this basis the total plankton of Lake Simcoe from May to October would average about 365.8 mgm. dry organic material per cubic metre. The annual crop as distinct from the amount of plankton present during the summer months is too complex for our present methods of calculation.

THE NITROGEN OF THE BOTTOM OOZE

As an index to the organic content of the bottom ooze and detritus layer, samples were submitted to a chemical analysis which determined the total organic nitrogen. The relation of the amount of nitrogenous material, presumably an indication of the nutritive value of the detritus, to the amount of bottom organisms present in different parts of the bottom of Lake Simcoe, is dealt with in the following section under indices to the richness of lakes. The average amount of total organic nitrogen present in the upper 5 cm. of the bottom deposits in Lake Simcoe was 1.045 mgm. per kgm. dry weight. This is equivalent to 156.7 gm. per sq. metre or 1567 kgm. per hectare.

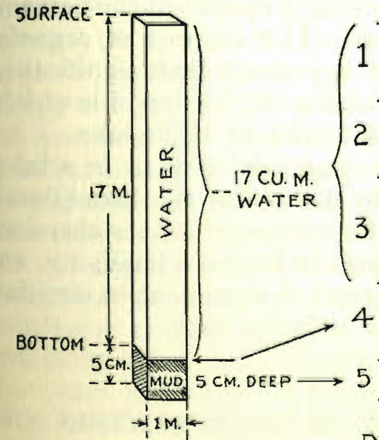
In his investigation of the connecting lakes of the Illinois river, Richardson (1921) found that the mud of the "deeper bottom land" lakes contained 2.7 mgm. organic nitrogen per kgm. dry weight. The mud of shallow weedy lakes contained 3.9 mgm. organic nitrogen. Deep water bottom deposits in Lake Simcoe show an average of 1.04 mg. organic nitrogen per kgm. dry weight.

It is not known what proportion of the nitrogenous material represented by 1567 kgm. organic nitrogen per hectare (1393 lb. per acre) is available as food for the bottom organisms. It is interesting, however, to note the great excess of this organic material over the organic nitrogen content of the macrofauna which amounts to only 0.93 kgm. per hectare (0.827 lb. per acre).

In the aforementioned "deep bottomland" lakes, Richardson found a bottom fauna of 396 kgm/ha live weight, about 79 kgm/ha dry weight. While the life conditions in these lakes are somewhat different from those in Lake Simcoe,

it is noteworthy that the bottom muds contained three times as much organic nitrogen and supported more than six times as much fauna.

Of the states in which organic materials may occur we have still to consider the nannoplankton, the dissolved organic material and the fish. The fish are as yet an unknown quantity but the work of Birge and Juday and their associates has provided a considerable body of data on the other two materials. Their work indicates that the nannoplankton of Lake George collected by a high-speed centrifuge, contained as much as forty times the organic matter of the net plankton. This amount is greater than usual for the nannoplankton in most lakes is from six to ten times the net plankton.



		DRY WEIGHT MGMS.	TOT. ORGANIC NITROGEN MGMS.
1	NET PLANKTON	851·8	83·3
2	NANNOPLANKTON	---	640·0
3	DISSOLVED AND SUSPENDED ORGANIC MATERIALS	---	6000·0
4	BOTTOM FAUNA	1238	93·0
5	DETRITUS & OOZE	---	156,700

DIAGRAM 4

DIAGRAM 4. The vertical distribution of nitrogenous organic matter (exclusive of fish) in Lake Simcoe.

The dissolved and colloidal organic matter in the lake has been shown to make up about 85 per cent. of the total organic matter in the water, the remaining 15 per cent. being made up of plankton (Birge and Juday, 1927). This relation between plankton and total dissolved organic material, and the former relation between net and centrifuge plankton, are the result of observations on a number of lakes. Applying them to Lake Simcoe may not be fully justified since the lakes from which the relations were derived were all smaller than Lake Simcoe.

Diagram 4 indicates the distribution of organic matter as measured by the total organic nitrogen in a vertical column of water, 1 sq. metre in cross-section and extending from the water surface to a depth of 5 cm. into the mud at an average depth, 17 metres, in Lake Simcoe.

