THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

INFLUENCE OF PHYSICO-CHEMICAL FACTORS ON HABITAT SELECTION BY RED SHINERS, *NOTROPIS LUTRENSIS* (PISCES: CYPRINIDAE)

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

WILLIAM J. MATTHEWS

Norman, Oklahoma

1977

INFLUENCE OF PHYSICO-CHEMICAL FACTORS ON HABITAT SELECTION BY RED SHINERS, *NOTROPIS LUTRENSIS* (PISCES: CYPRINIDAE)

APPROVED BY

Loren G. Hill

Gary D. Schnell

Alan P. Covich

Charles C. Carpenter

DISSERTATION COMMITTEE

ACKNOWLEDGEMENTS

I am deeply grateful to my major professor, Dr. Loren G. Hill, who was a constant source of guidance and encouragement. His extensive background in the response of fish to water quality factors proved invaluable during the present research. The other committee members, Drs. Gary D. Schnell, Charles C. Carpenter, and Alan P. Covich were highly cooperative, and provided innumerable valued suggestions and criticisms.

William D. Shepard assisted in the field on numerous occasions and gave the manuscript a most helpful critical review. Mr. William Thomas kindly permitted me access to his farm, on which the field work was done. Mary Ellen Kanak provided much help and advice with preparation of figures. Funds and equipment for this research were provided by the Department of Zoology and the Oklahoma University Biological Station.

This research would not have been possible without the help of the following persons, who all spent extensive time with me in the field, often under quite adverse conditions: K. Asbury, D. Butcher, C. Campbell, R. Cobb, B. Ferraro, R. Gratz, J. Grimshaw, J. Grzybowski, R. Harrell, J. Holt, R. Kinniburgh, D. McNeely, B. Magdych, J. Magovern, S. Maloney, J. Maness, R. Matthews, E. Miles, D. Niemann, P. Poecetah, J. Redfern, and C. Willey.

I am deeply indebted to my wife, Susan, who sacrificed a highly successful and enjoyable teaching career so that I could return to full-time graduate work. Several of her suggestions and ideas are incorporated in this research, and her assistance with figures and the manuscript was invaluable. Finally, I would like to express most sincere thanks to Susan and to our children, Scott and Amy, for their love and patience which made successful completion of this research possible.

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FOREWORD

This dissertation is presented as a paper prepared in a style appropriate for *Copeia*, to which it will be submitted for possible publication. Two appendices have been added to the dissertation to provide all field data for the benefit of future investigators. The citations of Matthews (1977) refer to this dissertation.

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Major Professor: Loren G. Hill

ABSTRACT: Field studies were combined with single and multifactor laboratory preference tests to determine the relative influence of several physico-chemical factors on red shiner habitat selection. Temperature, pH, and total dissolved solids were the water quality factors that had the greatest potential influence, while dissolved oxygen and turbidity were of limited importance in habitat selection by the species. Red shiners avoided temperature extremes during winter and summer in both the field and the laboratory. Values of pH encountered in the field ranged from 7.5 to 9.6, of which the shiners avoided highly alkaline conditions. Their response to pH was strong in the laboratory, usually characterized by preference for pH of 7.1 to 7.4, and an avoidance of values below neutral. The response of the species to total dissolved solids was strong in the laboratory, and they apparently responded to this factor in the field when the range exceeded 500 ppm.

Current speed was the physical factor to which red shiners responded most consistently, followed by depth. In all study periods, they preferred water deeper than 20 cm, with negligible flow. Shelter, shade, and substrate exerted less influence on their selection of habitat. The shiners avoided unsheltered locations and clean, unstable sand substrate. Their response to shade could be explained by their thermal preferences.

INFLUENCE OF PHYSICO-CHEMICAL FACTORS ON HABITAT SELECTION BY RED SHINERS, *NOTROPIS LUTRENSIS* (PISCES: CYPRINIDAE)

True habitat "selection" occurs when mobile organisms choose among compared alternatives (Wiens, 1976). Many freshwater fish are highly mobile, and the use of space by any of these species operates on a series of levels that results in successively more precise location of individuals. Smith and Powell's (1971) model of physiological and climatic screens is a useful and heuristic device in a consideration of habitat selection. Studies of space occupied by freshwater fish can be placed into four somewhat overlapping categories: (1) zoogeography; (2) distribution within a watershed; (3) habitat selection within a limited portion of a lake or stream; and (4) spatial relationships between individuals resulting from behavioral interaction.

At the first level the role of the individual is minimal, and its location is likely predilected by environmental limits of tolerance or zoogeographic history. At the second level, the individual may play a role in the distribution of the species by major movements during its lifetime, but, especially in large watersheds, it will likely be restricted to some longitudinal section of the stream.

Categories 3 and 4 differ from the former in one important aspect: the responses of individuals during a limited time determine their distribution within a habitat. Studies at the third level could be restricted to a portion of a stream through which an individual might move during one or two days. Consideration of space occupied at the fourth level might include as little as a few square meters of the substrate upon which behavioral interactions such as territorial encounters could occur. The present study fits within the third category.

This field and laboratory study evaluates, for the red shiner, Notropis lutrensis, the influence of several physico-chemical factors on its habitat selection. In the present paper, we use habitat selection, habitat preference, and similar terms to indicate the occurrence of a greater number of individuals in a specified set of conditions than would be expected if their distribution was random. We do not distinguish between selection mediated by specific sensors and that resulting from mild physiological stress upon the organisms. The factors we considered were: temperature, dissolved oxygen, pH, total dissolved solids, turbidity, current speed, depth, shelter, shade, and substrate type. Answers to the following questions are provided: (1) With respect to each of the physico-chemical factors, how did the field distribution of red shiners compare to random? (2) Did the responses of red shiners to water quality factors in laboratory gradient tests concur with the responses that they exhibited to those factors in the field? (3) In multifactor laboratory tests with opposed optima, which water quality factors exerted the greatest influence on red shiner habitat selection? (4) Were there seasonal differences in the responses of red shiners to any of the physico-chemical factors? (5) What was the overall relative influence of the variables considered upon habitat selection by the red shiner?

To answer these questions, we used a combined field and laboratory approach. First, at a given time of year, the field distribution of red shiners with respect to all variables was determined. Following this, we tested red shiners in single and multifactor gradients of water quality variables, using ranges in the laboratory commensurate with, or slightly exceeding, ranges measured in the field. We considered agreement between field and laboratory responses to a particular factor to strongly indicate its influence upon habitat selection by the species. The preferences of red shiners in multifactor gradients with opposed optima were also weighted heavily in establishing a hierarchy of importance of the variables.

The species selected for this study, *Notropis lutrensis*, is the most abundant cyprinid in Oklahoma (Miller and Robison, 1973) and is very common in streams throughout the Great Plains. It ranges over most of western-central United States in a variety of habitats, but is most abundant in streams where environmental conditions are often harsh and fluctuating. The species is obviously well-adapted for such conditions, and is tolerant of wide variations in environmental factors (Matthews and Hill, 1977). Despite this tolerance, portions of the available habitat in southwestern streams are often unacceptable, and it seems likely that red shiners have evolved the ability to discriminate between more or less favorable conditions.

Methods

Our investigation can be divided into five periods of combined field and laboratory studies: February-March 1976; May 1976; August-September 1976; October-November 1976; and late December 1976-early February 1977. Three phases of research were accomplished during each period: field study, single-factor laboratory gradient tests, and multifactor laboratory tests. All research for a study period was accomplished within 30 days, except for the final one. During that period, ice delayed field work and the research spanned a total of 41 days.

Description of the field study site.--Field studies were conducted on a 600 m length of the South Canadian River (along Cleveland-McClain County boundary near Norman, Oklahoma) and on Pond Creek (McClain County) close to its confluence with the river (Fig. 1). The river is a typical, shallow Great Plains stream, with drastic changes in flow and wide fluctuations of environmental conditions. At the study site the minimum width of the main channel varied from in excess of 150 m following spring rains to approximately 1 m in late summer and autumn. The position of the main channel shifted frequently over the unstable sand of the river bed which was approximately 200 m wide.

Ample water for red shiner survival was available in the study area. During even the driest periods, a pool approximately 250 x 50 m maintained water as deep as 1 m. The main channel did not exceed 1 m deep at the times we sampled, few snags or obstructions were present, and the entire area was amenable to seining.

Pond Creek followed a more permanent course than the river channel. Dirt banks were 1 to 2 m high in many places, and the creek was bordered by trees and tall grasses. Substrate in Pond Creek varied from sand to mud, and in many places included mixed bottoms with algae or detritus. The creek averaged approximately 10 m wide and 0.5 m deep in the study area most of the year, but was reduced in late summer and autumn to a series of small, isolated pools. At those times, water of the upper creek was not contiguous with the river, and collecting sites were changed to include only the river and the creek mouth (Fig. 1).

No known point sources of pollution were in the immediate vicinity, and the site was relatively inaccessable to the general public. Considerable physico-chemical variation was usually present within the study area, due to contrast between the river and creek and as a result of variation within those two habitats. Water chemistry values measured during preliminary investigations of the site are provided in Table 1. Elevation gradients in the portions of the streams studied averaged less than 1 m per km.

The river and creek contained relatively few species of fish, which is typical for streams of the Southwest. We collected 21 species from the study site and similar locations on the South Canadian River in seining from 1974-1977. Red shiners were numerically dominant overall, usually outnumbering the combined total of individuals for all other species.

Field research.--The study area was subdivided by habitat type (Fig. 1): the mainstream river channel, the river channel near banks, the lower creek, the upper creek, and the backwaters. In each subarea, the location of sampling points was determined by pacing distances determined by random numbers. The only exception was in August, when a long, large pool was sampled by uniformly spacing sample points.

A field study period consisted of two days, each divided into a morning and an afternoon subsampling period. During each study period, 25 sampling points were selected, which we attempted to use during each of the four subsampling periods. Logistical problems resulted in actual totals of 100, 100, 89, 97 and 98 samples in February, May, August, October, and December-January, respectively.

Adjacent sampling points were located a minimum of 15 m apart, although preliminary observations indicated that a seining crew could approach to less than 5 m of a group of red shiners before the fish exhibited increased movement. Red shiners, like many minnows, do not necessarily swim away from approaching field workers, but increase random movement, sometimes even swimming toward the seine. At each sampling point we collected fish by making a "best effort" downstream through a distance of 5 m, using a 1.22 x 3.05 m seine with 0.32 cm bar measure mesh. The field crew worked from downstream to upstream sampling points so that disturbed sediments or other material would not alter the portion of fish. Fish were identified, counted, and released alive if possible. Voucher specimens, and any of uncertain identity, were preserved in 10% formalim.

A water sample for turbidity and pH measurement was taken at each sampling point before it was seined; measurements of other variables were made afterward so as to minimize disturbance of fish. Field tests indicated that homogeneous conditions could be assumed to exist within 5 m longitudinal samples if obvious interfaces such as the confluence of the creek with the river were avoided. Seining caused no measurable changes in water chemistry values.

Temperature was measured with a Hach mercury field thermometer or by the temperature mode of a YSI Model 54A oxygen meter which was checked against a mercury thermometer.

Oxygen concentrations were determined during the first three sampling periods by the YSI oxygen meter, and during the last two by the azide modification of the Winkler method (American Public Health Association, 1970). Measurements of pH were made in the field by a Hach Model 1975 meter within minutes of the collection of fish and water samples. Total dissolved solids were determined by a Myron L Model 512T4 TDS meter calibrated with natural water standard 442, or were measured in micromhos by a YSI Model 33 salinity/conductivity meter and converted graphically to parts per million. Turbidity was measured in the laboratory by a Hellige turbidimeter on the same day that samples were collected. Depth was measured with a folding ruler, and current speed was determined by timing a floating object over a distance of 5 m (Robins and Crawford, 1954).

Shelter was estimated as: (0) no shelter, as in midstream over clean substrate; (1) minimal shelter, such as near the bank, or with leaf litter on the bottom; or (2) substantial shelter, such as undercut banks or rootlets in the water. No sampling points were used where shelter could impede seining, and few such locations existed in the study area. Shade was recorded as: (0) no shade; (1) up to 50% of the surface of the area seined was shaded; or (2) 50% or more of the surface was shaded. Substrate was designated as: (0) no sand present; (1) mixed substrate including some sand, often with algae or detritus; or (2) clean, unstable sand.

The field responses of red shiners to temperature, oxygen, pH, dissolved solids, turbidity, depth, and current speed were evaluated each time by dividing the measured range of each factor into four equal subranges--low (LO), medium low (MLO), medium high (MHI), and high (HI). The proportion of sampling points with values in each subrange was multiplied by the total number of red shiners collected to provide an "expected" number of fish to be collected in each subrange if distribution was random with respect to a given factor. For shelter, shade, and substrate the same procedure was used except only three categories (0, 1, and 2) were incorporated. G-tests of goodness of fit (Sokal and Rohlf, 1969) were used to compare the distribution of red shiners to expected.

Field data are presented as percent deviation from expected as calculated by:

$$\% \text{ Dev.} = \frac{f - \hat{f}}{N}$$

where f is the actual number of red shiners collected from stations in a subrange, $\hat{f}$ is the number expected, and N equals the total number of red shiners taken during that collecting period. Possible deviations with this formula are limited to less than 100%.

Temperature, oxygen, and pH values were variable, often presenting quite different available ranges in different subsamples of one sampling period. Pooling of the actual values from all 100 stations for analysis of these factors could produce unrealistic results. If, for example, fish always selected the warmest available temperature, there could be multiple peaks of preference exhibited over the pooled range, corresponding to the warmest temperatures available during different subsampling times. Accordingly, for these labile variables, percent deviation as presented for each seasonal sampling period consists of the average of percent deviation in each subrange (LO to HI) over all four subsampling periods. The actual values of subranges of dissolved oxygen, pH, and temperature during each subsampling period are in Table 2, along with the percent deviation in each subrange at each time. The result for temperature, oxygen, and pH is thus not a statement as to an absolute preferred value in the field, but is an indication of what portion of the available range was used by red shiners during a particular time of year. Percent deviation for all other factors in a given sampling period is based on pooled data from all 100 sampling points.

Laboratory experiments.--Field-acclimatized fish are recommended for preference experiments in which seasonal effects are a component (Norris, 1963; Richards et al., 1977). Fish for laboratory tests were brought directly from the field study site, held in aerated styrofoam containers, and used within 48 hours of collection. During this time, holding temperatures were allowed to change slowly until they were commensurate with the temperature of water used in laboratory tests (Table 3). As acclimation to temperature change can be rapid (Hutchison, 1976), fish used in temperature gradient tests were collected on the same day as the laboratory tests were conducted, except that one time fish were held overnight at a temperature within 2 C of the field collection temperature. No individuals were used in more than one laboratory test.

With field-acclimatized fish, we did not determine an exact "final preferendum" in the sense of Fry (1947) for any factor. The object of the laboratory tests was to determine preference trends within values of the factors similar to the available field ranges.

To compare laboratory and field responses to individual variables, the four subranges (LO to HI) in both field and laboratory were ranked from 1 to 4 in decreasing orders of their selection by fish. The formula for N from Kendall's rank correlation coefficient (Sokal and Rohlf, 1969) was used to provide an index of agreement between field and laboratory trends (Table 4). This value cannot be statistically tested as only four categories are being ranked, but the formula provides a numerical tool to assist in evaluating similarities of trends in laboratory and field results.

The gradient chamber developed for this research was a modification of the design of Jones (1947) and Hill (1968, 1969) in which outflow of water at a drain results in separation of the water in different sections of a trough. With this device it was possible to present fish with single or multifactor stepped gradients of temperature, dissolved oxygen, pH, total dissolved solids, or turbidity.

The complete apparatus (Fig. 2) had four separate chambers (A-D) within which a gradient could be established; thus, up to four simultaneous replicates of tests could be conducted. The gradient chambers were constructed by capping the ends of two sections of plastic pipe (10 cm diameter) and splitting them lengthwise to produce four usable troughs. A single gradient chamber had four sections; test water in each section came from a different 220-l reservoir in which water was premixed to desired conditions before testing began. For example, if a pH of 6, 7, 8, and 9 were mixed in reservoirs 1, 2, 3, and 4, sections 1 through 4 of each gradient chamber would also have that sequence of pH conditions, with a between-section transition zone approximately 6 cm wide.

Sequential branching of plastic plumbing from the reservoirs resulted in the splitting of flow from each reservoir to similar sections of all four gradient chambers, ensuring that the flow and the resulting gradients produced in all four chambers were very similar. Flow rates from all four reservoirs could be changed simultaneously and uniformly with a C-clamp (control box), and screw clamps on water lines to separate inlets allowed fine adjustments.

Details of a single test chamber are also depicted in Fig. 2. Water from a given reservoir entered the chamber through a plastic T-shaped pipe located in the middle of one of the four sections of the chamber. Ends of each T were plugged, and numerous holes 1.6 mm in diameter permitted flow of test water into the chamber. Water flowed longitudinally in opposite directions from the inlet T and exited through drain holes 4 mm in diameter located in the bottom of the chamber at the points of separation between sections. Depth of water in the test chambers was maintained at 4 cm by balancing inflow and outflow of water. Before each sampling period the apparatus was checked by colored dyes to insure that the gradients were produced as desired.

A cardboard blind, painted dull gray, was placed over the entire apparatus during testing. A slit permitted direct observation of fish, and there was a hole in the top for a camera. One fluorescent bulb, 183 cm long, was placed 80 cm above and parallel to the gradient chambers. Tests were conducted with the room lights turned off, and with a fan motor running continuously to muffle noises made by the experimenter. All tests were conducted during the afternoon to decrease any diel effects upon the results.

Non-chlorinated tap water from deep wells of the University of Oklahoma was used as the water source for all laboratory tests (see Table 1 for water chemistry values). Temperature gradients were achieved by adding hot water and refrigerated water or ice to the reservoirs as needed. Once established, temperatures in the 220-l reservoirs changed less than 1 C during a test run. Lowering of pH was accomplished by adding dilute hydrochloric acid to the reservoirs. The relatively high pH (8.6-9.0) of the tap water made it unnecessary to increase alkalinity of test water. Dissolved oxygen differences were produced by gradually filling all reservoirs with water which had an oxygen concentration of approximately 4 ppm, and then bubbling either air or compressed oxygen through the reservoirs in which higher concentrations were desired. Supersaturation was readily achieved when compressed oxygen was used. Gradients of total dissolved solids were produced by adding commercial table salt to the tap water, which had an initial dissolved solids value of 400 - 500 ppm. Tap water initially had no measurable turbidity; turbidity was increased by addition of bentonite clay to form a suspension (Horkel and Pearson, 1976). Preparation of water for multifactor tests was by combinations of the methods described above.

The design of the laboratory apparatus did not permit testing of the response of red shiners to current speed, depth, or substrate. In preliminary tests, gradients of shade were produced by covering the fluorescent bulb with black plastic, and a variety of structures were used to produce shelter within the chambers. The responses of red shiners in gradients of shade and to choices of shelter were erratic, and the laboratory conditions of these two factors did not seem to be good simulations of choices available in the field. Accordingly, we did not test further the responses of red shiners to shelter or shade.

