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Preliminary Aspects of an Ecological Investigation of Lake East Okoboji, Iowa

ROGER VOLKER²

Abstract. A preliminary study of some ecological factors of Lake East Okoboji was made in the period June 1960-June 1961. Chemical analyses were conducted to determine phenolphthalein alkalinity, total alkalinity, calcium hardness, total hardness, chloride, sulfate, pH, dissolved oxygen, iron, phosphate, nitrate, and silica. Collections of diatoms were made concurrently with the chemical analyses. Lake East Okoboji was found to be an alkaline, shallow, non-stratified, moderately hard water lake. A large spring and fall bloom of diatoms occurred, with a dense blue-green algal bloom in mid-summer.

A study of the ecology of Lake East Okoboji was considered desirable for several reasons. Lake West Okoboji, with which it is connected, is a deep lake which becomes stratified in summer while Lake East Okoboji is a shallow lake which does not become stratified. Lake East Okoboji supports a dense bloom of blue-green algae in mid-summer while populations of blue-green algae seldom reach bloom proportions in the West Lake. The latter lake has been studied intensively for many years, while, with the exception of Weber (1958), little work has been done on Lake East Okoboji. Thus, results obtained in this investigation would have added value because of possible comparison with Lake West Okoboji.

It has become increasingly evident that a broadening of the scope of chemical and physical analysis is vital to ecological investigations of fresh waters. For this reason the availability of a field testing kit such as the Hach Model DrEL (Engineer's Portable Water Testing Laboratory) was very helpful since it made possible the testing of a greater number of samples in a much shorter period of time than usual for laboratory tests of this type. In addition to this it was possible to test for a greater number of chemical variables in each water sample.

Materials and Methods

Each sample of lake water was analyzed for 12 different chemical constituents. In most cases water analyses were conducted at the site of collection, although in some instances water

¹ This investigation was begun in the summer of 1960 at the Iowa Lakeside Laboratory with support from the National Science Foundation through a High School Science Teacher Research Participation program administered by Iowa State University. It was continued privately during the academic year 1960-1961 while the author was teaching at Estherville, Iowa. In the fall of 1961 the investigation continued as part of a project supported by funds from the National Institutes of Health, Division of Water Supply and Pollution Control, for the project, "Ecology of Diatoms in Freshwater Habitats", under the direction of Dr. J. D. Dodd.

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samples were taken to the Lakeside Laboratory for analysis with the same water testing laboratory within 24 hours. The individual procedures, listed in Table 1, are adapted from Standard Methods (American Public Health Association, Inc., 1960) with only slight modifications in some instances.

Table 1. Water Testing Methods Used in Hach Portable Water Testing Laboratory^a.

<i>Test</i>		<i>Method</i>
Phenolphthalein Alkalinity	Volumetric	Titration with H ₂ SO ₄ using phenolphthalein as indicator.
Total Alkalinity	Volumetric	
Chloride ion	Volumetric	Titration with Hg(NO ₃) ₂ using diphenyl-carbazone as indicator.
Calcium Hardness	Volumetric	Titration with EDTA using CalVer II as indicator.
Total Hardness	Volumetric	Titration with EDTA using Eriochrome black T as indicator.
pH	Colorimetric	Wide range indicator (pH 4 - 10) giving colored solutions throughout pH range.
Sulfate ion	Turbidimetric	SO ₄ ⁼ is precipitated in acid solution with BaCl ₂ to form uniform sized BaSO ₄ crystals which remain suspended in solution.
Dissolved Oxygen	Colorimetric	Modified Alsterberg (azide) Method. Solutions of MnSO ₄ and KOH+Na ₃ N form precipitate of Mn(OH) ₂ which absorbs dissolved O ₂ . Acidification with H ₂ SO ₄ releases absorbed O ₂ which then oxidizes I ⁻ to free I ₂ , forming brown solution.
Iron	Colorimetric	Reduction of Fe ⁺⁺⁺ to Fe ⁺⁺ with hydroxylamine, then chelation with 1, 10-phenanthroline to form orange-red complex.
Phosphate (ortho) ion	Colorimetric	Stannous Chloride Method. (NH ₄) ₂ MoO ₄ reacts with PO ₄ ⁼ in acid to form molybdophosphoric acid which is then reduced with SnCl ₂ to the intensely colored complex, molybdenum blue.
Nitrate ion	Colorimetric	Reaction between NO ₃ ⁻ and brucine in acid to form yellow solution.
Silica	Colorimetric	(NH ₄) ₂ MoO ₄ reacts with SiO ₂ to produce a yellow solution of molybdosilicic acid. Oxalic acid is added to destroy any molybdophosphoric acid present. Yellow molybdosilicic acid is then reduced to heteropoly blue with aminonaphtholsulfonic acid, Na ₂ SO ₃ , and NaHSO ₃ .

