STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
OFFICE OF PUBLIC WORKS

WATER RESOURCES
TECHNICAL REPORT
NO. 38

A LIMNOLOGICAL STUDY OF LAKE BRUIN, LOUISIANA

Prepared by
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
In cooperation with
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
OFFICE OF PUBLIC WORKS
1985

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By

Charles R. Demas

U.S. Geological Survey

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PREFACE

The Louisiana District of the U.S. Geological Survey, in cooperation with the Louisiana Office of Public Works, Department of Transportation and Development, has been collecting background water-quality information on several oxbow lakes in Louisiana since 1977. This data-collection program is part of the Federal-State cooperative network. The program was designed to provide good background water-quality data and to identify problems present in these lakes so that intensified lake studies could be developed.

This project on Lake Bruin is the first intensive limnological study to result from the program. Other lakes remain a part of the network so that a greater understanding of the more serious water-quality problems can be identified prior to any in-depth investigation. Lakes which may become subjects of future investigations include Lake St. John, Lake St. Joseph, Lake Providence, and Lake Concordia.

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI)

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
foot per second (ft/s)	0.3048	meter per second (m/s)
gallon (gal)	3.785	liter (L)
inch (in.)	25.40	millimeter (mm)
	2.540	centimeter (cm)
inch per year (in/yr)	25.40	millimeter per year (mm/yr)
micromhos per centimeter at 25° Celsius (mhos/cm)	1	microsiemens per centimeter at 25° Celsius (S/cm)
mile (mi)	1.609	kilometer (km)
mile per hour (mi/h)	1.609	kilometer per hour (km/h)
pound (lb)	0.4536	kilogram (kg)
	453.6	gram (g)
square inch (in^2)	6,452	square centimeter (cm^2)

To convert temperature in degrees Celsius (°C) to degrees Fahrenheit (°F), multiply by 1.8 and add 32.

A LIMNOLOGICAL STUDY OF LAKE BRUIN, LOUISIANA

By Charles R. Demas

ABSTRACT

A limnological study of Lake Bruin, an oxbow lake in northeastern Louisiana, was conducted from June 1980 to December 1982 to define limnological processes of the lake and to determine the extent of contamination from domestic sewage and pesticides.

Lake Bruin was found to be a monomictic lake that stratified thermally in its deeper areas by mid-April and generally overturned during the last week in October. Dissolved-oxygen concentrations in the hypolimnion approached 0.0 milligrams per liter by April and remained low until after the fall overturn.

Major sources of inflow to the lake during the study were rainfall and runoff. There was little input to the lake from ground water. No hydraulic connection with the Mississippi River was observed.

Water in Lake Bruin is of good quality. Concentrations of all major ions in the calcium bicarbonate water were relatively low. Pesticides and minor elements were present in the water in very low concentrations. However, insecticides such as DDT, DDD, dieldrin, and chlordane were found in relatively high concentrations in samples from bottom material and fish-tissue samples. Concentrations in fish tissue were less than recommended limits of the Food and Drug Administration. Major sources of pesticides in the lake were agricultural runoff and resuspension of bottom material.

Productivity in Lake Bruin was high; however, net productivity was usually restricted to the upper 6.6 feet of water. Respiration often exceeded primary production below a depth of 6.6 feet. Algae common in Lake Bruin were *Lyngbya*, *Oscillatoria*, *Anacystis*, *Cyclotella*, *Melosira*, *Ankistrodesmus*, and *Dictyosphaerium*. Blue-green algae dominated the phytoplankton community during the summer. Nitrogen-phosphorus ratios indicated nitrogen was the potential limiting nutrient during some blue-green algae blooms; phosphorus appeared to be limiting at other times.

Concentrations of fecal-coliform and fecal-streptococci bacteria in lake water were low throughout the study, indicating minimal bacterial pollution from domestic sources.

Dominant benthic invertebrates were *Chaoborus*, *Chironomus*, *Potamothrix*, *Limnodrilus*, and unidentified tubificid worms. All are tolerant of low dissolved-oxygen concentrations.

Physical, chemical, and biological data indicate that Lake Bruin is eutrophic. However, its trophic condition has not yet progressed to a level that interferes with its use for primary and secondary recreation or as a source for domestic drinking water.

INTRODUCTION

Lake Bruin is an oxbow lake, a cut-off meander of the Mississippi River, located 4 mi north of St. Joseph, Louisiana, in the northeastern part of the State (fig. 1).

Lake Bruin is a popular recreational lake utilized heavily for fishing and other types of water activities. It has served in the past as a source of drinking water for several small communities situated along its shoreline and is still used by a few communities.

Historically, land adjacent to the lake was developed primarily for agricultural purposes, cotton being the dominant crop. In recent years the lakeshore has become increasingly enveloped by homes and cottages. Consequently, domestic sewage may be a potential source of pollution to the lake, through seepage from private septic systems or as direct input of untreated sewage to the lake.

Nonresidential shore areas border agricultural lands, and runoff from farmland is a major concern for water quality in Lake Bruin. Land use inside the horseshoe formed by the lake is primarily agricultural. Pesticides are used extensively on the principal crops, cotton and soybeans. Drainage into the lake is from both point and nonpoint sources. Local residents have stated that, at times (depending upon wind conditions), the lake receives direct input of pesticides from aerial application.

Physical and chemical data collected by both the U.S. Geological Survey and the Louisiana Department of Health and Human Resources indicate several potential problems in Lake Bruin. Such problems include high pesticide concentrations in bottom material and fish-tissue samples, anaerobic conditions in the deeper areas of the lake concurrent with supersaturation of dissolved oxygen in the surface waters during the summer season, and occasional fecal-coliform counts greater than recommended limits (200 colonies/100 mL, Louisiana Stream Control Commission, 1977) for primary-contact recreation. These findings indicated potential agricultural and sewage runoff problems, which could lead to premature organic and nutrient enrichment, greatly accelerating the natural rate of aging of the lake.

Unfortunately, the extent of pesticide, nutrient, and bacterial contamination within the lake was unknown. Compounding these problems was a lack of information on the basic limnological processes within the lake.

In July of 1981, the U.S. Geological Survey in cooperation with the Louisiana Department of Transportation and Development, Office of Public Works, began a limnological study of Lake Bruin to describe the physical, chemical, and biological characteristics of the lake and classify it with respect to its trophic condition (degree and rate of eutrophication).

Materials and Methods

All water-quality samples were collected according to methods listed in Brown and others (1970) and analyzed by the U.S. Geological Survey Central Laboratory-Atlanta, Doraville, Ga., using methods listed in Skougstad and others (1979). All subsurface lake samples for pesticide analyses were collected using a brass Kemmerer sampler. A PVC Van Dorn sampler was used to collect samples for minor-element analyses. Bottom-material samples for minor-element analyses were collected using a Teflon-coated[1] pipe dredge, and bottom material for pesticide samples was collected using a petite Ponar sampler.

On site water-quality properties--including pH, dissolved oxygen, temperature, and specific conductance--were measured using a Hydrolab Model 4041[1/] and redox potential was measured using a Hydrolab Model 6[1/] equipped with an ORP (oxidation-reduction potential) probe. Light penetration was determined with a Secchi disk and a Li-Cor Model 185B photometer[1/].

Phytoplankton and chlorophyll samples were dipped near the lake surface. Algal-growth potential (AGP) samples were collected bimonthly near the surface and near the bottom. All samples were processed and preserved according to methods listed in Greeson and others (1977). All analyses were done in the Atlanta laboratory. Diversity indices at the generic level were calculated using the following formula proposed by Wilhm and Dorris (1968, p. 478) and recommended by Slack and others (1973):

$$\bar{d} = - \sum_{i=1}^{s} \frac{n_i}{n} \log_z \frac{n_i}{n}$$

where d is a measure of diversity, n_i is the number of individuals per taxon, n is the total number of individuals, and s is the total number of taxa in the sample of the community.

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[1] Use of brand names does not imply product endorsement by the U.S. Geological Survey or the Louisiana Department of Transportation and Development.

Benthic-invertebrate samples were collected using a petite Ponar grab sampler (36 in^2). Benthic samples were sieved through a number 30 standard sieve and preserved in 70-percent ethyl alcohol (Weber, 1973). Benthic organisms were identified by project personnel using the following references: Barnes (1968), Brown (1976), Burch (1972), Mason (1973), Merritt and Cummins (1978), Needham and others (1935), Needham and Westfall (1954), Parrish (1975), Pennak (1978), Ross (1944), and Usinger (1968). Taxonomic identifications were verified in the Atlanta laboratory of the U.S. Geological Survey.

Core samples for lead-210 and cesium-137 dating to determine sediment deposition rates were collected by a diver using a 4-in. diameter PVC pipe 36-in. in length. After the core sample was removed from the substrate, it was sealed at both ends and stored frozen. Selected sections were then removed from the core, labeled as to distance from bed surface, placed in partially-vented containers, and air-dried. Analyses were done in the U.S. Geological Survey Central Laboratory-Denver, Arvada, Colo.

Fish were collected from Lake Bruin for pesticide-residue analyses using an experimental gill net (mesh size ranged from 1/2 to 2 1/2 in.). Whole fish, separated by species, were placed in a hexane (pesticide grade) rinsed, stainless-steel blender and blended until a uniform mixture was achieved. During each sampling trip, a maximum of four fish for each of the following species, Pomoxis annularis (white crappie), Ictalurus punctatus (channel catfish), and Dorosoma cepediatum (threadfin shad) were processed in the field, composited by species, and shipped to the Atlanta laboratory for analysis. Micropterus salmoides (largemouth bass) were collected and processed twice. Samples of hexane and de-ionized water used in the blending process were also sent for analysis to check for potential contamination.

Primary productivity was measured using light and dark bottle and diel oxygen-curve methods listed in Greeson and others (1977).

Description of the Study Area and Sampling Sites

Lake Bruin is an oxbow lake formed from a cutoff of the Mississippi River. It has a classic oxbow shape and reaches maximum depths of approximately 60 ft (near site 2, fig. 1). Lake-bottom composition ranges from fine sand to clay. The lake has a surface area of 4.7 mi^2 and a drainage area of 21.4 mi^2. It receives some inflow from a canal that drains Big Pond and also from Bayou Bruin. Both inflows enter at the western end of the lake (Brushy Lake) and are noticeable only during periods of heavy rainfall.

Bald cypress (Taxodium distichum) is the dominant emergent aquatic plant and lines much of the shore. Alligator weed (Alternantheia philoxeroides) and american pond weed (Potamogeton americanus) are also present and found predominantly in the southwestern end of the lake near and in the Brushy Lake area (fig. 1).

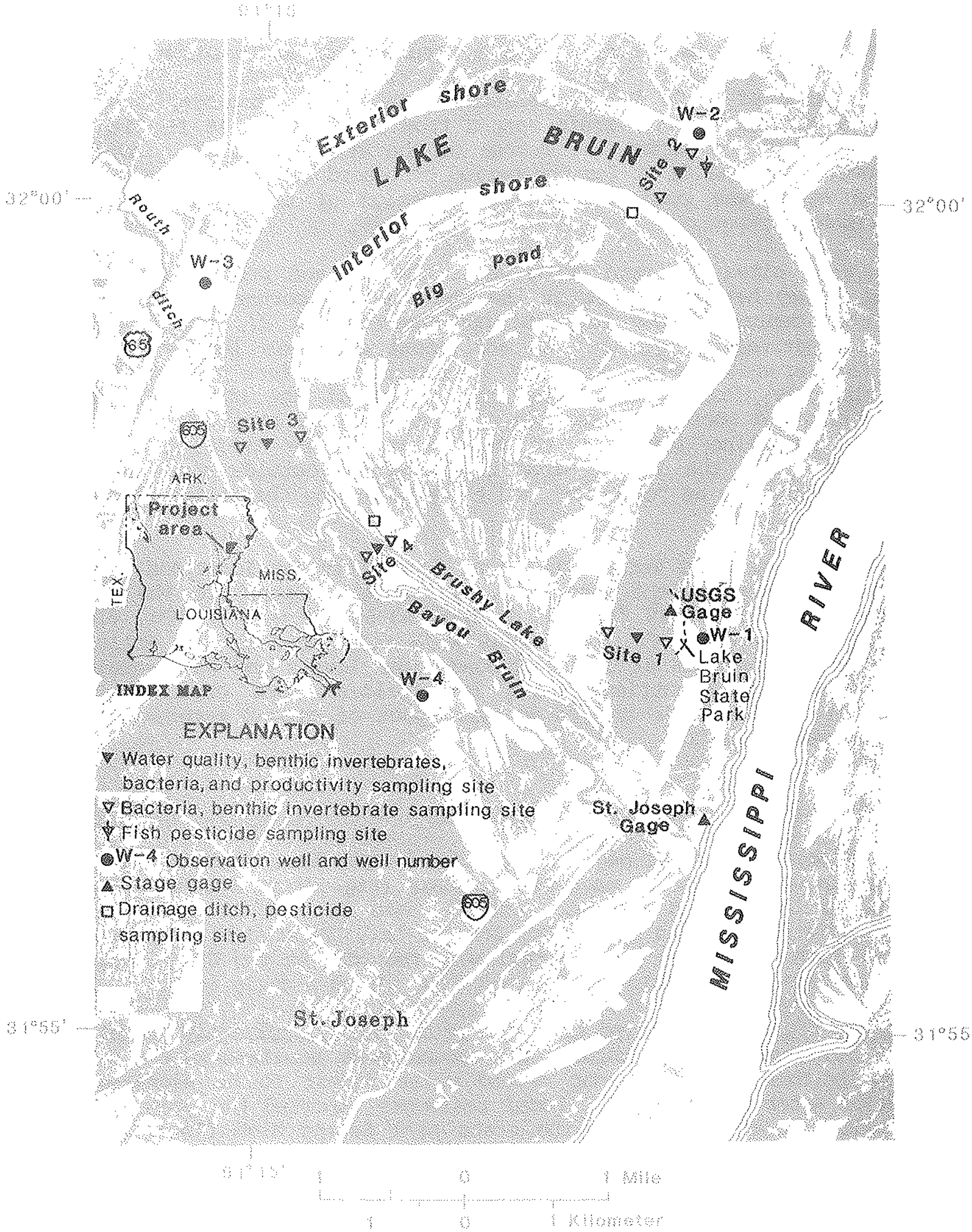

Figure 1.--Location of sampling sites, Lake Bruin.

The lake level is controlled by a structure on Routh Ditch at U.S. Highway 65; the structure has a crest elevation of 61.00 ft (a maximum crest elevation of 63.00 ft can be attained by use of stoplogs). Water-surface elevations of Lake Bruin ranged from 57.38 to 62.44 ft with an average of 59.90 ft during the course of the study (1981-83). Average lake elevation was 61.01 ft for the period of record (1977-82), indicating that the study was conducted during a period of below average lake elevation.

Sampling sites for monitoring water quality and productivity were situated midway between shores at the southwestern corner, southeastern corner, and center of the lake in approximately 16, 27, and 53 ft of water, respectively (fig. 1). An additional site was located in the Brushy Lake area; however, owing to low-water conditions this site was accessible only three times during the course of the study. Benthic invertebrates and bacteria were also collected at the sampling sites and along the shoreline (fig. 1) to help characterize their respective populations within the lake. Sites bordering the outside shore of the lake are referred to as "exterior" and those bordering the inside shore as "interior" (fig. 1).

Ground-water wells were situated at four different locations around the outer periphery of the lake (fig. 1). Screen depths for the wells were: well 1 (W1), 42-45 ft; well 2 (W2), 63-65 ft; well 3 (W3), 62-65 ft; well 4 (W4), 63-66 ft. All wells were referenced to the National Geodetic Vertical Datum of 1929. Ground-water levels and water-quality samples (inorganics, nutrients, and insecticides) were obtained from these wells to determine the potential impact of ground water on lake volume and water quality.

Water Sources

The Mississippi River stage at the St. Joseph, La., gage and ground-water levels were monitored on a weekly basis (fig. 2) to determine their relation to Lake Bruin stages. Rainfall and evaporation rates were recorded on a daily basis at the St. Joseph, La., National Weather Bureau Station. Lake elevations and rainfall were recorded at the U.S. Geological Survey gage at Lake Bruin State Park (fig. 3) on a daily basis.

It was orginally believed that Lake Bruin was hydraulically connected with the Mississippi River through the ground-water aquifers in the area; however, neither the river nor ground water appear to be significant sources of water to the lake. Local residents reported the presence of "sand boils" in the cove near the state park during high flows in the Mississippi River, indicating a ground-water connection with the river. Also, Whitfield (1975) reported that the Mississippi River alluvial aquifer, the major aquifer in the study area, is hydraulically connected to the major streams in the area and is recharged by these streams (especially the Mississippi River) during periods of high flow. Whitfield's map of the potentiometric surface of the Mississippi River

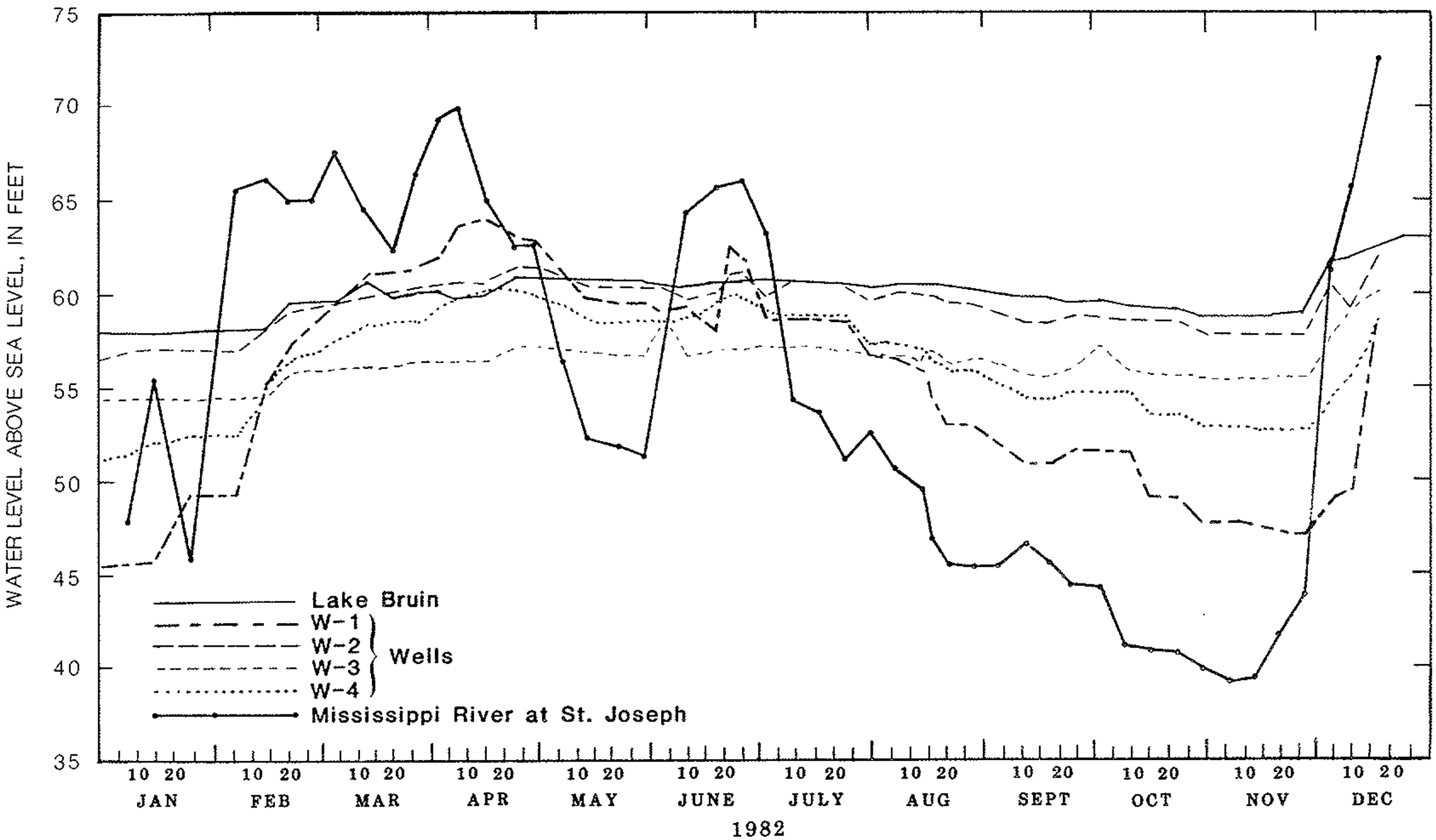

Figure 2.--Variations in Mississippi River stage at St. Joseph gage, Lake Bruin water surface, and ground-water levels around Lake Bruin.

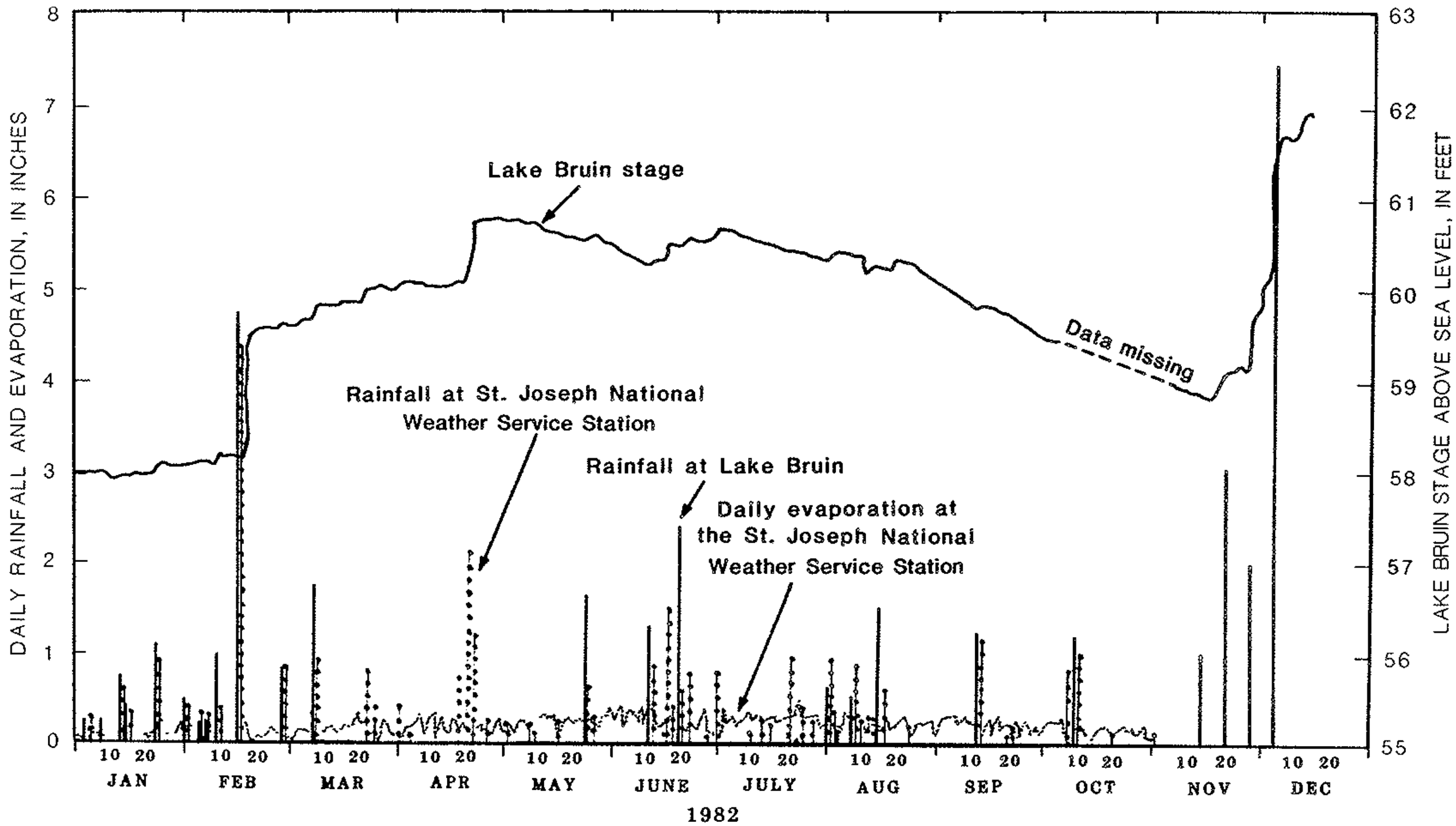

Figure 3.--Daily rainfall and evaporation in relation to daily lake elevations at Lake Bruin.

alluvial aquifer (1975, fig. 2) shows that ground water within a few miles of the river moves in a general southerly direction and eventually discharges to the river. Ground-water levels in wells 1 and 4, and to a lesser extent well 2, show this hydraulic connection quite clearly (fig. 2) and reflect the damming effect of the river on ground-water discharge during high river stages. Although major fluctuations in river stage were closely followed by major changes in ground-water level, fluctuations in lake level (fig. 2) do not correlate well with changes in river stage or ground-water level.

Changes in lake level are more closely associated with rainfall (fig. 3) and runoff. For example, in February 1982, lake elevations rose sharply immediately following a large rainstorm. River stages and ground-water levels also rose sharply during that month but preceeded the rise in lake elevation by several days. Similarly, another major rise in lake level that occurred in the latter half of April 1982 was immediately preceeded by heavy rainfall. River stages and ground-water levels were falling or had stabilized at this time. Conversely, a major fall in river stage, in July and August 1982, was followed by a corresponding decline in ground-water levels in wells 1 and 4, whereas lake elevations remained unchanged. Water levels in wells 2 and 3 fluctuated similarly to lake levels. Well 3 is the farthest of the four observation wells from the river and is separated from the river by Lake Bruin which may explain the difference in water-level fluctuations. Chemically, lake water and ground water from well 3 are very different in composition.

Flow from Bayou Bruin, Routh Ditch, and various drainage ditches into Lake Bruin was not observed during the study. It appears that these ditches and bayous input water to the lake only during major rainfall. In February, April, and December 1982 rainfalls of 4.35, 2.10, and 7.50 in., respectively, resulted in corresponding increases in lake stage of 1.25, 0.65, and 1.54 ft, indicating significant input into the lake by runoff and drainage. Runoff, through bayous and ditches, appears to be neglible when rainfall of lesser magnitude occurs, due to partial channel blockage by sediment, debris, and vegetation.

Acknowledgments

This study was originally conceived by Harold Leone, formerly of the U.S. Geological Survey, who was responsible for much of the project's design and execution of fieldwork. Special thanks are due the Louisiana State Park Commission which provided use of their launching and docking facilities during data-collection phases of the study.

WATER QUALITY

Temperature

The surface-water temperature in Lake Bruin ranged from a high of 35.3°C in August 1981 to a low of 8.9°C in January 1981. The lake was stratified for almost 8 months during 1981 (fig. 4). The lake started to stratify as early as late February and had a well pronounced thermocline by mid-April. The thermocline at site 2 ranged in depth from as shallow as 13 ft early in the year to as deep as 26 ft during the summer. Average thickness of the thermocline was about 6 ft and it was most frequently observed extending from depths of 20 to 26 ft.

Lake Bruin is a monomictic lake; that is, it overturns or mixes once a year. Overturn occurred during the last week in October for three consecutive years (fig. 4). Mixing occurred when surface waters cooled to about 19°C. The lake remained well mixed through January.

Seasonal variations in water temperature in Lake Bruin were very consistent during the study. Seasonal temperature-depth profiles (fig. 4), especially those recorded during April, May, June, and October, were almost identical from year to year, indicating very similar climatic conditions during the 3 years that the study was conducted.

Dissolved Oxygen

Dissolved-oxygen (DO) concentrations varied considerably throughout the lake, depending on depth, location, and season (figs. 5, 6, 7, and 8). Dissolved-oxygen concentrations ranged from a maximum of 12.3 mg/L at the surface to a minimum of 0.0 mg/L at depths below 18 ft during the course of the study.

At site 1 (fig. 5), large differences in DO concentrations between surface and bottom waters were noted as early as April. The DO concentration at this time was 11.1 mg/L at the surface and 2.0 mg/L at 26 ft. Dissolved-oxygen concentrations were less than recommended limits of 5.0 mg/L for freshwater aquatic life (U.S. Environmental Protection Agency, 1977) at this site for depths below 16 ft from April through August. Dissolved-oxygen concentrations less than 1.0 mg/L were common below depths of 19 ft at site 1. Profiles observed during the growing season (April-September) exhibited high DO concentrations in the upper 16 ft of the water column but dropped rapidly, approaching 0.0 mg/L below this depth. Dissolved-oxygen concentrations were quite uniform from surface to bottom during overturn and the colder, minimal growth months (October-January).

Three different types of seasonal profiles were observed at site 2 during the study and these profiles varied little from year to year (fig. 6). Profiles observed during the growing season had high DO concentrations at the surface, peak DO just below the surface, DO dropping rapidly

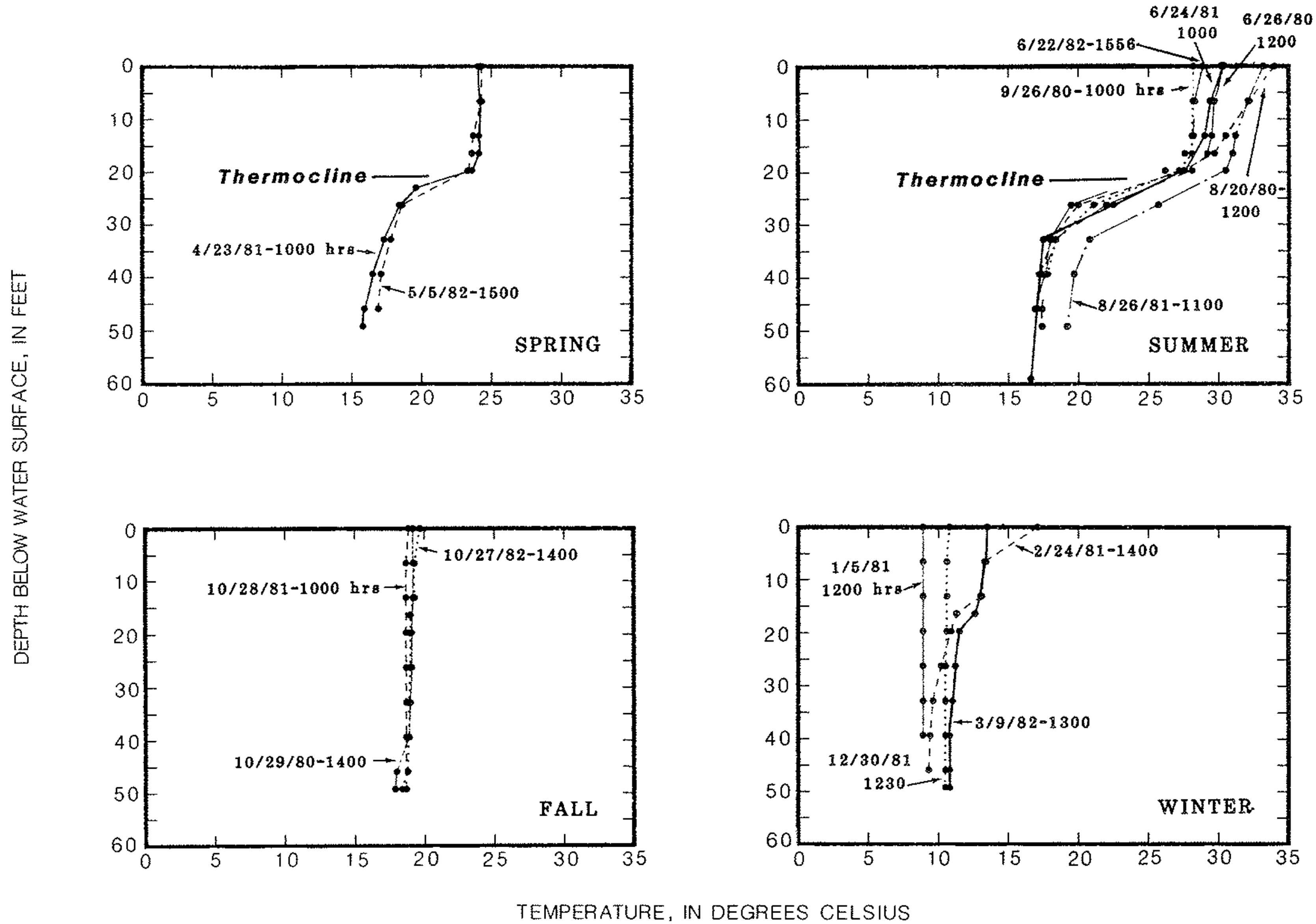

Figure 4.--Variation of water temperature with depth at Lake Bruin site 2, June 1980 through December 1982.