It is seen that the bottom fauna is relatively small, 93 mgm. nitrogen, as compared with the amount of plankton, 723.3 mgm. nitrogen, in the column of water above it. The whole of the living matter, plankton and bottom organisms, 816.3 mgm. nitrogen, is small as compared with the dissolved organic matter of the water, 6,000 mgm. nitrogen, and still smaller as compared with the enormous reserve in the bottom detritus, 156,700 mgm. nitrogen. The amount of organic material in the bottom deposits is perhaps least significant, since we have no means of determining the portion of it which is available for circulation in the nutriment of the lake.

The total amount of organic material present in a lake may be in some measure due to the age of the lake (Pearsall, 1921) and to the nature of its watershed. It is also due to the nature of the life conditions in the lake itself, *e.g.* an eutrophic lake has a greater amount of nutriment in circulation than an oligotrophic lake of a similar size.

SOME FACTORS AFFECTING THE CIRCULATION OF NUTRITIVE MATTER

The circulation of nutritive materials as indicated in diagram 3, page 122, involves three kinds of transformations. The elaboration of organic material by the phytoplankton and other aquatic plants, the feeding of one organism on another or on the dead fragments of another, and finally the decomposition of organic matter.

PLANT GROWTH

In a large lake, such as Lake Simcoe, the rooted aquatic plants are much less important than they are in smaller lakes, (page 89), and the phytoplankton is largely responsible for the conversion of inorganic materials into organic matter. The amount of phytoplankton is necessarily affected by such factors as the temperature, transparency of the water, the length of the growing season and the availability of dissolved nutrient salts. Domgalla and Fred (1926) have shown that the nitrate and free ammonia content of certain Wisconsin lakes decreased in midsummer while the amount of organic nitrogen increased. At this time the algae were most abundant, so that the increase in organic nitrogen was no doubt due to increased photosynthetic action. Rice (1916), after an investigation of the relation of plant growth to nitrogen in Winona lake, concludes that a very small amount of nitrates and nitrites suffice for a flourishing plant growth if the conditions for producing these compounds are present. Birge and Juday (1927) have shown that the organic content of water is usually about ten times as great as the total plankton, so that the bacteria have an abundant supply of nitrogenous materials which may be broken down into nitrates and nitrites.

Domgalla and Fred (*loc. cit.*) have demonstrated the influence of rains and surface water in increasing both the nitrifying and nitrate-reducing bacteria in the water. The whole question of the supply of inorganic nitrogen compounds for plant growth is bound up with the bacteria of the lake. In a lesser degree it is influenced by the inflowing spring and drainage water which have a high nitrate content.

FEEDING ACTIVITIES

Although the growth of phytoplankton is fundamental and essential in the production of food materials for the higher forms of life, the utilization of this fundamental material varies greatly in different lakes. Lundbeck's representation of the relation between the three "productions," (page 151), indicates that in deep eutrophic lakes there is a great production of phytoplankton "Urproduktion" and a moderate utilization of this material by the zooplankton and bottom fauna "Zwischenproduktion." In deep oligotrophic lakes the original production of phytoplankton is much smaller, but the degree of utilization more complete, while in shallow lakes of all kinds the utilization of the "Urproduktion" is lowest. The composition of the phytoplankton affects its usefulness as food for minute animals. In certain lakes, usually small, there is a large production of phytoplankton, but it is mostly composed of blue green algae which, instead of providing nutriment, may pile up on shore, decay and produce toxic materials.

Apart from the fact that the bottom fauna feed on the detritus, very little is known of this relation. It has been suggested that the great numbers of micro-organisms and bacteria living in the upper layers of the ooze are an important source of nutriment for the larger bottom organisms.

