chesapeake Bay (Beaven 1942). Temperature preference studies have been conducted on white perch from New Jersey (Terpin et al. 1977) and Delaware (Meldrim and Gift 1971); however, there are no available data on white perch from the Chesapeake Bay area. The objective of this research was to determine the final temperature preference of white perch collected in the Wicomico River, Maryland. This species has been reported to cause entrainment problems in the vicinity of estuarine based power plants (Meldrim and Gift 1971).

Materials and Methods

White perch were collected in fresh water (less than 1‰ salinity) in August 1977 from the Wicomico River, Maryland. The collection temperature was 27 C and fish were held initially in 76 l plastic trash cans at this capture temperature. Specimens collected ranged in standard length from 51 to 65 mm ($\bar{x}$ = 55 mm). All fish were collected by seine (7.6 × 1.8 m with .64 mesh) and were transported in 76 l plastic trash cans equipped with minomizers for aeration. Ice bags were placed in the water when necessary to prevent temperature fluctuations. Specimens were transferred by dip net from the trash cans to 38 or 76 l aquaria and held initially at their respective capture temperatures for 3 days. If fish developed fungal infections, they were treated with sulfa drugs and discarded if improvement was not shown in 2 days. Water temperatures in the aquaria were controlled with Supreme aquarium heaters and Koch refrigerator thermostats and were monitored daily. White perch were acclimated to the following temperatures at the rate change of 1 C per day: 6, 12, 18, 24, 30, 33 C. A five day holding period at each acclimation temperature preceded the temperature preference test. White perch were fed approximately .05 gm of Tetra-min Tropical Fish Food per fish each day, but were not fed on testing days to ensure consistency of stomach contents. Constant aeration in the holding aquaria maintained oxygen levels between 90–100% saturation. Photoperiod was maintained according to natural summer conditions via Vitalites. Light intensities at the surface of the aquaria ranged from 161.55 to 269.25 lm/m^2 (2769.5 lm/m^2 represents a sunny summer day). All tests were conducted between 0600-2200 hours.

The linear horizontal trough used in the preference trials was patterned after Meldrim and Gift (1971) and made of aluminum (3.6 × .203 × .254 m) coated with a non-toxic epoxy paint. Twelve heat lamps controlled by dimmer switches were secured beneath the trough to allow operation of heat lamps at increasing levels of intensity. Twenty-two thermistors were distributed horizontally along the trough at equal distances (190 mm) to record the temperature gradient. Cold water, introduced at one end of the preference trough from a Neslab circulating water bath was warmed as it flowed over the series of heat lamps to establish the horizontal gradient. The gradients for the 6, 12, 18, 24, 30, 33 C acclimation temperatures were 4–23 C, 8–29 C, 14–30 C, 18–34 C, 23–37 C, and 23–38 C, respectively. Water depth in the trough was maintained at approximately 4 cm. Overhead lights supplied constant illumination equal to approximately 238.51 lm/m^2 during the test.

A test specimen was introduced into the trough at its acclimation temperature followed by a 60 minute conditioning period that allowed for position effects which could interfere with the actual temperature preferred. This 60 minute orientation period was determined an appropriate amount of time to prevent fish from moving sporadically. After the orientation period, the position of each test specimen was recorded every minute for 20 minutes using overhead mirrors. Temperatures preferred by each fish were based on their proximity to one or more of the 22 thermistors, and six fish were tested individually at each acclimation temperature. The mean of the 20 observations was deemed the preferred temperature for that particular test (Stauffer et al. 1975). The "acute" method for determining final temperature preferendum was selected over the "gravitation" method to prevent fish from reacclimating during longer testing periods (Richards et al. 1977). Standard length and weight were recorded for each fish.

Linear regression, quadratic equation, and "eyeball" plots (Coutant 1977) were used in an attempt to determine the effect of acclimation temperature on preferred temperature (Fig. 1). Stepwise regression analysis selected the best fit for the data. The point at which each of the above curves intersected a theoretical line passing through the origin with a slope of 1 was considered as the final temperature preferenda (Fry 1947).

Results and Discussion

Preference temperatures for white perch are presented in Table 1. Fish consistently preferred higher tempera-

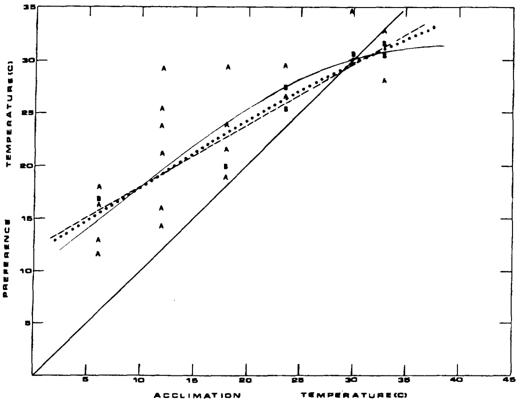

Fig. 1. Graphic relationship of preferred and acclimation temperature. Equation for linear regression (---) is P = .572A + 12.36 and quadratic equation (. . .) is P = .57A + .0002A^2 + 12.42. Eyeball plot (——) and 45° construction line (——) are noted. A = 1 observation, B = 2, C = 3.

