Primary production of Lake Baikal and its significance for the biolimnological processes in the lake

by K. K. Votintsev

Original title: Pervichnaya produktsiya Baikala i ee znachenie v biolimnicheskikh protsessakh v ozere

From: Izvestiya akademii nauk SSSR Seriya biologicheskaya (Academy of Sciences USSR News Biological series), (6) : 892-900, 1971

Translated by the Translation Bureau(TS)
Foreign Languages Division
Department of the Secretary of State of Canada

Department of the Environment  
Fisheries Research Board of Canada  
Great Lakes Biolimnology Laboratory  
Burlington, Ont.  
1973

18 pages typescript
PRIMARY PRODUCTION OF LAKE BAIKAL AND ITS SIGNIFICANCE FOR THE BIOLIMNOLOGICAL PROCESSES IN THE LAKE

K. K. VOTINTSEV
TRANSLATED FROM — TRADUCTION DE
Russian

INTO — EN
English

AUTHOR — AUTEUR
K. K. Votintsev

TITLE IN ENGLISH — TITRE ANGLAIS
PRIMARY PRODUCTION OF LAKE BAikal AND ITS SIGNIFICANCE FOR THE BIOLIMNO-
LOGICAL PROCESSES IN THE LAKE.

TITLE IN FOREIGN LANGUAGE (TRANSLITERATE FOREIGN CHARACTERS)
TITRE EN LANGUE ÉTRANGÈRE (TRANSCRIRE EN CARACTÈRES ROMAINS)
PERVICHNAYA PRODUKTSIYA BAikalA I EE ZNACHENIE V BIOLIMNICHESKIH
PROTSESSAKH V OZERE.

REFERENCE IN FOREIGN LANGUAGE (NAME OF BOOK OR PUBLICATION) IN FULL,
TRANSLITERATE FOREIGN CHARACTERS.
RÉFÉRENCE EN LANGUE ÉTRANGÈRE (NOM DU LIVRE OU PUBLICATION), AU COMPLET,
TRANSCRIRE EN CARACTÈRES ROMAINS.
Izvestiya akademii nauk SSSR
Seriya biologicheskaya

REFERENCE IN ENGLISH — RÉFÉRENCE EN ANGLAIS
Academy of Sciences USSR News
Biological series

PUBLISHER — ÉDITEUR
Akademiya Nauk SSSR

DATE OF PUBLICATION
DATE DE PUBLICATION

PLACE OF PUBLICATION
LIEU DE PUBLICATION
Leningrad, USSR

YEAR
VOLUME
ISSUE NO.
1971
-
6

NUMBER OF TYPED PAGES
DACTYLOGRAPHIÉES
18

REQUESTING DEPARTMENT
MINISTÈRE-CLIENT
Environment

TRANSLATION BUREAU NO.
NOTRE DOSSIER NO.
141276

BRANCH OR DIVISION
DIRECTION OU DIVISION
Eng., Sc. & Tech. Serv.

PERSON REQUESTING
DEMANDÉ PAR
M. Munawar

YOUR NUMBER
VOTRE Dossier NO

DATE OF REQUEST
DATE DE LA DEMANDE
September 26, 1972

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISEE
Information seulement

PRIMARY PRODUCTION OF LAKE BAIKAL AND ITS SIGNIFICANCE FOR THE BOLIMNOLOGICAL PROCESSES IN THE LAKE.

By K. K. Votintsev

This paper examines the primary production of Lake Baikal using the results of several years of limnological investigations of the lake carried out from 1964 to 1969. It evaluates the yearly gross production, its distribution over the lake's water area and by seasons. It investigates the correlation between primary production and the phytoplankton biomass and analyses the reasons for the high values of the P/B coefficients.

The ultimate fate of the primary production in the course of its transformation through the food chains of the ecosystem of the lake's pelagic zone is briefly discussed.

Conclusions are also drawn as to the high indices of the primary productivity of Lake Baikal and the high efficiency of its utilization in the food chains of the ecosystem of the lake's pelagic zone.