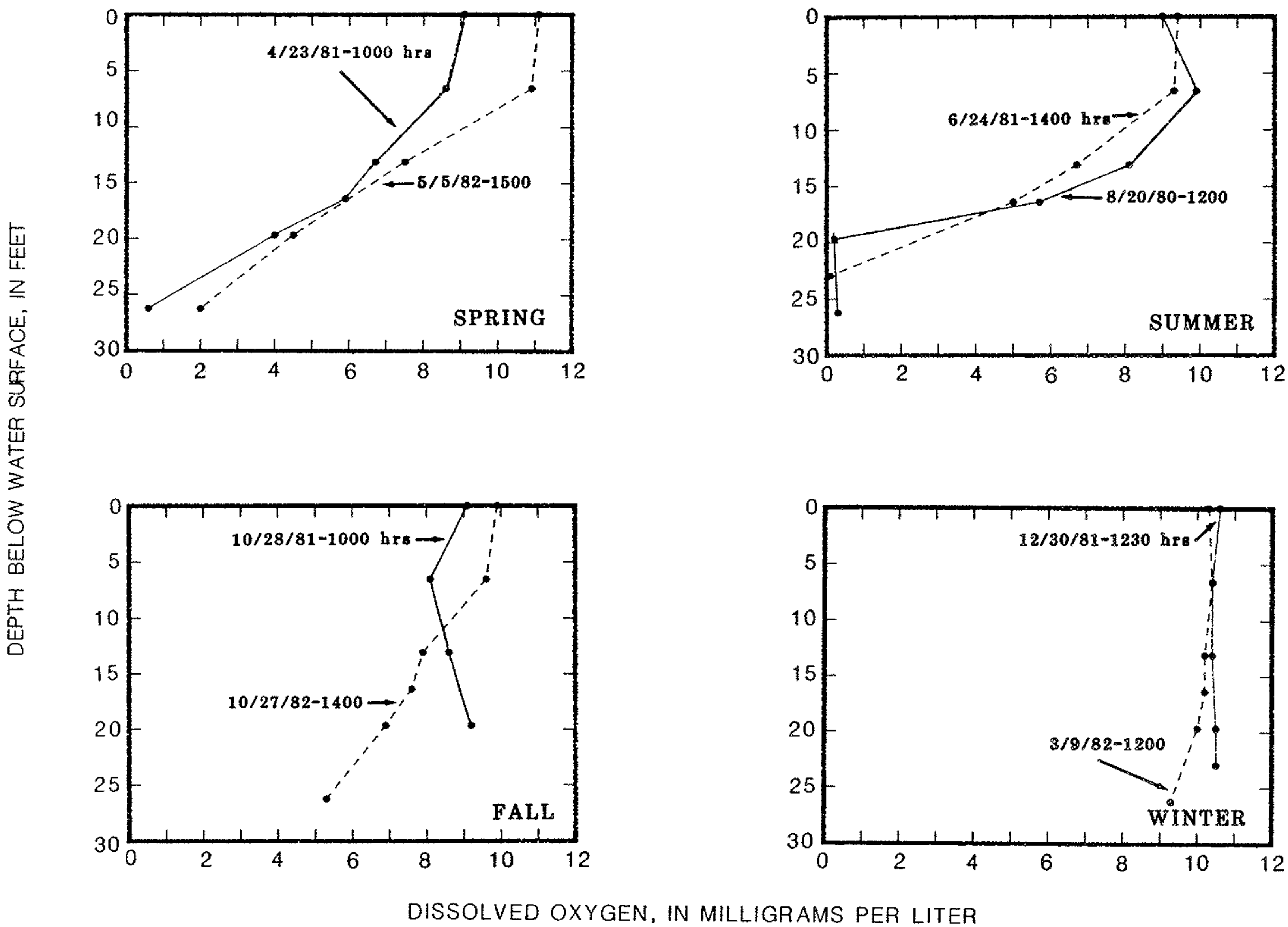

Figure 5.--Variation of dissolved-oxygen concentration with depth at Lake Bruin site 1, August 1980 through October 1982.

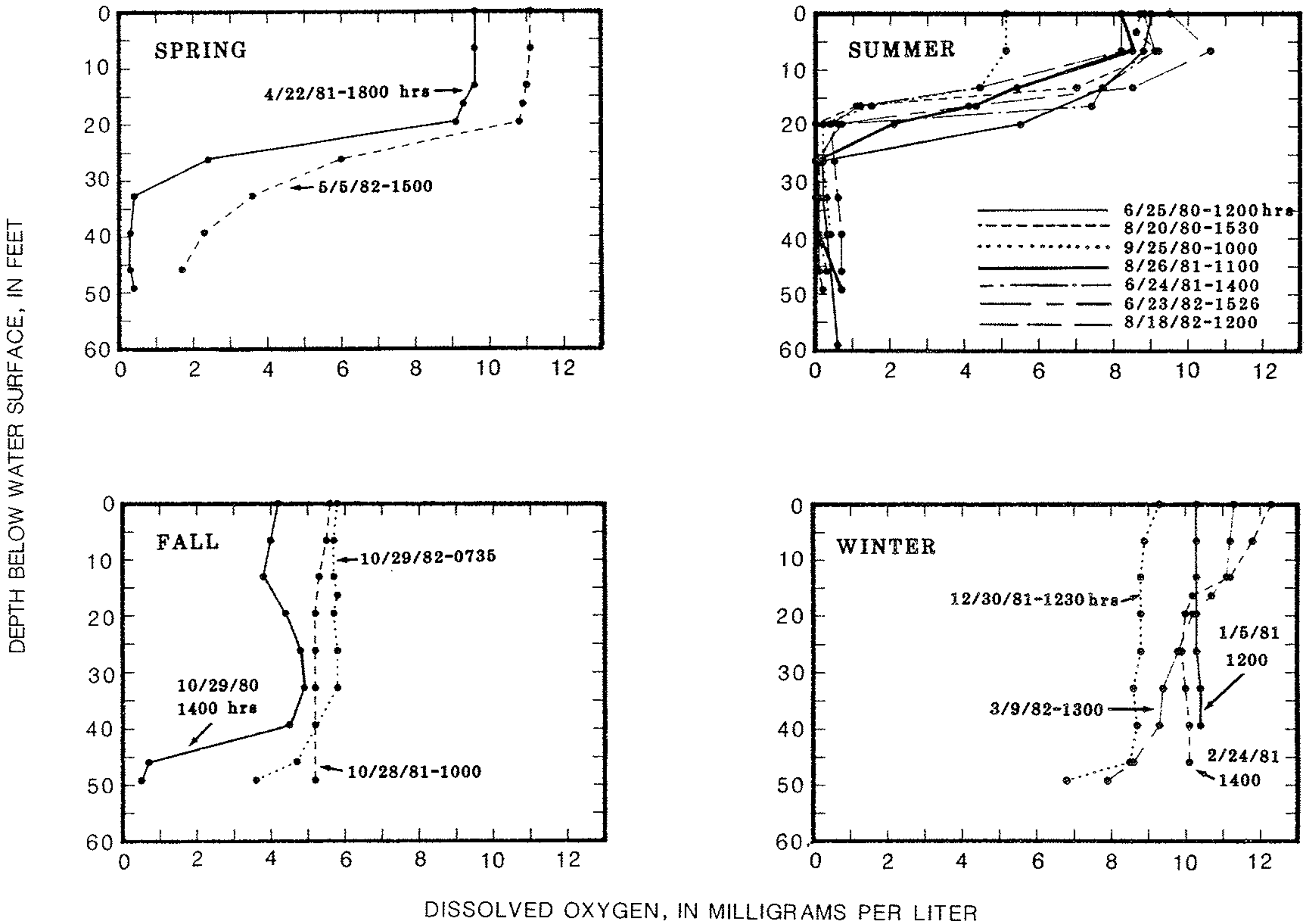

Figure 6.--Variation in dissolved-oxygen concentration with depth at Lake Bruin site 2, June 1980 through October 1982.

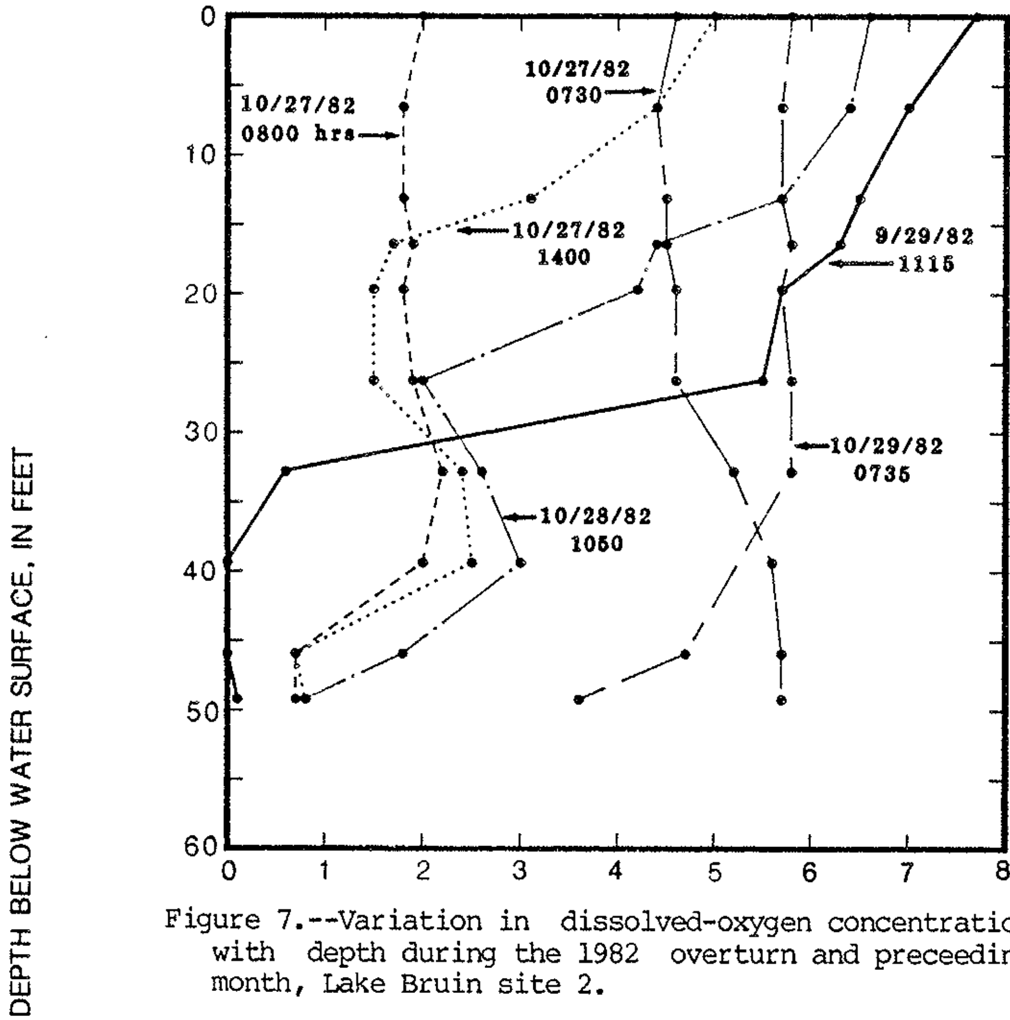

Figure 7.--Variation in dissolved-oxygen concentration with depth during the 1982 overturn and preceeding month, Lake Bruin site 2.

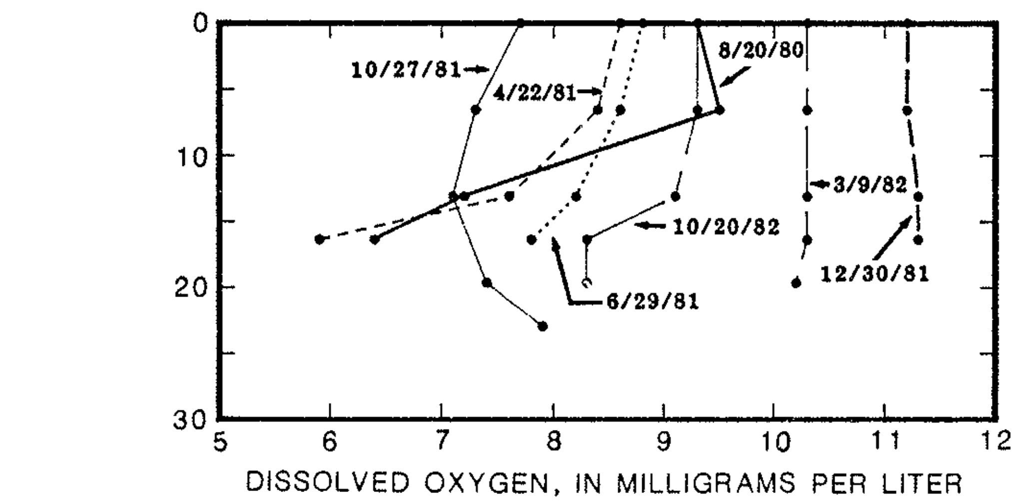

Figure 8.--Variation in dissolved-oxygen concentration with depth at Lake Bruin site 3, August 1980 through October 1982.

within the photic zone, and stabilizing close to 0.0 mg/L in the hypolimnion. During the colder months, DO profiles were relatively uniform from surface to bottom, with relatively high DO concentrations (7.0 mg/L or greater) present at all depths. Dissolved-oxygen profiles during and just after overturn were relatively uniform from top to bottom but DO concentrations were lower compared to concentrations in other profiles due to the immediate oxygen demand created by the mixing of the large volume of low-oxygen water from the hypolimnion with the smaller volume of oxygenated water from the epilimnon.

Dissolved-oxygen profiles at site 2 differed from profiles at the other two lake sites owing to the greater depths at site 2. Significant decreases in DO concentrations at depths were not observed here until April and occurred at greater depths (fig. 6) than at site 1. Dissolved-oxygen concentrations below the recommended limit of 5 mg/L varied with season and depth. In April DO concentrations less than 5.0 mg/L were observed only at depths greater than about 20 ft. In June DO concentrations less than 5.0 mg/L were at 17 ft and below and in August at 13 ft and below. This seasonal decrease in the percentage of the water column that contains recommended levels of DO is critical during the summer months. By August only 22 percent of the water column at site 2 had levels of DO capable of supporting fish in a nonstressing (high dissolved oxygen) environment. Sixty-eight percent of the water column had DO concentrations less than 0.5 mg/L. Compounding the problem of low DO in the hypolimnion is the high water temperature found in the oxygenated zone of the water column. Fish such as striped bass (Morone saxatilis) that require DO concentrations greater than 5.0 mg/L and moderate water temperatures (20°C or less) have difficulty surviving the summer season. The stress caused by low DO and high temperatures can and does result in mortalities in the striped bass population. Another problem created by this large column of low-oxygen water is a very high immediate oxygen demand during overturn. This is caused by the mixing of the deeper, low DO waters with the highly-oxygenated surface waters, creating a large (though temporary) drop in the oxygen content of the entire water column at this site. This was observed during the October 1982 overturn (fig. 7). Initial readings at site 2 on October 27, 1982, showed low DO concentrations for the entire water column. Surface DO concentrations were less than 2.0 mg/L in contrast to a DO reading of 7.7 mg/L recorded in late September 1982. Dissolved-oxygen concentrations in the lower part of the water column increased dramatically from the September readings, increasing from 0.0 mg/L in September to 2.0 mg/L in October for much of the lower water column. Wind conditions increased over the next few days (a steady 8-15 mi/h) resulting in continued mixing and a subsequent increase in DO throughout the water column. By the end of the sampling trip (October 29), DO concentrations had increased to 5.7 mg/L in most of the water column. The low surface DO concentrations were restricted to approximately half a mile area around site 2 (all deep water). (Dissolved-oxygen concentrations ranged from 7.6 to 9.5 mg/L and 7.2 to 9.3 mg/L from bottom to surface for sites 1 to 3, respectively, during this same period.)

Dissolved-oxygen concentrations rarely dropped below 5.0 mg/L at site 3 (fig. 8). As this was the shallowest sampling site in the lake, the wind caused almost continuous overturn resulting in relatively high DO concentrations evenly distributed in the water column. Unlike the other two lake sites, DO profiles at site 3 exhibited few distinctive seasonal patterns with only minor differences in DO concentrations from top to bottom. Dissolved-oxygen concentrations differed seasonally, primarily because of differences in oxygen solubilities with temperature, and to a lesser extent, because of differences in oxygen consumption and production by plants. The DO profile on August 20, 1980, exhibited a large drop in DO concentration with depth, unlike other profiles at this site. The DO concentration peaked just below the surface and decreased rapidly with depth. Unlike similar DO profiles at site 1, however, minimum DO concentrations were greater than 5.0 mg/L at the bottom.

Sediment

Suspended Solids

Mean concentrations of suspended solids were 8 mg/L at the three main lake sites (1, 2, and 3). In contrast to this, site 4 had a mean concentration of suspended solids of 77 mg/L. Site 4 is in an area of the lake that is filling in rapidly (according to long-time residents) and could be sampled only during high-water periods.

Sediment Deposition Rates

Core samples for lead-210 and cesium-137 analyses were collected twice at site 2 to determine sedimentation rates in the center of the lake. Lead-210 and cesium-137 data are listed in table 1 and indicate that the top 10 in. of bed material is well mixed (no significant difference in activity levels). The average of the first seven lead-210 values is 2.92 pCi/g and the individual values are within two sigma values of that average. The average of the last three lead-210 values is 1.80 pCi/g, and individual values are within two sigma values of the average. Thus, for the lead-210 decay curve there appears to be only two different values of lead-210. This indicates that approximately 12.5 in. of sediment was deposited at this site during the last 25 years. Deposition rates ranged from 0.31 to 0.78 in/yr with a mean rate of 0.56 in/yr. Because there are essentially only two different values of lead-210 for the decay curve, only rough values can be calculated for the deposition rate. The decay curves for lead-210 were drawn using net lead-210 values determined by subtracting the average cadium-226 value for the samples, considered the baseline value, from the gross lead-210 listed in table 1. The half life of lead-210 is 22.26 years. Cesium-137 data were used as a check on the lead-210 data on the basis of its association with atmospheric testing of nuclear devices (Dr. A. Yang, U.S. Geological Survey, written commun., 1983).

Table 1.--Lead-210 and cesium-137 activity levels from core samples collected at Lake Bruin site 2, June and October 1982

[Depth is measured in inches below lake bed and activity in picocuries per gram (pCi/g). Uncertainties (±) equal one sigma counting error]

Depth (inches)	Lead-210 (pCi/g)	Cesium-137 (pCi/g)
0.0 - 2.0	2.81 ± 0.12	0.78 ± 0.02
.0 - .5	2.70 ± .24	.79 ± .02
.5 - 1.5	2.95 ± .17	.73 ± .02
1.5 - 2.5	3.13 ± .15	.77 ± .02
2.5 - 3.5	3.18 ± .16	.77 ± .02
5.5 - 8.5	2.95 ± .12	.86 ± .02
10.0 - 11.0	2.78 ± .12	1.47 ± .02
19.0 - 20.0	1.72 ± .10	.30 ± .01
24.0 - 25.0	1.76 ± .12	.02 ± .01
25.0 - 27.0	1.93 ± .12	.56 ± .01

Inorganic Constituents

The quality of water in Lake Bruin appears to be good, considering the trophic condition of the lake. Concentrations of major inorganic chemical constituents are relatively low (table 2). Mean specific conductance was 145 µS/cm at the three lake sites during the study and ranged from 127 to 164 µS/cm at site 1, 130 to 171 µS/cm at site 2, and 131 to 166 µS/cm at site 3. Specific-conductance values as high as 258 µS/cm were recorded at site 2, but only at the bottom during prolonged periods of stratification.

Water in Lake Bruin is a calcium-bicarbonate type. Calcium, the major cation present, ranged from 16 to 21 mg/L at site 1 and 15 to 21 mg/L at sites 2 and 3 with a mean concentration of 18 mg/L for the three lake sites. Bicarbonate and carbonate, as measured by alkalinity as $CaCO_3$ (calcium carbonate), were the major anions present with a mean concentration of 68 mg/L for all lake sites. The other major cations such as magnesium, potassium, and sodium and anions such as chloride and sulfate were found in mean concentrations of 5 mg/L or less with little or no variation at the three sampling sites.

Chemical analyses indicate that all ground water in the Lake Bruin area is of the calcium-magnesium bicarbonate type (table 3). However, dissolved constituents in samples from wells 1 and 4 south of the lake

Table 2.--Variation in chemical and physical characteristics of lake water at four sites in Lake Bruin, June 1980 through October 1982

[Data are in milligrams per liter, except as shown. Microsiemens per centimeter, µS/cm; number of samples collected, n; maximum, max; minimum, min]

Site	Specific conductance (µS/cm at 25°C)				Suspended solids, residue at 105°C				Calcium, dissolved				Magnesium, dissolved				Sodium, dissolved			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	13	164	127	144	12	14	3	8	5	21	16	18	5	5.6	4.5	4.9	5	3.3	2.2	2.5
2	14	171	130	145	13	15	1	7	5	21	15	18	5	5.7	4.4	4.9	5	3.1	2.2	2.5
3	13	166	131	145	13	16	0	9	4	21	15	18	4	5.6	4.4	5.0	4	2.7	2.3	2.5
4	2	91	82	86	3	100	48	77	2	11	8.9	10	2	3.3	2.6	3.0	2	1.8	1.3	1.6

Site	Potassium, dissolved				Alkalinity				Chloride, dissolved				Sulfate, dissolved				Iron, dissolved, in micrograms per liter			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	5	4.2	3.4	3.8	11	74	61	68	6	3.2	1.4	2.2	5	5.0	1.0	3.0	4	20	6	12
2	5	4.3	3.3	3.8	10	75	62	68	7	2.9	1.9	2.2	5	5.0	1.3	2.5	4	180	10	50
3	4	4.3	3.7	3.9	10	81	61	69	6	2.7	1.9	2.2	4	5.0	.8	2.6	4	560	10	150
4	2	5.2	4.7	5.0	2	43	32	38	3	2.6	1.9	2.3	2	1.7	.7	1.2	2	80	70	80

Table 3.--Comparison of chemical constituents and properties in Lake Bruin water and ground water from nearby wells, 1982

[Nearby well site, W. Data are in milligrams per liter, except as shown. Microsiemens per centimeter, μS/cm]

Site	Date	Specific conductance (μS/cm at 25°C)	Dissolved solids, residue at 180°C	Calcium, dissolved	Magnesium, dissolved	Sodium, dissolved	Potassium, dissolved	Alkalinity	Chloride, dissolved	Sulfate, dissolved	Nitrogen, total
1	3-10-82	149	---	---	----	----	---	---	1.9	----	0.52
W1	3-11-82	1,130	666	140	63	13	6.1	650	3.0	0.2	1.9
2	3-10-82	149	---	---	----	----	---	---	2.0	----	1.1
W2	3-11-82	627	354	66	31	17	2.3	312	4.6	10	.98
3	3-10-82	148	---	---	----	----	---	---	2.1	----	.94
W3	3-11-82	536	322	51	32	14	4.1	292	4.8	.2	1.8
W4	3-11-82	1,180	747	---	----	73	3.0	708	12	.2	2.1
1	10-27-82	164	---	21	5.6	3.3	3.7	72	3.2	4.0	.6
W1	11- 9-82	1,130	690	170	50	14	7.4	712	4.6	.2	2.4
2	10-27-82	171	---	21	5.7	3.1	3.7	70	2.9	3.0	.9
W2	11- 4-82	600	380	81	26	16	2.5	322	4.9	12	.8
3	10-27-82	166	---	21	5.6	2.7	3.9	72	2.4	3.0	----
W3	11- 4-82	535	310	67	22	14	4.5	302	4.2	.2	1.8
W4	11- 4-82	1,260	760	130	64	69	3.2	760	12	.2	1.9

Site	Date	Nitrogen, dissolved	Phosphorus, total	Phosphorus, dissolved	Carbon, organic, suspended	Carbon, organic, dissolved	Iron, dissolved, in micrograms per liter	Fluoride, dissolved	Silica, dissolved	Manganese, dissolved, in micrograms per liter
1	3-10-82	0.58	0.05	0.02	1.4	4.0	------	---	--	-----
W1	3-11-82	1.7	.93	.02	1.9	3.7	------	0.4	13	3,400
2	3-10-82	.95	.06	.02	1.7	3.5	------	---	--	-----
W2	3-11-82	.92	1.6	<.01	.5	1.6	6,000	.5	8	350
3	3-10-82	.88	.05	.02	1.5	3.9	------	---	--	-----
W3	3-11-82	1.7	.68	<.01	1.0	3.0	------	.5	42	-----
W4	3-11-82	2.0	.52	.02	1.2	10	3,600	.6	25	-----
1	10-27-82	.3	.05	.03	1.3	4.9	6	---	--	5
W1	11- 9-82	2.3	----	.83	.9	4.0	24,000	.3	41	5,300
2	10-27-82	.5	.06	.02	1.2	3.9	180	---	--	370
W2	11- 4-82	.8	.97	.23	.9	2.8	8,100	.5	37	380
3	10-27-82	1.0	.05	.01	1.3	4.7	560	---	--	23
W3	11- 4-82	1.8	.33	.01	1.1	3.9	8,700	.4	34	650
W4	11- 9-82	1.8	.32	.11	.7	5.8	7,500	.7	26	2,600

were much higher than in samples from wells 2 and 3, immediately northeast and northwest of the lake, respectively, as shown in the following tabulation.

Well or source	Specific conductance (microsiemens per centimeter at 25°C)	Maximum concentrations (milligrams per liter)		
		Calcium, dissolved	Magnesium, dissolved	Alkalinity
Ground water south of Lake Bruin:				
1	1,130	170	63	712
4	1,260	130	64	760
Ground water north of Lake Bruin:				
2	627	81	31	322
3	536	67	32	302
Lake Bruin:	171	21	5.7	72

The large increase in calcium, magnesium, and alkalinity downdip (and down gradient) appears to be a local phenomenon and is probably related more to local differences in aquifer materials than the downdip distance between the northern and southern well sites. Specific conductances of ground water in the Mississippi River alluvial aquifer in the region of Lake Bruin range from about 400 to 1,300 μS/cm (Whitfield, 1975).

Lake water sampled concurrently with ground water differed significantly from the ground water in concentrations of the major ions (table 3); however, the general chemical composition of lake and ground water was similar. Specific conductance ranged from 148 to 171 μS/cm for lake water compared to 536 to 1,260 μS/cm for ground-water samples. Major cations (calcium, magnesium, and sodium) and alkalinity were 3 to 10 times greater in ground water than in lake water. Total and dissolved phosphorus, dissolved iron, and dissolved manganese were also found in much higher concentrations in ground water than in lake water. The large differences in chemical concentrations between lake and ground water, along with the poor correlation between ground-water and lake levels (p. 21), indicate that there is no significant relationship between ground water and lake water.

Nutrients

The major nutrients, nitrogen and phosphorus, were present in high concentrations and were relatively evenly distributed throughout the lake (table 4). Although differences in nutrient concentrations between lake sites were small, site 1 usually had the highest concentrations and site 3 the lowest of the main lake sites. Nutrient concentrations at site 4 usually exceeded those at all other sites. Nitrogen, in both the dissolved and total phases, was found predominantly in its organic state. Nitrogen as ammonia and as nitrite or nitrate (the nitrogen species most

Table 4.--Variation of nutrients in water and bottom material at four sites in Lake Bruin, June 1980 through October 1982

[Number of samples collected, n; maximum, max; minimum, min. Nutrients in water are in milligrams per liter, nutrients in bottom material are in milligrams per kilogram]

Site	Nitrogen, total, as N				Nitrogen, dissolved, as N				Nitrogen, organic, total, as N				Nitrogen, organic, dissolved, as N				Nitrogen, ammonia, total, as N			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	7	2.4	0.40	1.3	10	1.3	0.65	0.94	8	1.6	0.06	0.81	12	0.92	0.04	0.59	11	0.23	<0.01	0.07
2	10	1.6	.84	1.1	10	1.3	.69	.87	10	1.1	.40	.73	13	.90	.29	.56	11	.21	<.01	.07
3	11	1.4	.56	.98	12	1.2	.55	.83	11	1.2	.41	.70	13	.98	.26	.58	11	.15	<.01	.06
[a]4	3	4.0	1.5	2.6	3	1.6	1.3	1.4	3	2.2	1.3	1.8	2	1.3	1.1	1.2	3	.21	.03	.11

Site	Nitrogen, ammonia, dissolved, as N				Nitrogen, ammonia, total in bottom material, as N				Nitrogen, nitrite + nitrate, total, as N				Nitrogen, nitrite + nitrate, dissolved, as N				Nitrogen, ammonia + organic, total, as N			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	12	0.28	<0.01	0.09	3	340	36	160	11	0.29	<0.01	0.11	12	0.40	<0.01	0.15	11	2.4	0.20	1.0
2	13	.34	<.01	.10	3	330	60	230	13	.37	<.01	.15	12	.36	<.01	.15	14	1.4	.40	.85
3	13	.40	<.01	.09	3	100	33	62	13	.52	<.01	.16	13	.47	<.01	.18	13	1.3	.46	.76
[a]4	3	.05	<.01	.03	2	220	83	150	3	2.0	.01	.71	3	.31	.02	.13	3	2.2	1.4	1.9

Site	Nitrogen, ammonia + organic, suspended, as N				Nitrogen, ammonia + organic, dissolved, as N				Nitrogen, ammonia + organic, total in bottom material as N				Phosphate, total, as PO_4				Phosphate, ortho, dissolved, as PO_4			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	9	1.8	<0.01	0.46	12	1.2	0.3	0.71	3	7,200	2,800	4,600	2	0.09	<0.01	----	8	0.09	<0.01	0.04
2	11	.51	<.01	.19	13	.92	.39	.66	3	8,800	3,500	5,300	2	<.01	<.01	----	10	.09	<.01	.03
3	12	.52	<.01	.16	13	1.0	.44	.67	3	8,100	1,100	3,600	1	<.01	-----	----	9	.15	<.01	.05
[a]4	2	.90	.90	----	2	1.3	1.1	----	2	3,600	2,600	-----	1	.09	-----	----	3	.12	<.01	.07

Site	Phosphorus, total, as P				Phosphorus, dissolved, as P				Phosphorus, total in bottom material, as P				Phosphorus, ortho, dissolved, as P				Carbon, organic, suspended, as C				Carbon, organic dissolved, as C			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	13	0.07	0.03	0.05	10	0.10	0.01	0.04	1	47,000	---	----	12	0.03	<0.01	0.01	11	1.9	0.10	1.0	12	30	4.0	8.0
2	14	.31	.02	.06	11	.07	.01	.03	1	98,000	---	----	13	.03	<.01	.01	10	3.8	.20	1.3	13	41	3.5	8.2
3	13	.09	.03	.05	12	.08	<.01	.02	1	19,000	---	----	13	.05	<.01	.01	12	1.5	.30	1.0	13	16	3.6	6.0
[a]4	3	.26	.06	.19	2	.13	<.01	.06	-	-------	---	----	3	.04	<.01	.02	3	3.6	1.3	2.5	3	7.6	6.8	7.3

[a] Brushy Lake.

readily available to plants) was in relatively low concentrations as compared with the organic forms. Total ammonia as nitrogen was found at a maximum concentration of 0.23 mg/L (site 1) and 0.21 mg/L for the main lake sites and Brushy Lake, respectively. Mean concentration of total ammonia as nitrogen was 0.07 mg/L for the three lake sites and 0.11 mg/L for Brushy Lake. Total nitrite plus nitrate as nitrogen was found at a maximum concentration of 0.52 mg/L (site 3) for the main lake sites and 2.0 mg/L for Brushy Lake. Mean concentrations of total nitrite plus nitrate as nitrogen were 0.14 and 0.7 mg/L for the main lake sites and Brushy Lake, respectively. Total organic nitrogen, in contrast, was found in mean concentrations of 0.75 and 1.8 mg/L for the main lake sites and Brushy Lake, respectively.

Total ammonia in bottom material appeared to be related to depth, period of stratification, and oxygen concentration. Concentrations of total ammonia in bottom material were highest at the deepest site (site 2) during stratification and decreased as the water became shallower or under well-mixed conditions. The deeper water allows for more prolonged stratification and this results in oxygen depletion of bottom waters. In the absence of oxygen, the bacterial conversion of ammonia to nitrite plus nitrate is slowed or curtailed, and ammonia concentrations increase as organic material decays. This indicates that recycled nitrogen from bottom material may be a significant source of this macronutrient in Lake Bruin. Similar results were also observed for phosphorus.

