Effect of organic and inorganic fertilizers on development of the bacterioplankton in rearing ponds. (paper no. 20 in "Problems of pond pisciculture")

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Proceedings of the All-Union Scientific-Research Institute of Pond Fisheries.
THE EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON
THE DEVELOPMENT OF BACTERIOPLANKTON IN REARING PONDS†

E.Ya. Ivlieva

At the present time the important rôle of microorganisms in the
production processes taking place in water reservoirs is generally
recognized. The works of many investigators (Yu.S. Belyatskaya, 1958;
Kuznetsov, 1954; Yu.I. Sorokin, 1955a, 1955b, and others) have shown that
microorganisms constitute one of the most important trophic resources,
ensuring the development of planktonic and benthic feed animals for fish.

* The pagination of the text is thus indicated. Translator.
† In the Summary, the title includes the additional phrase:
"... during first and second years of running." Translator.
# Natural, unless otherwise indicated. Translator.
One of the most important tasks in the problem of raising the natural fish-productivity of water reservoirs is the ability to control the microbiological processes taking place in ponds.

The most widespread method of regulating the activity of the aquatic microflora is the fertilization of ponds.

The dependence of the bacteria content of ponds on the type of pond, on the intensity and method of fertilization, and on the nutrition of fish with artificial foods for various stocking densities, has been poorly studied.

Before us stood the task of elucidating the basic functional relationships in the development of microflora and the pace of microbiological processes in new ponds when inorganic, organic and combined fertilizers are put into them, for different densities of stocking with fry.

Observations were made in 1963-1964 at newly constructed ponds of the "Yakot" rybplemkhoz (Fish-breeding farm) in a team with other investigators. The dammed ponds are of the spawning type, have an area of about 0.05 hectares each, and had the upper layer of earth removed during construction. In the first year of exploitation (1963), the ponds were strongly filtered.

Liquid compost was used as the organic fertilizer, while ammonium nitrate and superphosphate served as inorganic fertilizers.

\[1 \text{ hectare} = 100 \text{ ares} = 100 \times (10 \text{ metres} \times 10 \text{ metres}) = 10^4 \text{ m}^2;\]
\[= 100 \text{ metres} \times 100 \text{ metres} = 10^{-1} \text{ km} \times 10^{-1} \text{ km} = 10^{-2} \text{ km}^2;\]
\[= 2.47106 \text{ acres}.\]
In order to determine the efficiency of liquid composts, we used composts prepared from various organic substances, namely: green vegetation, cattle manure, and bird droppings (Iylieva, 1965). The composts were used separately, and also in combination with inorganic fertilizers for various nitrogen doses (1 milligramme N/litre and 5 milligrammes N/litre) and for a constant dose of phosphorus (0.1 milligrammes P<sub>2</sub>O<sub>5</sub>/litre, vide the table).

In 1963, the experiments were done in triplicate (each variant in three parallel ponds); and in 1964, in duplicate.

In 1963, a datum density was adopted for stocking all (sic) ponds with fry, but in one pond there was a triple density and one pond was left unstocked. The ponds filled during the interval from the 15th to the 18th of July, and were immediately stocked with fish. In connection with the strong filtration, water had to be added to them every 3-5 days.

Inorganic fertilizers were put into the ponds every 3-4 days starting on the 15th of July. Organic fertilizers (liquid composts) were put in every 3 days, starting on the 5th of August.

In 1964, the fry-stocking density was taken as 5-fold and 10-fold with respect to the datum density. The ponds were stocked with fish during the period 25-30 July. During the second year, the ponds were filtered considerably less.

The introduction of inorganic fertilizers (ammonium nitrate and superphosphate) was begun on the 16th of June. The fertilizers were put in daily for the first five days, and then twice a week. The organic fertilizers (liquid composts) were put in three times a week, starting on the 22nd of June. The ponds were fertilized until the 18th of September.

† On the basis of other evidence it is clear that однократная плотность in a fish-stocking context has a known and recognized numerical value in the Soviet Union, although this value is not explicit in the present text nor is it known to the translator. # = one-fold density.  

Translator.
Work on the study of the microflora of the pond water was done in parallel with the study of the microbiological processes in the composts during their maturation. The composts were put into cement basins located on the dams near the experimental ponds.

