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SHORT PERIODIC CHANGES IN THE MICROBAL PLANCTON QUANTITY OF LAKE BALATON

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The monthly investigations carried out in the years of 1966—1968 in five standard sections of Lake Balaton throw light on the complexity of seasonal changes occurring in the quantity of bactrioplankton. In the very same year in various sections, or in different years for the same section the seasonal dynamics rather varied. These data called the attention to the fact that in order to be acquainted with the seasonal dynamics of the quantity of bacterioplankton and with the factors exerting influence on it in the case of shallow waters of vast extension, as is the case in Lake Balaton, we must carry out short periodic investigations (OLÁH, 1969a, b).

On the basis of these conclusions we carried out short periodic investigations in the years of 1968—1969 at some points of the open water of Lake Balaton. During these seasonal investigations we carried out a series of measurements which noted the daily changes in the quantity of saprophytic and total microbial plankton, in wind condition, in Secchi-transparency in temperature and in COD. Besides surveying the quantity of bacterioplankton we paid due attention to the quantity of phyto- and zooplankton as well during our winter and early spring investigations, the former were taken under the ice cover.

Material and method

Our short periodic investigations were carried out in the open water, some 500 metres from the shoreline beside a buoy in front of our Research Institute. On the 8th—27th September, 1968, 5th—13th February, 1969, 8th—12th April, 28th April to 7th May and between 13th and 16th August generally on every day, in some cases with a few days interval. Between 5th and 13th February, 1969 we carried out parallel investigations with the open water examination in the reedery in front of Research Institute. Besides the sites enumerated above, in front of our Institute, we made two surveis in Keszthely-Bay, between the 24th Juny and 4th July, and between the 8th—27th September, on every day, on the standard G section (TAMÁS, 1967) at some 500 metres from the shoreline.

To determine the quantity of the total microbial plankton we made good use of RAMUZOV's (1932) direct method, while the determination of phytoplankton quantity was made by DE NOYELLES's (1968) method. The vertical distribution of the quantity of zooplankton was determined from the

filtrates secured by a 90—100 μ bronze sieve of 5—5 litre of water. To render easy counting of the filtrate we used a mixture of dyes according to DE NOYELLES made of analine blue and eosine Y. By this differential staining the rotifers, and both young and mature crustaceans and their females with eggs stained with the various hues of blue and red, and by the different colour tones they could be easily distinguished. In counting saprophytic microorganisms we used the sodium-caseinate agar; and sealing-was made in the following hour of sample taking. The saprophytes were counted in the section M by using OPPENHEIMER's (OPPENHEIMER an ZOBELL, 1952) medium. The chemical oxygen demand (COD) was determined by $KMnO_4$.

Results and discussion

In section G, on the second day of our investigation of short period changes, on the 19th September, 1968 a high wind disturbed the sediment so much that Secchi transparency decreased to 12 cm from 108 cm *(Fig. 1)*.

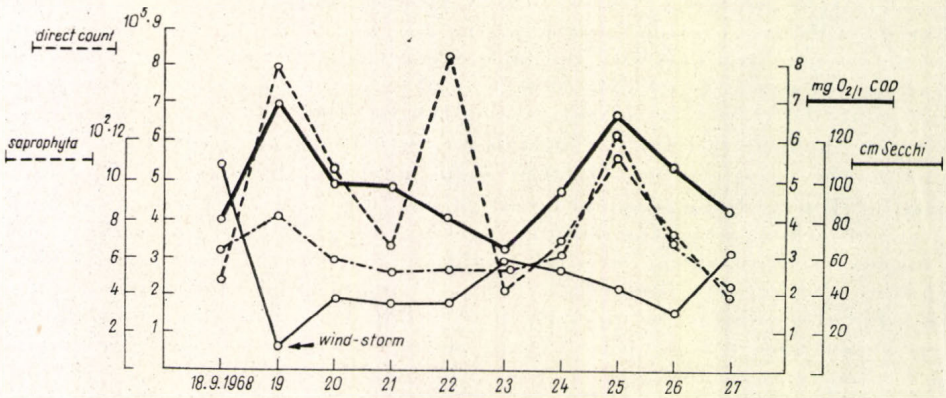

Fig. 1. Short periodic investigations in section "G" between 18th and 27th September, 1968

