PREFERRED TEMPERATURE OF THE COMMON SHINER, *NOTROPIS CORNUTUS*, IN RELATION TO AGE, SIZE, SEASON, AND NUTRITIONAL STATE[1]

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Abstract. Preferred temperatures were determined in a laboratory temperature gradient for the common shiner *Notropis cornutus* (Mitchill). Preferred temperature was correlated with age, size, season, and nutritional state. Preferred temperatures were higher than, and positively related to acclimation temperatures in all groups. Age, size, and starvation did not significantly affect the preferred temperature. Significant seasonal differences in preferred temperature were observed with spring-collected fish preferring higher temperatures than autumn-collected fish kept at the same ambient water temperature.

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Temperature is an environmental factor with profound effect upon aquatic poikilotherms such as the common shiner. Temperature preference contributes to behavioral regulation of body temperature in fishes, and its alteration may be an important non-lethal consequence of introducing heated effluents into the aquatic environment. Fry (1947) defines temperature preference as "the region, in an infinite range of temperature, at which a given population will congregate with more or less precision." Species differ considerably in regard to the temperature selected in a temperature gradient, and acclimation temperature has been shown to have a marked effect upon temperature preference (Fry 1971; Fry and Hochachka 1970). Most reports on fishes indicate that increased acclimation temperature results in increased preferred temperature (Meldrim and Gift 1971; Norris 1963; Pitt *et al* 1956).

MATERIALS AND METHODS

Common shiners, *Notropis cornutus* (Mitchell) were collected by seine from Owens Creek, in the northeast corner of DeKalb County, Illinois. After recording the ambient water temperature (field temperature) fish were transported to the laboratory in insulated containers and held at field temperature in temperature-controlled holding tanks. Autumn fish were collected from 24 September through 3 December 1972; spring fish were collected from 14 March through 4 May 1973.

The experimental apparatus was modified from the design used by Meldrim and Gift (1971). It consisted of a rectangular trough of galvanized steel coated on the inside with epoxy paint. The trough was 5.0 m long, 15 cm wide, and 30 cm deep.

Tap water was allowed to stand for several days; then non-experimental fish were introduced into the trough. Water was maintained at pH 7.6–7.8, the approximate range in the collection habitat. This water, from a temperature-controlled holding tank, entered one end of the trough via a variable-speed pump. The flowing water was heated by a linear arrangement of rheostatically-controlled 250 watt infrared bulbs beneath the trough. After flowing through the trough, the warmed water was returned to the holding tank to be re-cooled. The temperature of each 17 cm length of trough water was monitored using immersed copper-constantan thermocouples attached to a Honeywell Electronik 16 recorder.

The trough was filled initially to a depth of 8–10 cm with water at the field temperature. By adjusting the rheostats controlling the infrared bulbs, a 12–15°C temperature gradient was established along the length of the trough. This gradient extended from several degrees below field temperature to approximately 10°C above field temperature.

Three fish were placed in random positions in the trough and were allowed a period of adjustment. When opercular rate stabilized (within 1 to 1.5 hr in larger individuals), the fish were considered to be adjusted to the trough water. After this adjustment period, the fishes' positions were recorded at one-minute intervals for 20 minutes. All fish were tested within 24 hours of being collected, as recommended by Norris (1963).

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Autumn-collected fish were used for experiments involving age and size differences and nutritional state. These fish were categorized into 4 groups on the basis of standard length: 3–5 cm, 5–6.5 cm, 6.5–7.5 cm, and 7.5–13.4 cm. Standard lengths were determined according to Hubbs and Lagler (1964). Fish were also divided into 3 age groups based on scale counts (Fee, 1965): young of the year, 1 year old, and 2 years old and older.

