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LIMNOLOGICAL STUDIES
OF
BIG BEAR LAKE
CALIFORNIA



Pearson and Irwin--LIMNOLOGICAL STUDIES OF BIG BEAR LAKE, CALIFORNIA

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OPEN-FILE REPORT

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

Menlo Park, California, 1972

PREPARED IN COOPERATION WITH THE
BIG BEAR LAKE PEST ABATEMENT DISTRICT

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
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LIMNOLOGICAL STUDIES OF BIG BEAR LAKE,
CALIFORNIA

By

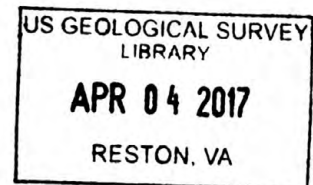
Elmer G. Pearson and George A. Irwin

Prepared in cooperation with the
Big Bear Lake Pest Abatement District

OPEN-FILE REPORT

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Menlo Park, California
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DEFINITION OF TERMS¹

- ALGAE:** the group of simple or primitive plants that generally are microscopic in size and live in wet or damp places.
- ALGAL BLOOM:** the relatively rapid increase in the total number of phytoplankton per unit time to the extent that their presence hinders the utility of a body of water for whatever the intended use.
- ANAEROBIC:** devoid of oxygen.
- CHEMICAL REDUCTION:** the addition of hydrogen to or the subtraction of oxygen from a substance; a reaction opposite to the chemical oxidation.
- DIATOMS:** a group of algae characterized by a cell wall of pectic materials impregnated with silica, giving it a glass-like appearance and texture.
- DRAINAGE AREA:** the land and water surfaces from which a lake derives its inflow of water.
- EPILIMNION:** the upper layer of water during periods of thermal stratification in a lake.
- EUPHOTIC ZONE:** the zone delimited by the vertical range of transmission of light effective in photosynthesis.
- HYPOLIMNION:** the bottom layer of water during periods of thermal stratification in a lake.
- LIMNOLOGY:** the science of fresh waters, especially of ponds and lakes, including the physical, chemical, and biological conditions.
- NUTRIENT:** any substance that is required by an organism for the continuation of growth, for repair of tissue, or for reproduction.
- ORGANISM:** a living plant or animal.
- PHYTOPLANKTON:** plant organisms of the plankton.
- PLANKTON:** passively floating or weakly swimming aquatic organisms of relatively small size that are at the mercy of the water currents.
- PRODUCTIVITY:** the total amount of organic matter that is formed from raw materials.
- THERMAL STRATIFICATION:** the distinct layering of a body of water because of thermal differences.
- THERMOCLINE:** the layer of water between the epilimnion and the hypolimnion where the temperature rapidly declines per unit depth from the upper margin to the lower margin.
- ZOOPLANKTON:** animal organisms of the plankton.

¹Greeson and Meyers (1969).

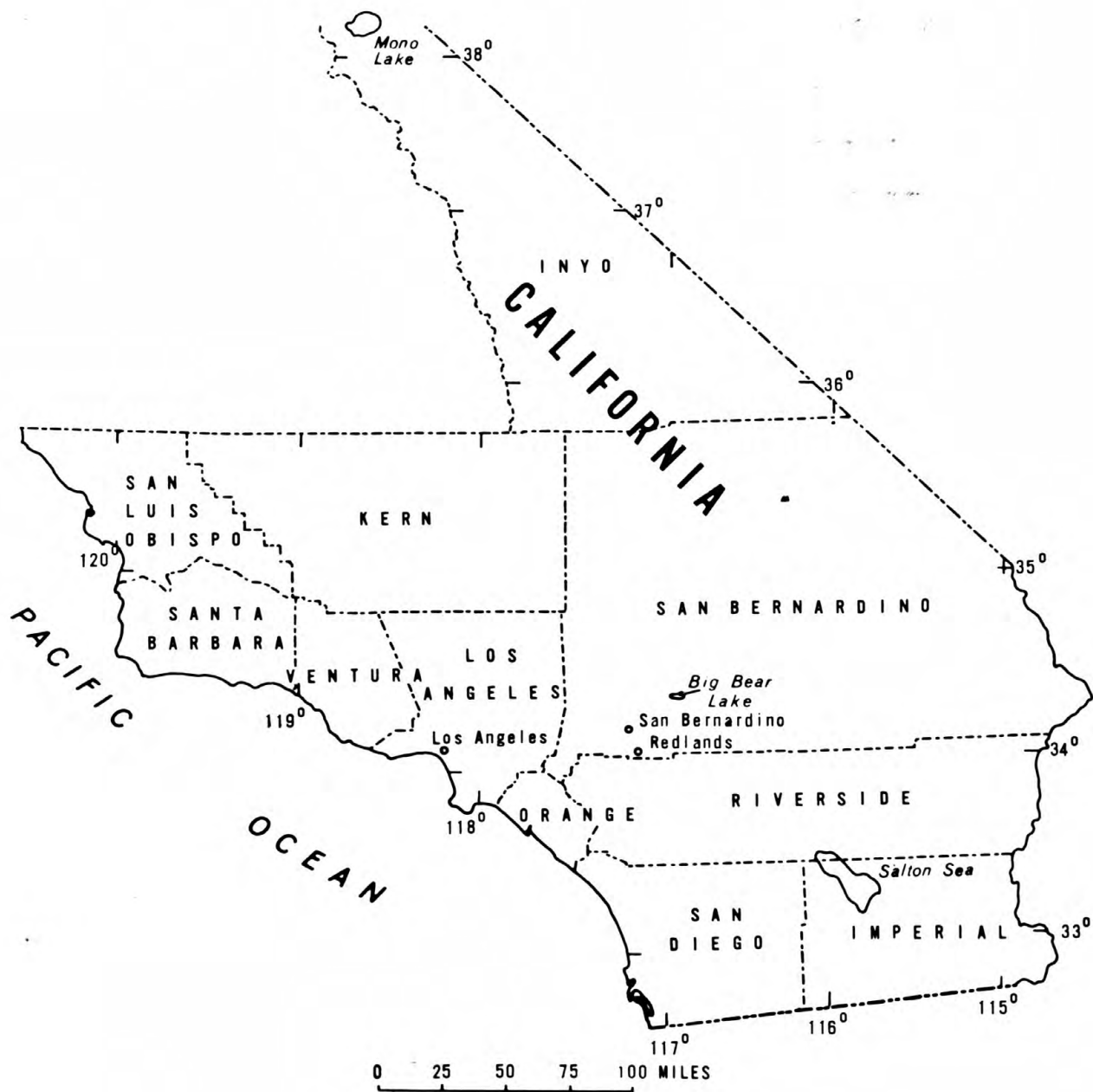


FIGURE 1.--Index map.

