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A Quarterly Standard Mineral Analysis of the Waters of Four Iowa Lakes in the Ruthven Area[1]

ADA HAYDEN

THE WATERS OF FOUR WISCONSIN DRIFT LAKES—LOST ISLAND, VIRGIN, ROUND AND TRUMBULL.

Characteristics of the lakes. The silt bottomed prairie lakes of Clay and Palo Alto Counties, Iowa, have shallow, hard, alkaline, turbid waters. They are located in the youngest of the glacial drifts, in which the soils are highly calcareous and rich in mineral salts. The more shallow lakes with relatively flat, saucer-like basins, support a rich population of rooted, submerged, and emergent vegetation which minimizes wave action. The lakes whose basins are deeper than four feet are unfavorable to the growth of emergent vegetation and rooted submerged types do not survive the wave action except in the shallow waters along the depositing shores.

Algal content. The algal content of the lakes studied served in some degree as an indicator of the physico-chemical condition of the water. The species and types as well as their quantity and periodicity vary in the different lakes. Some algae have significance as food of fishes, others as a unit in the food chains of both fishes and of diving ducks. In some lakes where plankton is abnormally abundant it is referred to as "water bloom". The water blooms constitute associations of algae, mostly of the blue-green group, whose recurrent abundance indicates the presence of excessive organic matter in the water.

Four lakes in the Ruthven area were examined in the field by methods used in standard water analysis for several years with reference to the occurrence of oxygen and carbon dioxide in their waters. As a supplementary study, mineral analyses were made of the waters of four lakes including Lost Island, Virgin, Round, and Trumbull at four seasonal peaks in the year of 1943 and 1944 (Fig. 1). The samples were taken toward the middle of November, the end of February, the middle of May, and the middle of August. The analyses were made by the Water Laboratory of the State Geological Survey, through the courtesy of Dr. H. G. Hershey.

Circulation in the lakes sampled. The lakes compared were all temperate lakes of the third order, which have a temperature throughout similar to that of the surface water and circulation continuous, except when ice covered. The mineral and gaseous constituents have

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[2]The Fish and Wildlife Service (U. S. Department of the Interior), Iowa State College, Iowa State Conservation Commission and the American Wildlife Institute Cooperating.

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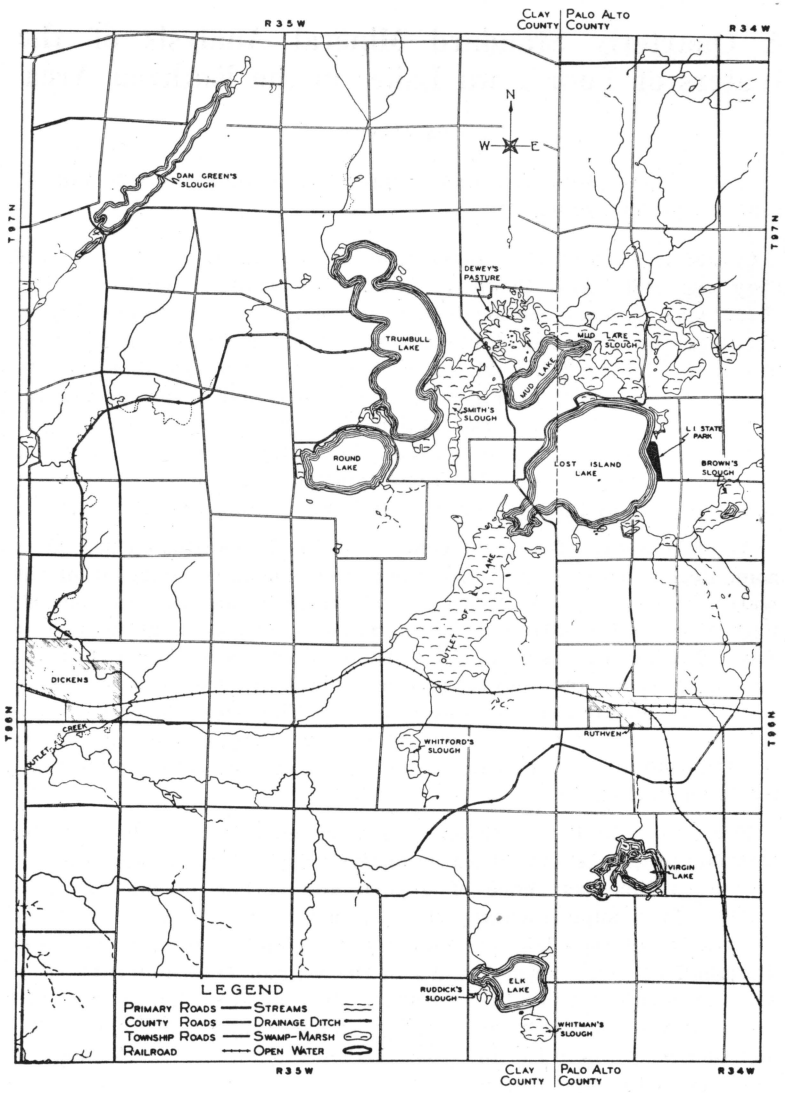