In each pond, test-samples of bacterioplankton were taken from six points with a sterile glass tube 11 millimetres in diameter. The tube was slowly lowered into the water perpendicularly to its surface. Thus, the tube cut out a column of water from the surface to the bottom. The water from the tube was transferred to sterile flasks with ground stoppers. Test samples were always taken prior to the introduction of fertilizers, and always at the same time (8 o'clock in the morning). In the laboratory, seedings were made from the test samples onto various nutritive media, and preparations were then prepared for a direct microscopic count of bacteria by the method of A.S. Razumova. Membrane filters N° 2 were used for this purpose, and twenty fields of view were counted in each preparation. In order to count the saprophytic bacteria growing on PNA (=RPA) (fish-peptonic agar), seedings were made from various cultures of the initial test-sample of water or compost. The dishes were incubated at a temperature of 22-23°C. A count of colonies was done after two days, and was done a second time ten days after seeding.

Concurrently with the determination of the total number of bacteria in the pond water, nitrifying microorganisms were determined on a liquid Vinogradskii medium; denitrifying ones, on an agarized Gil'tait medium; nitrogen-fixing microorganisms: Azotobacter, on an agarized Ashby medium; and the anaerobic nitrogen fixer (Clostridium pasteurianum), on a liquid Vinogradskii medium.

† Spelling conjectural. Translator.
THE DEVELOPMENT OF BACTERIOPLANKTON
AFTER THE PONDS WERE FILLED WITH WATER

The ponds were filled with water from a head pond having a total bacteria count of 2.5 million specimens per millilitre of water.

The dynamics of the numerical strength of the bacterioplankton in the ponds (1963-1964) as a function of the fertilizer doses and of the feeding of the fry with artificial foods are given in figures 1 and 2. From the graphs it is evident that during the period when the ponds were being filled the numerical strength of bacteria per millilitre of water was fairly high (in 1963, 6.5 million specimens; and in 1964, 3-5 (million?) specimens), which could have been the result of turbidity (muddying), especially in 1963. In that year, in connection with the precipitation of suspended particles, the quantity of bacteria diminished after a few days. Upon filling those same ponds for the second year of exploitation, an increase in the numerical strength of bacteria occurred, apparently due to substances entering the water from the silt which had accumulated during the predominantly vegetative period. Then, proportionately as the nutritive substances were expended, a diminution in the quantity of bacteria took place.

The total bacteria count after the precipitation of suspended particles in the control ponds (1963) was 2 million specimens/millilitre, and it remained almost without change during the entire vegetative period. The paucity of bacterioplankton in the control ponds, especially in the first year, was caused by the removal of the upper layer of soil when the ponds were constructed. Actually, according to the data of A.V. Aleksandriiskaya¹, the soil of the ponds was very poor in organic matter and biogenic elements.

¹ Published in the present symposium. (Author)
The phytoplankton in the ponds also developed very poorly; the water of the control ponds was always transparent.

Subsequently, the development of bacteria in the ponds, both in 1963 and in 1964, proceeded as a function of the conditions created in them under the action of various doses and types of fertilizer, and also as a function of the density of stocking with fry.

THE EFFECT OF ORGANIC FERTILIZERS ON THE DEVELOPMENT OF BACTERIOPLANKTON

In 1963, during the first half of August, the introduction into the ponds of liquid compost from cow manure was begun. An increase in the total quantity of bacteria was observed during this period. On the 15th of August, in the ponds where compost was used, the bacteria count was 5.5 million specimens/millilitre of water, whereas in the control ponds it was 2.5 million specimens/millilitre (*vide* Figure 1). Subsequently, the numerical strength of bacteria in the ponds fertilized by compost stayed at a considerably higher level than in the control ponds.

In 1964, in search for a more effective organic fertilizer, liquid compost obtained from bird droppings was tried. From the viewpoint of the dynamics of bacterioplankton, it turned out to be less effective.

