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EFFECT OF HYDROLOGICAL FACTORS ON THE GROWTH OF BOTTOM FAUNA

PAPERS OF THE KARELIAN BRANCH OF THE STATE RESEARCH INSTITUTE OF LACUSTRINE AND RIVERINE FISHERIES

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BY

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At the present time more than one hundred lakes, including all lymnological types, have been investigated in Karelia. As a result of comprehensive and complex investigations involving a considerable number of these lakes, a great deal of interesting data relating to the biology and hydrological properties of these bodies of water was gathered.

The problem of increasing the productivity of fisheries of these lakes confronts the investigators pursuing different tasks with the necessity of bringing to light, and providing the explanation of, the phenomena and processes occurring in each individual body of water; as well as the need to determine the interrelationships existing between the hydrological and biological factors, and the necessity of discovering optimal conditions for the growth of individual groups of aquatic organisms.

Among the many factors influencing the development of lacustrine fauna, an essential role is played by the influent and effluent systems of a particular lake the waters of which are in motion. This, in its turn determines the degree of influence exerted by the area of the catchment basin the end point of which is an individual lake. Most of the large and medium sized lakes of Karelia are fed by rivers, i.e. their waters are in motion.

The area of catchment basin and its physical and geographic features determine the level of water in lakes; its size determines the inflow and outflow of suspended and dissolved mineral and organic substances in an individual lake, and also determines to some extent the thermal properties of a lake. Many investigators: Kozhin (1930), Pravdin (1962), Gerd (1939), and others attached great importance to the influence exerted by the area of a catchment basin on the biology and water regimen of an individual lake, yet they did not work out any parameters expressing such an effect. In the course of the past few years particular attention was paid to this problem in the investigations of S.V. Grigor'ev (1958, 1959, 1965). This author has suggested, as suitable parameters, two quantitative indices: 1. the size of a specific catchment basin (ΔF), expressing the ratio of the total area of the catchment basin to the surface area of the corresponding lake; and 2. the conditional change of water (α wat), representing the ratio of the average inflow into a lake to its volume.

Whereas the first index reflects the effect of the size of the catchment basin as a complex geographic factor, the second index determines the degree of development of autochthonous processes in a lake.

In the present article we make an attempt to analyse the changes affecting the quantitative indices of benthic biomass as influenced by the degree of motion of water in lakes of different types. In order to avoid unduly complicating this investigation in its initial stages, we are going to confine ourselves to determining the benthic biomass as a whole, without differentiating it in accordance with its species components. There remain those aspects which up to now we have not touched upon: peculiarities of development of the benthic fauna as affected by the genetical type of a lake, its hydro-chemical properties, etc. All these complex problems cannot be dealt with within the framework of a fairly short article.

The data about the lakes of Southern Karelia - mainly the drainage basins of the rivers Shuya, Suna and Vodla where investigations were conducted over a period of many years - formed the basis of the article presented here. /90

The lakes of Karelia are noted for the low productivity of their fisheries; most of the investigators explain this fact by the existing unfavourable physico-geographic conditions. Among the latter the following may be mentioned: 1. a low mineralization of their waters; 2. small amounts of biogenic salts; 3. considerable humification of their waters; 4. insufficient penetration of heat in deep lakes; and 5. the presence of fish with a slow rate of development and growth ("Lakes of Karelia"). The average weight of the benthic biomass in Karelian lakes has been estimated to be equal to 11 kgs. per 1 hectare (Alexandrov, 1951); yet, the range of fluctuations (of such biomass) is fairly wide, from .7 (Lake Sandal) to 261.6 kg. per hectare (Lake Volnenyarvi). The lakes with the high benthic biomass are encountered mainly in the regions beyond the river Onega and lower reaches of the rivers Suna and Shuya; this is largely due to the existence of more favourable physico-geographic conditions: a wide distribution of basic rocks (shungites, diabases, dolomitized limestone, etc.), the presence of less podzolized soils, and a small area of marshland in their respective catchment basins.