^a Colorimetric tests employed a photoelectric colorimeter.

During the periods June-October 1960 and April-June 1961, 45 water samples were taken at random from each of 5 geographically distinct areas of the lake. In Figure 1 and Table 2

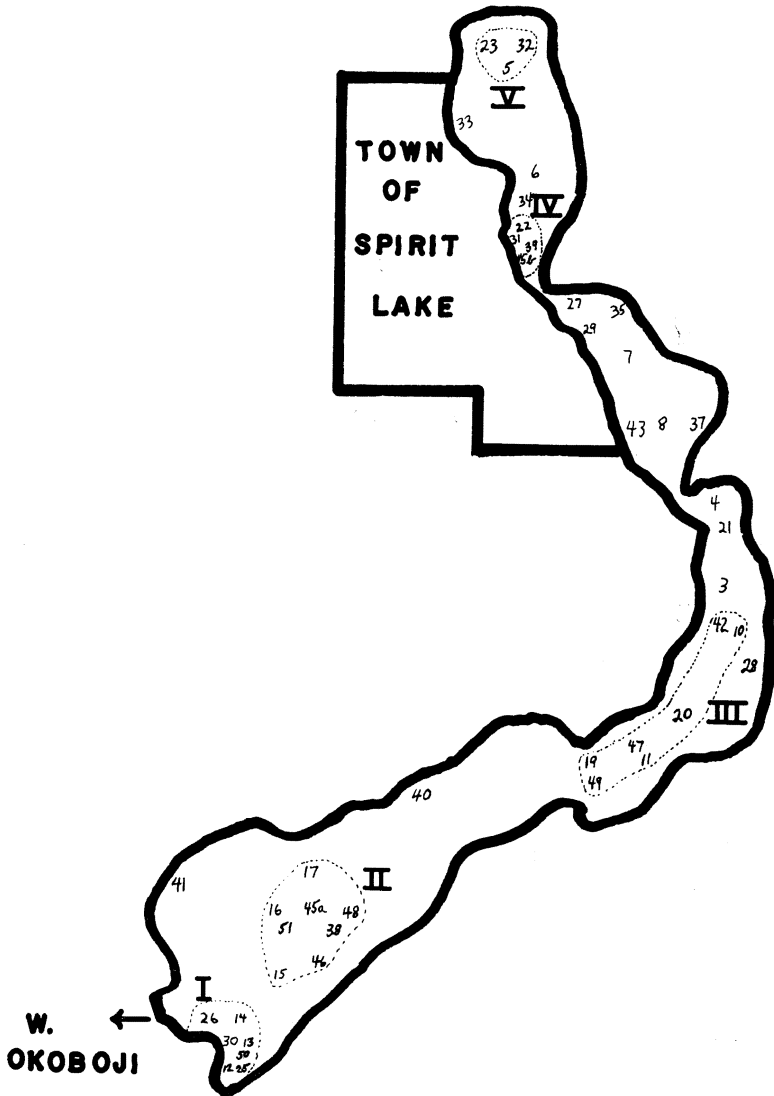


Figure 1. Lake East Okoboji Chemical Sample Stations.
 the areas are indicated as I, II, III, IV, and V while the numerals represent the locations of specific samples.