Subsequent to this the Secchi gradually increased until the 25th September, when again on the effect of gusts of wind it began to decrease. The COD of of the water in the 10-days period of investigation displayed an inverted value when compared to Secchi transparency values. On the 19th September, at the same time when the sediment was disturbed the COD values reached their peak, then as Secchi values increased they proportionately decreased, and on the 24th, when Secchi transparency decreased COD values again increased. The close relationship between the two factors seem to prove that due to the disturbance of water from the sediment a large amount of organic material passes into the water, especially at the site of investigation where the lake is very shallow. The quantity of saprophytic microorganisms is inversely proportional with Secchi transparency, while it is directly proportional with the organic material content. During the time investigation the quantity of total microbial plankton behaved similarly, only with the exception, that on the 22nd September we measured the highest of all, although at this time, Secchi transparency did not decrease and the chemical oxygen

demand did not increase either. All these facts apparently prove that with the disturbance of sediment, besides the great organic material increase in the water column, a significant quantity of bacteria passed from the sediment into the water. Furthermore, on the effect of the increased quantity of organic material content of the water column owing to the proliferation of bacteria even after the lag-phase the bacterium content of the water increases.

Simultaneously with the short periodic investigation of section G we carried out similar examinations in a site situated in front of our Researh Institute. On the 19th September, as the result of a very high wind Secchi values are extremely low here, too, but subsequently to this date they gradually increase, and the repeated decrease which was observed in section G from the 24th September, here, it was not observed *(Fig. 2)*. Accordingly

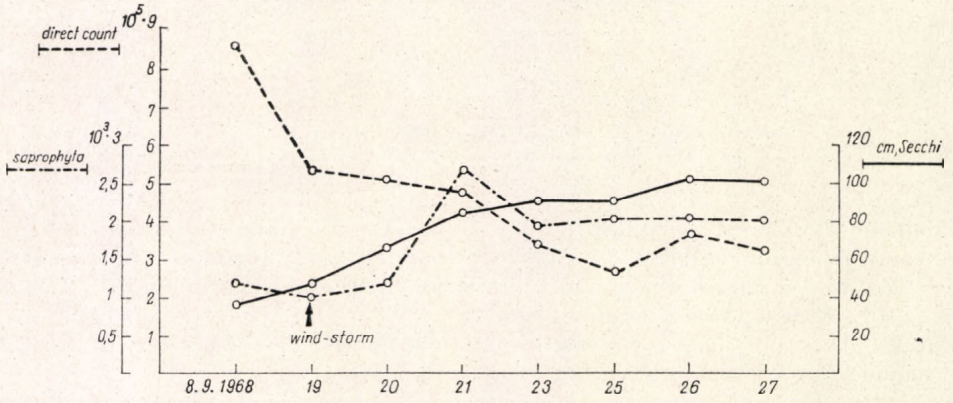

Fig. 2. Short periodic investigations in the open water in front of our Research Institute between 5th and 13th February, 1969

the quantity of the total microbial plankton simultaneously decreases as Secchi transparency increases, disregarding the slight increase which occured on the 26th September. However, the quantity of saprophytic microorganisms subsequent to the storm reach its maximum only after a two-days lag-phase, which is undoubtably the result of an intensive proliferation initiated by the agitation of mud occuring in the water.

Between the 5th and 12th February, 1969 we carried out investigations under the ice in front of our Research Institute. During the whole time of our investigation Secchi transparency was very large (270 cm) of the respective water column *(Fig. 3)*. The quantity of phytoplankton in the different water layers was rather significant $0.9-2.0 \cdot 10^4$/ml, and this value suffered no major changes. The stock of phytoplankton almost exclusively consisted of 4—5 μ big Chlamydomonas, which stains blue with the DE NOYELLES method, accompanied by a few Diatoms and other flagellates. The winter stock of phytoplankton, secured from under the ice, whose larger part comprised the tiny Chlamydomonas belong to μ-algae (RODHE, 1955; LUND, 1961; PENNAK, 1968). It is a well-known fact, that the μ-algae especially in the oligotrophic lakes are significant in the winter plankton (RODHE, 1955; PENNAK, 1968). According to LUND (1961) the more oligotrophic a lake the more important is the role of μ-algae in it. In the water examined by the above