It is more difficult to furnish on explanation of the wide fluctuations of the growth of benthic biomass in the lakes of the same geological and soil type or of those connected by a single channel. In this connexion it was of sufficient interest to analyze the influence, if any, exerted by the rate of motion of the water flowing through a particular body of water (as a hydrological factor) on the growth of benthic fauna, and to find out whether there exists any causal interrelationship between these two factors.

To attain this aim, we investigated those lakes differing in the abundance of their benthic biomass as influenced by the following hydrographic and hydrometerological conditions:

1. The lakes located close to each other and situated in the areas with similar geological and soil types; this approach enabled us to exclude the effect of dissimilar hydrochemical properties;

2. The lakes connected by a single channel but differing in the $\triangle$ F index (specific catchment index) and the α wat index (conditional change of waters index);

3. The lakes which had lateral connecting channels; and

4. The lakes for which a number of determinations of their biomass was available over a period of many years.

A comparison of the data relating to the benthic biomass of the lakes with catchment basin characteristics similar in respect of their physico-geographic conditions, showed that the highest indices of benthic biomass were found to exist in these lakes with a relatively low flow of water running through them; i.e. those lakes which possessed fairly low $\triangle$ F and α wat indices.

Quite characteristic in this respect are Lake Kroshnozero and Lake Shotozero belonging in the drainage basin of the river Shuya. The waters of these lakes are very similar in their hydro-chemical characteristics: their bicarbonate content fluctuates within 10 - 15 mg. per litre, and their potassium permanganate oxidability fluctuates within 9 - 15 mg. of O_2 (oxygen) per litre (Kharkevich, 1959). Lake Kroshnozero is a eutrophic

TABLE I

HYDROLOGICAL AND BIOLOGICAL FEATURES OF LAKES IN SOUTHERN KARELIA

Lake	Basin District	Surface Area in sq. km.	ΔF	α of waters	Depth in Meters Maximum	Average	* $\alpha = \frac{Hcp}{\sqrt[3]{F}}$	Type according to depth	Year of Investigation	The Biomass in kg. per hectare
				Lakes with high biomass of benthos						
Putkozero	Transonega	21.1	7.5	.19	43.0	19.5	5.0	Deep	1947	169
Kzoshnozero	Shuya	8.9	21.0	1.1	12.6	5.7	2.7	Normal Depth	1953	144
Peldozhskoye	do	5.7	26.0	1.5	9.0	6.0	3.3	do	1949	119
Shan'guima	do	2.0	-	-	5.6	3.2	2.5	do	1953	99
Yokhtozero	do	3.2	7.5	.6	10.0	4.1	2.8	do	do	106
Chogozero	do	1.4	-	-	10.5	4.1	3.6	do	do	67
Vatchel'skoye	Suna	29.6	5.3	.2	4.5	3.5	1.0	Shallow	1950	65
Chuzhmozero	Transonega	5.6	-	-	30.0	8.1	4.6	Deep	1947	60-170
Gakhkozero	do	4.8	-	-	15.0	7.1	4.2	do	1948	40-160
Sviatozero	Shuya	9.9	3.3	.13	17.2	7.0	3.5	Normal depth	1956	59
				Lakes with low biomass of benthos						
Salonyarvi	Shuya	46.0	56.0	4.4	14.5	3.1	1.1	Shallow	1948	1.6
Suoyarvi	do	58.0	33.0	2.5	24.0	3.5	1.2	do	do	5.3
Shotozero	do	74.0	75.0	7.4	10.1	3.1	.7	do	1955	3.3
Vagatozero	do	24.0	304.0	6.4	4.0	1.4	.5	do	do	11.5

* This column refers to Ivanov's (1948) coefficient of depth - the way it is expressed here is the way it is written in Russian - i.e. the letters have not been transliterated.
Ed.

body of water with a high benthic biomass (169 kgs. per hectare), while Lake Shotozero has a very low benthic biomass (7.4 kgs. per hectare). No less different are their hydrological indices. The figure expressing the Δ F index of Lake Shotoozero is three times higher than that corresponding to Lake Kroshnozero; and the α wat index of the former is seven times higher than that of the latter (Table 1).