When liquid composts are used, the development of bacteria in the ponds depends on the temperature of the water and on the quality of the compost. Under favourable temperature conditions, the decomposition of organic substances proceeds more rapidly, and a peak-like, single-summit curve is obtained (1963). With low temperatures, the organic substances decay at a slower rate, and the curve is more even (first half of the summer of 1964).
THE EFFECT OF STOCKING-DENSITY AND FEEDING OF FISH ON THE NUMERICAL STRENGTH OF BACTERIOPLANKTON

It is interesting to trace the dependence of the numerical strength of bacterioplankton on the stocking density of fish. In 1963, in the variant with the use of liquid compost only (vide Figure 3), the pond where there was two-fold stocking of fish was distinguished by a rich bacterioplankton. The quantity of bacteria in it was twice as great as in the parallel pond with one-fold stocking, and three times as great as in the pond where there were no fish. The same picture was observed in the case of mineral (inorganic) fertilizers only being used (vide Figure 4): in the pond with three-fold stocking of fish, there were 9 million specimens/ml of bacteria. In 1964 (vide Figure 2), there were very many more microorganisms for ten-fold stocking density than for five-fold.

Our biennial observations confirm the views of S.I. Kuznetsov (1954), who attributes great importance to that part of the dissolved substances in the water which (part) constitutes the products of lifetime excretions of the macro- and micro-population.

Our observations showed that in ponds where carp fry of the current year were fed with artificial foods, the quantity of bacteria in the water was, on the average, 2-2.5 times greater than in those ponds in which artificial food was not given.

Prior to the feeding of the current-year fry, the quantity of bacteria in the water was low, and was equal to the control in numerical strength (vide figures 1 and 2). In proportion to the accumulation of residues of artificial foods and fish faeces (feeding was begun on the 5th of August in 1963 and on the 15th of July in 1964), the quantity of
microorganisms began to increase sharply, and on the 3rd of August, 1964, it reached 10 million specimens/millilitre of water. Apparently, when fish are fed with artificial foods, a considerable proportion of these foods dissolves in the water prior to being eaten by the fish. The remainder of these foods "diffuses" along the bottom and throughout the water of the pond in the process of nourishing the fish (Lobacheva, 1959; Erokhina, 1961; Mukhina, 1963; Bakhtina, 1965). Evidently this contributes to the high indices of bacterioplankton numerical strength in ponds where feeding of fish is done. The obtained data on the numerical strength of bacteria in ponds with artificial feeding of fish coincide with the observation made at the ponds of the selective-breeding fish-farm "Isobelino" in 1956 (Lyakhnovich, 1962).

THE EFFECT OF INORGANIC FERTILIZERS

Besides the action of organic substances, one may trace the effect of inorganic fertilizers on the development of bacterioplankton.

In 1963, in ponds where only mineral (inorganic) fertilizers were used (vide Figure 1), with a one-fold stocking of carp fry, a bacteria count of as high as 8 million specimens/millimetre was obtained, whereas in the control ponds it was 2.5 million specimens/millimetre.

In 1964, inorganic fertilizers were introduced commencing 15 June, and their action could be judged until liquid composes began to be introduced. On the 22nd of June, 7 days after the introduction of inorganic fertilizers, an increase was detected in the numerical strength of bacteria in the ponds with 5 milligrammes N/litre by 5.5 million cells/millilitre of water (from their initial number), and in ponds with a 1 milligramme/litre N dose, by 3.5 million, whereas in the control ponds, only by 0.5 million. Thus, the
numerical strength of the bacterioplankton was found to be directly proportional to the dose of nitrogenous fertilizers. As inorganic fertilizers were introduced into the ponds, the number of bacteria began to increase with diverse intensity.

The intensive development of bacterioplankton when inorganic fertilizers were introduced into the ponds may be attributed to the utilization by the bacteria of the organic substance created by the phytoplankton, which is more numerous in fertilized ponds. Apparently, indirect assimilation of biogenic elements by bacteria also plays an essential rôle.

Zhadin, Rodina and Troshin (1957), in their experiments on the study of the utilization of mineral compounds by bacteria and by phytoplankton, thanks to the use of radioactive phosphorus $^{32}\text{P}$, which was introduced into the pond water, came to the conclusion that the utilization of mineral compounds by bacteria and by phytoplankton takes place almost to the same degree.

Thus, in fertilized ponds, the numerical strength of bacterioplankton increases several fold, which corresponds with the data obtained by many authors (Rodina, 1957, 1957a; Golovacheva, 1952; Kuznetsov, 1954; Belyatskaya, 1958; and others).