THE RUTHVEN AREA, IOWA.

Fig. 1. The Ruthven Area, Iowa.

relatively uniform distribution compared with temperate lakes of the first and the second order. Ice cover converts this type of lake temporarily into a condition which resembles the ice-covered lakes of the second order. Two periods, an open and an ice-covered interval, constitute the principal annual events. During the open seasons the continuous circulation provides (1) ample aeration at all depths; (2) disposal of gases formed in the bottom deposits by decomposition

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of plants; and (3) general distribution of substances passing into solution from the chemical changes in the bottom deposits, as well as from decay of plankton and other suspended materials.

During the ice-covered period, conditions of stagnation become established aand because of the shallow depth, may involve the greater part of the whole volume of water before the ice disappears in spring. In the smaller, shallower lakes of this type, a prolonged ice cover leads to a somewhat complete stagnation in which the zone devoid of oxygen reaches the ice and decomposition products accumulate, resulting in great mortality of the aquatic organisms.

The supply of oxygen and carbon dioxide. In the lakes under consideration, deficiency of oxygen has been a winter problem encountered in fish culture, particularly in periods of low water levels and heavy snowfall. In 1943-44, the waters were covered with the first ice sheets on November 12. The ice melted once and freezing set in again by November 19. However, there was open water in the middle of the larger lakes (Lost Island and Trumbull) at intervals during the winter. The contact of the water with the air through the open areas doubtless resulted in an exchange of gases between water and air, as cutting holes in the ice did when this method was used by the Fisheries Division of the State Conservation Commission. The latter method has not been effective, however, in re-aerating lakes (Biennial Report of State Conservation Commission 1942).

In hard water lakes, the balance of oxygen and carbon dioxide is of interest since most algae derive their carbon dioxide used in photosynthesis largely from the unstable bicarbonates of calcium and magnesium. Free carbon dioxide occurs chiefly at the inlets of lakes under consideration, or from the source of springs and seepage in the lake bed. It is seldom found in the summer, even near the bottom of the lakes observed, especially when water is in circulation. Carbon dioxid occurs in the comparatively insoluble monocarbonate or the relatively unstable bicarbonate form. However, toward winter free carbon dioxide in small percentages has sometimes been found.

Carbon dioxide, oxygen, and mineral salts are necessary for the synthetic, respiratory and assimilatory processes in algae. The studies of periodicity of algae show that there is a spring maximum of diatoms, sometimes followed by a second maximum in the fall; an early summer maximum of green algae, and a late summer and early fall maximum of blue-green algae. Algae may be grouped as spring, winter, summer or autumn annuals; perennials; and ephemerals. Fluctuating changes in the temperature, the occurrence of dissolved salts, light intensity, and dissolved gases undoubtedly have a marked effect upon periodicity; but the complexity of interaction of these forces prevents the identification of the specific action of each. The concentration of dissolved salts has been ascribed as a cause of fruiting which terminates the life cycle of the plant. How-

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ever, Transeau (1913 and 1916) has shown that there is little if any causal relationship between concentration of dissolved salts and fruiting.