*Numbers in the right-hand margin indicate the corresponding pages in the original.
One of the most important processes in the total complexity of biological processes is the primary production of organic matter. It is related both to the biotic cycle of the chemical elements in the water reservoir and to the bioenergetic transformation of organic matter.

To date scientists in various countries have done an enormous amount of work in studying the primary production which is generated in the water masses of inland lakes as well as of seas. The results of these studies are found in numerous scientific articles and collections. These were collected in the works of G. G. Vinberg (1960), Strickland (1960), G.G. Vinberg and O.I. Koblenz Mishke (1966), Lund (1964, 1965 and others), Lund and Talling (1957), Talling (1957, 1965 and oth.), Coulter (1963) and others. We do not intend, therefore, to summarize the results of this gigantic work. We should merely say that the chief efforts of these researchers were aimed at examining the quantitative indices and the regional differences of the primary production of water reservoirs.

The prime characteristic of almost all these studies is that they fail to study the real producers of organic matter — the phytoplankton. In most cases these works do not show which type of algae generate primary production, there are no data concerning the total phytoplankton biomass, nor are there comparisons between phytoplankton biomass values and the values of the primary production.

Thus, present studies of this problem are definitely geographically — geochemically oriented and the primary production data obtained, due to their abstract nature, do not answer the question of food supply even of the first heterotrophic link; they do not clarify possible trophic problems and do not permit to prognosticate the harvest of phytoplankton
nor the level of its use by the zooplankton.

In our investigation of the primary production of lake Baikal undertaken in relation to the overall study of its biological productivity we attempted to approach the subject from broader positions based on the general scheme of organic matter cycle in bodies of water (Galazii, Votintsev 1966). The results of these studies carried out by the Limnological Institute, Siberian Department of the Academy of Sciences of the USSR by us or under our direction are briefly outlined below.

* * *

The first set of information on the annual values of the primary production of lake Baikal obtained by Votintsev (1961) and Samarina (1960) in the region of the Bol'shie Koty village (Southern Baikal) was somewhat surprising: the production was high and this did not agree with the well-established notion in scientific circles regarding the ultra-oligotrophic nature of this lake. At the same time, when calculated in relation to a volume unit of lake waters (1 m$^3$) the values of the primary production of lake Baikal, even in the upper water layers where life is more abundant, were very small, rarely reaching $0.05 - 0.07$ mg C/liter of water per day, which is quite in keeping with the lake's ultra-oligotrophic nature.

The investigations of the primary production of lake Baikal which we carried out with A. I. Meshcheryakova and I.V. Glazunov from 1964 to 1969, using the method of synchronous surveys of the entire Baikal area, confirmed the high yearly values of its gross production. In this respect lake Baikal certainly does not occupy the last place among the other major lakes of the world.
Having studied the data on the primary production of lake Baikal and compared them with data from other water reservoirs, G. G. Vinberg (1960) came to the entirely valid conclusion regarding the apparent oligotrophy of this lake and others like it. In such lakes when a very low photosynthesis intensity index is observed, calculated in relation to a volume unit of water mass ($1 \text{ m}^3$), due to the high degree of transparency of the water, photosynthesis reaches considerable depths (60 to 70 meters in lake Baikal in summer - Bochkarev, Votintsev and Yasnitskii, 1950). As a result, the total gross primary production under one square meter of lake surface turns out to be quite considerable. G.G. Vinberg classifies lakes of this type among the secondary or morphometrically oligotrophic.