In freshwater, phosphorus is most often the key macronutrient limiting aquatic plant growth (Vollenweider, 1968; Lee, 1971; 1973; Vollenweider and Dillon, 1974). In Lake Bruin, phosphorus was found in similar concentrations at the three lake sites. Mean total phosphorus was found in relatively high concentrations favorable for growth of phytoplankton. Dissolved phosphorus was also present in high concentrations. Phosphorus concentrations in bottom material were determined only once during the study, but results indicate large amounts of phosphorus are stored in the bottom material. Phosphorus in bottom material was found in concentrations ranging from 19,000 mg/kg at site 3 to 98,000 mg/kg at site 2. Differences in phosphorus concentrations in bottom material, like ammonia in bottom material, are caused by the amount of mixing in the water column and the amount of time the bed material is oxygenated. Site 2, the deepest and most stratified site, had the highest concentration of phosphorus in bottom material, while site 3, the shallowest and most readily mixed site, had the lowest concentration of phosphorus in bottom material during the study. Site 1, intermediate in depth and degree of stratification, was intermediate in phosphorus concentrations in bottom material.

Concentrations of nitrogen and phosphorus were usually highest in Brushy Lake (site 4). The mean total nitrogen concentration during the growing season was two times greater at site 4 than at any of the sites in the main body of Lake Bruin (2.6 mg/L at site 4 versus a mean maximum concentration of 1.3 mg/L for the other three lake sites). The mean total phosphorus concentration was 0.19 mg/L at site 4, three times larger than the mean concentrations at the other lake sites. Ammonia in bottom material was also found in very high concentrations at site 4, ranging from 2,600 to 3,600 mg/kg, especially considering the shallow water at this site (2 to 4 ft). The nutrient data indicate that the Brushy Lake section is receiving large inputs of nutrients, probably due to agricultural runoff that enters Brushy Lake through drainage ditches. Much of the nitrogen entering Brushy Lake appears to be biologically unavailable. Ammonia, nitrite, and nitrate, the major nitrogen species utilized by algae, accounted for 31 percent of the total nitrogen present in Brushy Lake samples. In contrast, dissolved orthophosphorus, the major form of phosphorus utilized by algae, was the major form of phosphorus in the Brushy Lake samples. It appears that the biological significance of nitrogen input is small compared to that of phosphorus, which is in a form readily available to algae.

Minor Elements

Minor elements, with the exception of manganese, in water and bottom material collected from Lake Bruin were found in low concentrations at all sampling sites (table 5). Total and dissolved arsenic in water ranged from 1 to 11 μg/L at the three principal lake sites and 10 to 20 μg/L in Brushy Lake (site 4). Arsenic was also present in bottom material ranging from 5 to 39 μg/g for all sites.

Selenium, beryllium, and cadmium, in both the total and dissolved phases, occurred in concentrations at or below limits of detection for all water samples at all sites. Selenium and beryllium in bottom material occurred in concentrations at or below limits of detection and cadmium was found in concentrations ranging from less than 1 to 7 μg/g at all sites.

Chromium, copper, nickel, vanadium, and lead were all found in low concentrations in lake water and bottom material. Total chromium in water ranged from below levels of detection (10 μg/L) to 30 μg/L throughout the lake. Dissolved hexavalent chromium was not detected. Copper was present in water and bottom material at all sites and ranged in concentrations from 2 to 12 μg/L in water samples and 9 to 33 μg/g in bottom material. Nickel and vanadium in water were detected at all sites. Nickel in water was not detected or ranged from the limits of detection (1 μg/L) to 12 μg/L and in bottom material from 10 to 30 μg/g for all samples. Vanadium in water never exceeded 2 μg/L at any site. None of the above elements occurred in concentrations exceeding EPA (U.S. Environmental Protection Agency, 1975, 1977) criteria set for domestic water supplies or freshwater aquatic life.

Lead never exceeded the criteria for domestic drinking water (50 μg/L; U.S. Environmental Protection Agency, 1977, p. 82), in either the total or dissolved phase. Concentrations of total lead ranged from a maximum of 16 μg/L at site 1 to below levels of detection at all sites. Dissolved lead was never found in concentrations higher than 3 μg/L at any site, indicating only trace concentrations of the element in lake water. Lead in bottom material ranged from 10 to 40 μg/g for all samples.

Table 5.--Variation of minor elements in surface water and bottom material at four sites in Lake Bruin, June 1980 through October 1982

[Minor elements in water are in micrograms per liter (μg/L), minor elements in bottom material are in micrograms per gram (μg/g). Number of samples collected, n; maximum, max; minimum, min]

Site	Arsenic, total, as As				Arsenic, dissolved, as As				Arsenic, total in bottom material, as As				Beryllium, total recoverable, as Be				Berylium, dissolved, as Be				Beryllium, recoverable from bottom material, as Be				Cadium, total recoverable, as Cd			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	4	7	4	6	4	5	2	4	3	28	3	16	4	<10	<10	----	4	<1	<1	----	3	1	<1	----	4	1	<1	----
2	4	11	4	7	4	9	1	4	3	39	9	26	4	10	<10	----	4	<1	<1	----	3	1	<1	----	4	1	<1	----
3	4	7	5	6	4	5	4	4	3	14	5	11	4	<10	<10	----	4	<1	<1	----	3	1	<1	----	4	<1	<1	----
4	2	20	20	-	2	12	10	-	2	28	19	--	2	<10	<10	----	2	<1	<1	----	2	1	<1	----	2	<1	<1	----

Site	Cadmium, dissolved, as Cd				Cadmium, recoverable from bottom material, as Cd				Chromium, total recoverable, as Cr				Chromium, hexavalent, dissolved, as Cr				Chromium, recoverable from bottom material, as Cr				Copper, total recoverable, as Cu				Copper, dissolved, as Cu			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	4	1	<1	----	3	6	<1	-	4	10	10	10	4	<1	<1	----	3	11	9	10	4	10	2	5	4	6	1	3
2	4	<1	<1	----	3	7	<1	-	4	20	<10	--	4	<1	<1	----	3	12	9	10	4	12	2	6	4	4	1	2
3	4	<1	<1	----	3	6	1	3	4	10	<10	--	4	<1	<1	----	3	7	6	7	4	8	3	6	4	3	2	2
4	2	<1	<1	----	2	7	2	-	2	30	<10	--	2	<1	<1	----	2	12	10	--	2	12	7	--	2	5	3	-

Site	Copper, recoverable from bottom material, as Cu				Lead, total recoverable, as Pb				Lead, dissolved, as Pb				Lead, recoverable from bottom material, as Pb				Manganese, total recoverable, as Mn				Manganese, dissolved, as Mn				Manganese, recoverable from bottom material, as Mn			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	3	29	9	20	4	16	1	6	4	3	<1	----	3	30	20	20	4	60	20	40	4	30	1	14	3	680	550	630
2	3	31	26	28	4	6	1	4	4	2	<1	----	3	30	20	20	4	370	20	110	4	280	<1	--	3	980	920	940
3	3	19	16	18	4	12	2	6	4	<1	<1	----	3	20	10	20	4	50	30	40	4	23	<1	--	3	520	320	390
4	2	33	29	--	2	15	10	-	2	4	<1	----	2	40	20	--	2	100	90	---	2	2	2	--	2	640	430	---

Table 5.--Variation of minor elements in surface water and bottom material at four sites in Lake Bruin, June 1980 through October 1982--Continued

Site	Nickel, total recoverable, as Ni				Nickel, dissolved, as Ni				Nickel, recoverable from bottom material, as Ni				Selenium, total, as Se				Selenium, dissolved, as Se				Selenium, total in bottom material, as Se				Vanadium, dissolved, as V			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	4	8	<1	-	4	4	<1	-	3	30	10	20	4	<1	<1	----	4	<1	<1	----	3	<1	<1	----	4	2	0.1	1.0
2	4	3	<1	-	4	4	<1	-	3	30	20	20	4	1	<1	----	4	1	<1	----	3	1	<1	----	4	2	<.1	---
3	4	12	1	5	4	3	1	2	3	20	20	20	4	<1	<1	----	4	<1	<1	----	3	1	<1	----	4	2	.2	1.0
4	2	10	9	-	2	3	2	-	2	20	20	--	2	<1	<1	----	2	<1	<1	----	2	1	<1	----	2	2	1	---

Site	Zinc, total recoverable, as Zn				Zinc, dissolved, as Zn				Zinc, recoverable from bottom material, as Zn				Mercury, total, as Hg				Mercury, dissolved, as Hg				Mercury, recoverable from bottom material, as Hg			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
1	4	60	10	20	4	10	3	6	3	75	60	67	4	<0.1	<0.1	----	4	<0.1	<0.1	----	3	0.06	<0.01	----
2	4	50	<10	--	4	20	<3	-	3	82	61	73	4	.2	<.1	----	4	.2	<.1	----	3	.05	<.01	----
3	4	70	10	40	4	10	3	5	3	56	45	52	4	.2	<.1	----	4	.1	<.1	----	3	.90	<.01	----
4	2	60	50	--	2	6	4	-	2	89	80	--	2	.1	<.1	----	2	.1	<.1	----	2	.70	.06	----

Zinc occurred in relatively high concentrations in water and bottom material when compared to other minor elements analyzed. Total zinc concentrations in water ranged from 10 to 70 μg/L for all sites. Zinc in bottom material ranged from 45 to 89 μg/g for all sites. Zinc occurred in concentrations in Lake Bruin well below recommended limits of 5 mg/L for domestic water supplies and 100 μg/L for freshwater aquatic life (U.S. Environmental Protection Agency, 1977, p. 245).

Manganese was the only element that exceeded recommended limits for drinking water [50 μg/L dissolved manganese (U.S. Environmental Protection Agency, 1977, p. 95)]. This occurred once at site 2 in October 1982 during overturn when the concentration of dissolved manganese was 280 μg/L. Total manganese was 370 μg/L. These high manganese values in surface water were probably due to mixing of manganese-rich hypolimnetic water with less concentrated surface waters during the overturn (dissolved manganese was found in August 1981 surface and bottom water samples at site 2 in concentrations of less than 1 and 1,900 μg/L, respectively). Concentrations of total manganese at sites 1 and 3 in October 1982 were the highest observed during the study (60 and 50 μg/L, respectively). Manganese at these concentrations is not harmful to aquatic life but may cause taste and stain problems in domestic water supplies.

Mercury is an important element environmentally because of its toxicity to humans and aquatic life (U.S. Environmental Protection Agency, 1975, 1977). Mercury concentrations as high as 0.2 μg/L occurred in surface waters at sites 2 and 3 on two occasions early in the study and as high as 0.8 μg/L in the hypolimnion at site 2. Mercury in bottom material ranged from 0.90 μg/g at site 3 to below levels of detection (0.01 μg/g) at sites 1, 2, and 3. Mercury in bottom material is probably the source of the mercury found in the water column. Limits for mercury (U.S. Environmental Protection Agency, 1975, 1977) are 2.0 μg/L for domestic water supplies and 0.05 μg/L for freshwater aquatic life--0.1 μg/L is the lower limit of detection of mercury by the U.S Geological Survey laboratories. Mercury was not detected in water samples or bottom material collected at the end of the project.

Pesticides

Agriculture is the major land use in the area surrounding Lake Bruin. Use of pesticides for control of unwanted plant and animal pests has been and will continue to be an accepted agricultural practice in the region. Pesticides are usually applied to fields surrounding Lake Bruin by airplane. Aerial drift of pesticides and drainage from ditches surrounding agricultural fields have all added pesticides to the lake. Current criteria for pesticides detected in Lake Bruin water are listed in table 6.

Pesticides and PCB (polychlorinated biphenyls) in water and bottom material were sampled at the three lake sites on a bimonthly schedule during the project. Insecticide concentrations in water from the four observation wells around the outside periphery of the lake, from water and bottom material from ditches draining into the lake, and fish tissue were collected and analyzed on a less frequent basis (tables 7 and 9).

Table 6.--U.S. Environmental Protection Agency criteria for pesticides detected in Lake Bruin water samples collected June 1980 through October 1982

Pesticide	Domestic-water supply	Freshwater aquatic life
DDT------------------------	Minimize any exposure----	0.001 µg/L
DDD------------------------	-----do------------------	.001 µg/L
Dieldrin-------------------	-----do------------------	.0019 µg/L
Heptachlor-----------------	Any exposure-------------	.0038 µg/L
Diazinon-------------------	-----do------------------	[a].009 µg/L
Methyl parathion-----------	-----do------------------	(b)
2,4-D----------------------	100 µg/L-----------------	(b)
2,4-DP---------------------	(b)	(b)

[a] Below current levels of detection by standard analytical techniques of U.S. Geological Survey (1983).

[b] No criterion determined.

Each ground-water observation well was sampled twice for pesticides, during periods of low and high ground-water levels. Insecticides were not found in any of the ground-water samples, except for 0.003 µg/L of DDT in the April 1982 sample from well 1.

Pesticides were rarely found in detectable concentrations in lake water. Of the 28 pesticides included in the analysis program, only 8 were detected in any lake water samples (table 7), including DDD, DDT, dieldrin, heptaclor, diazinon, methyl parathion, 2,4-D, and 2,4-DP. Those pesticides and organic compounds for which analyses were performed but which occurred at concentrations less than detection limits in water and bottom material include:

Pesticide	Lowest level of detection Microgram per liter
In water:	
Perthane--------------------------	0.1
Polychlorinated napthalenes------	.1
Aldrin----------------------------	.001
Lindane---------------------------	.001
Chlordane-------------------------	.1
DDE-------------------------------	.001
Endosulfan------------------------	.001
Endrin----------------------------	.001
Ethion----------------------------	.01
Toxaphene-------------------------	1.0
Heptachlor epoxide---------------	.001

Pesticide In water: Continued	Lowest level of detection Microgram per liter
Methoxychlor	0.01
Polychlorinated biphenyls (PCB)	.1
Malathion	.01
Parathion	.01
2,4,5-T	.01
Mirex	.01
Silvex	.01
Trithion	.01
Methyl trithion	.01
In bottom material:	Microgram per kilogram
Polychlorinated napthalenes (PCN)	1.0
Aldrin	.1
Ethion	.1
Heptachlor	.1
Methoxychlor	.1
Malathion	.1
Parathion	.1
Diazinon	.1
Trithion	.1
Methyl trithion	.1
Perthane	.1

The herbicide 2,4-D occurred most frequently in lake water and was detected in 40 of 43 samples (table 8) in concentrations ranging from 0.02 µg/L at site 1 to 0.14 µg/L at site 4. These concentrations are less than the criterion (100 µg/L) for domestic-drinking water supplies (U.S. Environmental Protection Agency, 1977).

Dieldrin was detected in 17 of 45 lake surface samples analyzed, and concentrations ranged from 0.003 to 0.033 µg/L (table 7). The recommended limit for this compound in freshwater environments is 0.0019 µg/L; and for humans, minimum exposure (U.S. Environmental Protection Agency, 1980). Because the manufacture of dieldrin has been banned for several years, resuspension of lake-bottom material and agricultural runoff appear to be the major sources of this compound in the water column. Dieldrin in lake-bottom material had maximum concentrations ranging from 12 µg/kg at site 3 to 0.7 µg/kg at site 4; bottom material in drainage ditches near sites 4 and 2 had concentrations of 1.4 and 18 µg/kg, respectively. Standing water from a drainage ditch near site 2 contained 0.072 µg/L of dieldrin.

Diazinon was found in water samples collected at sites 1 and 3 and occurred in 9 of 28 samples collected at these sites. Concentrations ranged from maximums of 0.04 µg/L at site 1 and 0.02 µg/L at site 3 to below detectable limits at all sites. Criteria for protection of fresh-water life is 0.009 µg/L (National Academy of Sciences, National Academy of Engineers, 1973), which is below current levels of detection. No diazinon was found in drainage-ditch samples or bottom material at lake sites.

Table 7.--Variation in pesticide concentrations in water and bottom material from Lake Bruin and two ditches draining into the lake and in ground water from observation wells, June 1980 through October 1982

[Pesticide and organic compounds in water are in micrograms per liter. Pesticides and organic compounds in bottom material are in micrograms per kilogram. Number of samples collected, n; maximum, max; minimum, min]

	Lindane, total in bottom material				Chlordane, total in bottom material				DDD, total				DDD, total in bottom material			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
Site 1---	11	<0.1	<0.1	----	11	28	<1.0	15	14	0.010	<0.001	0.002	11	46	17	30
Site 2---	12	<.1	<.1	----	12	69	<1.0	25	14	.002	<.001	.001	12	140	51	94
Site 3---	11	1.2	<.1	0.19	11	20	6.0	13	14	.007	<.001	.001	11	68	16	28
Site 4---	3	<.1	<.1	----	3	37	<1.0	20	3	.049	.009	.026	3	150	59	110
Well 1---									2	<.001	<.001					
Well 2---									2	<.001	<.001					
Well 3---									2	<.001	<.001					
Well 4---									2	<.001	<.001					
Drainage ditch near site 4.	2	<.1	<.1	----	2	<1.0	<1.0	--	1	<.001	------	-----	2	65	61	---
Drainage ditch near site 2.	1	<.1	----	----	1	<1.0	----	--	1	<.001	------	-----	1	530	--	---

Table 7.--Variation in pesticide concentrations in water and bottom material from Lake Bruin and two ditches draining into the lake and in ground water from observation wells, June 1980 through October 1982--Continued

	DDE, total in bottom material				DDT, total				DDT, total in bottom material				Dieldrin, total			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
Site 1---	11	120	25	57	14	0.010	<0.001	0.002	11	18	<0.1	5.0	14	0.003	<0.001	0.002
Site 2---	12	220	36	110	14	.006	<.001	.001	12	82	<.1	26	14	.004	<.001	.001
Site 3---	11	88	20	58	14	.012	<.001	.002	11	27	1.7	7.3	14	.020	<.001	.003
Site 4---	3	230	64	150	3	.025	<.001	.015	3	3.9	2.8	3.5	3	.033	<.001	.030
Well 1---					2	<.001	<.001	-----					2	<.001	<.001	-----
Well 2---					2	<.001	<.001	-----					2	<.001	<.001	-----
Well 3---					2	<.001	<.001	-----					2	<.001	<.001	-----
Well 4---					2	.003	<.001	-----					2	<.001	<.001	-----
Drainage ditch near site 4.	2	70	29	---	1	<.001	------	-----	2	260	24	----	1	.072	------	-----
Drainage ditch near site 2.	1	320	--	---	1	<.001	------	-----	1	390	----	----	1	<.001	------	-----

	Dieldrin, total in bottom material				Endosulfan, total in bottom material				Endrin, total in bottom material				Toxaphene, total in bottom material			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
Site 1---	11	2.1	<0.1	0.7	11	0.7	<0.1	0.1	11	<0.1	<0.1	---	11	<10	<10	----
Site 2---	12	2.4	<.1	1.1	12	1.3	<.1	.2	12	.9	<.1	0.3	12	<10	<10	----

Site 3---	11	12	<.1	1.6	12	<.1	<.1	---	11	<.1	<.1	---	11	<10	<10	----
Site 4---	3	.7	<.1	.3	3	<.1	<.1	---	3	<.1	<.1	---	3	<10	<10	----
Well 1---																
Well 2---																
Well 3---																
Well 4---																
Drainage ditch near site 4.	2	1.4	<.1	---	2	<.1	<.1	---	2	<.1	<.1	---	2	66	<10	----
Drainage ditch near site 2.	1	18	----	---	1	<.1	----	---	1	<.1	----	---	1	<10	---	----

	Heptachlor, total				Heptachlor epoxide, total in bottom material				PCB, total in bottom material				Diazinon, total			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
Site 1---	11	<0.001	<0.001	-----	11	<0.1	<0.1	----	11	52	<1.0	6.0	14	0.04	<0.01	0.01
Site 2---	13	<.001	<.001	-----	12	<.1	<.1	----	12	56	<1.0	5.0	14	<.01	<.01	
Site 3---	13	.001	<.001	0.001	11	<.1	<.1	----	11	1.0	<1.0	1.0	14	.02	<.01	.01
Site 4---	3	<.001	<.001	-----	3	<.1	<.1	----	3	<1.0	<1.0		3	<.01	<.01	
Well 1---	2	<.001	<.001	-----									2	<.01	<.01	
Well 2---	2	<.001	<.001	-----									2	<.01	<.01	
Well 3---	2	<.001	<.001	-----									2	<.01	<.01	
Well 4---	2	<.001	<.001	-----									2	<.01	<.01	
Drainage ditch near site 4.	1	<.001	------	-----	2	1.5	<.1	----	2	1.0	<1.0	---	1	<.01	-----	----
Drainage ditch near site 2.	1	<.001	------	-----	1	<.1	----	----	1	<1.0	----	---	1	<.01	-----	----

Table 7.--Variation in pesticide concentrations in water and bottom material from Lake Bruin and two ditches draining into the lake and in ground water from observation wells, June 1980 through October 1982--Continued

	Methyl parathion, total				Methyl parathion, total in in bottom material				2,4-D, total				Mirex, total in bottom material				2,4-DP, total			
	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean	n	Max	Min	Mean
Site 1---	12	0.05	<0.01	0.013	10	<0.1	<0.1	----	12	0.09	0.02	0.05	11	<0.1	<0.1	----	12	<0.01	<0.01	----
Site 2---	13	.01	<.01	.008	11	<.1	<.1	----	12	.08	<.01	.04	12	<.1	<.1	----	12	<.01	<.01	----
Site 3---	13	.01	<.01	.008	10	<.1	<.1	----	11	.1	<.01	.04	10	<.1	<.1	----	12	<.01	<.01	----
Site 4---	3	.13	<.01	.047	3	<.1	<.1	----	3	.14	<.01	.05	2	<.1	<.1	----	3	.07	<.01	0.02
Well 1---	2	<.01	<.01																	
Well 2---	2	<.01	<.01																	
Well 3---	2	<.01	<.01																	
Well 4---	2	<.01	<.01																	
Drainage ditch near site 4.	1	.03	-----		2	5.1	<.1	----					2	3.0	<.1	----				
Drainage ditch near site 2.	1	.02	-----		1	<.1	----	----					1	<.1	----	----				

Table 8.--Frequency of occurrence of pesticides detected in surface samples from Lake Bruin, June 1980 through October 1982

	Number of samples in which compound was detected in concentrations greater than detection levels														
	Site 1				Site 2				Site 3				Site 4		Total number of samples
	1980	1981	1982	1983	1980	1981	1982	1983	1980	1981	1982	1983	1980	1981	
Number of samples collected---	2	6	5	1	2	6	5	1	2	6	5	1	2	1	45
								Insecticides							
DDD----------	1	-	1	-	1	-	-	-	1	-	-	-	2	1	7
DDT----------	1	1	1	-	1	-	1	-	1	-	1	-	1	1	9
Dieldrin-----	1	-	4	-	-	1	2	1	1	1	2	1	2	1	17
Heptachlor---	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Diazinon-----	-	3	1	-	-	-	-	-	-	4	1	-	-	-	9
Methyl parathion.	-	-	-	-	-	1	-	-	-	1	-	-	-	-	2
								Herbicides							
2,4-D--------	2	6	5	1	2	6	4	1	[a]1	[a]5	5	1	-	1	[b]40
2,4-DP-------	-	-	-	-	-	-	-	-	--	--	-	-	-	1	1

[a] One herbicide sample not analyzed during water year.

[b] Total number of herbicide determinations, 43.

DDT and its deriative DDD were found in water samples collected at all lake sites. DDT in surface samples of lake water was found in 9 of 45 samples collected and DDD in 7 of 45. Maximum concentrations of DDT in surface water ranged from 0.006 μg/L at site 2 to 0.025 μg/L at site 4. Maximum concentrations of DDD in surface water ranged from 0.002 μg/L at site 2 to 0.049 μg/L at site 4. No DDE was detected in surface-water samples. Criteria limit (table 6) for DDT is 0.001 μg/L for freshwater life and minimum exposure for human health. DDT and its derivatives, DDD and DDE, were found in high concentrations in bottom material from the lake sites and drainage ditches. DDT in bottom material from drainage ditches near sites 2 and 4 was 390 and 260 μg/kg, respectively. DDT concentrations in lake-bottom material ranged from 0.1 to 82 μg/kg. DDE in lake-bottom material ranged from 25 to 230 μg/kg at site 4.

Concentrations of DDD in lake-bottom material ranged from 16 to 150 μg/kg. DDE and DDD also were found in high concentrations in bottom material from the two drainage ditches sampled. DDE was consistently found in higher concentrations in bottom material than DDT or DDD, indicating ongoing degradation of DDT in the system. Main sources of DDT and DDD in lake water appear to be agricultural runoff and resuspension of bottom material.

The lack of DDE in lake water appears to be related to whether samples are collected from aerobic or anaerobic zones of the water column. Lake samples collected near the surface or from the hypolimnion shortly after stratification took place contained no detectable concentrations of DDE, while DDT and DDD were present in concentrations as high as 0.025 μg/L (site 3). In contrast, a sample collected from the hypolimnion in October 1981 at site 2 had a concentration of 0.28 μg/L DDE, 0.14 μg/L DDT, and 0.02 μg/L DDD. None of these compounds were present in surface samples collected at this time. This indicates that DDT and its deriatives are more closely associated with bottom sediments and that the amount of different breakdown products of DDT appear to be related to low concentrations of dissolved oxygen in the system. Gambrell and others (1981) reported similar findings on the fate of DDT (and its derivatives) in Mobile Bay. They found that DDT was stable in oxidized (aerobic) conditions but degraded rapidly to its breakdown products DDE and DDD under reduced (anaerobic) conditions. Redox potentials as low as -150 mv (millivolts) were recorded in the Mobile Bay study. Redox potentials in Lake Bruin ranged from -240 mv in the bottom material at site 2 during a prolonged period of stratification to +340 mv at the bottom during periods of non-stratification. This large variation in oxidation-reduction potential at the bottom during periods of stratification and nonstratification probably explains the fluctuation in concentrations of DDT and its derivatives in the bottom material and water column. Concentrations of DDT were highest during periods of nonstratification and at the time when the lake was receiving fresh inputs from agricultural runoff. Chemically, DDT was most stable under these environmental conditions. DDT concentrations were lowest during periods of prolonged anaerobic conditions (late summer and early fall) and low rainfall (fig. 9). Under these environmental conditions DDT was relatively unstable and decomposed to its breakdown products DDD and DDE. Data collected at site 2 indicated that DDT concentrations were highest in bottom material during the winter and spring months and lowest during the summer and early fall months.

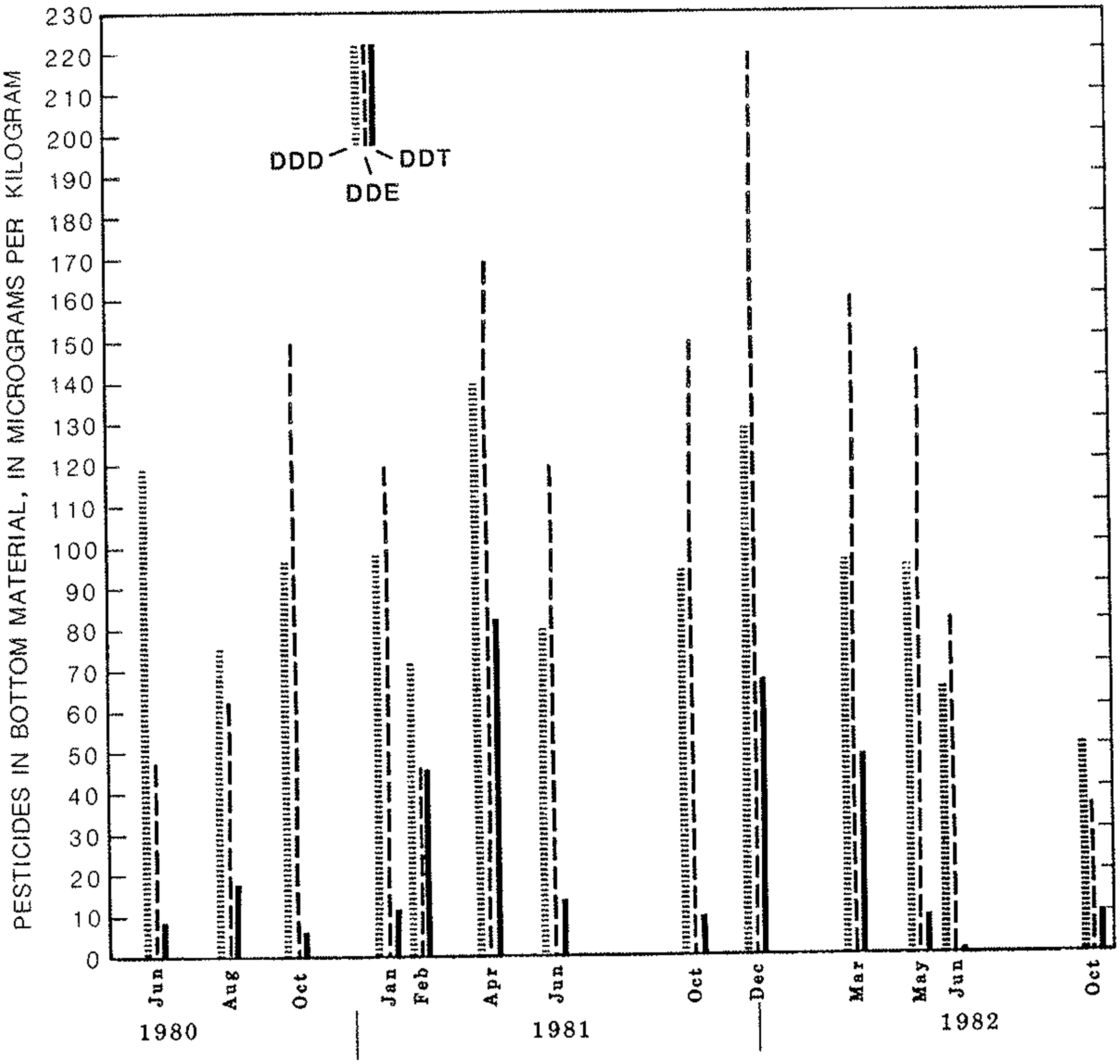

Figure 9.--DDD, DDE, and DDT in bottom material collected at Lake Bruin site 2, June 1980 through October 1982.

Insecticides in bottom material were sampled at shore and center cross-sectional stations at sites 1, 2, and 3 (table 9) in October 1981. Highest concentrations were found at midlake stations. Chlordane, DDD, and DDE concentrations at the midlake stations were two or more times greater than at the shore stations. For example, DDD at the site 2 midlake station was detected at a concentration of 95 µg/kg in bottom material as compared to concentrations of 32 and 6.6 µg/kg in the bottom material at the interior- and exterior-shore stations at this site. Similar differences between shore and midlake stations were observed at sites 1 and 3. Differences between insecticide concentrations in midlake bottom and shore-station bottom samples are probably due to differences in sedimentation. Wave action along the shore tends to keep in suspension or resuspend fine particulate matter, which is deposited in the deeper areas of the lake. Data from one set of filtered versus whole-water samples, tabulated below, indicate that most of the pesticides detected are associated with fine particulate matter.

Concentrations of pesticides in filtered and unfiltered samples

Pesticide	Filtered	Unfiltered
	(microgram per liter)	
DDD------------------------	< 0.001	0.016
DDT------------------------	< .001	.007
Dieldrin-------------------	.003	.023
2,4-D----------------------	.02	.02

The above results may explain why concentrations of bottom pesticides are highest at the midlake stations; however, more data are needed to verify this observation.

Table 9.--Insecticides and PCB in bottom material from shore and midlake samples, Lake Bruin, October 1981

[Data are in micrograms per kilogram]

Site		PCB	Chlordane	DDD	DDE	DDT	Dieldrin
1	Interior shore--	2	8.0	9.9	13	35	<0.1
	Midlake---------	<1	15	20	28	1.5	<.1
	Exterior shore--	<1	8.0	8.4	22	<.1	<.1
2	Interior shore--	5	63	32	52	3.8	<.1
	Midlake---------	<1	20	95	150	9.3	1.0
	Exterior shore--	<1	5.0	6.6	11	3.1	<.1
3	Interior shore--	<1	12	20	20	1.2	1.5
	Midlake---------	<1	25	110	110	2.7	<.1
	Exterior shore--	<1	4.0	15	15	11	<.1

At shore stations, insecticides in bottom material usually were found in higher concentrations at interior-shore stations compared to exterior-shore stations. Chlordane, DDD, DDE, and DDT were found in concentrations of 63, 32, 52, and 3.8 μg/kg, respectively, at the interior-shore station at site 2 compared to concentrations of 5.0, 6.6, 11, and 3.1 μg/kg, respectively, at the exterior-shore station. The differences observed between the interior- and exterior-shore samples may be due to more agricultural runoff entering the lake through drainage ditches from the interior of the lake compared to the exterior of the lake; however, until more shore samples are collected, no firm conclusions can be reached.