Before each test, conditions of temperature, dissolved oxygen, pH, and total dissolved solids were measured in each reservoir to insure that only the desired factors varied. Conditions used during each test, and conditions that existed in the field when test fish were collected, are provided in Table 3. For test gradients other than oxygen and temperature, air was bubbled continually through the reservoirs to insure mixing and provide fish with adequate oxygen in the test chambers. When only a temperature gradient was desired, air was bubbled through all reservoirs until oxygen concentrations were uniform throughout the system, and then shut off, to prevent cooler reservoirs from attaining higher oxygen concentrations than the warm ones.

Temperatures in the gradient tubes were monitored by YSI 12-channel telethermometers during all tests with the exception of those in March 1976. In these, temperature was measured immediately in water samples withdrawn through siphon tubes that were implanted in each section of each gradient chamber. Chemical gradients were monitored during testing by samples withdrawn through the siphon tubes.

To begin a test, the drain holes were closed from beneath the apparatus and tap water that had been aerated, but was otherwise unaltered, was used to fill the gradient chambers. Temperature of the holding water was within 3 C of the tap water to prevent thermal shock to the fish. A minimum of 30 min was allowed for the fish to become accustomed to the test chamber, then the drain holes were opened, flow started, and the desired gradient established. Flow of water was too slight to ripple the surface, and test fish exhibited neither rheotaxos nor hesitancy to move through any portion of the chambers. Red shiners readily adjusted to the chambers and usually began a period of general exploration almost at once. This exploratory behavior is desirable (Richards, et al., 1977) in that it ensures that fish are exposed to all conditions available to them and learn to negotiate any potential barriers. Richards et al. indicated that during this period social behavior is at a minimum and fish will not have had enough time for the fish to establish territories or dominance hierarchies.

Tests were normally conducted with 10 shiners per chamber and with either 3 or 4 test chambers in use at one time (unless otherwise noted in Table 3). Red shiners tested alone exhibited apparent fright and moved little in the test chambers. In groups of up to 10 individuals there was no apparent crowding; neither was there any obvious schooling. Reynolds and Thomson (1974) and Meldrim et al. (1974) similarly found it advisable to use groups of fish in gradient chambers.

A test run lasted 50 min, including a 10 min period following establishment of the gradient to allow fish time to sample the range of available conditions. After this initial 10 min the positions of fish in the gradients were recorded every 15 sec, on black-and-white film without a flash, until 35 exposures had been made. The time lapse of 15 sec between photographs was adequate for an individual fish to traverse the entire length of the gradient chamber. During the final 10 min of the test run, a second roll of film was used to make another 35 recordings of fish position in the apparatus.

We recorded a total of 9,241 control data points (one point = position of one fish at one time) while tap water passed through the apparatus at the usual rate, but no gradient established. The resulting distribution of fish indicated a slight "end effect" with 28.8, 20.7, 18.2, and 32.2% of the control fish in sections from left to right, respectively. This distribution differed significantly from uniform ($p < .005$) and, thus, was used as the "expected" baseline for distribution of red shiners in all tests. Data from the replicates of each test were pooled for determining preferences. "Preference" was considered to be shown for the section of the test chambers in which the greatest positive deviation from the expected number of fish occurred. Actual distributions of fish were compared to expected by g-tests of goodness of fit (Sokal and Rohlf, 1969). The results are presented as percent positive or negative deviation from expected, calculated in the same manner as for field results. The ranges presented for laboratory tests in Figs. 3-9 are the maximum and minimum values that existed within the chambers. The maximum and minimum values recorded in each section of the gradient chambers during a test are provided in Table 3.

Results

We seined the following numbers of red shiners during field sampling: February (11,249); May (6,912); August (10,576); October (19,182); and December-January (1,954). Complete field data are given by Matthews (1977) in Appendix A. Figs. 3-9 show all field and single-factor gradient test results. The results of multifactor laboratory tests are depicted in Fig. 10.

Large numbers of preadults, some as small as 14 mm standard length, overwintered in 1975-1976, apparently as a result of autumn spawning and an unusually mild winter. The population at the study site consisted mostly of small fish in February 1976, which exhibited substantial growth in the spring and produced a large number of adults in the summer. Summer drought greatly reduced the available habitat in 1976, and rains did not increase water levels substantially until after the October sampling period. Red shiners apparently had limited spawning success in 1976, as our collections in December and January did not include as many small fish as had been noted in December 1975 or February 1976. Seining after completion of the October collecting indicated that large numbers of red shiners were present in the study area, but their number declined drastically by December, presumably due to natural attrition.

Numerous correlations existed among physico-chemical factors in the field (Appendix B, Matthews, 1977), but none of the factor pairs consistently exhibited a mutual highest correlation. Dissolved oxygen was closely correlated with pH values during four of the sampling periods and temperature was strongly correlated with dissolved oxygen in three samples.

No consistent pattern of correlations between fish distribution and single physico-chemical factors existed. The abundance of red shiners was correlated with current speed in February; oxygen and substrate in May; shade in August; oxygen, pH, total dissolved solids, turbidity, depth, shelter, and shade in October; and substrate in December-January.

All field and laboratory results differed from expected at the .005 level, except for the response to shelter in the field in May (Fig. 9A), which was only significant at the .05 level. Significance tests thus provided no indication of relative responses in the field or laboratory and, thus, of deviation were used to compare the strength of response to various factors. Although all results were statistically significant, those with small percents of deviation were not considered biologically important.

Field sampling and single-factor laboratory tests.--In March and May, all of the water quality factors were included in laboratory tests. During August and October, only the water quality factors that appeared influential on red shiner habitat selection in the field were tested in the laboratory. Field temperatures approached those lethal to red shiners in parts of the study area in August, and red shiners showed a positive response to LO temperatures (18.0% deviation). Turbidity in August appeared potentially influential, with maximum absolute percents deviation of 16.4 to 55.9 during the subsampling periods. Temperature and turbidity were thus tested in the laboratory in August. In October, temperature and pH appeared most influential in the field, as 90.7% of the red shiners collected were taken within a 1.5 C range, and the response to LO pH (64.6% deviation) was stronger than the response to any other water quality factor. The range of total dissolved solids was so small in August (150 ppm) and October (180 ppm) that we omitted laboratory tests of this factor. The response of red shiners to oxygen concentrations was weak and variable in the laboratory in March and May, and field responses to this factor were not strong in August or October. It was thus not used in laboratory tests during the latter periods. Field response to pH did not exceed 9% deviation in August; thus it was not used in laboratory tests that month. The field range of turbidity in October was the smallest encountered (52 JTU) so it was not tested in the laboratory. In February 1977, we used all of the water quality factors in laboratory tests, except turbidity, to which the maximum field response was only 3.0% deviation.

Red shiners exhibited strongest responses to temperature during summer and winter. In February, they preferred MHI and HI field temperatures and avoided temperatures in the low half of the range (Fig. 3). Laboratory tests conducted during March for this period produced results that agreed with field trends: shiners selected the warmest temperatures available in a gradient which, in total, extended from 6.1 to 15.1 C (Fig. 3).

In December-January, red shiners responded positively to HI temperatures when the available range exceeded 6 C, but during two subsamples when this value was not exceeded the distribution of the shiners to existing temperatures was erratic. Red shiners tested in a thermal gradient in the laboratory during this period avoided cold and selected warm conditions, as they had done the previous winter.

Red shiners avoided MHI and HI field temperatures in August, selecting cooler portions of the habitat (Fig. 3). Tolerance was quite broad, however, with positive responses to temperatures as high as 35 C (Matthews, 1977). In August laboratory tests, shiners selected temperatures ranging from 26.3 to 35.1 C, with the strongest response at approximately 33 C. Although the laboratory selection trend differed from that in the field in August, red shiners in both situations avoided water warmer than 36 C.

In May, red shiners avoided temperatures below 18 C in the field. In the laboratory they selected the warmest portion of the gradients, where temperature exceeded minimal spawning temperatures (Fig. 3). While the shiners selected the warmest conditions in the laboratory at this time, lack of a clear trend in the field suggested that other factors may have overridden the effect of temperature upon habitat selection.

October was the only time in which field occurrence of red shiners could be related to an absolute temperature. A total of 17,389 individuals, representing 90.7% of the catch, were collected in 13 seine hauls at locations where temperature ranged from 11.5 to 13.0 C. During this period, red shiners were consistently collected from backwater pools in which daily temperature fluctuation was only 1 or 2 C versus thermal changes of up to 9 C from morning to afternoon at other locations. October laboratory results (Fig. 3) indicate a positive response to the temperatures in which most fish occurred in the field.

The index of comparison based on Kendall's N (Table 4) indicated agreement of field and single-factor laboratory tests of temperature in February, May, and December-January. Trends were not the same in field and laboratory in August and October according to this index, although the same absolute temperature was selected in field and laboratory in October, as previously noted.

In the field, red shiners exhibited positive responses to dissolved oxygen concentrations as low as 4.5 ppm, and avoided locations with high oxygen conditions (Fig. 4). The only exception was in January 1977, when 371 fish were taken at 21.2 to 22.4, equaling up to 200% saturation. Such supersaturated conditions occurred in beds of algae in calm water on sunny days.

No generalization was possible as to the responses of red shiners in laboratory oxygen gradients. They avoided strong supersaturation in February 1977 (Fig. 4), but exhibited a slight preference for mild supersaturation in May. In May and February 1977, they responded positively to oxygen concentrations as low as 4.5 and 5.3 ppm, but avoided concentrations of 5.7-5.9 ppm in March. Kendall's N indicated agreement of field and laboratory results in February-March and May 1976 (Table 4), but the negative value of the index in December-February indicated that field and laboratory results were contradictory at that time.

The responses of red shiners to pH in the field were not strong except in October, when they strongly preferred the lowest portion of the field range (Fig. 5). Minimum pH values encountered at that time (8.2) were the most alkaline found during the study. The shiners avoided the highest portion of the pH range in the field at all times, and tended to occur where conditions were nearer neutral.

In the laboratory, red shiners were presented with gradients that slightly exceeded field values toward acidity. In three of the four test periods they exhibited a strong laboratory preference for pH values of 7.1-7.4, indicating that when this was the only variable the shiners selected pH values slightly lower than those for which they showed a positive deviation in the field. In single-factor tests in March and February 1977, and in multifactor tests reported in a later section, shiners markedly avoided pH values below 6.9. Consistently positive values for Kendall's N (Table 4) indicated that preference trends were similar in the field and the laboratory.

Red shiners were found in greatest numbers in LO or MLO dissolved solids during February and May, when the values available in the field varied more than 500 ppm (Fig. 6). In laboratory gradients in March and May a very strong selection of low dissolved solids was noted. During the rest of our field work, dissolved solids varied over such a narrow range (150, 180, and 270 ppm in August, October, and December-January, respectively) that it seemed unlikely red shiners would discriminate within the available values. The relatively weak response in February 1977 of red shiners in a laboratory gradient commensurate with the field range in December-January indicated that the strong peak in field data at that time was probably due to another factor. Agreement between laboratory and field results (Table 4), and the strong response of red shiners in laboratory gradient tests in March and May, indicated that dissolved solids could, under certain circumstances, be a strong influence upon their habitat selection.

The response of the species to turbidity in the field and the laboratory was contradictory (Fig. 7). Although laboratory responses were consistently toward turbidities of approximately 100 JTU, red shiners in the field showed a strong selection for HI turbidity only once. Calculated values for Kendall's N were negative during two of three months that included laboratory tests (Table 4), indicating opposite results in the field and laboratory.

There was less variation in the response of red shiners to current speed than to any other factor studied (Fig. 8A). During all periods of field work they exhibited a preference for standing water and always avoided MLO, MHI, and HI current speeds. Greatest numbers of red shiners were taken at all times of year in locations without detectable flow, such as backwaters, pools along the main river bank, or the creek mouth when water was high in the river. Few were collected in the swift, shallow main river channel.

The species occurred in greatest numbers in water deeper than 20 cm (Fig. 8B). Although seining provided no data on the vertical positions of red shiners, visual observations indicated that they readily utilized the entire water column. In one particularly large school, observed at midday in February 1976, thousands of red shiners rested or swam quietly at all levels of the 25 cm water column, generally with a few centimeters between individual fish, both horizontally and vertically.

Since neither current speed nor depth could be directly tested in our laboratory apparatus, we reanalyzed all field data to determine if a response to those conditions might have overshadowed the response to all other factors. Samples from locations with depth less than 10 cm or current speed greater than 15 cm/sec were omitted, and percent deviation of occurrence of red shiners was recalculated for the remaining sampling points. With extreme samples for depth and/or current speed excluded, the overall trends with respect to other physico-chemical factors were nearly identical to those found in the original analysis. During most sampling periods, for most factors, there was no change in the response of red shiners. One exception was during February, when the strongest preference for total dissolved solids switched from LO to MLO, and the shiners showed a small negative response to the LO portion of the range. Obviously the relationships between red shiner distribution and the other physico-chemical factors were not artifacts of response to current speed or depth.

In the field, red shiners avoided areas without shelter. Response was mixed between a preference for minimal and substantial shelter (Fig. 9A). Apparently almost any available shelter, such as leaf litter, detritus, or the near proximity of a bank, helps create acceptable habitat for red shiners. Shelter seeking in the field appeared to be of secondary importance, however, as large schools of shiners were sometimes encountered in open water away from shelter. Within acceptable limits of other physico-chemical factors, the species probably had a propensity for some shelter, but they were strongly attracted to substantial shelter only once in the field.

Red shiners strongly selected well-shaded areas in the field in August and October (Fig. 9B), and at both times they also occurred in greatest numbers in the LO field temperatures. Shade was associated with vegetation along shore and with high dirt banks; thus separation of shade from shelter was difficult. During summer heat, however, shade-seeking was probably an influential factor in habitat selection, at least during the afternoon. In December-January the preference of the fish for unshaded areas probably was correlated with their preference for warmer field temperatures.

With the exception of August, when the response was very weak, shiners avoided substrates composed entirely of sand, and preferred substrates of sand mixed with other materials, or devoid of sand (Fig. 9C). The mixed category included bottoms consisting of sand and algae, which were common in October. In August and October bottoms without sand were not available as all backwaters where such substrates were found had dried up.

Multifactor laboratory tests.--During all sampling periods, red shiners exhibited strong responses to temperature in the field and in single-factor tests. For this reason, and because temperature is perhaps the most pervasive physical factor in the environment (Hutchison, 1976), this factor was included in multifactor tests at all times of year. The other factors selected for multifactor tests were those for which field and single-factor test results were in agreement, and for which conditions in the field made it seem likely that the factor could indeed have an influence upon habitat selection.

In March, three factors in addition to temperature were used for which red shiners had showed a strong laboratory response: oxygen, turbidity, and pH. We did not use total dissolved solids, despite a strong response to that factor in the laboratory, because conditions of total dissolved solids varied little within the creek and within the river in February. We considered that this factor could cause red shiners to select between river and creek locations, but that within either major habitat type this factor probably did not function in habitat selection.

Red shiners responded strongly to total dissolved solids, pH, temperature, and turbidity in single-factor tests in May, but total dissolved solids were eliminated from multifactor tests at that time for the same reason as in March. Reasons for selection of laboratory test factors in August-September and October-November have been given in a previous section. In February 1977, pH and temperature were tested in multigradients since pH was the water quality factor for which results of single-factor laboratory tests were strongest at that time, and because to that date both factors had appeared to have strong potential influence on distribution of red shiners.

In March 1976, warm temperatures commensurate with those selected in single-factor tests were presented to red shiners in a gradient simultaneously opposed by optima of dissolved oxygen, pH, and turbidity that had been selected in single tests (Fig. 10A). Response of the test fish indicated that temperature alone did not override the combined effect of all three opposing factors, but that its influence was substantial, as shiners did not prefer the right end of the chambers where optima of the other three factors were available. On the next day, the same combination of gradients was again presented to test fish, except that the pH optimum of 7.2-7.3 was moved nearer the middle of the test chambers, and a pH below neutrality (6.8-6.9) was presented at the extreme right end (Fig. 10B). Test fish exhibited a strong response for the section of the gradient intermediate between preferred temperature and pH, and avoided the section having conditions of oxygen and turbidity that had been selected when those factors were presented singly. The results indicated that pH and temperature influenced distribution of red shiners more strongly than oxygen or turbidity. A gradient was then tried in which temperature and pH optima were opposed (Fig. 10C). The results suggested that both factors were of approximately equal influence on red shiner distribution.

Preferred temperatures were presented to red shiners in opposition to combined optima of pH and turbidity in May (Fig. 10D). The results indicated a much stronger response to pH and/or turbidity than to temperature at that time. A test of pH versus turbidity (Fig. 10E) indicated that turbidity was of greater influence on red shiner distribution than was pH during May. A test of temperature versus pH in May (Fig. 10F) indicated both factors of approximately equal influence, with red shiners selecting an intermediate position between pH values and temperatures that they had selected in single-factor tests.

The test of temperature versus turbidity in September (Fig. 10C) slowed a clear response of test fish to temperature rather than turbidity. Tests of temperature versus pH in November (Fig. 10H) resulted in bimodal peaks of preference for temperature; shiners avoided pH values they had selected in single-factor tests.

In February 1977 (Fig. 10I), fish avoided previously selected warm temperatures that occurred in combination with pH of 6.7-6.9 and selected the same pH values that they had preferred in single-factor tests. Red shiners did not, however, enter preferred pH values at the right end of the gradient chambers, where they were combined with cold temperatures (3.7-2.5 C).

With the exception of May, multifactor test results indicated that either temperature or pH was the water quality factor with strongest influence upon red shiner habitat selection. Turbidity appeared most important in laboratory tests in May, and this factor may have overridden the influence of temperature in the field at that time.

Discussion

Habitat selection by mobile organisms is a complex process coupling monitoring of environmental factors with appropriate responses. Biotic variables that have been suggested to influence habitat selection of fish include predators, competition, prior experience, home range, and food (Sale, 1969; Neill and Magnuson, 1974). Below we examine the probability that such factors influenced the distribution of red shiners in the study area and the influence of physico-chemical factors on their habitat selection. We also consider, for fish of the South Canadian River, the applicability of Sale's (1969) model for habitat selection.

Few predatory fish, including young-of-year, were collected at the field site. The fluctuating environment of the study streams probably precludes continued occupancy by most larger fish species. The distribution of red shiners within the site was apparently not influenced significantly by predators.

In the present study, the large numbers of red shiners made it appear unlikely that they had been displaced from any portion of the habitat by competition from other species. Red shiners were the most abundant fish species, usually exceeding other species in numbers by an order of magnitude.

Prior experience or the use of home ranges appeared unlikely to strongly influence fish habitat selection in the ephemeral habitats of these unstable streams. The position of the river channel shifted frequently, sand-bottomed pools were scoured out and re-filled, and most of the upper creek dried up completely during the course of the study. Prior experience is probably more important to fish in stable habitats in which specialized substrates, such as coral or rock, are available (Sale, 1971; Quartermus, 1975). Red shiners occupied a variety of habitats in which one substrate type gradually merged with another.

Response to food could potentially influence habitat selection by red shiners, but algae, upon which the species commonly feeds (Laser and Carlander, 1971; Harwood, 1972) were widespread in the study area. Despite the fact that red shiners from the study area frequently had algal cells in the gut, they usually avoided algae beds in which oxygen was supersaturated or pH was high. Food was discounted by Mendelson (1975) as significantly influencing distribution of three Notropis species in a Wisconsin stream. They apparently selected habitat in response to other factors and used whatever food items were available in the locations occupied. The relative importance of food and temperature on fish habitat selection was investigated directly by Neill and Magnuson (1974) who offered bluegills (*Lepomis macrochirus*) food in the portion of a test chamber with an inappropriate thermal regime. They found that except for brief forays to feed, the fish remained in the part of the apparatus with preferred temperatures.