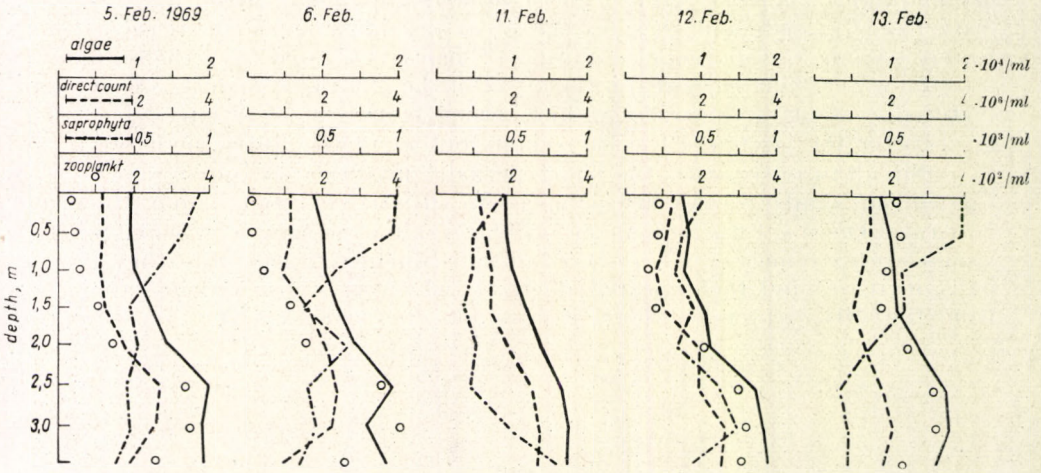

Fig. 3. Vertical short periodic investigations in the open water in front of our Research Institute between 5th and 13th February, 1969

mentioned authors the quantity of μ-algae was the largest during the time of their development 11—14.5 · 10^6/l. In Lake Balaton, during the investigated period the volume of the μ-alga population in the surface layers (0—1.5 m) 11 · 10^6, while in the bottom water (2.5—3.5 m) 18—18 · 10^6/l yielded good values. This particular, inverted stratification is also characteristic for the μ-algae.

The vertical distribution of the total microbial plankton was similar to that of phytoplankton. In the bottom water, the values surpassing 2 · 10^6/ml during the whole period of investigation hardly ever changed. In the surface layers the quantity of the total microbial plankton was 1—1.5 · 10^6/ml. The majority of the stock comprised a coccus form whose size was below 1 μ, which did not develop on the applied sodium-caseinate agar. The fact, that the distribution of this form was similar with the distribution of μ-algae refers to the relation of these two organisms. In spite of the large number of μ-algae and the great quantity of the total microbial plankton biomass the number of saprophytic organisms was low, and their vertical distribution did not follow that of the former. Generally, it was in the surface and bottom layers where maximum were reached.

The large biomass of nutritional organisms brought with it the formation of a significant zooplankton stock, which mainly consisted of the cold-loving *Cyclops vicinus* ULJ. and *Eudiaptomus gracilis* (G. O. SARS), accompanied by a few examples of *Daphnia hyalina* var. *galeata* (G. O. SARS) species. The majority of the stock comprised juvenile exemplars and females with eggs. The zooplankton primarily concentrated in the warmer bottom water layers rich in bacteria and μ-algae.

All this indicates that during winter, in the water of Lake Balaton covered by ice a stabile stratification occurs, thus, the role of short periodic changes is smaller. The strikingly high number of winter total microbial plankton in our opinion is connected with the mass proliferation of μ-algae. The great proliferation of μ-algae observed during the time of investigation is quite

unknown in Lake Balaton. This may be explained, partly by the lack of winter examinations, and partly by the fact, that the membrane filter suitable for the counting of μ-algae was not in use in the algological investigations of Lake Balaton. The generally used Utermöhl technique and the microscope are not suitable for the quantitative determination of μ-algae (RODHE, 1955; BERNHADR et al. 1967). Parallel with the open water investigations carried out under the ice cover, we did short periodic examinations in the reedery in front of our Research Institute *(Table 1)*.

