Journal of the Minnesota Academy of Science

Volume 8 | Number 1 Article 5

4-1940

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yield may be increased by fertilizing the lake, or the population density may be controlled so that the growth rate is more rapid. If the fish populations can be maintained at a proper balance, both in reference to population density and to age class distribution, the outlook for future fishing will be very bright.

EXPERIMENTAL SIMULATION OF WINTER ANAEROBIOSIS

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ABSTRACT

Typical lake bottom ooze was studied under anaerobic winter conditions at 0°, 5° and 10° C. for 120 days, with respect to survival of the constituent organisms and CO_2 production. More CO_2 was produced at 0° than at 5°, suggesting the presence of "cold-loving" anaerobic bacteria. Three dipterous larvae (*Chironomus plumosus, Chironomus decorus, Palpomyia sp.*) and an oligochaete (*Tubifex*) were able to endure 120 days of anaerobiosis in mixed populations. Temperature had a marked effect on survival. The data seemed to indicate that none of the organisms studied would be able to survive anaerobiosis indefinitely, with the possible exception of certain cryptomonad flagellates.

REGIONAL PLANKTON STUDIES IN MINNESOTA

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The magnitude of plankton produced in Minnesota and the great variety of conditions under which this plankton develops suggest many intriguing limnological problems. This present study is concerned with the distribution of planktonic species in several limnological regions of Minnesota. It has considered three distinct lake regions which may be termed the Superior region, the Chippewa region and the Prairie region.

All lakes selected for study from the Superior region are located in Cook County. They tend to be deep cold lakes ranging in depth from fifty to two hundred feet and may be considered as oligotrophic. Since the prevailing surface formations of the area are the Superior red drift and the exposed graywackes and gabbros, the basins of all except one are in bed rock. The lakes studied in the Chippewa region range in depth from thirty to ninety feet and are

warmer than those of the Superior. Their basins are in the middle Wisconsin red drift overlain by late Wisconsin grey drift and may be considered as eutrophic. All of these lakes lie within Itasca County in the Chippewa National Forest. The lakes of the Prairie region are scattered throughout the southwestern part of the state. Their basins are with one exception in the late Wisconsin grey drift and are extremely shallow ranging from ten to sixty feet in maximum depth. Their heat budgets are greater than any of the others studied.

The chemical nature of the water in the lakes showed definite regional variations. Average values of the nine lakes studied in the Superior region, of nine in the Chippewa region and of ten in the Prairie region are as follows:

Region	Superior	Chippewa	Prairie
Total hardness	15	132	131
H ion concentration	7.1	8.1	8.5
Dissolved solids	48 ppm.	174 ppm.	534 ppm.
Sulfates as SO_4	3.4 ppm.	8.2 ppm.	97.4 ppm.

In hardness the values of the Chippewa and Prairie lakes are very similar but their average values are both nine times greater than that of the Superior lakes. The hydrogen-ion concentration readings show greater differences between the regions and these differences are yet more striking in the values for the total dissolved solids.

Means have also been established for the total plankton populations which further reflect regional variation. The phytoplankton population expressed in terms of the mean number of individuals in one hundred litres of lake water for the nine Superior lakes, the nine Chippewa lakes and the ten Prairie lakes are 219,000, 672,000, and 3,196,000, respectively. Corresponding values for the zooplankton are 40,000, 435,000, and 15,000. The quantity of the phytoplankton is well correlated with the dissolved substances in the lakes but that of the zooplankton is not. This discrepancy in the number of zooplankters supports the contention of various workers that dissolved substances and phytoplankton are more interdependent than are phytoplankton and zooplankton. It may also mean that the zooplankters are more sensitive to chemical conditions and thrive best in an intermediate situation such as the lakes of the Chippewa region. Unfortunately the figures presented here do not include the nannoplankton which may be food for certain zooplankters.

All samples used in this study were collected during the last week of July, throughout August, or in the first week of September. The Superior collections were made in 1935, the Chippewa collections in 1936 and the Prairie collections in 1938. Attention is called to this discrepancy in the times of sampling. The identifications and

countings were not undertaken until 1939. The samples were secured in number twenty-five bolting silk conical nets and the individuals were enumerated in a Sedgewick-Rafter cell. The plants and animals were considered separately throughout. When the number of individuals of all the phytoplankton per one hundred liters of lake water had been determined this value was taken as the total plankton value or one hundred per cent. Then the percentage of each species of the phytoplankton in that total was computed. It was thus possible to determine a mean value for these percentages of each species within each region. This same procedure was followed for the several species of the zooplankton. In all, thirty-eight zooplankton species and one hundred and two phytoplankton species were found.

Table I presents the distribution of the more important phytoplankters encountered. In the first three columns headed "Frequencies" are the number of occurrences of each species in each region out of the possible maximum. In the second set of three columns are the mean percentage values for each region. Thus *Chroococcus minutus* was found in five of the nine Superior lakes studied, in four of the nine Chippewa lakes and in six of the ten Prairie lakes. In the Superior it had a percentage value of 1.2, in the Chippewa of .6 and in the Prairie lakes of 1.1. These two sets of values indicate both the constancy of appearance of a species and the density of its occurrence. The percentage values are good indices of relative importance within regions but it must be remembered that the actual average number of individuals in the Prairie is fifteen times the average value of the Superior and five times the same value of the Chippewa.