LIMNOLOGICAL STUDIES OF BIG BEAR LAKE, CALIFORNIA

By Elmer G. Pearson and George A. Irwin

ABSTRACT

Big Bear Lake exhibited seasonal changes in physical, chemical, and biological variables from June 1968 to June 1969.

Dissolved-oxygen concentrations were depressed during the summer resulting in anaerobic conditions near the bottom of the lake. Water temperature decreased with depth in spring and summer, although classical thermal stratification was not observed. The nutrient standing crop was sufficient to maintain two distinct seasonal phytoplankton blooms. There were phytoplankton growth periods during the winter of 1968 and the summer of 1969, but the maximum populations that were observed were not excessive.

During the study Big Bear Lake exhibited periods of biochemical stress symptomatic of organically enriched lakes; however, no attempt was made to determine the magnitude or rate of the eutrophication processes occurring in the lake.

INTRODUCTION

Big Bear Lake is a water supply for the San Bernardino and Redlands area in southern California (fig. 1). The lake is also intensively used for fishing and water sports.

In recent years there has been an increasing problem with nuisance phytoplankton blooms and depletion of dissolved oxygen in Big Bear Lake. The phytoplankton blooms and their related adverse conditions resulted in immediate public concern. Therefore, in the spring of 1968, the U.S. Geological Survey in cooperation with the Big Bear Lake Pest Abatement District began a limnological reconnaissance of the lake. The general purpose of the study was to collect preliminary data on chemical, physical, and biological conditions in the lake. The specific purpose was to determine if thermal stratification existed and, if it did occur, to make recommendations as to the feasibility of using artificial air injection to reduce the stratification.

The scope of the study included areal and vertical measurements of dissolved oxygen, water temperature, hydrogen ion concentration (pH), transparency, primary nutrients, and plankton. In addition, measurements to determine evaporation rates, lake bottom configuration, and lake currents were attempted. However, instrument failures resulted in insufficient data to allow for accurate measurement of these three variables.

The authors wish to thank J. R. Crippen and R. C. Averett for their kind support and many helpful comments. Special thanks go to G. G. Ehrlich and John Bath for their help with the chemical and biological data and analyses. In addition, the cooperation of the personnel of the Big Bear Lake Pest Abatement District and the Big Bear Valley Park District is gratefully acknowledged.

The report was prepared in the Garden Grove subdistrict of the U.S. Geological Survey in cooperation with the Big Bear Lake Pest Abatement District. The work was done under the general direction of R. Stanley Lord, district chief in charge of water-resources investigations in California, and under the immediate direction of L. C. Dutcher and James L. Cook, successive chiefs of the Garden Grove subdistrict.

DESCRIPTION OF BIG BEAR LAKE

Big Bear Lake was created by the construction of a multiple-arch dam across Bear Creek (fig. 2). The dam is 80 feet high with a crest length of 360 feet. The present dam was completed in 1912 and replaced a lower existing dam built in 1884. The structure is owned and operated by the Bear Valley Mutual Water Co. When full, the reservoir has an area of 2,960 acres, a volume of 72,200 acre-feet, and a water-surface altitude of 6,743 feet. The depth of the lake is generally less than 50 feet. The lake has several prominent bays and points; it is about 6 miles long and averages a mile wide when filled to capacity. The long axis lies almost due east-west in line with the prevailing winds. The dominant terrestrial vegetation consists of pine, fir, cedar, pinyon, juniper, scrub oak, and mountain mahogany.

The climate of the area consists of the usual warm summers and cold winters typical of the mountainous areas of southern California. Temperatures range from the high 80's in July and August to below zero in January and February. The average altitude of the 71.5-square mile drainage basin, including the area tributary to Baldwin Lake, is 7,300 feet..

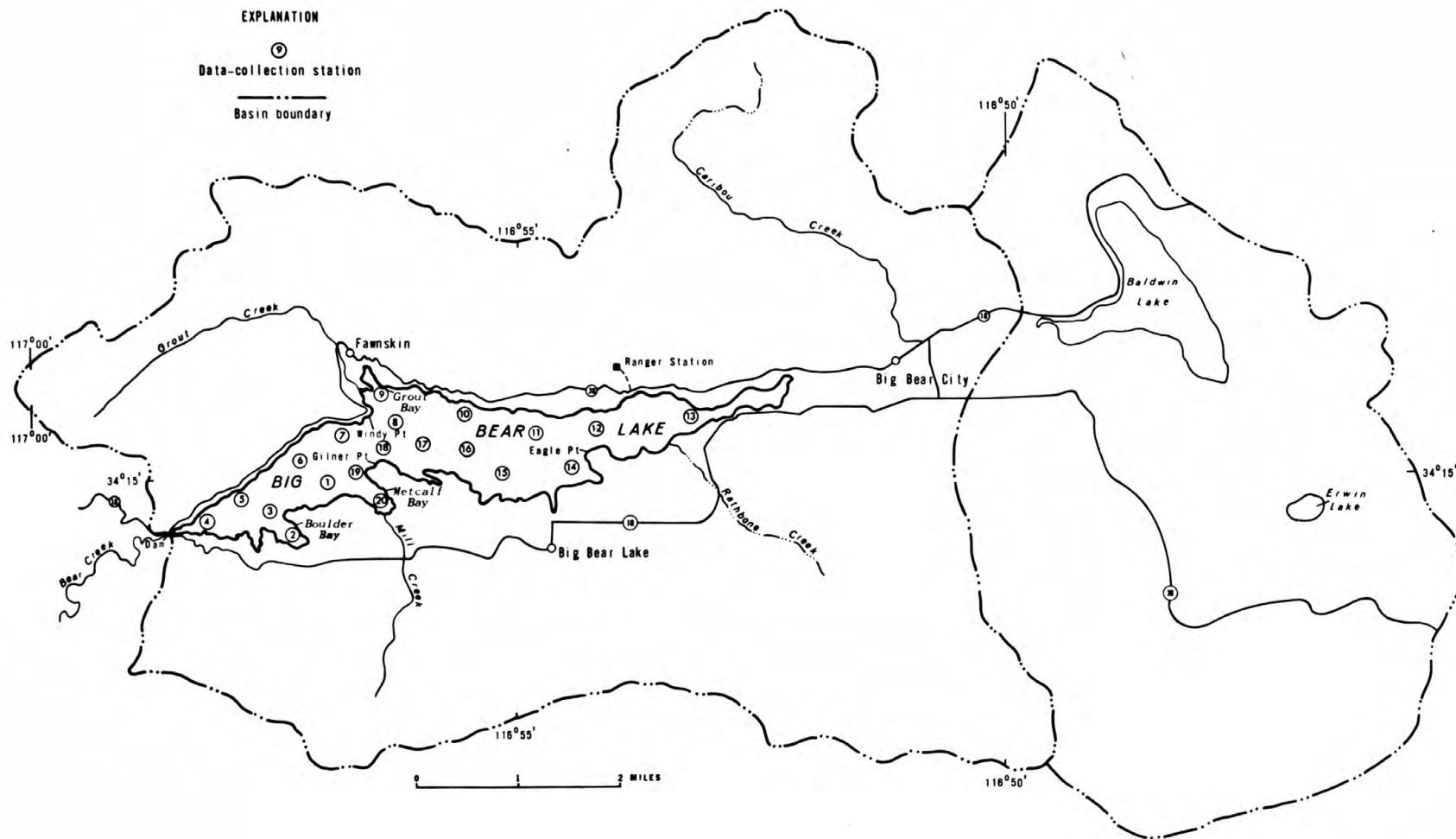


FIGURE 2.--Data-collection stations at Big Bear Lake.