According to the classification suggested by P.V. Ivanov (1948), Lake Kroshnozero belongs, as indicated by its calculated coefficient of depth (α), to bodies of water of normal depth (α = 2.7), and Lake Shotozero (α = .7) is shallow, i.e. the thermal conditions favour efficient heating up of benthic layers of water in the latter lake as compared with the former lake.

We investigated, in the basin of the river Suna, Lake Vatchel'skoye and Lake Sundozero. Lake Vatchel'skoye is a shallow body of water with a weak motion and flow of water and has a low α wat index (.2) and a small Δ F index (5.3); yet, its benthic biomass is 65 kgs. per hectare. Lake Sundozero belongs to the group of lakes with normal /92
depth (α = 2.4), has a strong flow of moving water, but its benthic biomass is only 4 kgs. per hectare; at the same time, its Δ F index is 25 times greater and its α wat index is 20 times higher than that of L. Vatchel'skoye.

A comparison of the biological indices of the above two lakes indicates that:
1. the motion and flow of water through a lake is apparently not only a factor which exerts a considerable influence on the growth of benthic animal organisms but 2. it also draws our attention to the fact that in making use of comparative method in biological studies (of the lakes) it is not enough to take into account only just a few peculiarities of the morphological structure of a depression housing those lakes.

In the examples described above, in the first case, a deep lake with a small volume of water flowing through it had higher indices for its benthic biomass, while, in the second case, low indices were possessed by a lake of normal depth with a small volume of water flowing through it.

In this respect the results of comparison of the hydrological features of lakes which have a high and low benthic biomass become fairly convincing. Our selection of such lakes was based on the data furnished in the reference volume entitled "Lakes of Karelia" (Table 1). The lakes with a slow motion of water (α wat does not exceed 1.5) are included in a group with a comparatively highly developed benthic fauna; these are mainly deep lakes with a normal depth. Among the lakes with a low benthic biomass are encountered bodies of water of different types: deep, shallow and those of normal depth; but all of them have high $\triangle$ F and α wat indices and also have a strong current of water flowing through them.

On analysing the hydrobiological data in respect of lakes connected by a short channel, we selected those bodies of water in which the relevant information was obtained during the same season of the same year, so as to exclude the possible effect of different hydro-meteorological conditions. To our regret, we were able to match only three pairs of such lakes, for in lakes of that type such investigations were conducted in an overwhelming number of cases during different years.

In Table 2 are shown the data in respect of 6 lakes (drainage basins of the rivers Shuya and Kem'), furnishing evidence of perceptible differences in the quantitative indices of their benthic biomass; at the same time, all such indices were found to be higher in those lakes having a low α wat coefficient. In Table 2 those lakes with a higher value of α wat are shown under No.1.

TABLE 2

THE VOLUME OF THE BIOMASS OF THE BENTHOS OF RUNNING WATER LAKES AS INFLUENCED BY THE VOLUME OF RELATIVE WATER EXCHANGE

#	Lake	River Running Through Lake	α Waters	Biomass in kgs per hectare	Year of Investigation	Source of Information
1	Salonyarvi	Shuya	4.4	1.6	1948	Gordeev,
2	Suoyarvi	do	2.5	5.3	-	1958
1	Kroshnozero	Mikkelitsa	1.1	143.9	1953	Sokolova,
2	Mikkel'skoye	do	7.1	30.0	-	1956
1	Kuito Sredneye	Kem'	1.1	1.1	1932	Slobodchikov,
2	Kuito Nizhneye	do	2.6	.07	-	Shaposhnikova, 1933

Таблица 2

Величина биомассы бентоса проточных озер в зависимости от величины условного водообмена

