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SEASONAL EFFECTS ON TEMPERATURE PREFERENCE IN YELLOW PERCH, *PERCA FLAVESCENS*

Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Duluth, Minnesota 55804

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SEASONAL EFFECTS ON TEMPERATURE PREFERENCE IN YELLOW PERCH, *PERCA FLAVESCENS*

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FOREWORD

Our nation's freshwaters are vital for all animals and plants, yet our diverse uses of water---for recreation, food, energy, transportation, and industry---physically and chemically alter lakes, rivers, and streams. Such alterations threaten terrestrial organisms, as well as those living in water. The Environmental Research Laboratory in Duluth, Minnesota develops methods, conducts laboratory and field studies, and extrapolates research findings

--to determine how physical and chemical pollution affects aquatic life

--to assess the effects of ecosystems on pollutants

--to predict effects of pollutants on large lakes through the use of models

--to measure bioaccumulation of pollutants in aquatic organisms that are consumed by other animals, including man.

This report describes the seasonal temperature preference of adult yellow perch. This report complements other reports describing the temperature requirements of this species and provides a basis for evaluation of laboratory gradient tanks as a short-cut method to measure thermal effects.

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ABSTRACT

Seasonal variations in temperature preferences of adult yellow perch (*Perca flavescens*) were sought by acclimating fish captured in the fall to 5, 10, 15, and 20C in the laboratory and determining their preferred temperatures in a horizontal temperature gradient trough. Temperatures selected in winter for fish acclimated to 5C ranged from 12 to 14C, considerably above the temperature region (6C and below) previously established for optimum gametogenesis. Final preferenda as determined from preferred temperature-acclimation temperature curves were 24 , 20 and 17C during winter, spring and summer respectively. Those in late summer were below published values (23.5C) for this species. It is concluded that there are no demonstrable effects, at least in winter and early spring which might reflect changing physiological needs and that temperature gradients in nature serve rather to attract perch to warm temperatures suitable for spawning in spring and conducive to growth in summer.

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ACKNOWLEDGMENTS

I wish to thank Dr. L.A.A. Read and Mr. J. Herringer of Wilfrid Laurier University for assistance in carrying out experiments. Mr. Steve Nepszy, Director of the Lake Erie Biological Research Station, Ontario Ministry of the Environment, kindly supplied the specimens of yellow perch.

SECTION 1

INTRODUCTION

STATEMENT OF PROBLEM

Recent proliferation of power generating plants has resulted in a corresponding increase in the amount of natural water used for cooling. Waste energy in the electric generating process is introduced to the water course in the form of a warm effluent. The effects on aquatic ecosystems of the warm effluent known either as thermal enrichment or pollution, depending on circumstances, are now the themes of an increasing number of investigations in the new field of thermal ecology. The perjorative term "thermal pollution" implies that the addition of calories (calefaction) has adverse effects on other water uses. In some instances, however, calefaction (a neutral expression) may confer advantages to some species at least at some stages in their life history. It has been shown, for example, that fish have an optimum temperature range for growth which is usually present in the aquatic environment for some time during the growing season. When the duration of this optimum temperature range for this physiological activity is prolonged through calefaction, growth of individuals will be enhanced. While increased growth rate, from the standpoint of anglers is beneficial since it provides them with trophy fish, the development of other life stages which require cooler temperature may be detrimentally affected.

It has been demonstrated that life stages in most fish have different thermal requirements and this is well illustrated by the rainbow trout (Salmo gairdneri). Several investigators have established the thermal requirements for this species over its life history. Garside (1966) found that the range for the optimum development of the embryos (2-10C) is somewhat below that for optimum growth of juveniles (17-18C) (Hokanson et al. 1977). There are numerous other examples of changing thermal requirements of a species with the life stage.

Perhaps the most detailed and thorough study of the thermal requirements of a species is that carried out by Brett (1971) and his associates with the sockeye salmon, Oncorhyncus nerka. They found from their studies on the relation of performance, metabolism, circulation and growth that the general physiological optimum for the species was centered around 15 C - also the firmly established preferred temperature for the species (Brett, 1952). For other fish a general agreement between the preferred or selected temperature and the temperature for the optimum growth has been demonstrated.

The thermal requirements of various life stages of Perca flavescens have also received attention, especially over the past several years (Hokanson, 1977). Gametogenesis in this species appears to require a prolonged period of cool temperature ($<$10C) for several months (Jones et al., 1976) but after their successful maturation the range for spawning is shifted upwards to the range 4-19 C encompassing an optimum of 8-11 C (Hokanson, 1977). Optimum temperatures for growth of the postembryonic stages appear to be in the region of 20 C (Hale and Carlson, 1972).

One of the urgent problems today is the setting of limits for thermal increments to natural waters supporting desirable species of fish in the light of the knowledge that thermal requirements of a species may change with life history and with season. Since considerable time and expense are required to establish thermal requirements of a species throughout its life it was proposed in the present study that the preferred temperatures as determined for various life stages and at various times of the year might provide useful first approximationsof a species' changing thermal requirements.

Some fish species display marked seasonal changes in temperature preference (i.e. changes independent of acclimation temperature) and that these often occurred during that part of the year when much of gametogenesis takes place. Sullivan and Fisher (1954) noted that brook trout (Salvelinus fontinalis) underwent pronounced changes in temperature preference at various seasons of the year. In March, temperatures selected increased abruptly by some four degrees from the previous month even though the temperature of the water in which they were being reared decreased slightly. In the fall of the year there was a corresponding decrease of the same magnitude under similar circumstances. Zahn (1963) found pronounced seasonal effects in the plaice (Pleuronectes platessa) and in the bitterling (Rhodeus sericeus). The temperatures selected by mature alewives (Alosa pseudoharengus) in Lake Michigan increased five to six degrees during May and June, at the peak of their onshore spawning migration (Otto, 1976). Investigators have usually been aware of seasonal effects and have usually taken them into account when carrying out preferred temperature studies. It was therefore felt that a fruitful line of enquiry would be an examination of seasonal changes in temperature selection in yellow perch. At the time the present research project on temperature preference in yellow perch was drawn up the published data were not conclusive and there was some evidence that seasonal effects existed.