To determine the effect of starvation on temperature preference, fish were isolated in field retaining tanks. Each retaining tank, a 38 liter plastic pail, contained a window covered with plankton netting. The tanks were placed (approximately 45 cm deep) in a pool area in the stream from which the fish were collected. Water from the stream entered the tanks through the windows, but particulate matter was excluded by the netting. On 26 October 1972, 50 specimens were collected and evenly divided between 2 such retaining tanks. Fish in one group were fed chopped beef and heart every second day, while the other group was not fed. Three fish were removed periodically from each tank and preferred temperatures determined in the experimental trough on 7 dates between 28 October and 27 November 1972.

Linear regression analysis was performed for preferred temperature as a function of field temperature and separate equations were calculated for each of the three age classes. Analysis of covariance was then used to assess differences among the slopes of the regression lines. The same statistical analysis was performed for each of the 4 size classes, each of the 2 seasons, and each of the 2 nutritional states (Zar 1974).

RESULTS

No significant difference was found between regression line slopes or line elevations for the 3 age groups and 4 size classes, indicating no difference between age or size groups in regard to the relationship between preferred and field temperature. Fish of all ages and sizes

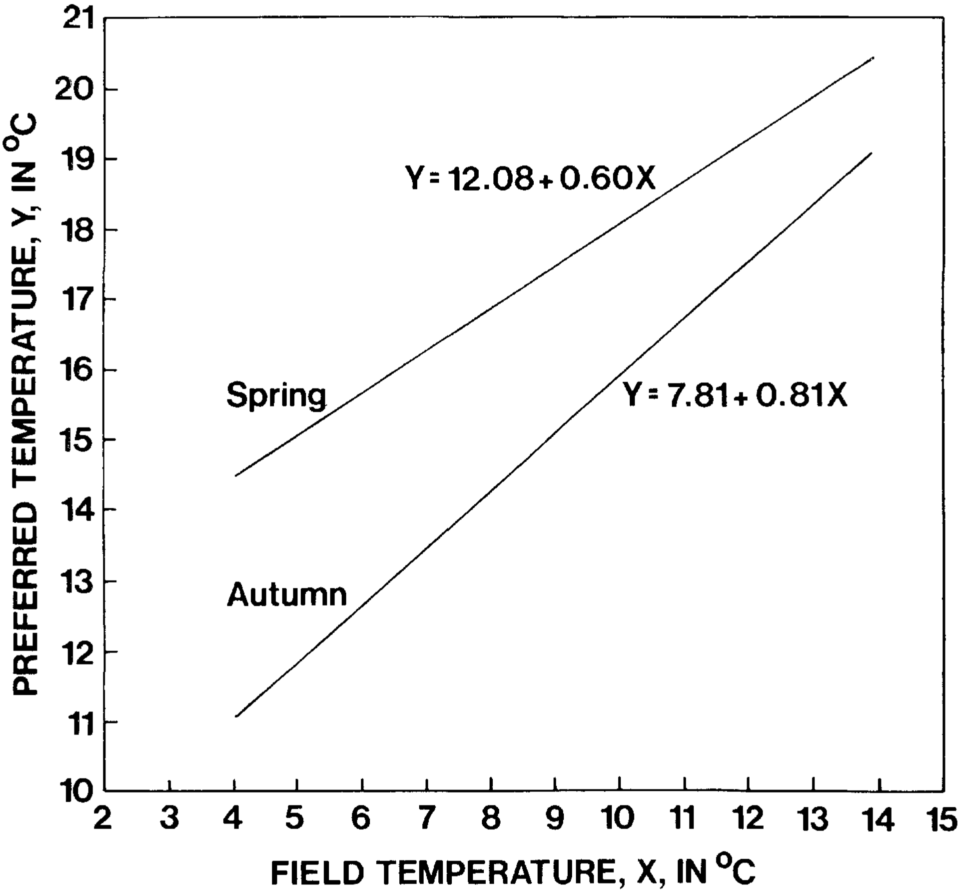

FIGURE 1. The relationship between preferred temperature and field temperature in *Notropis cornutus* during spring and fall seasons. For the spring regression equation, $r^2 = 0.52$ (number of data = 38); for autumn, $r^2 = 0.54$ (number of data = 32).

preferred higher temperatures than their acclimation temperatures within the experimental acclimation temperature range of 2° to 20°C.