THE EFFECT OF COMPOSITE FERTILIZERS

Especially intensive development of bacterioplankton was observed when organic and inorganic fertilizers were combined. In 1963, considerably higher peaks of bacteria numerical strength were characteristic of ponds with composite fertilizer than of ponds with purely inorganic or
purely organic fertilizers (11-13 million specimens/millilitre, vide Figure 1). In the variant with 5 mg/litre + compost, even the minimal content of bacteria in the water was expressed in figures of the same order as the mean numerical strength in ponds with some single fertilizer.

In 1964, in ponds (vide Figure 2) with pure organic fertilizer (bird compost), the numerical strength of bacteria rose very slowly. Only toward the beginning of September did it reach 6 million specimens/ml, and the maximum (7 million specimens/millilitre) was observed at the end of the season, i.e. on the 18th of September. The ponds of this variant were distinguished by massive development of green, filamentous algae and by comparatively poor fish growth.

Composite fertilizers secured, in this series of experiments, a sharply delineated peak in the numerical strength of bacterioplankton at the beginning of August (up to 13-15.5 million specimens/millilitre).

A.G. Rodina (1949, 1950), Ts.I. Ioffe et al. (1955) regard the development of bacteria which mineralize albumen (saprophytes) concomitantly with the introduction of fertilizers as a positive phenomenon, indicating the great effectiveness of these fertilizers, as saprophytes are extremely valuable microorganisms where feeding is concerned, and are utilized best of all by bacteriophagous planktonal animals.

The data obtained on saprophytic microorganisms are given in Figure 5. As may be seen from the figure, the development of saprophytic bacteria in the ponds basically follows the same regularities as the dynamics of the total number of bacteria reckoned by direct count.

In the experiments of 1963, in the variants with natural conditions,
and also in the ponds which were fertilized by compost only or by compost with a small dose of nitrogen (1 mg N/litre), the peak of the numerical strength of the saprophytes was comparatively low (3000 specimens/ml on the 15th of August). In ponds with feeding, and also in variants with a high nitrogen dose (5 milligrammes/litre) and with the same dose of compost, the development of saprophytes continued and the maximum was observed on the 29th of August. Saprophytes developed especially intensively in the variant with composite fertilizer and mineral (inorganic) fertilizer (5 mg N/litre) (about 8000 specimens/millilitre).

A similar phenomenon was observed in 1964. The maximum numerical strength of saprophytes was noted in variants with dense stocking of fish and composite fertilizers (3000 specimens/millilitre).

In the variant with compost on a background of a high nitrogen dose, it was 3500 specimens/millilitre. On a background of low nitrogen dose, compost, especially bird compost, turned out to be less effective. There were few saprophytes in the variant with only compost from bird droppings (0.6 thousand specimens/millilitre), which may be explained by the intensive development of filamentous algae in these ponds.

Not once in the course of two vegetative periods was the aerobic nitrogen fixer Azotobacter found in the water of the experimental ponds. Apparently, in the new ponds there was not a favourable environment for its development. The anaerobic nitrogen fixer Clostridium pasteurianum was encountered in all test-samples in the amount of 1-10 cells/millilitre at the beginning of the season, to 100-1000 cells/ml at the end of the season.

According to our data, the process of nitrification in the water

† *Sic!* If composite, why inorganic as well? Translator.
of the ponds was either absent or was observed to a very slight degree. The number of cells of nitrifying microorganisms in 1 millilitre of water was from 1 to 10 at the beginning of the experiment, and up to 100 in the ponds where organic fertilizers were used and there was a high stocking density of carp fry.

The process of denitrification was absent, as no denitrifying bacteria were found. Apparently, denitrifiers do not find conditions for their development in new ponds, where "matured" silt has not accumulated and where the water is saturated with oxygen to a high degree.

The mean annual numerical strength of microorganisms and of the various physiological groups in the experimental ponds is given in the table.

As is evident from the data in the table, the total numerical strength of bacteria turned out to be minimal in the control ponds without fertilizer or feeding, and was considerably greater with a five-fold stocking of fish than with one-fold (datum) stocking. The same behaviour was observed in other variants of the experiments as well (with feeding, with fertilization by composts, and with the use of inorganic fertilizers only). Introduction into the ponds of compost from cow manure led to a noticeable increase in the numerical strength of bacterioplankton. Compost from bird manure was, apparently, less effective. With five-fold stocking, it yielded the same values as were observed when compost from cow manure was introduced with one or two-fold stocking of fish. Introduction of compost on a background of inorganic fertilizers with a low dose of nitrogen (1 milligramme/litre) secured a considerable increase in the quantity of bacterioplankton in comparison with the ponds which were fertilized only by
composts. In this variant, the compost from bird droppings also turned out to be less effective than the compost from cow manure. A greater increase in the numerical strength of bacteria was observed when the nitrogen content of the pond water was brought up to 5 milligrammes/litre, in conjunction with compost. In the ponds with inorganic fertilizers only, a high dose (5 milligrammes/litre) of nitrogen also secured a considerable numerical strength of bacterioplankton. The maximum number of bacteria was found when composite fertilizer was combined with feeding of fish at a five-fold or ten-fold stocking of fry.