Minor variations were found between the chemical analyses taken in the summer and fall of 1960 and spring of 1961. Minor variations were also found between different areas of the lake. Because of these variations it was decided to represent graphically in Figure 2 the results of chemical analyses for each constituent as a range rather than simply as an average.

Table 2. Chemical Analysis Data⁴

AREA	SAMPLE	DATE	P ALK	T ALK	Ca HARD	TOT HARD	Cl ⁻	SO ₄ ⁼	Fe	PO ₄ [≡]	NO ₃ ⁻	SiO ₂
I	12	8/9/60	15	185	-	190	-	45	0	0	0.02	18
	13	8/9/60	-	200	-	195	-	60	0	0	0.04	13
	14	8/9/60	-	200	-	200	-	50	0	0	0.04	14
	25	8/15/60	5	180	7.5	200	7.5	45	0	0.005	-	3.2
	26	8/15/60	1	160	70	200	10	200	0	0.5	0.03	16
	30	9/17/60	20	170	60	200	5	30	0.15	-	-	18
	50	6/11/61	15	210	90	225	10	38	-	-	-	0.5
II	15	8/9/60	20	170	-	200	-	43	0	0	0.04	14
	16	8/9/60	-	200	-	195	-	30	0	0	0.04	13
	17	8/9/60	-	190	-	200	-	35	0	0	0.14	14
	38	4/29/61	20	170	65	190	10	35	0	0	0	1.4
	45a	5/20/61	1	205	75	210	10	40	0	0.005	-	1.5
	46	6/11/61	10	210	70	220	10	35	0	0.005	-	3.2
	48	6/11/61	20	215	90	220	10	20	-	-	-	3.1
51	6/11/61	12	205	90	220	-	-	-	-	-	-	
III	10	7/29/60	45	285	80	210	10	55	0.9	-	0.08	1.2
	11	7/29/60	30	100	80	205	10	45	0.5	-	0.08	7.5
	19	8/9/60	-	190	-	200	-	25	0	0	0.05	16
	20	8/9/60	-	200	-	210	-	25	0	0	0.05	17
	42	5/30/61	0	200	100	240	7.5	30	0	-	0	2.5
	47	6/11/61	10	210	100	225	7.5	38	-	-	-	3.2
	49	6/11/61	20	210	90	235	10	32	0	0.3	-	2.8
IV	22	8/14/60	30	190	80	220	11	55	0.05	0	0.03	22
	31	9/17/60	30	220	85	200	10	35	-	-	-	20
	39	4/30/61	15	160	70	180	10	32	0	0.2	0.05	0.5
	45b	6/16/61	0	215	95	240	15	38	0	0.4	-	3.5
V	5	7/29/60	30	220	100	225	12	38	0.15	-	0.06	1.1
	23	8/14/60	30	220	80	240	10	50	0.07	0	-	22
	32	10/2/60	20	275	120	207	23	42	0	0	0.1	10

⁴ Dash (-) indicates no test was made. All data is expressed as parts per million.

Discussion

Alkalinity, Hardness, pH, Chloride, Sulfate. Lake East Okoboji is set in calcareous glacial till of the Wisconsin drift and is dependent for its water largely upon rainfall and runoff from the surrounding land. The alkalinity, hardness, and pH readings obtained are characteristic of moderately hard, alkaline water. The pH range (7.5 - 9.2) is, perhaps, a reflection of daily variations in the photosynthesis/respiration quotient, a point not considered at the times of sampling. The significance of the concentrations of sulfate and chloride ions may become apparent when the diatom flora is analyzed.