The relationship between preferred and acclimation temperature in this species was reexamined at various times of the year to explore nonthermal seasonal effects. It was anticipated that any abrupt change in this relationship might reflect changing thermal requirements and that the hypothesis that temperature preference may be used as a first approximation of thermal requirements of a species could be tested.

FACTORS INFLUENCING PREFERRED TEMPERATURE

Thermal History

Temperature preference for most of the species studied is influenced by thermal history expressed either by thermal acclimation or acclimatization. The relationship between preferred temperature and acclimation temperature varies considerably in various species of fish. Typically preferred temperature rises with acclimation temperature although in some species there is essentially no change (Brett, 1952; McCauley and Tait, 1971) or even, in the instance of adult rainbow trout a decrease in preferred temperature (Garside and Tait, 1958). A scheme of classification for the various types of curves (Fig. 1) was compiled by Manfred Zahn (1962), from which he drew inferences about the general thermal requirements of various species.

Little work has been done on the role of acclimatization temperature itself in determining temperature preference since investigators have understandably favored the closely controlled laboratory experiments with their reproducible results. As mentioned earlier there is evidence that seasonal factors other than the annual march of temperature may influence temperature preference in some species.

Pesticides and Anesthetics

Since the process of temperature selection is mediated by the nervous system it would be expected that substances which effect nervous activity could also exert some influence on temperature selection. Ogilvie and Anderson (1965) showed that temperature preference of salmonids which had ingested DDT in their food underwent significant changes. Goddard, Lilley and Tait (1974) noted that lake trout exposed to the anesthetic MS222 did not display normal temperature selection until several days after treatment.

Diel Rhythms

There is not much evidence for the existence of diel rhythms in selected temperature although with the recent development of the behavioral thermoregulatory devices such effects even though subtle, may now be easily investigated. Figure 2 shows consecutive mean preferred temperatures for adult rainbow trout held for two weeks in a behavioral chamber constructed in our laboratory. No marked diurnal variations in temperature preference is apparent from thermograph tracing. Of ecological significance is the daily vertical migration of sockeye salmon described by Brett (1971) in which fish may feed in the epilimnion at night at 18 C but spend the day in deeper water at 6 C where low temperatures promote efficient utilization of food.

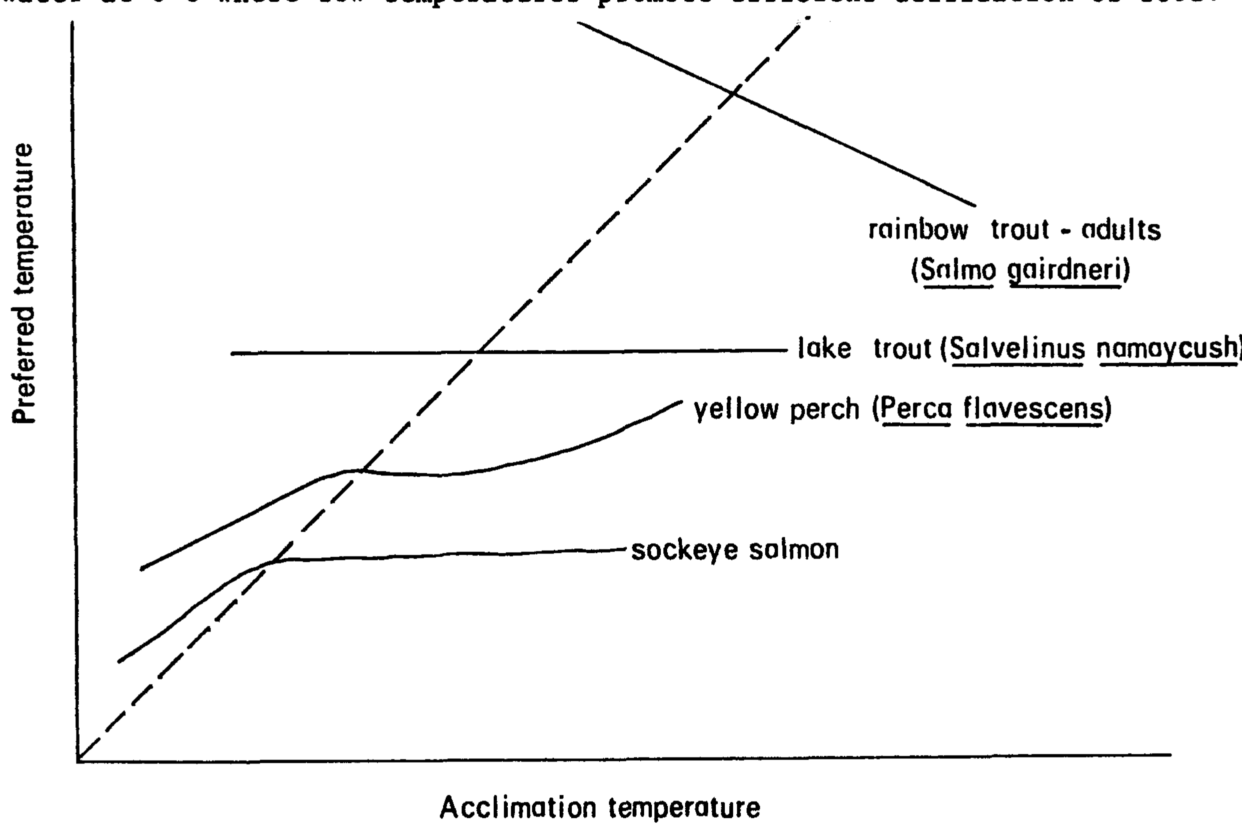

Figure 1. Examples of preferred temperature - acclimation temperature curves (Zahn, 1962).