The secondary oligotrophy of lake Baikal stands out clearly when the values of the primary production in deep-water areas of the lake are compared with the same values in the shallows and in well-protected shallow bays of the lake which are essentially eutrophic and where the water is very transparent (Table 1). Thus the production of phytoplankton in the Maloe More narrows increases from the South to the North during the period of summer vegetation - from the shallow eutrophicated areas to the deep water areas which are typical of lake Baikal. In the Bay of Mukhor (at the southern tip of Maloe More), a shallow water body with depths four to five meters in its outer limits and an average water transparency of 4 meters (measured with the Secchi disk) and which is completely covered in summer with higher aquatic vegetation, the production of phytoplankton during the period of summer vegetation was 36.5 grams C under 1 m$^2$ of lake surface. In the adjoining areas of the southern part of Maloe More
(near the mouth of the Sarma river), where the average transparency of the water was 6.0 to 7.5 m, the primary production was somewhat higher - 54.7 gr C. Finally, in the northern, deepest part of Maloe More, with an average water transparency of 12 meters, the production during the period of vegetation was 76.5 grams C under 1 m² of lake surface.

Identical data were obtained in the region of the Baikal shallows. Thus, in the cross section which extends from the channel of the river Selenga (the main tributary of lake Baikal), from Kharauz to the cape of Krasnyi Yar located on the western shore of the lake, and stretching from the shallows of the river Selenga to the deep-water area of lake Baikal where depths reach 1000 to 1100 meters near the Cape of Krasnyi Yar, the primary production during the period of summer vegetation was very similar at all stations. The transparency of the water, however, changed from 1.5 m near the station situated close to the delta

<table>
<thead>
<tr>
<th>Table 1. Gross primary production in various areas of lake Baikal. (in gr. C under 1 m² of the lake surface during the period of summer vegetation)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Station</strong></td>
</tr>
<tr>
<td>Cross section Kharauz Channel - Cape Krasnyi Yar</td>
</tr>
<tr>
<td>St.1 1.5 km from Kharauz</td>
</tr>
<tr>
<td>St.2 3.0 km from Kharauz</td>
</tr>
<tr>
<td>St.3 Middle of the lake</td>
</tr>
<tr>
<td>St.4 3.0 km from Cape Krasnyi Yar</td>
</tr>
<tr>
<td>Cross section Sukhaya river - Ol'khonskie Vorota</td>
</tr>
<tr>
<td>St.1 0.3 km from the river Sukhaya</td>
</tr>
<tr>
<td>St.3 Middle of the lake</td>
</tr>
<tr>
<td>St.5 3.0 km from Ol'khonskie Vorota</td>
</tr>
<tr>
<td>Male More</td>
</tr>
<tr>
<td>Mukhor Bay, outer part</td>
</tr>
<tr>
<td>At the mouth of the Sarma river 1 km from shore</td>
</tr>
<tr>
<td>At Khubyn Is., 2 km from shore</td>
</tr>
<tr>
<td>At the southern part of Maloe More</td>
</tr>
<tr>
<td>Cape Ota-Khyshun to Cape Budun, middle of the lake 10.5</td>
</tr>
<tr>
<td>Cape Arul - Cape Khoboi, middle of the lake</td>
</tr>
</tbody>
</table>
Average yearly values of the gross primary production in lake Baikal.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern Baikal</td>
<td>175.2</td>
<td>94.3</td>
<td>75.1</td>
<td>127.9</td>
<td>187.4</td>
<td>131.2</td>
</tr>
<tr>
<td>Central Baikal</td>
<td>104.4</td>
<td>113.9</td>
<td>-</td>
<td>155.7</td>
<td>149.5</td>
<td>130.9</td>
</tr>
<tr>
<td>Northern Baikal</td>
<td>142.8</td>
<td>78.9</td>
<td>59.7</td>
<td>180.7</td>
<td>132.9</td>
<td>119.0</td>
</tr>
<tr>
<td>Lake average</td>
<td>140.7</td>
<td>95.7</td>
<td>67.4</td>
<td>154.8</td>
<td>156.6</td>
<td>127.0</td>
</tr>
<tr>
<td>Make More</td>
<td>64.5</td>
<td>81.3</td>
<td>86.1</td>
<td>-</td>
<td>112.5</td>
<td>86.1</td>
</tr>
<tr>
<td>Barguzinskii Zaliv</td>
<td>66.9</td>
<td>86.1</td>
<td>88.5</td>
<td>-</td>
<td>-</td>
<td>80.2</td>
</tr>
<tr>
<td>Chivyrkuiskii Zaliv</td>
<td>95.7</td>
<td>110.1</td>
<td>68.9</td>
<td>-</td>
<td>-</td>
<td>90.9</td>
</tr>
</tbody>
</table>

To 9.0 and even 11.5 near the western shore and in the middle of the lake. It must be noted, that the Selenga shallows are quantitatively much richer in phytoplankton than the adjacent, open deep-water areas of lake Baikal (Votintsev and co-authors, 1963).