No biotic factors could be identified that were likely to have strongly influenced habitat selection by red shiners in the study site. Physico-chemical factors were thus considered to be of primary influence upon distribution of the fish within the available habitats. The correlation of various physico-chemical factors in the field during all study periods (Matthews, 1977) indicated the necessity of controlled laboratory tests in order to determine the response of red shiners to individual variables.

Trends of red shiner response to field temperatures during winter and summer sampling can be interpreted as an avoidance of extremes of temperature. The erratic selection response of the shiners below 6 C may indicate a cold threshold below which they become sluggish or respond little to thermal gradients. Low responsiveness to stimuli by fish in cold conditions was suggested by Breder and Nigrelli (1935), Norris (1963), Brown et al. (1970), Meldrim and Gift (1971), and Beitinger and Magnuson (1976). Red shiners collected in the field from temperatures near freezing seemed relatively inactive, struggling little in the seine. They became sluggish in the laboratory at such temperatures, exhibiting little response to touch.

An annual trend may explain the responses of red shiners to temperatures in May and October. While field temperatures were rising in May, shiners avoided LO field and laboratory temperatures, and showed a positive response to warm temperatures in the laboratory. In October, with falling field temperatures, red shiners selected locations in the LO portion of the available field range, with most being collected from 11.5-13.0 C, which they also preferred in the laboratory. Meldrim and Gift (1971) and Cherry et al. (1977) reported that the preferred temperatures of some species were higher during periods of rising field temperatures than when temperatures were falling. Such a yearly cycle of thermal preference could be related to the bioenergetic hypothesis proposed by Brett (1971) to explain daily movements of sockeye salmon (Oncorhynchus nerka). According to this hypothesis, fish move to optimal warmer temperatures for vigorous activities, such as feeding, and to metabolically conservative, cooler temperatures at other times. Preference for warmer temperatures during spring could be related to a pre-spawning physiological state and to an increase in feeding activity. Falling temperatures in autumn would signal the onset of cold weather during which feeding might decline. Winter survival at low rations would be favored by movement to cooler water, so long as temperatures near freezing were avoided.

Aggregation in large groups in October may also have lowered the metabolic rate of individuals due to a "schooling effect" as reported by Parker (1973) for red shiners and 12 of 13 other species that he tested. Other possible explanations for the aggregation of red shiners in pools in October include greater thermal stability, as previously indicated, and pH closer to preferred values (see below).

Oxygen concentration was probably not a strong influence on red shiner habitat selection, which agrees with the results of Dendy (1945), Whitmore et al. (1960), Jones (1952), Hill (1968), and Gebhart and Summerfelt (1974). These authors found that fish avoided oxygen concentrations below a threshold value that ranged from 2.0 to 4.5 ppm, but that above such values oxygen concentration had little effect on distribution of fish. Hill et al. (1973) and Reynolds and Thompson (1974) noted an avoidance of supersaturation by fish, which agreed with the response of red shiners. Supersaturation of oxygen can cause gas bubble disease (National Academy of Sciences and National Academy of Engineering, 1972) at concentrations such as we found in the field; it would thus be to the advantage of a fish to avoid such conditions.

Previous workers such as Burton and Odum (1945) have considered pH unimportant as a factor in fish distribution in the ranges normally encountered in the field. Jones (1948) reported non-responsiveness of sticklebacks (Gasterosteus aculeatus) to pH in laboratory gradients at ranges commensurate with normal field values. Our laboratory results with red shiners differed from Jones' results with sticklebacks. Red shiners are apparently highly sensitive to pH, which agrees with Bull (1957) that some fish can perceive pH changes of 0.04 to 0.10 in conditioned response experiments.

Cahn (1927) reported a strong relationship between pH changes and the daily movements of brook silversides (Labidesthes sicculus) in a northern lake, which could not be accounted for by changes in light, temperature, food, oxygen, or protection. He also demonstrated a difference in the pH of habitats occupied by juveniles and adults of this species that coincided with an increase in blood pH as they matured.

Preference of red shiners for pH approaching neutrality agreed with pH values observed by Shelford (1923) for 11 species of freshwater fish in the laboratory, which ranged from 7.2 to 7.85. Red shiners strongly avoided pH below 6.9, which may be related to either the Bohr or Root effects (Jones, 1972), in which the capacity of blood to transport oxygen declines as pH decreases. This interpretation should be viewed with some caution; there is considerable variation in the Bohr shift of various fish species, with species adapted for oxygen-poor waters generally exhibiting similar effects (Jones, 1972). The reason that fish avoided pH values in the upper field ranges was not clear. Possibly as the pH of environmental water departs further from the pH of fish blood, which varies from approximately 7.4 to 8.2 (Packer and Dunson, 1970; Randall and Cameron, 1973), it becomes increasingly difficult for buffering to keep internal pH within limits of tolerance.

Avoidance of high environmental pH may help explain the crowding of large numbers of minnows into backwater pools in October. With the exception of the backwaters, where pH was 8.2-8.5, pH values throughout the study site were 8.7 or greater at that time. The possibility exists that such crowding of fish into backwater pools caused the lower ambient pH, which in turn may have made the pools more suitable for red shiners. The greater thermal stability of the pools, previously discussed, also undoubtedly helped make them more acceptable fish habitat.

Most fish species are limited geographically by salinity, or total dissolved solids, but salinity gradients are not encountered in many freshwater streams. This factor has accordingly been considered of little consequence in the habitat selection of most freshwater fish (Hynes, 1970). Streams of the American Southwest, however, are subject to extreme fluctuations of salinity concentrations depending on rates of flow and runoff, and introduction of brine from oil wells has created drastic local salinity gradients during the last century (Clements and Finnell, 1955). Even a euryhaline species like the Red River pupfish (*Cyprinodon rubrofluviatilis*) requires up to eight hours to acclimate to salinity changes (Renfro and Hill, 1971).

The capacity of a fish of southwestern streams to seek out locations in which total dissolved solids are least altered during periods of environmental fluctuations would provide it with a longer period to adjust its osmoregulation. The red shiner apparently has this capacity, as indicated by strong laboratory preferences for values of total dissolved solids similar to those which it occupied in the field. A similar response has been found in Red River pupfish, which preferred their acclimation salinity concentrations in laboratory gradient tests (Hill and Holland, 1971). Red shiners appear to be highly responsive to concentrations of total dissolved solids and under some circumstances this may become a very important factor in habitat selection.

Turbidity was not encountered in the field at values harmful to freshwater fish (Wallen, 1951). No reports exist of fish selecting particular turbidities, although Grinsted (1965) and Swenson and Matson (1976) concluded that it influenced the distribution of fish in lakes by changing the depth of light penetration. Our laboratory studies indicated a preference of red shiners for turbidities of approximately 100 JTU, but disagreement between our laboratory and field results implied that the influence of turbidity upon their habitat selection was negligible. Red shiners thrive in conditions of frequent high turbidity (Cross, 1967), but their brilliant breeding coloration would suggest a historical affinity for water of greater clarity, in which colors would be more useful. Most minnows species found in continually turbid water do not develop bright breeding coloration.

Current speed is a major factor in red shiner ecology; they consistently avoided water with substantial flow, and preferred standing-water habitats. In the South Canadian River system, the red shiner's affinity for non-flowing water may result in their ecological separation from forms such as the Arkansas River shiner (*Notropis girardi*) and the emerald shiner (*Notropis atherinoides*), which occupied flowing water in main channels more than did red shiners.

Avoidance of shallow water could be due to the concomitant reduction in thermal stability or might be an adaptation to avoid stranding as water levels fall. Starrett (1951) reported that speckled chub (*Hybopsis aestivalis*) retreated from shallow water and thus escaped stranding, while several *Notropis* species commonly died in cut-off pools. Of course, red shiners in very shallow water would be more visible to little blue herons (*Florida coerulea*) and other wading birds that occur along the river.

Shelter has been reported more important in the ecology of salmonids (Baldes and Vincent, 1969), centrarchids (Stuntz, 1975), and reef fishes (Sale, 1971) than of cyprinids. Red shiners may have occupied sheltered areas because of concomitant shade or standing water. They were often taken in large numbers in open water of the lower creek where little shelter was available. We considered shelter to include the near proximity of a bank, which affords a fish protection from attack from one side. If only actual structure in the water had been considered shelter, the response of red shiners to this factor would have been much weaker.

Shade has been considered ecologically important to salmonids (Gibson and Power, 1975), centrarchids (Reynolds and Casterlin, 1976; Reynolds, 1977), and marine fishes (deVlaming, 1971; Reynolds and Thomson, 1974; Reynolds et al., 1977). Mixed preference tests by Stuntz (1975) indicated that for bluegills light was more important in habitat selection than temperature, cover, or substrate. None of our field evidence indicated that shade alone was critical to red shiners. Shade-seeking in August and October was likely related to a positive response to cool temperatures.

The importance of substrate upon distribution of most freshwater fish is restricted to selection of spawning sites (Hynes, 1970), although for some groups such as cichlids substrate may play a major role in habitat selection throughout life (Fryer and Iles, 1972). Red shiners spawn in a variety of habitats and substrate is probably of limited importance in their breeding ecology. Fish in this study were most often taken over muddy or mixed bottoms, but at these locations flow was usually negligible, and temperature and pH were more favorable than at locations with unstable sand substrates. Red shiners showed no preference for mixed bottoms that occurred in combination with shallow water or high temperatures. The positive response to any substrate type in this study probably resulted from the influence of other factors.

Sale (1969) presented experimental evidence to support a model for habitat selection in a reef fish, the manini (Acanthurus triostegus), in which levels of random movement by the fish resulted in occupancy of appropriate habitat. In his model, the level of random exploratory movement was continually regulated by feedback from the environment, increasing when habitat was inappropriate and decreasing or ceasing when improved or acceptable habitat was encountered.

Our work does not provide an experimental test of Sale's (1969) hypothesis, but the applicability of the model to fish streams of the Great Plains appears questionable. When water levels are relatively high and environmental conditions moderate, the immediate survival of a fish probably does not depend upon its selection of physico-chemical conditions. At such times, increased random exploration, resulting in the occupancy of appropriate environment, might be an adequate strategy for habitat selection.

During summer, however, the system may be characterized by limited areas of acceptable habitat interspersed within a greater proportion of habitat that is unacceptable or lethal, due to a factor such as temperature. In such a situation, habitat selection is more critical, and a fish that wanders even a few meters from a refuge might easily die before random movements bring it back to appropriate habitat. A fish that responded to gradients of temperature, pH, or some other factor, or that moved directly to a visual cue such as shade, would appear to have an increased chance of re-entering appropriate space and thus surviving. Streams of the southern Great Plains are environmentally harsh during hot, dry weather. Sale's (1969) mechanism for habitat selection, which was proposed for fish in a more stable environment, would seem too inefficient to be adaptive in streams of the American Southwest.

Conclusions

Current speed was the physical factor to which red shiners responded most consistently, followed by depth, in all field sampling periods. They markedly avoided swift currents and very shallow water. The responses of red shiners to other physical factors varied. Shade was probably of importance during hot weather, as it helped to provide cooler temperatures. Shelter likely had some influence on the distribution of red shiners within areas that were otherwise physico-chemically acceptable. The consistent avoidance of unstable sand substrate in the field was probably in response to other physico-chemical factors, although more food items are probably available over mixed bottoms.

Turbidity was probably the water quality factor that had the least overall influence upon movements of red shiners. Laboratory and field responses conflicted, and this factor was important in only one period in multifactor tests.

Dissolved oxygen had little influence on red shiner habitat selection over most of the ranges encountered, but the fish usually avoided supersaturation. Shiners readily occupied locations with low dissolved oxygen, but gave no indication of seeking any precise concentration. Low oxygen concentrations would probably influence habitat selection only if they neared depletion.

Red shiners exhibited a strong response to dissolved solids in the laboratory, which corresponded to their field preference when the range exceeded 500 ppm. Total dissolved solids can undoubtedly be very influential upon habitat selection if concentration gradients are encountered, but this condition was not regularly found in our field study.

A consideration of all field and laboratory results indicated that both pH and temperature could play important roles in red shiner habitat selection, and that neither factor was clearly of greater influence than the other. While response to pH in the field was not as strong as the response to temperature, shiners showed marked pH responses in the laboratory, particularly when the range extended below neutral. Multifactor tests indicated that either temperature or pH could be the water quality factor that exerted the greatest influence on their habitat selection. The influence of pH in the field is probably substantial when conditions produce pH ranges slightly greater than those we encountered.

Seasonal differences were noted in the responses of red shiners to temperature and shade. No seasonal patterns in the responses of red shiners to other physico-chemical factors could be discerned.

The influence of any variable upon habitat selection depends upon the entire milieu of conditions at a particular time, and organisms probably never select habitat solely as a function of one factor. The results of our study, however, suggest a hierarchy of influence of the variables that we considered. Of the physical factors, current speed was most important, followed by depth, with shelter, shade, and substrate less so. There were no good criteria for ranking the latter three in a particular order of influence. Of the water quality factors, temperature, pH, and total dissolved solids were of approximately equal potential influence on red shiner habitat selection. Dissolved oxygen was considerably less important, and turbidity was probably least influential of the water quality factors studied.

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TABLES

TABLE 1. WATER CHEMISTRY VALUES FOR SOUTH CANADIAN RIVER, POND CREEK, AND THE TAP WATER USED IN ALL LABORATORY EXPERIMENTS. Measurements for the river and creek were by a Hach DR-EL Engineer's Lab except that pH was measured by a Hach Model 1975 meter and total dissolved solids was measured by a YSI Model 33 salinity-conductivity meter. Determinations for tap water were made by Oklahoma Testing Laboratories, Oklahoma City, Oklahoma. -- = information not reported.

Factor	South Canadian River 1 Feb 1976	Pond Creek 1 Feb 1976	Tap Water 18 Dec 1974
pH	8.35	8.25	9.0
Bicarbonate (ppm)	240	260	354
Carbonate (ppm)	0	0	12
Hydrogen sulfide (ppm)	0	0	--
Sulfate (ppm)	275	145	23
Silica (ppm)	10	5	7.6
Chloride (ppm)	160	60	7
Total dissolved solids (ppm)	640	475	569

TABLE 2. RANGES OF LO, MLO, MHI, AND HI, AND PERCENTAGE DEVIATION IN EACH SUBRANGE DURING SUBSAMPLING PERIODS. The average percent deviation, which corresponds to the information provided in Figures 3 - 5 is also provided. -- = no fish expected.

Date and Time	LO range % Dev	MLO range % Dev	MHI range % Dev	HI range % Dev
Temperature (C)				
14 Feb 76 AM	11.3-11.9	12.0-12.6	12.7-13.3	13.4-14.0
	-22.4	-26.4	65.2	-16.4
14 Feb 76 PM	14.0-14.6	14.7-15.2	15.3-15.8	15.9-16.5
	-14.9	- 8.5	8.2	15.3
22 Feb 76 AM	1.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9
	-15.9	- 3.8	-26.0	45.7
22 Feb 76 PM	8.6-10.1	10.2-11.7	11.8-13.3	13.4-15.0
	-26.3	10.9	10.7	4.8
Average % Dev February 1976	-19.9	- 7.0	14.5	12.4
13 May 76 AM	11.5-13.6	13.7-15.7	15.8-17.8	17.9-20.0
	-15.9	18.3	- 1.4	3.6
13 May 76 PM	20.5-22.4	22.5-24.4	24.5-26.4	26.5-28.5
	-34.7	41.5	- 2.8	- 3.9
14 May 76 AM	15.0-17.3	17.4-19.7	19.8-22.1	22.2-24.5
	-19.5	- 1.3	24.8	- 4.0
14 May 76 PM	21.0-23.2	23.3-25.4	24.5-27.7	27.8-30.0
	- 7.5	14.7	--	- 7.2
Average % Dev May 1976	-15.9	18.3	- 1.4	3.6

Table 2 (Continued)

Temperature (C)

Date and Time	LO range % Dev	MLO range % Dev	MHI range % Dev	HI range % Dev
18 Aug 76 AM	26.0-27.2	27.3-28.4	28.5-29.7	29.8-31.0
	31.9	10.9	-12.1	-30.7
18 Aug 76 PM	30.0-31.7	31.8-33.4	33.5-35.2	35.3-37.0
	- 0.7	11.6	9.9	-20.8
19 Aug 76 AM	22.0-23.9	24.0-25.9	26.0-27.9	28.0-30.0
	37.4	- 8.5	-17.1	-11.8
19 Aug 76 PM	21.0-24.4	24.5-27.9	28.0-31.4	31.5-35.0
	3.4	2.7	7.9	-14.0
Average % Dev August 1976	18.0	4.2	- 2.9	-19.3
16 Oct 76 AM	7.5-9.9	10.0-12.4	12.5-14.9	15.0-17.5
	-23.9	14.6	37.3	-28.0
16 Oct 76 PM	12.0-13.8	13.9-15.7	15.8-17.6	17.7-19.5
	75.7	-58.3	- 4.3	-13.0
17 Oct 76 AM	8.0-10.3	10.4-12.7	12.8-15.1	15.2-17.5
	-22.6	39.4	-12.0	- 4.9
17 Oct 76 PM	12.0-13.7	13.8-15.4	15.5-17.2	17.3-19.0
	84.4	-31.9	-44.1	- 8.3
Average % Dev October 1976	28.4	- 9.1	- 5.8	-13.6

Table 2 (Continued)

Temperature (C)

Date and Time	LO range % Dev	MLO range % Dev	MHI range % Dev	HI range % Dev
26 Dec 76 AM	0.0-1.3	1.4-2.7	2.8-4.1	4.2-5.5
	-17.4	72.2	-25.8	-29.0
26 Dec 76 PM	3.5-5.4	5.5-7.4	7.5-9.4	9.5-11.5
	-18.7	-17.8	-22.2	58.8
27 Jan 77 AM	1.0-2.2	2.3-3.4	3.5-4.7	4.8-6.0
	9.7	-16.7	35.6	-28.6
27 Jan 77 PM	3.0-5.2	5.3-7.4	7.5-9.7	9.8-12.0
	-17.0	6.3	-20.0	30.7
Average % Dev Dec 76-Jan 77	-10.9	11.0	- 8.1	8.0

Dissolved Oxygen (ppm)

14 Feb 76 AM	5.8-7.1	7.2-8.5	8.6-9.9	10.0-11.4
	35.0	8.1	-43.5	0.4
14 Feb 76 PM	7.3-10.4	10.5-13.6	13.7-16.8	16.9-20.0
	- 5.7	24.6	0.7	-19.6
22 Feb 76 AM	8.8-11.0	11.1-13.2	13.3-15.5	15.6-17.8
	- 3.8	27.4	-12.2	-11.5
22 Feb 76 PM	11.2-13.3	13.4-15.5	15.6-17.7	17.8-20.0
	-15.0	23.7	10.2	- 8.9
Average % Dev February 1976	2.6	21.0	-11.2	-12.4

Table 2 (Continued)

Dissolved Oxygen (ppm)