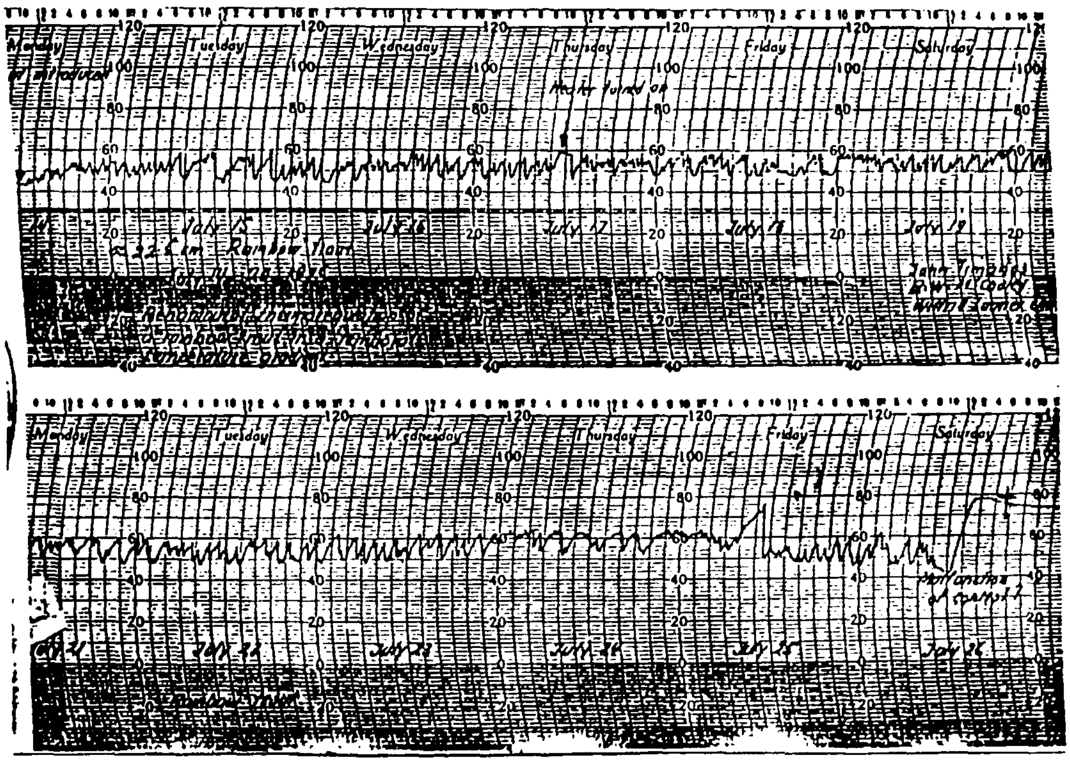

Figure 2. Preferred temperatures of a rainbow trout (Salmo gairdneri) over a ten day period as recorded in a behavioral chamber.

Age

Ferguson (1958) in his review of the distribution of fish in laboratory and field temperature gradients pointed out that discrepancies between data obtained by both methods may be attributed to the differences in age of laboratory subjects (conveniently small and therefore juvenile) and adult fish observed in the field. There is a general belief among investigators that the juvenile of a species are found in the warmer part of the natural temperature gradient than those frequented by adults. Comparisons from the literature, however, are made difficult because of variations in the type of apparatus and techniques followed (Zahn, 1962). McCauley and Read (1973) showed that in yellow perch the final preferendum of the young when tested under similar experimental conditions, exceeded that of the adults by several degrees Celsius. These results are not only in keeping with observations on the distribution of this species in the field but also with the data of other investigators who worked separately on either the adult or the juveniles (McCracken and Starkman, 1948; Ferguson, 1958; Barans and Tubb, 1973).

Other Factors

At the time of writing, there are some investigations being carried out in other laboratories on the effects of other environmental identities and factors on temperature preference. Social interaction (prey-predator and territoriality) health and light, under certain conditions, can effect the distribution of fish in a natural gradient or disrupt an otherwise perfectly well-planned laboratory experiment. Needless to say, the art of conducting experiments in temperature preference includes the suppression or control of these factors so that the directive effects of temperatures alone can be described. The reader is referred to Richards, Reynolds and McCauley (1977) for a detailed discussion of techniques of determining temperature preference in fish.

SECTION 2

CONCLUSIONS

Seasonal, non-thermal variations in preferred temperatures of yellow perch were not found using standard laboratory methods. It has been documented that this species requires temperatures below 10C for several months during the winter for successful gametogenesis but this change in thermal requirements was not reflected in the temperature preference of perch during this season. It is concluded that preferred temperatures, at least in laboratory acclimated fish cannot be utilized as first approximations of the thermal requirements of all life stages. It is suggested that temperature preference of perch in late winter functions with other environmental stimuli to direct fish during seasonal migrations to warm nearshore waters.

SECTION 3

RECOMMENDATIONS

The traditional laboratory approach followed in the present investigation failed to reveal any seasonal effects in preferred temperature in adult yellow perch independent of acclimation temperature. This was contrary to expectations since thermal requirements of the species do change during winter. Exposure of fish to constant temperatures for extended periods of time (i.e. acclimation) may alter normal responses to temperature gradients and thus result in experimental artifacts. The ambiguous findings of the present study re-emphasize the need to examine laboratory techniques and to continuously validate laboratory results by field observations. Field acclimatized fish, unlike laboratory acclimated fish, are exposed to many environmental stimuli which may modify distribution in nature. It is recommended that, when possible, acclimatized subjects be tested throughout the year especially when seasonal variations reflecting changing thermal requirements or annual migrations are sought.

SECTION 4

MATERIALS AND METHODS

STRUCTURE OF GRADIENT TROUGH

Temperature gradients were produced in a trough three meters long, 30 cm deep and 20 cm wide. Preheated water maintained at a constant temperature by a thermostatically controlled heater entered at one end, was progressively cooled by a heat exchanger consisting of a refrigerated coil along one side of the tank. Vertical thermal stratification, a disadvantage of horizontal gradient troughs, was greatly reduced by currents of compressed air introduced through air breakers spaced at regular intervals in the water along the side of the tank. By adjusting the rate of flow of water through the tank and by altering the temperatures of the fore-chamber along with that of the coolant, it was possible to produce gradients of about 8 C which were usually stable throughout the course of an experiment. A serious disadvantage of this gradient trough, however, was the inordinate amount of adjustment required by the operator to produce a gradient and this disturbed the scheduling of the experiments.

EXPERIMENTAL FISH

Two lots of adult yellow perch were obtained in the fall of two successive years from Lake St. Clair. Fish were accumulated over several weeks at the Lake Erie Fisheries Research Station and held in troughs supplied by running water before being transferred to the Waterloo laboratory. At Waterloo they were divided randomly into four experimental groups and reared at 5, 10, 15, and 20 C, respectively, in running water from the municipal water supply. They were held under a photoregime supplied by normal laboratory fluorescent lighting controlled by a time switch set each week in accordance with the natural photoperiod prevailing in Waterloo, Ontario. Figure 3 shows the natural yearly march of temperature of Lake St. Clair. The fish were trained to accept commercial trout food which was supplemented by meat and live minnows. The condition factors of the experimental fish after a year of holding was similar to that of fish in the local lakes.