TABLE 1

Time of investigation

	February, 5th	6th	11th	12th	13th
Phytoplankton 10^3 specimens/ml ...	2.1	2.2	2.8	2.1	1.9
Total microbial plankton, 10^6 specimens/ml	1.19	1.18	1.05	0.98	1.05
Saprophytes 10^3 specimens/ml	2.3	2.4	1.5	1.9	2.4
Zooplankton specimens/ml	110	90	84	98	110

The mass proliferation of μ-algae in the open water was completely lacking from the reedery. The phytoplankton stock which is significantly smaller than that of the open water consisted in Diatoms and spores with thick cell walls, and cysts. The quantity of the total microbial plankton was likewise smaller than in the open water, and the period under investigation showed no significant quantitative difference. On the contrary, the number of saprophytic microorganisms in the reedery was more than 10 times higher. The coccus form, smaller than one micron, was dominant in the open water was not found in the reedery, and the large-sized filament forms are dominant in the plankton. At any rate, in comparing the food supply of the open water and the water in the reedery, the latter was worse, which is not favourable for the formation of a large zooplankton stock in the shallow, cold-water reedery.

The daily investigations carried out between the 8th and 12th April showed no stabile vertical stratification as was observed in the winter under the ice cover *(Fig. 4)*. On the 9th April Secchi transparency decreased from 100 cm to 60 cm and consequently, the vertical distribution in the examined period continuously changed. During the investigation, the total microbial plankton and phytoplankton quantity displayed no significant variation, contrary to this, the quantity of saprophytic organisms increased in the total water mass two days after the decrease in Secchi transparency. Pronounced quantitative change occured with regard to the state in February, under the ice cover. The quantity of phytoplankton decreased, from among the 4—5 μ Chlamydomonas species only examplars existed, and the majority of algae was represented by Diatoms. Like it happened with phytoplankton, the quantity of the total microbial plankton decreased from $2 \cdot 10^6$/ml counted in February to $0.1 \cdot 10^6$/ml. The quantity of saprophytes compared to the state under ice, hardly changed.

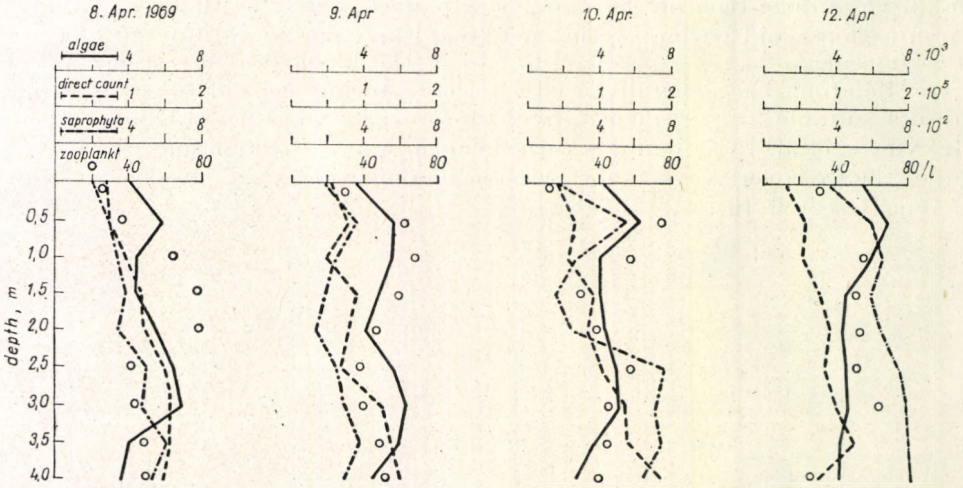

Fig. 4. Vertical short periodic investigations in the open water in front of our Research Institute between 8th and 12th April, 1969

Between the 28th April, 1969 and the 7th May with the increase in water temperature during the examined short period the quantity of the total microbial plankton increased more than four times of its initial value *(Fig. 5)*, and taking the state observed between the 8th and 12th April as basis, this change was ten times bigger. By the increase in temperature the number of saprophytic organisms increased, too. Between the 13th and 16th August *(Fig. 5)* with a high water temperature the quantity of the total microbial plankton, during the whole period of investigation, was around $0.5 \cdot 10^5$/ml, the number of saprophytes also decreased (200/ml). No significant short periodic change occured. These results indicate that on the effect of sediment disturbance besides the changes occurring in Secchi transparency and COD, the rapidly changing water temperature also may cause the significant short periodic changes of the saprophytic and total microbial plankton.

