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A quantitative study of the water quality and plankton of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake in Lake County, California

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A QUANTITATIVE STUDY OF THE WATER QUALITY AND PLANKTON OF UPPER BLUE LAKE, LOWER BLUE LAKE, AND THE OAKS ARM OF CLEAR LAKE IN LAKE COUNTY, CALIFORNIA

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INTRODUCTION

Upper Blue Lake, Lower Blue Lake, and Clear Lake are located in Lake County, California, and lie at an elevation of 400 meters in the midst of the northern Coast Range about 70 miles north of San Francisco Bay, midway between the Pacific Ocean and the Sacramento Valley. Appendix A shows the relative position and size of the lakes. Upper Blue Lake is 2.1 km long with a mean breadth of 0.19 km, and a mean depth of 12 meters (Report of NSF Study 9639, 1972). Lower Blue Lake is the smallest of the three lakes, and is only 0.8 km long with a mean breadth of 0.13 km (map measurement) and a mean depth of 3.5 meters. Clear Lake, the largest natural lake lying wholly within California, is 30.6 km long with a mean breadth of 6.0 km (Davis, 1933 Mauldin, 1960) and a mean depth of 6.5 meters (Goldman and Wetzel, 1963).

The three lakes are all part of the mountain-rimmed Clear Lake basin drainage system which now flows southeastward through Cache Creek and the eastern gorge into the Sacramento River. In the Jurassic and Cretaceous periods of the Mesozoic era, the sedimentary strata making up the Franciscan, Knoxville, and Cretaceous formations were deposited, and covered the area where the northern Coast Range and the Clear Lake basin now exist. The northern Coast

Range was formed largely from the uplifting, folding, and faulting of these strata during the late Tertiary and early Quaternary periods of the Cenzoic era (Weaver, 1949; Miller, 1957), accompanied by moderate volcanic activity in the Clear Lake area (Anderson, 1936; Brice, 1953). During this era, the Clear Lake drainage system originally consisted of two lakes, the lower one draining into the Sacramento River through Cache Creek, and the upper one draining through Cold Creek and the western gorge into the Russian River. A low range of hills at what is now the Clear Lake Narrows separated the two lakes. A lava flow from a nearby fissure formed a lava dam called Red Bank which blocked the outflow through Cache Creek and led to the raising of the water level in the lower Clear Lake. The water eventually broke through a low area in the range of hills at what is now Buckingham Peninsula and flowed into the upper Clear Lake system draining through Cold Creek.

Approximately 250 years ago, a massive landslide originating on the north side of Cow Mountain, descended from the southern side of the western gorge west of the Blue Lakes. The landslide filled the gorge to a level higher than the Red Bank lava flow at the eastern end of the upper Clear Lake, and the water broke through a low saddle in the lava cutting a gorge, called Redbank Gorge, across the lava. Water once again flowed through Cache Creek and the eastern gorge, but now from a single Clear Lake composed

of the original lower and upper Clear Lakes (Davis, 1933; Mauldin, 1960).

The overflow through Red Bank Gorge lowered the level of Clear Lake about 18 meters below its highest level. The water level of the western gorge was lowered sufficiently to permit the separation of the two Blue Lakes lying in the gorge from Clear Lake by the combined deltas of Middle Creek and Scott Creek (Davis, 1933). However, as late as 1873, C. A. Menifee wrote that during the winter, when the input of rainfall is at a maximum, the Blue Lakes were one with Clear Lake. The Blue Lakes are presently connected to Clear Lake only by the meandering intermittent flow of Scotts Creek.

Clear Lake appears to have had a long eutrophic history because of its shallow lake basin, intermittent thermal stratification, and warm summer waters (Horne, personal communication). The lake waters have long been enriched by seasonal runoff from the watershed especially during the winter rainy season from November through March when almost 85% of the mean annual rainfall of 28 inches occurs (Carpenter, et al., 1927; Stetson, 1957). Except for brief periods during the summer months, the warm, largely unstratified, and enriched waters are maintained in circulation by considerable wave development created by wind. The wind is funneled across the lake by the surrounding mountains, and the large surface area of Clear Lake allows

for a long fetch (Goldman and Wetzel, 1963). All of these factors have favored the development of turbid waters and high standing crop of phytoplankton that are characteristic of Clear Lake.

Similar conditions have existed on a much smaller scale at Lower Blue Lake, and it is probable that it has long been eutrophic also. Upper Blue Lake, with its deeper lake basin and well established summer thermal stratification, does not yet demonstrate the turbidity and large populations of phytoplankters characteristic of Lower Blue Lake and Clear Lake.

Eutrophication is regarded as the natural aging process of a lake and it normally takes many thousands of years. Younger oligotrophic or nutrient-poor lakes and mesotrophic or moderately enriched lakes generally become rich in nutrients, more productive, and shallower as they mature into eutrophic or nutrient-rich lakes (Hasler, 1947).

Eutrophication has progressed at an accelerated pace in many European and American lakes in recent years apparently due to increased enrichment from drainage of fertilized agricultural lands or from urban sewage (Hasler, 1947). The increase in the rate of eutrophication due to the enrichment of lake waters by the activities of man is called cultural eutrophication.

Cultural eutrophication can be considered to be a factor augmenting the naturally occurring enrichment of the

lakes under study. The lakes, hot springs, mineral waters, abundant fish, and mild climate of Lake County combined to lure settlers in increasing numbers after the 1850's, and many cleared the land and began farming (Palmer, 1881; Carpenter et. al., 1931). The population of Lake County in 1877 was approximately 7,000, and 14,676 acres of land were being cultivated in the county by 1880 (Palmer, 1881). The population had grown to 21,600 in 1972, and the farmland and orchard acerage in Lake County had grown to 26,105 acres in 1969 (California Statistical Abstract, 1972). The runoff from this fertilized agricultural land and the sewage from settlements around Clear Lake, and to a lesser extent around Upper and Lower Blue Lake, have been and are now adding to the naturally occurring enrichment of these lakes.

There has been recent work done on the primary productivity of Clear Lake (Goldman and Wetzel, 1963), on phytoplankton blooms in Clear Lake (Horne et. al., 1971), and on nitrogen fixation by blue-green algae in Clear Lake (Horne and Goldman, 1972; Horne et. al., 1972). Some water quality and plankton studies have been completed on Upper Blue Lake (Blue Lake Project, 1971; NSF Study 9639, 1972). However, there has not been a previous study including the concurrent sampling of the water quality and plankton of Upper Blue Lake, Lower Blue Lake, and Clear Lake.

This study was undertaken to examine any possible

associations between the measurements of water quality and lake conditions, and the quantity and composition of plankton present in Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake during the sampling period. A secondary objective of this study was to provide a record of these measurements. These measurements, when taken collectively, are important indicators of the trophic state or nutrient condition of the waters of the three lakes from February through October 1972.

MATERIALS AND METHODS

Sampling Area and Sampling Stations

Three sampling stations were chosen for this study and are represented in Appendix A. Station 1 (39°10'11"N. x 123°00'26"W.) was off of a swimming raft in front of Blue Lakes Lodge on the southeastern end of Upper Blue Lake, close to the outflow leading to Lower Blue Lake. Station 2 (39°09'45 N. x 122°59'51"W.) was located at the end of a fishing pier in front of Foster's Resort located in the center of the southwestern shore of Lower Blue Lake. Station 3 (39°08'27"N. x 122°43'14"W.) was the end of a long pier extending from a private beach opposite Star Dust Court in the Oaks Arm of Clear Lake.

A boat was available only at Upper Blue Lake, and it was used to reach Station 1. Station 2 on Lower Blue Lake, and Station 3 on the Oaks Arm of Clear Lake were chosen to provide the maximum sampling depth possible in the absence of an available boat.

Field Procedures

Water and plankton samples were collected during the last week of each month at all stations from February 1972 through October 1972. Before sampling began at each station, certain pertinent information was recorded on a field data sheet (Appendix B). The date and time sampling began was

recorded at each station, along with the air temperature and weather conditions. The depth of the water was then determined by lowering a Kemmerer water sampler gently to the bottom, and then reading the depth from the line which had previously been marked off in meters.

Fifteen water samples were collected at each station with a 1200 ml Kemmerer water sampler. Five water samples were obtained from the waters just above the station bottom, at the station mid-depth, and just below the water surface. Each of the first three of these samples at each depth was immediately analyzed at the station for water temperature, dissolved oxygen, and dissolved carbon dioxide.

Water temperature was found by quickly inserting a thermometer under the raised upper valve of the Kemmerer sampler into the water sample immediately after the Kemmerer was removed from the water. The thermometer was read one minute after insertion and the results were recorded in degrees C on the field data sheet for the station. Readings from the temperature probe of a Yellow Springs Instrument (YSI) Model 54 Oxygen Meter, available during the months of July and August, were within 1C of the thermometer readings. The oxygen meter was calibrated at the University of the Pacific according to the instruction manual prior to the beginning of sampling during these months to insure that it provided accurate temperature readings.

Dissolved oxygen in the second sample from each

depth at each station was measured with a Hach portable field test kit, Model AL 36 WR*, using a modified azide-Winkler method with a drop count titration (Hach, 1972).

The calibrated oxygen probe of the YSI Model 54 Oxygen Meter provided dissolved oxygen readings that were within one ml per liter of the Hach kit tests at the same station and depth during July and August. To further determine if the Hach kit tests were giving accurate readings, a precise determination of the dissolved oxygen present in the water samples taken during the month of October was attempted using a 200 ml sample and the Winkler method for use in the laboratory (APHA, 1971). Biological activity that would utilize and modify the dissolved oxygen content of the samples was arrested in the field by the addition of 1 ml of 2% sodium azide and 0.7 ml of concentrated sulfuric acid (APHA, 1971). The samples were placed in a styrofoam cooler, and were maintained at collection temperature until analysis.

The mg of dissolved oxygen per liter in each of the surface samples tested was determined using the following formulas:

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*The Hach kit, Model AL 36 WR, will hereafter be referred to as the small Hach kit.

(1) mg O_2/liter = 140 x $\frac{\text{Vt (Vol. of 0.025M thiosulfate used)*}}{\text{Vs (Vol. of sample being tested)}}$

(Giese, 1968)

(2) Solubility of O_2 corrected for elevation =

$$\text{mg } O_2\text{/liter} \times \frac{\text{(barometric pressure at 723 mm sampling elevation)}}{\text{760 mm (barometric pressure at sea level)}}$$

(Welch, 1948)

The results of this precise Winkler test were within 1 mg per liter of the Hach Winkler tests at the same station and depth. All previous determinations of dissolved oxygen by the small Hach Kit were judged to be accurate because they were consistently close to the readings of the calibrated oxygen probe, and the precise Winkler oxygen determination during the months that these tests were used.

Carbon dioxide dissolves in water according to the equilibrium reaction:

$$CO_2 + H_2O \rightleftharpoons \underset{\text{carbonic acid}}{H_2CO_3} \rightleftharpoons H^+ + \underset{\text{bicarbonate ion}}{HCO_3^-} \rightleftharpoons H^+ + \underset{\text{carbonate ion}}{CO_3^{=}}$$

*One liter of 0.025M thiosulfate utilized indicates 140 ml of oxygen (Giese, 1968).

The amount of carbon dioxide that dissolves in the water determines the amount of carbonic acid that is formed, and the degree to which the pH is reduced in the water sample.

The dissolved carbon dioxide present in a third Kemmerer water sample from each depth at each station was measured with the small Hach kit using sodium hydroxide as a titrant and 0.1% phenolphthalein solution as an end point indicator (Hach, 1972).

A fourth Kemmerer water sample from each depth at each station was run through a phytoplankton net into a labeled plankton sample bottle. The plankton in each bottle was immediately killed and preserved by the addition of 8 to 10 drops of a 7 part 70% methanol and 3 part 5% formalin v/v solution (Welch, 1948). All nine plankton sample bottles were then transported to the laboratory for analysis.

The fifth and final Kemmerer water sample taken from each station, was run into a clean, dry, 300 ml water sample bottle, maintained at collection temperature in a styrofoam cooler with ice as needed, and analyzed in the laboratory within 36 hours for dissolved orthophosphate, metaphosphate, and nitrate and nitrite nitrogen.

A Secchi disk was available during the months of August, September, and October, and was used to measure the depth of visibility or water transparency at all three stations.

Field Records

The field data sheet was designed to be utilized to conveniently record all pertinent information and measurements at each station.

Laboratory Procedures

A Hach Portable Water Engineer's Kit, Model DR-EL, employing colorimetric procedures, was used to measure dissolved orthophosphate, metaphosphate, and nitrate nitrogen in the samples returned to the laboratory.

Orthophosphate or inorganic phosphorous $\left[(PO_4)^{-3}\right]$ was measured by the stannous chloride method and direct colorimetric analysis (Hach, 1972).

The amount of soluble metaphosphate $\left[(P_2O_7)^{-3}(P_3O_{10})^{-5}\right]$ present in each water sample was measured using the test for total inorganic phosphate (ortho plus meta) (Hach, 1972). The metaphosphates were first converted to orthophosphates by boiling, and then measured by the stannous chloride method and direct colorimetric analysis to give total inorganic phosphate. Finally, the orthophosphate value for the sample determined by the previous test was subtracted from the total inorganic phosphate value to give the amount of metaphosphate present.

The dissolved nitrate nitrogen and nitrite nitrogen in each water sample was measured by the cadmium reduction

method with modified diazotization using 1-naphthylamine-sulfanilic acid followed by direct colorimetric analysis (Hach, 1972).

The nitrite nitrogen in the water samples was measured by the diazotization method using 1-naphthylamine-sulfanilic acid and direct colorimetric analysis (Hach, 1972). The results of this test gave the mg per liter of nitrite nitrogen in each water sample. This value is then subtracted from the mg per liter of total nitrate and nitrite nitrogen value obtained from the previous test to give the mg per liter of nitrate nitrogen present in each water sample.