Date and Time	LO range % Dev	MLO range % Dev	MHI range % Dev	HI range % Dev
13 May 76 AM	4.1-5.4	5.5-6.8	6.9-8.2	8.3-9.7
	- 2.2	45.7	-11.8	-31.7
13 May 76 PM	7.4-8.7	8.8-10.1	10.2-11.5	11.6-13.0
	15.4	-11.4	---	- 3.9
14 May 76 AM	6.8-8.1	8.2-9.5	9.6-10.9	11.0-12.4
	53.9	- 7.3	-24.5	-22.1
14 May 76 PM	4.5-7.6	7.7-10.8	10.9-14.0	14.1-17.2
	5.5	- 1.2	- 3.1	- 1.2
Average % Dev May 1976	18.2	6.5	-13.1	-14.7
18 Aug 76 AM	3.3-5.1	5.2-7.0	7.1-8.9	9.0-10.8
	- 1.7	30.1	- 0.8	-27.5
18 Aug 76 PM	7.1-8.5	8.6-9.9	10.0-11.4	11.5-12.9
	- 0.7	- 3.7	18.2	-13.9
19 Aug 76 AM	4.8-6.1	6.2-7.4	7.5-8.8	8.9-10.2
	13.4	28.8	-31.7	-10.7
19 Aug 76 PM	Equipment failure. Too few measurements to include			
Average % Dev August 1976	3.7	18.4	- 4.8	-17.4

Table 2 (Continued)

Dissolved Oxygen (ppm)

Date and Time	LO range % Dev	MLO range % Dev	MHI range % Dev	HI range % Dev
16 Oct 76 AM	9.4-11.0	11.1-12.7	12.8-14.4	14.5-16.2
	85.9	-27.7	-30.7	-27.4
16 Oct 76 PM	6.6-9.6	9.7-12.7	12.8-15.8	15.9-18.9
	75.8	-12.7	-48.1	-15.0
17 Oct 76 AM	9.8-11.9	12.0-14.0	14.1-16.1	16.2-18.3
	5.4	30.6	-28.0	- 8.0
17 Oct 76 PM	10.0-12.2	12.3-14.4	14.5-16.7	16.8-19.0
	- 2.9	55.7	-29.0	-23.7
Average % Dev October 1976	41.0	11.5	-34.0	-18.5
26 Dec 76 AM	10.0-11.8	11.9-13.6	13.7-15.4	15.5-17.3
	-18.9	-10.0	-54.5	83.4
26 Dec 76 PM	11.2-12.6	12.7-14.0	14.1-15.5	15.6-17.0
	65.9	-44.2	-10.7	-11.0
27 Jan 77 AM	12.9-15.2	15.3-17.5	17.6-19.9	20.0-22.3
	-20.8	-51.4	- 8.3	80.6
27 Jan 77 PM	12.9-15.6	15.7-18.4	18.5-21.2	21.3-24.0
	-11.3	- 1.8	-14.6	27.7
Average % Dev Dec 76 - Jan 77	3.8	-26.9	-22.0	45.2

Table 2 (Continued)

pH

Date and Time	LO range % Dev	MLO range % Dev	MHI range % Dev	HI range % Dev
14 Feb 76 AM	7.9	8.0	8.1	8.2-8.3
	35.0	- 4.2	- 6.2	-24.7
14 Feb 76 PM	7.8-8.0	8.1-8.2	8.3-8.4	8.5-8.7
	- 1.7	23.6	-10.8	-11.1
22 Feb 76 AM	7.9-8.0	8.1	8.2	8.3-8.4
	- 7.6	15.3	- 3.7	- 4.1
22 Feb 76 PM	8.2	8.3	8.4	8.5-8.6
	-15.2	9.3	18.7	-12.9
Average % Dev February 1976	2.6	11.0	- 0.5	-13.2
13 May 76 AM	7.5-7.6	7.7-7.8	7.9-8.0	8.1-8.2
	- 2.2	26.6	- 5.6	- 8.8
13 May 76 PM	7.6-7.7	7.8-7.9	8.0-8.1	8.2-8.4
	- 2.9	- 9.0	-15.2	27.1
14 May 76 AM	7.9-8.0	8.1	8.2-8.3	8.4-8.5
	0	-10.6	19.4	- 8.8
14 May 76 PM	7.5-7.7	7.8-8.0	8.1-8.3	8.4-8.7
	5.5	19.3	-24.0	- 0.8
Average % Dev May 1976	0.1	6.6	- 6.4	- 0.3

Table 2 (Continued)

pH

Date and Time	LO range % Dev	MLO range % Dev	MHI range % Dev	HI range % Dev
18 Aug 76 AM	8.4-8.5	8.6-8.7	8.8-8.9	9.0-9.2
	14.5	--	--	-14.5
18 Aug 76 PM	8.5-8.7	8.8-9.0	9.1-9.3	9.4-9.6
	- 0.7	- 0.4	23.1	-22.0
19 Aug 76 AM	8.0-8.2	8.3-8.4	8.5-8.7	8.8-9.0
	- 7.8	2.7	17.1	-12.0
19 Aug 76 PM	8.2	8.3	8.4	8.5-8.6
	2.1	7.9	-22.8	12.8
Average % Dev August 1976	2.0	3.4	5.8	- 8.9
16 Oct 76 AM	8.2-8.3	8.4-8.5	8.6-8.7	8.8-9.0
	91.3	--	-16.8	-74.5
16 Oct 76 PM	8.3-8.5	8.6-8.8	8.9-9.1	9.2-9.5
	55.5	28.9	-45.3	-39.1
17 Oct 76 AM	8.3-8.4	8.5-8.6	8.7-8.8	8.9-9.1
	27.0	--	- 7.6	-19.5
17 Oct 76 PM	8.2-8.4	8.5-8.6	8.7-8.9	9.0-9.2
	84.4	5.4	-24.4	-65.3
Average % Dev October 1976	64.6	17.2	-23.5	-49.6

Table 2 (Continued)

pH

Date and Time	LO range % Dev	MLO range % Dev	MHI range % Dev	HI range % Dev
26 Dec 76 AM	7.7	7.8	7.9	8.0
	- 4.3	60.7	-30.4	-26.1
26 Dec 76 PM	7.8	7.9	8.0	8.1-8.2
	- 8.0	-25.5	65.5	-32.0
27 Jan 77 AM	7.7-7.8	7.9	8.0	8.1-8.2
	-20.8	- 8.1	20.2	8.7
27 Jan 77 PM	7.8-7.9	8.0	8.1-8.2	8.3-8.4
	0	0	-28.5	28.5
Average % Dev Dec 76-Jan 77	- 8.5	6.5	7.2	- 5.2

TABLE 3. FIELD CONDITIONS AT COLLECTIONS OF TEST FISH, LABORATORY TEST CONDITIONS, AND RANGES USED IN SINGLE-FACTOR TESTS. For ranges used in multifactor tests, refer to the figure indicated. Temp = temperature (C), DO = dissolved oxygen (ppm), TDS = total dissolved solids (ppm), Turbid = turbidity (JTU). Where two figures are given they indicate ranges measured in laboratory tests. (2) = only two chambers were used.

Test	Date	Field				Laboratory				Test Range			
		Temp	DO	pH	TDS	Temp	DO	pH	TDS	Sec I	Sec II	Sec III	Sec IV
Temp	7 Mar 76	9.0	10.6	8.1	500	--	5.0 - 5.2	8.6	500	15.1 - 15.3	12.8 - 10.8	9.8 - 7.5	7.0 - 6.1
DO	4 Mar 76	8.9	9.0	7.9	400	18.5 - 19.0	-- -	8.8	550	11.5 - 10.5	9.4 - 7.7	7.3 - 6.8	5.9 - 5.7
pH	4 Mar 76	8.9	9.0	7.9	400	19.4 - 18.4	7.1	--	550	6.6 - 6.7	7.1 - 7.2	7.6 - 8.3	8.1 - 8.7
TDS	6 Mar 76	12.4	14.0	8.4	500	--	6.7 - 7.2	8.8	--	1200 - 1050	900 - 700	650 - 550	500 - 480
Turbidity	5 Mar 76	8.9	9.0	7.9	490	17.0 - 16.5	7.1 - 7.7	8.7 - 8.8	540 - 560	114 - 97	42 - 30	19 - 13	5 - 4
Temp vs DO pH, Turbid	10 Mar 76	14.5	10.0	8.3	590	--	--	--	--	See Fig. 10A			

Table 3 (Continued)

Test	Date	Field Temp	Field DO	Field pH	Field TDS	Laboratory Temp	Laboratory DO	Laboratory pH	Laboratory TDS	Test Range Sec I	Test Range Sec II	Test Range Sec III	Test Range Sec IV
Temp vs DO pH, Turbid	11 Mar 76 (2)	12.9	10.2	8.4	--	--	--	--	--	See Fig. 10B			
Temp vs pH	14 Mar 76 (2)	12.7	11.0	8.4	550	--	6.3	--	490	See Fig. 10C			
Temp	25 May 76	22.8	7.5	8.0	500	--	7.3 - 7.5	8.9	430 - 450	28.7 - 25.9	24.0 - 21.5	19.5 - 17.5	15.5 - 14.2
DO	23 May 76	23.5	7.0	8.1	590	20.7 - 21.4	--	8.9	460	4.5 - 4.9	6.3 - 6.9	9.1 - 9.5	13.2 - 15.2
pH	27 May 76	17.1	--	8.0	940	20.8 - 21.0	7.5	--	420	7.1 - 7.3	7.5 - 7.8	8.2 - 8.4	8.6 - 8.7
pH	21 May 76 (2)	24.0	6.7	8.3	--	20.7 - 21.0	4.6 - 4.7	--	430	8.7 - 8.4	8.1 - 7.8	7.9 - 7.5	7.3 - 7.2
TDS	20 May 76	22.0	8.0	8.0	620	20.0 - 20.3	6.3 - 6.6	8.9	--	1420 - 1200	1260 - 1000	830 - 660	470 - 430
Turbidity	23 May 76	23.5	7.0	8.1	590	21.5 - 22.1	8.7	8.9	460	245 - 120	180 - 69	16 - 5	3 - 1

Table 3 (Continued)

Test	Date	Field Temp	Field DO	Field pH	Field TDS	Laboratory Temp	Laboratory DO	Laboratory pH	Laboratory TDS	Test Range Sec I	Test Range Sec II	Test Range Sec III	Test Range Sec IV
Temp vs pH & Turbid	26 May 76	17.1	--	8.0	940	--	7.2 - 7.5	--	430 - 460	See Fig. 10D			
pH vs Turbidity	26 May 76	17.1	--	8.0	940	23.0 - 23.1	8.5 - 8.6	--	460	See Fig. 10E			
pH vs Temp	27 May 76	17.1	--	8.0	940	--	6.8	--	460	See Fig. 10F			
Temp	29 Aug 76	27.5	4.0	8.0	610	--	7.5 - 7.8	8.5	380 - 400	22.6 - 25.3	26.3 - 28.9	32.9 - 35.1	35.3 - 39.8
Turbidity	6 Sept 76	24.4	10.6	--	--	23.4 - 23.6	8.4 - 8.5	8.5	410	158 - 98	59 - 36	14 - 0	0 -
Temp vs Turbid	6 Sept 76	24.4	10.6	--	--	--	8.4 - 8.5	8.5	410	See Fig. 10G			
Temp	31 Oct 76 (2)	11.0	11.8	7.7	1050	--	8.0 - 9.3	8.7	450	24.5 - 22.1	18.9 - 18.0	13.1 - 11.9	10.9 - 8.0

Table 3 (Continued)

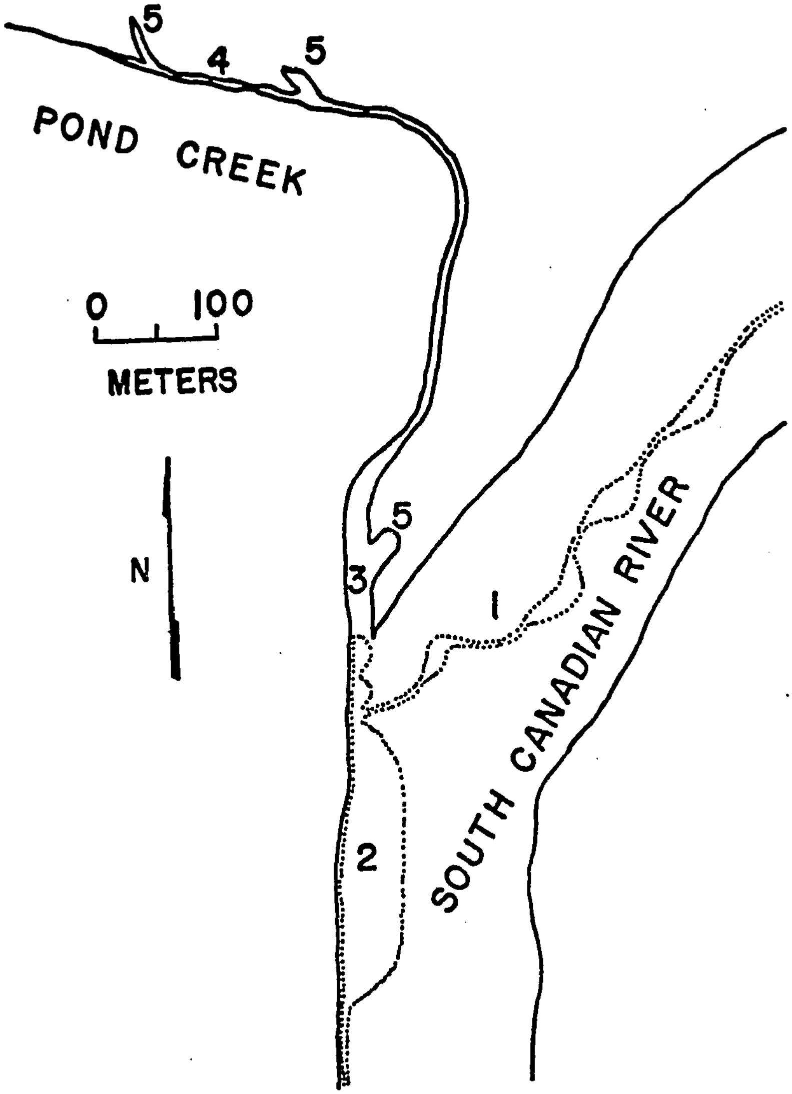
Test	Date	Field				Laboratory				Test Range			
		Temp	DO	pH	TDS	Temp	DO	pH	TDS	Sec I	Sec II	Sec III	Sec IV
pH	31 Oct 76	11.0	11.8	7.7	1050	19.0 - 19.2	8.5 - 9.1	--	450	9.0 - 8.9	8.7 - 8.4	8.1 - 7.9	7.6 - 7.3
Temp vs pH	6 Nov 76	11.0	7.8	7.4	650	--	8.3 - 8.9	--	390	See Fig. 10H			
Temp	5 Feb 77	0.1	18.0	8.3	540	--	11.3 - 11.7	8.8	330 - 370	14.2 - 12.8	11.5 - 10.1	6.0 - 5.1	3.8 - 3.1
DO	6 Feb 77	0.1	18.0	8.3	540	16.8 - 17.1	--	8.8	380	20.1 - 16.5	10.5 - 8.5	6.5 - 5.7	6.0 - 5.3
pH	4 Feb 77	5.0	15.5	8.1	600	17.9 - 18.0	8.2 - 8.4	--	360	6.9 - 7.0	7.1 - 7.2	7.8 - 8.1	8.6 - 8.7
TDS	4 Feb 77	5.0	15.5	8.1	600	17.0 - 17.2	10.0 - 9.5	8.6	--	385 - 400	450 - 500	585 - 630	710 - 730
Temp vs pH	5 Feb 77	0.1	18.0	8.3	540	--	11.3 - 11.7	--	330 - 370	See Fig. 10I			

TABLE 4. COMPARISON OF FIELD TRENDS WITH RESULTS OF SINGLE-FACTOR LABORATORY TESTS, BASED ON THE RANK ORDER OF RED SHINER PREFERENCE FOR SUBRANGES OF EACH FACTOR. The value given is Kendall's N, taken from Kendall's rank correlation coefficient (Sokal and Rohlf, 1969). Possible values are from 12 (perfect positive correlation) to - 12 (perfect negative correlation). -- = Laboratory test not conducted.

Factor	Kendall's N Value					
	Feb-Mar	May	Aug-Sept	Oct-Nov	Dec-Feb	Average
Temperature	8	4	0	-4	4	2.4
Dissolved oxygen	8	4	--	--	-3	1.4
pH	8	4	--	4	4	5.0
Total dissolved solids	8	8	--	--	4	6.7
Turbidity	4	-4	-8	--	--	-2.7

FIGURES

Fig. 1. Map of the field study site, McClain and Cleveland counties, Oklahoma. Numbers correspond to subdivisions by habitat type: (1) mainstream river channel, (2) river channel near banks, (3) lower creek, (4) upper creek, and (5) backwaters. Dotted lines indicate the location of water in August and October, and the area to which collecting was restricted during those sampling periods.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POND CREEK
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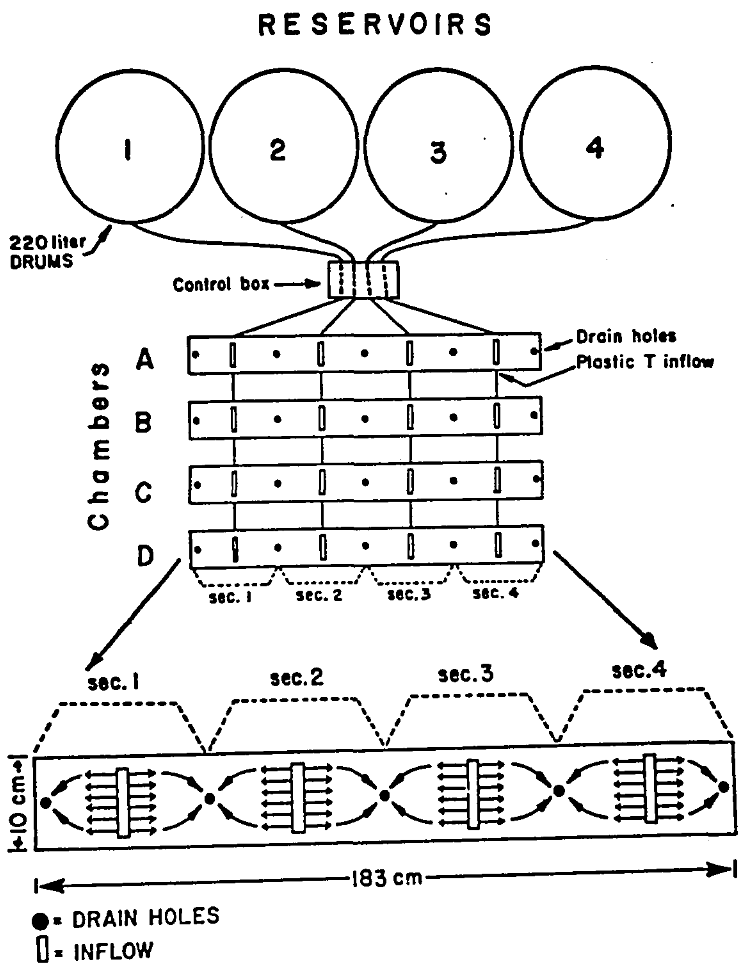
SOUTH CANADIAN RIVER

Fig. 2. Design of the gradient apparatus used in all laboratory studies. Details of one gradient chamber and the direction of flow of water are depicted in the enlargement at the bottom.


