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Theodore L. Jahn
State University of Iowa

A. B. Taylor
State University of Iowa

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THEODORE L. JAHN AND A. B. TAYLOR

For the past thirty years members of the staff of the Iowa Lakeside Laboratory have been interested in the flora and fauna of the Okoboji region. For a somewhat shorter period of time, whenever equipment has been available, studies have been made of the physical and chemical characteristics of the Okoboji Lakes in the hope of obtaining a better understanding of the environmental factors which affect the biological productivity of these bodies of water. The factors which determine the geographical distribution of any given species and the numbers of individuals of that species which are present at any given time are extremely numerous. The geology and climate of a given region determine the chemical and physical characteristics of the body of water which in turn determine the limits of biological existence.

Let us review briefly some of the fundamental relationships which exist between the plants and animals of a deep lake and the environment. Two absolute necessities for the existence of aquatic animal life are food and oxygen. The food supply is dependent either directly or indirectly on aquatic plants, and the plants, in turn, depend directly upon solar energy for their existence. Oxygen in the water is derived partly from the photosynthetic action of plants but mostly by diffusion from the atmosphere. The maximum depth to which the oxygen may diffuse, and consequently the greatest depth in which aerobic animals may live is limited, as we shall see presently, by the temperature of the water. The maximum depth at which aquatic plants may live is determined by the amount of light which is transmitted by the upper layers of the water.

Therefore, it is necessary for an understanding of the factors which determine the biological productivity of a lake to know something of the temperature cycle of the water and the closely dependent changes in oxygen tension, and of the depth to which solar energy in quantities sufficient to support plant life may penetrate. For this reason various members of the laboratory staff, especially during the past few years, have studied the temperature cycle, the oxygen cycle, and light penetration into the Okoboji Lakes as part of the laboratory research program. Today I wish

to discuss the temperature cycle. Development of other phases of the laboratory program mentioned above and many other phases which have not been mentioned will be reported by other investigators.

During midsummer the upper twenty to thirty feet of water in a deep lake is usually about 20° to 27°C. This layer is called the epilimnion. The next five to ten feet, which is known as the thermocline, is a region where the temperature decreases rapidly with depth. The remainder of the lake, that is, the water below the thermocline, is known as the hypolimnion and it is usually 5° to 10°C. The specific gravity of the warm water of the epilimnion is so much less than that of the cold water of the hypolimnion that normal wind action on the surface is incapable of mixing the waters. This thermal stratification is usually established early in the summer and is followed very soon by a stratification of the oxygen. Since oxygen can be brought into the lower waters only through mixing with water from the surface, this important gas is rapidly removed by the organisms present in the lower waters and it remains absent until the following autumn when lowering of the surface temperature again makes mixing possible.

Therefore, the volume of the lake which is capable of supporting aerobic animal life is greatly reduced by the formation of the thermocline. This is one of the principle reasons for studying temperature cycles — the data obtained allows us to calculate the volume of the lake which may be considered as being biologically productive. The temperature of the epilimnion is also important in that it has a direct effect upon the growth of aquatic animals, and even more important because it affects the growth of the sessile plants, phyto-plankton, and zooplankton which form the food chain for larger aquatic animals. Temperature apparently is also a factor in controlling the growth of blue-green algae which do not form an important part of the food chain but which are important mostly because of their nuisance value to swimmers and fishermen, and because of the anaerobic conditions which arise during their decay. In East Okoboji Lake the decay of algae produces a semi-anaerobic condition which apparently has highly deleterious effects upon the fish population. Relatively high temperature is by no means the only cause of the rapid growth of blue-green algae, but it seems to be a contributing factor. We are seldom seriously troubled by large amounts of algal growth in West Okoboji except when the surface temperature is unusually high (as in the summer of 1936). This is true in spite of the similar chemical constitution of East

and West Okoboji Lakes. In this respect we can state that in midsummer the average temperature of East Lake is usually a few degrees higher than that of West Lake. However, if it were not for the highly favorable chemical constitution of both of these lakes we probably would not be troubled by the large amount of algal growth.

The temperature cycle of West Okoboji was studied by Professor F. A. Stromsten during the summers of 1922 to 1927 and by the present authors during the summers of 1936 to 1939. During certain summers (e.g., 1925, 1926, 1927) the temperature cycle of West Okoboji has been highly abnormal for lakes of similar size and depth in this latitude. The bottom (30-40 meters) temperature sometimes became quite high (17°C. late in August, 1926), and the thermocline, if present at all, was very late in forming and was of short duration. However, during the summer of 1923 the depth-temperature curve resembled very closely the usual textbook diagrams. The variability of the depth-temperature curve for different years is due to a different relative effectiveness of wind action and solar radiation in mixing and in warming the surface water. Apparently if a low wind velocity prevails during late spring, the surface may become sufficiently warm so that abnormally high wind velocities would be necessary to change the thermal stratification. It seems as if the winds of the Okoboji region are usually sufficient to prevent thermal stratification until the bottom water has reached a temperature of 14°C. or higher. This high bottom temperature is so unsual that when first discovered it was the source of considerable comment among limnologists. Now we know that high bottom temperatures are normal for West Okoboji and that the supposedly normal condition for deep temperate zone lakes is quite unusual in West Okoboji.

During the summer of 1936 the bottom temperature was 12.5° to 13.5°C. for the month of June, and the prospect of a sharp thermocline being developed seemed rather small. However, during the first half of July consistently hot weather and low wind velocities allowed a thermocline to develop, and the surface temperature rose to an average of 29°C. for the upper ten feet. This is the highest recorded surface temperature for the open water of West Okoboji. The annual net heat income (number of calories per square centimeter necessary to raise the lake from 4°C. to the maximum temperature attained) also reached a maximum value of 24,000 calories per square centimeter. Records for previous years gave values of 18,000 to 21,000 calories.

During the summers of 1937 and 1938 the bottom temperatures were 13°-15°C. and the epilimnion temperatures were 24°-26°C. from the middle of July to the middle of August. The thickness of the epilimnion was 8-12 meters.

Emerson's Bay is a large bay about nine meters deep on the southwest side of the lake. It is separated from the main body of the lake by a reef which is covered by about 3 meters of water. During the summer of 1938 records were taken of the development and decline of the thermocline in this bay. The position of the thermocline was considerably higher than in the main body of the lake. Later in the summer (about August 2) the themocline in the bay was completely obliterated by a series of wind storms. Throughout the duration of the thermocline oxygen was absent from the hypolimnion and considerable amounts of hydrogen sulfide were present (analyses made by Professor Benjamin Peterson of Coe College).

One interesting observation which we made was that in Emerson's Bay the number of fishing boats present seemed to be closely related to the presence and absence of the thermocline. Apparently the removal of oxygen from the lower levels caused fish to migrate to the main body of the lake and to remain there for the duration of the thermocline.

IOWA LAKESIDE LABORATORY, and
ZOOLOGICAL LABORATORY,
STATE UNIVERSITY OF IOWA,
IOWA CITY, IOWA.