Dissolved Oxygen. The amount of oxygen present in a lake is dependent on several factors, including: (a) water temperature, (b) partial pressure of atmospheric oxygen in contact with lake surface, (c) concentration of dissolved salts in the water, (d) wave action, (e) photosynthesis, and (f) respiration of biota (Reid, 1961). In stratified lakes there may be an oxygen gradient from surface to bottom which follows closely the temperature gradient from surface to bottom. However, in Lake East Okoboji, which is a shallow lake subject to constant wave action, no distinct gradient for oxygen or temperature was found to exist at

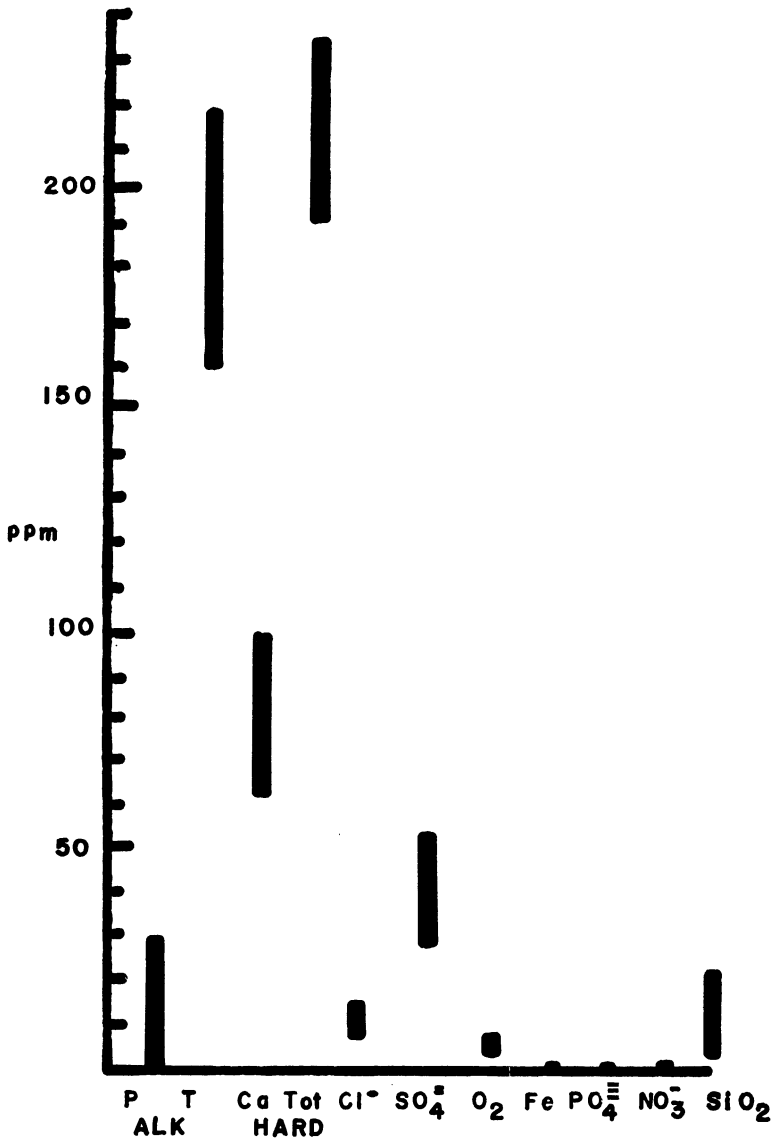


Figure 2. Lake East Okoboji Chemical Analyses, June-October 1960 and April-June 1961.

the time the chemical analyses were made. In midsummer 1960 the temperature in the deepest area (7 meters) varied only 2.8°C, from 24.9° at the surface to 22.1° at the bottom.