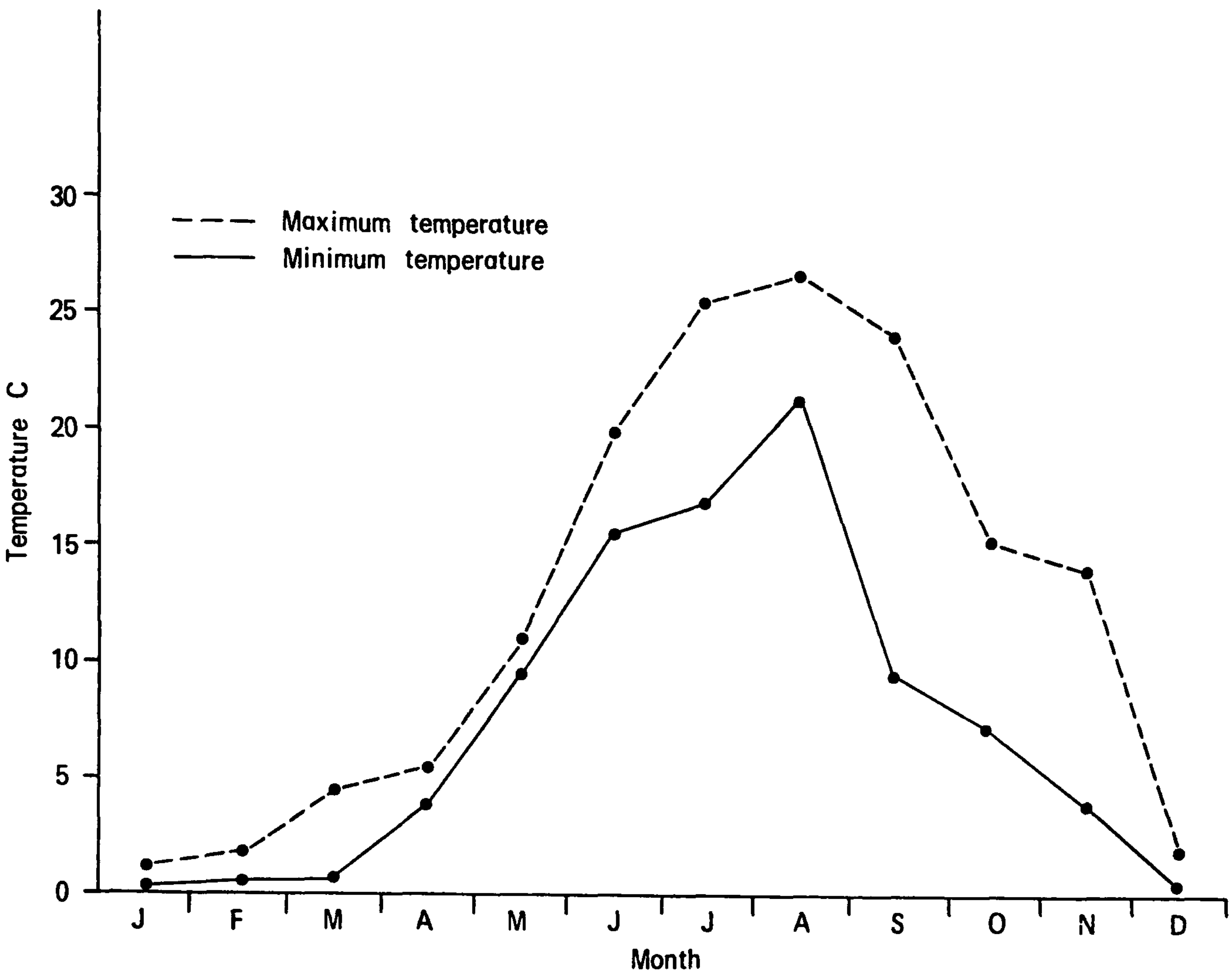

Figure 3. Seasonal variations in water temperature of Lake St. Clair, 1974.

PROCEDURES OF TESTING

Acclimation

Temperatures selected in a laboratory gradient by a sample of fish depend, for the most part, on thermal history expressed as thermal acclimation. For this reason, it is necessary to standardize the response of fish to a temperature gradient by holding them at a temperature level sufficiently long enough to erase the effects of previous thermal history. While information is available on the rate of gain and loss of thermal acclimation as measured by thermal resistance, there are very little data for this process with respect to temperature preference. It has been an article of faith with investigators that acclimation rates are approximately the same for changes in preferred temperature. The only published reference is that of Javaid (1972) who found that young-of-the-year salmonids could acclimate from 10 to 20 C within two days. Our own ancillary study on behavioral thermoregulation in rainbow trout illustrates how fish in a temporal temperature gradient increased their preferred temperature during the course of an experiment (Figure 2). As in most other studies on temperature preference, we took the conservative approach in regard to acclimation period, maintaining our samples of fish at the acclimation temperature for at least one month before determining preferred temperatures.

Determination of Final Preferendum

The final preferendum is the single value which characterizes the thermal preference of a species since it represents its eventual stable choice in an infinite range of temperatures. The most direct way of determining this value consists in leaving a sample of fish in the gradient apparatus until the region of temperatures favored by them does not change with time. Up to the present, this method has not been followed at least with spatial gradients because of the physical difficulties of maintaining temperature gradients for so long a time in an apparatus and holding fish for long periods in the confined space of a tank. In practice, workers have systematically determined preferred temperatures for fish acclimated to a series of acclimation temperatures, plotted these values against acclimation temperature, and by interpolation, graphically estimated that point for which preferred and acclimation temperatures coincide. When this method is adopted, care must be taken that the fish are kept in a thermal gradient for periods less than a day because of a gradual change in acclimation level resulting from exposure to higher or lower temperatures.