All glassware used in the field laboratory tests was cleaned by immersion in an acid cleaning fluid made of one part potassium dichromate, five parts distilled water, and five parts concentrated sulfuric acid (Johansen, 1940). After immersion for an hour, the glassware was washed thoroughly under running tap water, soaked for a few minutes in distilled water, rinsed with distilled water, and finally allowed to drip dry on paper toweling.

Each 25 ml plankton sample bottle was smoothly and slowly shaken to freely suspend all of the plankton organisms in the sample. One ml of this freely suspended sample was obtained using a one ml tuberculin plastic syringe without the needle. Half of this one ml sample was then delivered into each of the two open corners of a Sedgewick-Rafter Counting Chamber which had a cover glass placed obliquely

across the cell. The coverglass then rotated, sometimes with assistance, to fit squarely over and seal the counting chamber. The Sedgewick Rafter Counting Chamber was then ready to be counted. This procedure was redone if air bubbles were present. The plankton organisms were allowed to settle for ten minutes, and the counting chamber was then placed on the mechanical stage of a binocular microscope and studied at 125x. The stage was moved forward and backward (↓↑↓↑), and plankton was counted in strips the width of the microscopic field at 125 magnification, for a distance of 20 mm which is the width of the counting chamber. During the first two months of this study, the whole counting chamber of 36 strips was counted. This method proved impractical due to the excessive counting time required for each sample, and it was decided to count a portion of the chamber and then adjust the results to represent the number of organisms present in the whole counting chamber. During the month of April, three of the samples for February were analyzed by counting the whole chamber (36 strips), by counting half of the chamber (18 strips), by counting one third of the chamber (12 strips), and by counting one quarter of the chamber (9 strips). It was found that by counting every third strip in the chamber and then multiplying the results by three, a representation of the kind and total number of plankton present in the chamber was obtained that was not significantly different than the results obtained when the

whole chamber was counted. It was then decided to count one third of the counting chamber and multiply the results by three to determine the number of each kind of plankton present per ml of water sample tested.

Certain guidelines were followed in identifying and counting plankton. They are as follows:

a. The remains of plankters that obviously were dead before the sample was preserved were not counted because in a large percentage of these cases the plankter could not be identified.

b. Plankters, especially zooplankters, at the edge of the microscopic field were counted if more than half of their body was included in the field, and not counted if less than half of their body was included.

c. The average size of a strand or clump of certain phytoplankters was determined and counted as one. Specimens, strands, or clumps of each phytoplankter that were shorter or smaller than this average were counted as proportionally less than one, while those longer or larger than the average were counted as proportionately greater than one.

d. Since most of the plankters either sunk to the bottom of the chamber or rose to the top, each strip was counted twice. The first count was made of all plankton lying on the bottom of the chamber and the second count was made of all plankton lying just below the coverslip along this strip.

e. Plankters were identified to genera in almost all cases, and to species when possible. Appendix C lists the references utilized to identify the plankters. Occasionally it was not possible to key out a plankter to genus, and this plankter was placed in the most appropriate family and class so that it would still be counted in the division totals for plankters.

f. A comma was placed after each plankter listed on the plankton count sheet after a strip was completed even if the plankter did not appear in the strip. This procedure eliminated confusion about which row was being counted and permitted the counting of many plankters concurrently.

g. Samples with dense amounts of plankters were diluted 10:1.

The number of each plankter per cubic meter of water was found using the following series of calculations:

(1) No. of each plankter/ml of sample

= no. of each plankter counted x 3
[one third of chamber counted]

(2) No. of each plankter/sample

= no. of each plankter/ml of sample x 25
[volume of sample bottle = 25 ml]

(3) No. of each plankter/M^3 of water sampled

= no. of each plankter/sample ÷ water volume sampled in M^3
[water volume sampled by Kemmerer used ($0.0012M^3$)]
(Darnell, 1971)

Laboratory Records

Four forms were used to record the results of the water quality analysis and plankton counts. The results of the laboratory analysis of water quality were recorded on the laboratory data sheet included in Appendix B of this study. The initial plankton counts for each sample were tabulated on plankton identification and counting sheets (Appendix D) designed by the investigator which listed the major divisions and classes of the phytoplankters and zooplankters found during a previous study of Blue Lake, (Blue Lake Project, 1971). Below each division or class, the generic and specific names of the most commonly occurring plankters of the grouping were listed. After the number of each plankter present per M^3 of water was determined, the number was entered across from the appropriate genus or species listing on a plankter per M^3 summary sheet (Appendix E) for each station. The genus and species listings on Appendix E are identical to the listings on Appendix D, but are followed by the appropriate division or class so that the sum of the plankters in each grouping can be easily ob-

tained. A master data sheet of results (Appendices F through N) was obtained by combining the results for each depth at each station on the field and laboratory data sheets (Appendix B) with the appropriate results listed on the plankter per meter^3 of water sampled summary sheet (Appendix E).

Methods of Data Analysis

An examination of the master data sheet revealed the probability of numerous correlations. To facilitate the examination of the correlations, the data on the master data sheet were placed on punch cards. The data cards were then arranged to present the data from February through October in Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake in the following sequence: (1) all surface data, (2) all mid-depth data, (3) all bottom data.

A multiple correlation analysis was performed on each of the three data segments at the University of the Pacific Computer Center using a Burroughs ASSIST package with a Burroughs B-3500 Computer. Each of the 10 plankton measurements served separately as the dependent variable in 8 analyses utilizing the seven water quality measurements as independent variables. Partial correlations were obtained between each plankton measurement and each water quality measurement (Appendices O, P, and Q). The partial correlations represent the degree to which the two measurements under study are associated, and excludes any indirect associations via the remaining measurements. The signifi-

cance of the partial correlations was determined by using t value test statistics provided by the multiple corelation program.

The partial correlations between the numbers of plankters and the measurements of water quality with levels of significance less than 5% were considered to have associations too great to be attributed to chance.

RESULTS

The surface water quality and plankton measurements obtained in Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake are listed in Appendices F, G, and H. The mid-depth water quality and plankton measurements for these lakes are listed in Appendices I, J, and K, while the measurements of water quality and plankton for the bottom samples of these lakes are listed in Appendices L, M, and N.

The partial correlations between each plankton measurement and each water quality measurement in the surface samples were obtained from the multiple correlation analysis of the surface data from all three lakes. The multiple correlation analysis of all mid-depth data and of all bottom data yielded partial correlations between each plankton measurement and each water quality measurement of the mid-depth samples and the bottom samples of all three lakes. Matrices of all surface, mid-depth, and bottom sample partial correlations are given in appendices O, P, and Q respectively.

Those surface plankton and water quality measurement pairs having partial correlations with levels of significance less than 5% are listed in Appendix R. The plankton and water quality measurement making up each of

these correlation pairs in the surface samples are graphed to display the association visually (Appendix S, Figures 1 through 12).

DISCUSSION

The significant partial correlations obtained in this study between some of the measurements of water quality and phytoplankton indicate that a direct relationship may exist between certain of these factors in the aquatic environment. This discussion will center upon some of the possible explanations for these relationships in the surface samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake. The mid-depth and bottom water quality and plankton measurements and the signficant correlations obtained are not discussed in this study. This is because the lakes are of different depths, and the mid-depth samples were taken at a different depth in each lake, as were the bottom samples. Meaningful comparisons between lakes could not be made because the measurements or correlations being compared did not come from equivalent depths.

There is a significant correlation between the members of both the division Cyanophyta and the division Chlorophyta and the volume of dissolved oxygen present in the surface samples. Phytoplankton contribute to the dissolved oxygen content of waters in the eutrophic zone by liberating oxygen as a product of photosynthesis. Figure 1 of Appendix S shows that the dissolved oxygen content of surface waters of Upper Blue Lake steadily dropped from a

maximum of 10 mg/l in February to a minimum of 5.5 mg/l in July, followed by a steady increase to 8 mg/l by August. The populations of Cyanophytes and Chlorophytes were either absent or present in small numbers in Upper Blue Lake from the beginning of the study through September (Figures 2 and 3, Appendix S). In October there was a dramatic increase in the number of Cyanophytes and a slight increase in the number of Chlorophytes. The increased volume of dissolved oxygen recorded in October could be due to the increased numbers of phytoplankton present at that time. However, the slight increase in dissolved oxygen that began in August and continued through October may be due to another factor or factors. The water temperature in Upper Blue Lake decreased from 24C in August to 16C in October (Figure 8, Appendix S). The resultant increase in the solubility of oxygen in the cooler water may have been sufficient to account for the observed increase in dissolved oxygen from August through October.

This example illustrates the possibility that fluctuations of water quality and plankton may be significantly correlated and yet may not be directly related. This condition can occur when fluctuations in the monthly measurements of one or both of these factors are induced by interaction with one or more factors in the aquatic environment. The net result may be similar fluctuations in the measurements of water quality and plankton due to the interaction of

other environmental factors.

The dissolved oxygen content of the surface waters of Lower Blue Lake followed a pattern similar to that described for Upper Blue Lake except that the decrease in oxygen values from February through July was interrupted by a peak value of 11mg/l in June (Figure 1, Appendix S). There was no significant increase in the numbers of phytoplankton observed during June that could produce this high oxygen reading. It is possible that the high June reading could have been due to a significant increase in the amount of dissolved atmospheric oxygen in the surface waters. Such an increase could occur as a result of wind created wave action that would increase the absorption of atmospheric oxygen in surface waters (Reid, 1961). It does not appear that the June increase in oxygen can be attributed solely to wind effects because the weather was clear, sunny, and warm without any significant winds for two weeks prior to the June 28th sampling.*

There were blooms of Cyanophytes and Chlorophytes in Lower Blue Lake occurring during the period from July through October (Figures 2 and 3, Appendix S). The increase in dissolved oxygen observed in Lower Blue Lake during this

*During a period from 15 June to 25 August 1972, the investigator resided at Saratoga Springs less than one mile from Lower Blue Lake while participating in a National Science Foundation Study and passed by the lake daily.

period (Figure 1, Appendix S) could be due to the interaction of increased photosynthesis with increased solubility of oxygen in the waters as the water temperature decreased.

In the Oaks Arm of Clear Lake, evidence for a direct relationship between the numbers of Cyanophytes and dissolved oxygen appears to exist. There was a bloom of Cyanophytes in March that corresponded with the March measurements of dissolved oxygen of 16 mg/l* which was the maximum value obtained in this study. The dissolved oxygen measurements in the Oaks Arm of Clear Lake showed two lesser maxima, occurring in June and in September (Figure 1, Appendix S). It is possible that the same factors that contributed to the June increase in dissolved oxygen in Lower Blue Lake were in operation in the Oaks Arm of Clear Lake. The populations of Cyanophytes and Chlorophytes were small in June (Figures 2 and 3, Appendix S), so that an increase in dissolved oxygen in the surface waters due to extensive photosynthesis by these plankters is doubtful. The second bloom of Cyanophytes that occurred in July (Figure 2, Appendix S), and the bloom of Chlorophytes that occurred in August (Figure 3, Appendix S) did not appear to significantly increase the dissolved oxygen in the surface waters of Clear Lake, for the values of dissolved oxygen decreased in July to a mini-

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*It is recognized that values of this magnitude do not normally occur, but the large amount of algae present in the sample interfered with the precise determination of the titration endpoint.

mum of 6 mg/l in August (Figure 1, Appendix S).

The dissimilarities that were observed in oxygen and plankton relationships between the lakes may be the result of differences in the size and shape of the lake basin which subsequently determine the depth of the lake and the volume of water contained within the lake. Lake basin characteristics have long been considered by researchers to be significant in determining lake productivity and the trophic condition of a lake (Thienemann, 1927; Rawson, 1939, 1955). Both Upper Blue Lake and Lower Blue Lake are enclosed in the steep sided western gorge which was the former outlet for Clear Lake. The surface area upon which wind can act to induce water circulation and the littoral area where vascular plant productivity is highest are both reduced in these lakes. Clear Lake, which lies in a broad basin, exposes a large surface area to the wind. The extensive shoreline and gently sloping sides of the shallow lake basin favor extensive littoral development.

Upper Blue Lake is the deepest lake studied, with a mean depth of 12 meters. The lake basin is sufficiently deep to permit thermal stratification during the warm summer months. The measurements of water temperature and dissolved oxygen at the bottom of Station 1 in Upper Blue Lake in July and August were significantly less than the surface and mid-depth measurements, and were characteristic of waters of a well established hypolimnion (Odum, 1971). The investigator

verified the presence of the hypolimnion beginning at approximately 10 meters in depth during three SCUBA dives to the bottom of Station 1 in late July and early August.

The mean depth of the Oaks Arm of Clear Lake is 7.1 meters (Horne and Goldman, 1972). All of Clear Lake stratifies only for very brief periods in mid-and late summer because of the shallow lake basin and because wind originated wave motion keeps the lake mixing (Goldman and Wetzel, 1963). The mean depth of Lower Blue Lake is only 3.5 meters which appears to be sufficiently shallow to prevent stratification.

The fluxuations in the numbers of phytoplankton observed in Figures 2 and 3 of Appendix S are sufficient to be considered blooms according to two comprehensive definitions. Mackenthum et al. (1964) defined blooms qualitatively as the appearance of an unusually large number of cells of one or a few species of plankton per unit of water, often sufficiently dense as to be visible. Lackey (1945) defined a bloom quantitatively as 500 organisms of one or a few species of plankton per ml of water. The investigator has chosen to consider a bloom to be at least a tenfold increase in the number of a plankter per M^3 of water sampled within at least two months time, followed by a decrease to numbers approximating the base levels of the plankter within two months. This definition overcomes the objection of quantitative estimates that do not consider the factor of time or the differ-

ences in volume of individual plankters when an arbitrary number is chosen to represent a bloom. In addition, it eliminates the subjectives estimations of size and color that vary from investigator to investigator inherent in the qualitative definitions of a bloom.