The graphs, based upon four reports of water analyses made by the Iowa Geological Survey, are of a type used to determine minerals in underground waters of Iowa on the basis of samples taken from well waters. The results are reported on an ionic basis rather than a basis of hypothetical combinations in accord with the practices of the United States Geological Survey. The determinations are expressed in terms of the substance present in parts per million of water by weight, which is essentially the same as the number of milligrams of the substance per liter of water.

The waters of the prairie lakes located in the heart of the agricultural district though partly supplied with spring water, rain water, and snow water, derive the greater part of their volume from the run off of cultivated lands as well as the silt-laden water from tile ditches and inlet streams surrounded by cultivated fields. The ground water is the main source of bicarbonates, which become dispersed in the lake water by diffusion into the non-carbonated waters derived from snow and surface run off. Large quantities of organic matter as well as minerals which occur in cultivated soils derived from glacial till are conveyed by means of erosion, drainage, and run off into the lake waters which have been transformed from the original clear aspect to a silted condition. Some elements not reported in the analyses are thought to be significant in the growth and synthetic activities of algae. Among them are organic nitrogen and silicon.

Data of the mineral analyses. The data were taken at four seasonal periods with the intent of comparing the four bodies of water under the following conditions: (1) just before freezing when photosynthetic activities of most of the organisms were at a minimum and processes of conversion of organic materials into simpler forms were under way; (2) at the end of the quiescent, ice-covered period; (3) toward the height of the growing period; and (4) toward the end of the growing period (Fig. 2).

The constituents of the water, which were present as a trace and less than one part per million, were not charted. They include iron, manganese, nitrogen as nitrate (NO_3), and fluoride. Methyl orange alkalinity which followed closely the bicarbonate curve was not represented by graphs. Phenolphthalein alkalinity indicated of the carbonate (CO_3) bicarbonate graph was rarely present in these data.

Carbon-dioxide and hydrogen-ion relations. The hydrogen-ion concentration apparently has some value as an index to certain existing conditions in water, in addition to the possible direction of pH as a factor. For instance in the waters under consideration, varying degrees of acidity caused by the presence of carbon dioxide may be indicated and verified by test. The waters of Round and Trumbull Lakes have through the growing season a relatively high pH vary-

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ing from 8.3 to 8.7. The average for Trumbull is 8.3 and for Round 8.5. The H-ion concentration rises with the higher ranges of the normal carbonates in the water. In Lost Island and Virgin Lakes during the period of high content of carbonates, a pH of 10 to 11 is not uncommon in July and August when photosynthetic activity is high. The degree of alkalinity depends upon the quantity of the carbon dioxide removed by photosynthesis from the bicarbonate. The increase in alkalinity is limited. A pH of 11 is the maximum recorded in times of high photosynthetic activity. It appears that at this time some of the normal carbonates are precipitated. This precipitate sinks and leaves the high oxygen stratum in quiet waters with a decreased amount of fixed carbon dioxide. In this almost insoluble form the monocarbonate settles to the bottom or forms a precipitate on leaves and stems of the higher plants. The filamentous algae sometimes are carried to the bottom when they accumulate an excess of the monocarbonate.

A comparison of the data of analysis for Lost Island, Virgin, Round and Trumbull Lakes, with supplementary notes based upon field analyses.

1. The mineral analyses of the four lakes show considerable individuality in their characteristics with reference to the content of the ionic constituents of the water which are expressed in part per million. Fig. 2.

2. The four lakes are high ranking among fresh water lakes in total dissolved solids which vary in this type of lake from 15-300 p.p.m. Lost Island and Trumbull Lakes showed the greatest seasonal variation; but Round and Virgin Lakes maintained the highest relative uniformity.

3. The waters of Trumbull Lake ranked highest in total hardness, though the waters of Round were harder than Trumbull from November to March; but that order is reversed from May to August. Both Trumbull and Round Lakes ranked higher in calcium salts than magnesium. Lost Island and Virgin had more magnesium salts than Round or Trumbull. Calcium salts are less soluble than magnesium. The waters of Round Lake flowed into Trumbull in November and February. In August the waters of Trumbull flowed into Round. The water level determines when the outlet of Round becomes an inlet.