SECTION 5

RESULTS

BEHAVIOR OF FISH IN THERMAL GRADIENTS

In the routine determination of temperature preference in the laboratory, attempts are made to minimize or at least take into consideration gradients of other environmental identities; i.e. light, gravity, water velocity, etc. Time was allowed the experimental subjects to habituate to the environment of the test tank and for this reason the perch were introduced 24 hours into the gradient tank maintained initially at the acclimation temperature. In many instances the fish tended to congregate at the two ends of the trough, perhaps responding to a slight light gradient in which the ends of the tank were the darkest regions of the tank or displaying behavior known as a "fright huddle". It was found that the "end effect" bias could be over-ridden by directing a small, bright light on both end walls of the tank. By this means, distributions in the tank were largely influenced by temperature rather than by other factors. In spite of patience and resourcefulness of the operators in creating conditions in the gradient trough conducive to behavioral thermoregulation, the experimental subjects often did not respond to the thermal gradient. Much of the data of the present study obtained could not be used since it was apparent that the fish were not responding to temperature gradients. This imprecision in selecting temperature in this species had also been noted by other investigators and is reflected in the wide standard deviations quoted in their data (Barans and Tubb, 1973).

There was no noticeable trend to increased preferred temperature with sojourns of up to 24 hours in the gradient trough. The time for the perch to become habituated to the apparatus was considered to be three hours, and distributions of fish in the tank were not used in calculation of temperature preference before this period had elapsed.

PREFERRED TEMPERATURE

Modal temperatures of distributions of fish held at the four acclimation levels and tested at three seasons of the year for two years are summarized in Table 1. The data for winter and early spring are plotted in Figure 4 along with those of McCracken and Starkman (1948) who also studied the effect of acclimation temperature on preferred temperature at this time of the year. In view of possible non-thermal seasonal influences our late winter data may be compared with those of the previous study. The curve connecting the points of the 1948 study intersects the 45 degree diagonal in the vicinity of 20 C indicating a final preferendum of this value. Up to the 20 C acclimation level the data of the present study are in good agreement with those of the earlier work although they indicate a higher final preferendum.

Table 1. MEAN PREFERRED TEMPERATURES OF SAMPLES OF YELLOW PERCH HELD AT FOUR CONSTANT ACCLIMATION TEMPERATURES THROUGHOUT THE YEAR (C, standard deviations are shown in brackets)

Year	Season	Acclimation temperature, (C)				Final preferendum, (C)
		5	10	15	20	
1974	Winter	13.0 (1.9)	15.5 (2.3)	18.4 (2.2)	24.2 (3.0)	25
	Spring	12.3 (2.5)	18.8 (2.0)	20.2 (1.8)	20.2 (2.4)	21
	Summer	13.8 (1.6)	13.5 (1.8)	17.6 (2.6)	16.1 (2.1)	17
1975	Winter	12.0 (1.5)	14.2 (2.1)	18.0 (1.9)	23.2 (2.4)	30
	Spring	13.1 (2.1)	18.1 (1.9)	21.0 (1.6)	19.5 (2.5)	21.1
	Summer	13.5 (1.7)	14.1 (1.6)	18.1 (2.3)	17.0 (2.2)	18

CONDITION OF GONADS OF THE EXPERIMENTAL FISH

At the end of the series of preferred temperature determinations, experimental fish were sacrificed, the gonads weighed and histological sections prepared. The groups held at 5 and 10 C in 1974 showed evidence of sexual maturation when three females at 5 C and two at 10 C spawned in May. The phenomenon was noted the following year when two females spawned at the same two temperatures and one at 15 C. No tests were made, however, to determine egg fertility. Logarithms of ovary weight were plotted against logarithms of body weight. The scattering of points indicated that there were no real differences among gonadosomatic indices of fish reared at various temperatures.

Since the ovaries of the test fish are likely a heterogenous mixture of eggs in various stages of resorption and new development, no conclusions may be drawn. Interpretation of the apparent differences of the ovaries awaits the judgment of an experienced reproductive fish physiologist.*

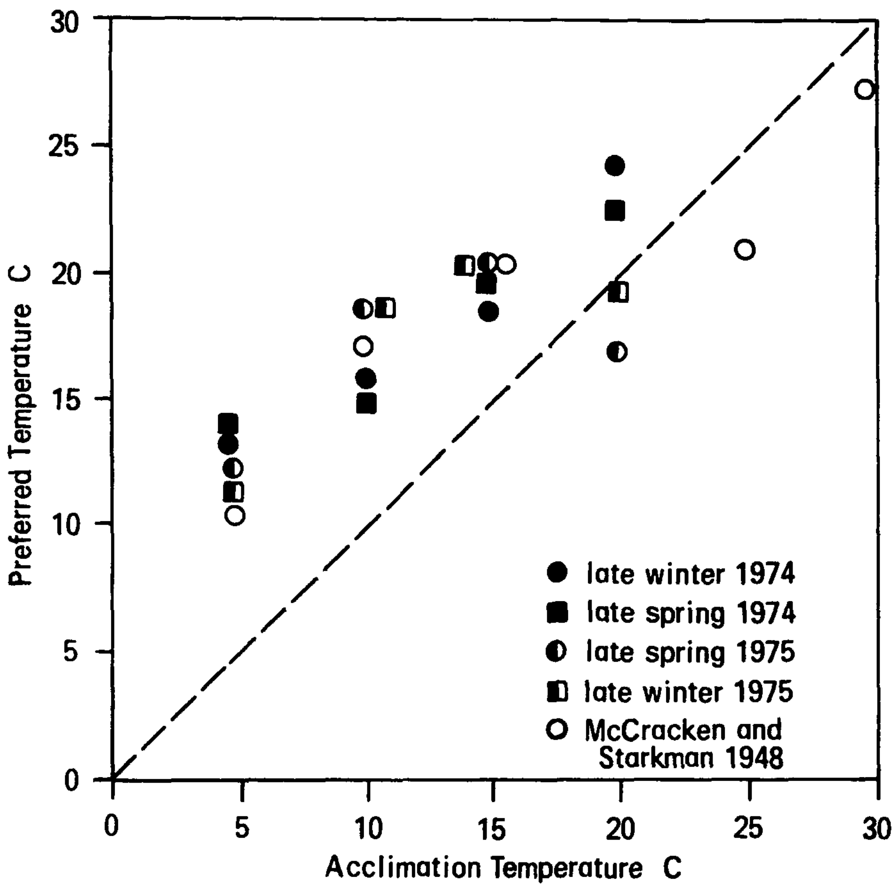

Figure 4. The relation between preferred and acclimation temperature in late winter and early spring.