Zooplankter populations also respond to the dissolved oxygen content of waters. There was a significant correlation between the numbers of copepods and the dissolved oxygen present in the surface samples. Figure 4 of Appendix S shows a bloom of copepods in the Oaks Arm of Clear Lake in March that corresponds with the high March reading of dissolved oxygen obtained during this study (Figure 1, Appendix S). This direct relationship did not exist in August at the Oaks Arm of Clear Lake when a second bloom of copepods occurred when the dissolved oxygen was at a minimum (Figures 4 and 1, Appendix S). The corresponding maxima in March could be due to the preference of the copepods for highly oxygenated waters to meet their respiratory needs. The copepods could also favor the oxygen-rich waters because they feed on the phytoplankton or phytoplankton consuming organisms that are often most abundant in these waters (Pennak, 1953; Odum, 1971).

The presence of large numbers of copepods with a low volume of dissolved oxygen in the August Oaks Arm surface samples indicates the possibility that factors other than oxygen are affecting the distribution of copepods. Pennak

(1953) has noted that copepods are in general tolaerant of a deficiency of oxygen. Pennak has also noted that Cyclops (a genus found in this study) has been collected from the hypolimnion of stratified lakes during summer and winter periods of stagnation and oxygen depletion. It appears that this copepod is feeding on anaerobic bacteria present at the surface of the bottom muds, and obtains its oxygen by intermittently returning to the upper oxygenated eplimnetic layer. Food was the primary determination in the distribution of copepods in this sample, and it may also be the factor accounting for the bloom of copepods in the surface samples in August. During August, the maximum bloom of Chlorophytes and the large numbers of Cyanophytes still present from the July bloom provided an abundant nutritional substrate upon which the copepods could feed (Figures 2 and 3, Appendix S).

There was a significant association between the Phylum Chlorophyta (Figure 3, Appendix S) and the levels of orthophosphate (Figure 5, Appendix S) in the surface samples. This relationship was expected because most phosphorous is absorbed by the phytoplankton as orthophosphate ions (Harvey, 1960) according to the following simplified stoichiometric equation:

$$106CO_2 + 16NO_3^- + HPO_4^{=} + 122H_2O + 18H^+ \quad (+\text{trace elements; energy})$$

P (Rate of production of organic material)

R (Rate of destruction of organic material)

$$\{C_{106}H_{263}O_{110}N_{16}P_1\} + 138O_2$$

algae protoplasm

(Stumm and Morgan, 1970)

Algal growth is responsible for the removal of soluble orthophosphate and nitrate nitrogen from waters with a molar ratio of 1:16. When the algae die, settle, and decompose, orthophosphate and nitrate nitrogen are released again with a molar ratio of 1:16 (Stumm and Morgan, 1970). During periods of algal blooms when the rate of production of organic material is greater than the rate of destruction of organic material, the phosphate and nitrate levels may be reduced sufficiently to become limiting.

Phosphorus in its various forms can be an element that is limiting to algal growth because of its limited abundance and its dependence on geochemical factors for replenishment, (Hutchinson, 1957; Odum, 1970).

The orthophosphate ion concentration of 46 central European lakes was consistently ten to a hundred times less

than the nitrate ion concentration, and, during the summer when most of these lakes were stratified, the orthophosphate ion concentration was reduced to traces less than 0.001 mg/l (Thomas, 1969). Sawyer (1952) concluded that phosphorus is the limiting factor in algal growth based on his study of 17 southern Wisconsin lakes, and because of a laboratory study in which he obtained increased growth of blue-green algae in natural water with a plentiful supply of phosphorus and a deficiency of nitrogen.

I obtained some evidence indicating that orthophosphate enrichment of lake waters results in increased algal blooms. The results of extensive laboratory algal culture in media prepared to match the conditions present in natural waters by Chu (1942) support this interpretation. Chu found that 14 different planktonic algae representative of the divisions Chlorophyta, Cyanophyta, and Crysophyta had fairly similar requirements for nitrogen and phosphorous. All of the algae flourished and were maintained for over two years in a media with nitrogen ranging from 1.0 to 7.0 mg/l and phosphorus from 0.1 to 2.0 mg/l. Their growth was hindered when the concentration of nitrogen was less than 0.2 mg/l and phosphorus was less than 0.05 mg/l, and also when the concentrations of nitrogen or phosphorus exceeded 20.0 mg/l. Figure 5 of Appendix S shows that the concentration of orthophosphate at Station 1 in Upper Blue Lake was greater than this minimum during four months of the sampling

period at Station 2 in Lower Blue Lake, while at Station 3 in the Oaks Arm of Clear Lake it was above this minimum during eight months of the nine month sampling period. Figures 3 and 4 of Appendix S show that the numbers of Chlorophytes and Cyanophytes, the two most abundant phytoplankters found during most of this study, were lowest in Upper Blue Lake, higher in Lower Blue Lake, and highest in the Oaks Arm of Clear Lake. This increase appears to be in response to the concentration of orthophosphate which exceeded the minimum established by Chu the least often in Upper Blue Lake, more often in Lower Blue Lake, and most often in the Oaks Arm of Clear Lake. The correlation between orthophosphate content and Chlorophyta populations supports this observation.

There was a significant correlation between the populations of the Class Bacillariophyceae and the dissolved carbon dioxide present in the surface samples. Figure 7 of Appendix S shows a bloom of Bacillariophyceae occurring in Upper Blue Lake in April, and maximum numbers of Bacillariophyceae occurring in Lower Blue Lake in February and continuing in slightly reduced numbers through June. Throughout this period the dissolved carbon dioxide in both lakes was never less than 10 mg/l (Figure 6, Appendix S). In addition, the maximum population of Bacillariophyceae in the Oaks Arm of Clear Lake occurred in March which corresponded with the maximum level of dissolved carbon dioxide

observed in the Oaks Arm of Clear Lake. From July through October the populations of Bacillariophyceae remained constant and at a lower level than the fluxuating populations characteristic of the period from February through June in Upper and Lower Blue Lake. At no time during the later period did the measured carbon dioxide concentration in the surface waters of these two lakes exceed 5 mg/l.

Although Prescott (1960) observed that excessive growths of phytoplankton can occur only in lakes which are amply supplied with CO_2 or with bicarbonates from which carbon dioxide necessary for photosynthesis can be extracted, carbon dioxide is not often a limiting factor. The level of dissolved carbon dioxide within most lakes is usually being sufficiently replenished by absorption from the atmosphere, and as a respiratory by product of lake organisms (Reid, 1961). Because of this, it is possible that the decrease in the numbers of Bacillariophyceae and the corresponding decrease in the amount of dissolved carbon dioxide observed in Upper Blue Lake, Lower Blue Lake, and to a lesser extent in the Oaks Arm of Clear Lake is the result of interaction with other factors in the aquatic environment.

Gaufin and McDonald (1965) observed that water temperature appeared to be the primary factor correlated with diatom populations during the summer months. As the temperature of Deer Creek Reservoir in Utah approached 21C, the population of the diatoms of the genera Asterionella and

Stephanodiscus declined rapidly. During the winter these same diatoms, along with Fragillaria and Cyclotella, became dominant in the colder ice covered waters. Representatives of these same genera were dominant in Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake. A study of Figures 7 and 8 of Appendix S show that the maximum numbers of Bacillariophyceae observed in this study occurred during the months of February through April when the measured water temperature was 16C or less, and the minimum populations occurred in July through September when the measured water temperature was 20C or greater.

Another factor that can interact with and influence the volume of dissolved carbon dioxide present in the surface samples is the assimilation of carbon dioxide in photosynthesis by algae. The lower concentration of dissolved carbon dioxide that was measured in Upper and Lower Blue Lake from July through October may be the result of increased daylight assimilation of carbon dioxide in photosynthesis by the increased numbers of Cyanophytes and Chlorophytes present during this period (Figures 2 and 3, Appendix S). In the Oaks Arm of Clear Lake, the dissolved carbon dioxide levels fluxuated between 5 and 15 mg/l throughout the study with maximum levels occurring in March and July (Figure 6, Appendix S). There were corresponding peaks in the numbers of Cyanophytes during these months (Figure 2, Appendix S). It appears that the photosynthetic consumption

of dissolved carbon dioxide by the Cyanophytes and other algae present in the Oaks Arm surface samples was not as significant a factor in reducing the dissolved carbon dioxide content as it was in Upper and Lower Blue Lake. It is possible that the large and shallow lake basin of Clear Lake is a significant factor in determining the dissolved carbon dioxide content of the lake. The wind blowing across Clear Lake has a long fetch, and is able to create small waves and induce surface water circulation throughout the lake permitting maximum absorption of atmospheric carbon dioxide. The fluxuations in the dissolved carbon dioxide measurements in the Oaks Arm could then be due to varying wind conditions across the lake.

The correlation between the numbers of the Class Ciliata and surface water temperature indicate that zooplankters also respond to temperature changes. The maximum surface water temperatures were recorded in this study on all three lakes from June through August, and ranged from 23C to 28C (Figure 8, Appendix S). During this three month period, ciliates were present in small numbers during July in Upper Blue Lake and Lower Blue Lake. Pennak (1953) has noted that the optimum temperatures for protozoans generally lie between 16C and 25C, which indicates that they favor warm waters. Noland (1925) noted that most free living species of protozoa, of which ciliates are predominant, show wide ranges of tolerance to single environmental factors

such as temperature, dissolved oxygen, dissolved carbon dioxide, and water pH. The combined effect of these physical factors in different localities favored the production of bacterial growth or algal growth in varying degrees. Most of the 65 species of ciliates that Noland studied were holozoic, and ingested algae, bacteria, and other zooplankters, although specific ciliates favored one of these food sources. Because one or more of the physical factors described previously consistently correlated with the food habits of the ciliates studied, Nolan concluded that the nature and amount of food available in an aquatic environment was the most significant factor studied in determining the distribution of ciliates. In addition, the food source was often observed to be less tolerant to changes in the factors studied than were the ciliates feeding upon them and limited the distribution of the ciliates.

In both Upper and Lower Blue Lake, the dissolved oxygen content and nutrient levels were sufficient to favor the growth of algae, and it is probable that the maximum population of Ciliata that developed in these lakes was due to the algal food source that became available at that time. The correlation between populations of ciliates and water temperature could then have been due to the response of the ciliates to fluxuations of the food supply partially brought about by changes in the water temperature.

There was a correlation between the Class Ciliata

and dissolved nitrite nitrogen. The production of nitrogen in the form of dissolved nitrite is an integral step in the production of nitrates by the denitrification of ammonia. The first step in the denitrification cycle is the production of ammonia in the aquatic environment by the decomposition of protoplasm and as an excretory product of the metabolism of organic matter by aquatic consumers. Nitrites are produced by the oxidation of ammonia by nitrite bacteria according to the formula:

$$(NH_4)_2CO_3 + 3O_2 \xrightarrow{\text{nitrite bacteria}} 2HNO_2 + CO_2 + 3H_2O + 148 \text{ calories}$$

(Ruttner, 1963)

Nitrogen in the form of dissolved nitrite is an intermediate and transitory form of nitrogen in the dentrification cycle. The nitrites are immediately oxidized by nitrate bacteria to form nitrates according to the following formula:

$$2HNO_2 + O_2 \xrightarrow{\text{nitrate bacteria}} 2HNO_3 + 44 \text{ calories}$$

(Ruttner, 1963)

Nitrogen in the form of dissolved nitrate is the most abundant form of inorganic nitrogen in the aquatic environment. The algae and bacteria that make up the food source of most ciliates commonly utilize nitrate nitrogen as

a source of nitrogen for growth (Odum, 1971). The ciliate food supply would respond to fluxuations in the levels of nitrate nitrogen rather than nitrite nitrogen, and the influence of the food supply on the association between ciliates and nitrate nitrogen would not exist.

There were small population of ciliates in July in Upper and Lower Blue Lake (Figure 9, Appendix S). The nitrite nitrogen levels in all three lakes were consistently 0.015 mg/l or less except for two higher readings in the Oaks Arm of Clear Lake (Figure 10, Appendix S). Evidence for the association between ciliates and nitrite nitrogen is not clear from a study of Figures 9 and 10 of Appendix S, and is not supported in the literature.

A negative correlation between the Phylum Cladocera and nitrate nitrogen indicates that when the value of one increases, the value of the other decreases. Cladocerans are filter feeders, and digest bits of algae, protozoans, bacteria, and organic detritus (Pennak, 1953). A reduction in the concentration of nitrate nitrogen could occur with an increase in the population of cladocerans if these cladocerans were responding to an increase in an algal food supply. Nitrate nitrogen would be utilized and reduced by the algae, and the cladocerans would thrive on the algae or other food organisms associated with the algae. Ruttner (1963) observed that the utilization of nitrate nitrogen during the summer stratification of moderately eutrophic lakes can lead

to the reduction and complete disappearance of nitrate from the epilimnion.

There was a reduced amount of nitrate nitrogen in all three lakes in June (Figure 11, Appendix S), and increased numbers of cladocerans at Upper Blue Lake and Lower Blue Lake during this month. There were increasing numbers of cyanophytes in all lakes in June (Figure 2, Appendix S), and greater numbers of Bacillariophyceae in Upper and Lower Blue Lake (Figure 7, Appendix S). In all cases, the numbers were less than the maximum populations observed during this study. Large numbers of chlorophytes did not appear until August (Figure 3, Appendix S). The algae could have been reduced to the modest numbers observed by grazing by the abundant cladocerans and other zooplankters present. However, the algae present could have been sufficient to reduce the nitrate nitrogen to the levels observed in June.

Many investigators have searched for one or two lake characteristics that would provide an accurate estimation of the trophic state or nutrient condition of the lake waters. Lakes have been classified by trophic type on the basis of mean depth, water transparency, bottom sediments, total dissolved solids, electrical conductivity, oxygen, benthic fauna, and algae. No one of these variables provided a consistent, comprehensive, and accurate determination of the trophic state of lake waters.

