Hydrobiologia vol. 40,3 pag. 355—359, 1972.

Metalimnic Layer in Lake Kinneret, Israel

by

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The metalimnion of stratified lakes is more than a simple increase in the thermic gradient. It is a special layer with properties of its own which have been described by different authors (BIRGE & JUDAY 1911, CZECZUGA 1959, SHAPIRO 1960). My purpose here is to describe the features and follow the evolution of such a layer in a subtropical lake, thermically stratified 9 months a year. It appears that this layer plays an important role in the general economy of the lake.

Lake Kinneret is located in the Northern part of Israel at – 209 m below MSL. It is 24 km long, 12 km wide and 42 m deep at its deepest point. The water temperature ranges from 15 to 30° C. The hypolimnic concentrations in H_2S—S and NH_4—N are respectively 11 and 1 mg/l.

To locate precisely the metalimnic layer (ML), I used a Metrohm Eh electrode equipped with 50 m cable and measured *in situ* the Eh values every meter or even every 0.5 m. The ML is reached when the Eh begins to increase. This sudden rise of the Eh is due to the drastic concommittant decrease of pH (Fig. 1A). The Eh was only used as a convenient and precise operational parameter.

A steady ML has been recorded from May to October; during this period, its depth moves down with the thermocline from 14 to 21 m; the ML shows daily up and down movements caused by internal waves (SERRUYA, SERRUYA & BERMAN, 1969). The temperature of the ML water varies from 19° C in May to 23° C in October. Its thickness varies from 1.5 to 0.10 m.

The succession of limnological events in Lake Kinneret easily explains the formation of a steady and strongly featured ML: the main bloom of algae, mainly composed of *Peridinium westii*, takes place from February to June. When the thermocline is stable, in April-May, there is still an important biomass in the epilimnion and many sinking dead cells are trapped in the metalimnic area.

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Received Aug. 8, 1971.

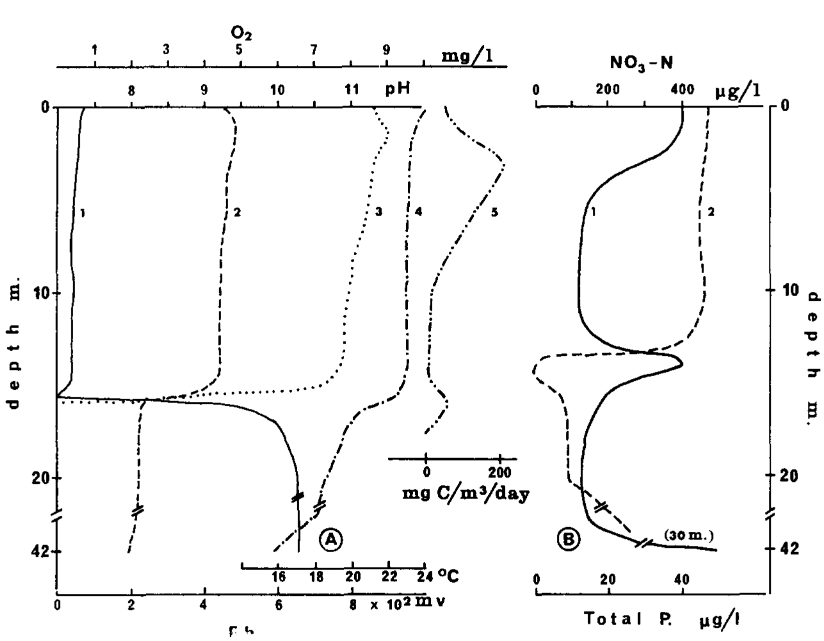

Fig. 1. Variations of some chemical and biological factors at the central station, 42 m deep. A. 1-Eh potential (the results are stated as differences with the maximum values of the profile and not as absolute potentials), 2-pH, 3-Oxygen, 4-Temperature, 5-Primary productivity (profiles measured in June 1970). B. 1-Total P, 2-Nitrate-Nitrogen (profiles measured in May 1969).

The microscopic examination of the water of the ML shows a high concentration of detritus.

From May onwards, reducing conditions develop in the ML. The concentration of oxygen ranges from 4.0 to 0.1 mg/l. Chemical investigation showed that the denitrification process, which was believed to take place only in the hypolimnion, begins in fact in this layer (Fig. 1B). On 25 May 1969 only 3 μg/l of NO_3—N were found in the ML while concentrations of 85 to 255 were found in the hypolimnion. A similar picture was observed until the end of June. At the same period, the concentrations of dissolved Mn and Fe began to increase in the ML and remained higher than those of the hypolimnion during the whole summer and fall (Fig. 2). For instance, on 25 October 1970, 470 μg/l of dissolved Mn were measured in the ML but in the hypolimnion the concentrations did not exceed 140 μg/l. Total P is also much higher in the ML than in the hypolimnion. In May 1969, the respective concentrations were 40 and 12 μg/l. Higher concentrations (50 μg/l) were recorded only near the bottom of the lake at 42 m. In the ML, T. Berman (1970) found a systematically marked maximum of alkaline phosphatase