RESERVOIRS
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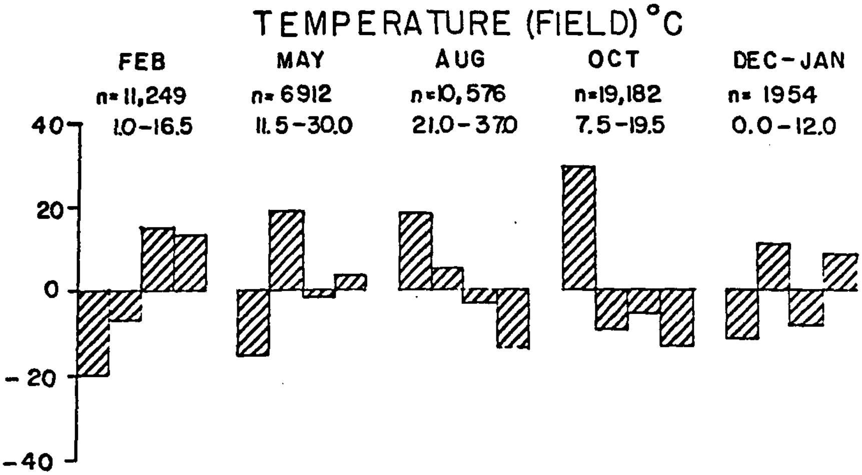
220 liter DRUMS
Control box
Drain holes
Plastic T inflow
Chambers
A
B
C
D
sec. 1
sec. 2
sec. 3
sec. 4
sec. 1
sec. 2
sec. 3
sec. 4
10 cm
183 cm
= DRAIN HOLES
= INFLOW

Fig. 3. Field and single-factor laboratory test results for temperature. Percent deviation from expected is represented on the vertical axis. Field categories from LO to HI are from left to right for each sampling period, sample sizes are indicated, and the range of temperature for each period is presented. Field temperatures measured in the categories LO to HI are listed in Table 2, and temperatures presented in each section of the laboratory gradients are given in Table 3.


TEMPERATURE (FIELD) °C
FEB
n= 11,249
1.0-16.5
MAY
n= 6912
11.5-30.0
AUG
n=10,576
21.0-37.0
OCT
n=19,182
7.5-19.5
DEC-JAN
n= 1954
0.0-12.0
40
20
0
-20
-40

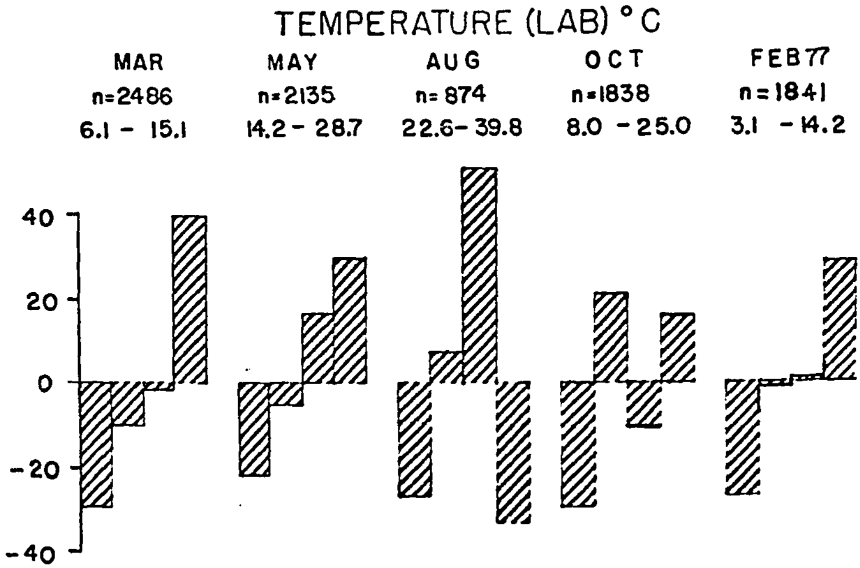
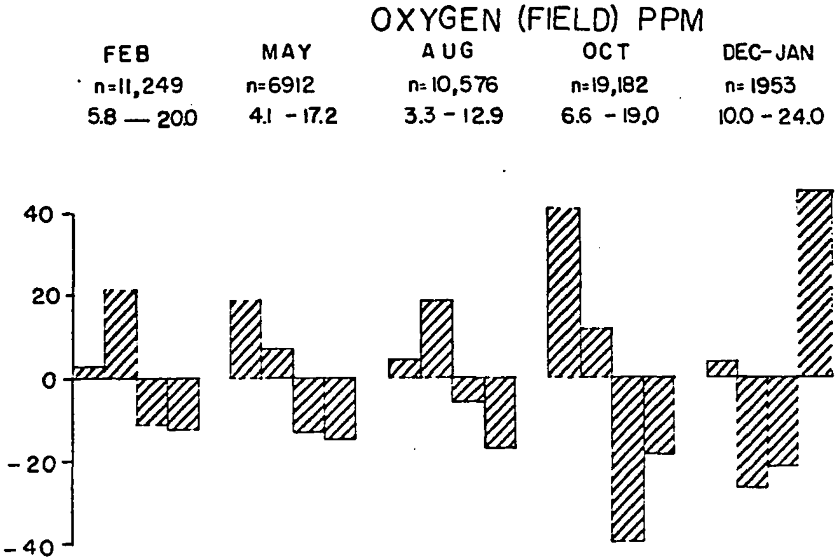

TEMPERATURE (LAB) °C
MAR
n=2486
6.1 - 15.1
MAY
n=2135
14.2 - 28.7
AUG
n= 874
22.6- 39.8
OCT
n=1838
8.0 - 25.0
FEB 77
n=1841
3.1 - 14.2
40
20
0
-20
-40

Fig. 4. Field and single-factor laboratory test results for dissolved oxygen. Percent deviation from expected is represented on the vertical axis. Field categories from LO to HI are from left to right for each sampling period, sample sizes are indicated, and the range of dissolved oxygen for each period is presented. Field measurements of dissolved oxygen in the categories LO to HI are listed in Table 2, and oxygen concentrations presented in each section of the laboratory gradients are given in Table 3.


OXYGEN (FIELD) PPM
FEB
n=11,249
5.8 — 20.0
MAY
n=6912
4.1 - 17.2
AUG
n=10,576
3.3 - 12.9
OCT
n=19,182
6.6 - 19.0
DEC-JAN
n=1953
10.0 - 24.0
40
20
0
-20
-40

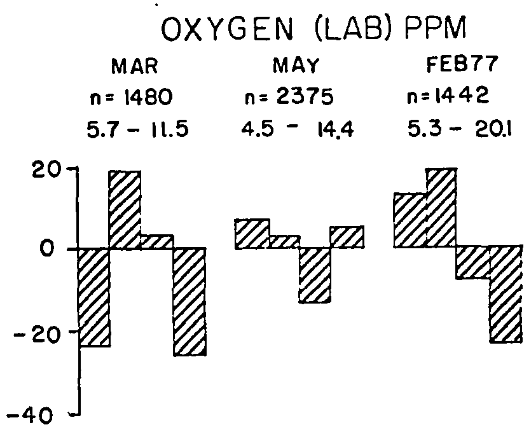
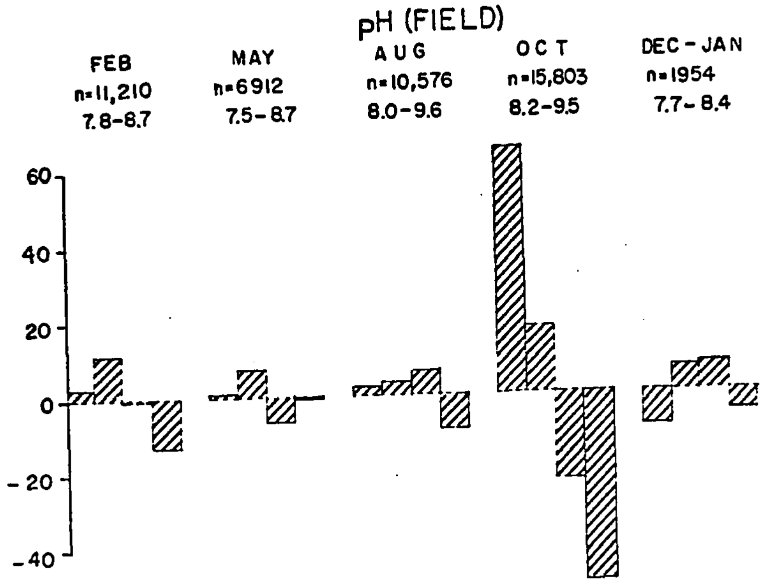

OXYGEN (LAB) PPM
MAR
n=1480
5.7 - 11.5
MAY
n=2375
4.5 - 14.4
FEB77
n=1442
5.3 - 20.1
20
0
-20
-40

Fig. 5. Field and single-factor laboratory test results for pH. Percent deviation from expected is represented on the vertical axis. Field categories from LO to HI are from left to right for each sampling period, sample sizes are indicated, and the range of pH values for each period is presented. Values of pH in the categories LO to HI are listed in Table 2, and pH presented in each section of the laboratory gradients are given in Table 3.


pH (FIELD)
FEB n=11,210 7.8-8.7
MAY n=6912 7.5-8.7
AUG n=10,576 8.0-9.6
OCT n=15,803 8.2-9.5
DEC-JAN n=1954 7.7-8.4
60
40
20
0
-20
-40

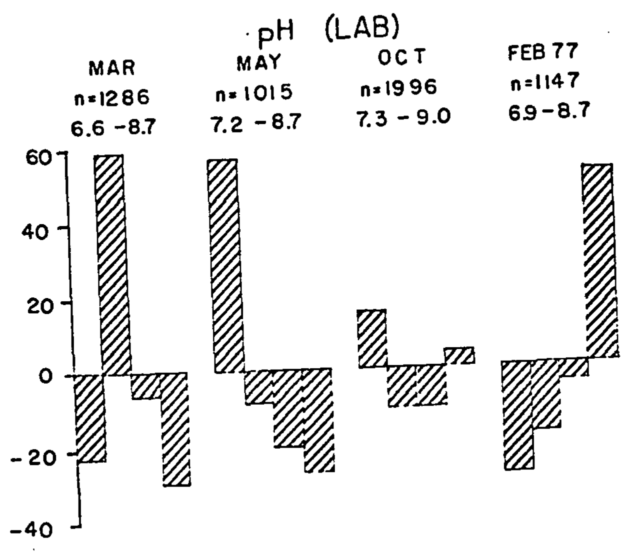
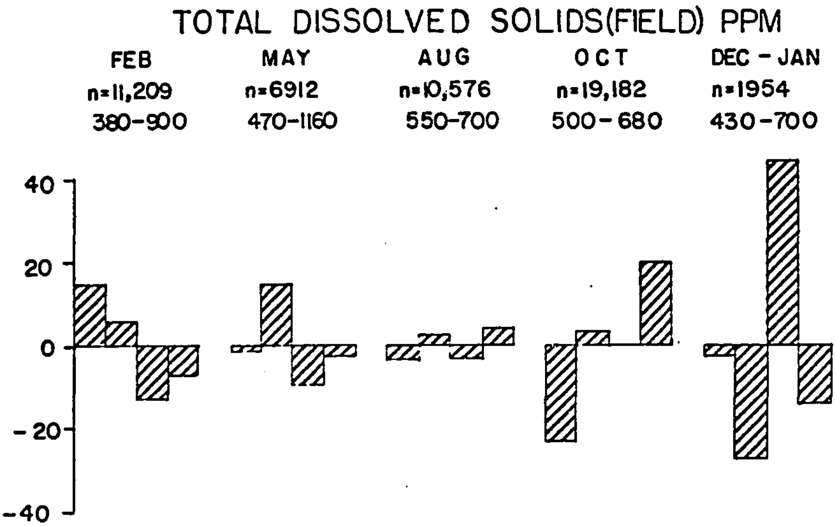

pH (LAB)
MAR n=1286 6.6-8.7
MAY n=1015 7.2-8.7
OCT n=1996 7.3-9.0
FEB 77 n=1147 6.9-8.7
60
40
20
0
-20
-40

Fig. 6. Field and single-factor laboratory test results for total dissolved solids. Percent deviation from expected is represented on the vertical axis. Field categories from LO to HI are from left to right for each sampling period, sample sizes are indicated, and the range of total dissolved solids for each period is presented. Values of total dissolved solids presented in each section of the laboratory gradients are given in Table 3.


TOTAL DISSOLVED SOLIDS(FIELD) PPM
FEB
n=11,209
380-900
MAY
n=6912
470-1160
AUG
n=10,576
550-700
OCT
n=19,182
500-680
DEC - JAN
n=1954
430-700
40
20
0
-20
-40

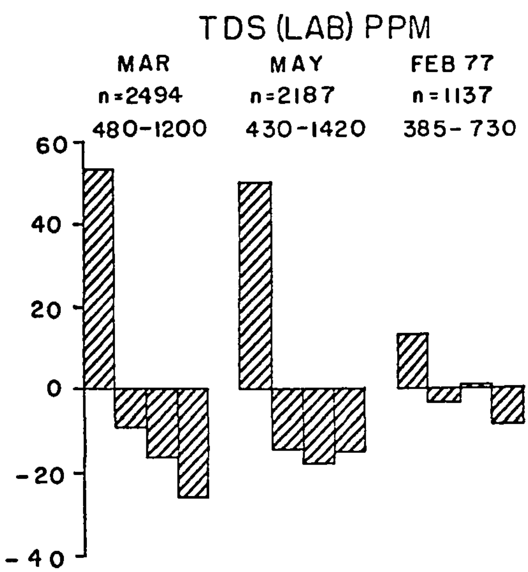
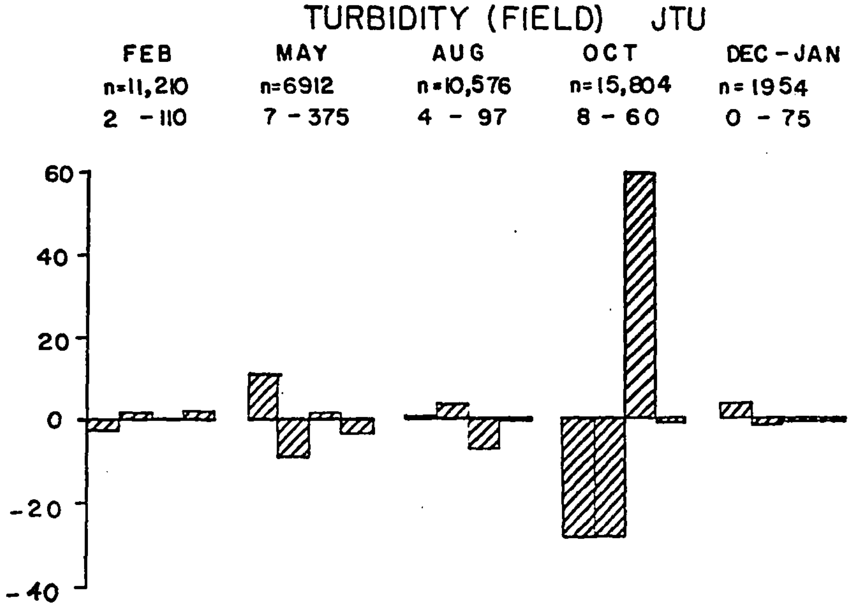

TDS (LAB) PPM
MAR
n=2494
480-1200
MAY
n=2187
430-1420
FEB 77
n=1137
385-730
60
40
20
0
-20
-40

Fig. 7. Field and single-factor laboratory test results for turbidity. Percent deviation from expected is represented on the vertical axis. Field categories from LO to HI are from left to right for each sampling period, sample sizes are indicated, and the range of turbidity for each period is presented. Values of turbidity presented in each section of the laboratory gradients are given in Table 3.


TURBIDITY (FIELD) JTU
FEB
n=11,210
2 - 110
MAY
n=6912
7 - 375
AUG
n=10,576
4 - 97
OCT
n=15,804
8 - 60
DEC - JAN
n= 1954
0 - 75
60
40
20
0
-20
-40

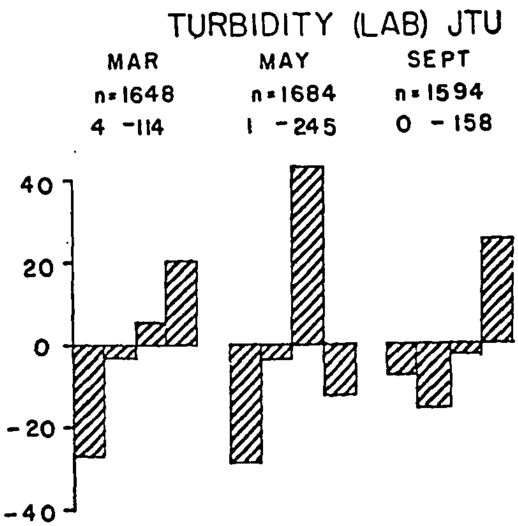
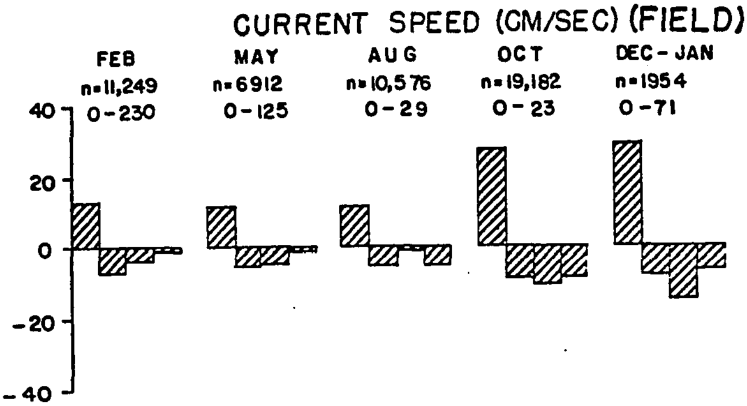
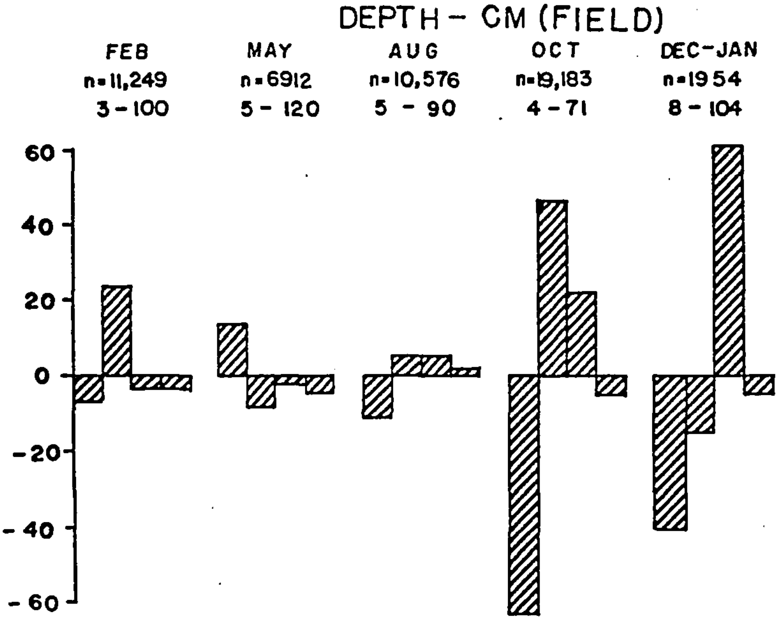

TURBIDITY (LAB) JTU
MAR
n=1648
4 - 114
MAY
n=1684
1 - 245
SEPT
n=1594
0 - 158
40
20
0
-20
-40

Fig. 8. Field results for current speed (A) and depth of the water (B). Percent deviation from expected is represented on the vertical axis. Field categories from LO to HI are from left to right for each sampling period. Ranges of field values in each period of field study are given on the figures.