Fish tissue from four different fish species, threadfin shad (Dorosoma cepedianum), channel catfish (Ictalurus punctatus), white crappie (Pomoxis annularis) and largemouth bass (Micropterus salmoides), were collected and analyzed for insecticide residues on five separate occasions during the study (table 10). Species of fish analyzed were selected on the basis of their position in the food chain. This was done to determine whether concentrations of insecticides in fish tissue increased as food sources changed from plankton feeders (planktivores) to fish eaters (piscivores).

Of the 17 organic compounds in the analysis program, 6 occurred in significant concentrations in the fish-tissue samples. However, none of the compounds occurred in concentrations that exceeded U.S. Food and Drug Administration (1983) recommended limits (table 11). The organic compounds identified in the fish were chlordane, DDD, DDT, DDE, dieldrin, and PCB.

Those organic compounds not detected in fish tissue were:

Organic compound	Lowest level of detection (micrograms per kilogram)
Aldrin	0.1
Endosulfan	.1
Endrin	.1
Gross PCN	1
Heptachlor epoxide	.1
Heptachlor	.1
Lindane	.1
Mirex	.1
Methoxychlor	.1
Perthane	1
Toxaphene	10

Concentrations of the compounds showed little or no relationship to species sampled. For example, chlordane ranged from 1 to 110 µg/kg for threadfin shad (planktivore), 14 to 83 µg/kg for channel catfish (omnivorous bottom feeder), 4 to 63 µg/kg for white crappie (piscivores), and 40 µg/kg for largemouth bass (piscivores) tissue samples.

All fish were collected near site 2, and concentrations of organic compounds in their tissue were definitely greater than in their surrounding environment. Chlordane in fish samples ranged from 1 to 110 µg/kg; whereas, it was never detected in water and ranged from 15 to 28 µg/kg in bottom material. Similarly, DDE in fish ranged from 47 to 700 µg/kg, in bottom material from 36 to 140 µg/kg, and was not detected in water.

Concentrations of organic compounds in fish showed some relation to percent fat content; however, this relationship appears to be species dependent, as shown in a comparison between concentrations in threadfin shad and channel catfish. Concentrations of organic compounds were highest in shad when fat content was highest (5.8 percent) and lowest when

Table 10.--Insecticides and PCB in tissue from selected fish species collected from Lake Bruin, May through December 1982

[Compounds in fish tissue are in micrograms per kilogram, in hexane rinse in micrograms per liter]

Species	Sampling date	Number of fish composited	Percent of fat content	Chlordane	DDD	DDE	DDT	Dieldrin	Gross PCB
Dorosoma	5- 6-82	3	4.8	66	62	540	72	2.9	<1
cepediatum	6-23-82	3	5.8	110	390	490	250	4.4	<1
(Threadfin shad)	8-18-82	3	1.0	<1	670	610	450	24	<1
	10-27-82	3	.8	10	11	50	1.3	.4	10
	12-15-82	1	3.2	24	38	140	7.5	1.1	64
Ictalurus	5- 6-82	4	7.0	14	60	140	15	1.7	6
punctatus	6-23-82	3	6.9	83	330	700	140	6.0	<1
(Channel catfish)	8-18-82	2	4.6	29	65	210	12	.7	<1
	10-27-82	2	3.0	27	90	330	35	3.8	<1
Pomoxis	5- 6-82	3	0.4	12	5.8	76	5.8	2.4	<1
annularis	6-23-82	3	3.4	52	110	590	110	2.7	<1
(White crappie)	8-18-82	3	3.0	63	19	550	19	4.1	<1
	12-15-82	1	3.2	4	6.8	47	6.8	1.2	<1
Micropterus	10-27-82	4	4.2	40	33	460	33	2.4	8
salmoides	12-15-82	3	4.0	40	100	56	100	6.2	550
(Largemouth bass)									
Hexane rinse-----	8-18-82	-	---	3.7	<0.001	<0.001	<0.001	1.7	<0.1

Table 11.--Administrative guidelines of the U.S. Food and Drug Administration for pesticides and PCB in finfish

[Compounds are reported in micrograms per kilogram]

Compound	Recommended limits
Aldrin	300
Chlordane	300
DDE	5,000
DDT	5,000
TDE[1]	5,000
Dieldrin	300
Endrin	300
Heptachlor	300
Heptachlor epoxide	300
Kepone	300
Mirex	100
PCB	5,000
Toxaphene	5,000

[1] Represents the sum of DDT and its derivatives.

the fat content was the lowest (0.8 percent). Catfish also contained highest concentrations of organic compounds when fat content was high (6.9 percent) but had the lowest concentrations at an intermediate level of fat (4.6 percent). White crappie also had the lowest concentration of organic compounds at an intermediate fat level (3.2 percent). Because samples represent composites, no conclusions could be drawn relating concentrations of organic compound to length or age of fish.

The concentration of organics in fish exhibited some seasonality. Threadfin shad, which ranged in total length from 6 to 11 in., contained highest concentrations in the late spring and summer months and lowest in late fall and winter. White crappie showed similar variations; however, more data collected on a seasonal basis comparing fish of the same age class are needed to determine whether concentrations of pesticides in fish do vary with season and determine what factors influence the degree of pesticide uptake by these fish.

An analysis of the mucous layer rinsed off of fish indicates that some pesticides (table 10), such as chlordane and dieldrin, can be trapped in the mucosal secretions of fish. How these pesticides become trapped in the mucous and whether they eventually become absorbed internally needs to be investigated. Such information may be useful in providing management techniques that minimize pollutant uptake by fish during lake restoration or dredging projects when resuspension of pollutants occurs.

Bacteria

Fecal-coliform and fecal-streptococci bacteria were sampled at three stations, sites 1, 2, and 3, in Lake Bruin during the period June 1980 through October 1982 and at one station, site 4, in Brushy Lake, June 1980 through October 1982 (table 12). Fecal-coliform concentrations were well below the State criteria for primary contact recreation (200 colonies/100 mL), secondary contact recreation (1,000 colonies/100 mL), and public-water supplies (2,000 colonies/100 mL) (Louisiana Stream Control Commission, 1977).

Bacterial counts, both fecal coliform and fecal streptococci, varied from site to site and from midlake to shore stations. Fecal-coliform counts were low at site 1 stations, ranging from a maximum of 40 colonies/100 mL at the midlake station to less than 1 colony/100 mL at all cross-sectional stations. Highest fecal-coliform counts occurred during August 1981 (exterior-shore station only) and June 1982. Most fecal-coliform counts from samples collected at site 1 cross-sectional stations (31 of 35) were less than 20 colonies/100 mL. Fecal-streptococci counts ranged from 1 colony/100 mL for all site 1 stations to 260 colonies/100 mL at the interior-shore station. Counts were highest during August 1981 when 260 and 130 colonies/100, respectively, were observed at the interior and the exterior stations. Most fecal-streptococci counts (74 percent) were less than 20 colonies/100 mL for the three stations at site 1.

Fecal-coliform counts were very low at the site 2 cross section, ranging from a high of 17 colonies/100 mL at the exterior-shore station to less than 1 colony/100 mL at all site 2 stations. No fecal-coliform counts exceeded 20 colonies/100 mL at this site. Fecal streptococci occurred in much higher numbers than fecal coliform at site 2. Counts as high as 170 colonies/100 mL (exterior-shore station) were recorded, the highest in June 1981 and May and June of 1982. Seventy-four percent of the fecal-streptococci samples from this site had counts less than 20 colonies/100 mL. Bacterial counts varied randomly in the cross section at site 2, and no conclusions can be drawn from the data as to the source of the bacterial populations at this site.

Fecal-coliform counts were highest at site 3; however, most counts (31 of 35) determined for site 3 stations were less than 20 colonies/100 mL. Fecal-coliform counts ranged from a maximum of 84 colonies/100 mL at the exterior-shore station to a minimum of less than 1 colony/100 mL at all stations. Fecal-streptococci bacteria ranged from a high of 107 colonies/100 mL at the interior-shore station to 1 colony/100 mL at the center and exterior-shore stations. Sixty-five percent of the fecal-streptococci counts at site 3 were less than 20 colonies/100 mL; comparatively high counts occurred in August 1981 and March through June 1982.

The one station at site 4 in Brushy Lake was sampled three times for bacteria. This site had the highest fecal-streptococci counts recorded, ranging from 50 to 960 colonies/100 mL. Fecal-coliform counts ranged from less than 10 to 60 colonies/100 mL.

Table 12.--Variation in fecal-coliform and fecal-streptococci bacteria at four sites in Lake Bruin, June 1980 through October 1982

[FC, fecal-coliform bacteria; FS, fecal-streptococci bacteria. Counts are number of colonies per 100 milliliters]

Date	Site 1						Site 2						Site 3						Site 4	
	Interior shore		Mid-lake		Exterior shore		Interior shore		Mid-lake		Exterior shore		Interior shore		Mid-lake		Exterior shore		Mid-lake	
	FC	FS	FC	FS	FC	FS	FC	FS	FC	FS	FC	FS	FC	FS	FC	FS	FC	FS	FS	FC
6-25-80	<20	<20	<20	<20	20	<20	<20	<20	<20	<20	<20	<20	20	<20	60	20	20	<20	60	140
8-20-80	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	50
10-30-80	2	<2	<2	8	2	<2	<2	<2	<2	26	2	<2	<2	20	<2	10	<2	<2	20	960
1- 6-81	---	---	1	1	---	---	---	---	2	<1	---	---	---	---	2	<2	---	---	---	---
2-25-81	<2	24	<2	18	<2	8	<2	6	<2	4	<2	6	2	2	<2	<2	2	<1	---	---
6-24-81	---	---	2	10	---	---	---	---	8	16	---	---	---	---	2	14	---	---	---	---
8-27-81	<2	260	<2	38	30	130	<2	110	<2	18	<2	60	<2	10	28	84	<2	90	---	---
10-28-81	4	3	1	36	1	1	---	1	10	18	<10	5	<1	2	1	42	<1	2	---	---
12-30-81	1	4	<1	1	<1	2	4	1	1	<1	3	2	3	2	<1	2	<1	1	---	---
3-10-82	2	34	3	23	3	15	2	16	4	40	17	170	2	22	6	57	5	86	---	---
5- 6-82	2	9	<1	---	<1	2	<1	60	1	16	1	50	<1	110	<1	63	1	82	---	---
6-22-82	8	16	40	38	26	20	14	52	4	32	8	82	6	16	14	56	84	28	---	---
10-27-82	6	4	<2	64	<2	2	<2	2	3	16	<2	4	2	14	1	1	2	6	---	---

Data from the limited bacterial sampling indicate that bacterial pollution of Lake Bruin by domestic sewage is not a problem at this time. Ninety-three percent of the fecal-coliform counts and 70 percent of the fecal-streptococci counts for all lake stations were 20 colonies/100 mL or less. The consistently low bacterial counts and the similarity of bacterial counts at shore stations versus midlake stations indicate that the lake receives very little bacterial input.

Phytoplankton

The number and kinds of algae and other aquatic organisms present in surface waters are dependent upon environmental conditions in these waters. Seasonal and annual changes in algal population densities and structure can be indicative of changing land-use practices, nutrient availability, and the general health of the body of water being studied. Specific types of phytoplankton have been reported to cause: (1) taste and odor problems in drinking water, (2) health problems to humans and animals, and (3) fish kills due to algal consumption of oxygen. They are also indicative of general trophic conditions in a water body (Palmer, 1962).

Phytoplankton samples were collected from the three Lake Bruin sites and the one Brushy Lake site on a bimonthly schedule (tables 13 and 14). The most common algae in the lake (in order of abundance) were the blue-green algae *Lyngbya*, *Oscillatoria*, *Anabaenopsis*, *Anacystis*, *Cylindrospermum*, and *Agmenellum*; the green algae *Ankistrodesmus*, *Dictyosphaerium*, and *Scenedesmus*; and the diatoms *Cyclotella* and *Melosira*. All the above genera include species that are listed as nuisance-type algae that can cause taste and odor problems and are tolerant of pollution (Palmer, 1962).

Large fluctuations in phytoplankton population densities were observed during the course of the study (fig. 10). Phytoplankton densities ranged from 1,800 to 740,000 cells/mL for all samples (table 14). Lowest concentrations occurred during the late winter and early spring (January-April), ranging from 1,800 to 16,000 cells/mL for all lake sites. Site 4, Brushy Lake, was not sampled during this time period because of extremely low water. Maximum phytophankton counts occurred from June through August, ranging from 130,000 to 740,000 cells/mL for all lake sites. In 1982, high phytoplankton densities at sites 1 and 3 continued into October. Phytoplankton counts for October 1982 were 320,000 cells/mL at site 1, 14,000 cells/mL at site 2, and 200,000 cells/mL at site 3. The October phytoplankton samples were collected during overturn. Water at sites 1 and 3, which had very high phytoplankton densities, was already well mixed throughout the water column (figs. 5 and 7); whereas, water at site 2 was still actively being mixed (fig. 6). It appears that the mixing at site 2 might be responsible for the low density at that site. Mixing would disperse the phytoplankton throughout the water column and reduce growth by the movement of phytoplankton out of the photic zone.

Table 13.--Total number of phytoplankton present in algae samples from Lake Bruin, June 1980 through October 1982

[Numbers are in cells per milliliter; n, total number of samples collected; p, presence noted in sample but not counted]

	Site 1 n = 14	Site 2 n = 14	Site 3 n = 14	Site 4 n = 3
Bacillariophyta-----------	---------	---------	---------	---------
Bacillariophyceae-------	---------	---------	---------	---------
Bacillariales---------	---------	---------	---------	---------
Nitzschiaceae-------	---------	---------	---------	---------
Nitzschia-----------	2,800	140	2,900	2,900
Eupodiscales------------	---------	---------	---------	---------
Coscinodiscaceae------	---------	---------	---------	---------
Cyclotella----------	12,000	7,900	7,400	4,400
Melosira------------	14,000	7,500	20,000	p
Stephanodiscus------	---------	160	340	---------
Fragilariales-----------	---------	---------	---------	---------
Fragilariaceae--------	---------	---------	---------	---------
Fragilaria----------	p	p	---------	---------
Synedra-------------	1,200	1,700	p	---------
Naviculales-------------	---------	---------	---------	---------
Naviculaceae----------	---------	---------	---------	---------
Navicula------------	70	---------	---------	---------
Chlorophyta---------------	---------	---------	---------	---------
Chlorophyceae-----------	---------	---------	---------	---------
Chlorococcales--------	---------	---------	---------	---------
Chlorococcaceae-----	---------	---------	---------	---------
Polyedriopsis-----	---------	p	p	---------
Schroederia-------	p	p	p	---------
Tetraedron--------	2,100	29	1,800	3,400
Coccomyxaceae-------	---------	---------	---------	---------
Elakatothrix------	---------	280	---------	---------
Dictyosphaeriaceae--	---------	---------	---------	---------
Dictyosphaerium---	11,000	3,200	2,100	1,600
Micractiniaceae-----	---------	---------	---------	---------
Acanthosphaera----	p	---------	---------	---------
Golenkinia--------	280	420	p	---------
Micractinium------	5,100	880	1,800	800
Oocystaceae---------	---------	---------	---------	---------
Ankistrodesmus----	15,000	13,000	15,000	11,000
Closteriopsis-----	---------	---------	---------	p
Chodatella--------	600	290	840	---------
Franceia----------	600	---------	p	---------
Kirchneriella-----	1,800	3,300	1,000	25,000
Oocystis----------	120	370	280	p
Quadrigula--------	p	---------	---------	---------
Selenastrum-------	4,200	490	4,600	p

Table 13.--Total number of phytoplankton present in algae samples from Lake Bruin, June 1980 through October 1982--Continued

	Site 1 n = 14	Site 2 n = 14	Site 3 n = 14	Site 4 n = 3
Chlorophyta-continued				
Treubaria---------	1,900	490	190	p
Palmellaceae--------	---------	---------	---------	---------
Sphaerocystis-----	---------	---------	---------	4,600
Scenedesmaceae------	---------	---------	---------	---------
Actinastrum-------	---------	---------	p	---------
Coelastrum--------	1,900	86	2,700	---------
Crucigenia--------	740	1,600	930	6,300
Scenedesmus-------	3,000	2,000	3,500	20,000
Tetrastrum--------	2,500	860	550	---------
Volvocales----------------	---------	---------	---------	---------
Chlamydomonadaceae------	---------	---------	---------	---------
Carteria-----------	---------	p	---------	---------
Chlamydomonas-------	3,800	1,700	2,300	4,100
Chlorogonium--------	---------	p	p	---------
Volvocaceae-----------	---------	---------	---------	---------
Pandorina-----------	---------	---------	1,600	---------
Zygnematales------------	---------	---------	---------	---------
Desmidiaceae----------	---------	---------	---------	---------
Cosmarium-----------	p	190	p	---------
Euastrum------------	---------	p	p	---------
Staurastrum---------	p	p	---------	---------
Chrysophyta--------------	---------	---------	---------	---------
Chrysophyceae-----------	---------	---------	---------	---------
Ochromonadales--------	---------	---------	---------	---------
Dinobryaceae--------	---------	---------	---------	---------
Stenocalyx--------	---------	350	p	---------
Ochromonadaceae-----	---------	---------	---------	---------
Ochromonas--------	---------	p	580	---------
Xanthophyceae-----------	---------	---------	---------	---------
Mischococcales--------	---------	---------	---------	---------
Sciadaceae----------	---------	---------	---------	---------
Ophiocytium-------	---------	490	---------	p
Cryptophyta--------------	---------	---------	---------	---------
Cryptophyceae-----------	---------	---------	---------	---------
Cryptomonadales-------	---------	---------	---------	---------
Cryptochrysidaceae--	---------	---------	---------	---------
Chroomonas--------	p	190	41	---------
Cryptomonadaceae------	---------	---------	---------	---------
Cryptomonas-------	p	740	780	---------

Table 13.--Total number of phytoplankton present in algae samples from Lake Bruin, June 1980 through October 1982--Continued

	Site 1 n = 14	Site 2 n = 14	Site 3 n = 14	Site 4 n = 3
Cyanophyta	---------	---------	---------	---------
Cyanophyceae	---------	---------	---------	---------
Chroococcales	---------	---------	---------	---------
Chroococcaceae	---------	---------	---------	---------
Agmenellum	83,100	57,000	58,000	340,000
Anacystis	300,000	180,000	250,000	37,000
Dactylococcopsis	p	---------	---------	---------
Nostocales	---------	---------	---------	---------
Hammatoideaceae	---------	---------	---------	---------
Raphidiopsis	7,700	3,100	---------	---------
Nostocaceae	---------	---------	---------	---------
Anabaena	13,000	6,600	p	43,000
Anabaenopsis	270,000	420,000	280,000	---------
Aphanizomenon	420	2,900	---------	---------
Cylindrospermum	152,000	150,000	170,000	---------
Oscillatoriales	---------	---------	---------	---------
Oscillatoriaceae	---------	---------	---------	---------
Lyngbya	1,100,000	870,000	1,100,000	---------
Oscillatoria	500,000	150,000	670,000	76,000
Euglenophyta	---------	---------	---------	---------
Euglenophyceae	---------	---------	---------	---------
Euglenales	---------	---------	---------	---------
Euglenaceae	---------	---------	---------	---------
Euglena	360	280	p	p
Phacus	p	---------	---------	p
Trachelomonas	2,200	490	240	550
Prrhophyta	---------	---------	---------	---------
Dinophyceae	---------	---------	---------	---------
Dinokontae	---------	---------	---------	---------
Ceratiaceae	---------	---------	---------	---------
Ceratium	240	p	---------	---------
Glenodiniaceae	---------	---------	---------	---------
Glenodinium	p	210	p	---------
Peridiniaceae	---------	---------	---------	---------
Peridinium	p	330	---------	---------

Diversity indices at the generic level were at their maximum when population densities were less than 35,000 cells/mL. The maximum diversity recorded at site 1 was 3.3 (May 1982); at site 2, 3.0 (October 1982); and at site 3, 3.2 (December 1981). Population densities were 19,000, 14,000, and 33,000 cells/mL, respectively. The diatoms *Melosira* and

Table 14.--Composition of phytoplankton communities in Lake Bruin, June 1980 through October 1982

[Diversity, generic level; n, total number of cells per milliliter per sample; percent of total population by genera]

Site 1

Date:	6-25-80	8-20-80	10-30-80	1-6-81	2-25-81	4-23-81	6-24-81
Diversity:	1.7	1.7	2.1	2.5	2.6	2.3	1.1
n:	190,000	590,000	82,000	15,000	2,700	16,000	550,000
	Lyngbya---------- 57	Oscillatoria---- 43	Anacystis-------- 38	Anacystis-------- 33	Anacystis-------- 38	Anacystis-------- 62	Lyngbya---------- 69
	Anacystis-------- 21	Lyngbya---------- 39	Oscillatoria---- 37	Melosira--------- 33	Melosira--------- 20	Agmenellum------- 10	Anabaenopsis---- 27
	Anabaenopsis---- 16	Anabaenopsis---- 15	Agmenellum------- 13	Agmenellum------- 16	Cyclotella------- 14	Others----------- 28	Others----------- 4
	Others----------- 6	Others----------- 3	Lyngbya---------- 6	Cyclotella------- 7	Crucigenia------- 9		
			Others----------- 6	Others----------- 11	Ankistrodesmus-- 8		
					Others----------- 11		

Site 2

Date:	6-25-80	8-20-80	10-30-80	1- 6-81	2-25-81	4-23-81	6-24-81
Diversity:	1.3	1.7	2.3	2.6	2.6	2.9	1.2
n:	280,000	260,000	60,000	11,000	1,800	7,000	740,000
	Lyngbya---------- 55	Anabaenopsis---- 52	Agmenellum------- 33	Anacystis-------- 33	Cyclotella------- 41	Anacystis-------- 50	Lyngbya---------- 68
	Anabaenopsis---- 41	Lyngbya---------- 26	Anacystis-------- 33	Melosira--------- 31	Anacystis-------- 18	Agmenellum------- 10	Anabaenopsis---- 24
	Others----------- 4	Oscillatoria---- 17	Oscillatoria---- 21	Crucigenia------- 14	Ankistrodesmus-- 17	Anabaenopsis---- 6	Anacystis-------- 8
		Others----------- 5	Others----------- 13	Agmenellum------- 7	Others----------- 24	Others----------- 34	
				Others----------- 15			

Site 3

Date:	6-25-80	8-20-80	10-30-80	1- 6-81	2-25-81	4-23-81	6-24-81
Diversity:	1.8	1.6	2.0	2.2	2.6	1.7	1.2
n:	210,000	400,000	61,000	16,000	5,200	11,000	710,000
	Lyngbya---------- 59	Oscillatoria---- 56	Anacystis-------- 46	Melosira--------- 52	Cyclotella------- 46	Anacystis-------- 72	Lyngbya---------- 70
	Anabaenopsis---- 17	Anabaenopsis---- 24	Oscillatoria---- 35	Anacystis-------- 27	Anacystis-------- 14	Agmenellum------- 6	Anabaenopsis---- 21
	Anacystis-------- 11	Lyngbya---------- 17	Agmenellum------- 8	Oscillatoria---- 8	Crucigenia------- 13	Others----------- 22	Anacystis-------- 8
	Oscillatoria---- 10	Anacystis-------- 3	Anabaenopsis---- 4	Others----------- 13	Others----------- 27		Others----------- 1
	Others----------- 3		Lyngbya---------- 3				
			Others----------- 4				

Site 1

Date:	8-27-81	10-28-81	12-30-81	3-10-82	5-06-82	6-22-82	10-27-82
Diversity:	1.1	1.9	2.7	1.8	3.3	1.1	2.3
n:	130,000	170,000	31,000	9,200	19,000	240,000	320,000
	Cylindrospermum- 79	Oscillatoria---- 60	Anacystis-------- 43	Cyclotella------- 61	Ankistrodesmus-- 25	Lyngbya---------- 77	Anacystis-------- 44
	Oscillatoria---- 13	Agmenellum------- 18	Melosira--------- 23	Melosira--------- 13	Anacystis-------- 19	Cylindrospermum- 19	Oscillatoria---- 30
	Lyngbya---------- 4	Anacystis-------- 12	Ankistrodesmus-- 7	Ankistrodesmus-- 12	Cyclotella------- 16	Others----------- 4	Agmenellum------- 11
	Others----------- 4	Others----------- 10	Others----------- 27	Anacystis-------- 9	Oscillatoria---- 5		Others----------- 15
				Others----------- 5	Others----------- 35		

Site 2

Date:	8-27-81	10-28-81	12-30-81	3-10-82	5-06-82	6-22-82	10-27-82
Diversity:	1.5	1.8	2.4	2.3	1.6	1.0	3.0
n:	160,000	140,000	26,000	15,000	40,000	150,000	14,000
	Cylindrospermum- 65	Oscillatoria---- 59	Anacystis------- 59	Anacystis------- 44	Anacystis------- 75	Lyngbya--------- 73	Oscillatoria---- 25
	Lyngbya--------- 23	Agmenellum------ 21	Melosira-------- 5	Cyclotella------ 25	Oscillatoria---- 7	Cylindrospermum- 25	Cylindrospermum- 22
	Anacystis------- 6	Anacystis------- 12	Dictyosphaerium- 5	Melosira-------- 14	Others---------- 18	Others---------- 2	Anacystis------- 14
	Ankistrodesmus-- 5	Others---------- 8	Cyclotella------ 4	Others---------- 17			Anabaena-------- 12
	Others---------- 1		Ankistrodesmus-- 4				Dictyosphaerium- 12
			Others---------- 23				Others---------- 15

Site 1

Date:	8-27-81	10-28-81	12-30-81	3-10-82	5-06-82	6-22-82	10-27-82
Diversity:	1.9	1.3	3.2	2.2	2.6	0.8	1.8
n:	210,000	330,000	33,000	13,000	19,000	370,000	200,000
	Cylindrospermum- 52	Oscillatoria---- 79	Anacystis------- 36	Melosira-------- 41	Anacystis------- 51	Lyngbya--------- 83	Oscillatoria---- 61
	Lyngbya--------- 23	Agmenellum------ 9	Melosira-------- 16	Anacystis------- 29	Agmenellum------ 12	Cylindrospermum- 16	Anacystis------- 23
	Anacystis------- 10	Anacystis------- 6	Agmenellum------ 12	Oscillatoria---- 12	Oscillatoria---- 7	Others---------- 1	Agmenellum------ 7
	Oscillatoria---- 9	Others---------- 6	Cyclotella------ 6	Cyclotella------ 10	Cyclotella------ 7		Cylindrospermum- 3
	Others---------- 6		Oscillatoria---- 4	Others---------- 8	Others---------- 23		Others---------- 6
			Others---------- 26				

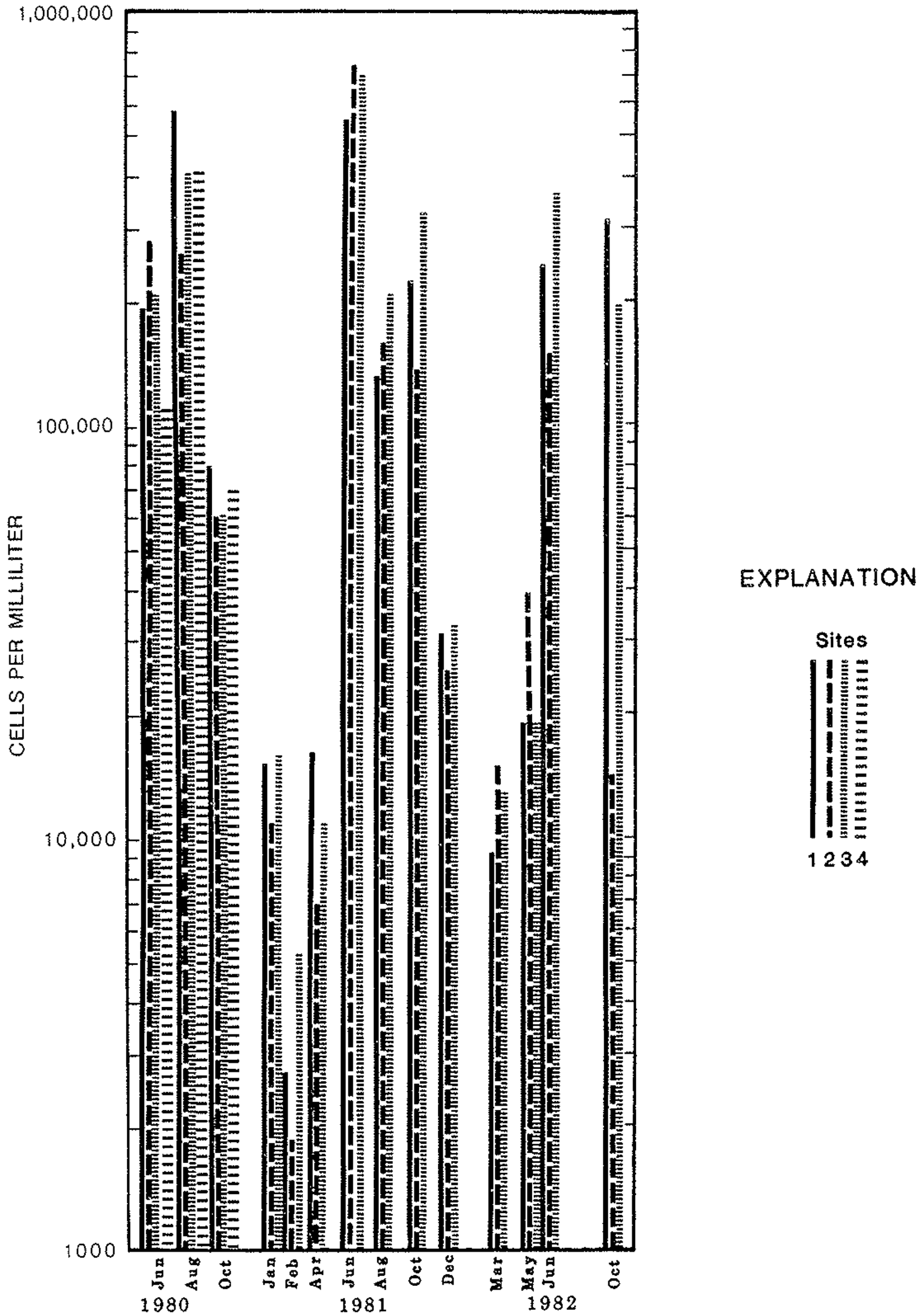

Figure 10.--Fluctuations in phytoplankton populations in Lake Bruin, June 1980 through October 1982.

Cyclotella, the green algae Ankistrodesmus and Dictyosphaerium, and the blue-green algae Oscillatoria, Anacystis, Agmenellum, and Cylindrospermum were the dominant algae present. Minimum diversities for all sites were recorded during the June 1982 sampling trip when diversities were 1.1, 1.0, and 0.8 for sites 1, 2, and 3, respectively. Population densities at these times were 240,000, 150,000, and 370,000 cells/mL, respectively. The dominant algae present during this sampling trip were the blue-green algae Lyngbya, Anabaenopsis, Cylindrospermum, Oscillatoria, Anacystis, and Agmenellum.

Blue-green algae were the most frequently identified algae during the course of the study. Lyngbya, Oscillatoria, Cylindrospermum, Anabaenopsis, and Anacystis were the algal genera most often associated with the summer bloom conditions. Usually only one or two of these blue-green algae dominated during bloom conditions, and the dominant algae changed from sampling trip to sampling trip. For example, at site 3 in June 1981 the population density was 710,000 cells/mL. Lyngbya and Anabaenopsis (in order of abundance) accounted for 91 percent of the algae observed in the sample. Two months later in August 1981 the phytoplankton population density had decreased to 210,000 cells/mL. Cylindrospermum, Lyngbya, and Anacystis were the dominant phytoplankton observed, accounting for 85 percent of the phytoplankton identified. In October 1981 the dominant phytoplankton changed to Oscillatoria and Agmenellum (88 percent of the phytoplankton observed), and the population density increased to 330,000 cells/mL. Similar changes in dominant species during bloom conditions were also observed at sites 1 and 2.

Blue-green algae were the only algae that achieved densities exceeding 100,000 cells/mL. Diatoms (Melosira and Cyclotella) and green algae (Dictyosphaerium and Ankistrodesmus) were not numerically important members of the phytoplankton community until after the blooms had ceased. It appears that environmental conditions are more favorable for these algae in the colder, nongrowing months of January through March when conditions are unfavorable for blue-greens.