This study gives an indication of the difficulty in-

volved with attempting to classify lakes by trophic type by using a single variable. The small numbers of significant partial correlations obtained between water quality measurements and plankton populations indicate that few factors act independently of other factors to produce a direct effect on another factor. Most of the factors studied interacted with other factors to produce the observed characteristics of a lake. It is therefore difficult to apply a single measurement of a lake characteristic that would provide an accurate estimation of the trophic state of lake waters.

The investigator has chosen to make a statement about the trophic state of each lake studied by considering some of the factors that enrich lake waters, and those factors within the lake that respond to or are affected by enrichment. Rawson (1960) has been successful in classifying lakes by considering more than one variable and the investigator feels that this procedure should be emphasized in future research.

Upper Blue Lake appears to have the least potential for enrichment of the lakes studied because of its deep lake basin. This basin permits the development of a deep hypolimnion that retains nutrients received from the epilimnion throughout summer stratification. These nutrients would not be available to phytoplankters and zooplankters until the stratification of the waters of Blue Lake was reduced sufficiently by the cooler fall surface water temperatures to

permit circulation of the waters once again by surface winds.

The shallower lake basins of Lower Blue Lake and Clear Lake are not sufficient enough to permit strong summer stratification of their waters, and to permit hypolimnetic development. A large portion of the total volume of the waters of these lakes is oxygenated and warm, and similar to the waters of the epilimnion of Upper Blue Lake. The waters are more enriched with nutrients throughout the summer because nutrients are being recirculated rather than migrating vertically downward and being absorbed by a colder noncirculating hypolimnion. The waters of Clear Lake are particularly rich in nutrients because of runoff from surrounding fertilized farm and orchard land during the winter rainy season, and because of the large input of sewage from many shoreline settlements.

The limited Secchi disk readings taken from August through October (Appendices F, G, and H) show a decrease in water transparency as one progresses from Upper Blue Lake to Lower Blue Lake, and finally to the Oaks Arm of Clear Lake. Hooper (1969) observed that changes in the transparency of the water column not due to suspended sediments can be indicative of the abundance of plankton organisms, and that transparency changes have been used to assess the rate and degree of eutrophication. Figures 2 and 3 of Appendix S show that Upper Blue Lake has the least amounts

of Cyanophyta and Chlorophyta, the two most common divisions phytoplankters observed in this study. The maximum transparency obtained in Upper Blue Lake was 5 meters which is characteristic of a lake that is moderately enriched. Lower Blue Lake, with larger amounts of Cyanophyta and Chlorophyta in the surface waters (Figures 2 and 3, Appendix S), had a reduced maximum transparency of 1 meter and is much more eutrophic than Upper Blue Lake. The investigator noted from plankton counts and the green color of the surface waters that the reduction in transparency in Lower Blue Lake was due to extensive growth of algae and not due to an increase in suspended sediments.

The Oaks Arm of Clear Lake had the largest amounts of Cyanophyta and Chlorophyta in the surface waters (Figures 2 and 3, Appendix S), and had a maximum transparency of only 0.5 meters. The reduction of water transparency to less than a meter because of extensive algal growth in the Oaks Arm of Clear Lake indicates that this basin of Clear Lake is markedly eutrophic.

Changes in the quantity and composition of plankton within a lake can serve as an index of the enrichment and eutrophic state of a lake. Phytoplankton respond to increases in essential nutrients, especially of nitrogen and phosphorus, with increased growth, and excessive blooms of phytoplankters are often the result of enrichment. Hasler (1947) described many lakes which received increased amounts

of nitrates and phosphates in recent years from runoff from fertilized agricultural land, or from increased sewage input from nearby settlements. The characteristic response of these lakes was increased plankton blooms, especially of Cyanophytes, during the summer months. Hammer (1964) found Cyanophytes to be the most common bloom producers in twenty-three southern Saskatchewan lakes. The three most common algae found were: Anabaena, Microcystis, and Aphanizomenon, and Hammer studied the effect of orthophosphate on these plankters. He found that Anabaena blooms lagged orthophosphate peaks by one to two weeks, while the concentrations of orthophosphate appeared to influence the growth of Aphanizomenon directly with the highest blooms developing in lakes with the highest orthophosphate concentration. Because of the response of Cyanophytes to increased nutrient availability, some investigators feel that they are useful indicators of cultural enrichment (Prescott, 1954; Brooks 1969).

Cyanophytes were present in all of the lakes studied. However, the quantity of Cyanophytes in Upper Blue Lake was slightly less than the quantity in Lower Blue Lake, and significantly less than the quantity in the Oaks Arm of Clear Lake (Figure 2, Appendix 3). The composition of Cyanophytes in all lakes was similar to that found by Hammer with Anabaena, Microcystis, and Aphanizomenon, common.

The orthophosphate concentration of Upper Blue Lake

was also slightly less than the concentration of orthophosphate in Lower Blue Lake, and significantly less than the orthophosphate concentration of the Oaks Arm of Clear Lake. It is possible that the Cyanophytes were responding to the increased levels of orthophosphate in a manner similar to that described by Hammer.

This study of the population of Cyanophytes and the concentration of orthophosphate within the three lakes studied indicates that there is a progressive enrichment of the lake waters as one considers Upper Blue Lake, then Lower Blue Lake, and finally the Oaks Arm of Clear Lake.

SUMMARY AND CONCLUSION

Upper Blue Lake, Lower Blue Lake, and Clear Lake are three popular recreational lakes in Lake County, California. The geological history of the lakes was briefly traced. Surface, mid-depth, and bottom water quality and plankton populations of the lakes were studied during a nine month period from February through October, 1972. Measurements were taken of water temperature, dissolved oxygen, dissolved carbon dioxide, orthophosphate, metaphosphate, nitrite nitrogen, and nitrate nitrogen. All plankters were identified, classified, and the number/M^3 of water sampled was determined.

A partial correlation analysis was performed on all of the water quality and plankton data. Each of the major plankton groupings served separately as the dependent variable and the water quality measurements served as independent variables. In the surface samples, the following positive correlations were found to be significant: Cyanophyta density with dissolved oxygen, Chlorophyta density with dissolved oxygen, and with orthophosphate, Bacillariophyceae density with dissolved carbon dioxide, Ciliata density with temperature, and with nitrite, and Copepoda density with dissolved oxygen. In addition, Cladocera density was inversely correlated with nitrate nitrogen.

The few significant correlations among the large number of water quality and plankton measurement pairs correlated indicate that few factors act independently of other factors to produce a direct effect on another factor. Most of the factors studied interacted with other factors to produce the observed characteristics of each lake.

Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake differ in the characteristics of the Lake basin, in the composition and quality of the plankton observed, and in the measurements of water quality. All of these factors contributed to the determination of the trophic state or nutrient condition of the lake waters. Evidence from this study indicates that Upper Blue Lake has the least amount of enrichment of its waters, while Lower Blue Lake has a slightly greater amount of enrichment, and the Oaks Arm of Clear Lake has the greatest amount of enrichment of its waters.

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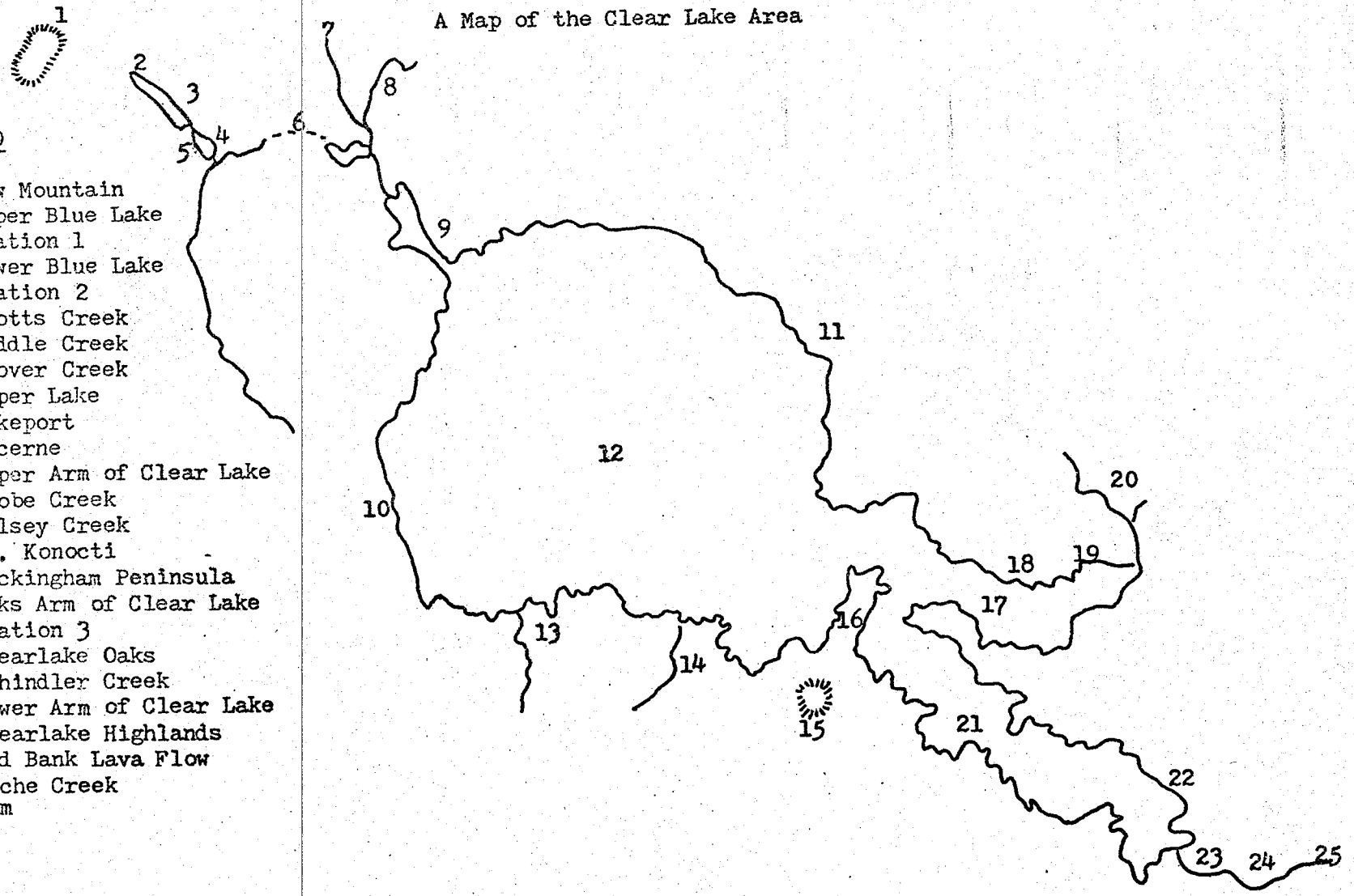
APPENDIX A

A Map of the Clear Lake Area



LEGEND

1. Cow Mountain
2. Upper Blue Lake
3. Station 1
4. Lower Blue Lake
5. Station 2
6. Scotts Creek
7. Middle Creek
8. Clover Creek
9. Upper Lake
10. Lakeport
11. Lucerne
12. Upper Arm of Clear Lake
13. Adobe Creek
14. Kelsey Creek
15. Mt. Konocti
16. Buckingham Peninsula
17. Oaks Arm of Clear Lake
18. Station 3
19. Clearlake Oaks
20. Schindler Creek
21. Lower Arm of Clear Lake
22. Clearlake Highlands
23. Red Bank Lava Flow
24. Cache Creek
25. Dam

APPENDIX B

Sample Field and Laboratory Data Sheets

Field Data

Station No. _____ Location _____

Date _____ Time _____

Weather _____ Air Temp. (°C) _____

Sample Depth (M)	Surface	Mid-Depth	Bottom
Water Temperature (°C)	_____	_____	_____
Oxygen (mg/liter)	_____	_____	_____
Carbon Dioxide (mg/liter)	_____	_____	_____
Water Sample Bottle Nos.	_____	_____	_____

Secchi Disk Clarity (M) _____/_____

General Notes

Laboratory Data

Sample Depth (M)	Surface	Mid-Depth	Bottom
Sample Bottle No.	_____	_____	_____
Orthophosphate (mg/liter)	_____	_____	_____
Metaphosphate (mg/liter)	_____	_____	_____
Nitrate (mg/liter)	_____	_____	_____
Nitrite (mg/liter)	_____	_____	_____

General Notes

APPENDIX C

List of References Utilized to Identify Plankton

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APPENDIX D

Plankton Identification and Count Sheet

Time/Date Sampled	Station Number	Sampling Method	Sampling Depth	Identified and Counted by
___/___	_____	_____	_____	_____

Number of Each Plankter/M^3 of Water Sampled

Number Counted	X	Sample Vol (ml)	X	Counting Factor	X	Dilution Factor	÷	Vol of Kemmerer ($0.0012M^3$)
( )		( )		( )		( )		( )

Cyanophyta (Blue Green Algae)

Aphanizomenon flos aquae _____

Anabaena spiroides _____

Lyngbya subcylindrica _____

Oscillatoria rubescens _____

_____

Chlorophyta (Green Algae)

Closterium sp. ( ) _____

Pediastrum sp. ( ) _____

Scenedesmus quadricauda _____

Spirogira sp. ( ) _____

Genicularia elegans _____

Ulothrix zonata _____

Mougeotia sp. ( ) _____

Stigeoclonium sp. ( ) _____

_____

_____

APPENDIX D (cont.)

Time/Date Sampled	Station Number	Sampling Method	Sampling Depth	Identified and Counted by
___/___	_____	_____	_____	_____

Crysophyta (Golden Brown Algae)

Mallomonas caudata_____

Dinobryon sp. ( )_____

Bacillariophyceae (Diatoms)

Asterionella formosa_____

Cymbella cistula_____

Fragilaria sp. ( )_____

Gyrosigma sp. ( )_____

Diatoma sp. ( )_____

Stephanodiscus niagarae (sm)_____

Stephanodiscus niagarae (lg.)_____

Navicula sp. ( )_____

Tabellaria fenestrata_____

_____

_____

_____

Protozoa

Sarcodinia

Amoeba hydrosoa_____

Rugipes bilzi_____

_____

APPENDIX D (cont.)

