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THE SIGNIFICANCE OF THE PYCNOCLINE IN TROPICAL LAKES

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ABSTRACT

The vertical temperature profile is a poor indicator of stratification in most tropical lakes. Data from Lake Bunyonyi, Uganda, showed, however, that the density profile highlighted discontinuity layers whieh were not obvious from the temperature profile. It is suggested that the vertical density profile and the region of maximum discontinuity, the *pycnocline*, could be adopted as a useful index of stratification, especially in tropical lakes.

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The vertical temperature profile is often used as a guide to the interpretation of the hydromechanics of a lake, but can sometimes be misleading. It is a convenient tool, since a sharp change in temperature with depth, i.e., a thermocline, reflects a change in the density of water; the physical basis upon which stratification relies. The thermocline was originally defined by BIRGE (1897) as that layer of water in which the temperature change is greater than 1° C per meter, but HUTCHINSON (1957, p. 428) realized the limitation of such a rigid definition and suggested the following modification; "the thermocline is defined as the plane of maximum rate of decrease in temperature. . . ." This could be applied to any lake, tropical or temperate, in which there was a vertical water temperature gradient. However, it can be seen in Fig. 1 that temperature and density of pure water is not rectilinearly correlated and whereas in the temperate climate a small thermal gradient is accompanied by a small density change, at tropical temperatures the equivalent gradient may reflect a density change three times as large. This is not always fully appreciated and the absence of a clear thermocline in many tropical waters can be misinterpreted as an indication of instability.

To overcome any possible misunderstanding the plotting of a relative density profile can be helpful. The profile is easily converted from a thermal profile by reference to a water density/temperature table (for example, HUTCHINSON 1957, Table 7, pp. 204-205, or the *Handbook of Chemistry and Physics*), and the units are relative to the density of "pure water" at 4° C and 1 atmosphere pressure. Other factors, includ-

ing pressure and the concentration of dissolved substances affect the density slightly, but in most cases can be ignored (RUTTNER 1963, p. 8, HUTCHINSON 1957), although there are occasions in which an apparently unstable stratification is found to be stabilized by a salt concentration discontinuity (RUTTNER 1963, p. 40).

The advantage of including a vertical density profile in a limnological report is demonstrated by reference to data collected from Lake Bunyonyi, a high altitude tropical lake in S.W. Uganda.

Figure 2 shows six vertical temperature profiles from Lake Bunyonyi (A to F), compared with one from Lac la Ronge (G), a temperate region lake in Saskatchewan, Canada, during summer stratification. It can be seen that in Lake Bunyonyi the temperature gradient from surface to bottom (40 m) was never greater than 6° C degrees and a conspicuous thermocline was absent. Lac la Ronge had a 12° C degree gradient and a distinct thermocline occurred just below 10 m.

When the temperature profiles were replotted as relative densities a similarity between the tropical and temperate lakes become apparent in some of the profiles. Not surprisingly, Lac la Ronge exhibited obvious density stratification but so did Lake Bunyonyi in sample periods A to D. In fact, the slope of profile A between 6 and 7 m was similar to that of Lac la Ronge at its thermocline between 11 and 14 m (0.225 g/l/m compared with 0.286 g/l/m).

Physical stratification is usually accompanied by chemical stratification where stability or permanence has been achieved. Chemical analyses of the water from sample period A in Lake Bunyonyi showed distinct chemical stratification with the chemocline occurring between 6 and 7 m (Fig. 3); i.e., exactly where the greatest density gradient was recorded. A correlation between density gradient and chemical profile was similarly demonstrated for period D at 9 to 12 m. No chemical analyses were performed for periods B and C. The density data for periods E and F demonstrated the disadvantage of insufficient samples along a vertical profile. Neither profile indicated sudden change in density with depth but both showed chemical discontinuity between 10 and 15 m. (For data on profile F, see BEADLE 1966, p. 159, Fig. 4). If samples had been taken, say, every meter a clinograde density curve similar to that of period D might have been apparent.

It can be seen that although the temperature profiles of Lake Bunyonyi did not have conspicuous thermoclines the vertical density gradients calculated from them did reveal stratification. Therefore, density gradients can be a more precise indicator of stratification and could be included in vertical profile data. The region of steepest gradient within the density profile is the *pycnocline* (derived from the Greek, *pykno:* dense), is defined as the plane of maximum rate of increase in water density.