In a given 24-hour period the oxygen content of fresh waters may exhibit a so-called "oxygen pulse" in which dissolved oxygen is at a minimum just before dawn and at a maximum in late

afternoon (Reid, 1961). However, this pulse is subject to considerable variation from one day to another or even during one day because of wave action and light penetration. The strong winds blowing across Lake East Okoboji cause moderately high waves (0.5 - 0.7 meters) tending to dissolve a greater amount of oxygen than would be absorbed during calm conditions. Even in the lake at any given time one area could sustain high waves while another area 2 or 3 miles distant could be quite calm. Thus, oxygen samples taken in the same day at widely separated points on the lake could vary because of differences in turbulence. Since Lake East Okoboji is shallow, churning caused by waves also affects the sediment on the lake bottom, causing much of it to be brought into suspension. Turbidity in the euphotic zone, increased by wave action, thus affected light penetration, photosynthesis, and in turn dissolved oxygen. Whether the decrease in dissolved oxygen due to reduced photosynthesis was offset by increased dissolved oxygen due to wave action during a windy day was not determined.

Because the heretofore mentioned variables were not noted at the time oxygen was being sampled, and because the determination of oxygen variation during a 24-hour period was not practicable during this investigation, no significance is attached to the oxygen variations reported. The range of oxygen concentration encountered throughout the entire sampling period 1960-1961 was 2.3 - 10 ppm, or 28% - 115% saturation. Since dissolved oxygen did not disappear at the bottom the oxidation-reduction cycles of iron, phosphorus, nitrogen, and other elements were not in operation as they are in stratified lakes.

Temperature. Lake East Okoboji is a shallow lake with an average depth of about 4-5 meters. Because the lake is subject to rather constant winds, no thermocline is established, and consequently no epilimnion or hypolimnion are differentiated. A yearly temperature curve is given in Figure 3.

Iron and phosphorus. Iron is widespread in the earth's crust but only under special circumstances does it appear as a dissolved component in water. Of its two ionic forms, ferrous iron can not exist in the presence of oxygen and ferric iron is precipitated as the insoluble hydroxide at a pH above 7.5 (Ruttner, 1953). Since Lake East Okoboji maintains a pH of 7.5 - 9.2 and always contained dissolved oxygen during the periods samples very little iron was expected. Tests for iron showed a trace present (0.05 - 0.5 ppm) in some cases and no iron present in others. Iron can also occur in organic compounds, the humic acids, and as colloidal particles of $\text{Fe}(\text{OH})_3$. Perhaps the trace amounts of iron detected in Lake East Okoboji were bound in organic molecules or present as colloids.

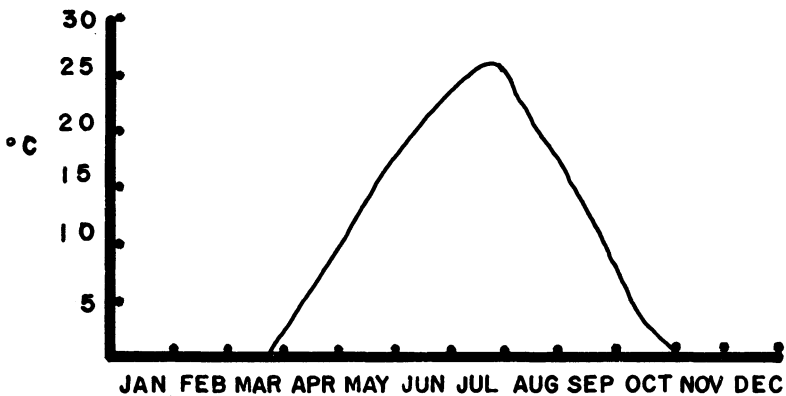


Figure 3. Lake East Okoboji Yearly Temperature, June 1960-June 1961.

Phosphorus occurs almost exclusively in fresh water in a fully oxidized state as the phosphate ion, PO_4^{\equiv} (Hutchinson, 1957). Only ortho phosphate is likely to be of importance in the environment, though some organic compounds containing useable phosphorus may exist also. At the height of an algal bloom there may be a great increase in the total organically bound phosphorus in the lake water, even though soluble phosphorus is undetectable. One condition for the development of such blooms may be rapid decomposition of dead organisms during warm weather and subsequent liberation of phosphate which would be taken up so rapidly by the growing algae it would not be detected as soluble phosphate.

Periodically tests were conducted to determine the presence of ortho phosphate. Only trace amounts (less than 0.5 ppm) were detected in some tests and in others no phosphate was present.