Benthic Invertebrates

Population densities and community composition of benthic-invertebrate populations can yield useful information on long-term water-quality conditions in an aquatic system. Benthic invertebrates are generally nonmobile. Consequently changes in community structure and population densities that cannot be accounted for by seasonal changes (pupation and emergence) can be indicative of changing environmental conditions, including water-quality trends.

Benthic invertebrates were collected from the bed material at three stations at each of four sites (figs. 1, 11, and 12) on a quarterly basis during the study. A total of 2,055 organisms were identified from 78 samples. Table 15 lists the total number of each species captured by site. Chaoborus (phantom-midge larvae); unidentified tubificid worms; Potamothrix and Limnodrilus (both tubificid worms); and Chironomus,

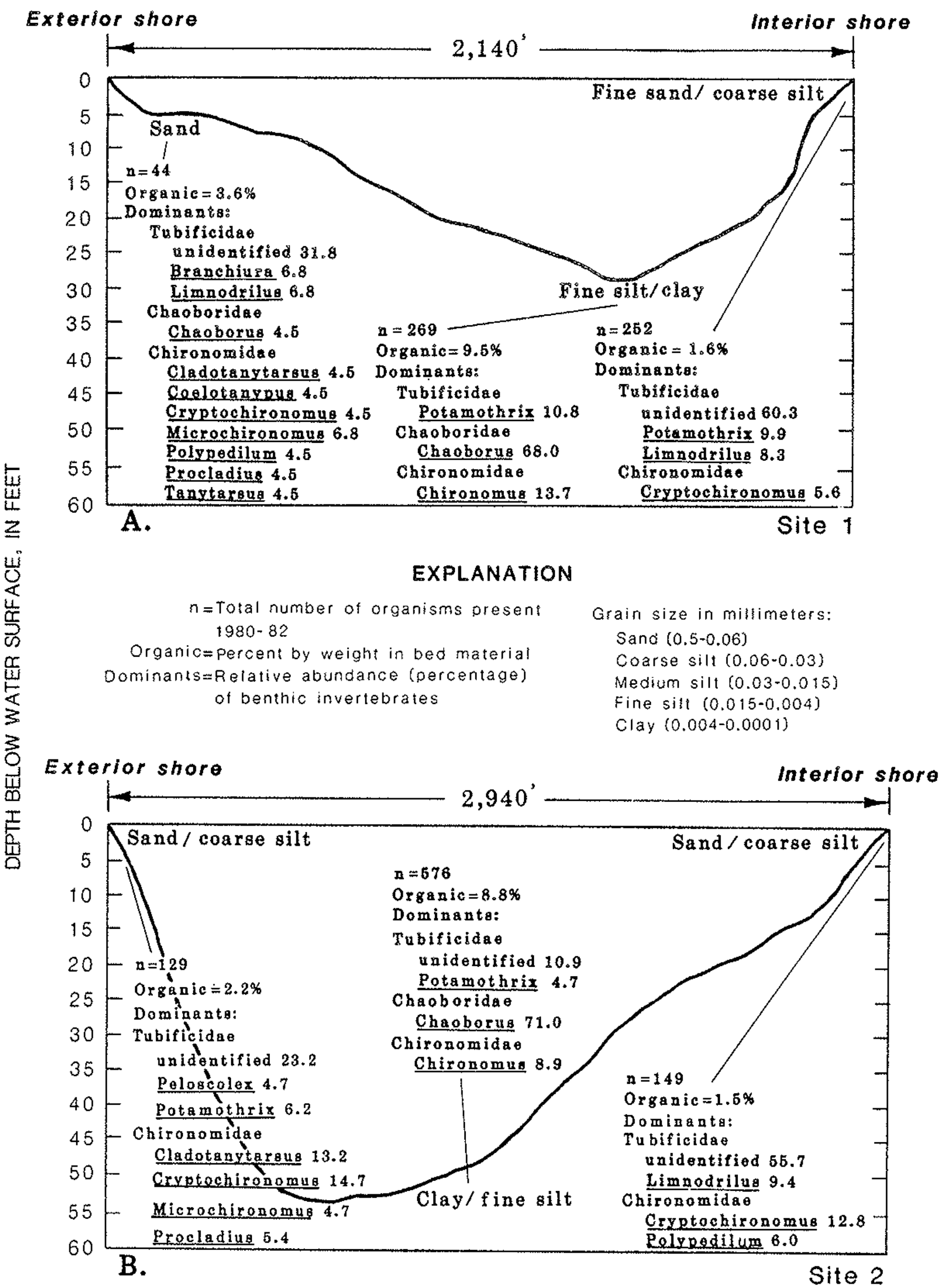

Figure 11.--Channel profile, associated benthic-invertebrate populations, substrate composition, and percentage of organic matter in bed material at Lake Bruin sites 1 and 2.

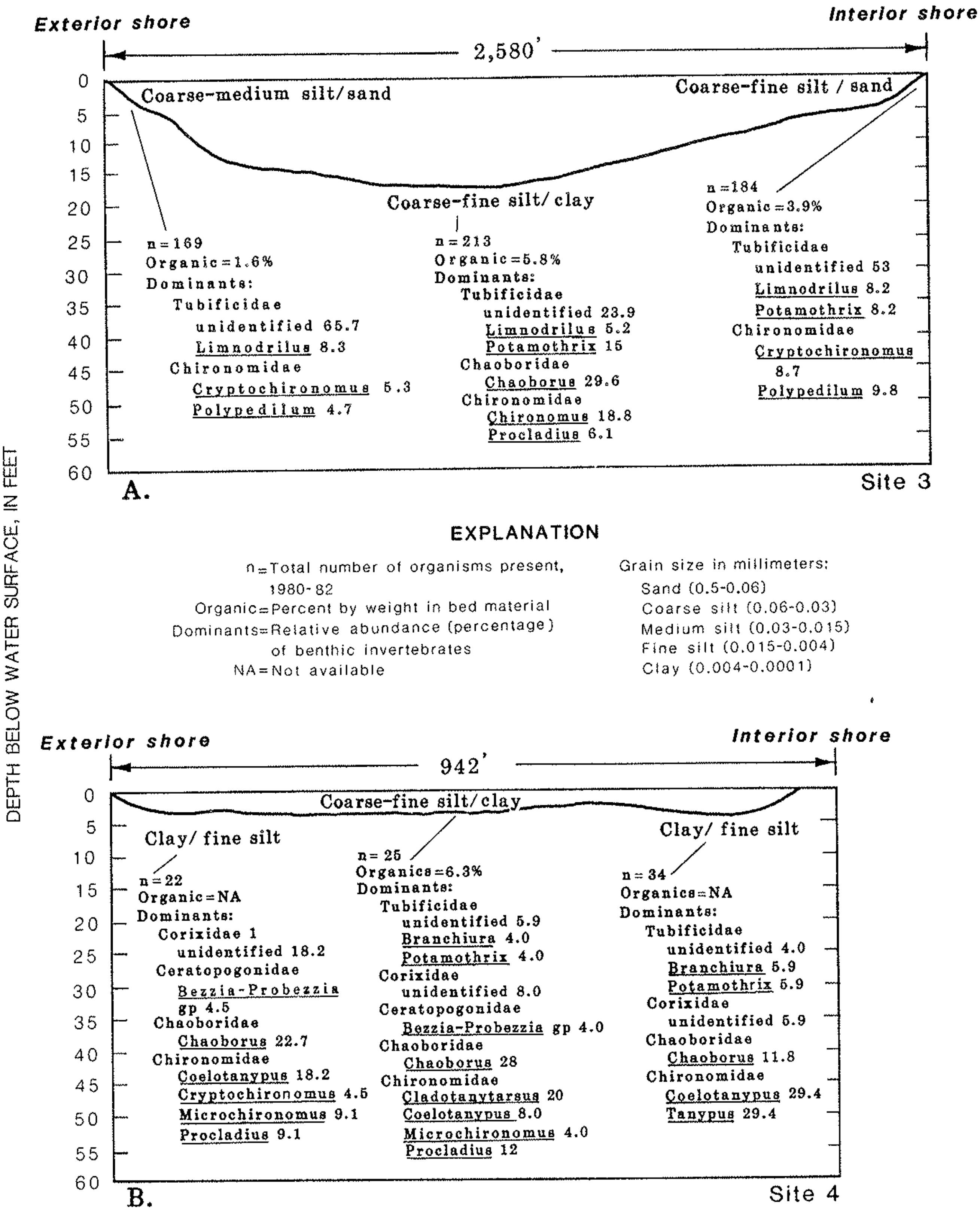

Figure 12.--Channel profile, associated benthic-invertebrate populations, substrate composition, and percentage of organic matter in bed material at Lake Bruin sites 3 and 4.

Table 15.--Total number of organisms in benthic-invertebrate samples from Lake Bruin, June 1980 through October 1982

[Number represents total organisms present in cross-section; x, presence of colonial-type organism in sample]

	Site 1 n = 14	Site 2 n = 14	Site 3 n = 14	Site 4 n = 3
Ciliatea				
Peritrichida				
Vorticellidae				
Carchesium------	x	---	---	--
Bryozoa				
Phylactolaemata				
Lophopodidae				
Pectinatella----	x	---	---	--
Nematoda				
Unidentified individual.	1	1	1	--
Rhabditida				
Diplogasteridae				
Diplogaster-----	1	---	---	--
Oligochaeta				
Plesiopora				
Tubificidae				
Unidentified immature.	176	176	259	2
Aulodrilus------	---	---	4	--
Branchiura------	3	4	2	3
Limnodrilus-----	30	34	41	1
Peloscolex------	1	9	2	--
Potamothrix-----	55	38	52	-3
Tubifex---------	---	---	1	--
Crustacea				
Copepoda				
Unidentified individual.	1	3	2	--

Table 15.--Total number of organisms in benthic-invertebrate samples from Lake Bruin, June 1980 through October 1982--Continued

	Site 1 n = 14	Site 2 n = 14	Site 3 n = 14	Site 4 n = 3
Arachnida				
Hydracarina				
Unidentified individual.	---	2	---	--
Pionidae				
Piona	---	1	---	--
Insecta				
Collembola				
Isotomidae				
Isotomurus	1	---	1	--
Odonata - Zygoptera				
Coenagrionidae				
Anomalagrion	---	---	1	--
Ephemeroptera				
Baetidae				
Neocloeon	2	---	---	--
Ephemeridae				
Hexagenia	---	---	1	--
Hemiptera				
Corixidae				
Unidentified immatures.	---	---	---	8
Coleoptera				
Elmidae				
Dubiraphia	---	8	---	--
Trichoptera				
Leptoceridae				
Oecetis	1	1	---	--
Diptera				
Ceratopogonidae				
Bezzia-Probezzia gp.	1	---	1	3
Chaoboridae				
Chaoborus	195	413	64	16
Chironomidae				
Unidentified individual.	1	1	1	--
Chironomus	37	56	46	--
Cladopelma	2	4	4	--
Cladotanytarsus	11	18	4	5
Clinotanypus	---	1	---	--

Table 15.--Total number of organisms in benthic-invertebrate samples from Lake Bruin, June 1980 through October 1982--Continued

	Site 1 n = 14	Site 2 n = 14	Site 3 n = 14	Site 4 n = 3
Coelotanypus----	2	---	---	16
Cryptochironomus	17	39	26	1
Glyptotendipes--	---	1	---	1
Microchironomus-	3	6	3	3
Nanocladius-----	---	---	1	--
Polypedilum-----	7	14	26	--
Procladius------	13	19	19	6
Tanytarsus------	2	---	---	12
Stratiomyidae				
Euparyphus------	---	---	1	--
Stratiomys------	---	---	1	--
Bivalvia				
Heterodonta				
Sphaeriidae				
Unidentified individual.	---	1	---	1
Sphaerium-------	---	3	2	--
Schizodonta				
Unionidae				
Immature-unidentified individual.	---	1	---	--

Cryptochironomus, Procladius, and Polypedilum (all midge-fly larvae) were the most abundant and frequently occurring organisms captured during the study. Most of these organisms possess physiological or behavioral adaptations that allow them to exist in waters with very low DO concentrations.

The density of benthic-invertebrate populations was low. The average number of organisms captured per grab was 26 (52 organisms/ft^2). One possible factor contributing to the low populations is the lack of sufficient detrital material upon which they can feed. Organic material measured by loss on ignition ranged from an average of 1.5 to 9.5 percent by weight for all the bed material sampled (figs. 11 and 12). Benthic-population densities were highest at those stations at the sites that had the highest average percentage of organic material in the bottom material. For example, at site 2 (fig. 11) more organisms (588) were collected at the center station than at either shore station (124 organisms at the exterior shore and 149 organisms at the interior-shore station). The average percent of organic material at the site 2 center station was 8.8; at the shore stations the organic material ranged from an average of 2.2 percent at the exterior shore to 1.5 percent at the interior shore. Similar variations in abundance of benthic organisms and organic material were observed at the other three sites (figs. 11 and 12).

At all sites, the highest benthic-population densities along with the highest percentages of organic material were found at the center stations. However, Chaoborus, (the most abundant benthic organism present at the center stations for sites 1, 2, and 3) feeds in the water column; thus, the previously noted relationship between the abundance of this benthic organism at the center stations and the amount of organic material present in the substrate may not apply to this specific organism. It may be that below certain threshold levels of organic matter in bottom material, factors such as substrate type, dissolved-oxygen concentrations, and depth are more important in determining benthic-invertebrate population sizes than the amount of organic matter present.

Benthic-invertebrate populations fluctuated both seasonally and within sites (table 16, fig. 13). Benthic community composition and abundance of organisms present were similar between the exterior- and interior-shore stations with the exception of the exterior-shore station at site 1 (differed in abundance only). Tubificid worms and chironomid midge-fly larvae were the most abundant and frequently captured organisms at the shore stations. Tubificid worms, including Limnodrilus, Potamothrix, Peloscolex, and Branchiura , occurred in 47 of 48 shore samples collected and accounted for 65 percent of the organisms collected at these sites. Chironomid midge-flies, including Cryptochironomus, Procladius, Polypedilum, and Cladotanytarsus occurred in 81 percent of the shore samples and accounted for 32 percent of the organisms collected at these stations. Other organisms collected at the shore stations included clams, beetle larva, aquatic mites, mayflies, and dragonflies. Benthic-population densities were highest at the interior-shore stations during February 1981 and June and October 1982. Population densities ranged from a low of 6 organisms/ft^2 at the site 2 interior station in October 1980 to a high of 130-136 organisms/ft^2 at sites 1, 2, and 3 in February 1981. Benthic-invertebrate populations showed similar fluctuations at all three interior stations (fig. 13), suggesting similar environmental conditions at the three stations. Benthic populations at the exterior stations also fluctuated in a similar fashion with the exception of the site 1 station. Populations were much reduced here and had an average population of 6 organisms/ft^2 compared to 32 and 42 organisms/ft^2 for stations at sites 2 and 3. Maximum population densities were 30, 72, and 102 organisms/ft^2, respectively, for sites 1, 2, and 3.

Table 16.--Composition of benthic-invertebrate communities in Lake Bruin, June 1980 through October 1982

[n, total number of organisms per sample; percentage of total sample by genera]

June 25, 1980					
Site 1					
n = 11		n = 31		n = 15	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	64	Chaoborus------	84	Unidentified tubificidae.	47
		Chironomus-----	16		
Procladius--------	18			Limnodrilus------	13
Cryptochironomus-	9			Microchironomus--	13
Total taxa----	5	2		6	
Site 2					
n = 7		n = 19		n = 6	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	71	Unidentified tubificidae.	5	Unidentified tubificidae.	67
Limnodrilus------	29	Limnodrilus----	5	Cryptochironomus-	16
		Chaoborus------	90	Tanytarsus-------	16
Total taxa----	2	3		3	
Site 3					
n = 14		n = 10		n = 12	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	57	Unidentified tubificidae.	40	Unidentified tubificidae.	50
Limnodrilus------	14	Chaoborus------	50	Limnodrilus------	8
Polypedilum------	21	Procladius-----	10	Hexagenia--------	8
Cryptochironomus-	7			Cladotanytarsus--	17
				Procladius-------	8
				Nanocladius------	8
Total taxa----	4	3		6	

Table 16.--Composition of benthic-invertebrate communities in Lake Bruin, June 1980 through October 1982--Continued

October 30, 1980					
Site 1					
n = 12		n = 50		n = 1	
Interior	Percent	Center	Percent	Exterior	Percent
Limnodrilus------	25	*Chaoborus*------	96	*Chaoborus*--------	100
Unidentified tubificidae.	17	*Tanypus*--------	2		
Cladotanytarsus--	25	*Limnodrilus*----	2		
Procladius-------	8				
Total taxa----	7	3		1	
Site 2					
n = 3		n = 50		n = 18	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	33	*Chaoborus*------	98	Unidentified tubificidae.	22
Limnodrilus------	33	Unidentified tubificidae.	2	*Limnodrilus*------	6
Piona-----------	33			*Cladopelma*-------	17
				Cladotanytarsus--	17
				Microchironomus--	17
Total taxa----	3	2		8	
Site 2					
n = 5		n = 17		n = 4	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	40	Unidentified tubificidae.	47	Unidentified tubificidae.	50
Potamothrix------	20	*Potamothrix*----	29	*Cryptochironomus*-	50
Aulodrilus-------	20	*Limnodrilus*----	12		
Cryptochironomus-	20	*Chaoborus*------	12		
Total taxa----	4	4		2	

Table 16.--Composition of benthic-invertebrate communities in Lake Bruin, June 1980 through October 1982--Continued

February 25, 1981					
Site 1					
n = 65		n = 19		n = 1	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	68	Chironomus-----	89	Unidentified chironomidae.	100
Limnodrilus------	8	Procladius-----	5		
Chaoborus--------	12	Unidentified tubificidae.	5		
Total taxa----	8	3		1	
Site 2					
n = 68		n = 231		n = 29	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	69	Chaoborus------	86	Unidentified tubificidae.	38
Limnodrilus------	10	Chironomus-----	5	Potamothrix------	28
Potamothrix------	3	Unidentified tubificidae.	3	Chironomus-------	7
Dubiraphia-------	3			Cryptochironomus-	14
Chironomus-------	3				
Cryptochironomus-	3				
Procladius-------	3				
Total taxa----	11	8		8	
Site 3					
n = 68		n = 49		n = 27	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	56	Unidentified tubificidae.	27	Unidentified tubificidae.	74
Potamothrix------	19	Potamothrix----	8	Limnodrilus------	4
Limnodrilus------	3	Chaoborus------	6	Polypedilum------	7
Chironomus-------	6	Chironomus-----	53	Cryptochironomus-	4
Cryptochironomus-	4	Procladius-----	6	Cladotanytarsus--	4
Polypedilum------	4			Procladius-------	4
Total taxa----	10	5		7	

Table 16.--Composition of benthic-invertebrate communities in Lake Bruin, June 1980 through October 1982--Continued

June 26, 1981					
Site 1					
n = 20		n = 46		n = 3	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	50	Chaoborus-----	93	Unidentified tubificidae.	67
Limnodrilus------	15	Unidentified tubificidae.	7	Potamothrix------	33
Polypedilum------	15				
Procladius-------	10				
Total taxa----	6	2		2	
Site 2					
n = 14		n = 33		n = 9	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	64	Chaoborus-----	45	Unidentified tubificidae.	11
Branchiura-------	7	Unidentified tubificidae.	48	Cladotanytarsus-	44
Cryptochironomus-	14	Limnodrilus---	2	Cryptochironomus-	33
Polypedilum------	14			Unidentified sphaeridae.	11
Total taxa----	4	3		4	
Site 3					
n = 8		n = 74		n = 8	
Interior	Percent	Center	Percent	Exterior	Percent
Branchiura-------	12	Unidentified tubificidae.	23	Branchiura-------	12
Limnodrilus------	12	Limnodrilus----	3	Limnodrilus------	25
Unidentified tubificidae.	50	Chaoborus------	68	Unidentified tubificidae.	38
Cryptochironomus-	12	Procladius-----	6	Chironomus-------	12
Bezzia, Probezzia gp.	12			Polypedilum------	12
Total taxa----	5	4		5	

Table 16.--Composition of benthic-invertebrate communities in Lake Bruin, June 1980 through October 1982--Continued

October 28, 1981

Site 1

n = 11		n = 12		n = 8	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	45	Potamothrix----	50	Unidentified tubificidae	12
Limnodrilus------	27	Limnodrilus----	8	Neocleon---------	12
Cryptochironomus-	18	Chironomus-----	33	Bezzia Probezzia gp.	12
Cladopelma-------	9	Procladius-----	8	Tanytarsus-----	25
				Cryptochironomus-	12
				Cladotanytarsus--	12
Total taxa----	4	4		7	

Site 2

n = 14		n = 39		n = 20	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	21	Unidentified tubificidae.	10	Branchiura-------	10
Limnodrilus------	21	Chaoborus------	90	Peloscolex-------	30
Polypedilum------	29			Cladotanytarsus--	25
Peloscolex-------	7			Cryptochironomus-	15
Cryptochironomus-	7			Procladius-------	15
Cladotanytarsus--	7				
Total taxa----	7	2		6	

Site 3

n = 10		n = 10		n = 26	
Interior	Percent	Center	Percent	Exterior	Percent
Limnodrilus------	40	Limnodrilus----	20	Limnodrilus------	15
Potamothrix------	10	Potamothrix----	10	Peloscolex-------	4
Unidentified tubificidae.	10	Inidentified tubificidae.	10	Unidentified tubificidae.	65
Polypedilum------	40	Chironomus-----	50	Cladopelma-------	4
		Procladius-----	10	Polypedilum------	8
Total taxa----	4	5		6	

Table 16.--Composition of benthic-invertebrate communities in Lake Bruin, June 1980 through October 1982--Continued

March 10, 1982

Site 1

n = 26		n = 47		n = 3	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	57	Potamothrix	49	Limnodilus	33
Limnodrilus	12	Limnodrilus	9	Diplogaster	33
Cryptochironomus	23	Unidentified tubificidae.	11	Polypedilum	33
		Chaoborus	9		
		Chironomus	21		
Total taxa	5	6		3	

Site 2

n = 7		n = 135		n = 2	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	29	Unidentified tubificidae.	9	Unidentified tubificidae.	100
Cryptochironomus	43	Potamothrix	10		
Chironomus	14	Chaoborus	51		
Procladius	14	Chironomus	27		
Total taxa	4	6		1	

Site 3

n = 27		n = 31		n = 9	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	63	Unidentified tubificied.	10	Unidentified tubificied.	56
Limnodrilus	7	Potamothrix	42	Limnodrilus	11
Polypedilum	11	Chaoborus	3	Cryptochironomus	22
Microchironomus	7	Chironomus	26	Polypedilum	11
Cryptochironomus	7	Cryptochironomus	6		
		Procladius	6		
Total taxa	6	8		4	

Table 16.--Composition of benthic-invertebrate communities in Lake Bruin, June 1980 through October 1982--Continued

June 23, 1982					
Site 1					
n = 42		n = 59		n = 6	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	81	*Chaoborus*	97	*Branchiura*	50
Limnodrilus	2	*Chironomus*	2	Unidentified tubificidae.	33
Cladotanytarsus	7	Unidentified tubificidae.	1	*Cladopelma*	17
Procladius	5				
Total taxa	6	3		3	
Site 2					
n = 26		n = 23		n = 9	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	58	Unidentified tubificidae.	48	Unidentified tubificidae.	11
Dubiraphia	4	*Limnodrilus*	17	*Limnodrilus*	22
Cryptochironomus	23	*Chaoborus*	26	*Chaoborus*	11
Polypedilum	12	*Chironomus*	8	*Cladotanytarsus*	11
				Polypedilum	22
Total taxa	5	4		7	
Site 3					
n = 35		n = 5		n = 51	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	49	*Limnodrilus*	60	*Potamothrix*	6
Limnodrilus	14	*Chaoborus*	20	Unidentified tubificidae.	80
Cryptochironomus	11	*Procladius*	20	*Polypedilum*	4
Procladius	9				
Polypedilum	9				
Total taxa	8	3		8	

Table 16.--Composition of benthic-invertebrate communities in Lake Bruin, June 1980 through October 1982--Continued

October 27, 1982					
Site 1					
n = 65		n = 5		n = 7	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	54	Chaoborus------	100	Unidentified tubificidae.	29
Potamothrix------	32			Procladius-------	29
Limnodrilus------	5			Chaoborus--------	14
Cryptochironomus-	3			Coelotanypus-----	14
Total taxa----	8	1		5	
Site 2					
n = 10		n = 45		n = 36	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	10	Unidentified tubificidae.	22	Unidentified tubificidae.	19
Limnodrilus------	10	Potamothrix----	22	Limnodrilus------	5
Potamothrix------	10	Limnodrilus----	13	Dubiraphia-------	14
Cryptochironomus-	50	Chaoborus------	42	Cryptochironomus-	22
Chaoborus--------	20			Cladotanytarsus--	11
				Microchironomus--	14
				Sphaerium--------	5
Total taxa---	5	4		10	
Site 3					
n = 17		n = 17		n = 32	
Interior	Percent	Center	Percent	Exterior	Percent
Unidentified tubificidae.	59	Unidentified tubificied.	29	Unidentified tubificied.	53
Chaoborus--------	6	Potamothrix----	53	Potamothrix------	6
Cryptochironomus-	18	Limnodrilus----	6	Limnodrilus------	12
Polypedilum------	12	Chaoborus------	6	Aulodrilus-------	6
		Chironomus-----	6	Cryptochironomus-	9
				Cladopelma-------	6
Total taxa----	5	5		8	

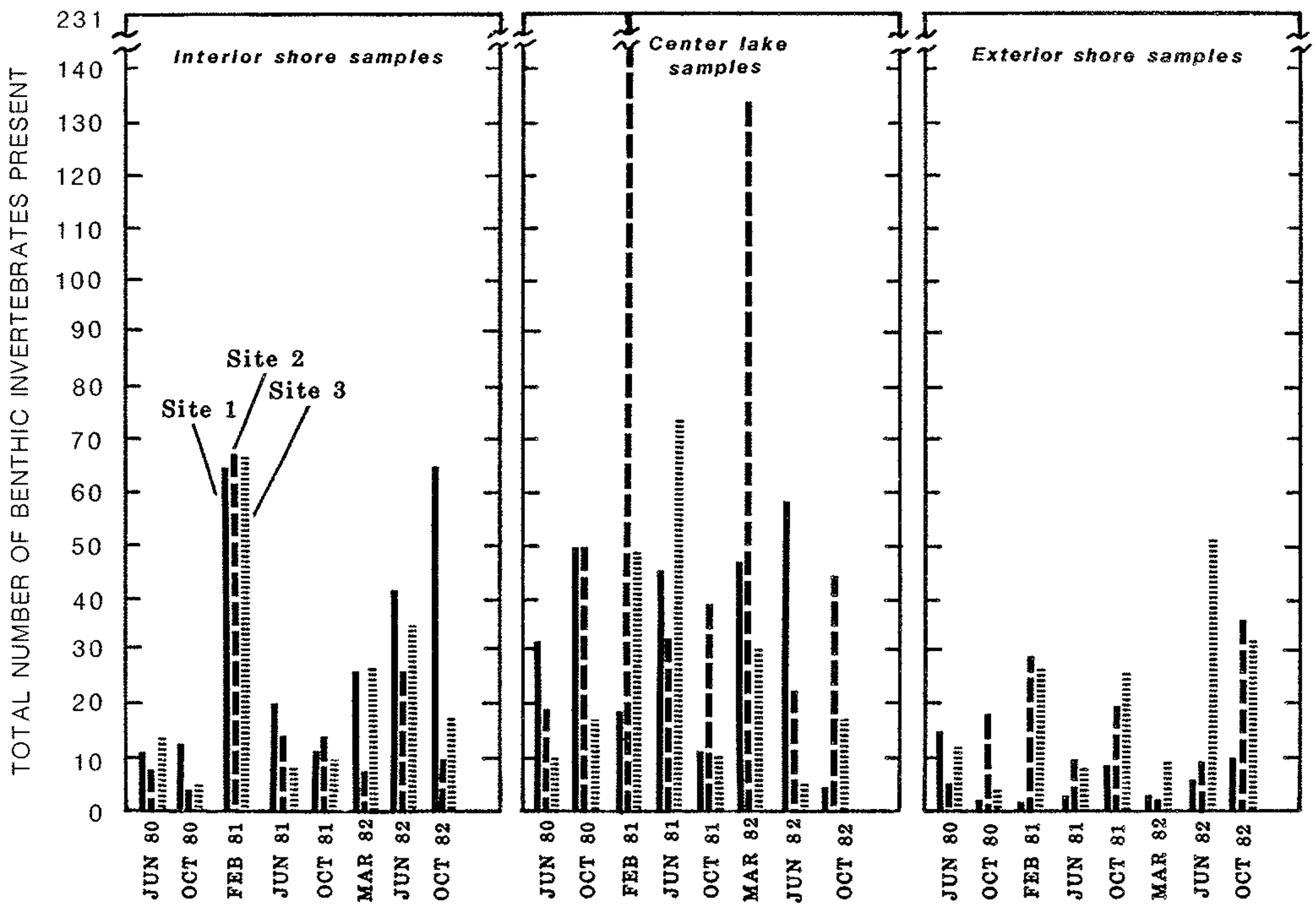

Figure 13.--Benthic-invertebrate populations by site, station, and date, Lake Bruin.

The lower population densities at site 1 compared with sites 2 and 3 may be due to the difference in substrate. Bottom material at site 1 (exterior) was sand; whereas, bottom material at the sites 2 and 3 (exterior) was silt and sand. Substrates composed entirely of sand are difficult to colonize because of their abrasive quality and lack of stability.

Benthic-population densities of the center-lake samples were generally higher than those of the shore samples and ranged from 10 to 108 organisms/ft^2 at site 1, 38 to 562 organisms/ft^2 at site 2, and 10 to 148 organisms/ft^2 at site 3. The mean benthic-population density for all center samples was 88 organisms/ft^2 compared with 48 and 28 organisms/ft^2, respectively, for the interior- and exterior-shore stations.

The shore and center samples also differed in benthic community composition. Chaoborus was the most abundant organism collected at the center stations but was rarely found in shore samples. This organism occurred in 92 percent of all samples collected and accounted for 62 percent of all organisms captured at the center stations. Tubificid worms, including Potamothrix and Limnodrilus, were less abundant in the center than along the shore. Tubificid worms occurred in 92 percent of the center samples and accounted for 23 percent of the organisms captured compared with 98 percent occurrence and 65 percent of the organisms at the shore stations. Chironomid larvae were also less abundant in benthic communities at the center compared to those on the shores. Chironomids, including Chironomus and Procladius, occurred in 63 percent of the samples collected and accounted for 15 percent (versus 32 percent for the shore samples) of all organisms captured at the center stations. Chironomus, rarely found in shore samples, also accounted for 78 percent of all chiromids collected and occurred in 50 percent of the center samples.

The differences between benthic communities at shore and midlake locations appear to be related to differences in substrate type, DO concentrations, and depth.

Benthic invertebrates were collected only twice at site 4 due to low water. Community composition was similar to those at shore stations collected in Lake Bruin; however, due to the few samples collected, no conclusions can be drawn from data other than population densities are low and the organisms present are facultative to tolerant of organic wastes.

Anacystis, a blue-green algae, occurred in numerous benthic samples (15) collected during the study. It was found near shore and at the center stations, in water as deep as 53 ft, in apparently healthy condition. What this algae feeds on or uses as an energy source and its significance to the benthic community is not known at this time and needs further study.

Eutrophication and Productivity

Eutrophication can be defined as the natural or artificial enrichment of a body of water and the associated effects of these added nutrients on the biological, chemical, and physical properties of the water body (National Academy of Sciences, 1970). Eutrophication can produce an array of undesirable symptomatic changes in the water body, including an increased production of algae and macrophytes, and deterioration of fisheries and water quality. These changes can interfere significantly with water uses (Bartsch, 1972). Eutrophication constitutes the natural aging process of lakes. A body of water may become eutrophic through natural processes, with little assistance from man. It is the artificial enrichment ("cultural eutrophication") and subsequent acceleration of this aging process that results from man's development of a drainage basin that has caused the term eutrophic to become synonymous with "pollution" in the eyes of the public.

Trophic conditions of lakes are characterized by several physical and biological factors, including algal types, algal concentrations (bloom conditions), high chlorophyll a concentrations, Secchi-disk depth and light penetration, total phosphorus concentrations, inorganic nitrogen concentrations, benthic-invertebrate fauna, hypolimnetic-oxygen depletion, and productivity (Rast and Lee, 1978; Taylor and others, 1980; Jones and Lee, 1982). Summaries of the expected changes in these factors resulting from the eutrophication of a water body and the levels of these factors in eutrophic lakes are provided in tables 17 and 18.