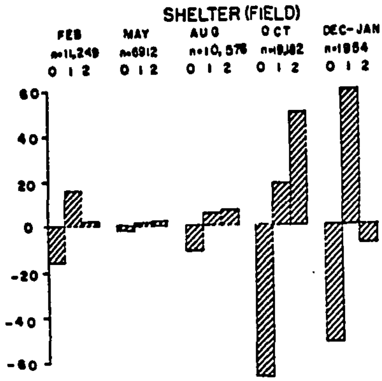

CURRENT SPEED (CM/SEC) (FIELD)
FEB
n=11,249
0-230
MAY
n=6912
0-125
AUG
n=10,576
0-29
OCT
n=19,182
0-23
DEC-JAN
n=1954
0-71
40
20
0
-20
-40

A


DEPTH - CM (FIELD)
FEB
n=11,249
3-100
MAY
n=6912
5-120
AUG
n=10,576
5-90
OCT
n=19,183
4-71
DEC-JAN
n=1954
8-104
60
40
20
0
-20
-40
-60

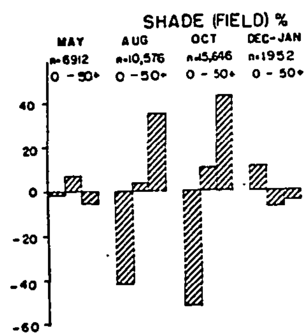
B

Fig. 9. Field results for shelter (A), shade (B), and substrate (C). Percent deviation from expected is represented on the vertical axis. Field categories from LO to HI are from left to right for each sampling period. Dotted lines for category 0 of substrate indicate that locations without sand were not available for sampling.

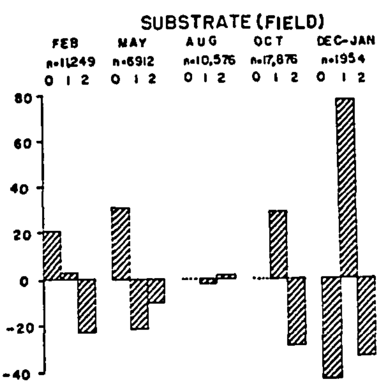


A

0= NONE, 1= MINIMAL, 2 = SUBSTANTIAL



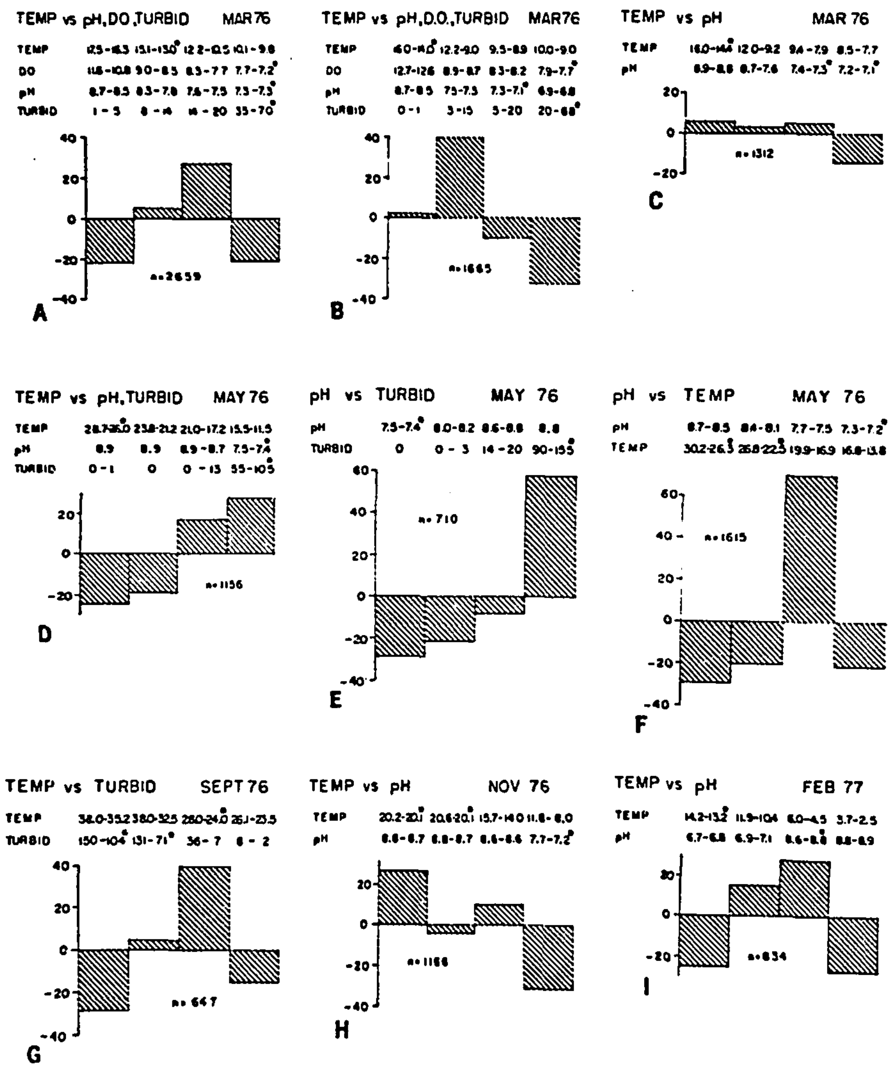
B



C

0= NO SAND, 1= MIXED W/SAND, 2= SAND ONLY

Fig. 10. Results of multifactor laboratory tests. The range of values presented in each section of the gradient chambers is provided at the top of each graph above the vertical column representing percent deviation from expected in each section. * = values selected in single-factor tests.


TEMP vs pH, DO, TURBID MAR 76
A
TEMP vs pH, D.O., TURBID MAR 76
B
TEMP vs pH MAR 76
C
TEMP vs pH, TURBID MAY 76
D
pH vs TURBID MAY 76
E
pH vs TEMP MAY 76
F
TEMP vs TURBID SEPT 76
G
TEMP vs pH NOV 76
H
TEMP vs pH FEB 77
I

APPENDICES

APPENDIX A

Original field data. STN = field sampling station, ADLT = adult, JUV = juveniles, ALL = all red shiners, TEMP = temperature, DO = dissolved oxygen, PH = pH, TDS = total dissolved solids, TURB = turbidity, CURR = current speed, CM = depth of water in centimeters, SHLT = shelter, SHDE = shade, BTM = substrate type, 99999 or 999.0 = missing data. Substrate type is as follows: 0 = no sand, 1 = mixed bottom types, 2 = all clean sand.

FEBRUARY, 1976

DATE	TIME	STN	RED SHINERS ADLT	JUV	ALL	TEMP C	DO PPM	PH	TDS PPM	TURB JTU	CURR CM/SEC	CM	SHLT	SHDE	BTM
21476	827	1	0	0	0	12.5	9.4	8.0	450	22	0	30	2	2	1
21476	835	2	0	3	3	11.5	9.7	8.2	750	13	100	30	2	2	2
21476	845	3	0	10	10	11.3	11.4	8.2	770	17	140	10	0	2	2
21476	852	4	0	0	0	11.3	10.2	8.2	760	19	100	70	1	2	2
21476	900	5	0	0	0	11.3	10.6	8.2	750	16	16	60	2	2	2
21476	924	6	0	74	75	12.0	10.2	8.2	700	13	80	5	0	2	2
21476	930	7	0	0	0	12.0	9.9	8.2	750	7	170	20	0	2	2
21476	935	8	0	3	3	11.8	9.6	8.2	800	18	40	5	0	2	2
21476	940	9	0	0	0	12.0	9.6	8.2	760	20	30	3	0	2	2
21476	945	10	0	0	0	12.0	9.2	8.2	720	16	30	10	0	2	2
21476	1000	11	0	8	8	13.8	10.4	8.2	490	28	30	25	2	1	1
21476	1015	12	0	0	0	13.8	9.2	8.3	445	4	0	5	0	2	1
21476	1021	13	0	0	0	14.0	9.4	8.2	490	19	30	5	0	2	2
21476	1030	15	0	1	1	13.9	9.4	8.2	490	17	20	10	0	2	1
21476	1100	16	0	72	72	11.8	9.6	8.1	460	16	10	20	0	2	1
21476	1110	17	0	690	690	12.8	8.4	8.3	500	15	0	25	0	2	1
21476	1120	18	60	1253	1313	13.0	5.8	7.9	520	18	0	25	1	2	1
21476	1130	19	5	145	150	12.0	10.2	8.2	480	17	0	20	0	2	1
21476	1145	20	5	2	7	12.3	10.4	8.2	480	10	0	25	0	2	1
21476	1200	21	0	0	0	12.1	11.2	8.2	485	9	0	80	1	2	2
21476	1215	22	0	1018	1018	13.3	10.6	8.3	485	15	0	50	0	2	0
21476	1230	23	0	0	0	12.8	9.0	8.2	500	6	0	90	0	0	1
21476	1240	24	0	0	0	13.3	7.4	8.2	485	20	0	85	2	1	2
21476	1250	25	0	0	0	13.0	8.0	8.1	490	15	20	90	1	0	1
21476	1400	26	0	0	0	16.3	11.8	8.4	500	23	0	40	2	2	1
21476	1410	27	0	134	134	15.5	10.7	8.5	690	11	10	40	1	2	2
21476	1415	28	2	26	28	16.5	11.0	8.5	830	35	50	50	2	2	2
21476	1420	29	0	1	1	15.3	10.9	8.4	880	18	140	100	0	2	2
21476	1430	30	0	1	1	15.0	10.6	8.3	880	13	100	80	0	2	1
21476	1440	31	0	3	3	15.3	10.6	8.5	880	18	90	15	0	2	2
21476	1450	32	0	0	0	15.3	10.4	8.5	900	17	30	5	0	2	2
21476	1500	33	0	0	0	15.3	10.7	8.5	890	14	50	30	0	2	2

21476	1510	34	0	0	0	15.0	10.7	8.5	900	15	100	35	0	2	2
21476	1520	35	0	0	0	15.0	10.6	8.5	900	7	150	40	0	2	2
21476	1523	36	0	411	411	16.3	13.6	8.6	880	5	0	10	2	2	1
21476	1530	37	0	0	0	15.3	14.6	8.3	540	9	0	15	1	2	1
21476	1535	38	0	74	74	15.0	11.1	8.4	510	19	0	15	0	2	1
21476	1540	39	0	198	198	15.2	11.2	8.4	510	23	0	12	1	2	1
21476	1545	40	0	3	3	14.9	10.5	8.4	510	5	10	5	0	2	1
21476	1600	41	0	140	140	14.0	16.5	8.5	495	6	0	15	1	2	1
21476	1615	42	0	16	16	14.0	18.5	8.5	500	6	10	20	0	2	1
21476	1630	43	0	118	118	14.5	18.9	8.5	500	11	10	25	0	2	1
21476	1640	44	0	0	0	14.5	20.0	8.7	510	15	0	15	0	2	1
21476	1645	45	0	0	0	14.5	17.6	8.7	500	9	30	20	1	2	1
21476	1710	46	0	37	37	15.0	7.3	7.8	550	49	0	20	1	2	1
21476	1720	47	0	0	0	14.5	19.6	8.5	500	20	0	25	0	2	1
21476	1725	48	0	1	1	14.0	18.6	8.5	510	15	0	70	0	2	1
21476	1735	49	0	0	0	14.2	18.7	8.5	490	17	0	50	0	2	1
21476	1745	50	0	444	444	15.5	10.9	8.2	500	47	0	30	0	2	2
22276	815	1	0	469	469	1.0	14.0	8.2	700	10	45	35	1	0	2
22276	830	2	0	0	0	1.0	12.5	8.2	700	25	230	35	1	0	2
22276	840	3	0	2	2	1.0	13.5	8.3	770	9	60	100	2	0	2
22276	851	4	0	0	0	1.9	12.5	8.0	700	18	30	5	0	0	2
22276	855	5	0	0	0	1.1	12.1	8.3	720	1999999		20	0	0	2
22276	857	6	0	0	0	1.1	12.0	8.3	755	23	53	20	0	0	2
22276	904	7	0	0	0	1.2	12.1	8.2	760	20	40	5	0	0	2
22276	910	8	0	32	32	1.8	12.5	8.2	755	10	0	30	0	0	2
22276	1000	9	6	971	977	7.0	12.4	8.3	430	8	0	25	1	0	1
22276	1004	10	2	143	145	7.8	12.2	8.3	450	15	0	10	0	0	1
22276	1010	11	0	0	0	8.5	13.6	8.3	460	9	0	10	1	0	1
22276	1015	12	0	1	1	8.5	13.4	8.3	420	8	15	10	1	0	1
22276	1023	13	0	0	0	8.9	11.7	8.3	690	17	40	5	0	0	2
22276	1100	13	0	0	0	5.2	11.6	8.3	430	5	10	30	0	0	1
22276	1115	14	12	543	555	7.9	12.5	8.3	425	25	0	40	0	0	0
22276	1124	15	0	2	2	5.5	12.6	8.3	420	10	0	15	1	0	0
22276	1127	16	0	0	0	5.2	13.4	8.3	425	10	15	20	0	0	0
22276	1130	17	8	267	275	5.3	13.8	8.2	430	6	10	50	0	0	0
22276	1135	18	0	10	10	5.1	14.0	8.2	450	7	0	15	1	0	1
22276	1145	19	25	880	905	8.8	12.2	8.1	420	26	0	20	1	0	0
22276	1155	20	0	3	3	7.1	8.8	7.9	430	12	0	50	1	0	0
22276	1200	21	0	1	1	6.0	15.9	8.199999		4	10	10	0	0	1
22276	1215	22	0	2	2	5.0	15.2	8.1	470	7	20	15	0	1	1

22276	1230	23	0	0	0	4.9	15.0	8.2	430	6	0	80	1	1	1
22276	1233	24	0	1	1	6.9	17.0	8.4	420	10	10	10	1	0	1
22276	1240	25	0	0	0	6.4	17.8	8.4	480	7	0	10	2	0	1
22276	1330	26	24	81	105	11.1	11.2	8.3	700	8	50	50	2	2	2
22276	1345	27	50	346	396	11.5	12.8	8.3	770	20	40	50	2	2	2
22276	1357	28	4	50	54	12.5	14.2	8.3	435	5	20	35	1	2	2
22276	0	29	0	0	0	10.5	11.3	8.3	725	2399999		10	0	0	2
22276	0	30	0	0	0	10.0	11.5	8.2	770	15	60	25	0	0	2
22276	1415	31	0	0	0	10.5	11.2	8.3	760	17	50	5	0	0	2
22276	0	32	0	84	84	11.0	11.4	8.3	770	11	0	50	0	0	2
22276	0	33	0	23	23	11.3	11.3	8.3	700	15	0	30	0	0	2
22276	0	34	1	407	408	13.0	14.6	8.3	430	11	0	30	1	1	1
22276	0	35	0	255	255	15.0	15.8	8.4	470	12	0	15	1	1	1
22276	0	36	0	155	155	12.0	14.0	8.2	430	18	0	30	1	0	1
22276	0	37	0	0	0	11.8	13.0	8.2	430	5	0	15	0	2	1
22276	0	38	0	2	2	11.1	12.6	8.2	420	15	20	5	1	2	2
22276	1620	39	0	16	16	8.6	14.6	8.4	410	7	0	30	0	2	1
22276	0	40	7	268	275	12.0	16.2	8.3	400	105	0	50	0	2	1
22276	0	41	0	107	107	9.5	18.6	8.4	380	6	0	10	0	2	0
22276	0	42	0	208	208	9.2	19.8	8.5	410	10	10	50	2	2	1
22276	0	43	0	5	5	9.2	19.2	8.2	410	9	0	35	0	2	0
22276	0	44	0	12	12	9.2	20.0	8.5	390	9	20	20	1	2	0
22276	0	45	30	608	638	11.2	14.0	8.4	410	22	0	80	2	2	0
22276	0	46	0	114	114	9.2	20.0	8.5	420	6	10	20	0	2	1
22276	0	47	0	39	39	9.5	19.5999999999999999				10	20	0	2	1
22276	1715	48	0	10	10	10.0	20.0	8.5	380	4	0	15	1	2	1
22276	1720	49	0	1	1	10.1	20.0	8.5	530	4	20	25	1	2	1
22276	1725	50	0	3	3	10.1	20.0	8.6	400	9	0	20	1	2	1

MAY, 1976

DATE	TIME	STN	RED SHINERS ADLT	JUV	ALL	TEMP C	DO PPM	PH	TDS PPM	TURB JTU	CURR CM/SEC	CM	SHLT	SHDE	BTM
51376	835	1	2	8	10	12.0	9.7	8.1	920	294	56	50	0	0	2
51376	842	2	20	0	20	11.5	9.3	8.0	950	240	42	70	2	2	2
51376	850	3	107	0	107	11.5	9.3	8.1	940	234	0	70	0	1	2
51376	900	4	82	21	103	11.5	9.4	8.2	990	297	71	30	0	0	2
51376	905	5	0	3	3	16.5	9.6	8.2	980	252	26	5	0	0	2
51376	914	6	0	0	0	16.0	9.6	8.1	980	216	71	40	0	0	2
51376	919	7	0	0	0	16.5	9.5	8.1	980	270	63	30	0	0	2
51376	922	8	1	0	1	17.0	9.5	8.1	980	225	42	10	0	0	2
51376	950	9	61	0	61	18.5	6.3	7.8	560	60	18	40	1	1	0
51376	1010	10	1	504	505	19.0	6.6	8.0	570	73	0	15	0	0	0
51376	1017	11	1	0	1	20.0	8.8	8.2	1060	32	0	10	0	0	0
51376	1020	12	16	7	23	18.5	6.6	7.9	560	105	56	25	2	0	1
51376	1025	13	530	0	530	18.0	6.3	7.8	570	84	15	30	1	2	0
51376	1107	14	97	0	97	19.5	4.1	7.6	540	270	0	40	0	0	0
51376	1115	15	4	0	4	17.5	6.3	7.9	480	90	13	30	0	0	1
51376	1130	16	0	0	0	17.0	7.5	7.9	480	80	11	30	1	0	1
51376	1140	17	1	0	1	17.0	7.3	8.0	470	92	11	120	1	0	1
51376	1145	18	1	0	1	18.0	7.8	8.0	480	135	11	30	0	0	1
51376	1150	19	10	3	13	18.5	8.4	7.9	510	147	10	25	0	0	1
51376	1200	20	3	0	3	19.0	5.1	7.5	760	12	0	50	2	0	0
51376	1215	21	27	0	27	18.0	8.5	7.9	480	48	10	30	2	2	1
51376	1225	22	69	0	69	18.5	8.1	8.1	480	85	8	25	0	0	1
51376	1230	23	10	0	10	18.0	8.4	7.9	480	72	9	25	0	2	1
51376	1240	24	7	0	7	18.5	8.8	8.0	500	54	11	25	1	2	1
51376	1245	25	90	24	114	18.5	8.7	7.9	500	66	12	20	0	2	1
51376	1410	26	101	0	101	24.0	8.3	8.3	920	188	0	30	0	0	2
51376	1420	27	120	0	120	23.5	8.9	8.3	920	231	38	25	0	0	2
51376	1428	28	0	0	0	22.5	9.2	8.3	940	288	14	10	0	0	2
51376	1430	29	0	0	0	22.0	9.0	8.2	960	285	50	50	0	0	2
51376	1435	30	3	0	3	22.0	9.1	8.2	970	285	72	25	0	0	2
51376	1435	31	3	0	3	22.5	9.1	8.2	930	165	33	35	2	1	2
51376	1450	32	301	28	329	22.5	8.5	8.3	960	240	23	25	0	0	2
51376	1500	33	21	1	22	22.5	9.0	8.2	890	115	26	70	0	2	2