Time/Date Sampled	Station Number	Sampling Method	Sampling Depth	Identified and Counted by
____/____	_____	_____	_____	_____

Mastigophora

Ceratium hirundinella_____

_____

Ciliata

Coleps hirtus_____

_____

Rotatoria

Testudinela patina_____

Asplanchia priodonta_____

Ascomorpha saltans_____

Keratella cochlearis_____

Kellicottia longespina_____

Conochiloides dossarious_____

Notholca striata_____

Trichocerca longiseta_____

Polyartha vulgaris_____

Brachionus calyciflorus_____

Brachionus plicatilis_____

Brachionus sp. ( )_____

_____

_____

APPENDIX D (cont.)

Time/Date Sampled	Station Number	Sampling Method	Sampling Depth	Identified and Counted by
____/____	_____	_____	_____	_____

Arthropoda

Cladocera

Daphnia pulex_____

Bosmina corregoni_____

Latona setifera_____

_____

Copepoda

Cyclops vernalis_____

Nauplius_____

Diptera

Chaoborus astictopus_____

_____

APPENDIX E

Plankter/M^3 of Water Sampled Summary Sheet

Time/Date Sampled ____/____

Station Number _____

ORGANISM (NO/M^3)	KS	KM	KB
Aphanizomenon flos aquae			
Anabaena spiroides			
Lyngbya subcylindrica			
Oscillatoria rubescens			
_____			
Cyanophyta (B.G. Algae)			
Closterium sp. ( )			
Pediastrum sp. ( )			
Scenedesmus quadricauda			
Spirogira sp. ( )			
Genicularia elegans			
Ulothrix zonata			
Mougeotia sp. ( )			
Stigeoclonium sp. ( )			
_____			
_____			
Chlorophyta (G. Algae)			

APPENDIX E (cont.)

Time/Date Sampled ____/____

Station Number _____

ORGANISM (NO/M^3)	KS	KM	KB
Mallomonas caudata			
Dinobryon sp. ( )			
_____			
Crysophyta (G. B. Algae)			
Asterionella formosa			
Cymbella cistula			
Fragilaria sp. ( )			
Gyrosigma sp. ( )			
Diatoma sp. ( )			
Stephanodiscus niagarae (sm.)			
Stephanodiscus niagarae (lg.)			
Navicula sp. ( )			
Tabellaria fenestrata			
_____			
_____			
_____			
Bacillariophyceae (Diatoms)			
Amoeba hydrosoa			

APPENDIX E (cont.)

Time/Date Sampled ____/____

Station Number _____

ORGANISM (NO/M^3)	KS	KM	KB
Rugipes bilzi			
Sarcodinia			
Ceratium hirundinella			
Mastigophora			
Coleps hirtus			
Ciliata			
Testudinela patina			
Asplanchia priodonta			
Ascomorpha saltans			
Keratella cochlearis			
Kellicottia longespina			
Conochiloides dossarious			
Notholca striata			
Trichocerca longiseta			
Polyartha vulgaris			

APPENDIX E (cont.)

Time/Date Sampled ____/____

Station Number _____

ORGANISM (NO/M^3)	KS	KM	KB
Brachionus calyciflorus			
Brachionus pilcatilis			
Brachionus sp. ( )			
_____			
Rotatoria			
Daphnia pulex			
Bosmina corregoni			
Latona setifera			
_____			
Cladocera			
Cyclops vernalis			
Nauplius			
Copepoda			
Chaoborus astictopus			
_____			
Diptera			

APPENDIX F

Surface Water Quality and Plankton Measurements Taken at Upper Blue Lake

WATER QUALITY	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Water temperature (^{o}C)	11.0	11.0	16.0	23.0	25.0	24.0	24.0	20.0	15.5
Dissolved oxygen (mg/l)	10.0	9.2	8.0	8.0	7.0	5.5	6.0	7.0	8.0
Dissolved carbon dioxide (mg/l)	10.0	15.0	15.0	15.0	10.0	5.0	5.0	5.0	5.0
Orthophosphate (mg/l)	.060	.010	.080	.040	.090	.015	.020	.030	.030
Metaphosphate (mg/l)	:0	.070	.010	.080	.010	.015	.010	.020	.020
Nitrate nitrogen (mg/l)	5.0	4.5	7.5	6.5	1.0	6.0	4.5	5.0	2.0
Nitrite nitrogen (mg/l)	.002	.002	.002	.001	.002	.002	.001	0	0
Transparency (M)	----*	----	----	----	----	----	5.0	3.0	2.0

*Measurement not taken.

APPENDIX F (cont.)

Surface Water Quality and Plankton Measurements Taken at Upper Blue Lake

PLANKTON ($No/M^3 x10^3$)	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Cyanophyta	0	62.5	187.5	----*	8,875.0	1,687.5	2,000.0	875.0	38,187.5
Chlorophyta	41.7	0	0	----	104.2	312.5	500.0	1,145.8	4,187.5
Crysophyta (excluding Diatoms)	20.8	0	0	----	0	875.0	437.5	187.5	62.5
Bacillariophyceae	1,374.5	23,187.5	80,437.5	----	15,937.5	895.8	1,687.5	1,312.5	1,687.5
Sarcodinia	0	0	0	----	041.7	41.7	41.7	0	0
Mastigophora	0	0	208.3	----	520.8	187.5	458.3	62.5	0
Ciliophora	0	0	0	----	0	20.8	0	0	0
Rotatoria	0	0	0	----	250.0	187.5	0	20.8	62.5
Cladocera	0	0	0	----	2,125.0	0	0	0	0
Copepoda	20.8	0	0	----	62.5	0	0	0	0

*Measurement not taken.

APPENDIX G

Surface Water Quality and Plankton Measurements Taken at Lower Blue Lake

WATER QUALITY	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Water temperature (°C)	11.0	17.0	17.0	25.0	27.0	24.0	23.0	21.0	15.0
Dissolved oxygen (mg/l)	11.0	9.0	8.5	8.0	11.0	4.5	4.5	6.0	8.0
Dissolved carbon dioxide (mg/l)	15.0	15.0	15.0	10.0	10.0	5.0	5.0	5.0	5.0
Orthophosphate (mg/l)	.020	.020	.120	.075	.002	.060	.040	.020	.110
Metaphosphate (mg/l)	.580	.190	.015	.115	.023	.040	.085	.100	0
Nitrate nitrogen (mg/l)	2.4	1.0	1.3	7.9	3.0	6.0	2.5	4.0	4.5
Nitrite nitrogen (mg/l)	.013	.006	.015	.006	0	0	.005	0	.003
Transparency (M)	----*	----	----	----	----	----	1.0	1.0	0.5

*Measurement not taken.

APPENDIX G (cont.)

Surface Water Quality and Plankton Measurements Taken at Lower Blue Lake

PLANKTON ($No/M^3 x 10^3$)	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Cyanophyta	0	187.5	187.5	----*	2,062.5	4,962.5	1,208.3	64,375.2	38,687.5
Chlorophyta	208.3	250.0	604.2	----	1,125.5	895.8	47,000.4	45,104.3	12,187.5
Crysophyta (excluding Diatoms)	0	187.5	1,875.0	----	62.5	7,562.5	0	416.7	0
Bacillariophyceae	28,750.0	5,250.0	3,187.5	----	13,187.0	2,437.5	1,666.7	3,229.2	5,812.5
Sarcodinia	0	0	20.8	----	20.8	0	0	0	0
Mastigophora	0	125.0	0	----	104.2	7,354.2	41.7	20.8	0
Ciliophora	0	0	0	----	0	20.8	0	0	0
Rotatoria	0	0	20.8	----	20.8	125.0	62.5	125.0	83.3
Cladocera	0	0	0	----	145.8	20.8	20.8	0	20.3
Copepoda	0	125.0	41.7	----	0	83.3	62.5	0	20.3

*Measurement not taken.

APPENDIX H

Surface Water Quality and Plankton Measurements Taken at the Oaks Arm of Clear Lake

WATER QUALITY	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Water temperature (°C)	10.0	17.0	16.0	22.0	27.0	28.0	25.0	22.0	15.0
Dissolved oxygen (mg/l)	9.5	16.0	8.0	10.0	10.5	9.5	6.0	8.0	7.0
Dissolved carbon dioxide (mg/l)	10.0	15.0	5.0	5.0	5.0	15.0	10.0	5.0	10.0
Orthophosphate (mg/l)	.160	.150	.025	.140	.070	.080	.250	.170	.180
Metaphosphate (mg/l)	0	.300	.145	.170	.080	.140	.190	.050	0
Nitrate nitrogen (mg/l)	7.0	1.5	4.5	4.0	3.0	3.0	4.0	7.0	4.5
Nitrite nitrogen (mg/l)	.030	.014	.015	.005	.070	.002	.004	.002	.007
Transparency (M)	----*	----	----	----	----	----	0.5	0.5	0.3

*Measurement not taken.

APPENDIX H (cont.)

Surface Water Quality and Plankton Measurements Taken at the Oaks Arm of Clear Lake

PLANKTON ($No/M^3 x 10^3$)	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Cyanophyta	416.7	112,500.0	1,312.5	----*	15,062.5	60,125.5	32,625.0	19,791.7	2,243.8
Chlorophyta	395.8	0	395.8	----	145.8	1,854.2	75,875.0	15,020.9	1,270.8
Crysophyta (excluding Diatoms)	0	0	0	----	0	0	875.0	0	0
Bacillariophyceae	395.8	6,250.0	562.5	----	1,791.7	1,333.3	3,041.7	833.3	500.0
Sarcodinia	20.8	0	41.7	----	0	0	0	0	0
Mastigophora	0	0	0	----	0	1,000.0	187.5	83.3	62.5
Ciliophora	0	0	0	----	250.0	0	0	0	0
Rotatoria	0	0	187.5	----	0	187.5	291.2	62.5	0
Cladocera	0	0	83.5	----	41.7	0	166.2	20.8	0
Copepoda	0	2,500.0	0	----	41.7	20.8	291.2	0	20.8

*Measurement not taken.

APPENDIX I

Mid-Depth Water Quality and Plankton Measurements Taken at Upper Blue Lake

WATER QUALITY	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Water temperature (°C)	----*	----	----	----	19.0	23.5	23.0	19.0	15.0
Dissolved oxygen (mg/l)	----	9.2	9.0	8.0	9.0	5.0	6.0	7.0	8.0
Dissolved carbon dioxide (mg/l)	----	15.0	10.0	10.0	10.0	5.0	10.0	5.0	5.0
Orthophosphate (mg/l)	----	.100	.030	.030	.014	0	.030	.060	.020
Metaphosphate (mg/l)	----	.150	.010	.050	0	.010	.010	0	.030
Nitrate nitrogen (mg/l)	----	5.5	9.5	5.0	1.3	6.0	2.8	4.0	3.5
Nitrite nitrogen (mg/l)	----	.002	.007	.002	.005	0	0	.001	0

*Measurement not taken.

APPENDIX I (cont.)

Mid-Depth Water Quality and Plankton Measurements Taken at Upper Blue Lake

PLANKTON ($No/M^3 x10^3$)	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Cyanophyta	0	62.5	0	----*	14,625.0	1,250.0	2,812.5	30,000.0	41,875.0
Chlorophyta	0	0	0	----	125.0	125.0	1,375.0	1,854.0	5,000.0
Crysophyta (excluding Diatoms)	20.8	62.5	0	----	0	708.3	0	229.2	187.5
Bacillariophyceae	2,179.2	62,250.0	54,937.5	----	40,916.7	458.3	4,937.5	2,687.5	4,000.0
Sarcodinia	0	0	0	----	0	0	0	0	0
Mastigophora	0	312.5	187.5	----	750.0	166.7	250.0	83.3	41.7
Ciliophora	0	312.5	0	----	0	20.8	0	20.8	0
Rotatoria	0	125.0	0	----	229.2	145.8	83.3	41.7	145.8
Cladocera	0	0	0	----	3,041.2	0	0	0	0
Copepoda	20.8	0	20.8	----	0	20.8	0	0	20.8

*Measurement not taken.

APPENDIX J

Mid-Depth Water Quality and Plankton Measurements Taken at Lower Blue Lake

WATER QUALITY	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Water temperature (°C)	----*	----	----	----	23.0	23.0	22.5	20.0	14.0
Dissolved oxygen (mg/l)	----	8.0	9.0	8.0	10.0	4.0	4.5	6.0	8.0
Dissolved carbon dioxide (mg/l)	----	15.0	20.0	10.0	10.0	5.0	5.0	5.0	7.5
Orthophosphate (mg/l)	----	.150	.080	.070	0	.080	0	.070	.070
Metaphosphate (mg/l)	----	.070	.050	.020	.015	0	.120	0	.050
Nitrate nitrogen (mg/l)	----	5.0	7.5	6.0	1.5	4.0	3.9	5.0	4.0
Nitrite nitrogen (mg/l)	----	.012	.013	.006	.005	0	.001	0	.003

*Measurement not taken.

APPENDIX J (cont.)

Mid-Depth Water Quality and Plankton Measurements Taken at Lower Blue Lake

PLANKTON ($No/M^3 x10^3$)	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Cyanophyta	----*	187.5	562.5	----	2,125.0	6,291.7	4,062.0	35,1042.	36,256.2
Chlorophyta	----	437.5	958.3	----	1,250.0	2,395.8	56,687.5	65,521.0	6,875.0
Crysophyta (excluding Diatoms)	----	500.0	6,562.5	----	0	4,500.0	62.5	416.7	0
Bacillariophyceae	----	9,062.5	1,687.5	----	7,020.8	3,604.2	2,333.3	3,750.0	3,375.0
Sarcodinia	----	125.0	20.8	----	20.8	0	0	0	0
Mastigophora	----	62.5	0	----	750.0	4,437.5	62.5	0	0
Ciliophora	----	0	0	----	0	0	0	0	0
Rotatoria	----	62.5	62.5	----	270.8	291.7	20.8	395.8	62.5
Cladocera	----	125.0	41.7	----	145.8	20.8	20.8	250.0	20.8
Copepoda	----	62.5	41.7	----	20.8	125.0	125.0	0	20.8

*Measurement not taken.