Much of the precipitation occurs as snow. The mean annual precipitation over the drainage basin ranges from less than 16 inches along the eastern divide to more than 30 inches at the western end. National Weather Service (U.S. Weather Bureau) records show that at the Big Bear Lake station the mean annual precipitation for 86 years has been 37 inches; for the year ending December 31, 1968, it was 13 inches, and for the year ending December 31, 1969, it was 56 inches. Across the divide to the north and east, precipitation declines rapidly and desert conditions prevail. In the high mountains to the south and west, the precipitation is greater than at Big Bear Lake. At Big Bear Lake a maximum 24-hour precipitation of about 6 inches will probably be exceeded once in 2 years. The corresponding statistic of precipitation intensity ranges from about 2.5 to 8 inches for the drainage basin.

The lake occupies 12 percent of its drainage basin, and thus some of its water supply comes directly from rain and snow. Most tributaries to the lake have little flow during much of the year. For example, in 1968, the total surface inflow to the lake was only 4.2 cubic feet per second in late summer. In contrast, in January and February 1969 an intensive storm caused Big Bear Lake to fill and spill for the first time since the winter of 1939, and for only the seventh time since the dam was constructed in 1884. Natural runoff at the dam averages about 9,000 acre-feet per year. The lake surface freezes during most winters and was frozen during the winter of the study period (1968-69).

STRATIFICATION AND THE REGIMEN OF WATER TEMPERATURE IN A LAKE

Stratification of water in lakes and reservoirs is usually a result of density differences caused by differential water temperatures. Pure water has its maximum density at 4°C (Celsius) and becomes progressively less dense as it cools from 4°C to the freezing point or warms from 4°C to the boiling point. Thus, water is least dense at its maximum summer temperature and increases in density as it cools to 4°C. Figure 3 illustrates this property. At the end of the winter season in the temperate zone, water in a reservoir is cold and has a high density. As the air temperature increases, the temperature of the lake water surface increases with a corresponding decrease in density, and the deeper water remains cooler and denser. The difference in density between the top and bottom strata of water eventually becomes great enough to prevent wind-induced mixing of the water mass, and thermal stratification occurs.

In a lake that is thermally stratified, limnologists recognize three distinct strata: (1) a relatively warm surface layer, the epilimnion; (2) a middle layer in which the temperature decreases rapidly with depth, the thermocline; and (3) a colder bottom layer, the hypolimnion. Figure 4 shows a curve representing the relation between temperature and depth during typical conditions of summertime thermal stratification.

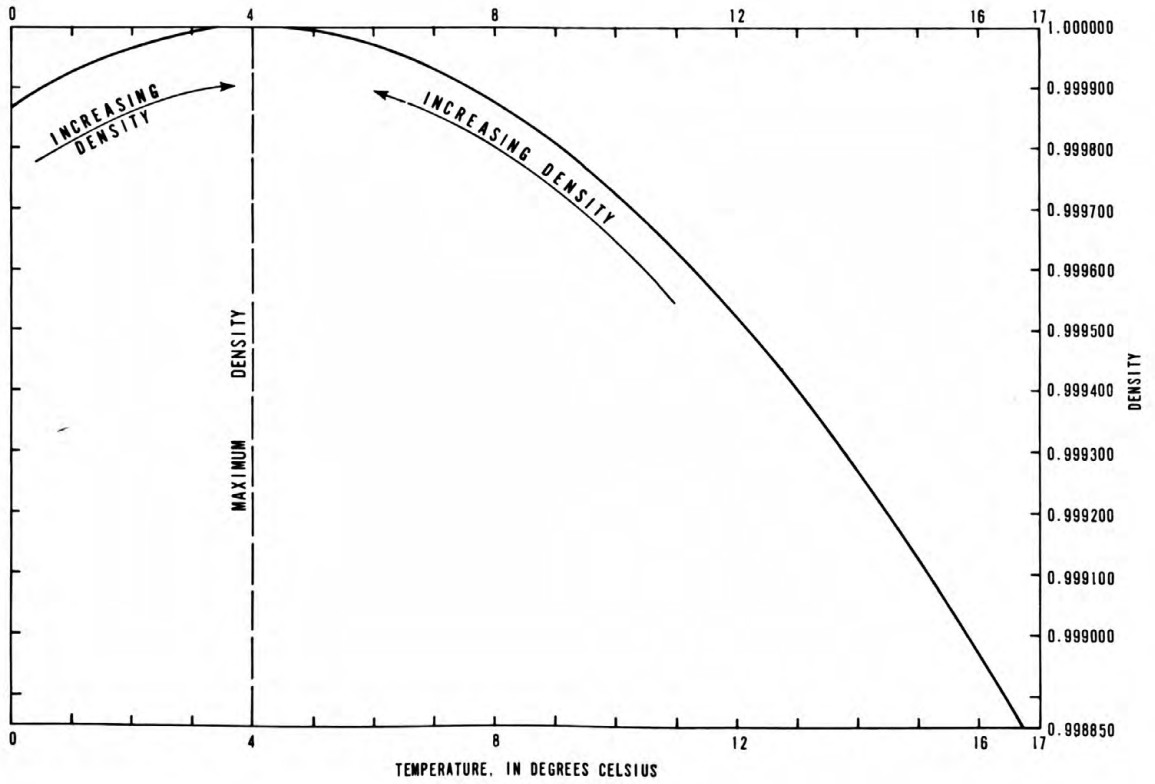


FIGURE 3.--Relation between density and temperature in pure water.