The mean annual numerical strength of saprophytes in general obeyed the same laws of behaviour as the total number of bacteria. However, the difference between variants in several cases was indistinctly manifested. Increase in the density of stocking of fish in 1964, and the accumulation in the ponds of organic material, did not entail a significant increase in the numerical strength of saprophytes, as might have been expected. Compost from bird droppings stimulated their development considerably more weakly than compost from cow manure. It was established by us (Ivlieva, 1965), that when introducing compost from bird droppings, the maximum numerical strength of bacteria, and, in particular, of saprophytes, is observed during the first days after introduction, and it then diminishes sharply. It is possible that in the described experiments, the favourable dates for introducing compost from bird droppings were missed. Thus, it may be considered that compost from bird droppings is less effective than compost from cow manure. Probably, compost from bird droppings should be introduced more often. Moreover, it is necessary to increase the dose and to use it at an earlier date after introduction. An especially high numerical strength of

* Sic! Translator.
saprophytes was observed in ponds with a high dose of nitrogen (5 mg/litre) and with composite fertilizer in 1963.

The numerical strength of nitrogen fixers and of the anaerobic nitrogen fixer (Clostridium pasteurianum) was especially intimately related to the accumulation of organic substance in the water, associated both with the introduction of fertilizers and with the denser stocking and feeding of fish. According to these indices, compost from bird droppings turned out to be even more effective than compost from cow manure.

**CONCLUSIONS**

1. The total number of bacteria in the control ponds of the first year of exploitation constituted 2.6 million specimens/ml, and did not undergo any essential change during the first vegetative period.

2. The total number of bacteria in the control ponds of the second year of exploitation was somewhat greater (3.4 million specimens/ml).

3. The introduction of liquid composts into the ponds evokes a noticeable increase in the numerical strength of the bacterioplankton (up to 6 million cells/millilitre).

4. With an increase in the stocking density of fish under the same conditions, the total number of bacteria rises substantially.

5. In ponds where artificial feeding of fish is done, the numerical strength of the bacterioplankton is 2-2.5 times higher than in ponds without feeding.
6. The introduction of inorganic fertilizers into the ponds also stimulates the development of bacterioplankton in general and of saprophytes in particular. With increase in the nitrogen dose, the numerical strength of the bacteria increases.

7. The same regularities (behaviour) were found in the dynamics of the numerical strength of saprophytic bacteria as in the dynamics of the total number of bacteria in the pond water.

8. Not once, in the water of the experimental ponds of all variants, was the aerobic nitrogen-fixer \textit{(Azotobacter)} found, nor were denitrifiers found, which is connected, apparently, with the absence of silt beds.

9. The numerical strength of the anaerobic nitrogen-fixer \textit{Clostridium pasteurianum} was found to vary directly as the accumulation of organic substances in the ponds.

10. The number of nitrifying bacteria was very small (1-100 cells/ml), and increased ten-fold by the end of the season.
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(Proceedings of the problem-thematical conferences of the Zoological Institute of the Academy of Sciences of the USSR, Issue VII, 1957)

23 Rodina, A. G.

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(The dynamics of the biomass of bacteria and the character of the microbial processes in fish-breeding ponds concomitant with organic and inorganic fertilization)

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24 Rodina, A. G.

Динамика содержания бактерий в воде и грунтах некоторых рыбоводных прудов Латвийской ССР при их удобрении.

(The dynamics of the bacteria content of the water and bottom-soil in certain fish-breeding ponds of the Latvian SSR concomitant with their fertilization)

Рыбное хозяйство внутренних водоемов Латвийской ССР.

(The fisheries of the inland water reservoirs of the Latvian SSR)

АН Латвийской ССР. Т. II, Рига, 1958.