Thus, the primary production rate in the open deep-water areas of lake Baikal is no less than that in the shallows which are easily warmed up, or in the highly eutrophic bays of the lake which are isolated from the influence of cold Baikal waters.

The primary production in the open areas of lake Baikal is, on the average, very similar in both its southern and middle troughs. Its mean yearly rate is, approximately, 130 gr C under 1 m² of the lake's surface according to the investigations carried out from 1964 to 1968. Northern Baikal is somewhat less productive: its mean yearly primary production for the same years is approximately 119 gr C (Table 2).

The annual variations in the primary productivity in the open areas of lake Baikal are even more significant (Table 2).

On the average, in the years 1964 - 1968, the yearly values of the primary production of the lake as a whole varied from a low of 67.4 gr C...
under 1 m² of lake surface in 1966 to a high of 156.6 gr C, i.e. it more than doubled.

<table>
<thead>
<tr>
<th>Seasons</th>
<th>1964</th>
<th>1965</th>
<th>1966</th>
<th>1967</th>
<th>1968</th>
<th>Average</th>
<th>Average %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spring</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March - June</td>
<td>69.6</td>
<td>31.2</td>
<td>16.8</td>
<td>63.6</td>
<td>19.6</td>
<td>50.16</td>
<td>40.3</td>
</tr>
<tr>
<td><strong>Summer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July - September</td>
<td>41.4</td>
<td>27.9</td>
<td>28.8</td>
<td>56.7</td>
<td>52.2</td>
<td>41.40</td>
<td>33.4</td>
</tr>
<tr>
<td><strong>Autumn</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>5.7</td>
<td>6.9</td>
<td>-</td>
<td>10.8</td>
<td>12.9</td>
<td>9.1</td>
<td>7.3</td>
</tr>
<tr>
<td><strong>Winter</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>November - February</td>
<td>23.7</td>
<td>23.7</td>
<td>23.7</td>
<td>23.7</td>
<td>23.7</td>
<td>23.7</td>
<td>19.0</td>
</tr>
</tbody>
</table>

The seasonal changes in the primary production values are characterized by minimum daily indices from November to March, a spring maximum from April to May, a July minimum, a second, August maximum and a gradual decrease in the following months.

In the open areas of lake Baikal approximately 40% of the mean yearly gross primary production is produced during the spring period (March - June), 33% in summer (July - September), 7% in October, and 19% in winter (November - February) (Table 3).

When we compare the values of the primary production of lake Baikal with the quantity of phytoplankton, we can easily see the differences between them. I. V. Glazunov and O. M. Kozhova (1966) first attempted to make this comparison in the Selenga region of lake Baikal using observations made during the summer periods of 1962 and 1963. It appeared that in the upper water layer of the lake the relation between the daily primary production rate of phytoplankton and its biomass, expressed in Corg, varies from 14.9 to 81.9 and is 34.5 on the average.
It is easy to calculate that with such a ratio between the phytoplankton production rate and its biomass, each cell would have had to split a minimum of 5 times a day, which is hardly likely, especially if we take into account the low temperature of lake Baikal waters.

Our photosynthesis intensity studies for two common species of Baikal phytoplankton, the Melosira (Melosira baicalensis) and the peridinians (Gymnodinium baicalense), which develop in spring while still under the ice (Votintsev, Popovskaya, 1965; Popovskaya, Votintsev, 1966), have shown that the diurnal primary production of Melosira at 0.1 - 0.6°C water temperature is between 9% and 21% of its original biomass, with average of 13%. For Gymnodinium daily primary production lies between 18 and 120% of the initial biomass and decreases as the concentration of algae in the test tube increases.