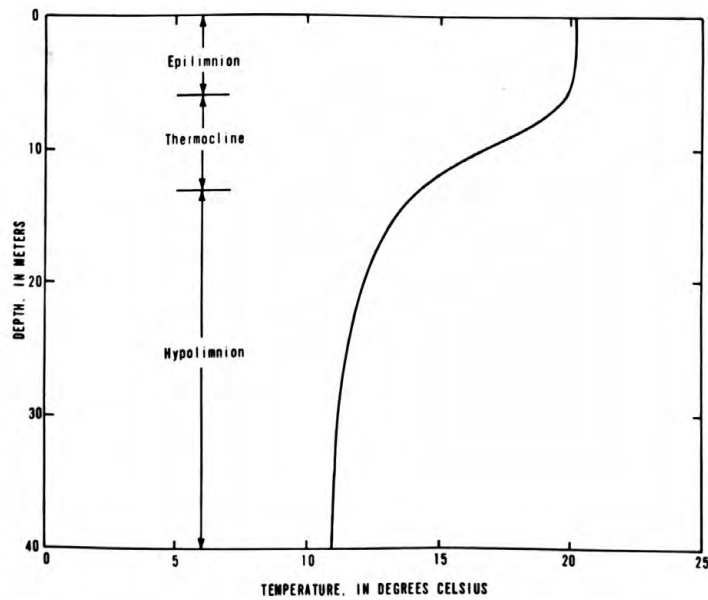


FIGURE 4.--Typical summer temperature profile of a lake, with temperature zones indicated.

In the epilimnion the decline in temperature is often less than 1°C per meter of depth; in the thermocline it is often more than 1°C per meter of depth, and in the hypolimnion the decline in temperature again becomes less than 1°C per meter of depth (Welch, 1952). In a stratified lake the demarcation between epilimnion and thermocline is usually distinct. The thermocline tends to form a rather effective barrier that prevents mixing between the epilimnion and the hypolimnion. However, wind-induced mixing usually maintains a fairly uniform temperature throughout the depth of the epilimnion.

METHODS

Twenty sampling stations were chosen in Big Bear Lake and are shown in figure 2. At these stations water samples were taken monthly during the period from June 1968 through June 1969 to be analyzed for dissolved-oxygen concentration, specific conductance, and pH. At the times of sampling, readings of water temperature and light penetration into the lake were also taken.

In addition, water samples were collected at some of the sites for analyses as to the quantities of selected ions, of nutrients, and of plankton. Samples were taken periodically at stations 4, 6, 8, 10, 12, and 16 for analyses with respect to the three primary nutrients--that is, nitrate-nitrogen, orthophosphate-phosphorus, and silica. Data as to plankton were obtained from samples taken at stations 4, 8, 9, 10, 12, and 16.

Measurements and analyses were made as appropriate in the field or in Geological Survey laboratories in Menlo Park or Sacramento, Calif. Standard equipment and methods were used.

Hourly readings of dissolved oxygen, water temperature, specific conductance, and pH at station 1 were recorded for a 24-hour period during June 18-19, 1969. Instrumentation and procedures were the same as those that were used during the monthly sampling program.

A complete tabulation of chemical data and plankton populations collected from June 1968 through June 1969 are available for inspection at the Water Resources Division district office in Menlo Park, Calif., and at the subdistrict office in Garden Grove, Calif.

RESULTS

Dissolved Oxygen

Figure 5 shows three sets of dissolved-oxygen profiles of Big Bear Lake. The profiles are from the eastern, middle, and western parts of the lake for October and December 1968 and April and June 1969. These months were selected to represent the general seasonal conditions of autumn, winter, spring, and summer. In October the dissolved-oxygen concentrations were stratified with depth; at the bottom concentrations exceeded 3.0 mg/l (milligrams per liter). In December the dissolved-oxygen concentrations did not indicate stratification and were in excess of 11.0 mg/l. In April there was a slight stratification with depth, although bottom concentrations exceeded 7.0 mg/l. In June dissolved-oxygen concentrations showed definite stratification. Dissolved-oxygen concentrations at lower depths were less than 1.0 mg/l throughout the lake. Areally the dissolved-oxygen trends in the lake were generally similar.

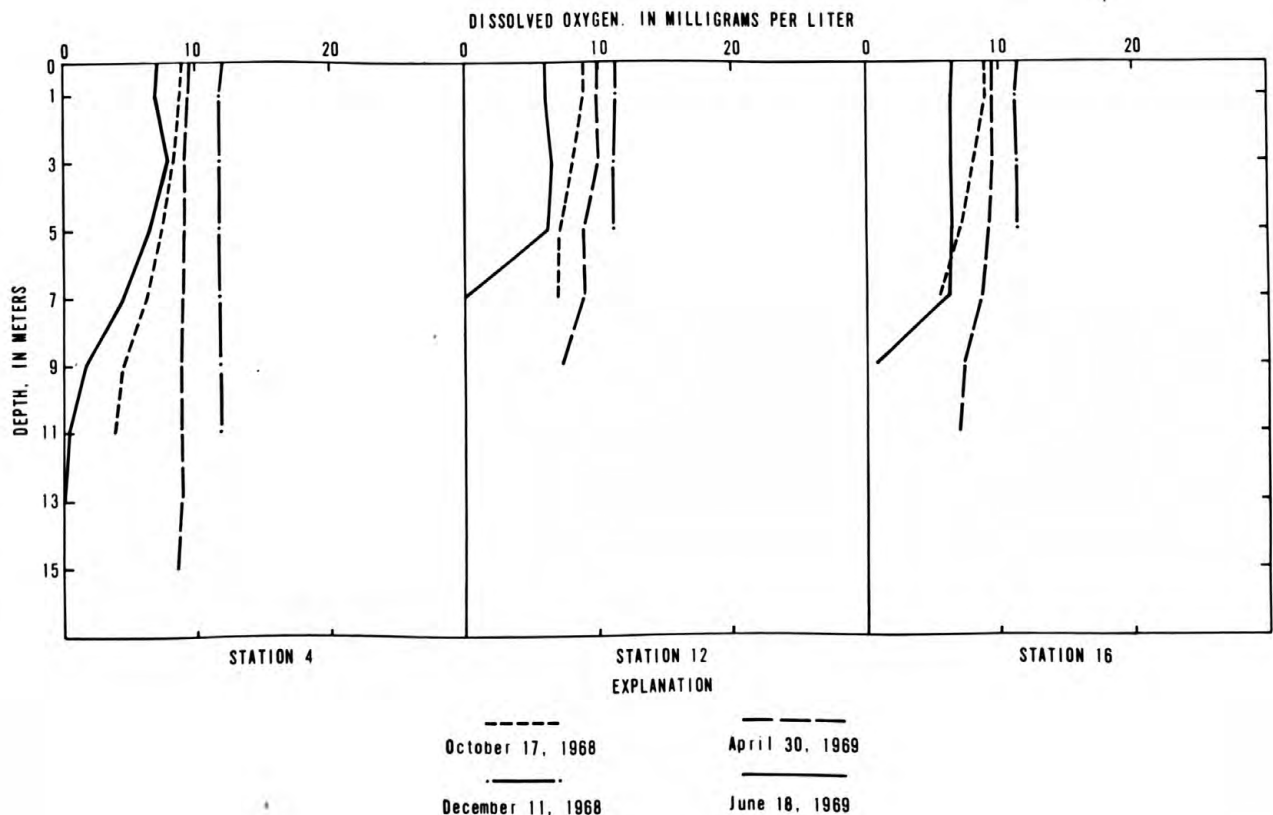


FIGURE 5.--Dissolved-oxygen profiles at three sites in Big Bear Lake.