The species of phytoplankton have been divided into three major groups; those occurring in all three regions, those found in two regions and those in only one. Of the eighteen species in three regions eight have been selected as representative. Of the twenty-eight appearing in two regions twelve have been presented and of the fifty-six species found in only one region sixteen have been listed.

From this table it is apparent that certain species were cosmopolitan but others apparently had definite preferences in their distribution. Section A under division II contains species from both the Superior and Chippewa while section B contains those from the Chippewa and Prairie. Also six species were found which appeared in the Superior and Prairie, that is, with a split distribution. However the smallness of their values was such as to indicate that perhaps they had been overlooked in the Chippewa lakes.

The same grouping is employed in division III to show that certain species were definitely restricted to lakes of one region. Species such as *Staurastrum cingulum* with a frequency of five and a percentage value of .7 were definitely considered as regional endemics. The genera also showed some interesting distributions. The cosmo-

TABLE I. DISTRIBUTION OF PHYTOPLANKTERS

	Frequencies			Percentages		
	S	C	P	S	C	P
I. Species occurring in three regions—						
Chroococcus minutus (Kuetz.) Naeg....	5	4	6	1.2	.6	1.1
Chroococcus dispersus (Keiss) Lemm...	6	3	6	2.9	1.2	1.3
Aphanocapsa delicatissima G.S. West...	4	3	7	1.1	.9	4.9
Microcystis aeruginosa Kuetz.....	3	9	10	1.1	5.2	12.2
Coelosphaerium Naegelianum Unger....	5	9	5	12.1	11.7	5.4
Staurastrum leptocladium Nordst.....	7	3	4	1.2	1.5	.3
Staurastrum paradoxum Meyen.....	5	5	3	1.2	1.5	.6
Ceratium hirundinella (O.F.M.) Schrank	7	9	8	1.4	18.9	10.8
II. Species occurring in two regions—						
A. in the Superior and Chippewa—						
Coelosphaerium Kuetzingianum Naeg...	1	1	..	3.0	.1	....
Dinobryon divergens Imhof.....	1	1	..	1.5	.1	....
Eudorina elegans Ehr.....	3	3	..	.1	.4	....
Staurastrum pentacerum (Wolle) Smith.	3	1	..	.7	1.2	....
Xanthidium subhastiferum W.West....	4	1	..	.2	1.9	....
B. in the Chippewa and Prairie—						
Aphanothece stagnina (Spren.) A.Br....	..	5	1	....	.3	.0
Gomphosphaeria aponina Kuetz.....	..	4	6	....	.5	1.2
Phormidium mucicola Naum. & H.Pest.	..	1	6	....	.1	3.4
Lyngbya limnetica Lemm.....	..	2	4	....	1.7	9.3
Lyngbya Birgei G. M. Smith.....	..	7	6	....	5.4	2.3
Anabaena spiroides v. crassa Lemm.....	..	5	2	....	.8	.6
Pediastrum simplex Meyen.....	..	5	7	....	.2	.7
III. Species occurring in one region—						
A. in the Superior—						
Chroococcus turgidus Naeg.....	2	..	..	.1	....	....
Anabaena baltica Schmidt.....	2	..	..	.1	....	....
Synura uvella Ehr.....	2	..	..	9.2	....	....
Quadrigula lacustris (Chod.) Smith.....	2	..	..	.5	....	....
Arthrodesmus triangularis Lag.....	2	..	..	.4	....	....
B. in the Chippewa—						
Merismopedia glauca (Ehr.) Naeg.....	..	2	..	....	.0	....
Lyngbya major Menegh.....	..	1	..	....	.2	....
Ulothrix subconstricta G.S. West.....	..	1	..	....	2.9	....
Staurastrum cingulum (West) Smith.....	..	5	..	....	.7	....
C. in the Prairie—						
Lyngbya contorta Lemm.....	..	..	1	....	....	.0
Coelastrum microporum Naeg.....	..	..	2	....	....	.5
Oocystis crassa Wittr.....	..	..	3	....	....	.6
Oocystis parva W.&G.S. West.....	..	..	2	....	....	.1
Actinastrum gracillimum G.M. Smith....	..	..	3	....	....	.3
Staurastrum Chaetocerus (Schr.) Smith.	..	..	2	....	....	.3
Peridinium cinctum Mueller.....	..	..	2	....	....	.3

politan genera encountered were *Chroococcus, Aphanocapsa, Aphanothece, Microcystis, Gomphosphaeria, Anabaena, Coelosphaerium, Pediastrum, Tetraedron, Coelastrum,* and *Staurastrum. Dinobryon* and *Xanthidium* were found in Superior and Chippewa lakes while *Lyngbya, Scenedesmus* and *Closterium* were present in the Chippewa and Prairie lakes. *Arthrodesmus* was peculiar to the Superior and *Oocystis* occurred only in the Prairie.