Consequently, in spring, when only one species of algae develops in large quantities in the plankton, the diurnal P/B coefficient is usually a mere tenth fraction of the initial biomass of the algae and only in rare instances does it reach 1.0 or slightly more.

The studies of phytoplankton distribution and of the daily primary production rate of the whole lake area conducted in 1964 - 1968 during complex surveys of lake Baikal have shown that, for instance, in the Selenga area of the Kharauz - Krasnyi Yar cross-section the daily P/B coefficient varies between 0.14 to 53.5, with an average of 12.56. In the Maloe More region this coefficient lies between 0.07 and 37.5, with an average of 6.36 (Votintsev and co-authors, 1971).

For the different basins of lake Baikal and for the lake as a whole the daily P/B coefficients in 1964 were as follows (Table 4).
Table 4. Ratios of daily rates of primary production (P) and phytoplankton biomass (B) in lake Baikal in 1964. Mean values for different basins of the lake in the 0 – 25 meter layer.

<table>
<thead>
<tr>
<th>Months</th>
<th>Southern Baikal</th>
<th>Middle Baikal</th>
<th>Northern Baikal</th>
<th>Average for the whole lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1964</td>
<td>0.24</td>
<td>0.48</td>
<td>5.18</td>
<td>0.69</td>
</tr>
<tr>
<td>June</td>
<td>1.11</td>
<td>0.70</td>
<td>3.14</td>
<td>1.36</td>
</tr>
<tr>
<td>July</td>
<td>0.96</td>
<td>3.17</td>
<td>1.34</td>
<td>1.66</td>
</tr>
<tr>
<td>August</td>
<td>44.64</td>
<td>10.95</td>
<td>35.15</td>
<td>20.52</td>
</tr>
<tr>
<td>September</td>
<td>18.24</td>
<td>13.75</td>
<td>19.78</td>
<td>17.57</td>
</tr>
<tr>
<td>October</td>
<td>26.00</td>
<td>10.86</td>
<td>11.60</td>
<td>13.15</td>
</tr>
<tr>
<td>November</td>
<td>0.02</td>
<td>0.00</td>
<td>0.25</td>
<td>0.08</td>
</tr>
<tr>
<td>March 1965</td>
<td>0.27</td>
<td>0.98</td>
<td>0.53</td>
<td>0.50</td>
</tr>
</tbody>
</table>

In spring and at the beginning of summer when the values of phytoplankton biomass are high, the P/B coefficient usually lies between 0.5 and 1.6. In August the picture changes abruptly. While the concentration of phytoplankton is very low, measured in tens of milligrams under 1 m² of lake surface in the 0 – 25 meter layer, the photosynthesis production is quite high – up to 14 to 31 gr in 24 hours under 1 m² and the P/B coefficient, therefore, rises to its maximum – to an average of 20.5 for the lake as a whole.

Thus, our data confirm very high P/B coefficient values in lake Baikal. The indexes observed are not the result of accidental analytical errors, since all primary production experiments were repeated three times and there was a strong similarity among parallel samples. As we saw earlier, they cannot be explained by the rapid division of algae cells.

Researchers (Popovskaya, 1964; Votintsev, Popovskaya, 1965; Votintsev and co-authors 1963) consider that one of the possible reasons for
the discrepancy between the intensity values of phytoplankton photosynthesis and its biomass lies in their not having made enough allowance for some minor algae forms during the processing of phytoplankton samples using the usual method of counting. N.I. Antipova (1965) considers that this could be due in part to the lack of allowance for a *Uroglenopsis* algae and this assumption is presently confirmed by G.I. Popovskaya's research (1968).

G. I. Popovskaya determined that there really exists in lake Baikal a very rich and peculiar world of micro-plankton algae, which she calls "ultranannophytoplankton" whose numbers and biomass can be quite considerable.