№	Озеро	Протекает река	$\alpha_{вод}$	Биомасса, *кг/га*	Год исследования	Источник сведений
1	Салонъярви	Шуя	4,4	1,6	1948	Гордеев,
2	Суоярви		2,5	5,3		1958
1	Крошнозеро	Микκелица	1,1	143,9	1953	Соколова,
2	Миккельское		7,1	30,0		1956
1	Куйто Среднее	Кемь	1,1	1,1	1932	Слободчиков, Шапошникова, 1933
2	Куйто Нижнее		2,6	0,7		

allochthonous processes will predominate in such lakes.

Up to the present time no clear understanding existed of the dynamics of the processes of water exchange in lakes of different types; it is for this reason that S.V. Grigor'ev (1959) stressed the conditionality of the idea conveyed by the coefficient α wat. While calculating the value of α wat it is permissible to assume that the entire water volume of a lake (with current flowing through it) participates in the general water exchange. Yet, when a lake is broken up into many pools, when its coast line is greatly indented and islands are present, not all the parts of such a lake - depending on the type of current flowing through it - will participate in the general water exchange with the same degree of activity.

In a lake the distribution of benthic biomass is not uniform. Depending on the morphology of the depression housing the lake, the character of the ground and soil, and /94 some other factors, the benthic biomass may fluctuate within wide limits. It is for this reason that considerable importance should be attached to the quantitative determination of the biomass of benthic animal organisms in different areas of lakes with current flowing through them. Let us first consider the case of distribution of the benthic fauna in lakes with the transverse-lateral direction of current flow; in such lakes individual areas are outside the main stream of water flow and, therefore, participate only sluggishly in the general water exchange. Among the lakes with this type of current flow, we have hydro-biological data on the following: Lake Gimol'skoye, Lake Kudamgubskoye (basin of the river Suna) and Lake Vodlozero (basin of the river Vodla).

Investigations of greater detail were carried out at Lake Gimol'skoye in 1948 and 1949. This is a shallow lake with a surface area of 80 sq. km.; it has a lacustrine riverine type of water exchange (α wat = 3.2; Δ F= 33), the river Suna flowing through it.

TABLE 3

QUANTITY OF BIOMASS OF THE BENTHOS OF DIFFERENT AREAS OF LAKE GIMOL'SKOYE IN KG PER HECTARE

Year of Investigation	Northern Pool *	Central Pool	Southern Pool	Average for the Lake
1948	39.01	6.15	18.73	18.3
1949	14.14	6.36	6.71	8.4

(* Pool = basin)

Таблица 3

Величина биомассы бентоса различных участков оз. Гимольского, *кг/га*

Год исследований	Северное плесо	Центральное плесо	Южное плесо	Средняя по озеру
1948	39,01	6,15	18,73	18,3
1949	14,14	6,36	6,71	8,4

Suna's waters rise from Lake Roiknavolotskoye with which Lake Gimol'skoye is connected by a short sound (channel?), the Sarbisalmi; reaching Lake Gimel'skoye, the river stream travels to central and southern pools of the same lake. As a result of the transverse - lateral flow of the river stream, the northern pool of Lake Gimel'skoye is outside the sphere of influence of Suna's waters, particularly so in the absence of mixing caused by the wind.

In Table 3 are given the data on the quantity of benthic biomass of different pools of Lake Gimel'skoye. Information obtained in the course of hydrobiological investigations extending over a period of two years furnishes evidence that its northern pool, where water exchange is at its lowest, has the highest benthic biomass.

A similar picture was observed in 1949 at Lake Kudamgubskoye situated lower than Lake Gumel'skoye, along the course of the river Suna, the waters of which pass in a mighty stream into the southern pool of the former lake. Because the water exchange between the northern and southern pools of that lake is impeded by a group of islands therefore the influence exerted by surface waters on the northern pool is virtually nil.