In tropical studies several authors including TALLING (1963), BEADLE (1966) and BEAUCHAMP (1953) have found it necessary to discuss mixing in relation to density but still adhere to the temperature gradients in their descriptions. The inclusion of the calculated density profile and the *pycnocline* in limnological studies, especially from the tropics, would simplify the comparisons of hydromechanics in tropical and temperate lakes and eliminate the possible misunderstanding of the vertical temperature profile. The latter would naturally still be important in its own right.

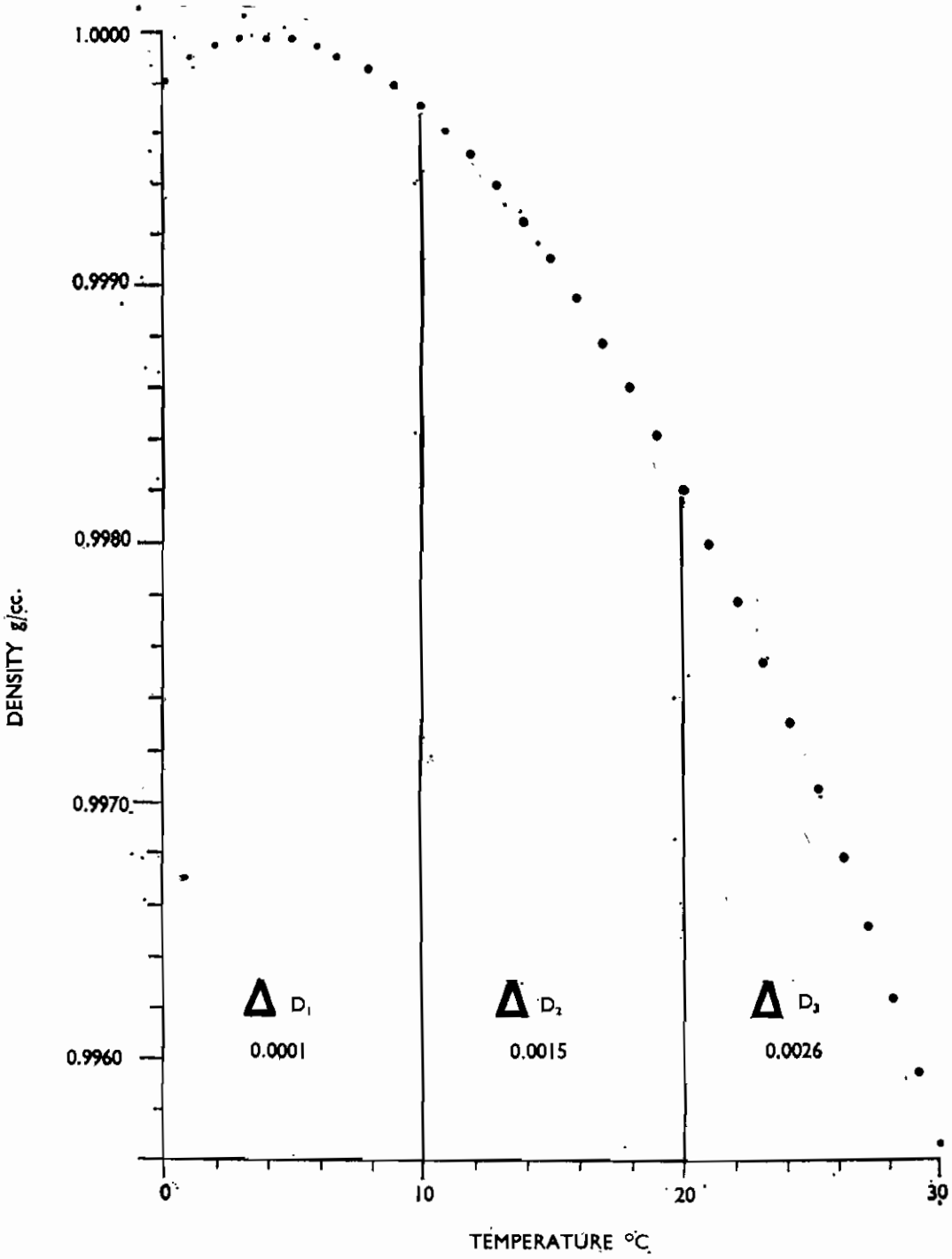

Figure 1. Relationships between temperature and absolute density of water.
ΔD_1, ΔD_2, & ΔD_3 are the density changes between 0°–10°C, 10°–20°C and 20°–30°C respectively.