Temperature

Water temperature of Big Bear Lake varied significantly with the season, with a June average of about 18.0°C and a December average of about 4.0°C.

Figure 6 shows vertical profiles of temperature for the sites and times that correspond with the data of figure 5. In October water temperatures ranged between 11.0° and 13.0°C and did not appear to be stratified. In December the water temperatures ranged between 2.5° and 4.0°C, and again the lake was not thermally stratified. In April a slight thermal stratification of about 2.5° between surface and bottom was apparent, with surface temperatures ranging from 10.5° to 11.5°C and bottom temperatures ranging from 8.0° and 9.0°C. In June slight thermal stratification occurred, with the maximum stratification occurring in the western part of the lake (station 4). At that site the surface temperature was 18.0°C, decreasing to 13.0°C at a depth of 13 meters. The slight thermal stratification observed indicates that induced mixing by air injection may not be necessary.

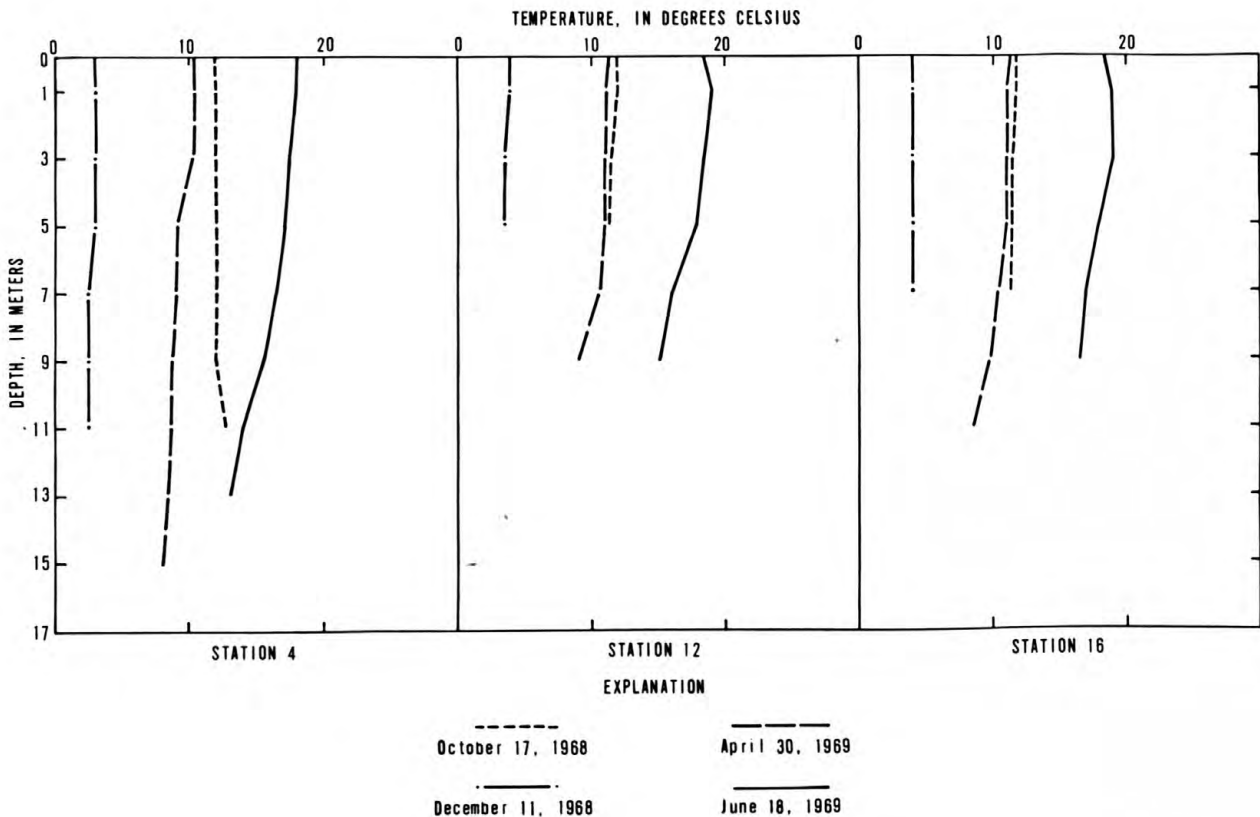


FIGURE 6.--Temperature profiles at three sites in Big Bear Lake.

Specific Conductance

The mean specific conductance of the water in Big Bear Lake was approximately 250 micromhos during the summer, autumn, and winter of 1968. A decrease in the specific conductance of the lake water occurred in the spring of 1969 and was caused by dilution of the lake water by the heavy precipitation that occurred in January and February of that year.

Hydrogen Ion Concentration (pH)

The hydrogen ion concentrations (pH) generally showed a variation within the water column of at least one unit at most sites during the monthly sampling program. pH readings of the lake water did not vary consistently with depth. No distinct seasonal pH pattern was observed. The maximum pH was 8.7 in October 1968. The minimum value of 7.1 was observed several times during the year.

Light Penetration

The depth of light penetration is a rough measurement of the euphotic zone or lighted region. In this zone photosynthetic activity can occur.

Periodic light penetration (transparency) estimates were made in Big Bear Lake. The average light penetration of the lake water was about 3 meters, but the range was 1.7 to 4.5 meters. Lower transparencies were generally observed in the eastern part of the lake.

Nutrients

Table 1 shows vertical distribution of nitrate-nitrogen, orthophosphate-phosphorus, and silica at stations 4, 12, and 16 for October and December 1968 and April and June 1969. These months and stations were selected to represent general seasonal and areal conditions of Big Bear Lake.

Nitrate-nitrogen concentrations were maximum in December and were significantly reduced during other seasons. Concentrations of nitrate-nitrogen during the year, with few exceptions, were generally uniformly distributed with depth.

Orthophosphate-phosphorus concentrations throughout the lake were maximum in June. Concentrations of orthophosphate-phosphorus from autumn to spring were uniformly distributed with depth; however, in summer definite stratification occurred with higher concentrations near the bottom of the lake.

TABLE 1.--Selected nutrients at three sites in Big Bear Lake

[Analyzing laboratory: U.S. Geological Survey, Menlo Park, Calif.]