The availability of bottom organisms as food for bottom-feeding fish is discussed on page 151. In Lake Simcoe the whitefish are thought to feed down to depths of 30 metres, and since 94 per cent. of the total area of the lake is less than 30 metres in depth, most of the bottom fauna is available as fish food. In lakes with more marked stratification the low oxygen supply below the thermocline prevents the fish from feeding in the deep water during a large part of the summer season. In such lakes the upper water is usually very warm so that the bottom-feeding fish are confined to a fairly narrow feeding range (Lundbeck's frasszone, 1926).

The organic material in the food organism is never completely utilized by the individual which eats it, so that at each successive step in the food chain there is a small loss of the organic material manufactured in the original photosynthetic action of the phytoplankton. Schaperclaus (1925) has shown that fish are able to make use of from one-third to one-quarter of the potential food value of bottom organisms, measured as calories.

DECOMPOSITION PROCESSES

Of the nature and rate of bacterial decomposition on the bottom we have comparatively few data. Mention has been made above of the inoculation of the lake water by bacteria brought in by rain and drainage water. The importance and something of the rate of the activity of these bacteria has been studied by Domgalla and Fred (1926), Domgalla, Fred and Peterson (1926) and Rice (1916).

A second factor in the decomposition of bottom materials is the digestive action of such forms as the Oligochaeta and chironomid larvae in the detritus of deep water. Alsterberg (1925) has made a thorough study of the activities of the oligochaetes and compares them with the earthworms as described by Darwin (The Formation of Vegetable Mould through the Action of Worms, 1890). The chironomid larvae are also responsible for some working over of the bottom detritus, but they are more limited in their scope since they have horizontal cases near the surface of the ooze, while the Oligochaeta, as shown by Alsterberg, are able to feed at depths of 3 to 6 cm. below the surface. Since the posterior portion of their bodies projects from the upper surface of the mud (for respiration), a part of the material eaten is brought to the surface. Microscopic examinations have shown that the flocculent material of the upper ooze layer is largely of such "coprogenous" formation.

The loss of organic material through sedimentation is greatest in the polyhumus or peaty type of lake bottom and least in the oligohumus type. In the former the organic materials are incompletely decomposed and the accumulating material is buried and lost in the bottom deposits. The latter type of bottom supports a larger amount of fauna which is more successful in keeping the detritus used up and decomposed. Two main factors tend to prevent the loss of organic materials by sedimentation. The oligochaetes work through the upper 5 cm., devour the organic material and bring some of it back to the surface. The heavier silt, settling to the bottom, sinks through the flocculent detritus which is accordingly left on the surface of the deposit. Even in an oligo-humus mud, such as that of Lake Simcoe, there is some loss through sedimentation since layers III and IV contained 0.7 and 0.56 mgm. organic nitrogen per kgm. dry weight, (page 75). These layers are lower than 5 cm. from the surface of the ooze, and the organic material represented by the above quantities of organic nitrogen is probably lost to the circulation of the lake.

INDICES OF THE RICHNESS OF LAKES

The term "richness of a lake" might be applied either to the amount of living matter or the total amount of nutritive material per unit volume. The term "productivity" has been used by various investigators to indicate sometimes the capacity for fish production, sometimes with reference to the total flora and fauna supported by the lake. The capacity for fish production bears no constant relation to the amount of other organisms in the lake as will be indicated on pages 150-152. The following paragraphs contain a discussion of "richness" as indicated by the total organic material in circulation in a lake. The question of fish production is taken up on page 167.

THE PLANKTON

An abundance of plankton is usually associated with an abundant bottom fauna and a low oxygen supply in deep water, while a scarcity of plankton is found in lakes with a scarcity of fauna and a high oxygen content (page 92). The plankton is therefore a general indication of the conditions which we describe as eutrophic and oligotrophic. Further than this, the amount of plankton may or may not be an index of nutritive conditions. In Thienemann's dystrophic lakes the humus content of the mud is the significant feature with the nutritive and oxygen conditions of only secondary importance.

Plankton as an index to richness of a lake is subject to three important limitations.

The quantity of plankton fluctuates greatly during the growth season, due to "pulses" of different organisms. It is necessary to sample the plankton regularly throughout the season if we wish to estimate the total plankton of the lake.