The research which we carried out together with A. I. Meshcheriakova in 1968 in the Maloe More area of lake Baikal established that microplankton algae constituted 60 - 70% of the daily gross primary production during the summer period. It was further established that microplankton algae have a P/B coefficient ranging from 0.50 to 2.27, with an average of 1.0.

This research has shown that generally the intensity of microalgae photosynthesis varies concurrently with the variations in the values of their effective production. Nevertheless, it is not possible to establish a direct proportionality between these two values. As a rule, the effective production rate is always many times (up to 10) smaller than the production of micro-algae, calculated using the photosynthesis intensity data measured in vitro (both values were expressed in equivalent indexes).

We can thus conclude that, although micro-algae do play an important role in the total production process of the lake, their active
presence can only partly account for the discrepancy between the phytoplankton biomass and its primary productivity.

No doubt, differences in breathing intensity of algae in the light and in darkness also have an influence on the P/B coefficient values (Brown, Weiss 1959; Hoch, Owens 1963; Voskresenskaya 1965 and others) as does the emission of assimilators by the algae into the environment during their lifetime. Indeed, if a part of the assimilators is secreted by the algae into the environment (Goriunova, 1966), that part of the production expended on them is taken into account during the photosynthesis, but cannot be taken into account in the calculation of the phytoplankton biomass, which is the reason for the higher reading of the P/B coefficient.

The clarification of the quantitative role of all these factors is a task for future research.

Is there a direct proportionality between the photosynthesis rate and the algae biomass?

In an attempt to answer this question we carried out related studies in the spring of 1964 and 1965 during the period of massive vegetation of Melosira and Gymnodinium when these species constituted up to 95 to 98% of the overall phytoplankton biomass. The results we obtained showed that the daily accretion to the Melosira biomass, calculated according to the rate of gross photosynthesis and with the chemical composition of these algae being taken into account, constituted on the average 110% of their effective daily production measured on the basis of the numerical growth of its cells. This ratio was 104% in the case of Gymnodinium. Consequently, the intensity of the photosynthesis is proportionate to the accretion of the total biomass for both these species. We
are puzzled, however, that in both cases the effective daily production rate and the gross photosynthesis production rate should have been so close. This is likely explained by the fact that our research coincided in time with the period of the logarithmic growth of the algae. It may also have been induced by the short duration of our experiments (24 hours) in low temperature conditions during which there is a slowing down of the destruction processes and of the intravital emissions by the algae of part of the assimilators into the environment. These factors probably also account for the low P/B coefficient in lake Baikal during spring, fall and winter periods.

* * *

It seems to us that an answer to the question of the future existence of organic matter produced is the natural outcome of primary production studies in a body of water. It is only through the understanding of the further transformation processes of the organic matter generated by primary production in the food chain of the ecosystem of the water reservoir that we will be able to evaluate correctly in this case its biological usefulness.

It is known that in lake Baikal the predominant part of the useful production is related to the ecosystem of the pelagic zone, since the main commercial animals of this lake, such as the Baikal herring (omul'), the pelagic goby and the seal (Phoca Sibirica) inhabit the thicker water layers of the lake. It is also known, that phytoplankton produces most of the primary production of lake Baikal. The role of bottom algae is secondary. Their gross annual production hardly reaches 25 thousand tons (Votintsev, 1961) which is less than 1% of the
gross primary production of Baikal phytoplankton.

The above mentioned facts show that it is worthwhile to study the bio-energetic transformation of organic matter in the pelagic zone of lake Baikal. The quantitative calculations of these processes have already been published (Votintsev, 1971). We, therefore, do not intend to dwell on them in detail in this paper but will merely outline the most important general conclusions.

Table 5.

Biotic balance of the ecosystem of the pelagic zone of lake Baikal, in large colonies under 1 m² of lake surface per year.

