[Translated by J.E.M. Horne]

MANUILOVA E.F. (1962) The influence of blue-green algae on development of the zooplankton.

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Many have observed the reduction of the quantity of zooplankton in the presence of water blooms. It is known that in seas zooplankton as it were avoids places of accumulation of blue-green algae. To elucidate this phenomenon several theories have been suggested. However, even the most acknowledged of these - the theory of Hardy founded on the chemical influence of algae on zooplankton, is far from revealing all the complexity of the inter-relationships between these groups of organisms.

M.A. Messineva and V.Ya. Pankratova (1941) showed that the number of bacteria in the presence of the decomposition of phytoplankton could after 24 hours increase by 2,000 times. According to the investigations of K.A. Guseva (1952), the dying-off of blue-green algae is accompanied by an increase in the numbers of saprophytic bacteria and zooplankton. At the same time, as our previous observations showed (Manuilova, 1953) in the presence of blooms there may be a sharp fall in the total numbers of bacteria.

Taking into consideration the food importance of bacteria (Rodina, 1950) and their role in the productivity of reservoirs (Rodina, 1951), and also such circumstances as that the algae themselves sometimes can serve as food of a number of organisms, one cannot but suppose that water blooms must in significant measure determine the food conditions of zooplankton.

Arising from this, by observations on one of the tributaries of the Rybinsk reservoir - the River Shumorovka - we tried by simultaneous collections to trace the changes in numbers, not only of zoo- and phytoplankton but also of bacteria. The plankton was collected by quantitative nets with suitable numbers of gauze (for zooplankton, No. 49, pbytoplankton, No, 77) and bacteria were taken account of by the method of direct calculation on membrane filters.

The place of observation, - the lower reach of the river - has an area of about 800 m^2 and a depth in the channel part up to 5 m, in the flood plain up to 2 m. Visible current in the river is absent.

Water bloom in the river occurs annually. With one exception all outbursts of bloom for a period of 3 years observed were connected with massive development of Aphanizomenon. Only during the first outburst in 1954 did Microcystis predominate. The duration of the interval between peaks of blooming depends on temperature. At 20°-25° the peaks of blooming follow one another after 6 - 8 days, at temperatures below 20* after 12 - 18 days. The number of blue-greens usually grows gradually and sharply increases to the day of the peak, after which follows their death.

The complex of zooplankton in the River Shumorovka bears a lacustrine character. Thus as in lakes where water bloom is observed, here Cladocera predominate in biomass. Of these the principal massive species appear Daphnia cucullata and Bosmina coregoni coregoni. Rotifers are numerous in the river and represented by the usual widely-distributed forms (Keratella cochlearis, Polyarthra trigla and others). Of the copepods, the only massive species appears to be Mesocyclops oithnoides. As characteristic components of the zooplankton appear protozoans of the group of little-ciliated infusoria.

Not a single representative of the zooplankton of the River Shumorovka could utilise Aphanizomenon for food. Filaments of this algae are too strong for the filtrators, and for this reason they cannot be ingested by rotifers. The number of Mesocyolops bears a definite relation to infusoria, which evidently appear also to be their basic food in this reservoir.

In 1956, parallel with the collections in the reservoir we carried out observations in the laboratory on cultures of various Cladocera in river water. Eliminating from it the algae and detritus by filtration through a coarse grade of membrane filter, and changing the water daily, we in this way allowed the crustaceans only bacterial food, contained in natural water. Survival of the crustaceans for the period of the 2½ months of the experiment was not uniform and deteriorated or improved depending on the change of intensity of reproduction of the bacteria, which was judged by observation of the time of development of a generation of bacteria in natural water. The experiments carried out show that bacteria in the River Shumorovka have fundamental importance with regard to the food of filter feeders. It is known that bacteria are also utilised by rotifers and protozoans. Consequently the whole complex of zooplankton in the River Shumorovka is found to be dependant on bacterial food.