51376	1510	34	20	0	20	22.0	8.9	8.2	660	56	17	40	1	2	0
51376	1520	35	12	0	12	21.5	8.8	8.1	660	48	17	40	1	2	1
51376	1540	36	48	405	453	23.0	8.9	8.2	650	66	8	20	0	0	0
51376	1550	37	0	1	1	28.5	13.0	8.4	940	40	0	30	0	0	0
51376	1600	38	2	1	3	21.0	8.9	8.0	550	68	38	20	2	0	1
51376	1640	39	17	0	17	21.5	7.4	7.6	810	13	0	40	2	2	0
51376	1645	40	18	0	18	24.5	9.3	7.8	490	94	0	25	0	0	0
51376	1655	41	17	0	17	21.5	9.7	7.9	510	55	8	25	0	0	1
51376	1700	42	7	0	7	21.0	9.3	8.0	530	49	14	25	0	0	1
51376	1705	43	0	0	0	21.5	9.3	8.0	550	59	14	50	0	0	1
51376	1709	44	3	0	3	21.5	9.1	8.0	540	36	0	30	0	0	1
51376	1712	45	9	0	9	21.0	9.0	7.8	540	41	0	20	1	0	1
51376	1715	46	17	0	17	21.5	9.2	8.0	530	50	11	30	1	2	1
51376	1720	47	273	24	297	20.5	9.1	8.0	540	48	16	25	1	2	1
51376	1725	48	15	0	15	21.0	8.9	8.0	530	72	0	20	0	0	1
51376	1735	49	12	0	12	21.0	9.2	8.0	540	42	0	25	0	2	1
51376	1740	50	1	0	1	21.0	9.1	8.1	540	63	0	35	2	2	1
51476	830	1	54	0	54	15.3	8.6	8.2	990	132	23	50	2	2	2
51476	845	2	37	1	38	15.5	8.6	8.2	950	92	29	50	0	2	2
51476	850	3	23	3	26	16.0	9.0	8.2	940	140	12	60	0	0	2
51476	910	4	134	41	175	16.0	10.2	8.3	1140	140	0	15	0	0	2
51476	915	5	17	0	17	16.0	9.9	8.3	1130	210	45	20	0	0	2
51476	922	6	4	0	4	15.0	9.9	8.4	1130	139	29	20	0	0	2
51476	927	7	0	0	0	15.5	9.6	8.3	1130	150	56	30	0	0	2
51476	932	8	1	0	1	15.5	9.6	8.3	1120	180	125	45	0	0	2
51476	1000	9	271	287	558	19.5	6.8	8.2	730	47	14	40	2	1	0
51476	1020	10	290	0	290	19.0	7.2	8.2	725	29	0	30	2	0	0
51476	1032	11	56	20	76	20.0	6.9	8.5	710	40	36	25	2	0	2
51476	1045	12	0	1	1	21.5	12.4	8.4	950	24	0	5	0	0	0
51476	1100	13	266	575	841	21.0	8.1	8.2	640	39	14	20	0	0	0
51476	1145	14	1	0	1	24.5	12.4	8.1	620	38	0	40	0	0	0
51476	1148	15	14	1	15	19.0	10.0	8.1	640	23	0	25	0	0	1
51476	1152	16	8	0	8	18.5	9.9	8.1	620	16	0	40	1	0	1
51476	1155	17	0	0	0	18.5	10.4	8.2	620	19	0	100	1	0	1

51476	1205	18	22	0	22	18.5	11.1	8.2	615	11	0	50	0	0	1
51476	1210	19	113	0	113	21.0	10.9	8.1	720	14	8	20	0	0	1
51476	1217	20	101	0	101	20.0	8.0	7.9	780	8	5	40	2	1	0
51476	1230	21	5	4	9	18.5	11.2	8.2	575	10	0	20	1	2	1
51476	1240	22	1	27	28	19.5	11.3	8.2	580	10	0	15	1	0	1
51476	1250	23	59	0	59	17.5	10.8	8.3	610	12	7	20	0	1	1
51476	1255	24	33	0	33	19.5	12.2	8.2	580	15	6	20	0	2	1
51476	1300	25	52	3	55	19.5	11.2	8.3	590	15	9	30	0	2	1
51476	1415	26	79	3	82	22.5	9.6	8.7	1120	375	36	40	0	0	2
51476	1420	27	189	53	242	22.0	9.6	8.7	1140	195	42	20	0	0	2
51476	1430	28	27	1	28	22.5	9.6	8.6	1150	132	50	20	0	0	2
51476	1435	29	0	0	0	23.0	9.4	8.6	1160	225	63	30	0	0	2
51476	1440	30	32	18	50	24.0	9.6	8.6	1110	195	0	10	0	0	2
51476	1447	31	16	0	16	23.0	9.2	8.6	1050	128	29	30	0	2	2
51476	1455	32	11	0	11	23.0	9.5	8.4	920	97	24	40	2	2	2
51476	1505	33	1	11	12	23.0	9.6	8.5	1100	158	29	110	2	2	2
51476	1509	34	18	17	35	23.5	10.0	8.4	770	41	14	20	0	2	0
51476	1515	35	37	4	41	22.0	9.5	8.4	775	25	13	40	2	2	0
51476	1525	36	39	0	39	23.0	9.6	8.2	775	40	8	30	2	2	0
51476	1540	37	0	0	0	30.0	13.3	8.7	890	26	0	10	0	0	0
51476	1545	38	4	0	4	23.5	9.6	8.3	750	24	63	20	2	0	2
51476	1635	39	4	5	9	30.0	17.2	8.3	610	48	0	30	1	0	0
51476	1640	40	17	2	19	23.0	13.5	8.1	600	25	0	25	0	0	1
51476	1647	41	1	0	1	22.5	12.5	8.2	610	17	5	90	1	0	1
51476	1655	42	2	0	2	22.5	13.5	8.1	610	25	0	100	0	0	1
51476	1700	43	0	0	0	22.5	13.2	8.2	610	20	0	40	0	0	1
51476	1712	44	35	244	279	24.0	11.1	7.9	740	11	0	10	1	0	1
51476	1730	45	114	0	114	21.0	4.5	7.599999		15	0	25	2	2	0
51476	1740	46	6	0	6	23.0	13.4	8.2	600	19	9	20	2	2	1
51476	1745	47	40	32	72	22.0	14.1	8.2	600	29	0	15	2	0	1
51476	1750	48	21	0	21	22.0	12.9	8.2	610	25	0	25	0	2	1
51476	1755	49	36	6	42	22.5	13.4	8.2	610	9	0	30	0	2	1
51476	1800	50	72	0	72	22.0	13.2	8.3	610	36	8	30	0	2	1

AUGUST, 1976

DATE	TIME	STN	RED SHINERS ADLT	JUV	ALL	TEMP C	DO PPM	PH	TDS PPM	TURB JTU	CURR CM/SEC	CM	SHLT	SHDE	BTM
81876	820	1	0	675	675	26.5	6.1	9.2	590	26	0	5	0	0	2
81876	840	2	29	48	77	28.0	3.3	9.1	605	36	0	20	0	0	2
81876	900	3	1	298	299	26.5	3.8	9.2	600	28	0	15	0	0	2
81876	920	4	9	13	22	26.5	4.0	9.1	610	20	0	90	0	0	2
81876	930	5	8	287	295	26.0	6.5	9.2	600	46	0	15	0	0	1
81876	940	6	9	12	21	26.0	6.2	9.1	600	17	0	50	2	0	1
81876	950	7	0	1	1	28.5	8.7	9.1	610	12	0	10	0	0	2
81876	1000	8	14	47	61	29.0	9.1	9.2	625	20	0	25	1	2	2
81876	1020	9	37	376	413	28.0	7.8	8.4	625	80	0	30	1	1	1
81876	1035	10	0	0	0	31.0	10.8	9.2	610	17	8	5	0	0	2
81876	1040	11	0	0	0	31.0	9.0	9.2	650	16	10	5	0	0	2
81876	1045	12	0	0	0	31.0	9.0	9.2	650	11	10	5	0	0	2
81876	1050	13	0	1	1	30.0	8.5	9.2	650	16	0	35	2	1	2
81876	1245	14	0	0	0	34.5	9.6	9.4	550	24	0	25	0	0	2
81876	1250	15	0	0	0	35.0	9.9	9.4	580	14	0	10	0	0	2
81876	1255	16	0	2	2	34.0	10.0	9.4	560	24	0	25	2	1	2
81876	1300	17	0	0	0	35.0	11.4	9.6	600	11	0	10	0	0	2
81876	1305	18	0	0	0	36.0	10.0	9.4	600	4	14	6	0	0	2
81876	1330	19	29	149	178	30.0	7.1	8.5	650	88	0	30	1	2	1
81876	1350	20	0	0	0	37.0	9.1	9.4	640	9	0	6	0	0	2
81876	1400	21	76	412	488	36.0	8.8	9.4	650	20	0	20	1	2	2
81876	1402	99	0	0	0	37.0	10.6	9.2	675	11	0	18	2	2	2
81876	1405	22	35	1691	1726	35.0	10.2	9.3	650	14	0	19	2	2	2
81876	1410	23	0	8	8	35.0	11.6	9.4	650	24	0	10	0	0	2
81876	1430	24	19	734	753	35.0	10.5	9.3	675	13	0	20	0	2	2
81876	1445	25	7	263	270	35.0	11.2	9.2	650	19	0	34	0	0	2
81876	1500	26	28	165	193	34.0	10.6	9.0	650	34	0	60	0	2	2
81876	1505	27	0	6	6	34.0	9.6	9.3	640	69	0	9	0	0	2
81876	1515	28	63	119	182	33.0	10.6	9.1	600	42	0	58	0	2	2
81876	1520	29	1	39	40	34.0	10.8	9.1	600	49	0	13	0	0	2
81876	1525	30	17	1115	1132	33.0	10.6	9.1	600	42	0	25	0	2	2
81876	1530	31	1	9	10	34.0	10.0	9.1	600	47	0	10	0	0	2
81876	1545	32	0	0	0	33.0	11.2	9.1	625	54	0	15	0	2	2
81876	1555	33	5	62	67	36.0	11.5	9.1	600	57	0	10	0	0	2

81876	1555	34	0	0	0	37.0	12.9	9.2	600	9999	0	5	0	0	2
81876	1556	35	0	0	0	37.0	11.2	9.2	610	49	0	9	0	0	2
81876	1558	36	8	3	11	37.0	12.2	9.1	610	54	0	18	0	0	2
81876	1600	37	5	603	608	35.0	8.6	9.2	625	24	0	18	0	2	2
81876	1605	38	0	0	0	35.0	10.3	9.2	625	27	0	19	0	2	2
81976	830	1	0	0	0	23.0	6.0	8.4	650	37	0	10	0	0	2
81976	835	2	0	18	18	23.0	999.0	8.2	650	47	0	13	0	0	2
81976	840	3	2	31	33	23.0	6.1	8.4	650	28	0	10	0	0	2
81976	850	4	0	0	0	24.0	6.0	8.4	650	19	0	10	0	0	2
81976	855	5	4	104	108	23.0	5.0	8.5	650	54	0	14	0	0	1
81976	905	6	1	394	395	22.0	4.8	8.2	650	39	0	28	0	0	2
81976	910	7	1	1	2	24.0	4.8	8.4	650	88	0	13	0	0	2
81976	915	8	7	0	7	23.0	999.0	8.5	650	17	0	38	0	0	2
81976	930	9	3	40	43	23.0	5.2	8.3	650	20	0	13	0	0	2
81976	938	10	11	267	278	22.0	6.0	8.3	650	14	0	38	0	0	2
81976	950	11	0	31	31	23.0	7.0	8.4	640	40	0	38	0	0	2
81976	1000	12	27	528	555	23.0	6.7	8.5	640	25	0	51	0	1	2
81976	1001	13	2	1	3	22.0	8.1	8.5	640	37	0	25	0	0	2
81976	1005	14	2	19	21	24.0	8.2	8.5	620	17	0	25	2	1	2
81976	1015	15	11	108	119	24.0	7.0	8.3	650	14	0	18	1	0	2
81976	1020	16	8	132	140	23.0	7.2	8.3	630	23	0	15	1	2	2
81976	1030	17	1	5	6	27.0	7.8	8.3	630	14	0	23	2	0	2
81976	1100	18	13	20	33	27.0	7.8	8.4	630	19	0	23	1	0	2
81976	1110	19	5	86	91	26.0	7.5	8.3	640	70	0	28	0	0	1
81976	1115	20	0	0	0	27.0	8.2	8.3	640	17	29	10	0	0	2
81976	1120	21	0	0	0	28.0	8.2	8.4	640	18	0	8	0	0	1
81976	1128	22	0	0	0	27.0	7.7	8.2	650	19	25	10	0	0	2
81976	1130	23	0	0	0	27.0	7.5	8.2	640	16	12	15	0	0	2
81976	1145	24	0	0	0	30.0	10.2	8.6	620	9	0	10	0	0	1
81976	1140	25	1	2	3	28.0	8.6	8.2	640	24	0	30	2	2	2
81976	1310	26	0	0	0	32.0	9.0	8.0	610	35	0	10	0	0	2
81975	1310	27	2	0	2	29.0	7.2	8.1	650	19	0	18	0	0	2
81976	1315	28	0	3	3	30.0	7.8	8.5	660	25	0	13	0	0	2
81976	1317	29	29	68	97	29.0	6.0	8.5	660	64	0	43	1	1	2
81976	1330	30	1	15	16	32.0	9.6	8.5	630	38	0	10	0	0	2
81976	1331	31	8	77	85	21.0	8.5	8.5	610	26	0	23	1	0	2

81976	1350	32	1	11	12	34.0	8.1	8.7	620	97	0	9	0	0	2
81976	1400	33	18	156	174	30.0	11.0	8.5	650	29	0	23	0	2	2
81976	1430	34	0	1	1	32.0	999.0	8.6	66C	42	0	13	0	0	2
81976	1440	35	4	365	369	32.0	999.0	8.5	670	36	0	79	0	2	2
81976	1445	36	2	106	108	34.0	999.0	8.6	640	36	0	23	0	0	2
81976	1450	37	9	129	138	34.0	999.0	8.5	650	35	0	43	0	0	0
81976	1500	38	0	0	0	35.0	999.0	8.7	650	34	0	15	0	0	2
81976	1501	39	0	1	1	32.0	999.0	8.7	670	25	0	15	0	0	2
81976	1515	40	1	14	15	34.0	999.0	8.7	660	23	0	15	0	2	2
81976	1517	41	5	40	45	31.0	999.0	8.6	690	39	0	25	0	0	2
81976	1525	42	4	73	77	26.0	999.0	8.4	700	63	0	25	1	2	1
81976	1530	43	0	0	0	35.0	999.0	8.8	660	27	28	8	0	0	2
81976	1535	44	0	0	0	35.0	999.0	9.0	650	36	0	10	0	0	1
81976	1537	45	0	0	0	34.0	999.0	8.6	660	28	26	13	0	0	2
81976	1543	46	0	0	0	35.0	999.0	8.6	660	28	19	10	0	0	2
81976	1545	47	0	0	0	35.0	999.0	9.0	680	16	0	13	0	0	1
81976	1548	48	0	0	0	34.0	999.0	8.6	650	27	0	25	2	0	2
81976	1550	49	0	0	0	35.0	999.0	8.6	650	24	0	13	0	0	2
81976	1555	50	0	8	8	35.0	999.0	8.7	650	24	0	20	0	0	2

OCTOBER, 1976

DATE	TIME	STN	RED SHINERS ADLT	JUV	ALL	TEMP C	DO PPM	PH	TDS PPM	TURB JTU	CURR CM/SEC	CM	SHLT	SHDE	BTM
101676	830	1	0	0	0	7.5	12.6	8.8	550	14	0	5	0	0	1
101676	840	2	4	2	6	8.0	10.4	8.9	550	25	0	19	0	0	1
101676	900	3	0	0	0	7.5	13.1	8.7	550	10	0	6	0	0	1
101676	905	4	0	0	0	8.0	14.8	8.7	550	16	0	9	0	0	1
101676	910	5	0	0	0	8.5	12.5	8.9	550	23	0	11	0	0	1
101676	915	6	0	0	0	9.0	13.2	8.9	550	23	0	15	0	0	2
101676	923	7	30	4	34	10.0	14.5	8.9	550	10	0	38	0	0	2
101676	945	8	0	1	1	10.0	12.5	8.8	550	24	0	13	0	0	1
101676	952	9	5	0	5	11.0	15.7	8.8	550	15	0	66	2	0	2
101676	1010	10	69	0	69	10.5	12.8	8.9	550	40	0	56	2	0	1
101676	1038	11	0	0	0	10.5	12.3	8.9	550	17	0	15	0	0	2
101676	1046	12	11	5	16	11.0	11.1	9.0	550	24	0	25	2	0	1
101676	1056	13	2	0	2	11.0	12.1	8.8	550	20	0	41	0	0	1
101676	1105	14	0	0	0	12.0	12.6	8.9	575	28	0	10	0	0	1
101676	1130	15	0	0	0	13.5	14.6	8.8	575	11	10	9	0	0	2
101676	1135	16	20	0	20	13.0	13.7	8.7	525	20	8	30	2	2	2
101676	1142	17	3143	235	3378	11.5	9.4	999.0	560	99999	0.	30	2	2	1
101676	1237	18	3099	292	3391	13.0	10.9	8.2	575	48	0	27	2	1	1
101676	1305	19	0	0	0	17.0	13.1	8.8	500	17	10	4	0	0	1
101676	1310	20	0	0	0	17.0	16.2	8.8	550	17	20	5	0	0	1
101676	1315	21	0	0	0	17.5	15.2	8.8	550	10	20	8	0	0	1
101676	1320	22	0	0	0	17.0	13.9	8.7	550	11	19	5	0	0	1
101676	1325	23	0	0	0	17.0	13.2	8.9	575	20	23	5	0	0	1
101676	1330	24	0	0	0	17.0	13.9	8.9	550	15	12	8	0	0	1
101676	1335	25	1	0	1	16.0	15.3	999.0	575	20	10	18	1	1	2
101676	1520	26	0	0	0	19.5	18.9	9.5	550	20	0	5	0	0	1
101676	1524	27	0	0	0	17.0	15.0	9.3	550	33	0	23	0	1	2
101676	1530	28	0	0	0	18.5	18.0	9.3	550	33	0	8	0	0	1
101676	1535	29	0	0	0	15.0	12.4	9.2	550	33	0	14	1	2	2
101676	1540	30	0	0	0	19.5	14.4	9.1	550	43	0	10	0	1	1
101676	1545	31	143	4	147	14.5	16.4	9.1	550	38	0	30	1	2	2
101676	1600	32	22	0	22	14.0	15.0	9.1	550	26	0	53	2	2	2
101676	1610	33	193	29	219	14.0	15.4	9.1	550	40	0	71	2	2	2