* The slides are at present in possession of the writer and are available for inspection by any interested investigator.

SECTION 6

DISCUSSION

REVIEW OF PREFERRED TEMPERATURE STUDIES ON YELLOW PERCH

In spite of a variety of techniques and apparatus there appears to be good general agreement among the published preferred temperature data of perch. When the data of various authors are plotted on the same graph the relation between preferred temperature and thermal history expressed as acclimation or acclimatization temperature may be described by an envelope of positive slope enclosing the experimentally determined points (Fig. 5). The similarity between curves for both acclimated and acclimatized fish is evidence that there is no strong influence for seasonal effects apart from water temperature. The data of McCauley and Read (1973) seem to be anomalous since they lie several degrees below the envelope. No reason is apparent for their depressed values. Since they were tested in the early fall in a vertical gradient it is suggested that they may have displayed a type of "predictive thermoregulation" as defined by Neill (1976). Neill proposed that some fish species may anticipate seasonal changes in spatial thermal gradients and move towards the future region of preferred temperature. Since yellow perch in the lake move to deep water with the passing of summer, fish in the vertical gradient of McCauley and Read may have responded seasonally to a hydrostatic gradient and swam lower in the tank. Some support for this speculation is provided by field data depicting graphically the depth and thermal distribution of adult perch in Lake Opeongo, Algonquin Park, from June to September (Fig. 6). During July and August the mean of the thermal distributions lies between 20 and 21 C but drops precipitously about the beginning of September - a time marking the beginning of spermatogenesis and secondary growth of ova (Turner, 1919).

Figure 7 is an interpretation of La Rue Well's 1972 study of the seasonal distribution of fish species in Lake Michigan as determined by bottom trawls. He recorded numbers of fish captured in relation to depth and temperature at increasing distances from shore. Adults were usually found in the warm, inshore waters displaying a final preferendum slightly under 20C in July. These field observations are in essential agreement with laboratory data although any non-thermal seasonal effects are obscured because of decreasing temperature gradients when water bodies cool from August onwards.

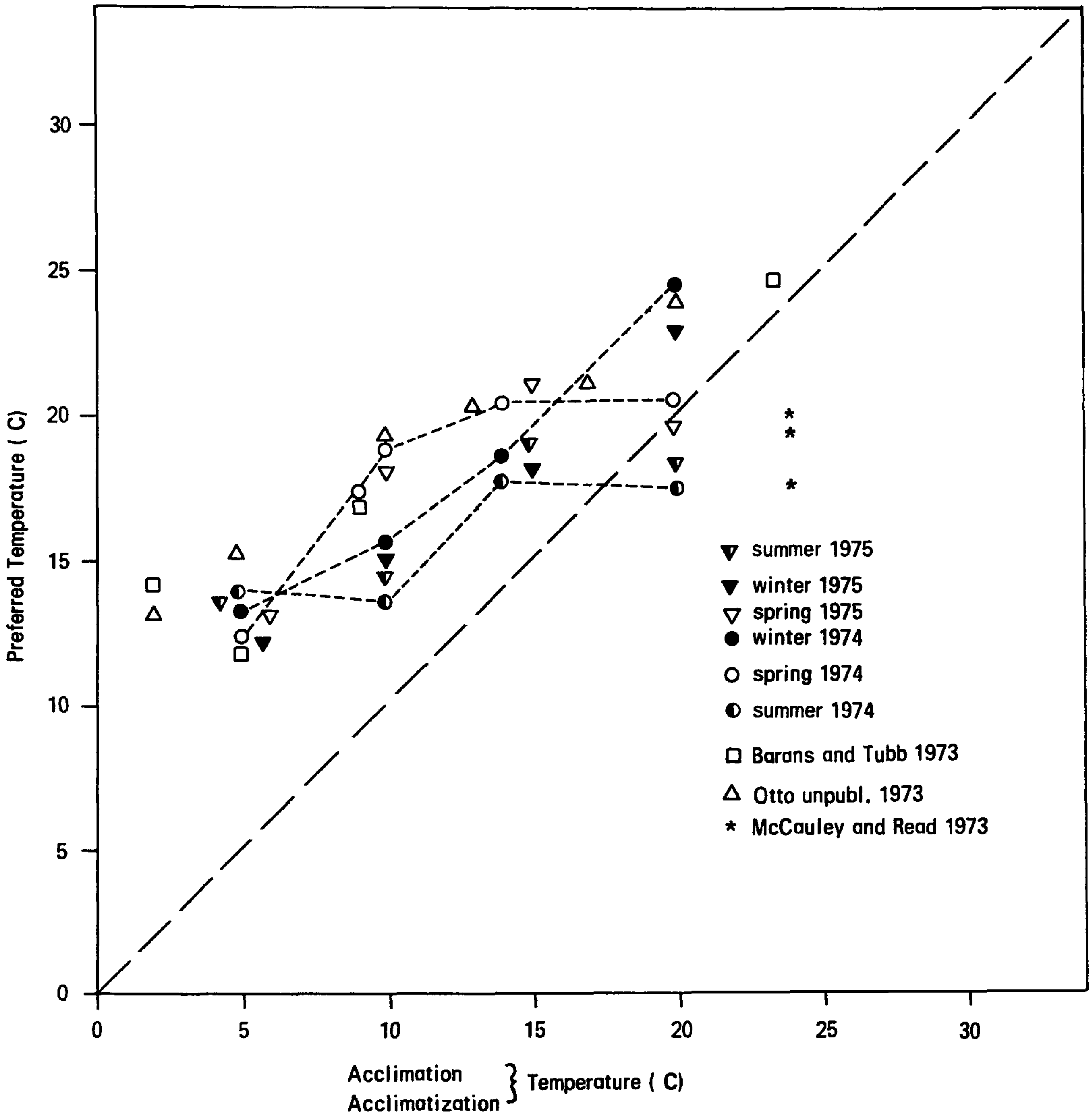

Figure 5. Summary of the preferred temperature relations of adult yellow perch.