The variation in methods of sampling and analysing makes it difficult to compare the results of different plankton studies. Recent developments in the collection of plankton by centrifuging and in the chemical analysis of the sample will make the data much more comparable in the future.

The quantity of plankton is not always sufficient since the nutritive value varies with the quality of the haul. An overabundance of such forms as the blue green algae may result in decomposition and the production of toxic substances although they represent a richness of organic matter.

THE BOTTOM FAUNA

As has been demonstrated by Lundbeck, Thienemann and others, the quality of the bottom fauna in the deeper water gives some indication of the trophic condition of the lake (page 92). Like the plankton, the amount of bottom fauna varies seasonally, but in the latter case the variation is uniform and not subject to sudden pulses. The difficulty of sampling the large number of dredgings necessary to produce a representative estimate and the variation in methods of recording quantitative statistics all combine to make bottom fauna a difficult method of testing the richness of a lake.

THE ROOTED AQUATIC PLANTS

The amount of rooted and submerged vegetation as an index to the productivity of fish of lakes was suggested by Klugh (1926) in a paper in which he summarizes the available data on the role of such plants in the nutrition of lakes.

The rooted aquatics, especially in small and shallow lakes, play a very important part in sheltering and providing food for animals and in adding to the soluble nutritive materials by their decay. In the larger lakes they have a much less noticeable effect. In Lake Nipigon, for instance, the great fish production could not be predicted from the scanty vegetation around its shores.

The detritus, as Klugh remarks, receives a contribution from the decay of rooted aquatic plants, but in a lake as large as Lake Simcoe this amount is very small. A microscopic examination of the detritus from the deeper parts of Lake Simcoe revealed an insignificant proportion of allocthonous detritus, produced near shore or on land, as compared with the autocthonous detritus produced in the open water. A larger lake such as Lake Nipigon has still less allocthonous material in its detritus.

It would appear that in large lakes the amount of rooted aquatic vegetation was limited by the shore conditions, since exposed and rapidly shelving shores are unfavourable for plant growth in contrast to shallow, irregular shores which support a heavy growth. In such cases the rooted vegetation could not be proportional to the amount of nutritive material in the lake. At the other extreme, small, shallow and weed-choked lakes may support an enormous invertebrate fauna but few fish, and, as Professor Klugh remarks at the beginning of his paper, "From the practical standpoint the most important consideration in regard to a lake is its capacity to produce fish."

THE ORGANIC CONTENT OF THE WATER

Recent work on small lakes of northeastern Wisconsin (Birge and Juday, 1927) has indicated that the plankton forms on an average about a seventh of the total organic material in the lake water. The average organic content of these lakes was 14.6 mgm. per litre. The authors suggest that the dissolved organic matter, being much in excess of the plankton and fairly constant in quantity, resembles the organic matter of soil which is little affected by the crop which it supports.

Domgalla and Fred (1926) show that in five lakes near Madison, Wisconsin, including Lake Mendota, the total

organic nitrogen varies between 0.6 and 1.4 mgm. per litre throughout the season. The inorganic nitrogen in the form of nitrates and free ammonia was usually about 0.25 mgm. per litre. While the plant growth used up some of this inorganic material at midsummer and caused an increase in the organic nitrogen, this exchange involved only a small quantity, roughly one-fifth, of the total nitrogen of all kinds in the water.

Birge and Juday (1927) demonstrated that the plankton showed a fairly constant relation to the total organic matter in the water. In more than one-half the lakes studied the plankton was between 10 and 20 per cent. of the total organic matter.

The available data suggest the possibility of the organic content of the water as a satisfactory index to the richness of the lake as a whole, though the condition in large lakes has not been investigated. In small lakes the total organic material in the water appears to be fairly constant and closely related to the plankton fauna which the lake supports.

THE ORGANIC DETRITUS

The detritus has been shown in diagram 3 (page 122), in a central position among the four other states of nutritive matter, a position which indicates something of the actual relations existing between these materials. The detritus is partly dependent on the plankton for its derivation; it provides food for the bottom fauna and, in its decomposition, dissolved organic and inorganic nutritive matter is returned to the water. Is it possible that the richness (organic content), of the detritus is indicative of the general richness of the lake?