Less characteristic is the growth of benthos in Lake Vodlozero, where investigations were carried out by the Karelian branch of GosNIORKH (Gordeeva-Pertseva, 1964). The lake has three clearly defined pools: northern, middle and southern. The main tributaries empty into its northern and middle pools. Two rivers issue from the lake : the river Sukhaya Bodla and the river Vama. The southern pool of the lake has no large tributaries and its exchange of waters with the other pools is relatively low, but this pool is the richest in its benthic biomass (46.2 kgs. per hectare). In Table 4 is shown the distribution of benthic biomass in the three main pools of Lake Vodlozero.

TABLE 4

DISTRIBUTION OF THE BIOMASS OF BENTHOS IN DIFFERENT POOLS* OF LAKE VODLOZERO (GORDEEVA-PERTSEVA, 1964) IN KGS PER HECTARE

Northern Pool	Middle Pool	Southern Pool	Average for the Lake
26.0	18.0	46.2	26.1

*(Pool = basin)

Таблица 4

Распределение биомассы бентоса в плесах оз. Водлозера, *кг/га*
(Гордеева-Перцева, 1964)

Северное	Среднее	Южное	Среднее по озеру
26,0	18,0	46,2	26,1

As has been pointed out by L.I. Gordeeva-Pertseva, the least amount of biomass (less than 5 kgs. per hectare) is found in the river estuaries and areas of active water exchange.

The index of conditional water exchange (α wat) calculated on the basis of the average yearly inflow, makes it possible to evaluate, though very approximately, the effect of the volume of water in the catchment area. The value of α wat will then undergo changes in accordance with the degree of humidification of the surface of the catchment area (Grigor'ev, 1959).

/95

In Karelia fluctuations of the drainage occur within wide limits. The longest period of observation (extending over fifty years) on the drainage among the rivers of Karelia is available for the river Suna; its basin is typical in its many features, and the data on its drainage are sufficiently representative for tracing the character of changes affecting the humidification patterns of the territory of Karelia over a period of many years.

During that period the modulus coefficient of drainage of the river Suna fluctuated between .58 and 1.90. According to the data of Petrozavodsk hydrological-meteorological observatory, the following years (placed in order in accordance with a decrease in the figure representing the average yearly outflow) should be regarded as the most abundant in water: 1962, 1923, 1957, and 1935; and the years with the least abundance of water: 1947, 1960, 1959, 1935, 1946 and 1948 (the years placed in order in accordance with an increase in the figure representing the average yearly outflow).

It would be natural to expect that a significant decrease in the autochthonous state of a lake will occur when the figure representing the outflow increases, while the role of allochthonous processes will undergo an increase at the same time.

TABLE 5

FLUCTUATIONS OF THE BIOMASS OF THE BENTHOS OF SIAMOZERSK GROUP OF LAKES DURING YEARS OF DIFFERENT LEVELS (TABLE) OF WATER (SOKOLOVA, 1962; SOKOLOVA, FILIMONOVA, 1962)

	Characteristics of the year		Biomass in kgs per hectare						
			Siamozero	Kroshnozero			Mikkel'skoye	Imat	Pavshol'skoye
Year	Thermal	Abundance level of water	Yearly Average	Spring	Summer	Fall	Fall	Summer	Summer
1932	Average	reduced outflow	31.2*	-	-	-	-	-	-
1946	Warm	low water level	-	-	156.7**	-	-	-	-
1948	do	do	-	-	210 ***	-	-	-	-
1952	Average	abundant water flow	-	-	-	-	35	-	-
1953	do	Average	-	172.9	65	70	-	-	-
1954	do	do	28.2	-	-	-	30	-	-
1955	do	abundant in the spring low in the summer-fall	31.3	-	-	-	-	-	-
1956	do	average	47.9	-	-	-	-	43.5	16.1
1959	Warm	low	67.1	-	-	-	-	-	-
1960	do	do	69.4	94.6	58.7	25.2	-	-	-
1961	do	high	17.1	27.2	-	-	-	-	-
1962	Cold	high	-	-	16.3	10.2	8.1	19.6	14.3