TABLE II. DISTRIBUTION OF ZOOPLANKTERS

	Frequencies			Percentages		
	S	C	P	S	C	P
I. Species occurring in three regions—						
Difflugia lobostoma Leidy	4	4	7	7.3	9.1	26.0
Rattulus cylindricus Imhof	6	7	3	2.7	6.3	.2
Polyarthra platyptera Ehr	6	8	6	2.7	8.9	1.9
Keratella cochlearis Gosse	8	8	9	16.0	30.4	23.5
Notholca longispina Kellicott	7	1	1	4.0	.5	.0
Daphnia longispina O.F.M.	5	6	9	1.0	10.1	6.4
Ceriodaphnia lacustris Birge	1	1	3	.2	.2	.4
Bosmina longispina Lydig	6	5	1	2.3	4.3	.1
Chydorus sphaericus O.F.M.	4	4	4	2.1	1.3	1.9
II. Species occurring in two regions—						
A. in the Superior and Chippewa—						
Pedalion mirum Hudson	1	1	--	.1	.1	----
B. in the Chippewa and Prairie—						
Codonella cratera (Leidy) Vorce	--	1	6	----	.8	.9
Filinia longiseta (Ehr.) Harring	--	1	4	----	.4	2.2
III. Species occurring in one region—						
A. in the Superior—						
Difflugia urceolata Carter	3	--	--	2.3	----	----
Brachionus urceus L.	2	--	--	1.2	----	----
Sida crystallina O.F.M.	6	--	--	5.0	----	----
Diaptomus minutus Lilljeborg	7	--	--	17.8	----	----
Cyclops leuckarti Claus	7	--	--	10.2	----	----
B. in the Chippewa—						
Diaptomus oregonensis Lilljeborg	--	5	--	----	2.4	----
Cyclops bicuspidatus Claus	--	9	--	----	18.9	----
C. in the Prairie—						
Epistylus flavicans Ehr	--	--	2	----	----	3.5
Rattulus longiseta Schrank	--	--	2	----	----	.5
Rattulus latus Jennings	--	--	2	----	----	.2
Keratella quadrata O.F.M.	--	--	2	----	----	2.9
Brachionus angularis Gosse	--	--	2	----	----	1.1
Asplanchna priodonta Gosse	--	--	5	----	----	1.9
Daphnia pulex de Geer	--	--	2	----	----	3.5
Diaptomus siciloides Lilljeborg	--	--	7	----	----	12.3
Cyclops viridis Jurine	--	--	9	----	----	5.6

Table II is constructed for zooplankton in the same manner as Table I. The values given therein are entirely independent of the plant values since the total number of animals in each lake was taken as one hundred per cent. It is apparent that the zooplankton was distributed in the same general manner as the phytoplankton, though not necessarily in a related manner. There were cosmopolitan species and there were those more restricted. The values of the zooplankters are in most cases more striking than the values of the plants. With the exception of *Notholca longispina* whose values indicate a tendency toward the colder lakes with softer water all of the cosmopolitan species are uniformly distributed. However, the three species which appeared in two regions were not strongly represented in both of those regions but tended toward an extreme. The species found in only one region have noticeably strong values.

In summarizing, the following points may be noted: (1) average values of the dissolved substances in the lakes studied show that the Superior, Chippewa and Prairie regions presented three distinct physical limnological situations, (2) though some of the phytoplankton species were generally distributed many exhibited preferences and were restricted regionally, (3) the zooplankton also showed cosmopolitan species as well as many that were decidedly restricted, (4) the total phytoplankton population was correlated with the dissolved substances in the water and although such may be the case for the zooplankton the two groups of the plankton did not react to that set of factors similarly.

NOTEWORTHY PLANTS FROM THE DULUTH AREA

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The plant life in the Duluth area is surprisingly rich in floristic novelties. Intensive collecting and field study during the last four years revealed several species hitherto unreported from the state.[1] Moreover, it added factual knowledge pertinent to distribution and floristic composition of plant communities.

In the Duluth area the assemblage of introduced European species is striking and apparently in harmony with the social development of the community which has served from the time of the early pioneers as a gateway to the northwest by linking the railway with the seaway. In addition, infiltrations of floral elements from the east, south and west, as manifested by inclusions of coastal plain as well as western species, increase the complexity of plant populations.

The abundance of luxuriantly growing European species is probably the result of duplication of their original environment in the Lake Superior region, the long periods of dormancy under a protective covering of snow, and the abundant rainfall and cool summers. A few are mentioned here because of their preponderance and weedy character. On the exposed hills the most successfully acclimated species is *Ranunculus acris* L. Somewhat less abundant but plentiful are *Carum Carvi* L. and *Chrysanthemum Leucanthemum* L.

Previously several species of European origin have been reported by the author as new records for the state. The following adventives, *Anthemis tinctoria* L. and *Valeriana officinalis* L. are tending to become established along boulevards and rocky woods in the eastern section of the city. They seem to have escaped from gar-

[1] Lakela, Olga. 1938. Rhodora 40. 279–280.