[Constituents in milligrams per liter]

Date	Depth (meters)	Station 4			Station 12			Station 16		
		Nitrate- nitrogen (NO ₃ -N)	Ortho- phosphate- phosphorus (PO ₄ -P)	Silica (SiO ₂)	Nitrate- nitrogen (NO ₃ -N)	Ortho- phosphate- phosphorus (PO ₄ -P)	Silica (SiO ₂)	Nitrate- nitrogen (NO ₃ -N)	Ortho- phosphate- phosphorus (PO ₄ -P)	Silica (SiO ₂)
Oct. 17, 1968	0	0.047	0.03	0.80	0.003	0.07	1.1	0.012	0.05	1.1
	1	.010	.03	.75	.015	.03	1.1	.016	.03	1.1
	3	.011	.02	.90	.007	.02	1.0	.014	.05	1.1
	5	.010	.02	.90	.015	.03	1.1	.015	.06	1.3
	7	.009	.03	.85				.022	.03	1.1
	9	.010	.02	.75						
Dec. 11, 1968	0	.039	.01	.60	.072	<.01	.70	.057	.01	.60
	1	.048	<.01	.60	.079	.01	.70	.056	<.01	.65
	3	.040	<.01	.65	.085	.01	.65	.056	<.01	.70
	5	.039	.02	.60	.134	.02	.70	.059	.01	.65
	7	.038	<.01	.65				.055	.01	.70
	9	.043	.01	.60						
Apr. 30, 1969	0	.022	.01	4.8	.007	.01	5.0	.007	.01	5.0
	1	.012	.01	4.8	.010	.01	5.0	.005	.02	4.9
	3	.021	<.01	4.8	.011	.02	4.6	.007	.09	5.0
	5	.019	.01	4.8	.015	.02	5.1	.020	.02	5.2
	7	.017	.02	4.8	.011	.01	5.4	.012	.02	5.1
	9	.018	.02	4.8	.030	.03	5.2			
	11	.023	.02	4.8						
	13	.020	.02	4.8						
	15	.030	<.01	4.9						
June 18, 1969	0				.025	.11	4.3			
	1	.010	.04	3.6	.015	.13	4.2			
	3				.016	.14	4.3			
	5	.019	.02	3.6	.008	.08	4.2			
	7				.014	.27	4.7			
	9	.022	.22	5.2						
	11									
	13	.028	.40	5.7						

Silica concentrations were less than 1.5 mg/l throughout the lake in the autumn and winter. In the spring the silica concentration increased to about 5.0 mg/l and remained near this level into summer. Silica concentrations did not vary significantly with depth.

Chemical Composition

Table 2 shows the chemical analyses of water of Big Bear Lake. The water type is calcium magnesium bicarbonate with a dissolved-solids range of 94 to 141 mg/l. Individual samples collected July 24, 1968, at 1 and 9 meters show no significant chemical variation with depth. The water sample collected March 16, 1969, shows the dilution effect of the heavy precipitation that occurred during January and February 1969.

TABLE 2.--*Chemical analyses of water at station 4, Big Bear Lake, Calif.*

[Analyzing laboratory: U.S. Geological Survey, Sacramento, Calif.]

Date of collection	7-24-68	7-24-68	3-16-69
Depth (meters)	1	9	5
Results in milligrams per liter			
Iron, total (Fe)	0.01	0.01	0.04
Calcium (Ca)	29.0	30.0	19.0
Magnesium (Mg)	9.4	9.3	6.1
Sodium (Na)	9.9	9.6	7.4
Potassium (K)	3.0	3.0	2.3
Bicarbonate (HCO ₃)	146	146	90
Sulfate (SO ₄)	3.0	4.0	5.0
Chloride (Cl)	7.5	7.7	5.6
Fluoride (F)	.2	.2	.1
Boron (B)	.0	.0	.03
Sum of constituents	138	141	94
Hardness as CaCO ₃	111	113	72
Noncarbonate hardness as CaCO ₃	0	0	0
Percent sodium	16	15	17
Specific conductance (micromhos at 25°C)	256	256	172
pH	7.6	7.0	--
Temperature (°C)	20.3	20.0	2.2

Plankton

Phytoplankton and zooplankton samples were collected monthly from 1- and 5-meter depths at stations 4 and 12. Figure 7 shows the mean monthly phytoplankton and zooplankton populations from July 1968 through June 1969 at the two sites.

Phytoplankton and zooplankton populations varied with seasons, and populations were generally larger at station 4. The maximum phytoplankton population of 45,000 organisms per liter was found in June 1969 at station 4 at a depth of 1 meter. The minimum population of 54 organisms per liter was found in March 1969 at station 12 at a depth of 5 meters. The maximum zooplankton population of 890 organisms per liter was found in December 1968 at station 4 at a depth of 5 meters. The minimum population of three organisms per liter was found in March 1969 at station 12 at a depth of 1 meter.

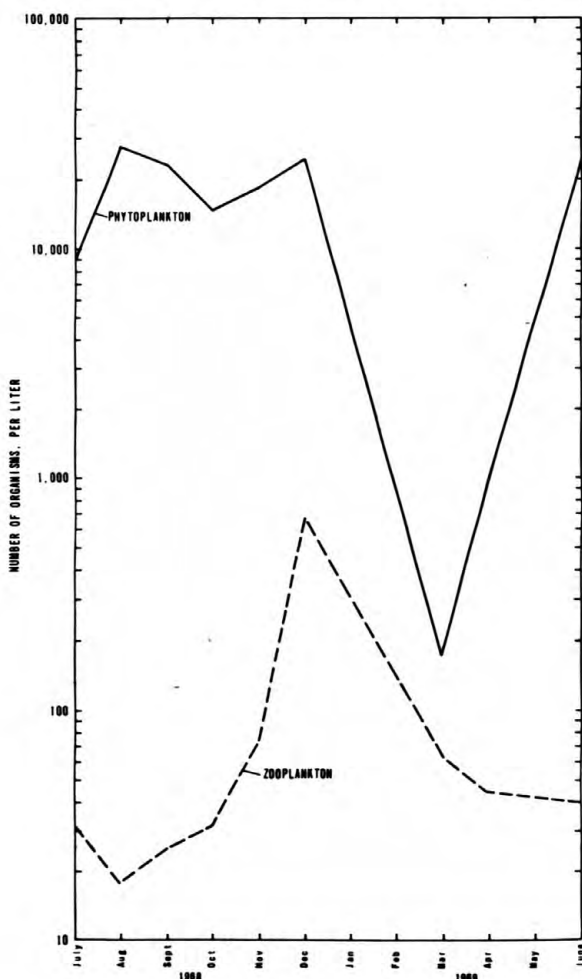


FIGURE 7.--Mean monthly population of plankton, at stations 4 and 12, July 1968 through June 1969.