TABLE 1. Temperature (C) preference data for *Morone americana* (ranges are presented in parentheses).

	Acclimation Temperatures (C)					
Obs.	6	12	18	24	30	33
1	17.0 (13.0–22.5)	15.8 (14.5–18.5)	29.2 (16.0–30.0)	26.9 (22.0–32.0)	30.1 (30.0–31.0)	31.7 (26.0–32.0)
2	16.5 (16.0–18.0)	14.0 (13.5–14.5)	18.5 (14.0–25.0)	25.3 (19.5–30.0)	34.8 (32.0–34.0)	32.5 (25.0–33.0)
3	17.7 (17.0–19.0)	23.5 (22.0–29.0)	19.9 (14.0–24.0)	27.3 (27.0–28.0)	30.5 (30.5–30.5)	30.5 (30.5–30.5)
4	16.0 (15.5–16.5)	29.0 (29.0–29.0)	21.2 (20.0–22.0)	26.3 (25.0–32.0)	30.5 (30.5–30.5)	30.2 (28.0–32.0)
5	11.2 (10.5–12.0)	25.1 (22.0–27.0)	23.6 (22.0–23.0)	27.2 (23.5–28.0)	30.2 (30.5–34.0)	31.3 (31.0–31.5)
6	12.6 (12.0–15.0)	21.0 (21.0–21.0)	19.7 (16.0–23.5)	25.2 (22.5–28.0)	29.6 (29.0–30.0)	29.7 (29.0–30.0)
$\bar{x}$ =	15.2 (13.0–22.5)	21.4 (13.5–29.0)	22.0 (14.0–30.0)	26.3 (19.5–32.0)	31.0 (30.0–34.0)	30.7 (25.0–33.0)

tures than their acclimation temperatures for all acclimation temperatures between 6–30 C. An acclimation temperature of 33 C resulted in a selected temperature lower than this value. A temperature of 33 C was selected as the highest acclimation temperature due to mortality of several individuals at higher temperatures.

The final temperature preferendum is defined as the point where preferred temperature equals acclimation temperature and to which an animal will finally select regardless of its previous thermal history (Fry 1947). Theoretically, the final temperature preferendum is the temperature which an organism will prefer given sufficient time and expanded temperature gradient. Richards et al. (1977) discussed the validity of various methods used to calculate the final preferendum from acute preferred temperature vs. acclimation temperature curves. The linear least squares regression equation $P = .572A + 12.36$ where P is the preferred temperature and A the acclimation temperature explained 85% of the data. Calculated temperature preference using this method was 28.9 C (Fig. 1). Other statistical transformations were compared with linear regression in an attempt to obtain a better fit for the data. The quadratic equation $P = .57A + .0002A^2 + 12.42$ explained 85% of this data with calculated final temperature preference of 29.3 C (Fig. 1). Other transformations and higher order polynomials did not significantly explain more of the data. In a recent symposium, Coutant (in Richards et al. 1977) stated that he preferred to eyeball the final preferendum from the data points. Using this method a temperature preference value of 30.6 was recorded (Fig. 1).

Meldrim and Gift (1971) found a final preferendum of 32 C for white perch from the Delaware River (see Coutant, 1977, for this calculated value). Pertinent conclusions from their study indicated that field temperature and salinity affected temperature preference. Final preferenda of 23.0, 22.8 and 21.5 C were recorded for New Jersey white perch populations acclimated to 5.0, 8.0 and 10.0 C, respectively (Terpin et al. 1977). However, acclimation temperatures used by these investigators did not include the higher acclimation temperature regimes of this study which may account for significantly different values. Other data on New Jersey white perch indicate an upper lethal temperature of 30.6 C (Dorfman and Westman 1970) but the methodology and season were different in their investigation than the data presented here. Although temperature preference data is available on white perch from other geographic areas, comparisons with populations from the Wicomico River, Maryland would be misleading due to the effect of geographic location (Hall 1978). Age, size, season, physiological state and social interactions could also cause discrepancies in the temperature preference response (McCauley 1977).

Factors responsible for temperature preference responses are environmentally related. Local populations of white perch had adaptive features such as behavioral and physiological responses which are genetically controlled. Biochemical adaptation to environmental conditions such as temperature represent a possible mode in temperature selection. Somero and Hochachka (1971) reported that habitat temperature influenced quantities and types of molecules present in the chemistry of an organism. These investigators also concluded that adult poiklotherms may demonstrate a considerable degree of "biochemical restructuring" on a seasonal basis in response to environmental temperature.

Since temperature is a dominant environmental variable controlling life process of organisms, it is not surprising that mobile organisms such as white perch exhibit locomotor responses to thermal stimuli. The white perch in this study expressed final temperature preference responses ranging from 28.9 to 30.6 C depending upon the method used for interpretation.