(Academy of Sciences of the Latvian SSR. Volume II, Riga, 1958)

25 Rodina, A. G.

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(Nitrogenous fertilizers of fish-breeding ponds and denitrification)

Рыбное хозяйство внутренних водоемов Латвийской ССР. АН Латвийской ССР. Т. II.

Riga, 1959.

(Fisheries of the inland reservoirs of the Latvian SSR. Academy of Sciences of the Latvian SSR. Volume II, Riga, 1959)
26 Rodina, A. G.

*Mikrobiologiya* udobryaemykh prudov.
(The microbiology of fertilized ponds)

*Rybnoe khozyaistvo* vnutrennikh vodoemov
(Fisheries of the inland water reservoirs of the Latvian SSR, Volume III, Riga, 1959)

27 Sorokin, Yu. I.

*O bakterial'nom khemosinteze v ilovykh otlosheniakh.*
(On bacterial chemosynthesis in silt beds)

(Microbiology, Volume XXIV, Issue 4, 1955)

28 Sorokin, Yu. I.

*Opridendnie velichiny khemosintesa v vode Rybinskogo vodokhranilishcha s primeneniem C14.*
(Determination of the value/magnitude of chemosynthesis in the water of Rybinsk Reservoir by the use of C14)

(Transactions (Doklady) of the Academy of Sciences of the USSR, Volume 105, N. 6, 1955)
The dynamics of the numerical strength of bacterioplankton in the rearing ponds of the first year of exploitation (mean indices by variant):

1. Natural conditions;
2. feeding with artificial foods;
3. fertilization with liquid compost from cow manure;
4. inorganic fertilizer: $5 \text{ mg N / l} + 0.1 \text{ mg P / l}$;
5. composite ones (compost + inorganic fertilizer: $5 \text{ mg N/l} + 0.1 \text{ mg P/l}$);
6. water temperature.

Left-hand ordinate: Million specimens/millilitre.

Right-hand ordinate: Temperature, °C.

Abscissa: Dates (self-explanatory).

Key to symbols: * morning,
# evening.
The dynamics of the numerical strength of the bacterioplankton in the rearing ponds of the second year of exploitation (mean indices by variant):

1. Natural conditions;
2. feeding with artificial foods;
3. fertilization with liquid compost from bird droppings;
4. composite fertilizer & five-fold† stocking with fish;
5. composite fertilizer & ten-fold stocking with fish;
6. water temperature.

Left-hand ordinate: Million specimens/millilitre.

Right-hand ordinate: Temperature, °C.

Abscissa: Dates (self-explanatory).

Key to symbols: * morning, \\# evening.

† vide Footnote† on page 3. Translator.
Figure 3.

The dynamics of the numerical strength of bacterioplankton as a function of the stocking density of carp fry:

1 Pond unstocked with fish;
2 pond with one-fold (datum) stocking with fish;
3 pond with two-fold stocking with fish.

Ordinate: million specimens/millilitre.

Figure 4.

The dynamics of the numerical strength of the bacterioplankton as a function of the stocking density of carp fry:

1. Pond with one-fold (datum) stocking with fish;
2. Pond with three-fold stocking with fish.

Ordinate: Million specimens/millilitre.

Abscissa: Dates (self-explanatory)
The dynamics of the numerical strength of saprophytic bacteria:

1. Natural conditions;
2. the use of liquid compost from cow manure;
3. feeding with artificial foods;
4. mineral (inorganic) fertilizers (5 mg N/l + 0.1 mg P/l);
5. composite fertilizer (5 mg N/l + 0.1 mg P/l + compost from cow manure);
6. composite fertilizer (1 mg N/l + 1.0 mg P/l + compost from cow manure).