4. The two larger lakes, Lost Island and Trumbull, had higher temperatures than the two small lakes in May and August.

5. The green organisms of the four lakes appear to depend chiefly for their carbon dioxide supply on the bicarbonates of the water, since no constant surplus of free carbon dioxide exists. The bicarbonate (HCO_3) supply for all of the lakes is high, but its fluctuation is considerable and is probably modified by the relative consumption and release of carbon dioxide in respiratory processes of the biotic population which includes plankton, other algae, rooted seed plants; and in fish-stocked lakes, an artificial element of the population.

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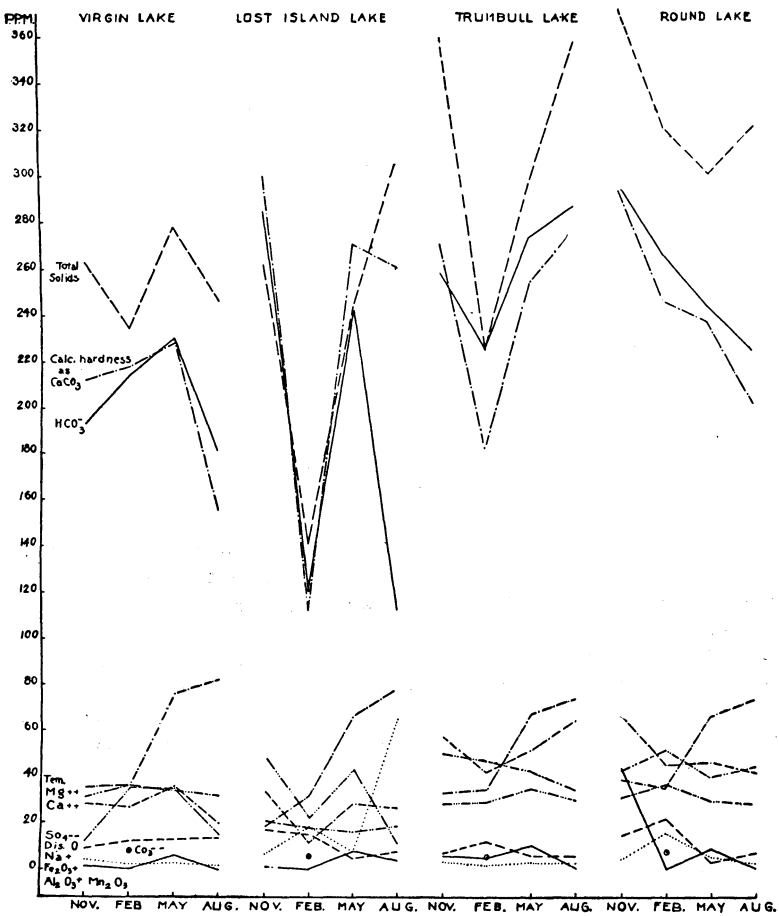

Fig. 2. A comparison of the data of mineral analyses, taken at four seasonal periods for Lost Island, Virgin, Trumbull and Round Lakes.

In the analyses, the carbonate (CO_3) is recorded at the end of ice cover in February only. However, analytical data taken in the field show the carbonate (CO_3) to be absent through August and September in Round, Trumbull and Virgin Lakes but present in Lost Island in all of the quarterly tests and whenever tests were made from May through October (Hayden 1943). The presence of the carbonate in the field is shown by the phenolphthalein test, and the failure of the water sample to respond to the test for carbonate after standing, appears to indicate considerable instability of the form in which carbon dioxide exists at a specific time. Samples which respond negatively in the field to the test for free carbon dioxide will sometimes contain small quantities of carbon dioxide

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after standing. (Tests were made in daylight periods, so the effect of carbon dioxide production in darkness has not been recorded).

6. Field analyses during the summer months showed considerable uniformity of dissolved oxygen content in Trumbull and Round Lakes but greater variation in Virgin and Lost Island Lakes.

From the Botany and Plant Pathology Section, Iowa Agricultural Experiment Station[1].

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