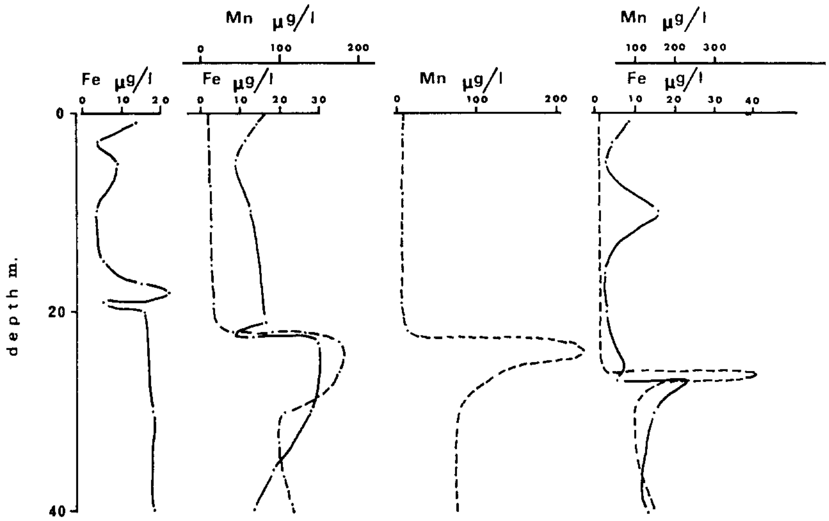

Fig. 2. Variations of dissolved Fe and dissolved Mn. .——.——.: Mn; .—.—.—.: Fe. The measurements were carried out on the following dates (from left to right): 13 September 1970, 18 October 1970, 25 October 1970, 1 November 1970.

activity indicating that this layer plays a decisive role in the nutrient regeneration.

The primary productivity, measured by the *in situ* technique of C^{14}, shows a distinct peak in the ML (Fig. 1A). In the light bottles the productivity is often smaller than in the dark bottles, showing an important potential chemosynthesis. The actual productivity measured in the light bottles exposed in the ML depends on the quantity and quality of light reaching the metalimnion. From April to July, only 1 to 3% of the incident green light (VG^9 filter) reaches the ML; then the metalimnic productivity is lower than in August when 4 to 9% of the incident green light and 0.1 to 0.8% of the incident blue light (BG^{12} filter) reach this area.

Two types of organisms participate in the photosynthesis:

1) Algae, especially *Tetraedron*, *Stephanodiscus*, *Elakatotrix*, *Cosmarium*, *Cryptomonas*, *Peridinium* species. In summer important populations of blue green algae (*Microcystis* and *Oscillatoria*) were observed in the ML: in August 1970, the concentration of blue green algae was 10 times higher in the ML than in the epilimnion. The selective growth of blue green algae in this layer is similar to the development of Oscillatoria on the bottom of artificial reservoirs (LEVENTER, 1969) where identical conditions (H_2S, abundant organic matter, important bacterial population) prevailed. These facts strongly suggest that the growth of the blue green algae is enhanced

by the bacterial activity and probably by the bacterial production of CO_2.

2) Photosynthetic sulfur bacteria of the *Chlorobium* species; these bacteria grow in the lower part of the ML in contact with the hypolimnic H_2S which they oxidize (TRUPER & GENOVESE, 1968). The existence of sulfur bacteria in this layer increases the total biomass of the primary producers and their activity maintains a constant flux of nutrients through the thermocline during the stratification period, slowing down the process of impoverishment in nutrients of the epilimnion.

The heterotrophic community is also well represented: 600 to 700 is the usual number of organisms per liter in this layer, that is 2 or 3 times more than in the upper layers. The Cyclopidae and especially the Nauplius stages form 90% of the metalimnic zooplankton. Moreover, only an intensive development of the heterotrophic bacteria can account for the strong denitrification process taking place in the ML.

All these facts explain the rather high values of the oxygen consumption measured in this layer (till 1.0 mg/l/24h.) This parameter is certainly underestimated since the method used (dark bottles hanging in the ML without contact with the H_2S layer) does not take into account the oxidation of H_2S into thiosulfate which SOROKIN (1970) claims is a chemical process.

By its chemical and biological features the ML is similar to a certain extent to the mud water interface and its role may be much more important than underlined before. The metalimnic "interface" supplies, at least in warm lakes, very favourable conditions for blue green algae and their growth intensity can serve as a reliable index of eutrophication in these types of lakes. Moreover, in summer, the nearly perfect homothermy of the epilimnion (and then its excellent mixing) tends to destroy the ML and spread its components in the whole epilimnion. The mechanism explains how, in Lake Kinneret, the blue green algae which are first restricted to the ML show an epilimnic peak in August-September, in spite of the low nutrient content of the water: any increase of the nutrient load of the lake at this specific period may transform this peak into a bloom, and we have taken into consideration these delicate equilibria in the management programme of the lake.

SUMMARY

Chemical and biological investigations of Lake Kinneret showed that reducing conditions prevailling in summer in the metalimnion

cause an early and intense denitrification process accompanied by the release of dissolved Fe and Mn. These conditions are favourable to the development of sulfo-bacteria and blue green algae. The role of this layer is discussed.

Acnowledgment

I thank M. Gophen for making available zooplankton data and B. Hepher for valuable criticisms.

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