Remarks:

* B.Ya. Slobodchikov and G. Kh. Shaposhnikova (1933)

** M.B. Zborovskaya (1948)

*** B.M. Alexandrov (1951)

A comparison of hydro-biological data of a number of lakes during the years of variable abundance of water showed that fluctuations of the volume of drainage in the drainage basin may exert influence upon the growth of benthic animal organisms. A limited amount of information on the benthos during the years with extreme fluctuations of humidification in drainage basins does not permit us to make a more definite evaluation of this correlation.

For the analysis of the hydro-biological data, we made use of the information gathered by the Siamozersk expedition. These data amassed during investigations extending over a period of many years are unique for Karelia. In Table 5 are given figures representing the abundance of benthic biomass for different lakes, as well as the general characteristics of hydro-meteorological conditions obtaining during each year. The thermal regimen was evaluated by determining the average monthly temperature of the air during the warm period of the year; and the yearly abundance of water (or otherwise) was determined by ascertaining the figures representing the average yearly and the maximum outflow of water.

A comparison of the weight of benthic biomass during the years with variable abundance of water for the lakes of Siamozersk group indicates the existence of a tendency toward a decrease in the quantity of benthic biomass during the years with an abundant flow of waters.

The least favourable hydro-meteorological conditions affecting the growth of benthic fauna are those during the years in which low temperatures are combined with an abundance of waters during the warm season of the year. For the moment it is still very difficult to ascertain which of these factors exerts the main influence on benthic fauna, owing to the paucity of the available data. Yet, investigations carried out by the Siamozersk group lead one to the idea that, under conditions obtaining in Karelia, the possible dominant factor in individual years can be ascribed to the factor of drainage. Let us discuss this in detail.

There exists, in respect of Lake Siamozero and Lake Kroshnozero, a very great amount of data gathered over a period of many years and dealing with the detemination of benthic fauna of these lakes. Of particular interest are those data relating to the second lake, enabling us to trace the seasonal progress of the growth of benthic fauna (Table 5).

The highest average annual benthic biomass (67-69 kgs. per hectare) was found in Lake Siamozero during warm years of low waters, and the lowest (altogether 17 kgs. per hectare) during a warm year with an abundant flow of waters. The hydro-biological data in respect of Lake Kroshnozero indicate that there is a characteristic seasonal fluctuation in the quantity of benthic biomass; its quantitative indices undergo a decrease in all seasons during those years with a high degree of humidification in the catchment basin. /97

As has been indicated above, in Lake Gimel'skoye a collection of hydro-biological samples was carried out during 1948 and 1949. It will be seen from Table 3 that the average benthic biomass of the whole lake and that of the individuals pools was lower in 1949 in comparison with 1948. An analysis of the hydro-meteorological conditions obtaining during those years showed that the volume of drainage of the river Suna in 1949 was 40 per cent higher than it was in 1948. The latter year was warm and had a low water volume.

Summing up, we may arrive at the following preliminary conclusions.

1. Parallel with an increase in the velocity and volume of water passing through a lake, its capacity to accumulate autochthonous substances decreases.

2. When attempting an evaluation of the trophic potential of a lake, on the basis of a preliminary reconnoitring investigation, it is also necessary to take into account the hydro-meteorological conditions of that particular year.

In conclusion we may say that as a result of the gradual accumulation of relevant data furnished by complex investigations it would become possible:

1. To ascertain the validity and veracity of the facts described above; and

2. To establish the existence of some more definite correlations between the hydrological factor and the growth of biological processes in bodies of fresh water.

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GLOSSARY

Trudy	Papers
Sev. NIIGiMa	Northern Research Institute of Hydrography and Meteorology
Ac.Sc.USSR	Academy of Sciences of the USSR
GosNIORKH	State Research Institute of Lacustrine and Riverine Fisheries