**Ordinate:** Thousands of specimens per millilitre.

**Abscissa:** Dates (self-explanatory).
Table.

The mean seasonal numerical strength of bacterioplankton and of individual physiological groups of microorganisms in the experimental ponds:

<table>
<thead>
<tr>
<th>N°</th>
<th>Variants of the experiment:</th>
<th>Year</th>
<th>α</th>
<th>β</th>
<th>γ</th>
<th>δ</th>
<th>ε</th>
<th>ζ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Natural conditions</td>
<td>1963</td>
<td>3</td>
<td>1</td>
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<td>0.2</td>
<td>4.0</td>
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<tr>
<td>2</td>
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<td>1964</td>
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<td>1</td>
<td>3,400</td>
<td>1.0</td>
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<td>6.0</td>
</tr>
<tr>
<td>3</td>
<td>Compost from cow manure</td>
<td>1963</td>
<td>1</td>
<td>0</td>
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<td>0.6</td>
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<td>5.0</td>
</tr>
<tr>
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<td></td>
<td>1963</td>
<td>1</td>
<td>1</td>
<td>4,107</td>
<td>0.9</td>
<td>0.5</td>
<td>7.0</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>1963</td>
<td>1</td>
<td>2</td>
<td>4,776</td>
<td>1.0</td>
<td>0.6</td>
<td>8.0</td>
</tr>
<tr>
<td>6</td>
<td>Compost from bird droppings</td>
<td>1964</td>
<td>2</td>
<td>5</td>
<td>4,600</td>
<td>0.4</td>
<td>2.0</td>
<td>6.0</td>
</tr>
<tr>
<td>7</td>
<td>1 mg/l N + 0.1 mg/l P + cow compost</td>
<td>1963</td>
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<td>1</td>
<td>5,757</td>
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<td>1.0</td>
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<tr>
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<td></td>
<td>1964</td>
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<td>1.2</td>
<td>2.0</td>
<td>50</td>
</tr>
<tr>
<td>9</td>
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<td>2</td>
<td>5</td>
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<td>0.7</td>
<td>17.0</td>
<td>44</td>
</tr>
<tr>
<td>10</td>
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<td>80</td>
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<tr>
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<tr>
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<td>1</td>
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<tr>
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<td>5</td>
<td>7,500</td>
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<td>18.0</td>
<td>171</td>
</tr>
<tr>
<td>14</td>
<td>5 mg/l N + 0.1 mg/l P + bird compost + feeding</td>
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<td>5</td>
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<td>1964</td>
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<td>10</td>
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<td>59.0</td>
<td>173</td>
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<tr>
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<td></td>
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<td>Feeding</td>
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<td>4.0</td>
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<tr>
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<td></td>
<td>1964</td>
<td>2</td>
<td>5</td>
<td>6,400</td>
<td>0.9</td>
<td>2.0</td>
<td>19</td>
</tr>
</tbody>
</table>

Remark: When calculating the mean values, cognizance was not taken of the data of the first observation, which was made prior to fertilizing the ponds. (Author)

α The number of ponds.
β Stocking density, sht. = shtuk (Stk! This means the number of head or specimens, whereas the suffix -fold is implied by the text. Translator)
γ Numerical strength of microorganisms, thousands/millilitre.
δ Saprophytes, thousands/millilitre.
ε Nitrifiers.
ζ Clostridium pasteurianum.
Среднезсезонная численность бактериопланктона и отдельных физиологических групп микроорганизмов в опытных прудах