In lakes of a dystrophic type (page 92), the bottom fauna has been found low in quantity and with little relation to the high organic content of the bottom deposits. The high degree of humosity or peaty nature of the bottom is unfavourable for the bottom fauna. In the oligo- or eutrophic types the bottom fauna production and plankton are respectively poor and rich but the bottom fauna is limited less by the available food supply (detritus), than by the oxygen content of the deeper water. It is therefore unlikely that in any of these types the amount of organic detritus on the bottom will provide an index to the amount of life in the lake.

A preliminary experiment to determine the relation of the nutritive material in the bottom deposits to the amount of bottom fauna was carried out in Lake Simcoe during 1927 and 1928. Bottom fauna samples were taken with the dredge and screened as described on page 16. The weight of the organisms from each dredging was determined by drying and weighing rather than by calculating on a basis of average dry weight per individual, which was the method employed in the general survey.

The bottom materials were collected with the heavy sampler and determination of the total organic nitrogen were made by the Kjeldahl method on the material from the upper 5 cm. of the mud. A dredging and a sample of bottom material were taken simultaneously at each of twenty-six stations at depths of 11 to 34 metres in widely scattered parts of the lake. The data from these samples are presented in table 16 along with the date of sampling.

The samples were taken mostly in May and June in order to reduce the error resulting from seasonal variation in the amount of bottom fauna. While the relation between amount of fauna and the organic content of the ooze is not readily seen from the table, the same data, presented as graph XI, indicate that the two quantities vary in an inverse ratio. In other words, those places in which the organic nitrogen is high support a smaller fauna than locations in which the organic nitrogen is low. That several of these points are far from the curve is not surprising in view of the error inherent in the sampling of bottom fauna (page 18), and the variation in individual dredgings taken from one locality, (page 19). At twenty-one of the twenty-six stations the correlation between bottom fauna and the amount of nitrogen was quite marked.

Certain analyses were made to test the method of samp-

TABLE 16. Showing the depth, the amount of bottom fauna and the nitrogen present in the ooze at twenty-six stations in Lake Simcoe.

Station no.	Depth in metres	Date	Bottom organisms per 500 sq. cm.		Total organic nitrogen upper 5 cm. of mud p.p.m. dry weight
			Dry wt. mgm.	Total org. nitrogen mgm.	
1	19	May 28	57	3.44	0.97
2	19	"	26	2.28	1.07
3	17	"	35	2.00	1.08
4	17	June 30	74	3.76	0.82
5	13	"	42	3.00	1.02
6	33	"	35	3.40	1.08
7	30	Sept. 22	16	1.32	1.11
8	21	Aug. 3	46	3.40	1.04
9	28	May 16	40	2.85	1.02
10	31	"	10	1.95	1.20
11	32	"	60	3.20	1.05
12	34	May 17	30	....	1.19
13	34	"	40	....	1.70
14	40	"	40	2.42	1.95
15	20	May 19	20	....	1.50
16	38	"	50	2.91	0.86
17	38	May 21	30	2.7	1.15
18	38	"	20	2.4	1.10
19	37	May 23	40	2.8	1.10
20	37	"	60	2.73	0.90
21	34	"	43	2.65	0.95
22	28	"	40	....	0.60
23	14	May 24	22	....	1.05
24	15	June 6	20	....	0.40
25	15	" 7	110	4.38	0.60
26	11	" 20	105	3.9	0.85

ling the bottom deposits and to indicate the nature of the organic material present. These results are to be considered before proceeding with the discussion of the reasons for the inverse relation indicated above.

The samples of bottom material from the deeper water were taken from the upper 5 cm. of the core brought up by the heavy sampler. This depth was chosen since it roughly corresponds with layers I and II (page 73), in which most of the organic detritus is found. Table 6 on page 75, indicating the distribution of total organic nitrogen in the various strata of the bottom deposits, shows that layers I and II include the part of the deposits which is richest in organic matter. The nature of the organic nitrogen was determined by a further analysis of four samples, the composition of which is shown in table 17.