ACKNOWLEDGMENTS

Special thanks are rendered to the Academy of Natural Sciences of Philadelphia, Benedict, Maryland for use of their facilities in collecting specimens. I am indebted to Gary Lucas for his assistance in finding and collecting these specimens. I would also like to acknowledge the computer facilities of Maryland State College Information Center, Towson, Maryland for statistical analysis of the data.

REFERENCES

BEAVEN, G. F. 1942. Annual Report. Chesapeake Biol. Lab., Md. Dept. of Res. and Educ., Publ. 56:1–35.

COUTANT, C. C. 1977. Compilation of temperature preference data. *J. Fish. Res. Board Can.* 34:739–745.

DORFMAN, D., AND J. WESTMAN. 1970. Responses of some anadromous fishes to varied oxygen concentrations and increased temperatures. Rutgers Univ. Water Resources Research Inst., Partial completion and termination report, 75 p. Selected Water Resources Absts. 3(18):39.

ENVIRONMENTAL PROTECTION AGENCY. 1974. 316(1) technical guidance - thermal discharges. (Draft). U. S. Environ. Prot. Agency Plan. Div. Off. Wat. Haz. Mater.: 187 p.

FRY, F. E. J. 1947. Effects of the environment on animal activity. Univ. Toronto Stud. Biol. Ser. 44, Publ. Ont. Lab., 68:1–91.

GIFT, J. J. 1977. Application of temperature preference studies to environmental impact assessment. *J. Fish. Res. Board Can.* 34:746–749.

GOODE, G. B. 1903. American Fishes. Dana Estes & Co., Boston:35–36.

HALL, L. W. 1978. The effect of geographic location on the temperature preference on the white perch, *Morone americana*. M. S. Thesis. Frostburg State College, Frostburg, Md. 59 p.

MCCAULEY, R. W. 1977. Laboratory methods for determining temperature preference. *J. Fish Res. Board Can.* 34(5):749–752.

MCKEE, J. E. 1968. The impact of nuclear power on air and water resources. *Engineering and Science* 31(9): 12–22, 31–32.

MELDRIM, J. W., AND J. J. GIFT. 1971. Temperature preference, avoidance and shock experiments with estuarine fishes. Ichthyological Assoc., Bull. No. 7, 76 p.

RICHARDS, F. P., W. W. REYNOLDS, AND R. W. MCCAULEY. 1977. Temperature preference studies in environmental impact assessments: An overview with procedural recommendations. *J. Fish Res. Board. Can.* 34(5):728–761.

SOMERO, G. N., AND P. W. HOCHACHKA. 1971. Biochemical adaptation to the environment. *Am. Zool.* 11:159–167.

STAUFFER, J. R., JR., D. S. CHERRY, K. L. DICKSON, AND J. CAIRNS, JR. 1975. Laboratory and field temperature preference and avoidance data of fish related to the establishment of standards, p. 119–139. *In* S. B. Saila (ed.), Fisheries and Energy Production: A symposium. D. C. Heath and Company, Lexington, Mass.

TERPIN, K. M., M. C. WYLLIE, AND E. R. HOLMSTROM. 1977. Temperature preference, avoidance, shock and swim speed studies with marine and estuarine organisms from New Jersey. Ichthyological Assoc., Bull. No. 17, 86 p.

LENWOOD W. HALL, JR.[1]
CHARLES H. HOCUTT
J. R. STAUFFER, JR.
Appalachian Environmental Laboratory
Center for Environmental and Estuarine Studies
University of Maryland
Frostburg State College
Frostburg, Maryland 21532

---

[1] Present address: Academy of Natural Sciences of Philadelphia, Benedict Estuarine Research Laboratory, Benedict, Maryland 20612.

Salinity Stress in Harpacticoid Copepods

ABSTRACT: Three species of intertidal harpacticoid copepods, *Tigriopus japonicus, Tachidius brevicornis* and *Tisbe* sp., were tested for their response to salinities ranging from 0‰ to 210‰. At 90‰ *Tigriopus* became dormant, but could be reanimated if placed in 30‰ seawater within 18 hours. *Tachidius* became dormant at 60‰ but could also be revived if placed in 30‰ seawater. *Tisbe* died shortly after an exposure to seawater of 45‰. Death was brought about in *Tigriopus* and *Tachidius* by salinities of 150‰. Naupliar, copepodite, and adult stages of *Tigriopus* withstood the salinities equally well, while egg sacs could tolerate five times the length of exposure of these stages. The respiratory rate of *Tigriopus* was 3.76 (±1.32) $\mu l\ O_2\ hr^{-1}$ mg dry wt^{-1} for active adults and 0.03 (±0.01) $nl\ O_2\ hr^{-1}$ mg dry wt^{-1} for adults in the dormant state. The duration of dormancy, with successful revival, appears to be limited to the time before the loss of the vital water content of the tissues due to the high osmotic pressure. The ability to enter dormancy in times of stress may have high survival value to some intertidal copepods.

Introduction

The harpacticoid copepods form a significant part of the fauna of the intertidal zone. The copepods of the genus *Tigriopus* are cosmopolitan; representatives have been reported from Japan, the Pacific coast of North

0160-8347/79/020132-04$01.50/0