On the basis of some of these characteristics, data in table 19 suggest Lake Bruin is in a eutrophic condition. For example, only 1 of 42 phytoplankton samples (2 percent) had algae concentrations less than those listed as being typical for eutrophic lakes.

Chlorophyll a concentrations at the three Lake Bruin sites ranged from 2.6 to 30.0 μg/L for all samples. Mean concentrations were 12 μg/L, 13 μg/L, and 14 μg/L for sites 1, 2, and 3, respectively, corresponding to the eutrophic boundary value in table 17. Chlorophyll a values exceeded the 12 μg/L threshold value for eutrophic lakes listed by the U.S. Environmental Protection Agency (Taylor and others, 1980) for all sampling months except February; however, 48 percent of all Lake Bruin chlorophyll a samples were below the threshold value.

Secchi-disk readings for eutrophic lakes are typically less than 2 m in depth. All Secchi-disk readings taken in Lake Bruin were less than 2 m in depth (table 19). Mean readings were 1.09 m, 1.21 m, and 0.99 m for sites 1, 2, and 3, respectively. There appeared to be little correlation between Secchi-disk readings and total phytoplankton numbers; however, other factors such as suspended solids appear to have masked the relationship. Future lake studies need to investigate the relation between total phytoplankton counts and Secchi-disk readings in southern waters and determine how accurately the readings predict phytoplankton numbers; great savings in resources can be achieved by using this relatively simple test. (Turbidity was monitored in Lake Bruin and never exceeded 5 nephelometric turbidity units during the study period.)

Table 17.--Characteristics of eutrophic lakes

[From Taylor and others, 1980. milligrams per liter, mg/L; grams per cubic meter per day, $(g/m^3)/d$; meters, m; micrograms per liter, µg/L]

Characteristic	Approximate boundary value for eutrophic lakes
Inorganic phosphorus	0.01-0.015 mg/L.
Total phosphorus	.02- .03 mg/L.
Inorganic nitrogen	.30 mg/L.
Primary productivity	> .75 $(g/m^3)/d$.
Hypolimnetic dissolved-oxygen percent saturation.	< 10
Secchi disk depth	< 2-3 m.
Chlorophyll *a*	> 6.4, [a]>10.0, [a]>8.8, [b]>12.0 µg/L.
Algal assay control yield	0.81-20.0 mg/L.
Phytoplankton concentration	>15,000 1,000 when blue-green algae are dominant. >5,000 when blue-green algae are not dominant.
Phytoplankton types	Diatoms--Melosia *Cyclotella rana*. Blue-greens--*Anabaena* *Aphanizomenon* *Oscillatoria rubescens*.
Bottom fauna	Chironomids.

[a] In lakes not dominated by macrophytes.

[b] Level used by U.S. Environmental Protection Agency.

Phosphorous and nitrogen are considered to be the potentially growth limiting macronutrients used by phytoplankton for growth in aquatic systems. In most freshwater systems, phosphorus is the macronutrient limiting the maximum potential biomass. In some eutrophic systems, however, nitrogen is the limiting nutrient (Rast and Lee, 1978).

In Lake Bruin total phosphorus concentrations ranged from a minimum of 0.02 mg/L at site 2 to a maximum of 0.09 mg/L at site 3. Mean total phosphorus concentrations at sites 1, 2, and 3 were 0.05 mg/L, 0.04 mg/L, and 0.05 mg/L, respectively. Total phosphorus concentrations exceeding 0.02 to 0.03 mg/L are considered to be symptomatic of eutrophic lakes (table 17). Of a total of 39 total phosphorus samples collected at the three Lake Bruin sites, only one was less than 0.03 mg/L, suggesting that phosphorus was present in concentrations indicative of eutrophic conditions for the entire study period.

Table 18.--Trophic criteria and their responses in eutrophic lakes

[I, values increase with eutrophication; D, values decrease with eutrophication. Adapted from Brezonik, 1969, and Taylor and others, 1980]

Physical	Chemical	Biological[1]
Transparency (D) (Secci-disc reading).	Nutrient concentrations (I) (for example at spring maximum).	Algal bloom frequency (I).
Morphometry (D) (mean depth).	Chlorophyll *a* (I)	Algal species diversity (D).
Suspended solids (I)	Conductivity (I)	Littoral vegetation[2] (I).
	Dissolved solids (I)	Zooplankton (I).
	Hypolimnetic oxygen deficit (I).	Fish (I).
	Epilimnetic oxygen supersaturation (I).	Bottom fauna[3] (I).
	Sediment type	Bottom fauna diversity (D).
		Primary production (I).

[1] Biological criteria all have important qualitative changes, such as species changes as well as quantitative (biomass) changes as eutrophication proceeds.

[2] Littoral vegetation may decrease in the presence of high phytoplankton densities.

[3] Bottom fauna may decrease in numbers in hypolimnetic waters with high concentrations of H_2S (hydrogen sulfide), CH_4 (methane), and CO_2 (carbon dioxide), or low concentrations of O_2 (oxygen).

Inorganic nitrogen, nitrite (NO_2) + nitrate (NO_3) + ammonia (NH_4), occurred in concentrations ranging from 0.02 to 0.52 mg/L for all lake sites. Lowest concentrations of inorganic nitrogen were found during May-August samplings (table 19). Mean concentrations of inorganic nitrogen at the three Lake Bruin sites were 0.25 mg/L at site 1, 0.22 mg/L at site 2, and 0.27 mg/L at site 3. Twenty-two of 39 nutrient samples collected from Lake Bruin, had concentrations of inorganic nitrogen below the eutrophic boundary value of 0.30 mg/L (table 17). This is significant because inorganic nitrogen was frequently present (56 percent of the time) in concentrations below those believed typical of euthrophic lakes. This suggests nitrogen may be a limiting factor during some periods of the year. This is further substantiated by comparisons of N:P mass ratios calculated using available forms of nitrogen (inorganic nitrogen, including nitrite + nitrate and ammonia as N) and phosphorus (dissolved orthophosphorus as P) with total phytoplankton present and the different classes of phytoplankton that compose the algal community (figs. 14 and 15). According to Rast and Lee (1978), Chiaudani and Viglis in 1974, using Selenastrum cultures, indicated that nitrogen was the limiting nutrient for N:P mass ratios below 5:1. For N:P ratios of 10:1 or greater, phosphorus was limiting. Phosphorus and nitrogen could be limiting at N:P mass ratios between 5 and 10 although a wider range in N:P ratios has been observed in laboratory studies. Rast and Lee (1978) suggested an N:P mass ratio of 7-8:1 as the

Table 19.--Phytoplankton populations, nitrogen-phosphorus ratios, Secchi-disk readings, chlorophyll concentrations, algal growth potential, total phosphorus, and dissolved inorganic nitrogen from three sites in Lake Bruin

[Phytoplankton and algal groups are in cells per milliliter. Micrograms per liter, µg/L; milligrams per liter, mg/L]

Date	Phytoplankton (Total number present)	Blue-green algae (Total number present)	Diatoms (Total number present)	Green algae (Total number present)	Nitrogen-phosphorus ratio	Secchi Disk, (cm)	Chlorophyll A (µg/L)	Chlorophyll B (µg/L)	Algal-growth[a] potential (mg/L)	Phosphorus, total as P (mg/L)	Nitrogen, inorganic, dissolved as N (NO_2+ NO_3+NH_4) (mg/L)
Site 1											
6-25-80	190,000	190,000	-----	------	[b]35.7/1	---	9.9	0.4	0.5	0.07	0.03
8-20-80	590,000	590,000	-----	------	[b]29.4/1	110	7.6	<.1	2.2	.05	.22
10-30-80	82,000	79,000	1,100	700	7.2/1	106	21	5.0	----	.06	.32
1- 6-81	15,000	7,500	5,900	1,100	20.3/1	---	19	2.4	----	.05	.45
2-25-81	2,700	1,000	920	720	[b]14.5/1	88	2.6	<.1	13	.07	.32
4- 3-81	16,000	12,000	520	2,400	3.2/1	140	8.9	<.1	.3	.04	.21
6-24-81	550,000	550,000	-----	------	6.3/1	112	10	<.1	5.1	.04	.19
8-27-81	130,000	120,000	-----	2,100	4.5/1	95	16	<.1	.3	.07	.30
10-28-81	170,000	160,000	950	9,200	[b]5.9/1	104	15	1.8	----	.03	.13
12-30-81	31,000	15,000	8,300	7,600	[b]20.8/1	93	7.5	2.0	----	.04	.46
3-10-82	9,300	840	7,200	1,200	19.4/1	---	6.7	<.1	.3	.05	.43
5- 6-82	19,000	5,300	3,200	11,000	[b]2.3/1	130	16	2.3	<1	.04	.05
6-22-82	240,000	240,000	-----	3,300	4.1/1	115	7.6	<.1	<1	.04	.09
10-27-82	320,000	300,000	2,400	16,000	-------	110	24	<.1	<1	----	----
Site 2											
6-25-80	280,000	270,000	-----	------	[b]3.2/1	---	19	1.3	0.5	0.02	0.07
8-20-80	260,000	260,000	-----	------	[b]2.7/1	150	6.8	<.1	6.2	.04	.04
10-30-80	60,000	58,000	710	------	[b]8.1/1	97	20	5.1	----	.03	.18
1- 6-81	11,000	4,600	3,700	2,600	16.7/1	---	15	2.0	5.4	.05	.37
2-25-81	1,800	440	740	540	14.5/1	87	8.3	<.1	.5	.07	.32
4-23-81	7,000	3,500	430	1,000	3.0/1	135	30	<.1	.3	.04	.20
6-24-81	740,000	730,000	-----	------	2.0/1	128	9.1	<.1	2.8	.04	.09
8-27-81	170,000	160,000	-----	9,600	10.6/1	105	15	1.0	----	.06	.47
10-28-81	140,000	140,000	-----	2,000	[b]7.7/1	110	5.2	<.1	11	.04	.17
12-30-81	27,000	17,000	2,500	7,300	[b]20.3/1	130	10	<.1	.2	.03	.45
3-10-82	16,000	7,300	5,700	1,200	18.1/1	---	19	<.1	.6	.06	.40
5- 6-82	40,000	33,000	1,900	4,100	[b]2.7/1	170	12	<.1	<1	.03	.06
6-22-82	150,000	150,000	980	------	[b]2.3/1	120	6.8	<.1	<1	.03	.05
10-27-82	14,000	10,000	640	13,000	-------	100	11	<.1	2	----	----
Site 3											
6-25-80	220,000	210,000	1,800	1,800	[b]0.9/1	---	25	1.5	0.9	0.09	0.02
8-20-80	400,000	400,000	-----	------	[b]2.3/1	100	8.3	<.1	2.1	.04	.05
10-30-80	61,000	58,000	550	1,200	2.7/1	101	25	7.0	----	.04	.12
1- 6-81	16,000	5,900	8,500	1,300	[b]17.2/1	---	20	3.2	5.6	.05	.38
2-25-81	5,200	730	2,400	1,900	21.7/1	92	2.5	<.1	4.1	.08	.48
4-23-81	11,000	8,300	790	1,300	1.2/1	110	18	<.1	.3	.05	.13
6-24-81	710,000	710,000	-----	------	7.5/1	75	10	<.1	5.0	.04	.33
8-27-81	210,000	200,000	-----	11,000	11.8/1	80	20	2.0	.6	.07	.52
10-28-81	330,000	320,000	-----	5,400	5.2/1	102	13	1.1	1.1	.05	.23
12-30-81	33,000	17,000	7,500	7,000	[b]15.8/1	75	14	<.1	.7	.04	.35
3-10-82	13,000	5,300	6,700	930	10.9/1	---	6.3	<.1	.3	.05	.48
5- 6-82	19,000	13,000	2,000	3,300	[b]9.5/1	120	13	<.1	<1	.03	.21
6-22-82	370,000	370,000	-----	------	[b]11.8/1	120	9.6	<.1	<1	.04	.26
10-27-82	200,000	190,000	-----	4,400	-------	110	17	<.1	2	----	----

[a] Lowest detection level was changed to 1, April 1982.
[b] Value based on calculation using lowest limit of detection value of dissolved orthophosphorus, as P.

Table 20.--Gross and net primary productivity and respiration at three sistes in Lake Bruin

[Gross primary productivity, GP; net primary productivity, NP; respiration, R; in milligrams of oxygen per cubic meter per day]

Date	Surface			6.6 feet			13.2 feet			16.5 feet			19.8 feet			26.4 feet			39.6 feet		
	GP	NP	R	GP	NP	R	GP	NP	R	GP	NP	R	GP	NP	R	GP	NP	R	GP	NP	R
Site 1																					
6-25-80	2.6	0.6	2.0	0.7	---	1.3	0.1	---	1.2	---	---	---	0.0	---	0.9	0.0	---	0.8			
9-25-80	1.2	---	1.4	.3	---	1.2	.3	---	.9	.0	---	0.6	.0	---	.0	---	---	---			
1- 5-81	.6	.5	.1	.0	---	.0	.0	---	.0	.0	---	.0	---	---	---	---	---	---			
4-22-81	.9	---	1.7	.3	---	1.6	.2	---	1.2	.1	---	1.1	---	---	---	---	---	---			
6-24-81	3.8	2.8	1.0	1.8	0.8	1.0	.7	---	.8	.0	---	.8	---	---	---	---	---	---			
8-26-81	1.4	.7	1.2	1.0	---	1.3	.2	---	1.3	.0	---	1.3	---	---	---	---	---	---			
12-30-81	1.3	.7	.6	.3	---	.6	.0	---	.8	.1	---	.8	---	---	---	---	---	---			
3- 9-82	.8	.6	.2	.0	---	.2	.1	---	.2	.2	---	.4	---	---	---	---	---	---			
5-11-82	2.0	1.6	.4	1.0	.7	.3	.3	---	.3	.1	---	.3	.1	---	.3	---	---	---			
6-22-82	1.3	.9	.4	.8	.4	.4	.1	---	.4	.1	---	.6	.0	---	.6	---	---	---			
10-27-82	1.7	1.1	.6	.5	---	1.3	.1	---	1.3	.0	---	1.5	---	---	---	---	---	---			
Site 2																					
6-25-80	1.4	---	2.0	0.9	---	1.8	0.1	---	1.5				0.1	---	1.5	0.0	---	1.4	---	---	---
9-25-80	.5	0.5	.0	.0	---	.0	.0	---	.0				.0	---	.0	.0	---	.0	0.0	---	0.0
1- 5-81	.9	.6	.3	.5	.3	.2	.2	---	.3				.0	---	.0	.0	---	.0	.0	---	.0
4-22-81	.8	---	1.5	.3	---	1.6	.3	---	1.5				.0	---	1.5	.0	---	1.0	.0	---	.8
6-24-81	2.8	1.6	1.2	1.8	.6	1.2	.7	---	1.2				.3	---	1.2	.0	---	.9	.0	---	.7
8-26-81	2.1	1.3	.8	.8	---	.9	.0	---	.9				.0	---	.9	.0	---	.9	.0	---	.7
12-30-81	.7	.4	.3	.2	---	.4	.1	---	.5				.2	---	.6	.2	---	.6	.1	---	.4
3- 9-82	.8	.1	.7	.0	---	.7	.1	---	.8				.1	---	.8	.1	---	.7	.2	---	.7
5-11-82	1.1	.7	.4	.7	.4	.3	.3	---	.3				.2	---	.3	.0	---	.3	.0	---	.2
6-22-82	.8	---	1.2	.7	---	1.1	.3	---	1.0				.0	---	.8	.0	---	.6	.0	---	.6
10-27-82	.7	---	1.4	.1	---	1.4	.0	---	1.2				.0	---	1.4	.0	---	1.4	.0	---	1.4
Site 3																					
6-25-80	3.6	2.5	1.1	0.8	---	1.1	0.0	---	1.0	---	---	---									
9-25-80	.2	.1	.1	.1	.1	.0	.0	---	.0	.0	---	0.0									
1- 5-81	.7	.6	.1	.4	.2	.2	.2	---	.2	.1	---	.2									
4-22-81	1.4	---	1.8	.6	---	1.8	.8	---	1.8	.0	---	1.6									
6-24-81	1.9	.4	1.5	.3	---	1.5	.0	---	1.5	.0	---	1.4									
8-26-81	1.6	.8	.8	.6	---	.8	.1	---	.8	.0	---	.8									
12-30-81	1.2	.4	.8	.4	---	.9	.0	---	.7	.0	---	.7									
3- 9-82	.6	.1	.5	.0	---	.4	.0	---	.5	.0	---	.5									
5-11-82	1.2	.6	.6	.6	---	.6	.2	---	.6	.1	---	.5									
6-22-82	1.2	---	1.3	.4	---	1.1	.2	---	1.3	.2	---	1.3									
10-27-82	1.7	1.1	.6	.5	---	1.3	.1	---	1.3	.0	---	1.5									

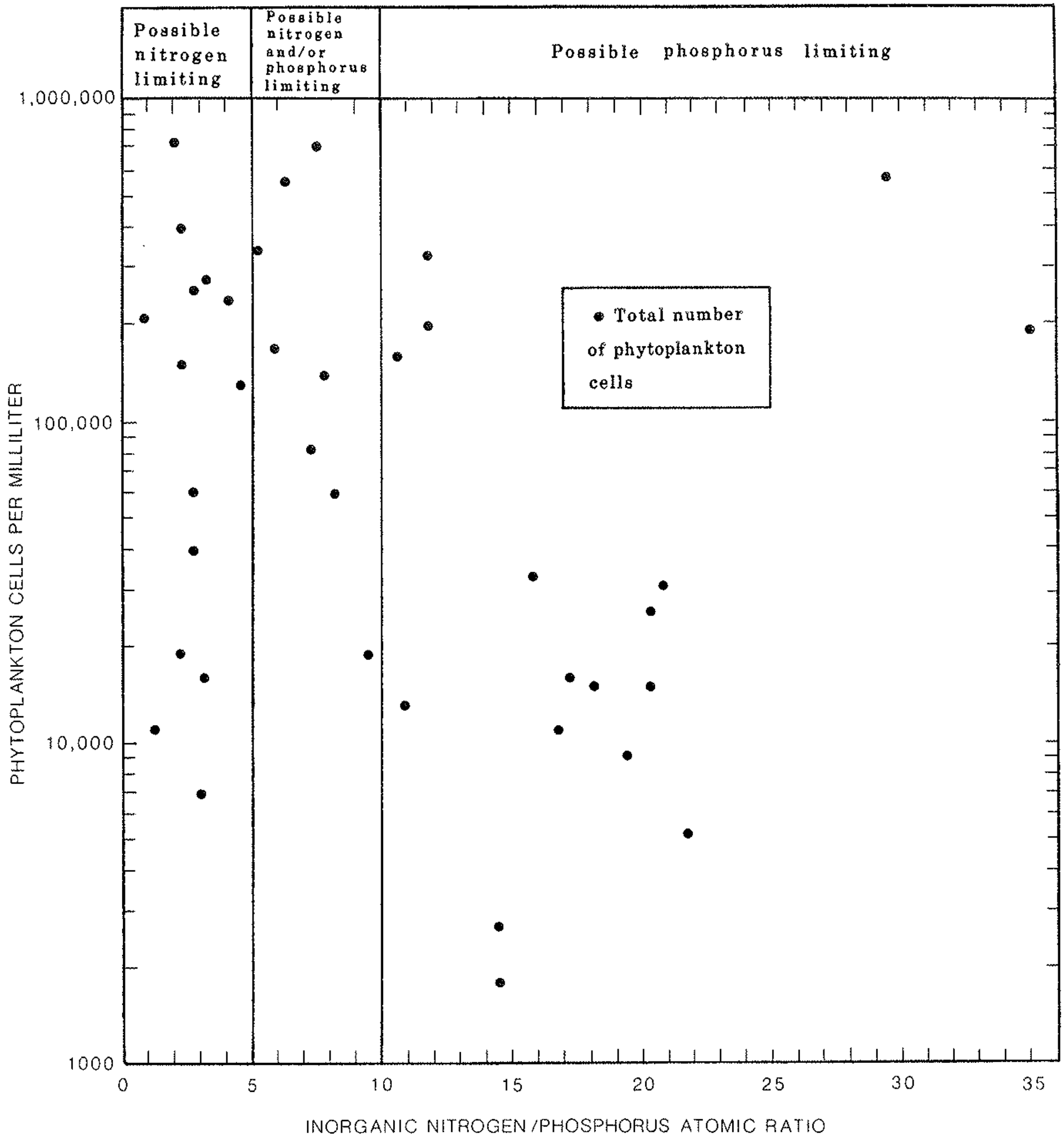

Figure 14.--Variation in Lake Bruin phytoplankton numbers versus nitrogen-phosphorus ratios.

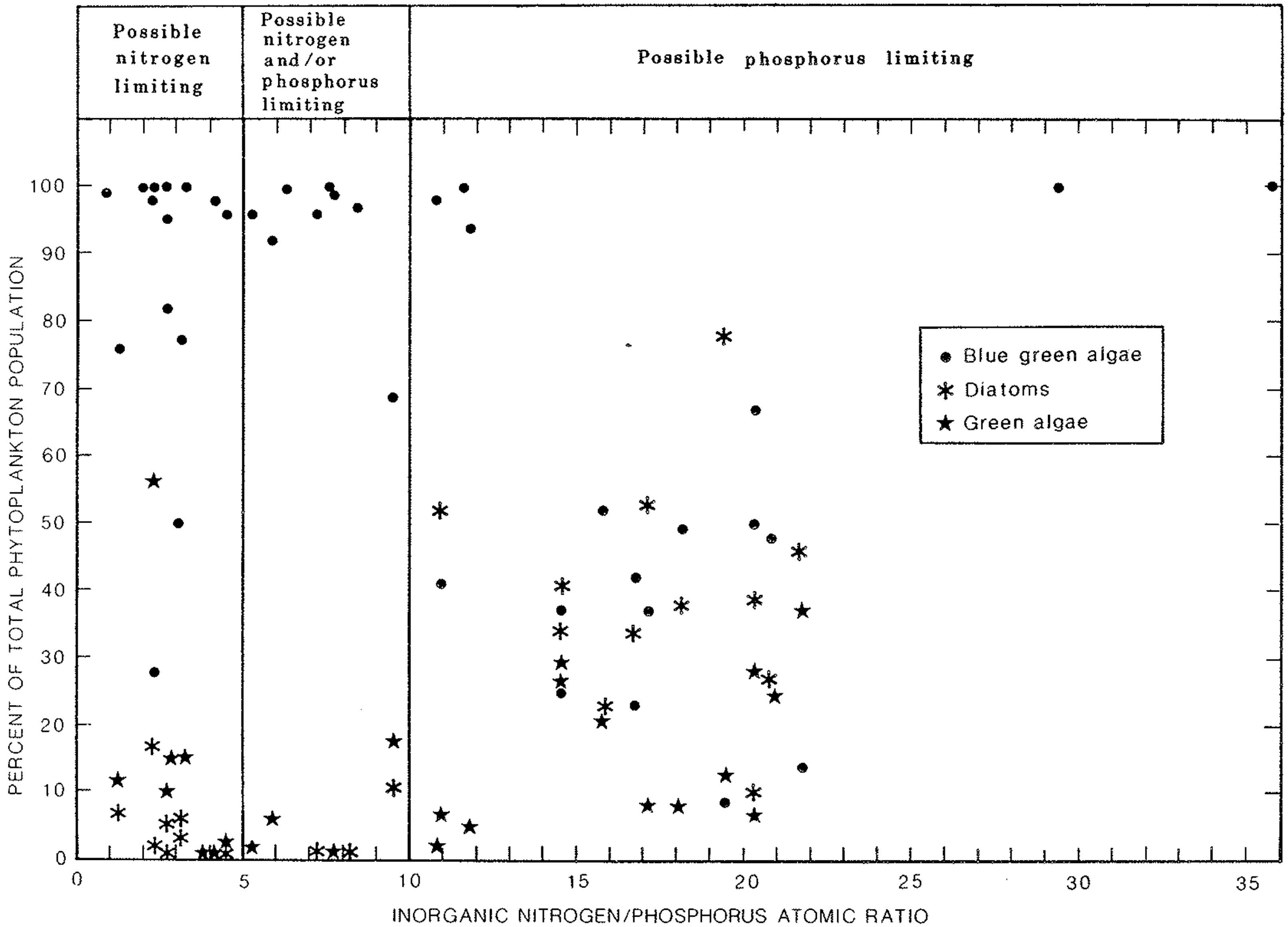

Figure 15.--Variation in Lake Bruin phytoplankton community composition versus nitrogen-phosphorus ratios.

critical boundary value corresponding to Redfields idealized N:P atomic ratio of 16:1. On the basis of a boundary N:P mass ratio ranging from 5-10, 44 percent of the phytoplankton samples from Lake Bruin were potentially phosphorus limited; 36 percent were potentially nitrogen limited; and 20 percent could be limited by either or both nutrients (fig. 14). If Rast and Lee's critical boundary N:P mass ratio of 7-8:1 is used, 49 percent of the Lake Bruin samples show potential phosphorus limitation, 44 percent show potential nitrogen limitation, and 7 percent could be limited by either or both nutrients.

Comparisons of N:P mass ratios with percent composition of the phytoplankton populations yielded interesting, though not unexpected, results (fig. 15). When N:P mass ratios suggested nitrogen limitation, blue-green algae averaged 87 percent of the phytoplankton population. Blue-green algae accounted for 90 percent or more of the phytoplankton community in about 71 percent of the samples collected. Blue-green algae were much less abundant when phosphorus was the potential limiting nutrient. During such conditions, blue-green algae accounted for 50 percent or less of the total population in about 53 percent of the samples collected. Diatoms and green algae were the dominant phytoplankton during times of potential phosphorus limitation. Diatoms accounted for about 35 percent of the phytoplankton community when phosphorus was the potential limiting nutrient, compared to only 5 percent when nitrogen was the potential limiting nutrient. Dominance by blue-green algae during times of potential nitrogen limitation is probably due in part to the ability of blue-green algae to fix atmospheric nitrogen in the forms usable for metabolism (Ruttner, 1963).

Although N:P mass ratio calculations offer potential for predicting whether nitrogen or phosphorus is the controlling factor for phytoplankton growth in Lake Bruin, some caution is necessary in interpreting the results. In September 1982, nutrients and AGP (algal-growth potential) samples were collected from the surface and the hypolimnion at site 2 in Lake Bruin. Algal-growth potential determinations were run on unaltered lake water and lake water spiked with nitrogen or phosphorus. Results were the following:

	Surface	Bottom
N:P ratio--------------	2.26:1	2.59:1
AGP unspiked-----------	1.0 mg/L	1.0 mg/L
AGP spiked with N------	1.0 mg/L	5.0 mg/L
AGP spiked with P------	8.0 mg/L	24.0 mg/L

N:P mass ratios suggest nitrogen limitation of phytoplankton growth while AGP data suggest phosphorus limitation. Other factors that limit interpretation of these data include extremely high available nitrogen and phosphorus concentrations in the hypolimnetic samples (1.65 mg/L inorganic nitrogen, 0.29 mg/L dissolved orthophosphorus as P), different algae used in the AGP culture tests than normally found in Lake Bruin, and lack of phytoplankton analyses for comparison with nutrient data. Nutrient limitation in Lake Bruin is clearly a topic requiring further study because such knowledge is important in assessing proper management strategies in lake restoration projects.

Primary productivity and hypolimnetic-oxygen depletion are also important indicators of the trophic condition of a lake. Lakes with primary productivity rates exceeding 0.75 gram of carbon or oxygen per square meter per day and hypolimnetic dissolved-oxygen saturation levels of less than 10 percent are considered eutrophic (Taylor and others, 1980). Dissolved oxygen and temperature were monitored on a diel and seasonal basis to help define productivity in Lake Bruin (figs. 16-27) and were found to vary by site, depth, season, and temperature, especially near the bottom. Percent saturation of dissolved oxygen near the bottom at site 1 ranged from 30 percent in the spring to 0.02 percent in the summer, 64 percent in the fall, and 99 percent in the winter. At site 2, the only site with a pronounced summer thermocline, oxygen saturation near the bottom was 6 percent in the spring, 2 percent in the summer, 4 percent in the fall, and 87 percent in the winter. The percent satuaration of dissolved oxygen at site 3 near the bottom was 21 percent in the spring, 35 percent in the summer, 80 percent in the fall, and 100 percent in the winter. Differences between hypolimnetic sites in percent oxygen saturation are likely related to depth differences at the sites and the effects of mixing (the deeper the site, the less mixing). Hypolimnetic dissolved-oxygen saturation levels, however, were indicative of eutrophic conditions in Lake Bruin at sites 1 and 2 during the summer months.

Productivity was monitored in Lake Bruin using the light and dark bottle technique (table 20) and variation of on site dissolved-oxygen concentrations during 24-hour periods (figs. 28, 29, 30, and 31). Gross primary and net productivity, measured in grams of oxygen per cubic meter per day, near the surface was high at the three Lake Bruin sites and varied in the following manner:

Oxygen light- and dark-bottle method	Site 1	Site 2	Site 3
	grams of oxygen per cubic meter per day		
Gross primary productivity----	0.6-3.8	0.5-2.8	0.2-3.6
Net primary productivity------	.0-2.8	.0-1.6	.0-2.5

As expected, highest primary-productivity rates occurred during summer months, and lowest primary-productivity rates were observed during winter and fall months (figs. 28-31). Primary-production rates, both net and gross, were well above levels typical for eutrophic lakes.

Light-dark bottle experiments and light-attenuation studies show little net primary production below the 6 ft depth in the lake (figs. 28-31). Respiration exceeded or equaled photosynthesis at site 1 at a depth of 4 ft in the spring and summer, 3 ft in the fall, and 4 ft in the winter (fig. 28). At site 2 (fig. 29) respiration equaled or exceeded photosynthesis at a depth of 1.0 ft in the spring, 5 ft in the summer, and 3 ft in the fall and winter. Site 3 (fig. 30) showed the most variation in depths where respiration rates equaled or exceeded photosynthesis. These depths ranged from less than 1 ft in the spring and fall to more than 6 ft during the summer.

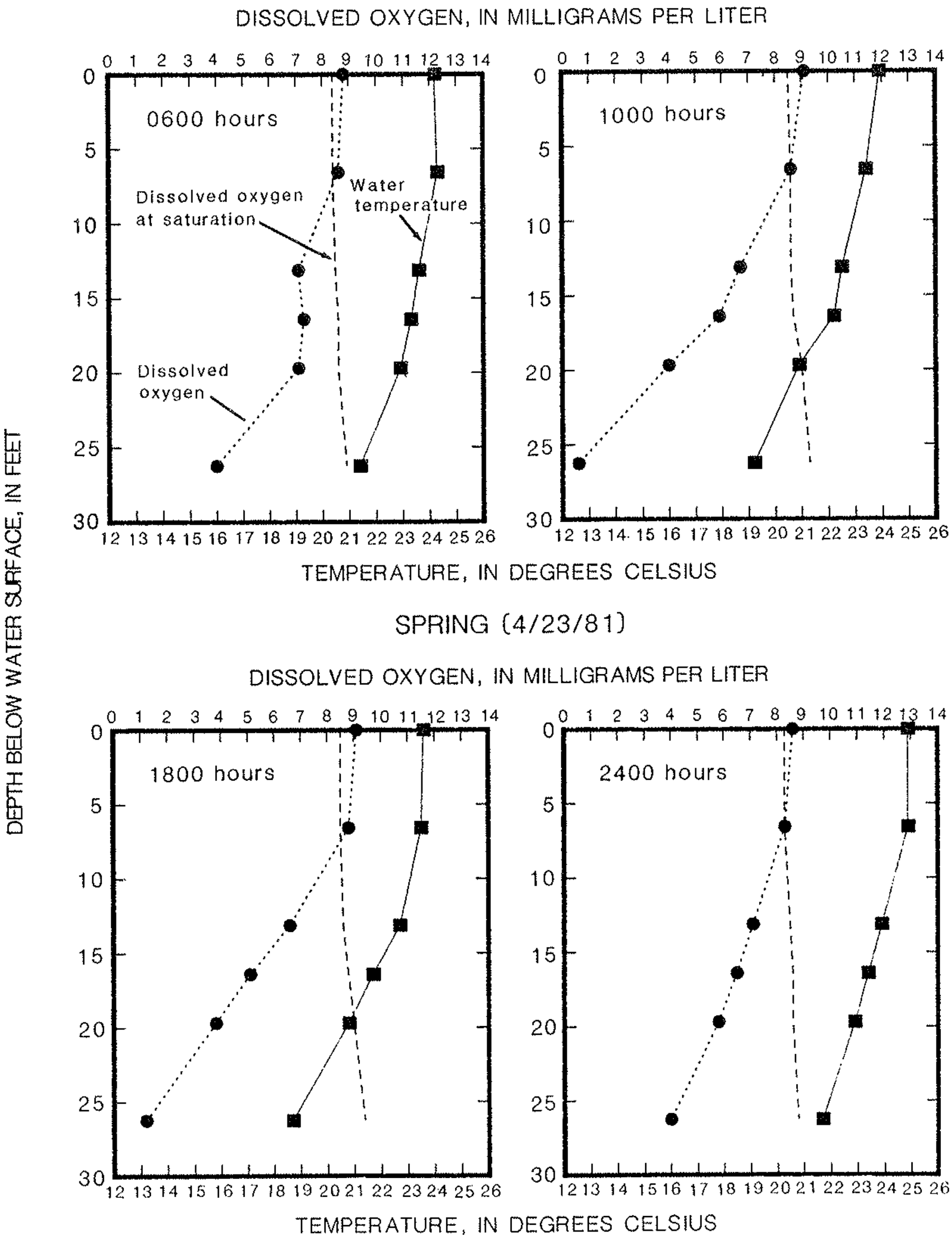

Figure 16.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 1, spring 1981.