Twenty-Four-Hour Study

Table 3 shows the diurnal variation of dissolved-oxygen concentration at station 1 at frequent intervals from 1000 hours June 18 to 1000 hours June 19, 1969. The dissolved-oxygen concentrations at 1, 3, and 5 meters did not vary significantly in the 24 hours. The concentrations ranged between 5.2 and 7.7 mg/l. The maximum dissolved-oxygen concentration was 8.0 mg/l at 1100 hours at the surface. The minimum concentration was 5.2 mg/l at 1300 hours at a depth of 5 meters. At 7 meters dissolved-oxygen concentrations were generally less than 6.0 mg/l and the diurnal range was 2.4 to 6.4 mg/l. Below 7 meters the dissolved-oxygen concentration decreased. At 11 meters the dissolved-oxygen concentration was zero for several hours.

Water temperature at station 1 during the 24-hour period decreased with depth (table 4), but at any of the depths that were sampled it varied only slightly with time. Maximum water temperatures were at the surface and ranged from 17 to 19.5°C. The minimum water temperatures were at a depth of 11 meters and ranged from 13 to 15.5°C.

The hydrogen ion data are limited because the time interval from 1800 to 0600 hours was not sampled, nor were samples read at 0800 and 0900 hours. The data collected show that the pH values were more than 8.0 from the surface to a depth of 7 meters (table 5); below 7 meters pH values decreased to a minimum of 7.5. However, pH values did not vary greatly at individual depths during the study period.

Specific conductance of the lake changed little during the 24-hour period (table 6). It averaged 188 micromhos with a range of 170 to 195 micromhos decreasing only slightly with depth.

TABLE 3.--*Dissolved oxygen in milligrams per liter for the 24-hour study at station 1*

Depth (meters)	June 18, 1969												June 19, 1969							
	Hours												Hours							
	1000	1100	1200	1300	1400	1500	1600	1700	1800	2000	2100	2300	0200	0445	0545	0700	0800	0900	1000	
0	6.8	8.0	7.2	7.1	7.0	6.9	6.9	6.9	7.0	7.2	7.3	7.0	7.0	6.8	6.7	6.8	7.0	6.8	6.8	
1	7.2	7.7	7.1	7.1	7.0	7.0	6.8	6.9	7.0	7.2	7.2	7.0	7.0	7.0	6.6	6.7	6.8	6.7	6.8	
3	6.3	7.4	7.6	7.7	7.2	6.6	7.0	6.9	7.0	7.3	7.2	6.8	6.6	6.7	6.8	6.9	7.1	6.8	6.8	
5	5.9	7.4	5.8	5.2	5.9	7.1	7.3	6.9	7.1	6.8	6.8	6.5	5.4	5.6	5.8	5.8	6.2	5.7	5.9	
7	3.5	3.5	2.4	3.8	3.4	4.6	5.3	5.5	5.2	6.4	5.4	3.7	3.5	4.2	4.4	4.3	4.0	4.2	4.4	
9	5.9	3.4	2.7	3.0	2.9	3.3	2.8	3.7	3.7	2.9	3.2	1.6	.2	.3	.5	.9	1.0	2.7	2.6	
11	1.3	2.2	2.0	2.2	2.7	.4	1.0	.4	.0	.1	.2	.0	.0	.0	.0	.0	.0	.0	.0	

TABLE 4.--*Water temperature in degrees Celsius for the 24-hour study at station 1*

Depth (meters)	June 18, 1969											June 19, 1969							
	Hours											Hours							
	1000	1100	1200	1300	1400	1500	1600	1700	1800	2000	2100	2300	0200	0445	0545	0700	0800	0900	1000
0	18	18.5	18	19.5	19	18	18	18	18	17.5	17	17.5	17.5	17	17	17.5	17.5	18.5	19
1	18	18	18	19	18.5	18	18	18	18	18	17.5	18	18	17.5	17.5	18	18	18	18.5
3	17	17.5	18	18	18	18	18	18	18	18	18	17.5	17.5	17.5	18	18	18	18	18
5	17	17	17	17	17	17.5	17	18	18	18	18	17.5	17	17	17	17	17	17.5	17.5
7	16.5	16.5	15.5	16	16	16	17	17	17.5	18	17	16	16	16	16	16	16	16	16
9	15	15	15	15.5	15	15.5	16	16	16.5	17	16	15	15	14	14.5	14.5	15	15.5	15
11	15	15	14.5	15	15	15	15	15	15	15.5	14	13.5	13	13.5	14	14	14	14	14
Average	16.6	16.8	16.6	17.1	16.9	16.9	17.0	17.1	17.3	17.4	16.8	16.6	16.4	16.1	16.3	16.4	16.5	16.8	16.9
Maximum difference	3	3.5	3.5	4.5	4	3	3	3	3	2.5	4	4.5	5	4	4	4	4	4.5	5

TABLE 5.--*pH values for the 24-hour study at station 1*

Depth (meters)	June 18, 1969									June 19, 1969	
	Hours									Hours	
	1000	1100	1200	1300	1400	1500	1600	1700	0700	1000	
0	8.3	8.2	8.5	8.5	8.4	8.3	8.2	8.5	8.0	8.4	
1	8.5	8.5	8.6	8.5	8.5	8.5	8.5	8.5	8.2	8.6	
3	8.4	8.5	8.6	8.5	8.4	8.4	8.4	8.5	8.4	8.6	
5	8.3	8.4	8.4	8.4	8.3	8.4	8.4	8.4	8.4	8.6	
7	8.0	8.2	8.1	8.0	8.0	8.1	8.2	8.3	8.1	8.3	
9	7.7	7.9	7.8	7.7	7.7	7.8	8.0	7.9	7.7	7.9	
11	7.6	7.7	7.7	7.7	7.6	7.6	7.7	7.5	7.5	7.7	

TABLE 6.--*Specific conductance in micromhos at 25°C for the 24-hour study at station 1*

Depth (meters)	June 18, 1969									June 19, 1969
	Hours									Hours
	1000	1100	1200	1300	1400	1500	1600	1700	1000	
0	190	192	195	192	195	190	190	190	188	
1	190	190	194	191	194	190	190	190	189	
3	190	190	190	188	188	188	189	188	188	
5	188	188	188	188	170	185	188	186	187	
7	180	188	190	188	190	188	185	182	188	
9	185	188	188	170	190	186	182	187	189	
11	180	185	188	188	188	188	185	188	185	

Relation Between Phytoplankton and Nutrient Concentration

The relation of phytoplankton population and nutrient concentration for the period August 1968 to June 1969 is shown in figures 8 and 9.