<table>
<thead>
<tr>
<th>Варианты опыта</th>
<th>Год</th>
<th>Число прудов</th>
<th>Численность микроорганизмов, тыс/м³</th>
<th>Сапрофиты, %</th>
<th>Нитрификаторы</th>
<th>Clostridium pasteurianum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Естественные условия</td>
<td>1963</td>
<td>3</td>
<td>6 200</td>
<td>0,8</td>
<td>0,2</td>
<td>4,0</td>
</tr>
<tr>
<td>То же</td>
<td>1964</td>
<td>2</td>
<td>3 359</td>
<td>0,6</td>
<td>0,3</td>
<td>5,0</td>
</tr>
<tr>
<td>Компост из коровьего навоза</td>
<td>1963</td>
<td>1</td>
<td>4 107</td>
<td>0,9</td>
<td>0,5</td>
<td>7,0</td>
</tr>
<tr>
<td>То же</td>
<td>1963</td>
<td>1</td>
<td>4 776</td>
<td>1,0</td>
<td>0,6</td>
<td>8,0</td>
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<tr>
<td>Компост из птичьего помета</td>
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<td>5 450</td>
<td>0,4</td>
<td>2,0</td>
<td>6,0</td>
</tr>
<tr>
<td>1 мг/л N + 0,1 мг/л P + компост коровьего</td>
<td>1963</td>
<td>3</td>
<td>5 757</td>
<td>1,1</td>
<td>1,0</td>
<td>25</td>
</tr>
<tr>
<td>То же</td>
<td>1964</td>
<td>2</td>
<td>8 700</td>
<td>1,2</td>
<td>2,0</td>
<td>50</td>
</tr>
<tr>
<td>1 мг/л N + 0,1 мг/л P + компост птичьего</td>
<td>1964</td>
<td>2</td>
<td>6 200</td>
<td>0,7</td>
<td>17,0</td>
<td>44</td>
</tr>
<tr>
<td>5 мг/л N + 0,1 мг/л P + компост коровьего</td>
<td>1963</td>
<td>1</td>
<td>4 779</td>
<td>2,7</td>
<td>1,0</td>
<td>80</td>
</tr>
<tr>
<td>То же</td>
<td>1964</td>
<td>3</td>
<td>7 776</td>
<td>3,1</td>
<td>1,6</td>
<td>90</td>
</tr>
<tr>
<td>5 мг/л N + 0,1 мг/л P + компост птичьего</td>
<td>1963</td>
<td>3</td>
<td>6 733</td>
<td>3,4</td>
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<td>120</td>
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<tr>
<td>То же</td>
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<td>2</td>
<td>7 500</td>
<td>11,5</td>
<td>18,0</td>
<td>171</td>
</tr>
<tr>
<td>5 мг/л N + 0,1 мг/л P + компост птичьего + кормление</td>
<td>1964</td>
<td>2</td>
<td>10 200</td>
<td>1,8</td>
<td>58,0</td>
<td>173</td>
</tr>
<tr>
<td>То же</td>
<td>1964</td>
<td>2</td>
<td>11 000</td>
<td>2,3</td>
<td>59,0</td>
<td>173</td>
</tr>
<tr>
<td>Кормление</td>
<td>1963</td>
<td>3</td>
<td>4 379</td>
<td>2,3</td>
<td>0,3</td>
<td>4,0</td>
</tr>
<tr>
<td>То же</td>
<td>1964</td>
<td>2</td>
<td>6 400</td>
<td>0,9</td>
<td>2,0</td>
<td>19</td>
</tr>
</tbody>
</table>

Примечание. При вычислении средних величин не принимались во внимание данные первого наблюдения, проведенного до начала удобрения прудов.
SUMMARY

Effect of organic and inorganic manures on development of the bacterioplankton in rearing ponds during first and second years of running

In 1963–64 the dynamics of the bacterioplankton and some physiological groups were being studied in new ponds in relation to doses and complex fertilizers. Stocking rates of carp fry and artificial feed. 15 series of experiments were carried out in 36 ponds. Liquid composts made of cow dung and poultry manure (1 l per 100 m² of water surface every two days) were used as an organic manure, and ammonium nitrate and superphosphate as inorganic fertilizers (1 mg N/l + 0.1 mg P/l + and 5 mg N/l + 0.1 mg P/l/ every 3 or 4 days).

It was found that the total amount of bacteria in unfertilized ponds without feeding during the first year of running was 2.6 million per ml and 3.4 million during the second year of running.

Due to introduction of the liquid composts into the ponds the amount of bacteria increased to 6 million per ml. With an increase of stocking rate the total amount of microorganisms significantly increased. In the pond with artificial feeding the amount of bacteria was 2 or 2.5 times higher than in the ponds without feeding. Mineral fertilization also stimulated development of bacterioplankton. With an increase of nitrogen dose from 1 mg/l to 5 mg/l the amount of bacteria increased. At complex fertilization the total amount of bacteria was more than at utilization of only inorganic or organic fertilizers.

The dynamics of saprophytic bacteria is similar to the general dynamics in pond water. Aerobic nitrogen fixing bacteria (Osotobacter) and denitrification bacteria were never observed in experimental ponds of all series. Apparently it is connected with the lack of silt deposits.

Anaerobic nitrogen fixing bacteria Clostridium pasteurianum was found in all samples in amount of from 1 to 10 kl/ml at the beginning of the season and up to 100–1000 kl/ml at the end. Its amount was in direct relation to accumulation of the organic matter in the ponds.

The amount of the nitrifying bacteria was not great (1–100 kl/ml). It increased tenfold towards the end of the season.

Note: The abbreviation kl which appears in the penultimate and final paragraphs presumably stands for the Russian word kletka, meaning "cell".

Translator