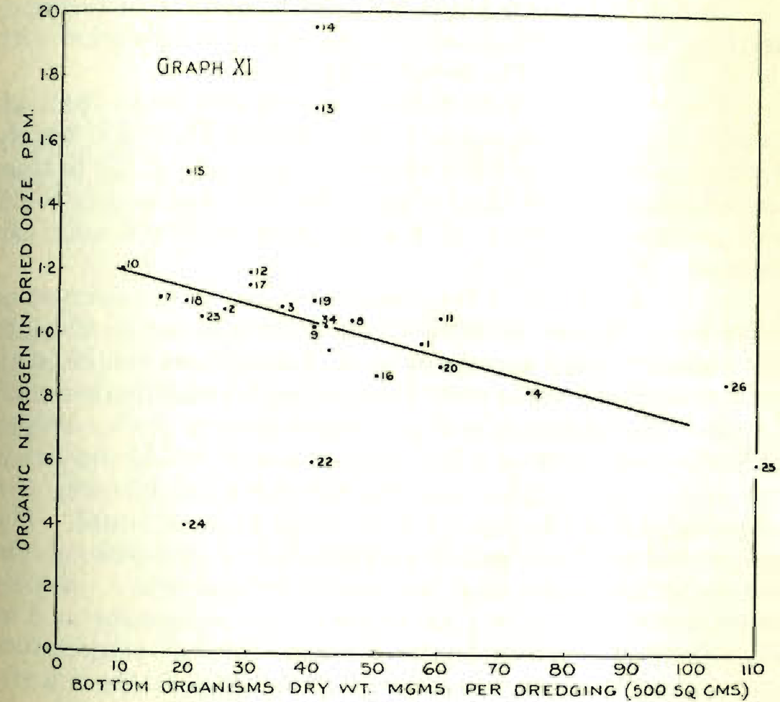
TABLE 17. Showing the nature of nitrogenous materials in the bottom ooze.

Sample	Per cent. moisture	Amounts of nitrogen expressed in p.p.m. dry weight				
		Total N:	Free ammonia	Albuminoid ammonia	Nitrates	Nitrites
1.......	83.6	0.847	0.052	0.647	0.00012	trace
2.......	85.4	1.066	0.052	0.526	0.00024	0.000012
3.......	82.5	1.020	0.039	0.558	0.0003	0.00003
4.......	70.0	1.080	0.012	0.816	0.0009	0.000042
Average	80.4	1.003	0.039	0.637	0.0004	0.000021

Having indicated in a general manner the nature of the nitrogenous materials in the bottom ooze, we may return to the relation between this material and the bottom fauna.

As indicated in graph XI, a large fauna is found where the organic nitrogen content of the detritus is small, and vice versa. It might appear that where the bottom fauna was abundant the greater number of organisms were able to eat a large proportion of the detritus while a smaller fauna required less food and allowed the detritus to accumulate. This, however, would not be a stable condition since, if no other factor was limiting, the organisms would tend to increase or decrease to reach an equilibrium with the available food supply. It is therefore probable that some factor, other than food, limits the abundance of bottom organisms, giving rise to richer and poorer communities, after which the inverse ratio of fauna to food can be explained as suggested above by the greater or lesser consumption of the available food supply.

Frequent mention has been made of the uniformity of the bottom in the deep water of Lake Simcoe, and under these apparently uniform conditions it is difficult to suggest any factor which would account for an irregular distribution of the organisms on the deeper part of the lake bottom. Since the oxygen supply of the lower water has a marked effect on



GRAPH XI. The relation between the amount of organic matter in the bottom ooze and the amount of fauna at twenty-six stations in Lake Simcoe.

the distribution of bottom fauna (page 84), it may be suggested that the "other factor" which is responsible for minor fluctuations in the density of the fauna, is the oxygen supply on the surface of the mud. In order to test this possibility, a method of sampling the water at the surface of the mud must be developed since the "microschichtung" phenomenon, (page 84), makes the usual determination of bottom oxygen quite inadequate. It is also possible that currents might affect an irregular distribution of bottom organisms either through unequal distribution of the oxygen supply, through unequal distribution of detritus or more directly through their effect on the distribution of eggs or larvae of aquatic insects.