No significant difference was found between the slopes of the regression lines for spring and autumn fish. A significant difference, however, was found between line elevations ($P<0.005$), which indicated a difference in the preferred temperature between fish collected from the 2 seasons (see figure 1). At any acclimation temperature within the tested range of 4° to 14°C, spring fish selected warmer temperatures than autumn fish, and all fish apparently preferred temperatures above the acclimation temperature.

The difference between starved and non-starved fish over a field temperature range of 4° to 9°C in the relationship between preferred and field temperatures was not significant.

DISCUSSION

In all of the experimental procedures preferred temperature was directly related to acclimation temperature. This is the typical response found in fishes, although the temperature preferendum may reach a maximum at some acclimation temperature and decrease at acclimation temperatures above this (Fry and Hochachka 1970). Javaid and Anderson (1967a) found that in the rainbow trout, *Salmo gairdneri*, and the Atlantic salmon, *Salmo salar*, an increase in the acclimation temperature resulted in an increase in the preferred temperature. However, Garside and Tait (1958) reported that an increased acclimation temperature had a negative correlation with temperature selection in rainbow trout.

While no difference in preferred temperature was found among sizes or ages of *N. cornutus*, such differences have been observed in some other species. Neill (1971) compared a heated effluent outfall area to 3 reference areas of similar bottom, slope, aquatic vegetation, and exposure to wind and found that large carp, *Cyprinus carpio*, and small black crappies, *Pomoxis nigromaculatus* were more abundant in the outfall area, while small carp and large crappies were more abundant in the reference areas.

Norris (1963) found preferred temperature to be a function of age in the opaleye, *Girella nigricans*, during development from pre-juvenile to juvenile, but not in adult fish. Other investigators have shown differences in temperature preferendum between young and adult fishes of a number of species, although the differences were not always manifest at all seasons (Barans and Tubb 1973; McCauly and Read 1973; Meldrim and Gift 1971; Reutter and Herdendorf 1976). In species exhibiting preferred temperature differences between young and adults, such differences are typically more pronounced in autumn and winter, and least in summer (Reutter and Herdendorf 1976), yet our autumn-tested *N. cornutus* displayed no age difference in temperature preference.

Doudoroff (1938) reported that the starvation of *Girella nigricans* resulted in no detectable change in the selected temperature. However, Javaid and Anderson (1967b) found that starvation did affect three species of salmonids: Atlantic salmon; brook trout and rainbow trout. The observed effect was variable as starvation decreased the preferred temperature of the latter two species but the Atlantic salmon exhibited a higher preferred temperature after a period of starvation. Our study with the common shiner disclosed no effect of starvation on the temperature preferendum of *Notropis cornutus*.

The preferred temperature of *Notropis cornutus* was significantly higher in spring than it was in autumn. This finding agrees with reports of other investigators on a number of other fish species. Sullivan and Fisher (1953), Barans and Tubb (1973), and Reutter and Herdendorf (1976) found considerable differences in the preferred temperatures of a number of fish species when tested during two or four seasons.

Fry (1971) noted a great deal of variability in the preferred temperatures determined by various investigators for both *Cyprinus caprio* and *Salmo gairdneri*. He ascribes this variability to the season of the year in which the test was performed as did Zahn (1963) and Meldrim and Gift (1971). The difference observed between seasons in our Common Shiner study also maybe associated with an innate mechanism, probably responding to photoperiod as related to season. The seasonal differences in responses of fishes to environmental temperature has important implications in the assessment of potential effects of industrial thermal discharges into natural waters. Laboratory studies can aid in such assessments only with consideration and knowledge of the contribution of seasonal acclimatization on the response of the fish species.

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