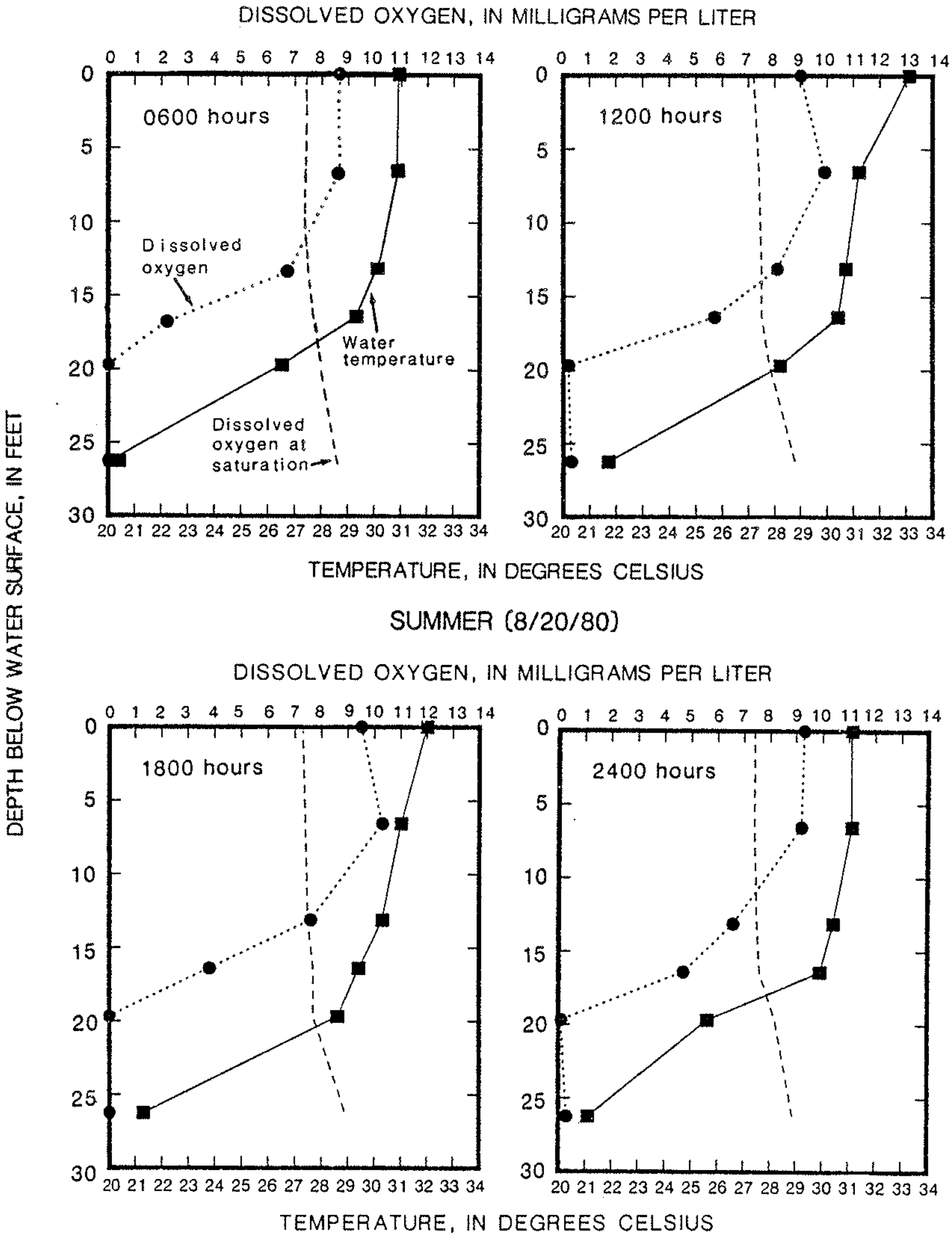

Figure 17.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 1, summer 1980.

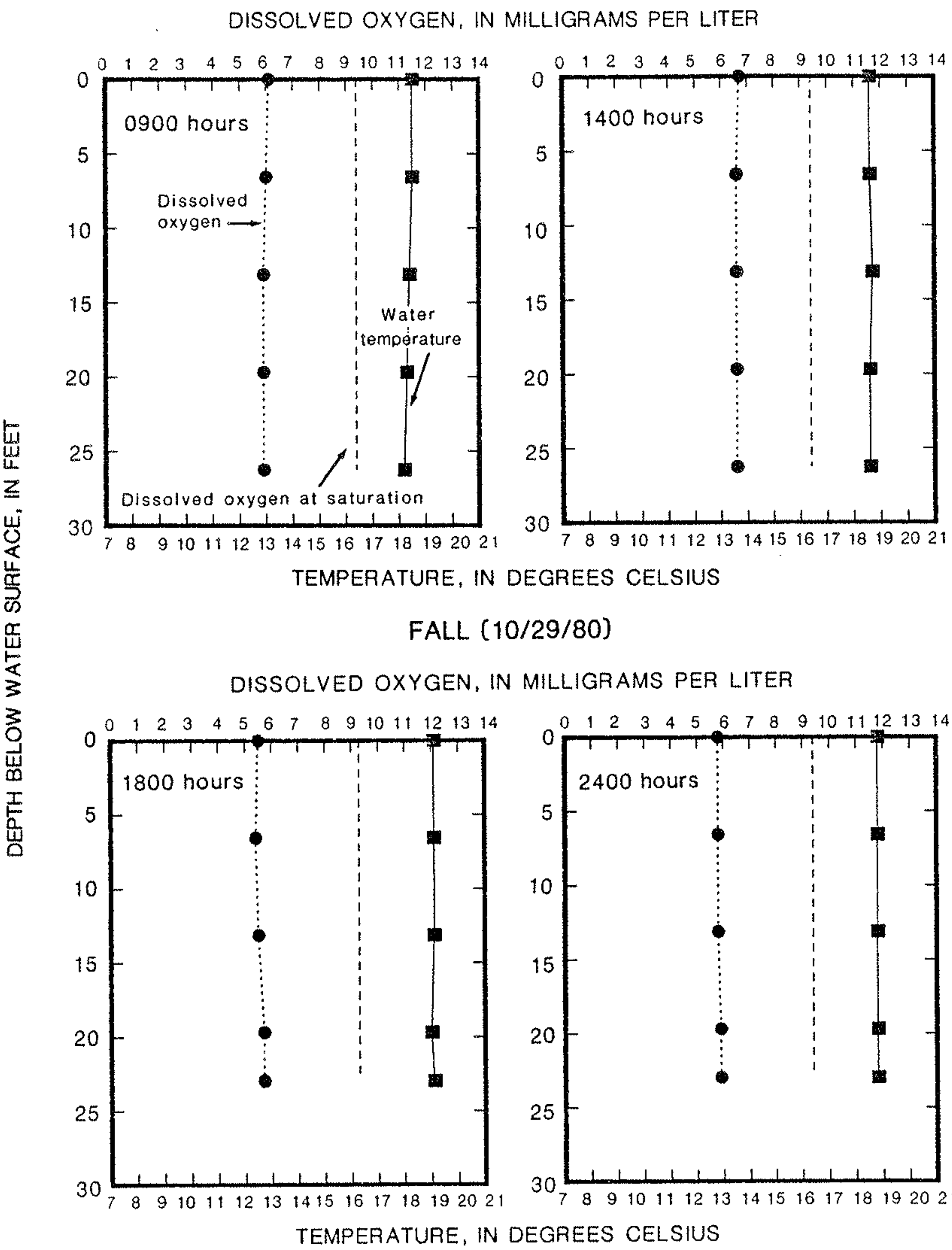

Figure 18.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 1, fall 1980.

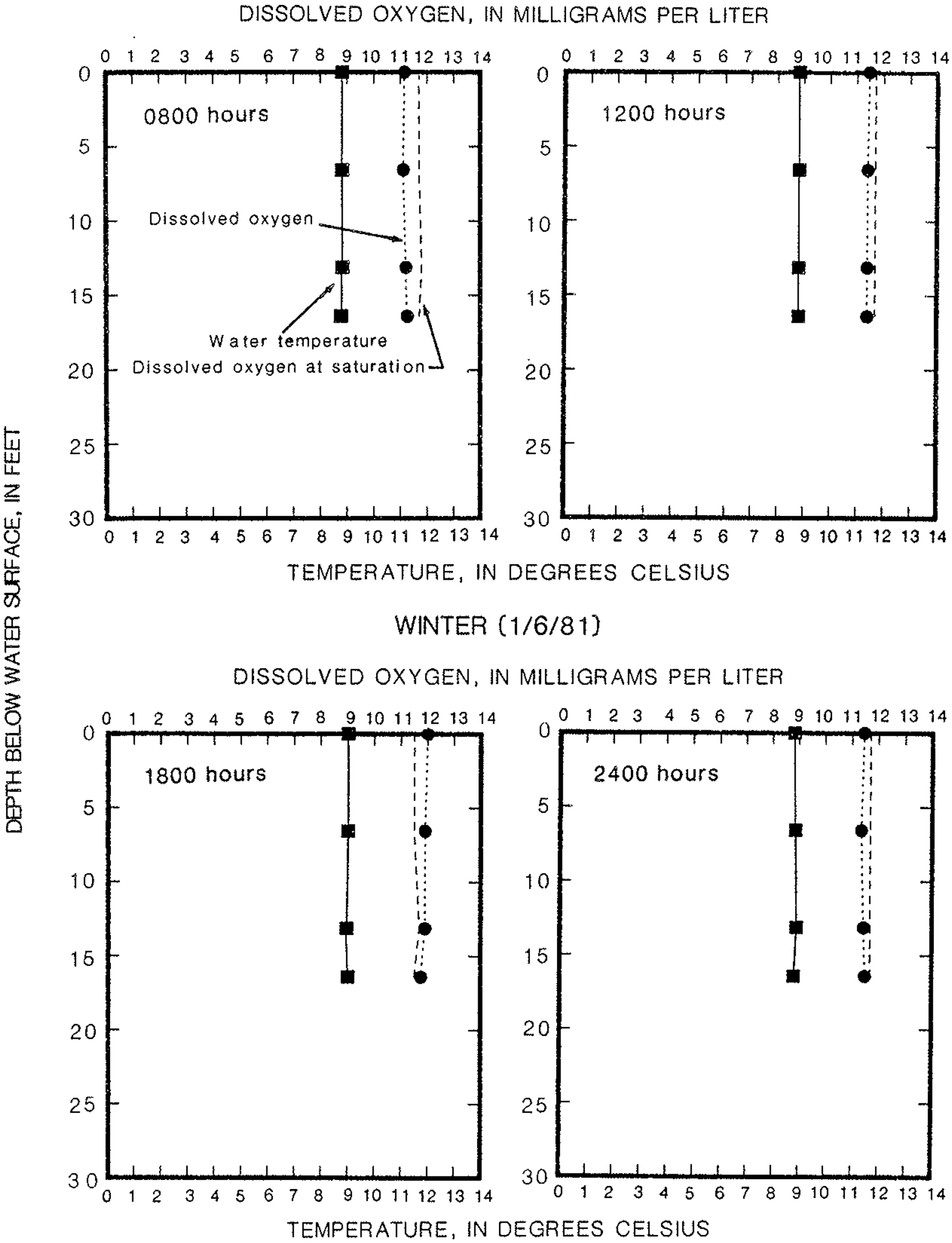

Figure 19.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 1, winter 1981.

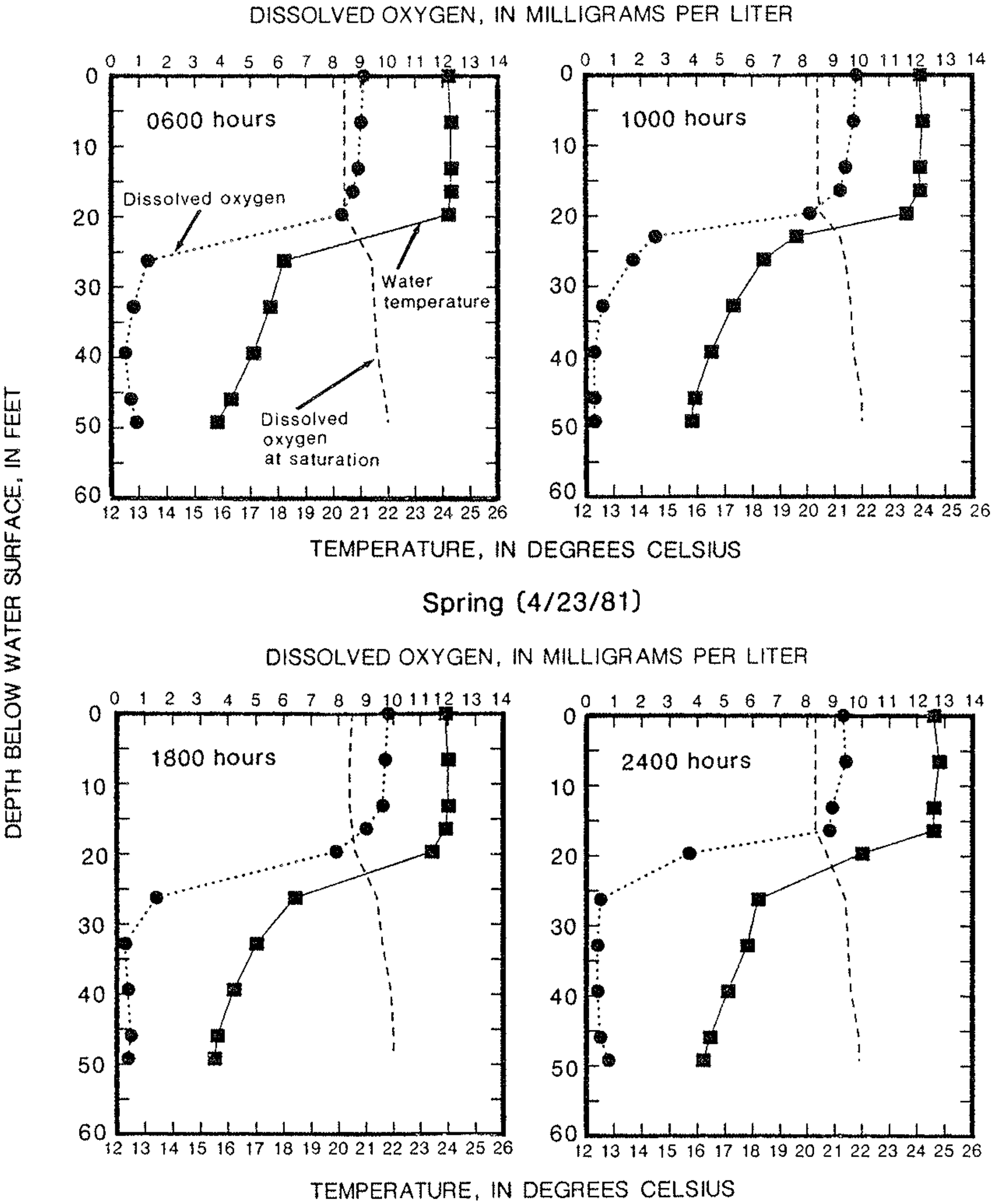

Figure 20.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 2, spring 1981.

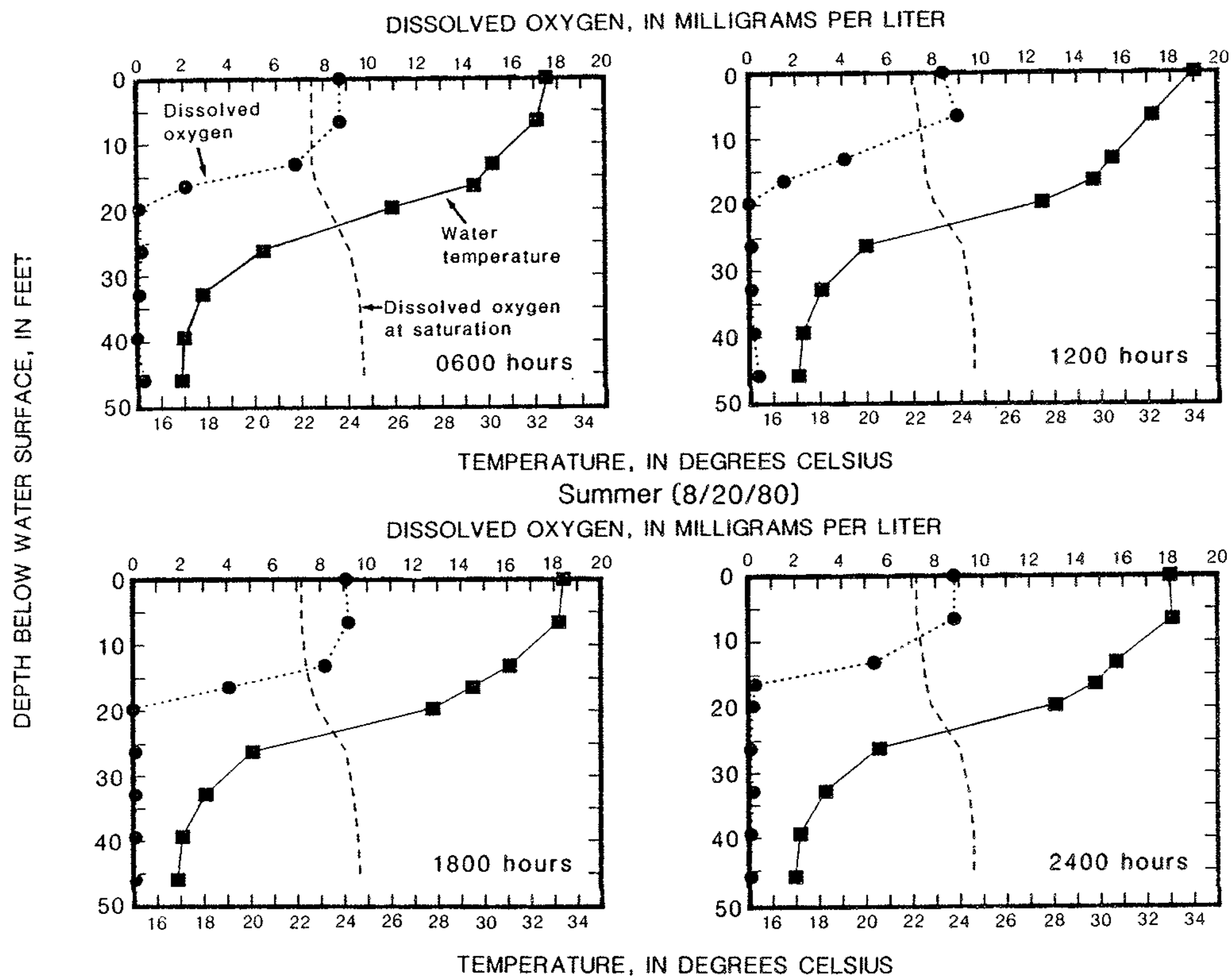

Figure 21.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 2, summer 1980.

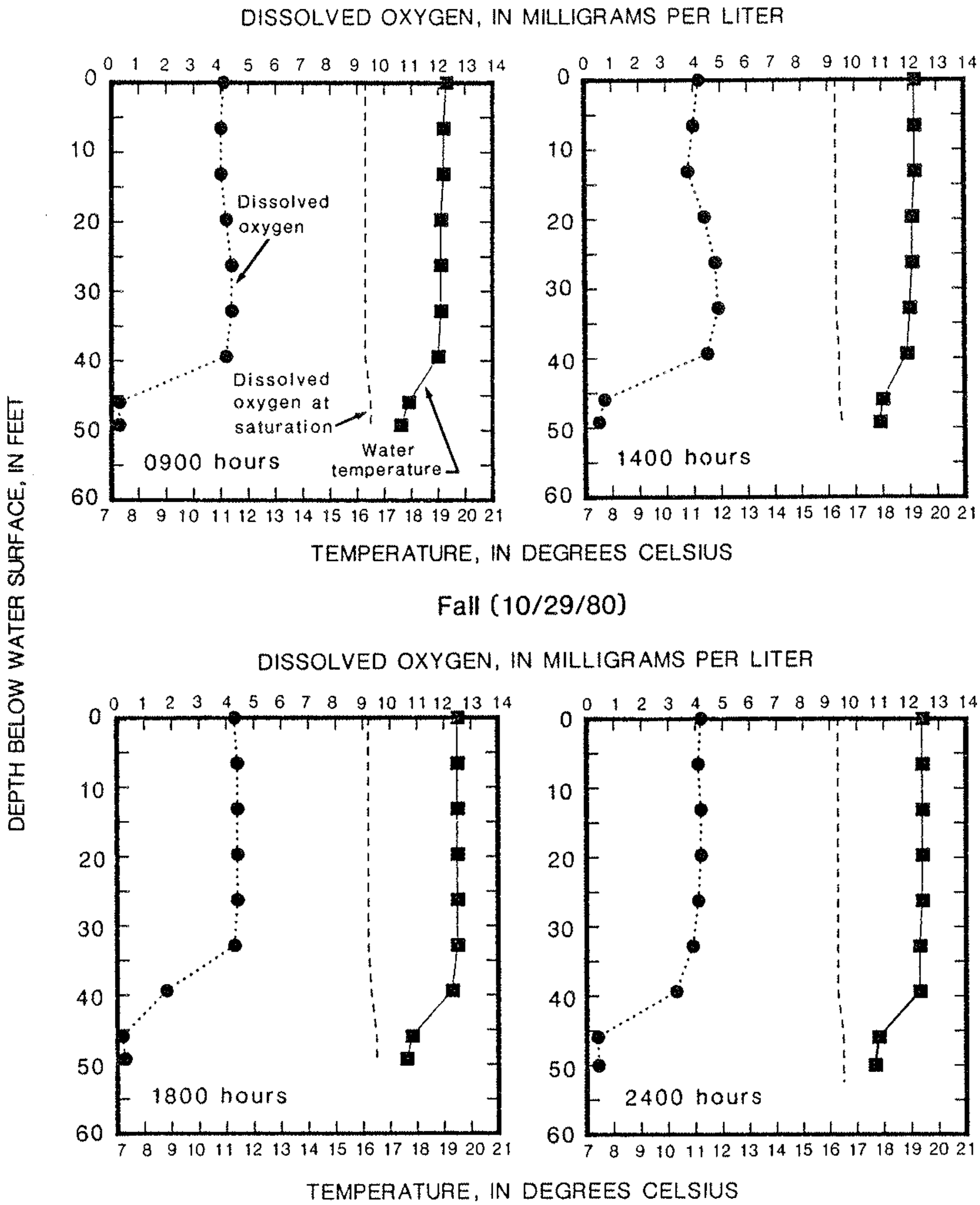

Figure 22.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 2, fall 1980.

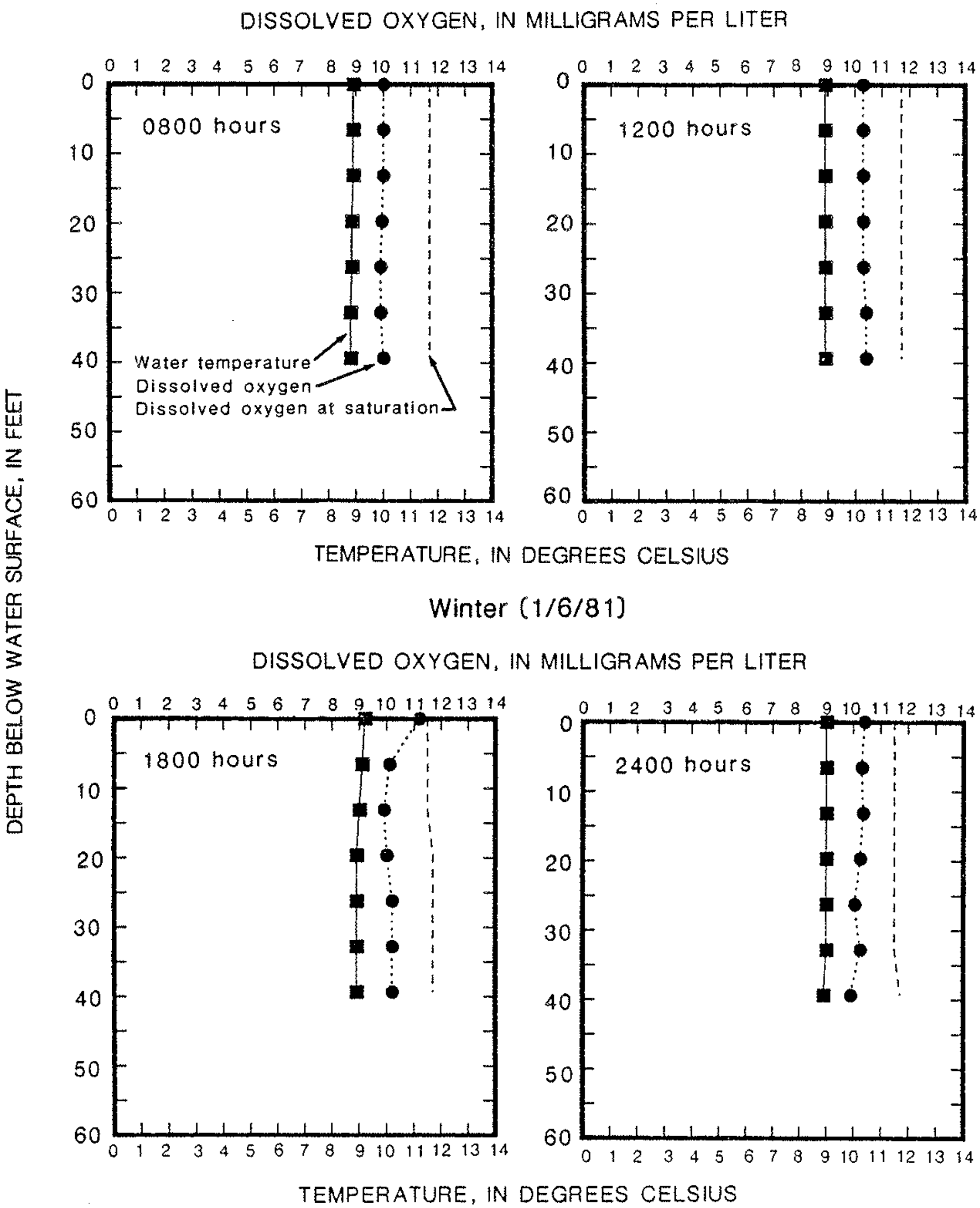

Figure 23.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 2, winter 1981.

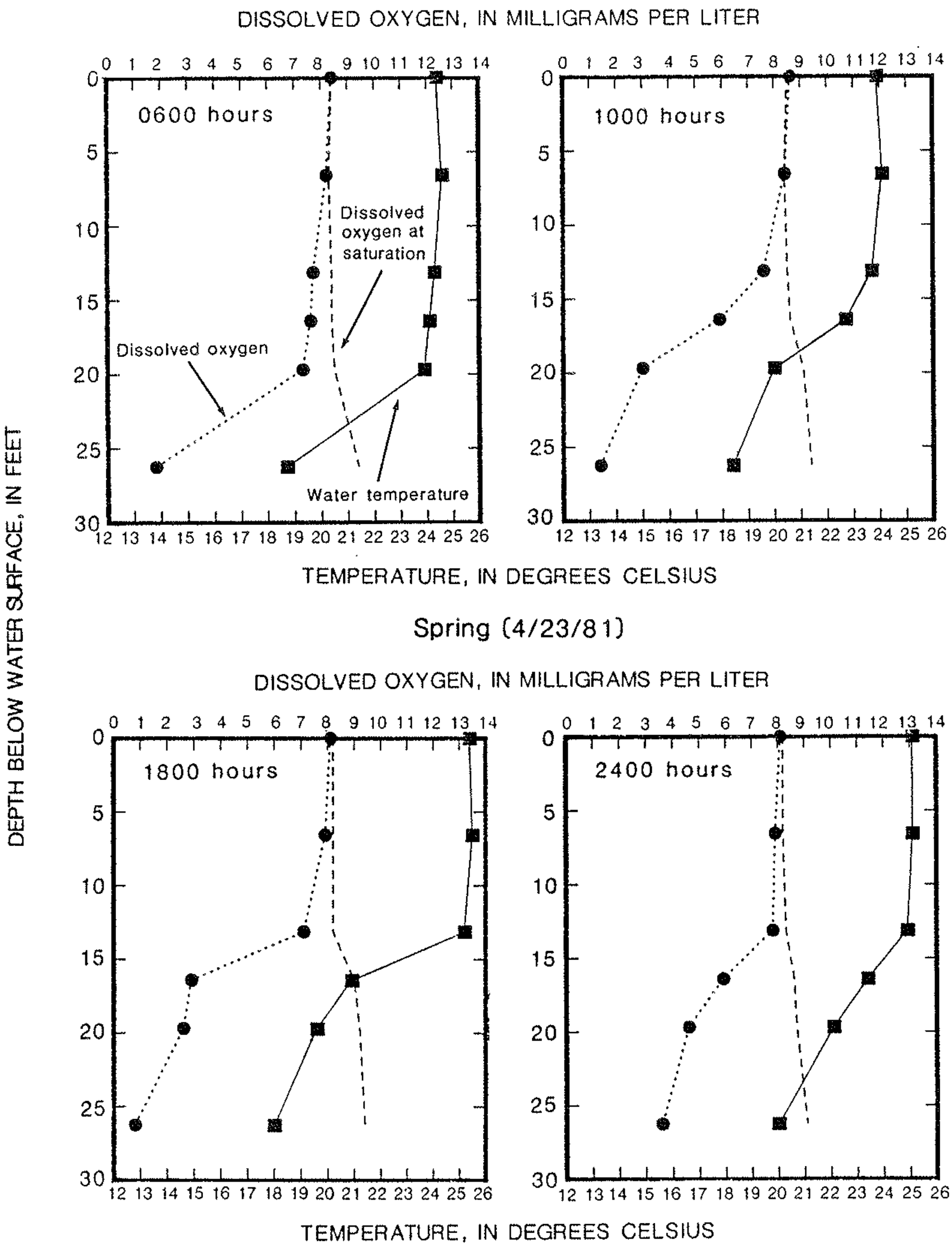

Figure 24.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 3, spring 1981.