Phytoplankton population and nitrate-nitrogen declined from August 1968 to October 1968. In December 1968 the nitrate-nitrogen concentration increased sharply, perhaps because heavy precipitation during November and December washed accumulated nitrogenous materials into the lake. This increased nutrient supply was the probable cause of the phytoplankton growth increase that was observed during December. The dominant genus encountered during the summer and autumn of 1968 and winter of 1969 was *Anacystis*, a blue-green alga. In March 1969, the nitrate-nitrogen reached high levels, while the phytoplankton populations were at the lowest levels. The decline in phytoplankton was perhaps caused by generally colder water and light inhibition by ice formation. In April the phytoplankton population increased slightly. In June the phytoplankton population increased significantly. The dominant genus at this time was *Stephanodiscus*, a centric diatom. The nitrate-nitrogen concentration decreased slightly from April concentrations. The steady decrease in the nitrate-nitrogen from March to June was probably the result of phytoplankton uptake. The rapid increase in phytoplankton from April to June, while the nitrate-nitrogen concentration remained nearly constant, suggests that other factors, such as light, water temperature, or phosphorus, stimulated the production of the phytoplankton.

The orthophosphate-phosphorus concentration generally declined from August 1968 to April 1969. But the concentrations increased significantly in June 1969, particularly at station 12. The phytoplankton increase in June 1969 might have been partly stimulated by this increase in orthophosphate.

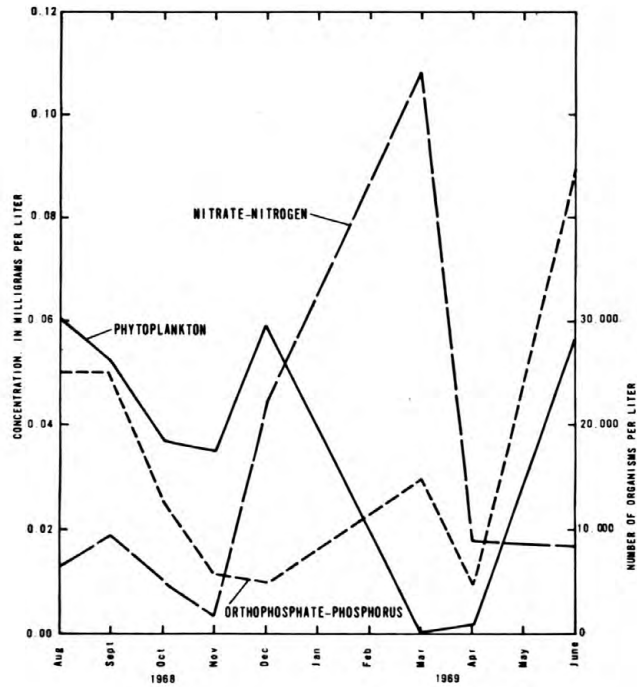


FIGURE 8.--Phytoplankton populations and concentrations of nitrate-nitrogen and orthophosphate-phosphorus for station 4, August 1968 to June 1969.

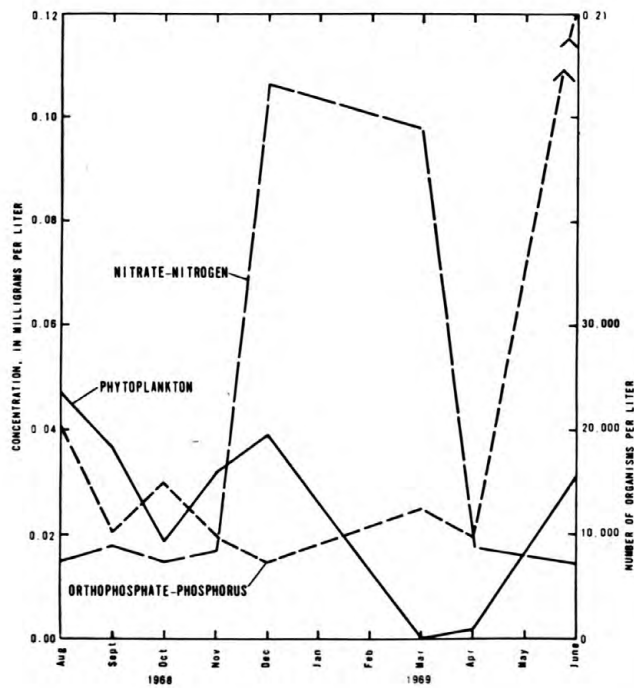


FIGURE 9.--Phytoplankton populations and concentrations of nitrate-nitrogen and orthophosphate-phosphorus for station 12, August 1968 to June 1969.

SUMMARY AND CONCLUSIONS

Big Bear Lake exhibited only the normal seasonal variations in dissolved oxygen, temperature, specific conductance, nutrients, and phytoplankton.

Dissolved oxygen in the lake showed definite stratification during the summer months; in July 1968 and June 1969 at lower depths the concentration was frequently near zero. In the autumn and the spring there was some stratification, while during the winter no stratification was observed and the concentration of dissolved oxygen was high.

Thermal stratification occurred throughout the lake in spring and summer with the maximum stratification in June. The deeper western part of the lake (station 4) showed a thermal variation of 5.0°C between the surface and a depth of 13 meters, with a maximum change per meter of 0.75°C . The general shallowness of Big Bear Lake and the frequency of winds apparently keep the water mass sufficiently mixed to prohibit lengthy periods of thermal stratification. Induced mixing by air injection is probably not needed.

Nitrate-nitrogen concentrations in the autumn, spring, and summer were low and generally ranged between 0.01 and 0.03 mg/l throughout the lake. In the winter an increase in nitrate-nitrogen occurred, probably entering the lake from the first surface runoff of the season.

Orthophosphate-phosphorus concentrations were generally low and uniformly distributed throughout the lake from autumn to spring. High concentrations of orthophosphate-phosphorus occurred near the bottom in the summer.

Dissolved-oxygen concentrations varied significantly at lower depths during the 24-hour study conducted in June 1969. It began decreasing below 7 meters, and at 11 meters the concentration was zero for several hours. Water temperature and pH decreased with depth but remained stable at individual depths throughout the 24-hour period.

Two phytoplankton growth peaks occurred during the study period, one in the winter and one in the summer. Although the increases in the algal populations were apparent seasonally, the actual numbers of organisms were not excessive.

This study investigated some of the important physical, chemical, and biological features of Big Bear Lake. Lakes are an ever-changing feature of the landscape and their limnological mechanisms can vary from year to year, sometimes with rapid and severe effects. Consequently, the findings of any one year cannot be used to predict, with any certainty, the limnological conditions likely to be encountered in future years. This is particularly true in areas where the activities of man are present. In such places environmental quality may change rapidly as a result of man's alteration of the watershed.

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