APPENDIX K

Mid-Depth Water Quality and Plankton Measurements Taken at the Oaks Arm of Clear Lake

WATER QUALITY	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Water temperature (°C)	----*	----	----	----	25.0	26.0	24.0	20.0	14.0
Dissolved oxygen (mg/l)	----	----	11.0	10.0	8.0	7.0	5.0	6.0	6.0
Dissolved carbon dioxide (mg/l)	----	----	10.0	10.0	15.0	15.0	7.5	10.0	10.0
Orthophosphate (mg/l)	----	----	.030	.170	.050	.120	.270	.180	.280
Metaphosphate (mg/l)	----	----	.095	.050	.090	.040	.150	.040	0
Nitrate nitrogen (mg/l)	----	----	9.0	6.0	5.5	5.0	3.0	4.0	4.0
Nitrite nitrogen (mg/l)	----	----	.005	.002	.004	.005	.002	.003	.010

*Measurement not taken.

APPENDIX K (cont.)

Mid-Depth Water Quality and Plankton Measurements Taken at the Oaks Arm of Clear Lake

PLANKTON (No/M^3x10^3)	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Cyanophyta	458.3	22,500.0	4,125.0	----*	6,218.8	21,937.5	35,625.0	39,375.1	4,406.2
Chlorophyta	229.7	0	291.7	----	0	7,583.3	55,000.0	54,791.8	4,062.5
Crysophyta (excluding Diatoms)	0	0	0	----	0	62.5	2,500.0	0	0
Bacillariophyceae	645.8	2,500.0	2,333.3	----	0	2,187.5	6,875.0	2,395.8	1,375.0
Sarcodinia	0	0	41.7	----	0	20.8	0	0	62.5
Mastigophora	0	0	0	----	0	2,750.0	0	62.5	0
Ciliophora	0	0	0	----		20.8	0	0	0
Rotatoria	0	1,250.0	145.8	----	0	791.7	0	145.8	0
Cladocera	0	1,875.0	83.3	----	20.8	62.5	0	229.2	20.8
Copepoda	0	625.0	20.8	----	0	104.2	1,041.7	125.0	20.8

*Measurement not taken.

APPENDIX L

Bottom Water Quality and Plankton Measurements Taken at Upper Blue Lake

WATER QUALITY	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Water temperature (°C)	----*	----	----	----	16.0	13.5	15.0	18.0	15.0
Dissolved oxygen (mg/l)	----	7.2	5.0	6.0	7.0	1.0	1.5	6.0	7.0
Dissolved carbon dioxide (mg/l)	----	15.0	20.0	15.0	25.0	10.0	5.0	5.0	5.0
Orthophosphate (mg/l)	----	.300	.050	.040	.085	.010	.040	.040	.030
Metaphosphate (mg/l)	----	0	.020	.100	.055	0	.010	.010	.020
Nitrate nitrogen (mg/l)	----	3.0	5.0	6.0	2.4	6.0	3.2	5.0	3.5
Nitrite nitrogen (mg/l)	----	.007	.003	.004	.003	.004	.001	0	.001

*Measurement not taken.

APPENDIX L (cont.)

Bottom Water Quality and Plankton Measurements Taken at Upper Blue Lake

PLANKTON ($No/M^3 x 10^3$)	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Cyanophyta	62.5	437.5	375.0	----*	3,875.0	3,062.5	750.0	28,500.0	12,437.5
Chlorophyta	20.8	250.0	0	----	41.7	291.7	750.0	6,750.0	875.0
Crysophyta (excluding Diatoms)	20.8	62.5	0	----	0	333.3	0	62.5	0
Bacillariophyceae	2,375.0	32,937.5	59,250.0	----	13,229.2	1,020.8	13,583.3	6,250.0	1,479.2
Sarcodinia	0	0	20.8	----	0	0	0	0	0
Mastigophora	0	250.0	0	----	187.5	208.3	20.8	62.5	20.8
Ciliophora	0	0	0	----	0	0	0	62.5	0
Rotatoria	0	0	750.0	----	250.0	166.7	62.5	83.3	41.7
Cladocera	20.8	187.5	41.7	----	1,208.3	62.5	20.8	0	0
Copepoda	20.8	0	83.3	----	0	83.3	41.7	0	0

*Measurement not taken.

APPENDIX M

Bottom Water Quality and Plankton Measurements Taken at Lower Blue Lake

WATER QUALITY	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Water temperature (°C)	----*	----	----	----	22.0	23.0	22.5	19.0	14.0
Dissolved oxygen (mg/l)	----	8.0	7.0	2.0	4.0	3.0	3.5	4.0	7.0
Dissolved carbon dioxide (mg/l)	----	15.0	20.0	15.0	25.0	5.0	7.5	5.0	5.0
Orthophosphate (mg/l)	----	.080	.060	.080	.040	.040	.025	.060	.020
Metaphosphate (mg/l)	----	.130	.065	.090	0	.030	.085	.030	.070
Nitrate nitrogen (mg/l)	----	3.5	6.5	4.5	0.8	5.0	4.5	6.0	3.0
Nitrite nitrogen (mg/l)	----	.005	.017	.015	.004	0	.001	0	.006

*Measurement not taken.

APPENDIX M (cont.)

Bottom Water Quality and Plankton Measurements Taken at Lower Blue Lake

PLANKTON ($NO/M^3 x 10^3$)	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Cyanophyta	----*	125.0	2,083.3	----	2,062.5	5,375.0	1,468.8	3,187.5	42,812.5
Chlorophyta	----	562.5	1,604.2	----	437.5	937.5	20,395.8	28,812.5	14,812.5
Crysophyta (excluding Diatoms)	----	250.0	8,812.5	----	0	166.7	125.0	62.5	0
Bacillariophyceae	----	15,312.5	5,145.3	----	5,604.2	1,541.7	2,625.0	2,312.5	6,562.0
Sarcodinia	----	62.5	20.8	----	20.8	0	0	0	0
Mastigophora	----	312.5	0	----	0	1,875.0	62.5	0	20.8
Ciliophora	----	0	0	----	0	0	0	0	0
Rotatoria	----	0	299.2	----	0	166.7	166.7	41.7	437.5
Cladocera	----	0	62.5	----	83.3	20.8	0	0	62.5
Copepoda	----	0	41.7	----	62.5	104.2	41.7	20.8	62.5

*Measurement not taken.

APPENDIX N

Bottom Water Quality and Plankton Measurements Taken at the Oaks Arm of Clear Lake

WATER QUALITY	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Water temperature (°C)	----*	----	----	----	25.0	25.0	23.5	20.0	14.0
Dissolved oxygen (mg/l)	----	11.0	9.0	10.0	8.0	5.5	5.0	8.0	6.0
Dissolved carbon dioxide (mg/l)	----	15.0	15.0	10.0	25.0	10.0	7.5	10.0	12.5
Orthophosphate (mg/l)	----	.040	.060	.090	.280	.220	.280	.240	.320
Metaphosphate (mg/l)	----	.210	.120	.050	.060	.110	.150	.010	0
Nitrate nitrogen (mg/l)	----	2.5	3.5	5.0	2.6	2.0	2.0	4.0	4.0
Nitrite nitrogen (mg/l)	----	.008	.010	.003	.015	0	.005	.002	.006

*Measurement not taken.

APPENDIX N (cont.)

Bottom Water Quality and Plankton Measurements Taken at the Oaks Arm of Clear Lake

PLANKTON (No/M^3x10^3)	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.
Cyanophyta	458.3	312.5	6,966.7	----	5,375.0	1,625.0	16,875.0	140,000.4	6,739.6
Chlorophyta	780.8	62.5	62.5	----	291.7	7,166.2	84,563.3	32,604.3	875.0
Crysophyta (excluding Diatoms)	20.8	0	0	----	0	0	0	0	0
Bacillariophyceae	541.7	1,187.5	7,708.3	----	7,125.0	187.5	6,875.0	1,979.2	833.3
Sarcodinia	0	0	0	----	0	0	0	0	0
Mastigophora	0	62.5	0	----	0	729.2	0	83.3	0
Ciliophora	0	0	0	----	0	0	0	0	0
Rotatoria	0	0	20.8	----	20.8	83.3	416.7	62.5	0
Cladocera	0	0	83.3	----	20.8	0	0	62.5	0
Copepoda	0	250.0	20.8	----	0	20.8	0	41.7	0

*Measurement not taken.

APPENDIX O

Matrix of Partial Correlations Between Each Plankton Measurement and Each Water Quality Measurement of All Surface Samples

	WATER QUALITY						
PLANKTON	°C	O_2	CO_2	PO_4^{-3}	$P_2O_7^{-4}$	NO_3^-	NO_2^-
Cyanophyta	0.1688	0.4598	-0.1714	0.2865	-0.0064	-0.2422	0.2571
Chlorophyta	0.0930	0.3745	-0.0776	0.4443	0.2528	-0.1853	-0.0669
Crysophyta (excluding Diatoms)	0.1049	-0.1745	-0.1030	-0.0131	0.1136	0.1114	-0.0524
Bacillariophyceae	-0.1568	-0.0943	0.3339	-0.1191	-0.0337	-0.0160	-0.0028
Sarcodinia	0.0169	-0.0284	-0.0554	-0.1787	-0.1553	0.0017	0.0665
Mastigophora	0.1401	-0.1512	-0.0363	-0.0206	0.0605	0.0587	-0.0514
Ciliophora	0.4302	-0.0728	-0.0708	-0.2985	-0.2329	-0.2251	0.8823
Rotatoria	0.1404	-0.2741	0.0075	0.2492	0.0046	-0.2804	-0.0491
Cladocera	0.1219	-0.1480	0.2279	0.1524	-0.2529	-0.3954	0.0311
Copepoda	0.1039	0.5873	-0.1050	0.3135	0.0478	-0.1729	-0.2525

APPENDIX P

Matrix of Partial Correlations Between Each Plankton Measurement and Each Water Quality Measurement of All Mid-Depth Samples

	WATER QUALITY						
PLANKTON	^{o}C	O_2	CO_2	PO_4^{-3}	$P_2O_7^{-4}$	NO^{-}_3	NO_2^{-}
Cyanophyta	.4462	.1261	-.2152	.2517	.0569	.0639	-.0860
Chlorophyta	.4509	.1369	-.1696	.3265	.3687	.2724	-.3351
Crysophyta (exluding Diatoms)	.3463	-.2030	-.0906	.2416	.0951	.2943	-.1417
Bacillariophyceae	-.1974	.1334	.2005	-.1551	.1186	-.1765	-.2037
Sarcodinia	-.1966	-.0016	.1827	-.2619	-.2393	-.1512	.2071
Mastigophora	.4036	-.2022	.2441	-.0873	-.1592	.0116	-.1168
Ciliophora	-.2169	-.1071	.3739	-.1420	.4572	-.2086	-.4845
Rotatoria	.2059	-.2123	.2135	-.1602	-.1105	-.0838	-.0885
Cladocera	.0109	.0947	.1343	-.1707	-.2119	-.3279	.0990
Copepoda	.1814	-.2603	-.0446	.3705	.3726	.0692	-.2614

APPENDIX Q

Matrix of Partial Correlations Between Each Plankton Measurement and Each Water Quality Measurement of All Bottom Samples

	WATER QUALITY						
PLANKTON	°C	O_2	CO_2	PO_4^{-3}	$P_2O_7^{-4}$	NO_3^-	NO_2^-
Cyanophyta	.5518	.4810	-.4469	-.2594	-.2564	-.1800	.3455
Chlorophyta	.2909	.2350	-.2471	.4101	.4474	.1818	-.1089
Crysophyta (excluding Diatoms)	.1118	-.2065	-.0546	-.1127	-.1035	.5986	.2210
Bacillariophyceae	-.3581	-.0748	.4250	.2087	-.0934	.1079	-.3132
Sarcodinia	-.1275	-.0377	.3039	-.0370	.1018	.1005	-.1717
Mastigophora	.2093	-.0797	.0195	.0472	.1326	.1747	-.1835
Ciliophora	.2462	.2388	-.1492	.1424	-.1846	.0568	.0022
Rotatoria	.1124	-.1229	.1718	-.0096	.1051	.2374	-.1293
Cladocera	.0750	.0413	.4390	-.0892	-.0812	-.1173	-.1988
Copepoda	.2469	.1342	.0423	-.2344	.1235	-.0329	-.0018

APPENDIX R

THE SIGNIFICANT PARTIAL CORRELATIONS BETWEEN THE NUMBERS OF PLANKTERS AND MEASUREMENTS OF WATER QUALITY IN THE SURFACE SAMPLES OF UPPER BLUE LAKE, LOWER BLUE LAKE, AND THE OAKS ARM OF CLEAR LAKE, AND THE LEVEL OF SIGNIFICANCE OF EACH OF THESE CORRELATIONS

CORRELATED PAIRS	VALUE	LEVEL OF SIGNIFICANCE
Cyanophyta x oxygen	0.4598	1.0%
Chlorophyta x oxygen	0.3745	5.0%
Chlorophyta x orthophosphate	0.4443	1.0%
Bacillariophyceae x CO_2	0.3339	5.0%
Ciliophora x temperature	0.4302	2.5%
Ciliophora x nitrite	0.8823	0.1%
Cladocera x nitrate	-0.3954	-2.5%
Copepoda x oxygen	0.5873	1.0%

APPENDIX S. Figures Showing Monthly Changes in Plankton Density and Measurements of Water Quality of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