101676	1630	34	0	3	3	14.0	13.3	9.0	550	33	0	10	0	2	2
101676	1634	35	0	0	0	14.0	12.9	9.0	550	17	099999		0	2	2
101676	1640	36	3	6	9	14.0	13.1	9.1	575	17	0	38	0	2	1
101676	1644	37	3	0	3	15.0	6.6	9.0	575	14	0	11	2	2	2
101676	1647	38	0	0	0	15.0	12.8	9.0	575	13	0	6	0	2	1
101676	1653	39	19	0	19	15.0	10.2	9.1	550	20	0	30	2	2	1
101676	1720	40	1891	152	2043	13.0	8.7	8.6	550	12	0	53	2	2	1
101676	1745	41	3530	146	3676	12.0	7.5	8.3	575	48	0	25	2	2	1
101676	1807	42	0	0	0	13.5	14.2	9.2	550	16	10	8	099999		1
101676	1810	43	0	0	0	14.0	11.0	9.2	550	25	20	6	099999		1
101676	1813	44	0	0	0	14.0	15.2	9.2	550	17	20	8	099999		1
101676	1820	45	0	0	0	14.0	14.3	9.2	550	20	19	9	099999		1
101676	1825	46	0	0	0	14.0	16.0	9.2	550	18	23	6	0	1	1
101676	1827	47	0	0	0	13.5	13.2	9.1	550	15	12	10	0	0	1
101676	1832	48	0	0	0	15.0	8.2	9.0	550	61	0	51	299999		1
101776	910	1	0	0	0	8.0	12.7	9.0	550	33	0	5	0	0	1
101776	945	2	0	0	0	8.5	14.4	9.0	530	20	0	25	1	0	2
101776	955	3	0	0	0	9.0	13.6	8.7	540	26	0	8	0	0	1
101776	1000	4	0	0	0	10.0	12.5	8.7	530	25	0	13	0	0	2
101776	1005	5	0	0	0	10.0	14.5	8.7	540	25	0	11	0	0	1
101776	1010	6	0	0	0	10.5	13.6	8.8	530	29	0	19	0	0	2
101776	1015	7	188	84	272	9.5	10.6	9.1	530	26	0	38	2	0	2
101776	1040	8	0	0	0	11.5	12.9	9.0	530	28	0	11	0	0	2
101776	1045	9	12	0	12	9.0	9.8	8.9	530	25	0	71	2	1	2
101776	1055	10	0	1	1	10.0	13.1	9.0	540	25	0	58	2	0	2
101776	1105	11	0	0	0	12.0	12.2	9.0	540	48	0	9	0	0	1
101776	1110	12	1	0	1	10.0	13.6	8.7	540	14	0	36	0	2	2
101776	1120	13	0	0	0	11.5	14.7	9.0	550	20	0	36	0	0	1
101776	1125	14	0	0	0	13.0	12.1	8.8	560	17	0	10	0	0	2
101776	1135	15	0	0	0	13.5	13.5	8.9	560	20	7	8	0	0	1
101776	1200	16	441	51	492	15.5	12.1	8.9	570	16	8	33	1	2	2
101776	1215	17	623	65	688	12.0	12.4	8.8	570	15	0	51	2	2	1
101776	1230	18	340	320	660	12.5	12.9	8.3	680	48	0	33	1	2	1
101776	1255	19	0	0	0	17.0	16.4	9.0	550	26	13	5	0	0	1
101776	1300	20	0	0	0	17.5	15.0	8.9	550	25	17	6	0	0	1

101776	1305	21	0	0	0	17.5	15.3	9.0	560	19	16	5	0 0	1
101776	1310	22	0	0	0	16.5	15.7	8.9	550	15	13	6	0 0	1
101776	1320	23	0	0	0	16.0	15.4	8.8	550	21	5	6	0 0	1
101776	1325	24	0	0	0	16.5	12.4	8.8	550	24	7	9	0 0	1
101776	1327	25	0	1	1	15.0	18.3	8.8	570	15	0	41	2 1	2
101776	1515	26	0	0	0	19.0	19.0	9.2	530	48	0	5	0 0	1
101776	1520	27	0	0	0	16.5	18.0	9.1	520	41	0	19	0 1	2
101776	1525	28	0	0	0	18.5	15.9	9.1	510	33	0	8	0 0	1
101776	1530	29	0	0	0	14.0	14.7	9.0	520	25	0	10	0 2	2
101776	1540	30	0	0	0	16.5	14.4	9.0	540	25	0	10	0 0	1
101776	1545	31	0	0	0	14.0	13.1	8.8	530	27	0	15	0 2	1
101776	1546	32	3	0	3	14.0	14.9	8.8	520	20	0	41	2 2	2
101776	1555	33	0	0	0	15.0	17.4	9.0	530	48	0	10	0 1	1
101776	1605	34	3	0	3	14.0	13.0	8.8	530	25	0	66	2 2	2
101776	1610	35	16	0	16	15.9	13.9	8.8	540	19	0	48	2 2	2
101776	1620	36	0	0	0	15.0	15.0	8.9	540	35	0	18	0 1	1
101776	1625	37	0	0	0	16.0	11.1	9.0	550	19	0	36	0 2	2
101776	1640	38	0	0	0	16.0	11.4	9.0	550	16	0	10	0 2	1
101776	1641	39	0	0	0	16.0	12.8	8.9	560	18	8	8	0 2	2
101776	1645	40	51	0	51	17.0	18.1	9.0	560	20	8	33	2 2	2
101776	1700	41	250	132	382	15.0	10.0	8.6	580.	16	0	33	2 2	1
101776	1800	42	3070	463	3533	12.0	12.5	8.2	680	48	0	43	199999	1
101776	1815	43	0	0	0	15.0	16.8	9.0	550	12	13	8	099999	1
101776	1820	44	0	0	0	15.0	16.5	9.0	550	20	17	8	099999	1
101776	1825	45	0	0	0	15.0	18.8	9.0	560	13	16	5	099999	1
101776	1830	46	0	0	0	15.5	13.0	9.0	550	15	13	4	099999	1
101776	1835	47	0	0	0	16.0	13.6	9.0	550	33	5	8	099999	1
101776	1845	48	0	0	0	16.0	15.3	9.1	550	14	7	13	099999	1
101776	1850	49	3	0	3	15.5	15.0	9.1	550	14	0	36	299999	1

DECEMBER, 1976 - JANUARY, 1977

DATE	TIME	STN	RED SHINERS ADLT	RED SHINERS JUV	RED SHINERS ALL	TEMP C	DO PPM	PH	TDS PPM	TURB JTU	CURR CM/SEC	CM	SHLT	SHDE	BTM
122676	815	1	0	0	0	0.0	15.2	7.9	540	5	56	33	1	0	2
122676	825	2	0	0	0	0.5	14.9	8.0	600	5	29	23	0	0	2
122676	835	3	0	0	0	0.5	14.8	7.9	610	9	12	104	2	0	2
122676	845	4	0	0	0	0.5	16.0	8.0	600	7	5	10	0	0	1
122676	900	5	0	0	0	2.0	15.2	7.8	600	3	0	43	1	0	1
122676	906	6	747	417	1164	2.5	17.2	7.8	590	3	0	60	1	0	1
122676	945	7	1	0	1	4.0	15.1	7.9	600	5	13	15	1	1	1
122676	1010	8	0	0	0	5.0	14.7	8.0	590	3	5	8	0	0	0
122676	1015	9	0	0	0	5.0	999.0	8.0	610	3	16	10	1	1	0
122676	1030	10	0	0	0	2.0	13.4	7.9	600	7	50	33	0	0	2
122676	1035	11	0	0	0	2.5	11.8	8.0	625	5	50	23	0	0	2
122676	1045	12	0	0	0	2.5	17.3	7.8	620	7	28	20	0	0	2
122676	1050	13	0	0	0	2.5	14.4	8.0	650	7	36	15	0	0	2
122676	1120	14	13	0	13	5.5	10.0	7.8	480	25	0	23	1	0	0
122676	1130	17	0	0	0	4.0	14.4	7.8	550	3	0	46	1	1	0
122676	1137	18	1	0	1	4.0	15.2	7.8	550	2	0	30	0	0	0
122676	1150	19	0	0	0	4.0	13.6	7.9	575	3	9	15	0	0	0
122676	1200	20	0	0	0	4.5	11.4	7.8	575	2	0	25	1	0	0
122676	1215	21	0	0	0	4.5	14.3	7.9	580	5	0	15	0	1	0
122676	1230	22	0	0	0	4.5	999.0	7.9	600	3	0	10	0	1	0
122676	1240	23	4	0	4	5.5	15.2	7.8	540	2	0	50	1	1	0
122676	1255	24	1	0	1	3.5	999.0	7.7	575	2	0	23	0	1	0
122676	1300	25	0	0	0	3.5	11.3	7.8	570	1	0	50	0	1	0
122676	1400	26	0	0	0	8.5	12.9	8.1	650	6	56	33	1	2	2
122676	1412	27	0	0	0	8.5	13.5	8.2	650	5	29	23	0	0	2
122676	1420	28	0	0	0	8.5	12.9	8.1	680	8	12	104	2	2	2
122676	1425	29	0	0	0	9.0	12.8	8.1	670	5	5	10	0	0	2
122676	1430	30	0	4	4	10.0	12.9	7.9	610	5	0	43	1	2	1
122676	1445	31	3	1	4	10.5	11.9	8.0	620	3	0	60	1	2	1
122676	1500	0	186	157	343	10.5	11.9	8.0	620	3	0	60	1	2	1
122676	1455	32	0	0	0	11.5	11.3	8.1	650	5	13	15	1	1	0
122676	1520	33	0	0	0	10.5	14.9	8.0	600	2	5	8	0	2	0

122676	1525	34	0	0	0	11.0	13.1	8.0	650	6	16	15	0	2	0
122676	1532	35	0	0	0	10.0	11.2	8.0	700	7	50	33	0	0	2
122676	1540	36	0	0	0	9.5	12.5	8.1	700	5	50	23	0	0	2
122676	1545	37	0	0	0	9.5	13.0	8.2	700	6	28	20	0	0	2
122676	1550	38	0	0	0	9.5	15.2	8.1	700	5	36	15	0	0	2
122676	1635	39	3	0	3	8.0	12.7	8.0	650	8	0	23	1	0	0
122676	1640	40	2	0	2	7.0	16.0	8.0	640	5	0	25	0	0	0
122676	1645	41	3	0	3	7.0	15.2	7.9	640	8	0	25	0	0	0
122676	1650	42	0	0	0	7.0	16.1	7.9	600	5	0	100	1	2	0
122676	1655	43	0	0	0	6.0	17.0	999.0	560	99999	0	30	0	2	0
122676	1700	44	0	0	0	5.5	13.3	7.9	550	4	0	15	0	2	0
122676	1705	45	0	0	0	7.5	12.8	8.0	560	10	0	25	2	2	0
122676	1715	46	0	0	0	5.0	12.6	7.9	540	3	0	15	0	2	0
122676	1720	47	0	0	0	4.0	14.0	7.9	550	5	0	10	0	2	0
122676	1725	48	1	1	2	4.0	12.2	7.9	550	3	0	50	1	2	0
122676	1730	49	0	0	0	3.5	12.2	7.8	550	4	0	23	0	2	0
122676	1735	50	0	0	0	3.5	13.9	7.8	550	6	0	50	0	2	0
12777	755	1	0	0	0	1.0	16.4	8.2	450	14	63	58	2	0	2
12777	810	2	0	0	0	1.0	16.9	8.1	520	6	50	9	0	0	2
12777	815	3	0	0	0	1.0	16.2	8.2	530	10	25	97	0	0	2
12777	820	4	0	0	0	1.5	16.1	8.2	530	9	6	23	0	0	2
12777	835	5	0	0	0	1.0	18.0	8.1	520	12	25	38	2	0	2
12777	845	6	116	42	158	1.5	22.3	8.0	510	5	0	56	0	0	1
12777	915	7	111	88	199	3.5	21.2	8.2	530	1	0	25	1	1	0
12777	955	8	0	0	0	4.0	21.8	8.2	510	3	14	13	1	0	0
12777	1000	9	0	0	0	4.0	22.0	8.2	520	4	16	15	0	0	0
12777	1010	10	0	0	0	2.0	17.4	8.0	520	11	50	20	0	0	2
12777	1020	11	0	0	0	2.0	15.4	8.1	520	10	71	34	0	0	2
12777	1020	12	0	0	0	2.5	17.8	8.1	520	10	50	22	0	0	2
12777	1030	13	0	0	0	3.0	15.9	8.0	520	10	50	36	0	0	2
12777	1105	14	0	1	1	6.0	15.9	7.9	430	72	0	15	1	0	0
12777	1118	15	5	3	8	4.0	15.4	8.0	520	4	0	18	0	0	0
12777	1140	16	1	0	1	5.0	17.5	8.2	540	3	0	20	1	0	0
12777	1150	17	0	0	0	5.0	16.4	8.0	530	4	0	30	0	0	0
12777	1155	18	0	0	0	5.0	16.8	7.8	530	3	0	38	0	0	0
12777	1200	19	0	0	0	5.0	16.7	8.0	530	2	0	15	0	0	0
12777	1225	21	0	0	0	5.0	14.9	7.8	520	2	0	13	0	1	0
12777	1230	22	0	0	0	5.0	13.3	7.9	540	3	13	20	1	2	0
12777	1240	23	0	0	0	3.0	12.9	7.8	540	1	0	18	1	1	0

12777	1245	24	0	0	0	4.0	14.9	7.8	560	1	4	15	0	0	0
12777	1255	25	0	0	0	3.0	14.5	7.7	560	5	0	8	0	1	0
12777	1350	26	0	0	0	8.0	13.3	8.1	520	11	63	58	2	2	2
12777	1400	27	0	0	0	9.0	15.8	8.1	600	12	50	9	0	0	2
12777	1402	28	0	0	0	9.0	16.2	8.0	560	7	25	97	2	2	2
12777	1408	29	0	0	0	9.0	15.6	8.0	560	10	6	23	0	0	2
12777	1415	30	4	0	4	10.0	17.8	8.1	570	6	25	38	2	2	2
12777	1425	31	9	5	14	11.0	22.4	8.3	540	7	0	56	1	2	1
12777	1440	32	3	0	3	11.5	21.1	8.3	520	2	0	25	1	1	0
12777	1505	33	0	0	0	11.0	21.0	8.2	520	5	14	13	1	1	0
12777	1510	34	0	0	0	11.0	20.9	8.2	540	3	16	15	0	1	0
12777	1515	35	0	0	0	10.0	14.5	8.1	590	11	50	20	0	0	2
12777	1518	36	0	0	0	10.0	12.9	8.1	580	11	71	34	0	0	2
12777	1522	37	0	0	0	10.0	14.4	8.1	600	11	50	22	0	0	2
12777	1530	38	0	0	0	9.5	14.6	8.1	600	7	50	36	0	0	2
12777	1605	39	7	0	7	12.0	14.0	7.9	500	51	0	15	1	0	0
12777	1612	40	4	2	6	6.0	19.9	8.0	550	5	0	18	0	0	0
12777	1620	41	0	0	0	5.5	17.0	8.0	560	3	0	20	0	0	0
12777	1625	42	3	0	3	4.0	15.9	8.0	550	1	0	30	0	0	0
12777	1630	43	2	1	3	4.5	15.9	8.0	550	7	0	38	0	0	0
12777	1635	44	1	0	1	4.0	16.2	7.8	550	3	0	15	099999		0
12777	1705	45	1	0	1	5.0	24.0	8.0	510	20	0	20	199999		0
12777	1712	46	0	0	0	3.5	18.5	7.9	600	2	0	13	099999		0
12777	1715	47	0	0	0	3.5	18.7	7.9	590	4	13	20	199999		0
12777	1720	48	0	0	0	3.0	20.5	7.9	590	4	0	18	199999		0
12777	1730	49	0	0	0	3.0	19.7	8.0	580	4	4	15	099999		0
12777	1735	50	0	0	0	3.0	20.5	8.4	590	8	0	8	099999		0

APPENDIX B

Product moment correlation values between field factors that were correlated at the .05 level or higher. ** = $p < .01$.

February 1976

Factors	Correlation	Factors	Correlation
Temp - pH	0.309**	pH - Turbidity	-0.220
Temp - Substrate	0.251	TDS - Current	0.652**
Oxygen - pH	0.590**	TDS - Substrate	-0.234
Oxygen - Current	-0.248	Current - Substrate	-0.243
Oxygen - TDS	-0.395**	Depth - Shelter	0.293**
Oxygen - Turbidity	-0.254		

May 1976

Factors	Correlation	Factors	Correlation
Temp - Oxygen	0.394**	pH - Current	0.273**
Temp - pH	0.276**	pH - Shelter	-0.226
Temp - Turbidity	-0.316**	TDS - Turbidity	0.608**
Temp - Current	-0.315**	TDS - Current	0.543**
Oxygen - pH	0.460**	TDS - Substrate	-0.435**
Oxygen - Turbidity	-0.236	Turbidity - Current	0.609**
Oxygen - Shelter	-0.212	Turbidity - Shelter	-0.313**
Oxygen - Substrate	0.250	Turbidity - Shade	-0.265**
pH - TDS	0.619**	Shelter - Shade	0.353**
pH - Turbidity	0.234		

APPENDIX B (Continued)

August 1976

Factors	Correlation	Factors	Correlation
Temp - Oxygen	0.820**	pH - Substrate	0.263
Temp - pH	0.722**	TDS - Substrate	0.319**
Temp - TDS	0.488**	Turbidity - Substrate	0.288**
Oxygen - pH	0.560**	Current - Depth	-0.232
Oxygen - TDS	0.340**	Depth - Shade	0.339**
Oxygen - Shade	0.270	Shelter - Shade	0.361**
pH - TDS	0.783**		

October 1976

Factors	Correlation	Factors	Correlation
Temp - Oxygen	0.403**	Turbidity - Current	-0.365**
Temp - pH	0.352**	Current - Depth	-0.436**
Temp - Flow	0.398**	Current - Shelter	-0.318**
Temp - Depth	-0.257**	Current - Shade	-0.241
Oxygen - pH	0.371**	Current - Substrate	0.288**
Oxygen - Current	0.275**	Depth - Shelter	0.773**
Oxygen - Depth	-0.237**	Depth - Shade	0.415**
Oxygen - Shelter	-0.337**	Depth - Substrate	-0.407**
Oxygen - Shade	-0.245**	Shelter - Shade	0.472**
pH - TDS	-0.440**	Shelter - Substrate	-0.294**
pH - Shelter	-0.234	Shade - Substrate	-0.326**
TDS - Shade	0.212		

APPENDIX B (Continued)

December 1976-January 1977

Factors	Correlation	Factors	Correlation
Temp - pH	0.316**	TDS - Turbidity	-0.339**
Temp - TDS	0.353**	TDS - Substrate	0.262**
Temp - Shade	0.329**	Current - Shade	-0.267**
Oxygen - pH	0.394**	Depth - Shelter	0.492**
Oxygen - TDS	-0.399**	Depth - Shade	0.249
pH - Current	0.365**	Depth - Substrate	0.361**
pH - Substrate	0.217	Shelter - Shade	0.356**