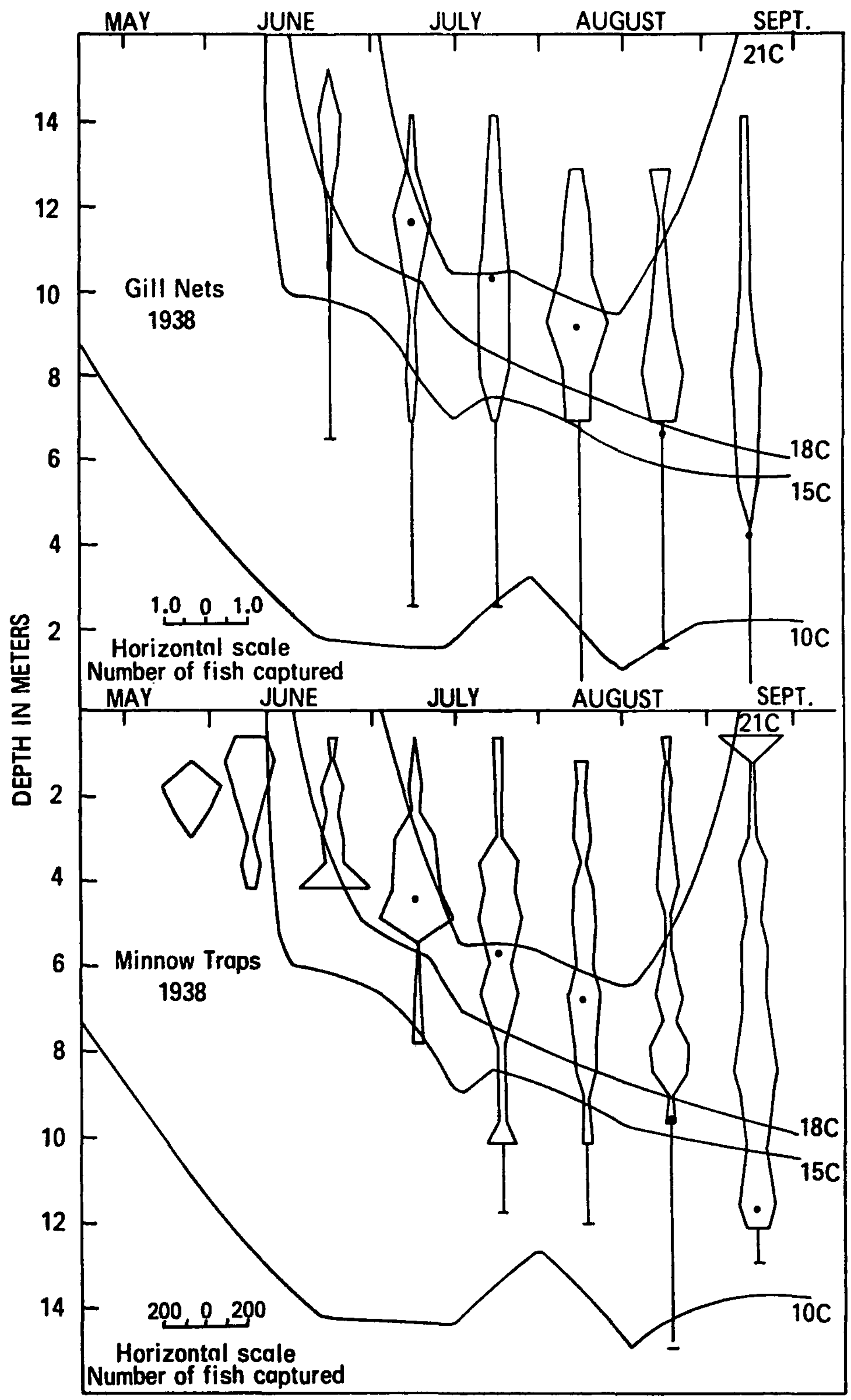

Figure 6. Observed vertical distributions of yellow perch in relation to season, depth and temperature in Lake Opeongo. Frequency polygons depict numbers of fish captured at various depths. Modified from Ferguson (1958).