It should be mentioned that the amount of nitrogenous detritus, as indicated in table 16, showed no correlation with the depth at which the sample was taken.

From the above consideration it would seem that, although the organic material in the bottom detritus is largely derived from the plankton and serves as food for the bottom organisms, the amount of organic material in the detritus is not always indicative of the amount of life a lake can support.

A consideration of the possible indices to the richness of lakes has led to the conclusion that there is as yet no absolute criterion, although certain indicative conditions can be more easily examined and result in more useful information than others. For instance, a single determination of the oxygen in the deeper water of a lake at midsummer might show that the lake was eutrophic and suggest the usual features of a eutrophic lake, *i.e.* rich plankton and bottom fauna. The occurrence of the larvae of a single species of chironomid on the bottom mud might give the same information. In most cases it is still necessary to examine several features such as the plankton, bottom fauna, detritus, bottom temperature and oxygen before arriving at any conclusion as to the richness of the lake.

FISH PRODUCTION AS RELATED TO BOTTOM FAUNA

The relation between fish production and bottom fauna had been investigated only in small ponds until Alm (1922), correlated these features in fifteen lakes of southern Sweden. He designated the relation of fish caught per hectare to live weight of bottom fauna per hectare as the **Fb** coefficient. As might be expected, the **Fb** coefficient varied greatly in different lakes, but Alm was able to demonstrate that most of the variations could be correlated with the type or condition of the lake. As a result of his work he distinguished three types among the fifteen lakes studied.

	No. of lakes	Maximum depth	Average bottom fauna, live wt.	Average Fb coeff't.
1. Deep lakes with high coefficient	5	18-98m.	7 kgm/ha	1:3.6
2. Lakes of moderate depth with low coefficient	4	8-14m.	60 kgm/ha	1:17
3. Shallow lakes with high coefficient	6	2-6m.	60 kgm/ha	1:2.5

In these lakes the lowest coefficient was 1:31, in a small lake 8 metres deep with a *C. plumosus* type of fauna. The highest coefficient, 1:0.8, was found in a lake 30 metres deep with a *Tanypus* fauna, and a second very high coefficient, 1:0.9, in a large lake 2.5 metres in depth and a fauna in which *Corethra* larvae were predominant.

Alm's work indicated that the deep lakes with a high coefficient had either oligochaete or *Tanypus* types of fauna; the other two classes showed no correlation between type of bottom fauna and **Fb** coefficient. A further observation was that the lakes with a smaller quantity of bottom fauna usually had higher coefficients.

Lundbeck (1926) relates the fish production to the bottom fauna and carries the relation further to "Urproduktion" which is the contribution of plants to the nutritive matter of the lake, both by building up organic material and by their decomposition products. The bottom fauna he mentions as the chief component of the "Zwischenproduktion" and the fish as the "Endproduktion." The theoretical relation between the original, intermediate and final productions in different lakes is shown by Lundbeck (1926*a*, page 54) to be as follows:

	Urproduktion	Zwischen-produktion	Endproduktion
1. Deep eutrophic lakes (rich in food, poor in O_2)..........	100	40	25
2. Deep oligotrophic lakes (rich in in O_2, poor in food)........	100	85	60
3. Shallow lakes of all kinds.....	100	20	20

Although the deep oligotrophic lakes show the most complete utilization of the Urproduktion, the amount of this fundamental plant-produced nutriment is small in the oligotrophic type of lake so that the final result is a smaller production of fish in an oligotrophic lake than in either of the other two types.