Einsele, cited by Ruttner (1953), found that Fe^{+++} would form a precipitate of FePO_4 in alkaline water if PO_4^{\equiv} was present, in addition to $\text{Fe}(\text{OH})_3$, and that both compounds were deposited in the sediment of the lake. If there is lack of oxygen in the sediment the iron can be reduced from Fe^{+++} to Fe^{++} , freeing the phosphate which then can go into solution. However, in Lake East Okoboji, where there was no lack of oxygen at the bottom, the FePO_4 presumably remained undissolved.

Dissolved Gases. Tests for the presence of dissolved CO_2 were made occasionally but always with negative results. This was expected since molecular CO_2 from atmospheric sources or from respiration would be incorporated promptly into the carbonate-bicarbonate buffer system of the lake water. Similarly tests for H_2S , NH_3 , and CH_4 were always negative, as expected from the lack of anaerobic conditions existing at the times of sampling.

Nitrate and Nitrite. Nitrate is the universal inorganic form of nitrogen in the epilimnion of eutrophic lakes, but since it is taken up in large amounts by the phytoplankton the amount found is usually very small and it is not unusual for it to disappear completely (Ruttner, 1953). In a stratified lake a gradient may exist between nitrate, nitrite, and ammonia corresponding to the oxygen gradient from high oxygen to trace amounts. In Lake East Okoboji oxygen was always present and no definite top to bottom gradient existed; thus nitrite and ammonia were not expected to be present. Several tests were conducted to determine the presence of these three forms of nitrogen but only nitrate was present in trace amounts (less than 0.05 ppm) in some samples and in many it was completely absent.

Silica. The element silicon is present almost universally in some form in all natural waters either as undissociated silicic acids, H_2SiO_3 and H_4SiO_4 , or as undissolved colloidal silica, SiO_2 . The method for determining silica may be subject to inaccuracies because two yellow silicomolybdic acids are produced in the silica test in which ammonium molybdate is added to the water sample acidified with H_2SO_4 (Hutchinson, 1957).

While silica is not a constituent of protoplasm it is of importance in the formation of diatom frustules. Diatom blooms constitute the most important mechanism by which silicon may be removed from lake water. Dying diatoms, falling to the lake bottom, may lose some silica to the water, and there appears to be evidence that silica reenters the cycle from lake sediments containing frustules of dead diatoms. Certain benthic diatoms apparently can use silica bound in aluminosilicates with which their slime sheaths come in contact (Hutchinson, 1957). Silica contained in runoff water from the surrounding land also enters the lake continuously.

The silica content of Lake East Okoboji varied from 0.5 - 22 ppm, with the higher readings obtained in August and September 1960 and the lower readings occurring in late April, May, and early June 1961.

Diatom Collections. The main methods of collecting diatoms from Lake East Okoboji were plankton net tow and rock scrapings, though some collections were made by pumping bottom water through a plankton net to concentrate the diatoms. In the June-November 1960 and April-June 1961 periods 197 collections were made. In the laboratory the samples were treated with 30% hydrogen peroxide and potassium dichromate to remove extraneous organic matter as well as protoplasm from the diatom frustules. The "cleaned" diatoms were dried on cover slips and permanently mounted in Hyrax.

Two noticeable blooms of diatoms occurred in Lake East Okoboji. The spring bloom, beginning in May, was characterized by species of *Fragilaria*, *Gomphonema*, *Navicula*, and *Synedra* growing on rocks and other submerged objects. In late May and throughout June species of *Asterionella*, *Melosira*, and *Stephanodiscus* appeared in the plankton samples to climax the bloom. During July and August diatoms were greatly diminished in number. In September and October a second bloom of diatoms appeared.

Epiphytic species developed as growths on the attached green alga *Cladophora*, and *Stephanodiscus* was present in plankton samples.

A complete species list for the diatoms of Lake East Okoboji has not been compiled but preliminary examination indicates it will contain between 200-300 species.

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