The calculation of the bacteria which we carried out permits us to cite the following data on the change of their numbers during the bloom. In 1954, in the period preceding the bloom, the total number of bacteria oscillated from 2 million to 671 thousand in 1 cm^3. During the first outbreak of the bloom it fell to 290 thousand, in the interval between the first and second outbreak it increased to 700 thousand, during the second outbreak it fell to 229 thousand and rose after this to 1454 thousand per cm^3.

In 1956, besides direct calculation, we carried out observations on the intensity of reproduction of bacteria by means of experiments on the determination of duration of development of a single generation (by the accepted microbiological method, Ivanov, 1955). A week before the bloom, a single generation of bacteria developed in 9 hours. On the day of the peak of the first outburst of the bloom (26 June) the time for one generation had increased to 46 hours. Already by the day following the maximum number of algae it fell to 16.8 hours. This shows that reproduction of the bacteria began to be more intensive. A marked bacterial outburst with high total numbers (1200 thousand in 1 cm^3) was observed on the third day after the maximum of the bloom. During the second peak of the bloom (4 July) at the beginning of the experiment the total number of bacteria was fairly high, but at that the bacteria apparently did not reproduce, judging by the fact that their numbers in the experimental vessels at the end of the experiment were less.

Corresponding to the changes of the content of bacteria are found fluctuations in the numbers and biomass of zooplankton during blooming. According to the observations of 1955 and 1956, with collections at 1-3 day intervals, it turned out that the moment of the peak of the bloom was usually accompanied by a more or less sharp fall in numbers and biomass of zooplankton (fig. l). During these days there were always very many organisms dying at the moment of capture, especially daphnids. In the Cladocera at the same time reproduction comes to an end in the days of maximum bloom and the majority of them, and sometimes all, have empty brood chambers. Thus, during the bloom in June 1956, on the day of maximum numbers of algae, all Cladocera with the exception of a single _Bosmina_ were sterile. After two days, the mean number of eggs in _Daphnia cucullata_ was 1.7, in _Bosmina coregoni_ - 2. After five days it increased in _Daphnia_ to 2, in _Bosmina coregoni_ to 2.1., in _Bosmina lorgirostris_ to 3.

Taking into account that, in the principal massive species of the River Shumorovka - D. cucullata and B. coregoni - in high summer temperatures broods can follow after 1 - 2 days and full maturity ensues on the 4th/5th day of life, it is easy to imagine that the intervals between peaks of blooming which, as already shown above amount in the R. Shumorovka at high temperatures to 6 - 8 days, are sufficient for significant renewal of their populations. Just as quickly able to restore the number of their population are the rotifers, which possess a short individual period of development. Last, in the Copepoda, it is rather prolonged, as they do not have the chance of such mobility of population dimensions as the daphnids and rotifers. The change of numbers of Mesocyclops, depending on the growth of Protozoa, we deduced in 1954. In June and the beginning of July of that year the infusoria reached a quantity of 10,000 per litre. Their number strongly increased and reached about 120,000 per litre during the bacterial outburst between the first and second peaks of the bloom. With the sharp fall in total number of bacteria on the day of the maximum of the second outburst of algal growth, protozoans were not found in the plankton. Up to this moment no special change in the numbers of Mesocyclops was noted. In the same day, when the protozoans were absent, the numbers of Mesocyclops fell from 150 thousand to 18 thousand in lm^3, after which, during the whole summer and autumn, they did not reach such high numbers as before the beginning of the bloom.

Looking at the development of plankton in the R. Shumorovka in different years, one can see that each of them had its own peculiarities. In 1954, with the high summer temperatures, low water level, and a large supply of nutrient substances (NH_4 - 0.65, Fe - 0.70, Si 2.0, P - 0.025 mg/l) the development of plankton proceeded especially rapidly so that it became apparent not only in its numbers but also in the variety of specific composition of massive-forms. The biomass of zooplankton reached a maximum in the period of bloom in July, when it amounted to about 8g in 1 m^3.

