Thermal Stratification in Lakes

EARLY in this century, Thienemann[1] and Naumann[2] described the physical conditions in deep freshwater lakes in the temperate zone. They found a yearly cycle of events which depended on the thermal stratification of the water. Their findings, and the conclusions they drew from them, can be summarized briefly, as follows. In winter and early spring, the temperature and density of the water mass is almost uniform from the surface of the lake to the bottom, so that the viscosity of the water is the only hindrance to mixing by wind. In late spring and early summer this state of affairs changes because the surface layers become warmed up by increased radiation from the sun and conduction from a warmer atmosphere, and by the inflow of warmer rivers. The result of this warming is that, in summer, a warm upper layer of less dense water, the epilimnion, comes to lie over a cold deeper water mass, the hypolimnion. The two are separated by a region of very steep vertical temperature gradient, the thermocline, with the result that mixing by wind is impossible.

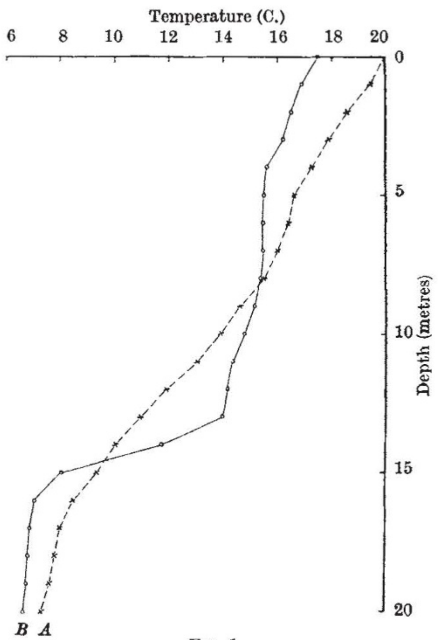

FIG. 1.

Since photosynthesis can only take place in the upper layers of the water, that is to say in the epilimnion, the available supply of salts for the planktonic algæ must be that which is dissolved in the water above the thermocline. Thus the continuous existence of the thermocline, with the consequent separation of the epilimnion from the hypolimnion, has important biological consequences, namely, the restriction of algal growth by limiting the salt supply. Thienemann and Naumann suppose that this state of separation exists continuously for the whole summer and well into the autumn, in fact throughout the period of maximal solar radiation. Consequently, the salt supply of the upper layers of water can first be renewed in late autumn, when the thermocline breaks down owing to the cooling of the epilimnion. Then free circulation is again possible, and water richer in salts from greater depths can reach the surface.

We have taken regular temperature observations in the north basin of Windermere extending over several months during the spring and summer of 1936. Our findings do not agree with those of the Continental workers, for the thermocline in Windermere, in this year at any rate, can be very unstable. It can appear and disappear in the course of a few days. Sometimes the state of affairs postulated as permanent by Thienemann and Naumann was found, but at other times there was a uniform temperature gradient from the surface to a depth of 20 metres without any trace of a thermocline. The presence or absence of a thermocline can be correlated with the weather. When it is calm there is no thermocline at all, but windy weather is always followed by the appearance of a region of sharp temperature gradient. The depth at which the thermocline appears depends on the strength of the wind; the stronger the wind the greater the depth. It can occur at any depth in Windermere from just below the surface down to 15 metres. After a thermocline has been formed during a period of active mixing by wind, it disappears again within two days if the weather becomes quiet.

In Fig. 1 the curve *A* represents the state of affairs during the period August 25–29, 1936, when the weather was uniformly fine and windless. Curve *B* obtained on August 31, 1936, at the same place, shows that a thermocline had been formed at a depth of 13–15 metres by a strong wind blowing on the intervening day, August 30.

Some of the factors which lead to the formation of the thermocline are not yet clear, and nearly all those concerned with its disappearance are still obscure. But the biologically important fact remains, that the thermocline is not a continuous feature of the summer conditions in temperate lakes. Sometimes it is not there at all, and when it appears the depth at which it occurs varies greatly. This must lead inevitably to a re-orientation of ideas about the biological productivity and the heat budgets of temperate lakes.

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[1] A. Thienemann, *Verh. naturhist. Ver. preuss. Rheinl.*, **70** (1913).
[2] E. Naumann, *Handl. K. Svensk. Vetenskapakad.*, **56** (1917).

The Half-Drill Strip System Agricultural Experiments

PROF. R. A. FISHER and Dr. Barbacki have recently published a paper in the *Annals of Eugenics* entitled "A Test of the Supposed Precision of Systematic Arrangements"[1]. There is a good deal in the paper with which I am not in agreement and with which I hope to deal elsewhere, but a letter from a friend of mine in Australia, who had heard at second-hand that Fisher's "results showed not only that the half-drill strip failed to give a valid estimate of error but was less accurate", shows that it would be better not to let such rumours get a start, for they are quite unfounded.

In the paper, the crop on a uniformly treated field was assigned to two imagined treatments *A* and *B* on a systematic plan in which eight strips of the width of a half-drill were assigned to *A*, and eight to *B*, in the usual arrangement of an eight