In order to make a more accurate correlation between the food value of the bottom fauna and its utilization, Schaperclaus (1925) and others have made use of the caloric value of the bottom organisms in calculating the rate at which the bottom fauna is utilized by fish and the loss in energy entailed in this transfer. While this work has at present no economic application, it is tending towards an accurately determined **Fb** coefficient based on the yearly production of bottom fauna which will be of great value in estimating the fish-producing capacity of a lake.

The utility of the **Fb** coefficient as yet is subject to several limitations. It does not directly consider the plankton-feeding fish nor the species which we do not catch. For instance, Lake Simcoe has a large population of perch, ling and suckers, very few of which are ever taken in fishing. It is also clear that the fish caught per year may be greater or less than the annual production. Over a short period a high **Fb** coefficient might indicate only overfishing or a low **Fb** might show either low production or incomplete utilization of the crop.

The value of the **Fb** coefficient is in the provision of even a rough method of comparing the fish production of lakes and in calling attention to the differences in capacity for fish-

production as dependent on nutritional factors, depth, and other physical and ecological conditions in the lake.

In Lake Simcoe the average catch of fish during the past sixty years has been about 130,000 lb. per annum, valued at at $9,000 (page 166). Estimating the live weight of the bottom fauna as 55 lb. per acre (live weight is approximately five times dry weight), this represents an **Fb** coefficient of 1:75. For the period from 1868-1908, the average fishery of 50,000 lb. per year is represented by an **Fb** of 1:200. For the period from 1908 to 1928, the average catch was 234,000 lb. and the **Fb** 1:42; and for the same period the average catch in deep water, 10 to 45 metres, was 19,000 lb., which for an area of 200 square miles represents the extremely low coefficient of 1:310. In the shallow water (1-10 metres) the **Fb** coefficient was for the same period, 1:15.

The lowest coefficient found by Alm was 1:31, which is higher than the present value for Lake Simcoe. It is quite evident that the crop of fish taken from Lake Simcoe is very low, especially in the deeper water where the **Fb** coefficient is only 1:310. The value would suggest that the productive capacity of this area was not being properly utilized, a point which is further discussed on page 167, part III.

SUMMARY OF PART II

The circulation of food materials is summarized in diagram 3 (page 122), which shows the nutritive material of the lake divided into five states and indicates something of the way in which materials are transformed from one state to another.

The bottom organisms in Lake Simcoe form the major part of the food of whitefish, suckers and carp, as well as much of the food of perch and bass and a small quantity of the food of the ling and the cisco. The chief bottom-food organisms are the ephemerid nymphs, Mollusca and chironomid larvae, the ephemerid nymphs being unusually important in view of their small numbers as compared with other bottom organisms.

A comparison of the amounts of nutritive material present in different states indicates that the total plankton is about eight times as great as the bottom fauna per unit area. The living organic matter in the form of plankton and bottom fauna is small, about 0.5 per cent., in proportion to the amount of organic matter present in the water and the upper 5 cm. of the bottom deposits.

Different lakes vary in the amount of phytoplankton "Urproduktion" which they support, in the extent to which this material is utilized to produce zooplankton and bottom fauna "Zwischenproduktion," and in the extent to which the zwischenproduktion is used to produce fish "Endproduktion." These variations have been shown to depend in some measure on the depth and trophic condition of the lake.

No one feature of the life or life conditions in a lake will provide an absolute index to its richness, (amount of nutritive material present). The various indices—bottom fauna, plankton, organic content of the water, rooted aquatic plants, bottom oxygen, etc., vary greatly as to their utility and the ease with which they may be determined.

The **Fb** coefficient, relation of fish caught to bottom fauna present per unit area, is as yet not wholly satisfactory, but it is of some value in providing a limited method of comparing the crop of fish taken from lakes, and is of greater value in calling attention to the fact that certain factors, such as depth and trophic condition, are responsible for variation in the productive capacity of lakes. The extremely low **Fb** coefficient in Lake Simcoe is thought to indicate a very incomplete utilization of its possibilities, especially in the deeper water.

PART III

THE FISHERIES OF LAKE SIMCOE

THE HISTORY OF FISHING IN LAKE SIMCOE

On August 17, 1615, