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THE QUANTITY, VERTICAL AND HORIZONTAL DISTRIBUTION OF THE TOTAL BACTERIOPLANKTON OF LAKE BALATON IN 1966/67

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The important role of the diversified mineralizing activity of the microorgansms in the material and energy turnover of water bodies is well known (KUZNETSOV, 1952; BROCK, 1966). However, the significance of bacterial biosynthesis concomitant with decomposition was emphasized only recently (SOROKIN, 1967).

Energy liberated during mineralization represents in fact the basis of the synthesis of full value proteins (in relation to nutrition) accumulated in the bacterial cell. And as the sole source of food, the bacterial cell is utilized by a wide range of aquatic animals (GORBUNOV, 1946; RODINA, 1948, 1950; SOROKIN, 1966). Since bacterial biosynthesis is directly founded on organic substances eliminated from the chain of utilization of aquatic animals, the entire process will, in an ecological sense, hardly differ from primary production (SOROKIN, 1965).

This direct trophic role of the bacteria corroborates the justification of approaches which seek to connect the trophity of waters and their bacterial biomass. Owing to earlier methodological difficulties, however, little is known on the qualitative and quantitative conditions of the bacterioplankton.

As RAZUMOV's (1932) direct method, now is general use, renders a possibility for the exact quantitative survey of the bacterioplankton, the present work attempted a survey by this method of the seasonal, quantitative conditions of the bacterioplankton in the open water of Lake Balaton.

Data submitted by ZIH (1929) and HARANGHY (1941) give information on the heterotrophic bacterial flora of Lake Balaton. However, the results obtained by an indirect method, though valuable from several points of view, fail to present a complete picture of the quantitative conditions of the total microflora.

Material and methods

The material of the present study consists of samples taken for an algological investigation during a period of fifteen months (August, 1966—November, 1967). Samples fixed previously by acetic acid and lugol's solution were conserved in formalin. The samples derive from 3 points each of the 5 standard sections of Lake Balaton (TAMÁS, 1967). The period of time of the monthly collectings at the 15 sample localities did not exceed 48 hours, thus it was possible to work on approximately synchronous samples — an essential feature in view of the rapid changes occurring in bacterioplankton.

The total number of bacteria present in the samples was established by RAZUMOV's method. 10—40 ml of the well shaken sample was filtered through a N 2 Soviet membrane filter, stained by carbolic eritrozine and counted under an apochromate lens (100 × 25).

Results

Seasonal vertical distribution

In section M, the number of bacteria varied between 1 — 9 · 10^5/ml in the samples originating from different water depths. The vertical distribution is extremely diverse *(Fig. 1)*. The maximum number of individuals appeared in the surface samples in September, and in the middle ones during October and November; on the other hand, a reverse vertical distribution showed at locality Mo in September and October. At 2 m depth, maximum values appeared in November only at size M1 and in September at Mo. During spring, the distribution of the baterioplankton was uniform in all three localities.

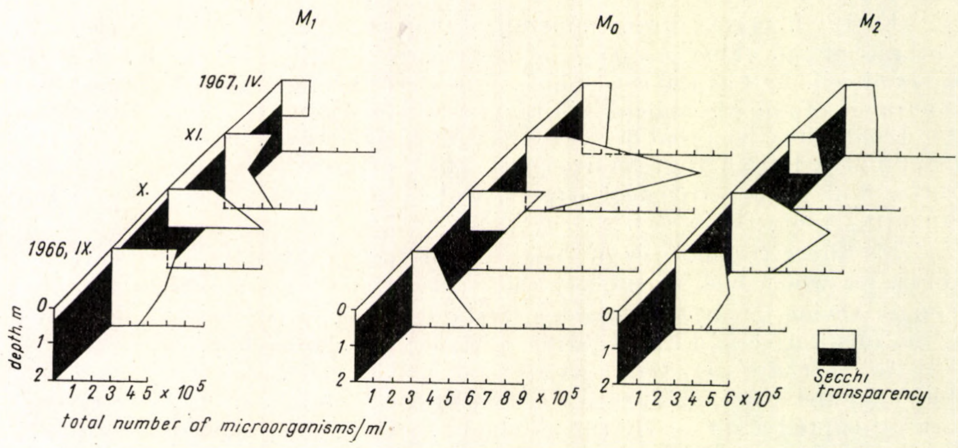

Fig. 1. The seasonal vertical distribution of the bacterioplankton at three points of section "M"

In section K, *(Fig. 2)*, the number of bacteria fluctuated between 1 — 8 · 10^5/ml at different water levels during autumn. In November, the entire water column is characterized by a relatively uniform 2 · 10^5 bacteria/ml. In April 1967. an identical vertical distribution was found at all three points of the section. Maximum values showed at the surface and at a depth about 2 m.

In section G, samples were taken also in August, 1966 *(Fig. 3)*. The summer month was characterized by a conspicuously uneven vertical distribution. The number of bacteria varied between 2 — 5 · 10^5/ml; maxima appeared at the surface and, excepting site G1 at a depth of about 3 m. In November, the water body was homogeneous also here, similarly to the situation in section

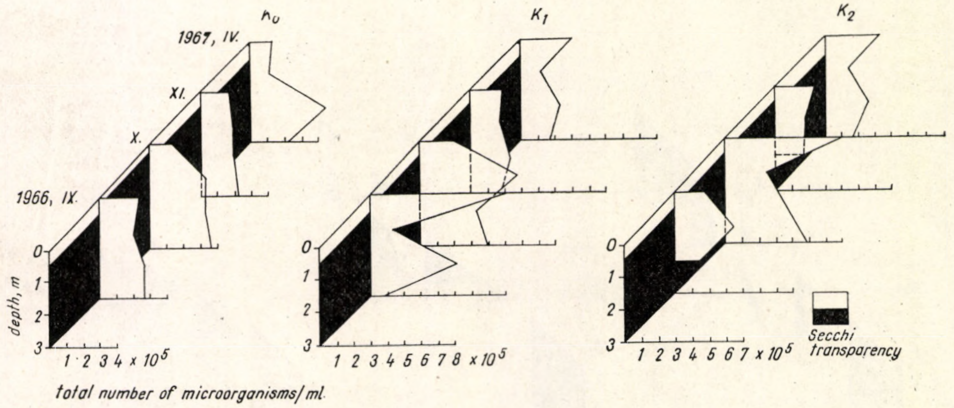

Fig. 2. The seasonal vertical distribution of the bacterioplankton at three points of section "K"

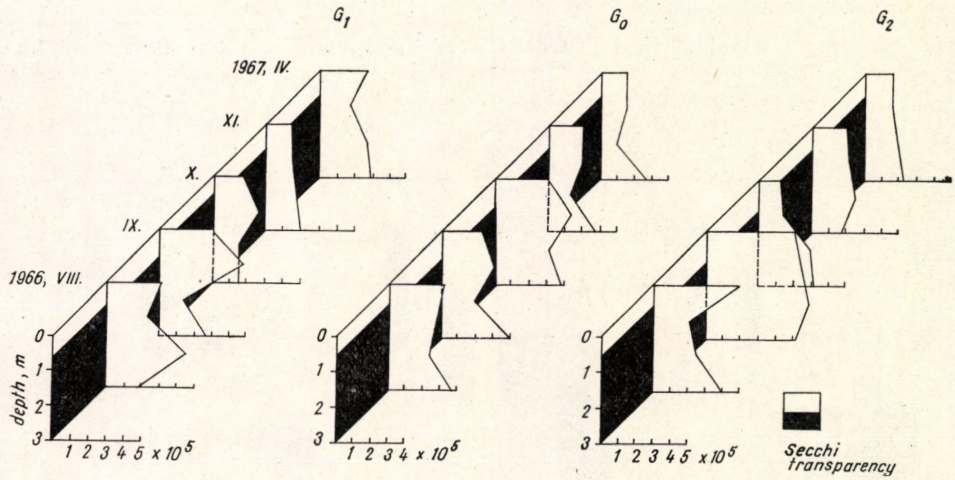

Fig. 3. The seasonal vertical distribution of the bacterioplankton at three points of section "G"

K, with an average number of bacteria $2 \cdot 10^5$/ml. The September—October distribution is characterized by the maximum evolving at about 1 m, divergently from that of the summer month. The vernal vertical distribution, characterizing section K, appeared here also partly.

In section A, considerable differences in the number of individuals occurred in the samples of both summer and autumnal samples. The amount of bacteria varied between $1 - 8 \cdot 10^5$/ml, and the maximum values were found most frequently on the surface. No picture, characteristic of sections K and G, emerged in the spring month, a nearly uniform vertical distribution showing with an average $1{,}5 \cdot 10^5$/ml number of bacteria *(Fig. 4)*.

As compared to the preceding sections, the distribution of bacteria was more uniform in section E. The uniform vertical distribution was usually distorted by the higher number of bacteria formed at greater water depths *(Fig. 5)*.

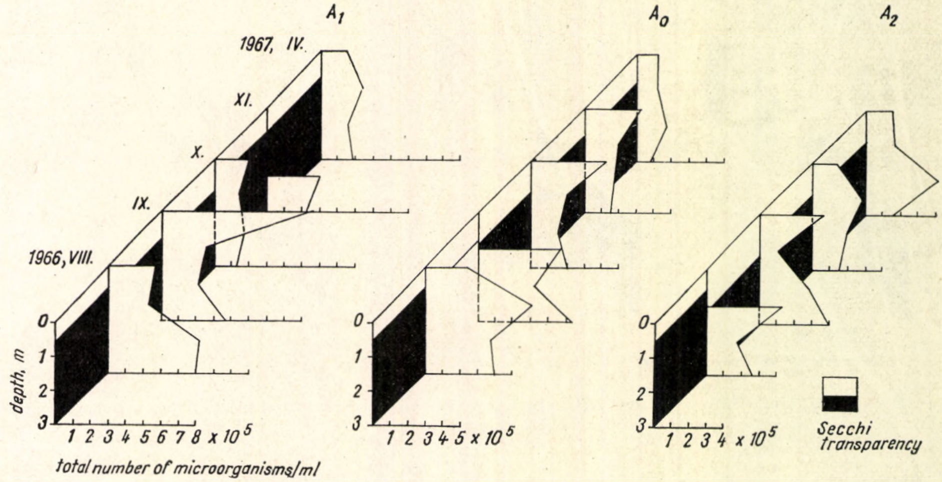

Fig. 4. The seasonal vertical distribution of the bacterioplankton at three points of section "A"

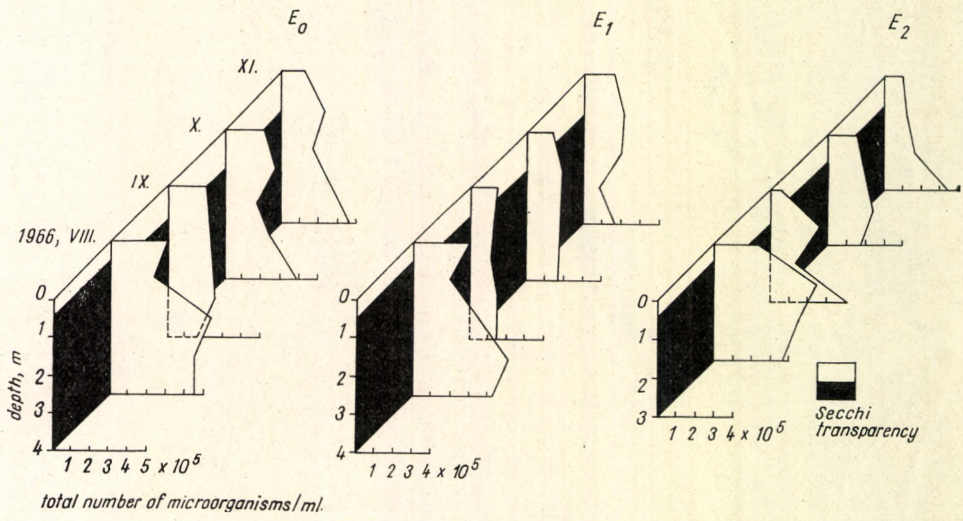

Fig. 5. The seasonal vertical distribution of the bacterioplankton at three points of section "E"

Seasonal horizontal distribution

Two prominent values appeared in section M during the investigated period *(Fig. 6):* a smaller value (slightly more than $4 \cdot 10^5$ bacteria per ml) in October, 1966, and a higher one (nearly 1 million bacteria per ml) in August, 1967. Aside of these, the differences between the sites within the section were smaller. In the period studied, the average number of bacteria was $2{,}3 \cdot 10^5$/ml, and the number of individuals increased significantly at all three localities only in July, 1967.

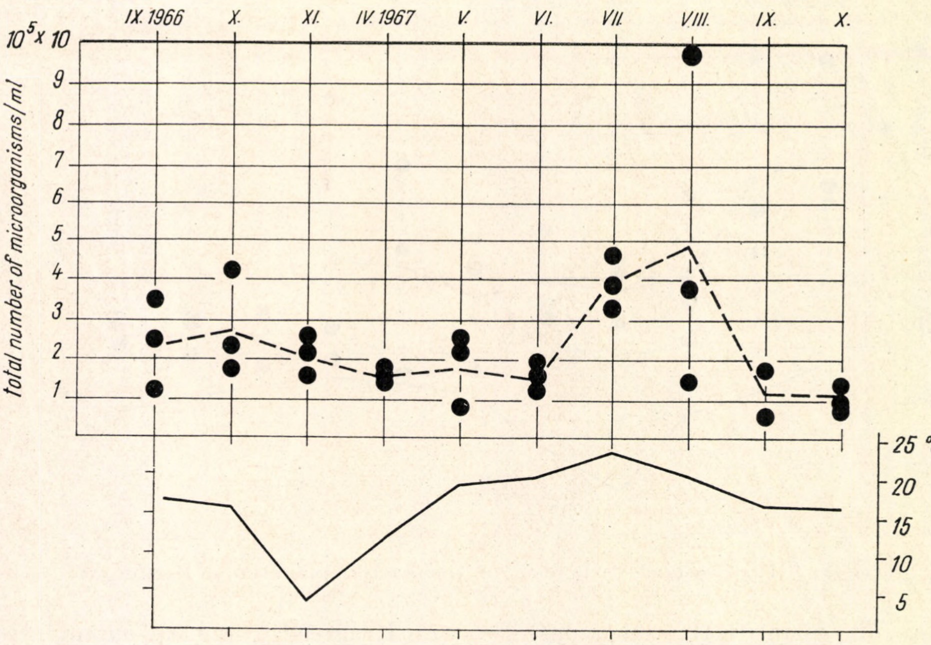

Fig. 6. The seasonal dynamism of the bacterioplankton in section "M"

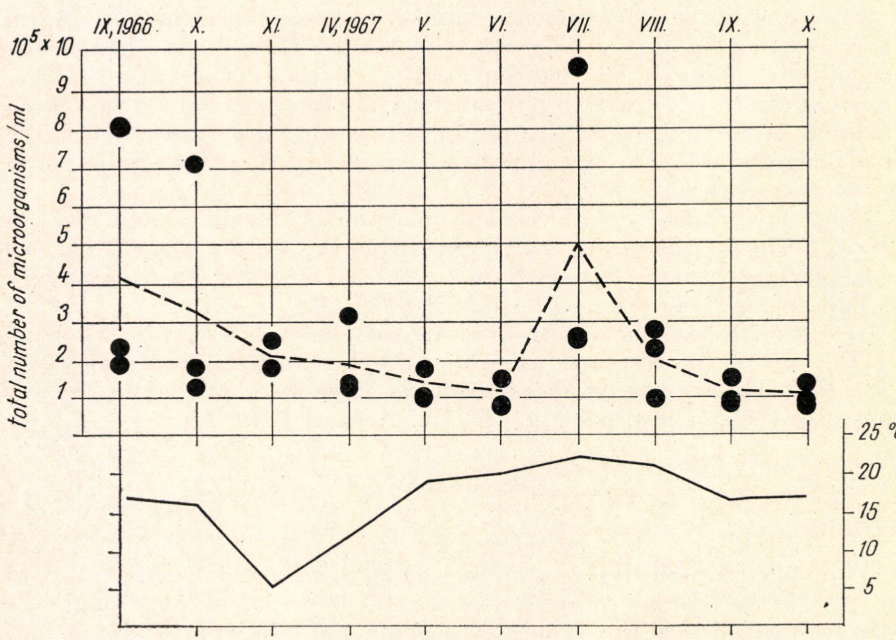

Fig. 7. The seasonal dynamism of the bacterioplankton in section "K"

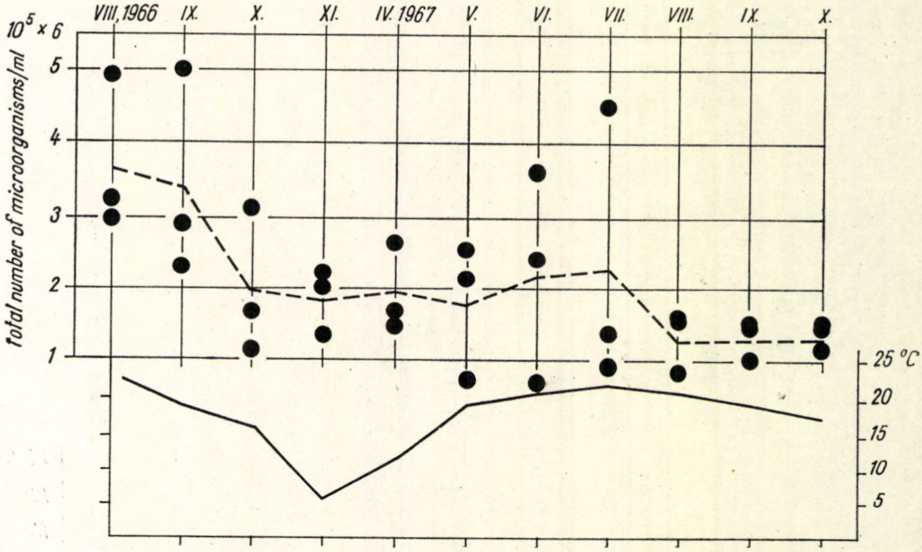

Fig. 8. The seasonal dynamism of the bacterioplankton in section "G"

The quantitative conditions of section K agreed to a great extent with those found in section M. However, prominent values were more frequent at the sites within the section and their order of magnitude also approached 1 million *(Fig. 7)*. Aside of these, the amount of bacteria was nearly identical in the investigated period.

According to the 1966 data, the number of bacteria was high at all three points of section G during August—September *(Fig. 8)*. A characteristic feature of the amount of the bacterioplankton was the considerable differences measured at the three sites within the section, appearing in half of the surveys. The amount of bacteria became more uniform during the colder months. The order of magnitude of the prominent values reached $5 \cdot 10^5$ bacteria per ml, while the average was $2 \cdot 10^5$/ml.

The number of bacteria increased in section A during September, 1966, and May, 1967. The fluctuation of values within the section was smaller, with the sole prominent value having been $8 \cdot 10^5$ bacteria per ml in September, 1966. The average value was $2{,}1 \cdot 10^5$/ml *(Fig. 9)*.

In section E, maxima evolved in August, 1966, and May, 1967. Values within the section hardly vary, excepting the prominent figure $4{,}4 \cdot 10^5$/ml in April, 1967. The average number of bacteria, as compared to that of the other sections, was the smallest in section E ($1{,}6 \cdot 10^5$/ml) *(Fig. 10)*.

Discussion

Seasonal vertical distribution

Available data are meagre with respect to the vertical distribution of the microflora of lakes. In his comprehensive work, KUZNETSOV (1952) points out that the vertical distribution is highly variable depending on the character of the lake and the prevailing season. In lakes with a temperature and chemical

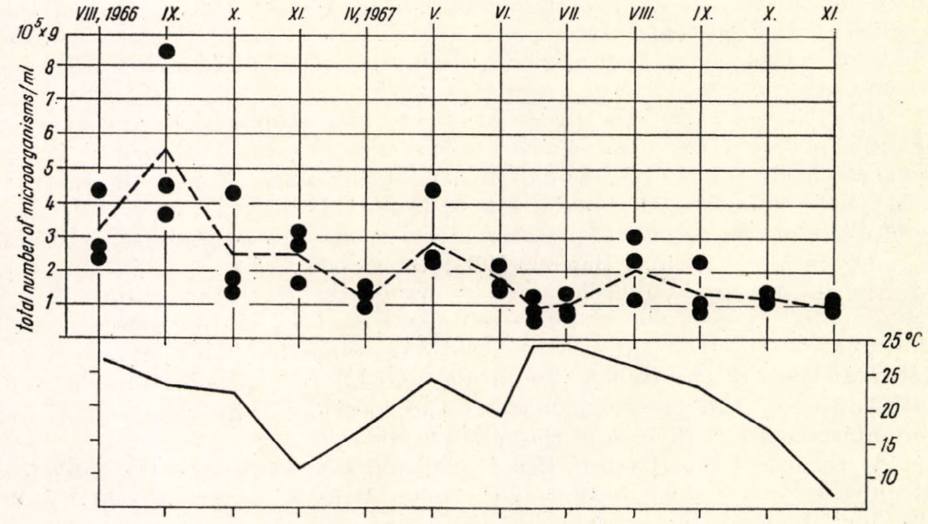

Fig. 9. The seasonal dynamism of the bacterioplankton in section "A"

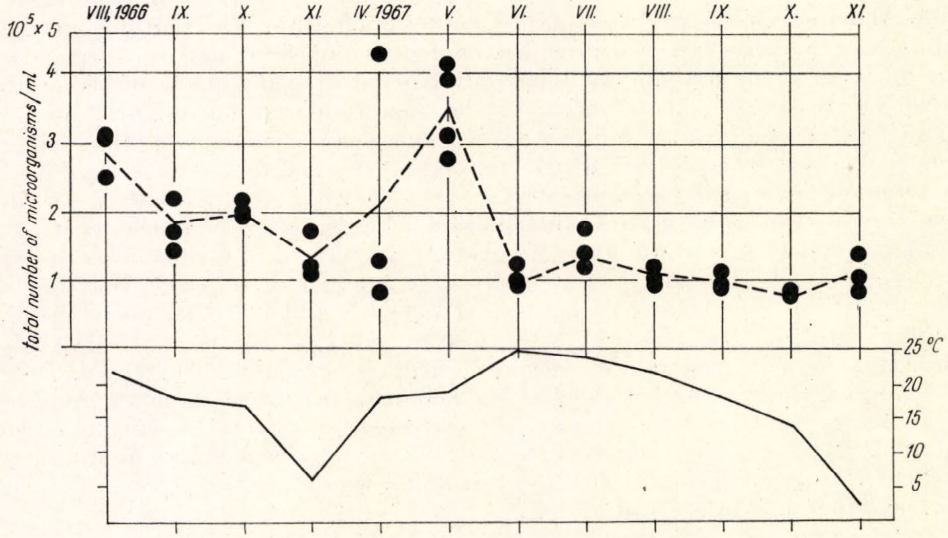

Fig. 10. The seasonal dynamism of the bacterioplankton in section "E"

stratification the bacterioplankton displays a definite and stabile vertical distribution. The maximum of the total microflora evolves generally in the metalimnion (YEGOROVA, 1951; OTZEVSKI, 1966; OVERBECK, 1966, 1968). According to KUZNETSOV's data deriving from the Beloie Lake, the maximum of the bacterioplankton was also in the metalimnion in August, 1932, but it became definitely delimited to the epilimnion in August, 1933. The data also reveal that the bottom water contains invariably more bacteria. During periods of complete circulation, the distribution of bacteria, apart from the bottom maximum, is uniform in the water body.

In stratified lakes, the distribution of heterotrophic bacteria shows a different picture. The most significant maximum is in the surface layers (POTTER and BAKER, 1961), and this is usually correlated with the distribution of the phytoplankton (OVERBECK, 1966, 1968). The high number of heterotrophic bacteria in the bottom water layers is also an apparently universal phenomenon (POTTER and BAKER, 1961; OTZEVSKI, 1966).

Hardly any pertaining data are known on the vertical dynamics of the bacterioplankton of shallow and constantly disturbed lakes (RAZUMOV and ZAHAROVA, 1948; OTZEVSKI, 1966). OTZEVSKI conducted some investigations on several lakes of the Balkan Peninsula, and his results point to a definite stratification of the bacterioplankton. The location of the maximum and minimum layers was diverse in the lakes studied.

As regards Lake Balaton, ZIH (1929) and HARANGHY (1941) published data on the vertical distribution of the heterotrophic bacteria. Their results show unequivocally the uneven vertical distribution of the bacteria. Owing probably to the disordered position of the maximum—minimum layers, HARANGHY renounces stratification, basing his inferences on surveys made in the "Well", the deepest point of the lake.

The results of our 65 vertical surveys made in Lake Balaton irrefutably show the uneven distribution of the bacterioplankton. Fluctuations in the number of bacteria in the diverse water depths appeared mostly during the summer and autumnal months, with only November being characterizable by a comparatively even distribution of the bacterioplankton. Similarly homogenous distribution can be found in the various sections also during the springtime surveys. If the position of the maximum—minimum layers is examined in details, the vertical distribution will be found strikingly diverse even within the same section. The vertical distribution is thus most dynamic is nature, changing and forming in a state of constant movement. By ZIH's (1929) and HARANGHY's (1941) data, the heterotrophic microflora of Lake Balaton is characterizable by a similar dynamism. OTZEVSKI's (1966) studies made on the shallow eutrophic lakes of the Balkan also revealed the uneven vertical distribution of the bacterioplankton. According to RAZUMOV and ZAHAROVA (1948), the vertical distribution of the bacterioplankton in a shallow but extensive water reservoir shows a highly intricate picture, especially during the summer months. It follows that the vertical distribution of the bacteria in standing bodies of water with a large surface area and a small depth is widely effected by the dynamism of the water.

The extensive and shallow waters of Lake Balaton is deeply agitated even by moderately strong wind. Depending on the force of the wind, particles of diverse size and rate of sedimentation enter the water-body. Variation is further increased by the different quality per sections of the sediment, indeed, sediment may considerably vary even within the same section (ENTZ et al. 1963). All these results in the diversity of available food of the various sections of water, allowing the formation of bacterial populations highly different both qualitatively and quantitatively. However, details of these processes can be exposed only by short-term studies.

Seasonal horizontal distribution

On the basis of the average amount of the bacterioplankton, not great differences can be found between the sections investigated. The number of bacteria was the highest in sections M and K ($2,3 \cdot 10^5$) and the smallest in section E ($1,6 \cdot 10^5$). The highest values reached 1 million per ml in sections M, K and A, and only about $5 \cdot 10^5$/ml in sections G and E.

Literature has some summarized data on the amount of the bacterioplankton of diversely trophic lakes (KUZNETSOV, 1952; ROZUMOV, 1962; RODINA and KUZMITSKAYA, 1963; THSERBAKOV, 1967). Accordingly, on the basis of the amount of the bacterioplankton, Lake Balaton approached the oligotrophic waters, even though the maximum values reached the order of magnitude of the bacterioplankton of mesotrophic lakes. ZIH's (1929) and HARANGHY's (1941) statement therefore, namely that Lake Balaton is poor in heterotrophic bacteria, still holds true with respect to the total of the microflora.

If the excessive values are disregarded, the differences are small in the seasonal course. Maxima evolved in sections G, A and E at the end of the summer and the beginning of the autumn in 1966; a strong maximum appeared in section E, evolving at a smaller rate also in section, A, in May, 1967; and the 1967 maximum showed in sections M and K in June.

Increasingly more data become available concerning the seasonal fluctuation of the bacterioplankton (KUZNETSOV, 1960, 1961, 1965; OVERBECK and BABENZIEN, 1964; POTAYENKO, 1968); however, investigations extending over a number of years are still needed to exactly determine the annual course of the bacterioplankton of Lake Balaton. It should be born in mind that the regular seasonal dynamics of the microflora present in the deeper lakes is probably wanting or appearing in a very intricate form owing to the constant but irregular disturbance of the sediment rich in nutritive substances. To know more about it, investigations extending over several years, including also short-period surveys, are needed.

Summary

1. Applying RAZUMOV's direct method, the total number of bacteria at 15 standard sites in the open water of Lake Balaton has been determined; the studies were based on the vertical and horizontal samples taken monthly in 1966 and 1967.

2. Compared with the earlier data referring to the heterotrophic bacteria, the number of total bacteria proved to be 10,000 times higher.

3. In 1966 and 1967, the average number of bacteria was $2,2 \cdot 10^5$/ml in the open water of Lake Balaton, and the most prominent values reached one million.

4. The seasonal course of the total bacterioplankton was different in the diverse section in both years. In the case of the shallow, cnnstantly disturbed waters of the lake changes involving shorter periods play a presumably greater role in the quantitative evolvement of the bacterioplankton.

5. In the open water of the lake, the vertical distribution of the bacterioplankton is characterizable by unevenness. Owing to the dynamism of the water the distribution is extremely mobile and short-lived.

Acknowledgement

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A BALATON TELJES BAKTERIOPLANKTON MENNYISÉGE, VERTIKÁLIS ÉS HORIZONTÁLIS ELOSZLÁSA 1966/67-BEN

Oláh János

Összefoglalás

1. Szerző RAZUMOV direkt módszerével meghatározta a Balaton nyíltvizének 15 standard pontján az össz baktérium-számot az 1966. és 1967. évek havonkénti vertikális és horizontális mintáiból.

2. A korábbi, heterotróf baktériumokra vonatkozó adatokkal összevetve az össz baktérium szám 10 000-szer magasabbnak bizonyult.

3. Az 1966. és 1967. években a Balaton nyílt vizében átlagosan 2,2 . 10^5/ml baktérium volt és a kiugró értékek elérték az 1 milliót.

4. A különböző szelvényeken a szezonális lefutás mindkét évben eltérő volt. A sekély, állandóan felkavarodó Balaton esetében a bakterioplankton mennyiségének alakításában a rövid periódusú változásoknak feltehetően nagyobb a szerepük.

5. A Balaton nyíltvizében a bakterioplankton vertikális eloszlását az egyenlőtlenség jellemzi. Az eloszlás a víz dinamizmusa miatt rendkívül mozgékony, rövid életű.

ОБЩЕЕ ЧИСЛО БАКТЕРИОПЛАНКТОНА ОЗЕРА БАЛАТОН ПО ВЕРТИКАЛЬНОМУ И ГОРИЗОНТАЛЬНОМУ РАСПРЕДЕЛЕНИЮ В 1966—67 ГОДАХ

Я. Олах

1. Автор с помощью прямого метода РАЗУМОВА определил общее число бактерий на 15 стандартных станциях озера Балатон из вертикальных и горизонтальных проб, собранных в 1966/67 годах в каждый месяц.

2. По сравнению с прежними данными, относящимся к сопрофитам, общее число бактерий в озере Балатон оказалось в 10 тысяч раз больше упомянутых данных.

3. В открытой воде озера Балатон в 1966/67 годах в среднем было найдено 2,2.10^5/мл бактерий, а самые высокие значения равнялись 1 миллионам.

4. На различных поперечных сечениях сезонное колебание было различно в обоих годах.

В озере Балатон, характеризующемся частыми перемещениям и низким уровнем воды, в количественных изменениях бактериопланктона важную роль играют прежде всего кратковременные изменения.

5. Вертикальное распределение бактериопланктона в открытой воде озера неравнамерное, чрезвычайно вариабельное и эфемерное ввиду подвижности воды.