There was quite a different picture of the development of plankton in 1956. With the large water-content of the year, the low summer temperatures, and the lower, by comparison with 1954, content of nutrient substances in July (NH_4 - 0.33, Fe - 0.14, Si - 0.7, P - 0.0075 mg/l), the plankton was weakly developed. The blue-green algae after the first outburst, which took place at the end of June, did not reach great numbers, and in the middle of July were met only singly. Diatom algae at this time were absent. As the investigations of S.I. Kuznetsov (1954) show, phytoplankton appears to be the fundamental source of nutrient substances for bacteria in the reservoir. In accordance with this, growth of algae in the R. Shumorovka being very weak in July 1956, there was no bacterial outburst for the space of the greater part of July, and development of bacteria was retarded (the time of one generation was about 48 hours). The biomass of zooplankton on account of this had a very low index.

Triennial observations tell us that in the River Shumorovka the water blooms must be accounted a factor favouring production of zooplankton (fig. l). Thus, in the year 1954 in the period of most intensive summer bloom, with the average number of cells about 67 thousand in lm^3* the mean biomass of zooplankton reached 4.6 g/m^3 . In 1955, with average numbers of blue-greens - about 17,000 in 1 cm^3 - the biomass of zooplankton was 3 times less and equalled 1.54 g/m^3. In 1956, when average numbers of cells of blue greens in the stated period comprised about 4,000 the mean biomass of zooplankton was 1.19 g/m^3.

* This appears to be a misprint and should read "67,000 in 1 cm^3"

While attaching fundamental importance to the provision of bacterial food and the time of the bloom, we do not deny the food significance of the algae themselves at this moment, when they are found in a disintegrating state. The possibility cannot be excluded of pernicious action on the zooplankton of the products of disintegration of blue-green algae. However, in the observations on the R. Shumorovka we did not observe a mass death of zooplankton in the days of sharp reduction of quantity of algae. We also did not establish the toxic influence of blue-green algae on zooplankton. All these questions are subject to further study.

Recognizing the enormous importance of bacteria in the growth of zooplankton during blooming, one must consider extremely important in the study of this phenomenon the answer to the question on the inter-relationship between blue-green algae and bacteria. A.S. Razumov (1948) recognizes that blue-green algae secrete toxic substances which act perniciously on bacteria. But there are data witnessing to the possibility of food competition between blue-green algae and bacteria. So notes Pennak (1946), American scientists support the concept of Pearsall (1932), which considers that blue-green algae develop in massive quantities only in the presence of adequate provision of organic substances. K.A. Guseva (1912) showed experimentally that in combined cultures blue-green algae more actively utilised food substances than bacteria.

Proceeding from these data and having available materials on the plankton from a series of reservoirs, we surmise that in reservoirs with different/providing of food substances, ratios of intensity of growth of blue-green algae and bacteria can be different, and consequently the bloom can affect the growth of the zooplankton unequally.

The River Shumorovka is adequately provided with nitrogenous compounds and other nutrient substances in view of the situation of its drainage basin among cultivated fields. Judging from the mean data, the period of greatest intensity of production of zooplankton in the River Shumorovka coincides with the period of maximum bloom, and as a rule takes place in July. The same coincidence of the period of maximum production of zoo- and phytoplankton is observed in the Volga reach of the Rybinsk reservoir, with noticeable flow, and Lake Il'men. As we have observed, in two small eutrophic lakes - Zaozer and Kolomensk - and in the lake-like slow-flowing central reach of the Rybinsk reservoir, during the summer bloom a decline is observed in the development of the zooplankton, and the curve of the dynamics of its biomass has a two-peak character (Manuilova, 1957). Thus it can be seen that the development of blue-green algae appears as an important factor, determining not only the intensity but also the direction of the process of production of zooplankton. Further investigations of this problem will provide an important link in solving the problems of the biological productivity of reservoirs.

Notice

Please note that these translations were produced to assist the scientific staff of the FBA (Freshwater Biological Association) in their research. These translations were done by scientific staff with relevant language skills and not by professional translators.