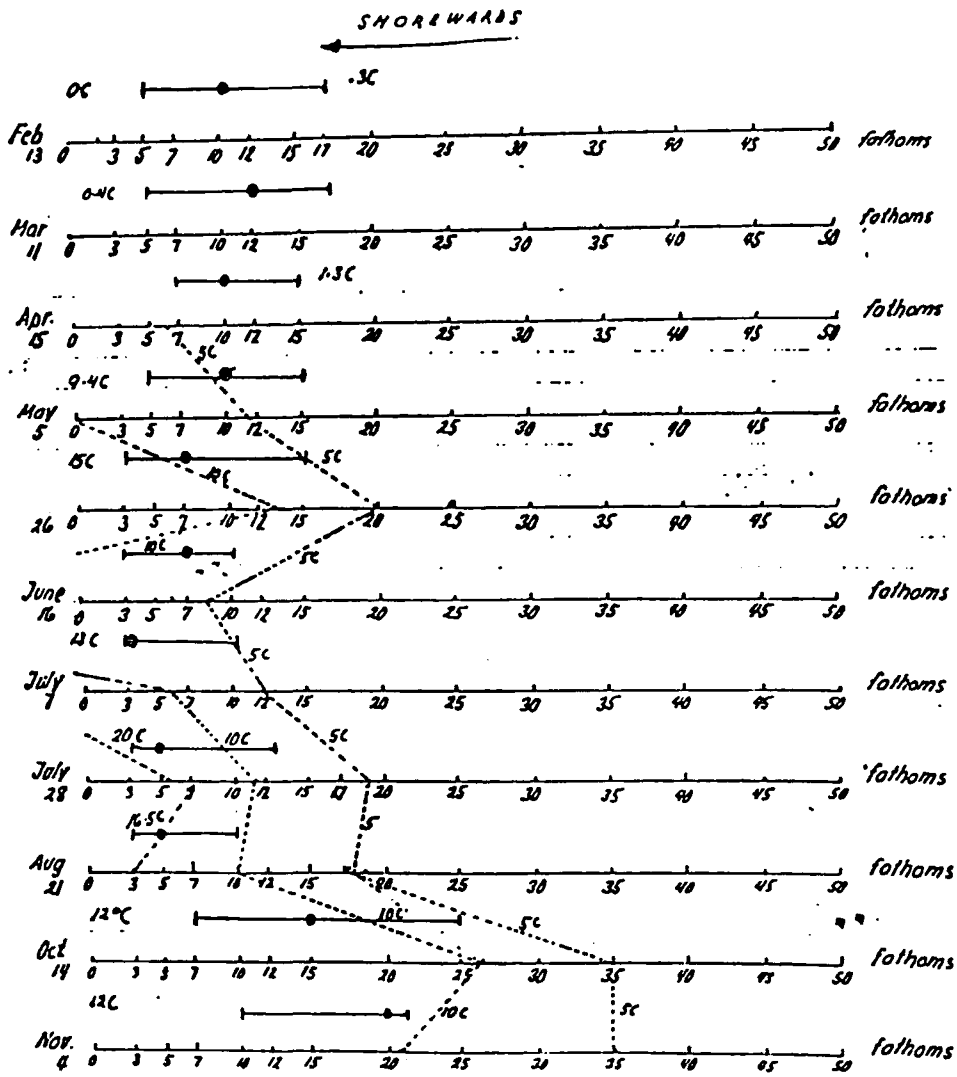

Figure 7. Seasonal depth distributions of yellow perch (year II+) in Lake Michigan. Distributions are depicted as modes bracketed by upper and lower limits of distribution. Dotted lines indicate isotherms connecting depths of equal temperatures (Wells, 1968).

THE ROLE OF TEMPERATURE PREFERENCE IN THE LIFE OF THE YELLOW PERCH

One of the shortcomings of laboratory investigations on temperature preference of fish is the unnatural compression of the temperature gradients in experimental tanks. The data from which preferred temperatures of yellow perch were calculated by Ferguson (1958) and McCracken (1948), for instance, were obtained using a vertical tank having a depth of about one metre. The field information with which the laboratory data was compared, on the other hand, was obtained by observing fish in natural thermal gradients of greater dimensions. In some field studies on the movements of fish in and around thermal effluents, the "natural" thermal gradients are compressed and a phenomenon resembling behavioral thermoregulation has been recorded (Neill et al. 1972; Spigarelli et al. 1972). It seems difficult to conceive, however, that fish spread out some fifty metres in the vertical temperature gradient existing in a lake in the temperate region during the period of summer stratification are continually moving up and down the water column many times a day as they do in a laboratory gradient tank, in an effort to regulate their body temperature. It is clear that, as usual, laboratory findings must be applied with reservation to the field situation since other gradients (light, gravity, water velocity, food availability, etc.) and other non thermal inputs affecting temperature selection are acting simultaneously.

From perusal of the literature and from contemplation of the results of the present study the significance of temperature preference in the life of the yellow perch is considered to be summarized below. The selected temperature response in perch serves (along with other gradients) to direct the movements of perch to thermally favourable habitats. During the winter season the environment of the species is cooler than ten degrees C for a period long enough to ensure development of the gonads (Jones et al. 1976). The results of the present investigation along with those of Barans and Tubb (1973) indicate that adult perch in mid-winter would choose temperatures above 12 degrees C if these were present in the environment. Since temperatures of this range do not occur naturally until early spring, the opportunity to move to these warmer waters is not normally present. The proximity of warm effluents, of course, could lure fish into unfavorably high temperatures.

Temperature preference during the growing season likely serves to direct fish into waters which have the optimum temperature range. The upward ascension of fish up the temperature gradient early in spring ensures that lake dwelling populations move shorewards to warmer waters where spawning and incubation of embryos take place. Our work and that of others indicate that, unlike some species (see introduction) there are no obvious seasonal effects apart from temperature as a function of season on the temperature selection in yellow perch. Barans and Tubb (1973), argue however, that in the perch of their study which were collected seasonally from Lake Erie and kept in a long, horizontal temperature gradient for periods up to a week, there were differences in the final preferendum over the year. Even granting this, the apparent final preferendum for adult perch sampled in midwinter was 15 C, some 10 degrees C above the optimum for gametogenesis.

There is a hint of seasonal differences in the data of the present investigation although there is a suggestion (see Fig. 5) that perch in lakes move to cooler waters in September, these may be ascribed to artifacts in the particular experimental method followed herein. Exposure of fish to constant temperatures may have interfered with the normal process of maturation and consequently affected the response to temperature gradients, especially in the summer. Samples held at 15 and 20 C, for instance, did not spawn indicating that they were egg bound and were resorbing eggs. This unusual physiological state may have affected their responses to temperature gradients and given rise to artificial temperature preferences. Further research is necessary to separate the effects of the experimental method on preferred temperature value from real seasonal influences. The technique of maintaining fishes at constant temperatures for an unnaturally long duration (i.e. spanning several seasons) should be checked by determining the final preferendum of acclimatized fish. In principle this would involve allowing fish to remain in a laboratory temperature gradient until the selected temperature becomes stable. In practice this has been difficult because of problems of maintaining stable thermal gradients in tanks and holding fish in confined space.

Recent development of temporal gradients in the last five years have allowed this approach to be taken at least with some species (Neill et al. 1972; Reynolds, 1973; Beitinger, 1974). Neill et al found that juvenile yellow perch regulated temperatures in the shuttlebox so that they fell in the preferred temperature range although they pointed out that data for perch were more variable than those for the other five species studied.

The results of the present study emphasize the need for the re-examination of techniques used in the determination of temperature preference in fish. In response to this need, the writer and four other workers in the field held a symposium (Richards, Reynolds, and McCauley, 1977) in which temperature preference methodology was reviewed and evaluated. The data of the yellow perch study also underline the necessity of reviewing the ecological significance of temperature preferenda of species of fish in general.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

Seasonal variations in temperature preferences of adult yellow perch (Perca flavescens) were sought by acclimating fish captured in the fall to 5, 10, 15, and 20C in the laboratory and determining their preferred temperatures in a horizontal temperature gradient trough. Temperatures selected in winter for fish acclimated to 5C ranged from 12 to 14C, considerably above the temperature region (6C and below) previously established for optimum gametogenesis. Final preferenda as determined from preferred temperature-acclimation temperature curves were 24, 20, and 17C during winter, spring and summer respectively. Those in late summer were below published values (23.5C) for this species. It is concluded that there are no demonstrable effects, at least in winter and early spring which might reflect changing physiological needs and that temperature gradients in nature serve rather to attract perch to warm temperatures suitable for spawning in spring and conducive to growth in summer.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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