<table>
<thead>
<tr>
<th>Organisms</th>
<th>B</th>
<th>P</th>
<th>P/B</th>
<th>K₂</th>
<th>T</th>
<th>T/B</th>
<th>A</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary production</td>
<td>3.0</td>
<td>874.8</td>
<td>324</td>
<td>0.9</td>
<td>97.2</td>
<td>32.4</td>
<td>972</td>
<td>-</td>
</tr>
<tr>
<td>Bacterioplankton</td>
<td>9.4</td>
<td>314.8</td>
<td>32</td>
<td>0.5</td>
<td>262.5</td>
<td>27.8</td>
<td>601.5</td>
<td>601.5</td>
</tr>
<tr>
<td>Zooplankton</td>
<td>6.0</td>
<td>80.5</td>
<td>13.5</td>
<td>0.24</td>
<td>245.2</td>
<td>40.8</td>
<td>325.7</td>
<td>407</td>
</tr>
<tr>
<td>Epischura filtrator</td>
<td>3.1</td>
<td>4.7</td>
<td>1.5</td>
<td>0.26</td>
<td>13.3</td>
<td>4.3</td>
<td>18.0</td>
<td>22.5</td>
</tr>
<tr>
<td>Predators:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyclops</td>
<td>0.3</td>
<td>3.4</td>
<td>11.3</td>
<td>0.27</td>
<td>9.2</td>
<td>30.6</td>
<td>12.6</td>
<td>15.7</td>
</tr>
<tr>
<td>Macrohectopus</td>
<td>0.3</td>
<td>3.4</td>
<td>11.3</td>
<td>0.27</td>
<td>9.2</td>
<td>30.6</td>
<td>12.6</td>
<td>15.7</td>
</tr>
<tr>
<td>Fishes:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omul' (Baikal herring)</td>
<td>1.9</td>
<td>0.38</td>
<td>0.2</td>
<td>0.33</td>
<td>0.66</td>
<td>0.4</td>
<td>1.14</td>
<td>1.4</td>
</tr>
<tr>
<td>Baikal cod</td>
<td>3.69</td>
<td>2.95</td>
<td>0.8</td>
<td>0.45</td>
<td>3.52</td>
<td>0.9</td>
<td>6.47</td>
<td>8.1</td>
</tr>
<tr>
<td>Pelagic goby</td>
<td>0.23</td>
<td>0.23</td>
<td>1.0</td>
<td>0.21</td>
<td>0.84</td>
<td>3.7</td>
<td>1.07</td>
<td>1.34</td>
</tr>
<tr>
<td>Baikal seal</td>
<td>1.26</td>
<td>0.22</td>
<td>0.18</td>
<td>0.17</td>
<td>1.08</td>
<td>0.8</td>
<td>1.30</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Note:  

- B - biomass; P - production; T - Exchange waste (destruction);  
- A - assimilation; A = T + P; R - ration; A = 0.8R; K₂ = P/A.

An average of 3925 thousand tons C орг of primary production is formed in lake Baikal annually and up to 230 thousand tons C орг of allochthonous matter, mostly of plant origin, are brought in.

In addition to the allochthonous organic matter, Lake Baikal annually receives approximately 20 thousand tons of nitrogen and six thousand tons of phosphorus in the form of their organic compounds which are later broken down in lake Baikal.
In the formation process of primary production of organic matter, the phytoplankton of Baikal uses up 286 thousand tons of mineral nitrogen and 62 thousand tons of mineral phosphorus annually. These quantities represent 13 and 21% respectively of the total content of these elements in lake Baikal waters.

The degree of utilization of solar radiation energy by the Baikal phytoplankton is similar to that of the oceanic plankton. It represents on the average 0.09% of the total solar radiation on the lake's surface.

In the process of bioenergetic transformation of organic matter in the Baikal ecosystem an average of 75% of newly formed organic matter is subjected to destruction annually. The balance together with the oxidation resistant organic matter of allochthonous origin constitutes the so-called "water humus" which is subjected to destruction in the next eight to ten years. Thus, there is no accumulation of organic matter in the waters of lake Baikal. Only a small part of the total quantity of organic matter settles in the benthic deposits of the lake. Up to 60% of its annual quantity undergoes sedimentation and is destroyed. No more than 0.7 - 1.0% of the annual production of organic matter in lake Baikal is buried in the benthic sediments.