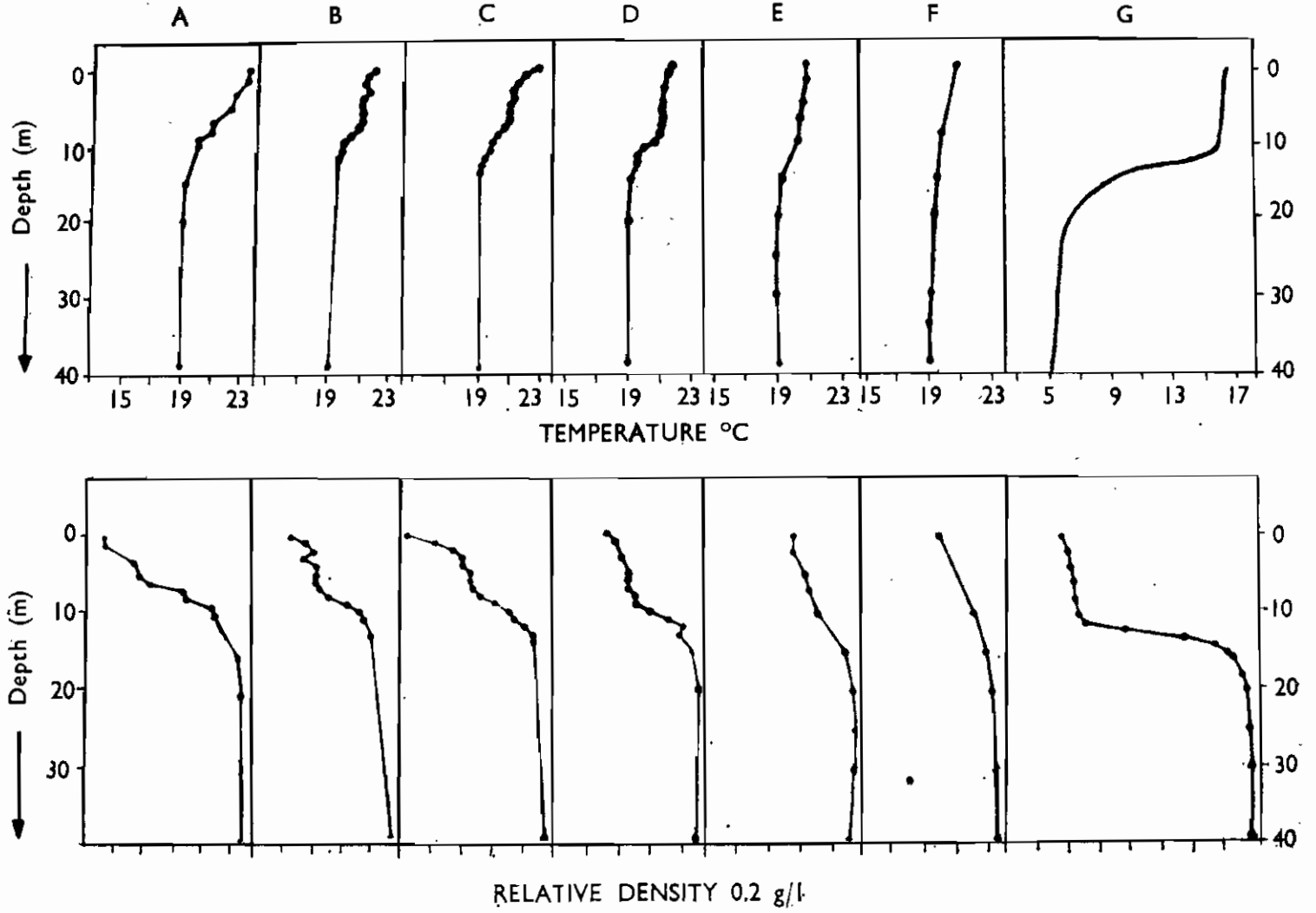

Figure 2. Comparison of temperature and relative density vertical profiles of Lake Bunyonyi (A–F) and Lac la Ronge (G).
A Lake Bunyonyi 13.30 hrs., 9th April 1969 D Lake Bunyonyi 13.00 hrs., 17th April 1969
B „ 10.30 hrs., 12th „ „ E „ 15.30 hrs., 27th May „
C „ 14.45 hrs., 12th „ „ F „ 9.00 hrs., 19th June 1963 from BEADLE 1966
G Lac la Ronge — 10th August 1948 from HUTCHINSON 1957 Fig. 135

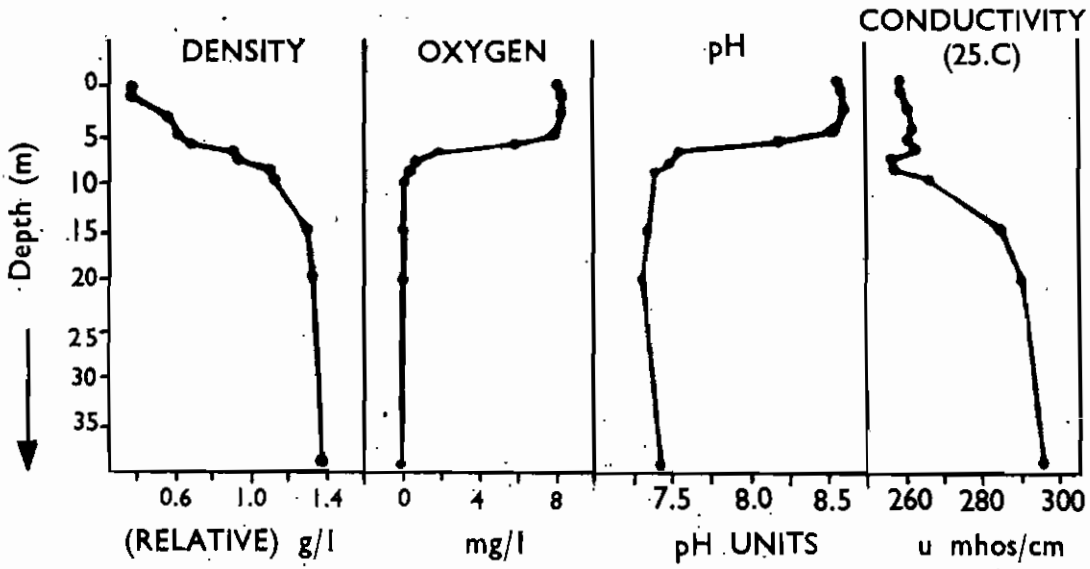

Figure 3. Stratification of oxygen, pH, and conductivity compared with density in Lake Bunyonyi, 13.30 hrs April 1969. Note the clear pycnocline in the density profile between 6 and 7m which corresponds to oxygen and pH discontinuities at the same depth.

REFERENCES

Beadle, L. C. (1966). Prolonged stratification and deoxygenation in tropical lakes. (i) Crater Lake Nkugute, Uganda, compared with Lakes Bunyonyi and Edward. *Limnol. Oceano. 11:* 152-163.

Beauchamp, R. S. A. (1953). Hydrological data from Lake Nyasa. *J. Ecol. 41:* 226-239.

Birge, E. A. (1897). Plankton studies on Lake Mendota, (ii) The Crustacea from the plankton from July, 1894, to December. *Trans. Wis. Acad. Sci. Arts Lett. 11:* 274-448.

Handbook of Chemistry and Physics (1962). The Chemical Rubber Co., Cleveland, Ohio.

Hutchinson, G. E. (1957). *A Treatise on Limnology, Vol. 1, Geography, Physics and Chemistry.* J. Wiley and Sons, Jne., New York. 1015 pp.

Talling, J. F. (1963). Origin of stratification in an African rift lake. *Limnol. Oceanog. 8:* 68-78.

Ruttner, F. (1963). *Fundamentals of Limnology.* Third edition (English translation). University of Toronto Press. 242 pp.