APPENDIX S

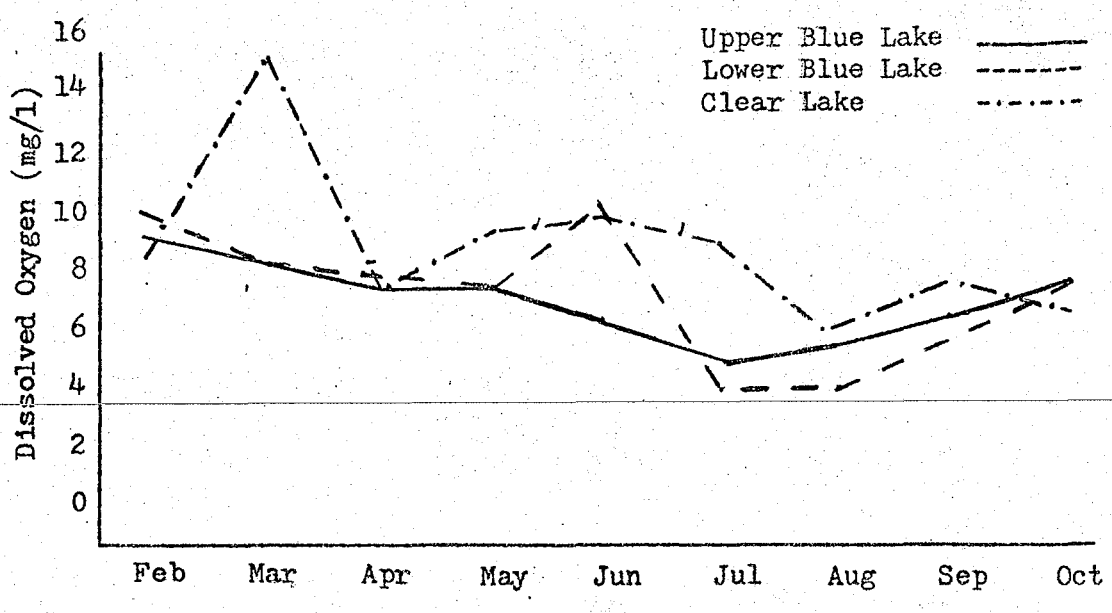

Figure 1. Monthly Changes in the Dissolved Oxygen Content of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

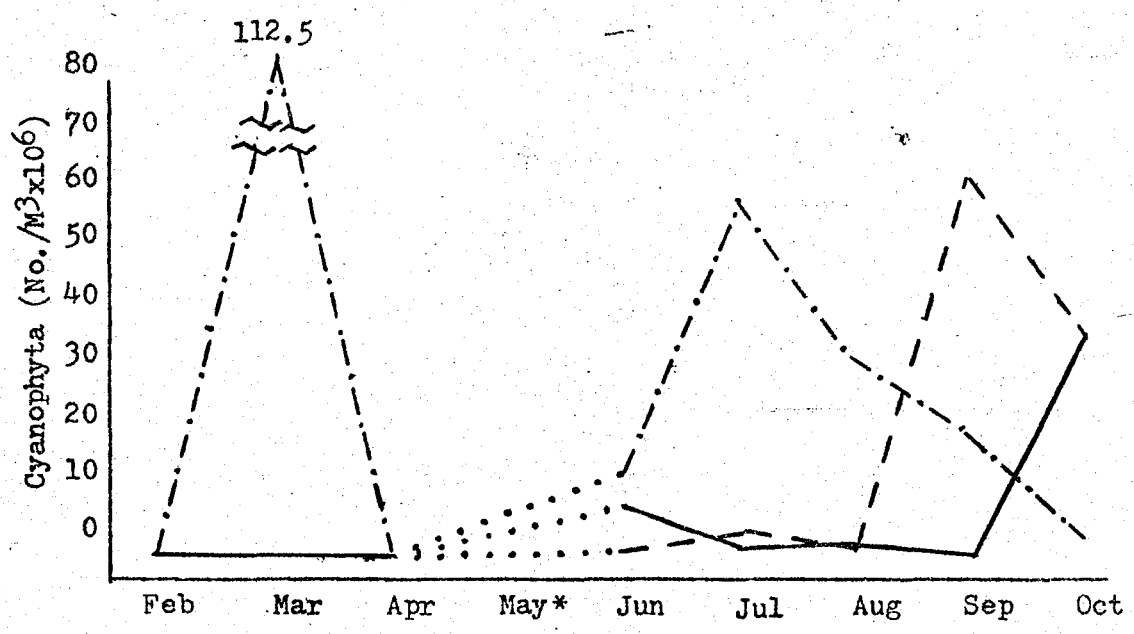

Figure 2. Monthly Changes in the Cyanophyta Density of the Surface Water Samples of Upper Blue, Lower Blue Lake, and the Oaks Arm of Clear Lake.

*May plankton data not available.

APPENDIX S (cont.)

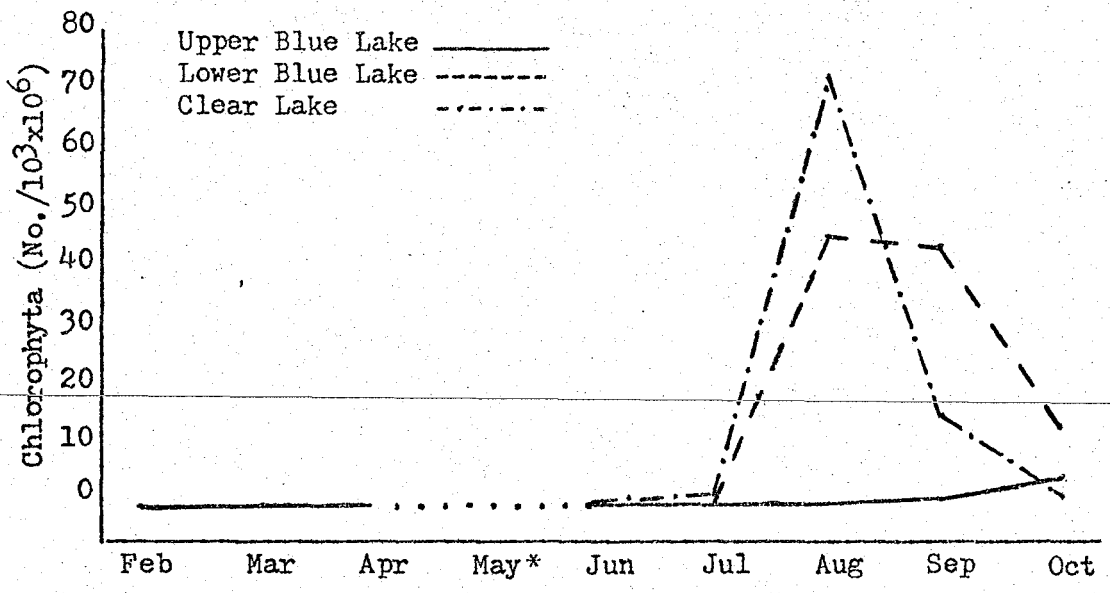

Figure 3. Monthly Changes in the Chlorophyta Density of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

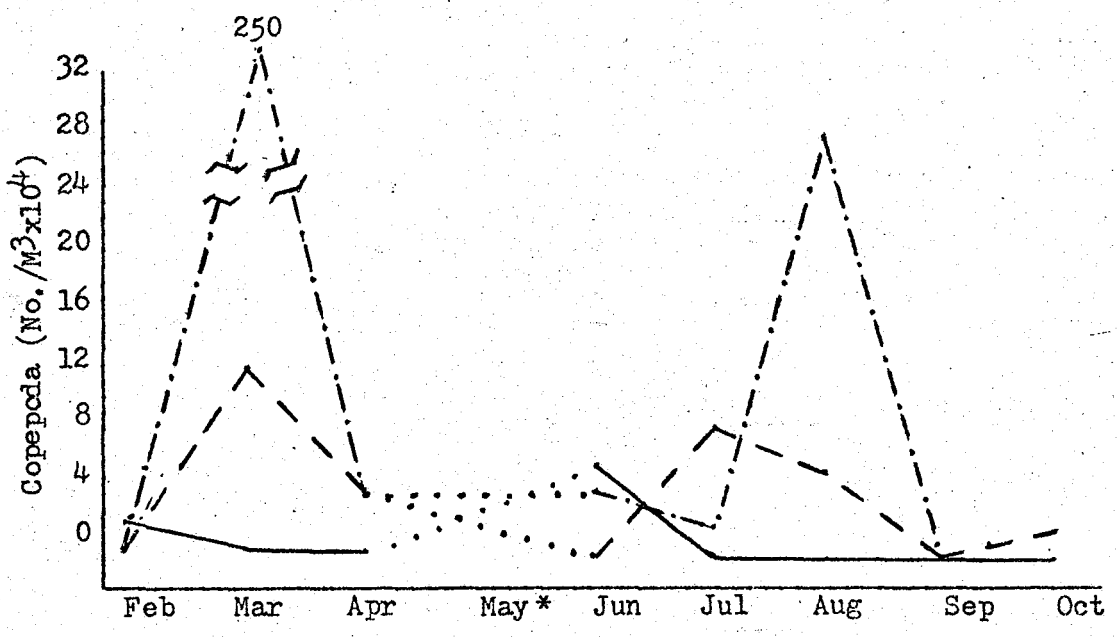

Figure 4. Monthly Changes in the Copepoda Density of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

*May plankton data not available.

APPENDIX S (cont.)

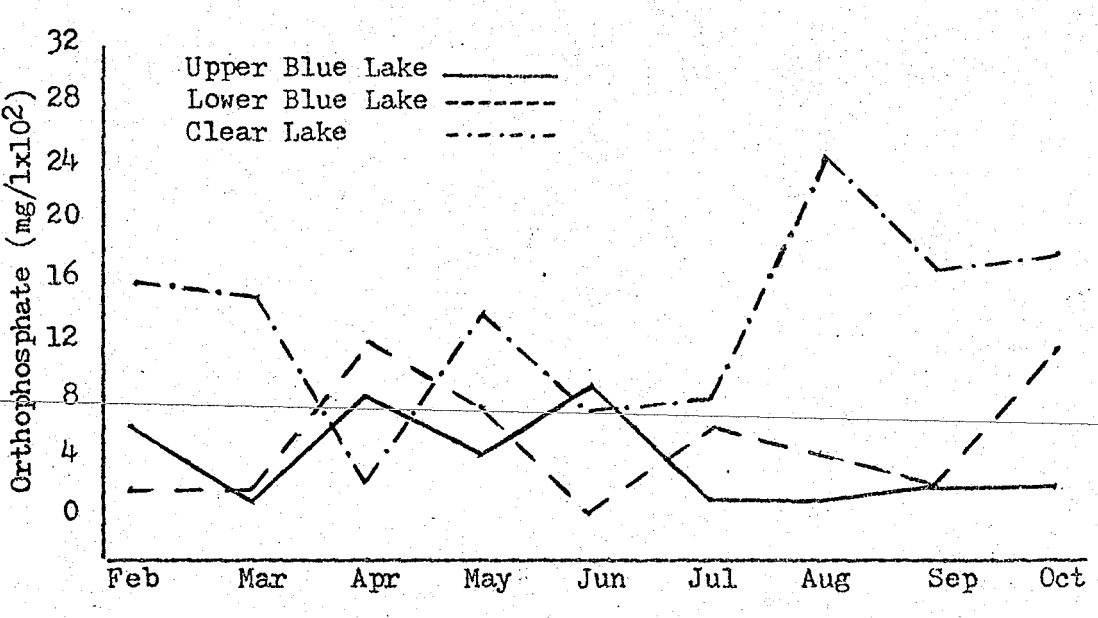

Figure 5. Monthly Changes in the Orthophosphate Content of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

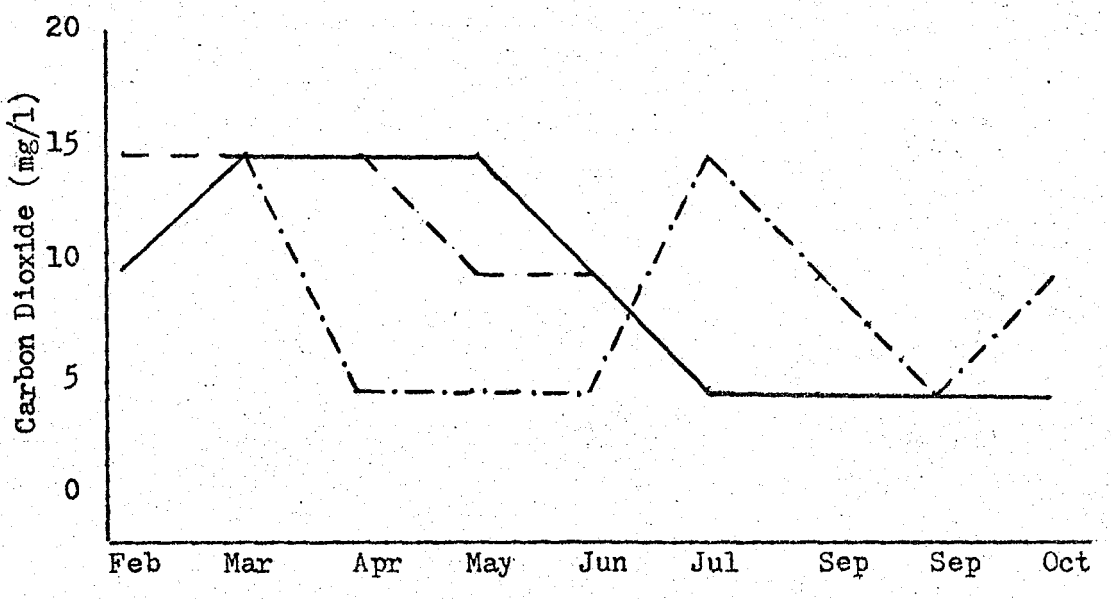

Figure 6. Monthly Changes in the Dissolved Carbon Dioxide Content of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

APPENDIX S (cont.)