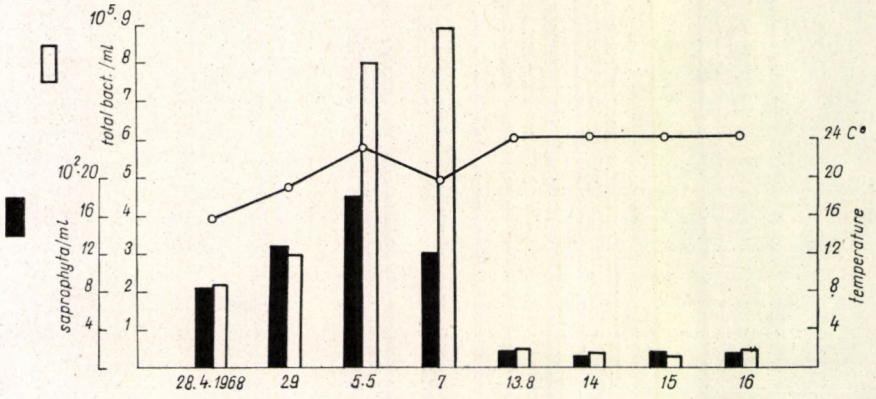

Fig. 5. Short periodic investigations in the open water in front of our Research Institute between 28th April and 16th August, 1969

The short periodic investigations carried out between the 18th and 27th September, 1969 on section G and in the open water stretching in front of our Research Institute *(Figs. 1* and *2)*, indicate that in the different basins of Lake Balaton the order of magnitude of the short periodic changes is not identical. In a section of Lake Balaton, which is the richest in nutritive materials, in Keszthely-Bay, our short periodic investigations also prove this *(Table 2)*.

TABLE 2

Time of investigation

	21st May	24th June	27th June	4th July
Secchi, cm	72	25	64	52
Total microbial plankton 10^5 specimens per ml	5.2	6.7	9.2	6.8
Saprophytes 10^2 specimens per ml	1.9	3.2	4.4	1.3
Water temperature °C	16	21	22	24.5

On the 24th June as the result of a very high wind Secchi transparency decreased to less than its half. The effect of the disturbance in the sediment occurred only three days later with a significant measure. The number of the saprophytic organisms is higher as the result of organic materials getting into the water from the sediment, this number at times attained the hundredfold of its initial value. The organic material which was introduced into the water medium was quickly consumed and by the 4th July the number of saprophytes was again rather low. The very fast proliferation of the saprophytic organisms and their rapid decrease in number prove that the sediment of Keszthely-Bay contains a large quantity of organic material and that the water possesses an intensive self-purifying capacity. All these emphasize that the sediment of the lake, whose water is frequently disturbed, has a close relationship with the water.

In comparing the data of the short periodic examinations with the investigational result obtained by recent monthly analysis (Oláh, 1969a, b), it becomes clear that in the seasonal dynamics of the microbial plancton of Lake Balaton the spring and summer maximum and the summer-late summer minimum seem to be the most significant values, which besides Lake Balaton, are also applicable to the similarly shallow Velence Lake of large water area (Oláh and Vásárhelyi, 1970). We need further data to generalize the significant maximum formed during winter time.

Summary

1. The short periodic changes of the saprophytic and total microbial plancton varied according to seasons: (a) in winter, under the ice the short periodic change was not significant; (b) in spring, with a temperature rise a significant short periodic change was observed even without a decrease in Secchi transparency (c) while in summer, with a decrease in Secchi transparency

in Keszthely-Bay the number of saprophytes increased by several order of magnitude, the, without a Secchi decrease we measured no significant short periodic change; (d) in autumn, the sudden decrease in transparency brought about pronounced short periodic changes. Consequently, we attached importance in the short periodic changes to temperature and to the wind disturbing the sediment.

