Thermal Stratification in some New Zealand Lakes

V. H. Jolly

The effect of thermal stratification is so great that it controls the structure on which the biological framework rests. Once a lake becomes thermally stratified the upper stratum, the *Epilimnion,* and the lower stratum, the *Hypolimnion,* form two distinct entities separated by the *Thermocline.* The vertical temperature variation within the upper and lower strata is small, but the difference between the two may be great. The thermocline provides the transition zone, and here the fall in temperature may be several °C. per metre. A drop of 1°C. per metre is considered by Birge to produce sufficient differential water density to segregate the epilimnion from the hypolimnion.

Once a thermocline becomes stabilized it may last several months. During this period the utilisation of the nutrients in the trophic zone of the epilimnion alters the chemical composition of the upper stratum, whilst metabolic processes in the hypolimnion reduce the oxygen in the lower stratum. Thermal stratification therefore implies chemical stratification to a greater or lesser degree depending on the depth of a lake, and the standard of its productivity.

It is well established that thermal stratification is dependent on two groups of factors: climatic, and morphometric. The climatic factors of heat and wind vary seasonally. The morphometric factors are constant for long periods and they control the effects of climate. Thus the sun supplies the heat, and the wind the work for warming a lake, but size, shape, and depth determine the effect of the wind in creating waves and oscillations. An example of the effect of morphometry on climate is shown by comparison of the temperature records for a twelve-month period of Lake Rotorua and Lake Tikitapu (Blue Lake). These lakes are but a few miles distant from each other and, though Lake Tikitapu is 400 ft. higher in altitude, they may be considered as being subject to a very similar climate. Rotorua is 69.5 sq. kilometres in area with an island which occupies less than 2 sq. kilometres, whilst Tikitapu is but 1.55 sq. kilometres. Both are somewhat similar in shape which is roughly circular. Although the bed of Rotorua is uneven with large areas of shallows; there is a considerable area which is comparable to the maximum depth of Tikitapu namely 24 metres. However Rotorua over the period of twelve months remained vertically isothermous whilst Tikitapu was thermally stratified for six months. These dissimilar temperature conditions may be partly due to the fact that Rotorua has an uneven floor, and Tikitapu is more sheltered by mountains, but it is largely due to the difference in size whereby the wind attains sufficient force to maintain complete circulation in the lake of large area, but not in the lake of small area. Careful observations where hot springs occur on the shores of Lake Rotorua show they are not of sufficient heat or volume to invalidate the above conclusions.

Two periods of stratification are normal in continental lakes of the temperate zone: summer stratification when the warmer and less dense water forms the epilimnion, and winter stratification when the surface is frozen and the warmer but denser water lies at the bottom. When this double stratification occurs there are two "overturns" when the water is in complete circulation, one in autumn and one in spring. In none of the New Zealand lakes which I have observed is there any winter stratification; that is, the surface waters do not fall below 4°C. However there must be shallow lakes in the south and at high altitudes where this does occur. In the observed lakes there is therefore but one period of complete circulation, which is in winter.

The time of the year at which the thermocline forms and its duration are influenced by climate and may vary from year to year. The vertical depth at which it occurs appears to be influenced by morphometry. Generally speaking, when climatic conditions are equal, the smaller the lake the higher the vertical level of the thermocline, and the earlier it forms, for the smaller the size the less disturbance there is by wind. Table 1 gives the vertical position of the thermocline in some New Zealand lakes.

The significant feature is the low level at which the thermocline is stabilised in the above lakes by comparison with lakes in the northern hemisphere. In Lakes Geneva, Windermere, and Baikal the critical temperature fall occurs at approximately the 20 metre level. Lake Geneva, though several sizes larger, is comparable in degrees of latitude and depth with Lake Wakatipu, where the temperature fall is below the 50 metre level. The only known published record of a thermocline at a greater depth is given for Lake Edward (40-60 metres), and the authors, Worthington and Beadle, considered that stratification might be due to chemical influences rather than temperature.

Table 1. *Main features of lakes studied.*

Lakes	*Latitude* (°*S. lat.*)	*Altitude* (*metres*)	*Size* (*sq. km.*)	*Length* (*km.*)	*Av. Width* (*km.*)	*Max. Depth* (*metres*)	*Thermocline* (*depth in m. during Feb.*)	
Hayes	45	330	2.59	3.0	0.86	32	14—18	(1953)
Tikitapu	38	413	1.55	1.3	1.2	24	15—18	(1956)
Tarawera	38	297	44.2	10.5	4.2	83.5	18—25	(1956)
Manapouri	46	182	145	19.3	7.5	444	25—32	(1953)
Taupo	39	360	616	40.25	15.3	163	25—30	(1956)
Wakatipu	45	309	291	79.0	3.8	378	54—57	(1954)

Seiches which are both surface and subsurface oscillations of water produced by wind and other meteorological factors are known in certain conditions to raise and lower the thermocline at regular intervals. The longer the axis of a lake the greater is the opportunity for oscillation. Such fluctuations have been observed in Lakes Taupo and Wakatipu, and though they are undoubtedly important in initiating the original level they do not affect the thermocline level under normal conditions.

It must be concluded, I believe, that the somewhat unique thermal stratification of New Zealand lakes is directly related to the frequent and variable winds consistent with an insular position and irregular topography.

Acknowledgements.—This work has been carried out with the assistance of grants from the University of New Zealand, the Royal Society of New Zealand, and the Marine Department; and with the help of the Department of Internal Affairs.

DISCUSSION

R. M. CASSIE said that the temperatures of water given were for fresh water in every case. In Hauraki Gulf there is a thermocline with a temperature drop from 20°C. to 17°C. during the summer period. Snapper are usually caught at about 10 fathoms having swum up into the warmer water to spawn. Divers have seen sharp discontinuities that indicate very quick changes in temperature. He asked if Miss Jolly had followed up any correlations of plankton and water temperatures.

MISS JOLLY said this was difficult because plankton does not come into surface waters in daytime. Much more was taken between sunset and dawn; it occurs both above and below the thermocline. Light appeared to affect plankton rather than temperature.

B. T. CUNNINGHAM said that observations on lakes in North Auckland showed that a thermocline can sometimes develop in lakes where there is not much wind. Those lakes are comparatively small and shallow, with thermocline at 3-5 metres.