Therefore, a moving balance between the produced and consumed organic matter has now been established in lake Baikal.

The transformation of organic matter in the food chain of the ecosystem of lake Baikal is primarily related to a relatively small (in number of species) group of organisms - aborigines of the lake. These are phytoplankton species of the genus *Melosira*, *Cuclotella*, *Syne- dra*, *Cymnodinium*, the phytophagous crustacean *Epischura* (*Epischura baicalensis*),
the planktonic predator *Macrohectopus Branickii* and the Baikal cod (Table 5).

The degree of utilization of organic matter in the trophic chain of the lake — on the average 25 to 30% in each trophic level — points to the stress which exists in the food relationship and the high degree of adaptation to the environment of lake Baikal's endemic forms. This is particularly noticeable if we compare their production with the production of the recent settlers in lake Baikal — *Cyclops Kolensis* and the Baikal herring. Thus the *Epischura* produces 8.2% of the annual primary production of lake Baikal, whereas the *Cyclops kolensis* production is only 0.5 — 0.6%. The Baikal pelagic goby and the Baikal cod utilize 0.3% of the annual primary production to produce their biomass, whereas the Baikal herring uses only 0.04%.

As was mentioned before, up to 75% of the primary production of organic matter in lake Baikal is subjected to destruction in the course of one year. Bacterial processes play here a very important role. The study of the energy flow in the trophic chain of lake Baikal's pelagic zone shows that in the course of a year approximately 60% of the primary production is subjected to destruction in the form of dead phytoplankton, dead bodies of heterotrophic organisms and the lifetime emissions of the organic world of lake Baikal.

As is well known, the active life of micro-organisms is not only associated with the destructive processes of various organic residues, processes during which a re-generation of biogenic elements takes place until they become mineral compounds used up by plant organisms. The life of microorganisms also involves the production of live protein of microbic bodies used as food by heterotrophic organisms. The food value of
the detritus becomes clear as a medium for the intensive activity of microorganisms and also of their intensive evolution. During periods of low phytoplankton quantities and biomass in lake Baikal, the existence of zooplankton organisms is possible because of the availability of this organic matter of microbial bodies. This also explains the discrepancy between the phyto- and zooplankton biomass observed in lake Baikal during certain periods, i.e. the luxuriant development of zooplankton when phytoplankton biomass indexes are low.

As a summary we can affirm that the main roles in the biome of the pelagic zone of lake Baikal are played by the trophic links and the relationships which have developed during the long evolution history of this lake and of its organic world. The latter leads us to believe that the presently planned regeneration of the ichthyofauna of lake Baikal through the acclimatization of new commercially viable forms of life is not really practical, as it will not bear tangible results in the short term (tens of years and even centuries). This is well illustrated by the history of adaptation of the Baikal herring in the lake. In spite of the long period of time elapsed since its introduction in Lake Baikal (in the postglacial period - approximately 15-20 thousand years ago), the part played by the Baikal herring in the total fish productivity of the lake even during years of its high abundance has never exceeded 18 to 20% of the total production of pelagic fish.

LITERATURE


Limnological Institute, Academy of Sciences, USSR.
K. K. Votintsev

PRIMARY PRODUCTION OF LAKE BAIKAL AND ITS SIGNIFICANCE FOR THE BIONEOMOLOGICAL PROCESSES IN THE LAKE.

Lamnological Institute, Academy of Sciences, USSR.

The primary production of the Lake Baikal is considered in the present paper on the basis of year long limnological investigations of the lake carried out during the years 1964 - 1969. The year gross production, its distribution over the lake's water area and seasonal influences were evaluated. The correlation values of the primary production and the phytoplankton biomass are elucidated and the causes of high values of P/B coefficients are investigated.

The ultimate fate of the primary production in the course of its transformation through the chains of the ecosystem of the lake's pelagic zone is briefly discussed.

Conclusions are drawn as to the high indices of the primary productivity of lake Baikal and high efficiency of its utilization in the food chains of the ecosystem of the lake's pelagic zone.