2. In winter, under the ice we found a stabile stratification and in the bottom layer the quantity of the total mikrobial plankton ($2 \cdot 10^6$/ml) surpassed the values measured in spring, summer and autumn. The high number of bacteria bears a close connection with the winter formation of the μ-algal stock exceeding even $19 \cdot 10^6$/l. All these conditions made possible the development of a significant stock of zooplankton. The mass proliferation of μ-algae in the reedery was lacking and the quantity of the total microbial plankton was likewise smaller, consequently, the number of zooplankton is also low.

3. The seasonal short periodic investigations, beside the first description of high winter values, support the previously observed spring maximum an summer-late summer minimum in the seasonal dynamics.

Acknowledgmenet

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RÖVIDPERIÓDUSÚ VÁLTOZÁSOK A BALATON MIKROBIÁLIS PLANKTON MENNYISÉGÉBEN

Oláh János

Összefoglalás

1. A szaprofita és teljes mikrobiális plankton rövidperiódusú változásai évszakonként különbözőek: *a)* télen, jég alatt nem mértünk jelentős rövidperiódusú változást; *b)* tavasszal a hőmérséklet emelkedésével Secchi átlátszóság változás nélkül is jelentős rövidperiódusú változás volt; *c)* nyáron Secchi átlátszóság változással a Keszthelyi-öbölben több nagyságrenddel változott a szaprofiták száma Secchi változás nélkül nem mértünk jelentős rövidperiódusú változást; *d)* ősszel az átlátszóság hirtelen változása jelentős rövidperiódusú változásokat eredményezett. A rövidperiódusú változásban a hőmérséklet és az üledéket felkavaró szél játszanak fontos szerepet.

2. Télen, jég alatt stabil rétegezettséget találtunk és az alzati rétegben a $2 \cdot 10^6$/ml-t elérő teljes mikrobiális plankton mennyiség a tavaszi, nyári és őszi értékeket is meghaladta. A magas baktériumszám a $19 \cdot 10^6$/l-es nagyságot is meghaladó μ-alga állomány téli kifejlődésével kapcsolatos. Mindez jelentős zooplankton állomány kialakulását tette lehetővé. Az μ-algák tömeges elszaporodása a nádasban hiányzott, és a teljes mikrobiális plankton mennyisége is kisebb, ennek megfelelően a zooplankton szám is alacsonyabb volt.

3. Az évszakonkénti rövidperiódusú vizsgálatok a magas téli értékek első leírása mellett megerősítik a szezonális dinamikában korábban megfigyelt tavaszi maximumot és a nyári-nyárvégi minimumot.

КОРОТКИЕ ПЕРИОДИЧЕСКИЕ ИЗМЕНЕНИЯ В КОЛИЧЕСТВЕ МИКРОПЛАНКТОНА БАЛАТОНА

Я. Олах

1. Короткие периодические изменения сапрофитного и тотального микробного планктона проявляют сезонную изменичивость: *а)* в подлёдных условиях зимы периоди ческие изменения незначительны; *б)* с ростом темперетуры весной они проявляют значительные размеры даже в отсутствие снижения показателя прозрачности Secchi; *в)* летом, одноаременно со снижением показателя прозрачности Secchi в Кестхейском заливе, число сипрофитов увеличивается на несколько порядков, тогда как в отсутствие снижения показателя Secchi мы не наблюдали заметных которких периодических изменений; *г)* осенью резкое снижение прозразности находится в связы с выраженными короткими периодическими изменениями. Для коротких периодических изменений представляются важными температура и ветер, вызывающий взмучивание осадков.

2. В подлёдных условиях зимы обнаруживается устойчивая стратификация, когда в придонном слое количество тотального микробного планктона ($2{,}10^6$/млЗ) превышает значения, отмеченные весной, летом и осенью. Высокое число бактерий коррелирует с распределением мелких хламиномонад (μ-algae), количество которых зимой в придонном слое превышает $19 \cdot 10^6$ л. Все эти условия делают возможным развитие значительных запасов зоопланктона. В тростниковых зарослях массового развития μ-algae не наблюдали, и, соответственно, количество тотального микробного и зоопланктона было меньше.

3. Исследование коротких периодических изменений, а также первое описание высоких зимних значений, подтверждают прежние наблюдения относительно весеннего и максимума летного-позднелетнего минимума в сезонной динамике.