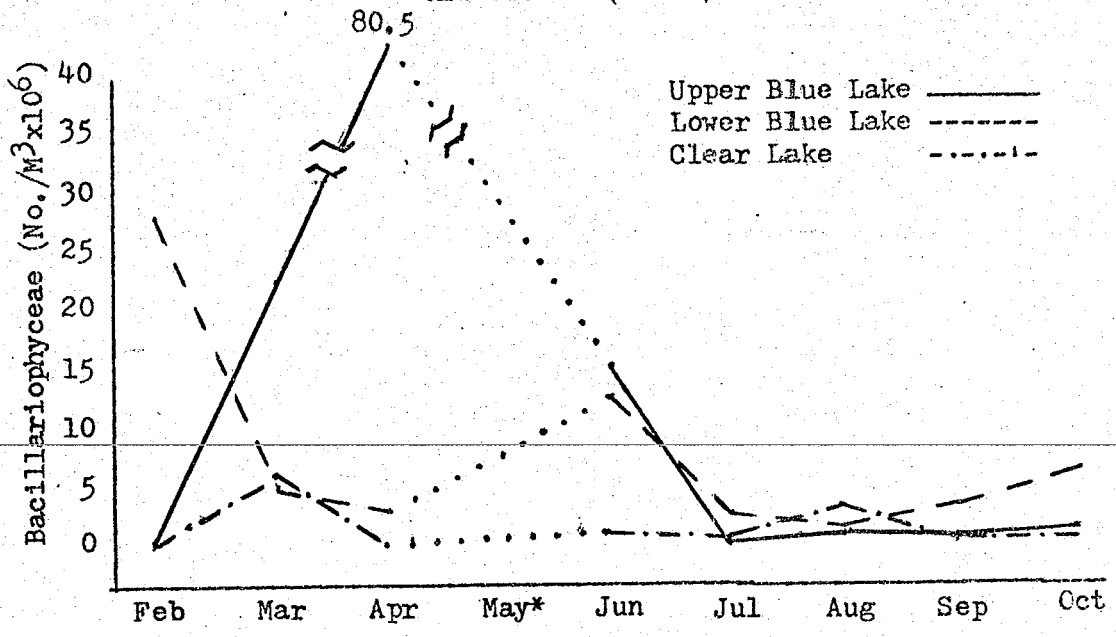

Figure 7. Monthly Changes in the Bacillariophyceae Density of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

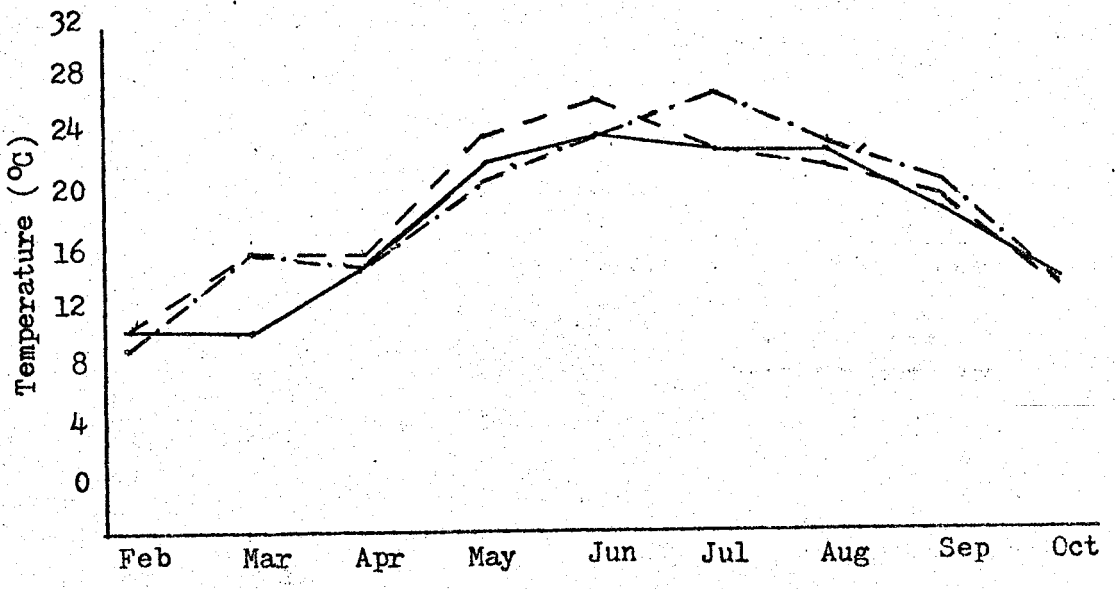

Figure 8. Monthly Changes in the Water Temperature of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

*May plankton data not available.

APPENDIX S (cont.)

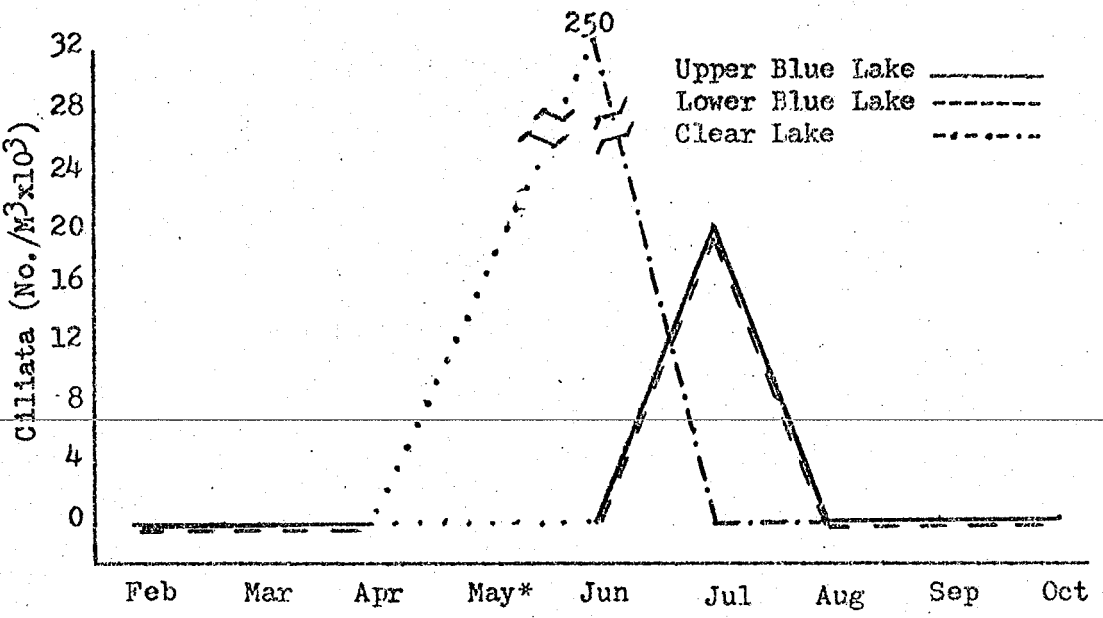

Figure 9. Monthly Changes in the Ciliata Density of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

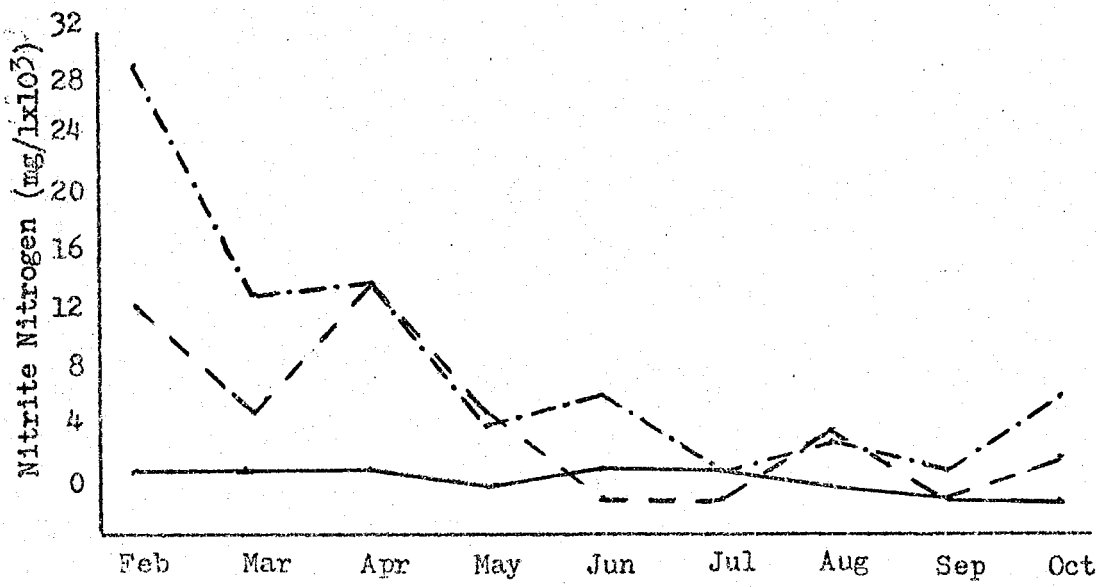

Figure 10. Monthly Changes in the Nitrite Nitrogen Content of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

*May plankton data not available

APPENDIX S (cont.)

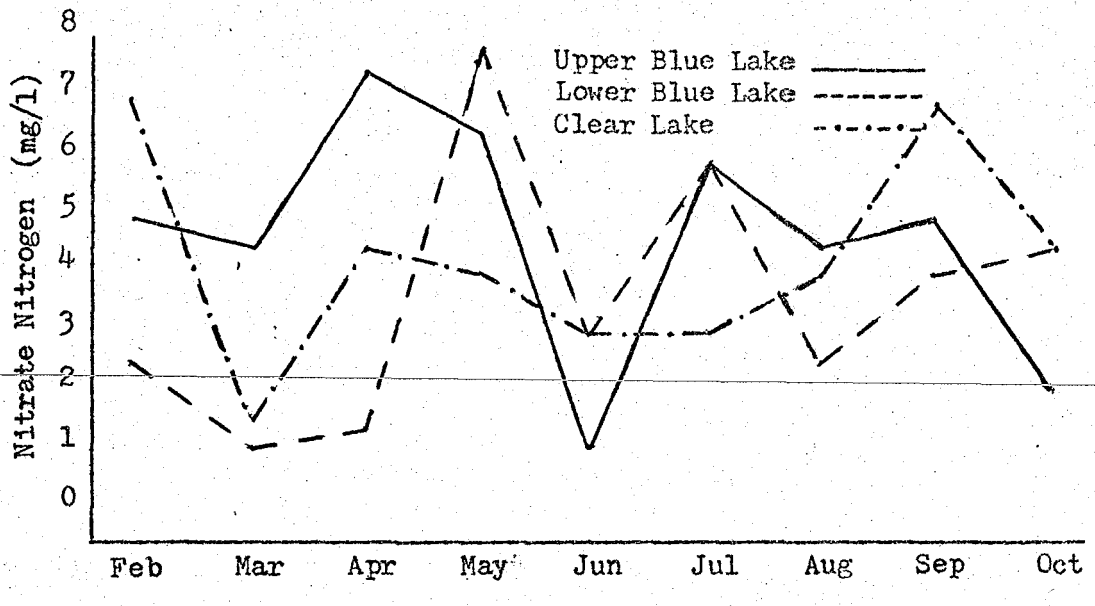

Figure 11. Monthly Changes in the Nitrate Nitrogen Content of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

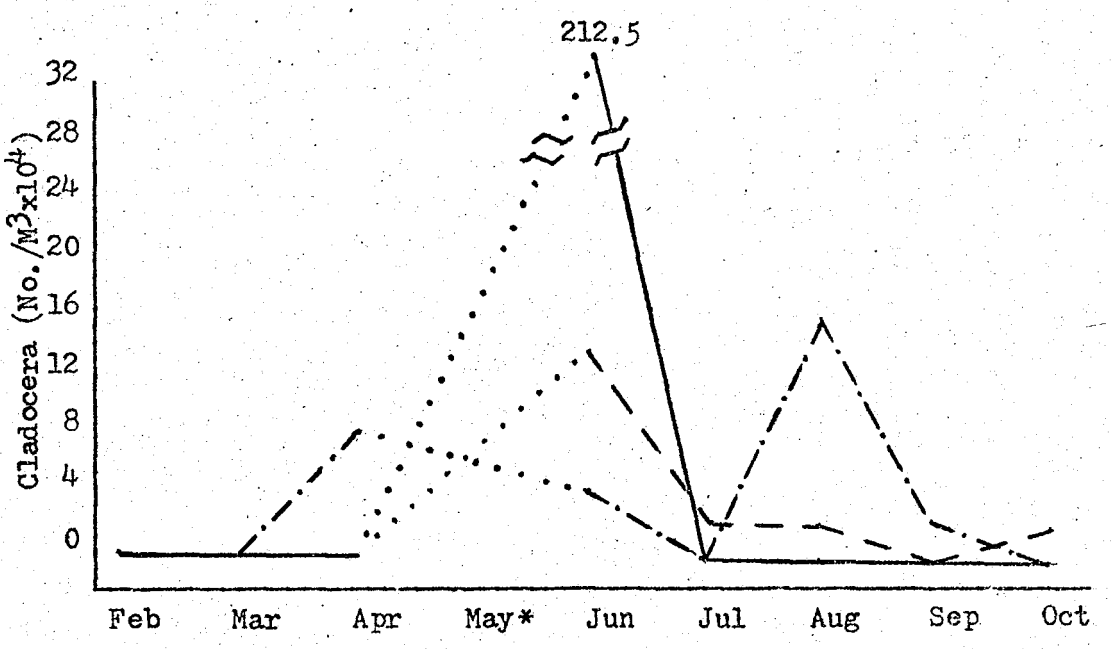

Figure 12. Monthly Changes in the Cladocera Density of the Surface Water Samples of Upper Blue Lake, Lower Blue Lake, and the Oaks Arm of Clear Lake.

*May plankton data not available.