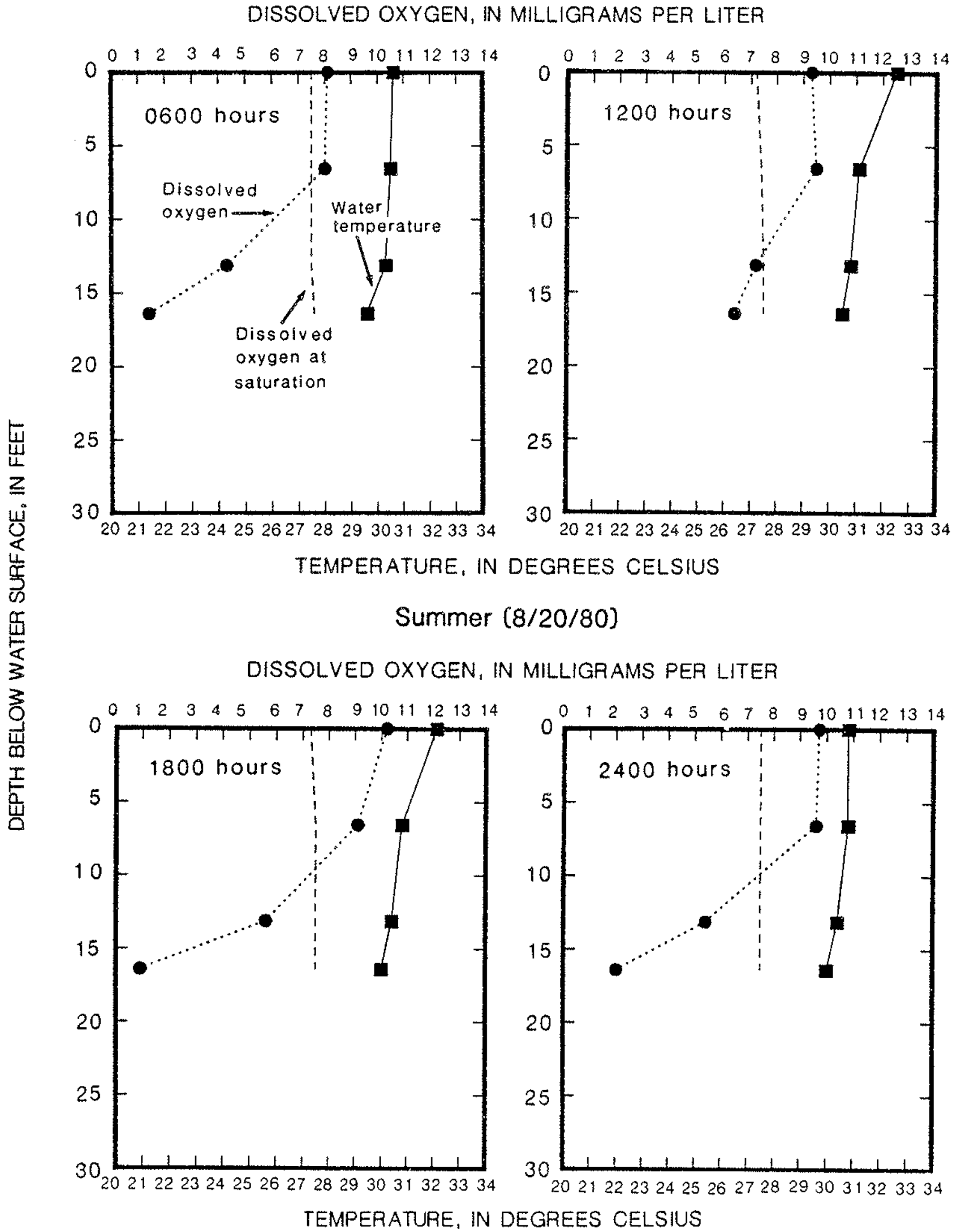

Figure 25.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 3, summer 1980.

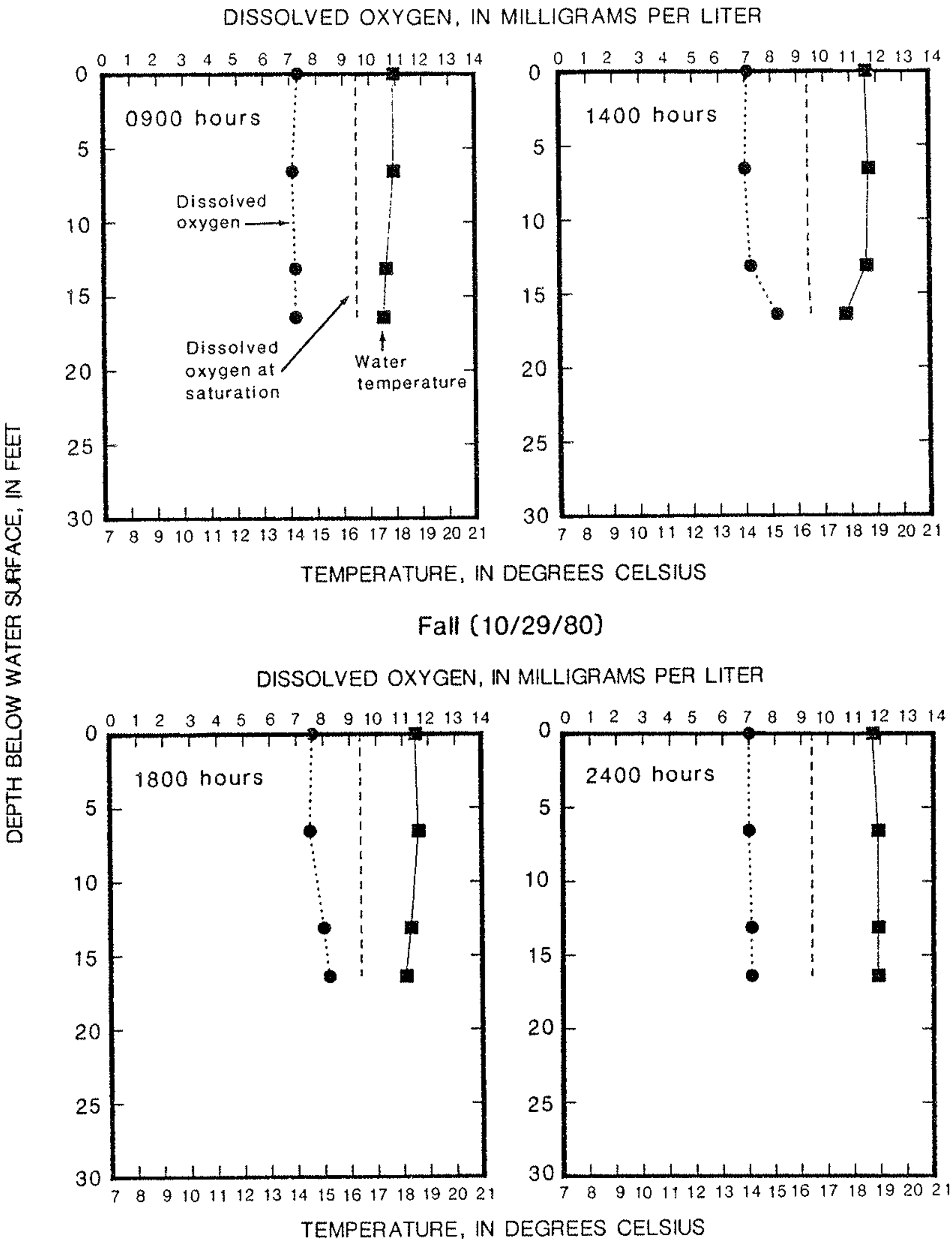

Figure 26.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 3, fall 1980.

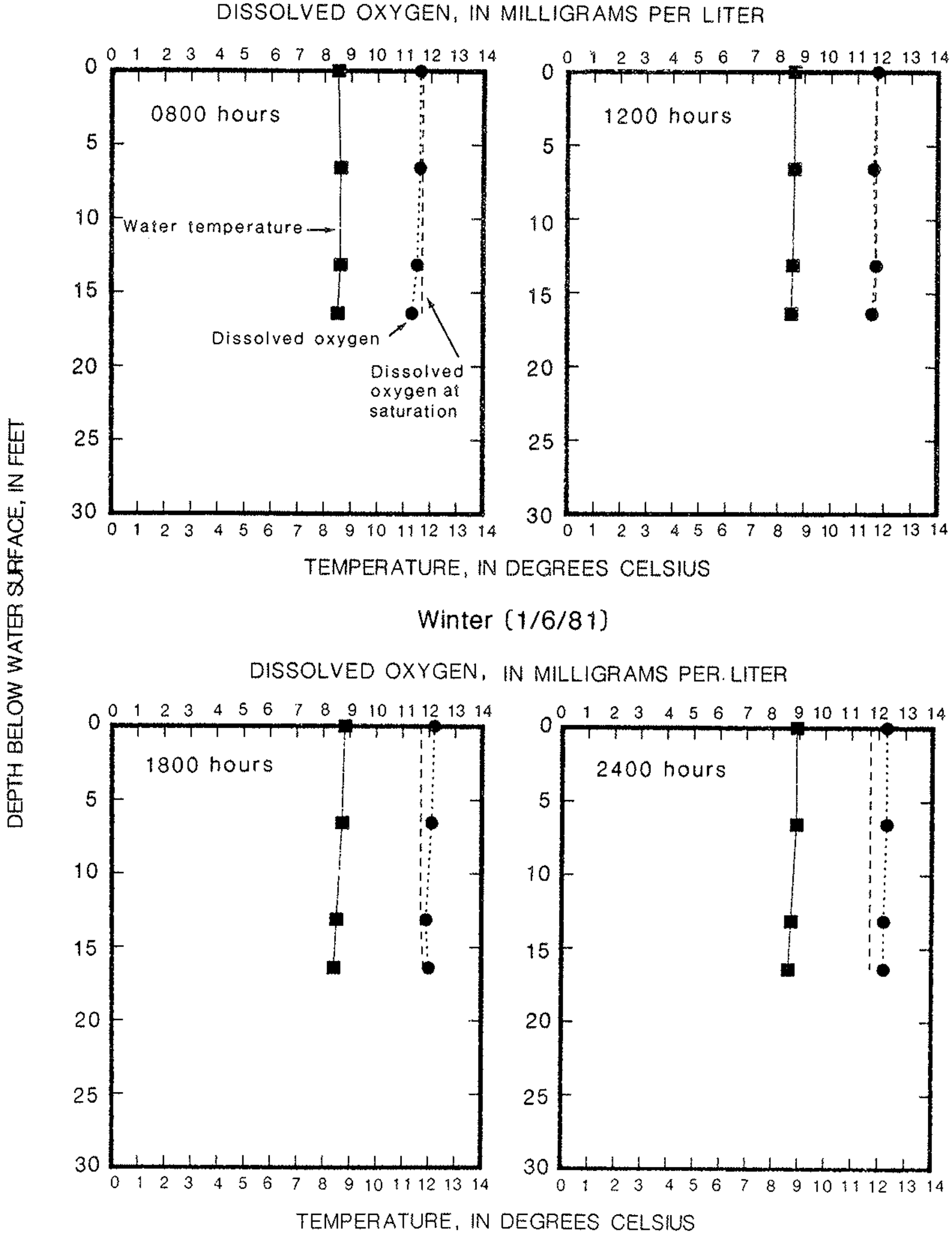

Figure 27.--Diurnal variation in dissolved oxygen and temperature at Lake Bruin site 3, winter 1981.

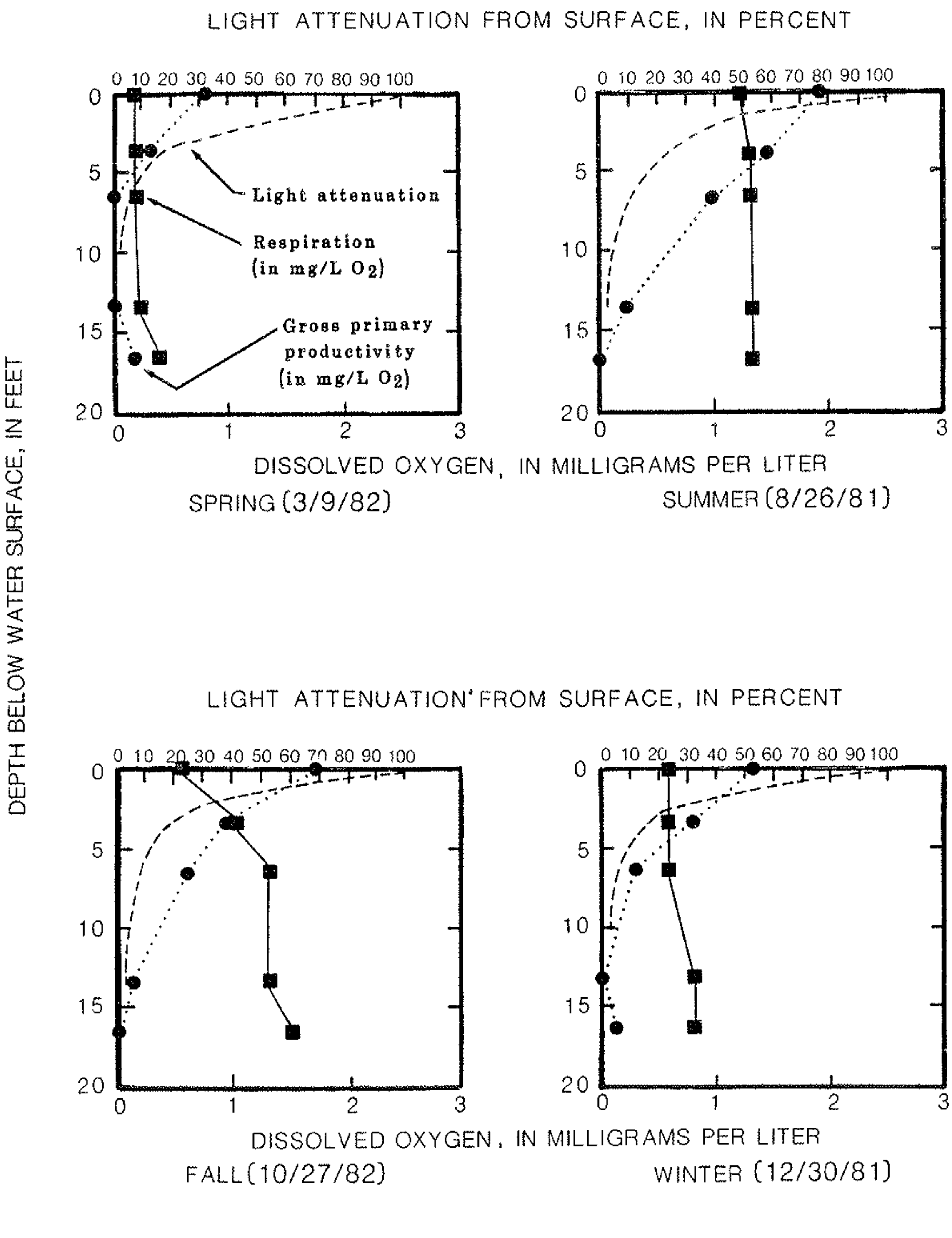

Figure 28.--Seasonal variation in gross primary productivity, respiration, and light attenuation at Lake Bruin site 1.

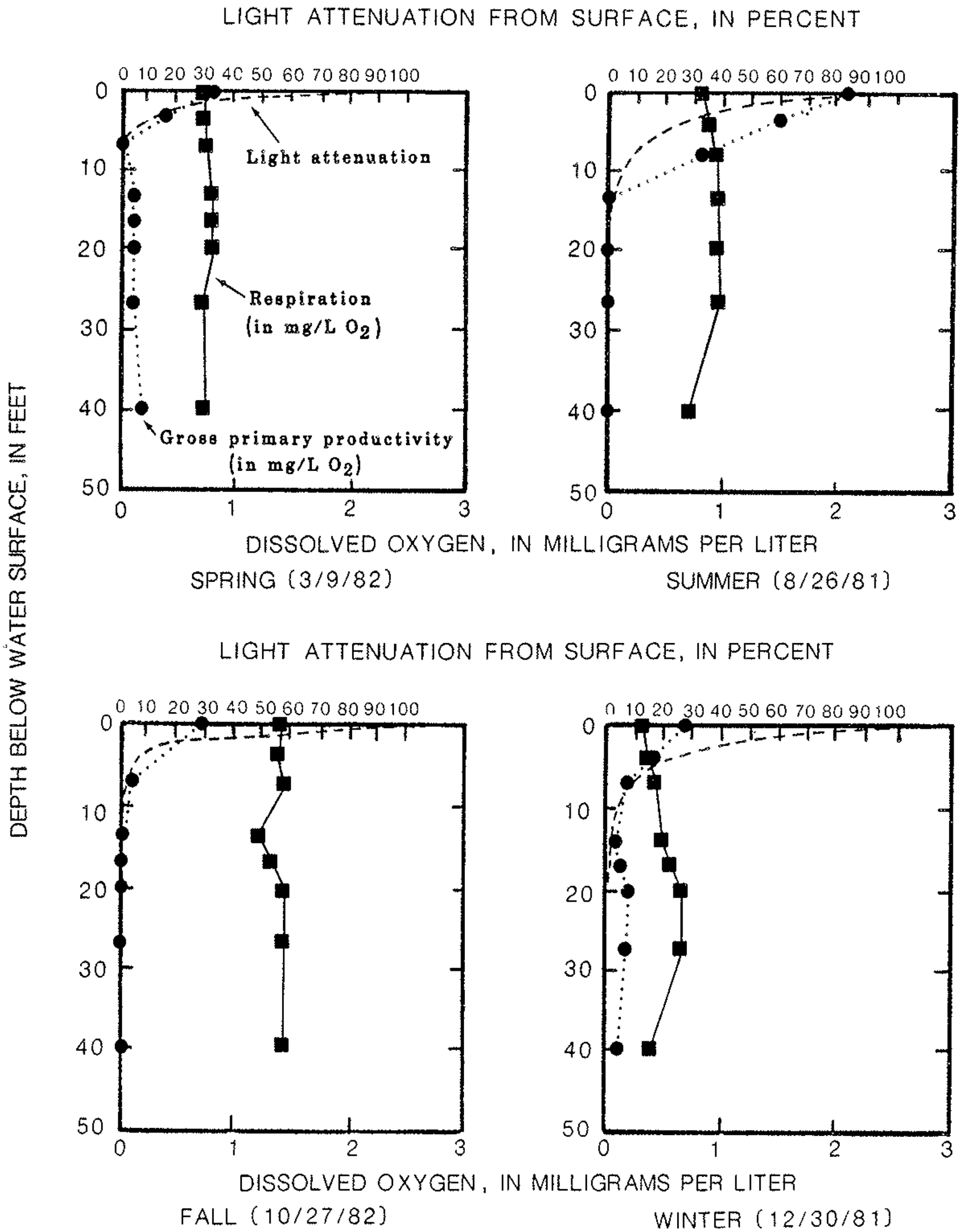

Figure 29.--Seasonal variation in gross primary productivity, respiration, and light attenuation at Lake Bruin site 2.

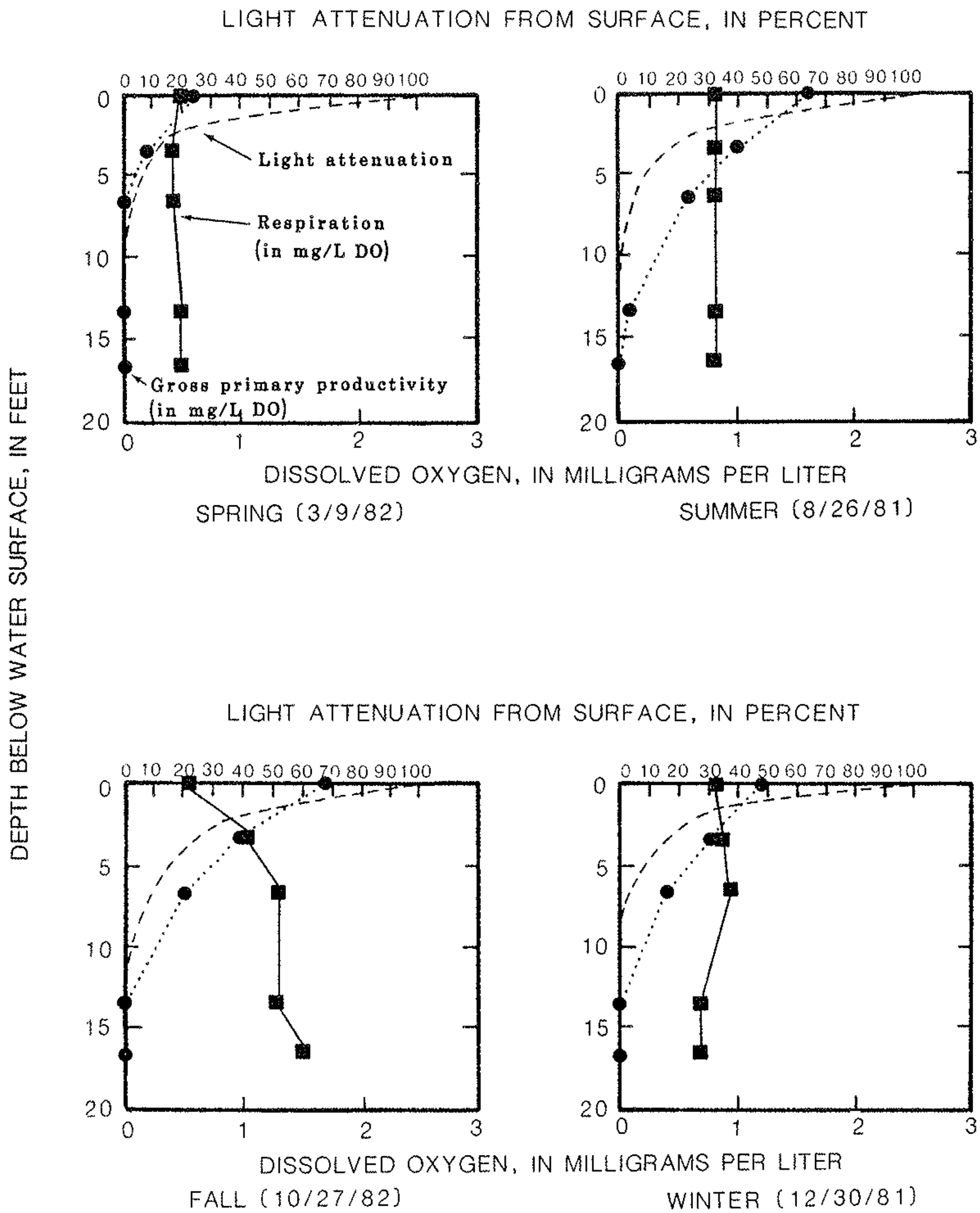

Figure 30.--Seasonal variation in gross primary productivity, respiration, and light attenuation at Lake Bruin site 3.

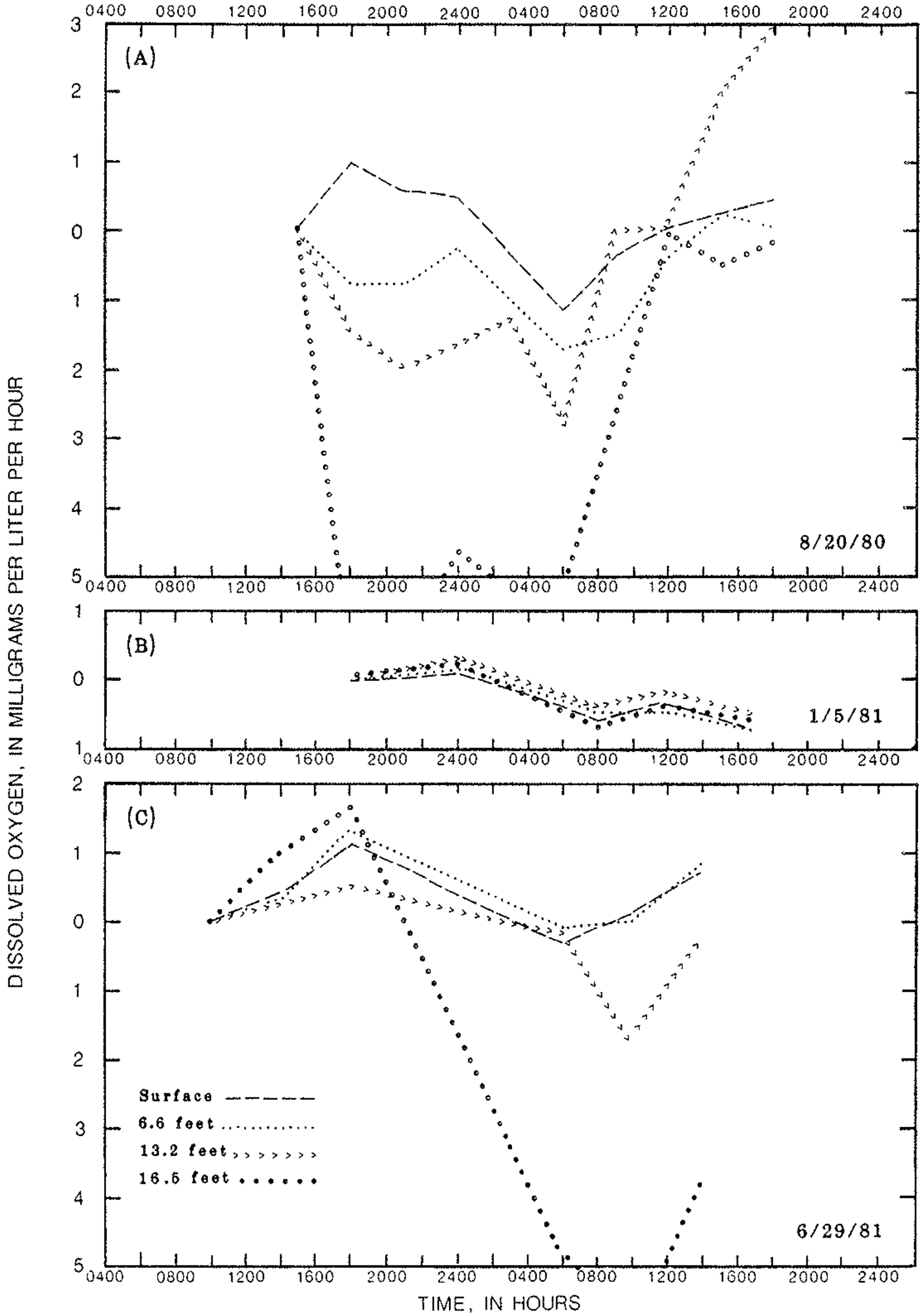

Figure 31.--Rate of oxygen change, in milligrams per liter per hour, by depth at Lake Bruin sites 1, 2, and 3.

Light-attenuation data agreed with light and dark bottle results. In most instances, light levels--at or near the depth at which light and dark bottle results indicated respiration equaled or exceeded primary production--were 10 percent of the incident surface light levels. For example, at site 1 (fig. 28) light attenuation at the 10-percent level occurred at depths of 4 ft in the spring and summer, 3 ft in the fall, and 4 ft in the winter, similar to the results of the light and dark bottle technique for determining the depth at which respiration equaled primary production. Similar results were observed at sites 2 and 3 (figs. 29 and 30).

Diel variations in dissolved oxygen also showed little net productivity below the depths indicated by the light and dark bottle observations. Plots of changes of dissolved oxygen versus time at different depths at site 3 (fig. 31) show a net gain in oxygen at the surface and either no gain or a net loss of oxygen at the 6.6 ft depth, and below, for all seasons. This narrow band of highly productive water is due to the very dense algal populations present at these sites and the concurrent rapid decrease in light intensity due in part to the dense phytoplankton populations observed during these studies.

SUMMARY AND CONCLUSIONS

Lake Bruin is a relatively deep, monomictic oxbow lake formed from a cutoff of the Mississippi River. It has a classic oxbow shape and is approximately 60 ft in depth near its center. It has a surface area of 4.7 mi^2 and a drainage area of 21.4 mi^2. Lake bottom material composition ranged from fine sand to clay.

Rainfall and runoff are the major sources of water in the lake. Stage and water-quality data indicate little input of water from ground-water sources or the Mississippi River.

Temperature of Lake Bruin ranged from 35.3°C in the summer to 8.9°C in the winter, during the sampling period. The lake was stratified for almost 8 months of the year in its deeper areas. Temperature stratification began as early as late February and was well pronounced by mid-April. The thermocline ranged in depth from 13 ft early in the year to 26 ft during the summer. Average thickness of the thermocline was about 6 ft, and it was most frequently observed to extend from depths of 20 to 26 ft. Overturn occurred during the last week in October for 3 consecutive years during the study.

Dissolved-oxygen concentrations varied considerably throughout the lake, depending on depth, location, and season. Dissolved-oxygen concentrations ranged from a maximum of 12.3 mg/L at the surface to a minimum of 0.0 mg/L at depths below 18 ft during the course of the study. Dissolved-oxygen concentrations were at or approached 0.0 mg/L in the hypolimnion during the growing season (March through October) and did not increase until after overturn when concentrations of 7.0 mg/L or higher occurred at all depths.

Major ions in Lake Bruin waters were found in low concentrations. Specific conductance ranged from 127 to 177 µS/cm during the study with a mean of 145 µS/cm at the three lake sites. Calcium is the major cation and bicarbonate is the major anion present. Calcium ranged from 15 to 21 mg/L (mean, 18 mg/L) and alkalinity ranged from 61 to 81 mg/L (mean, 68 mg/L). Other major anions (including chloride and sulfate) and cations (including magnesium, potassium, and sodium) were found in mean concentrations of 5 mg/L or less throughout the lake. Little or no variation in the major ions in lake water was observed in samples collected at the three different sites.

Minor elements (with the exception of manganese) in water and bottom material were in low concentrations at all sampling sites. During overturn manganese concentrations were as high as 370 µg/L and its presence in the water was possibly due to mixing of manganese-rich water in the hypolimnion with less concentrated surface water during the overturn. Manganese at the concentrations found is not harmful to aquatic life but may cause some taste and stain problems in domestic-water supplies.

Pesticides were rarely found in detectable concentrations in lake water. Pesticides detected in lake water included DDD, DDT, dieldrin, heptaclor, diazinon, methyl parathion, 2,4-D, and 2,4-DP. The most frequently occurring pesticide, 2,4-D, occurred in concentrations ranging from 0.02 to 0.14 µg/L, all below EPA criteria for drinking water supplies (100 µg/L). Dieldrin was second in frequency and occurred in concentrations greater than EPA recommended limits (0.0019 µg/L) for protection of freshwater aquatic life. DDT and DDD were also found in detectable concentrations greater than EPA recommended limits for protection of freshwater life.

Major sources of insecticides in Lake Bruin appear to be resuspension of bottom material and agricultural runoff through drainage ditches. High concentrations of DDT, DDE, DDD, and dieldrin were found in samples collected from the lake bottom and drainage ditches. Comparison of filtered samples with unfiltered samples indicate that most insecticides are transported attached to sediment particles, indicating installation of settling basins in drainage ditches could decrease the amount of insecticides transported into the lake by runoff.

Insecticide residues were present in all fish species sampled (Ictalurus punctatus--channel catfish, Dorosoma cepedianum--threadfin shad, Pomoxis annularis--white crappie, and Micropterus salmoides--largemouth bass). Concentrations of chlordane, DDD, DDT, DDE, dieldrin, and PCB were found in fish tissues at concentrations less than Food and Drug Administration recommended limits. Little relationship was found between the different fish species sampled and concentrations of insecticides detected.

Bacteria, both fecal coliform and fecal streptococci, were found in very low concentrations during the study and were well below Louisiana criteria for primary and secondary contact recreation and public-water supplies. Comparisons of bacterial samples collected near the shore and in the center of the lake indicate little or no bacterial pollution from domestic sewage.

Phytoplankton occurred in extremely high concentrations during the summer months, ranging from 100,000 to 740,000 cells/mL in June and August samples. The most common algae present in the lake (in order of abundance) were the blue-green algae: Lyngbya, Oscillatoria, Anabaenopsis, Anacystis, Cylindrospermum, and Agmenellum; the green algae: Ankistrodesmus, Dictyosphaerium, and Scenedesmus; and the diatoms: Cyclotella and Melosira. Blue-green algae dominated phytoplankton samples during the summer, but green algae and diatoms were more important in the winter. All of the above genera of algae include species listed as nuisance-type algae which can cause taste and odor problems and are tolerant of pollution.

Populations of benthic invertebrates had a mean density of 52 organisms/ft^2. Chaoborus (phantom-midge larvae), unidentified tubificid worms, Potamothrix, Limnodrilus, (both tubificid worms), Chironomus, Cryptochironomus, Procladius, and Polypedilum (all midge-fly larvae) were the most abundant and frequently occurring organisms captured during the study. Most of these organisms possess physiological or behavioral adaptations that allow them to exist in waters of low dissolved-oxygen concentrations, and all are tolerant or facultative of organic pollution.

Gross primary productivity in Lake Bruin near the surface was high and ranged from 0.5 to 3.8 grams of oxygen per cubic meter per day near the surface. Highest primary productivity occurred during the summer and lowest occurred during the winter and fall. Productivity was restricted to the upper 6.6 ft of the water column. Below that depth respiration exceeded primary productivity.

Nitrogen-phosphorus ratios suggest that phosphorus is the limiting nutrient when green algae and diatoms are the dominant phytoplankton, but nitrogen is limiting during the large blue-green summer algal blooms. Algal-growth potential data also suggest potential phosphorus limitation.

Large concentrations of inorganic phosphorus and inorganic nitrogen, high primary productivity, lack of dissolved oxygen in the hypolimnion, shallow Secchi-disk readings, high chlorophyll a and phytoplankton concentrations, and composition of phytoplankton and benthic-invertebrate communities are all indications of the eutrophic conditions in Lake Bruin.

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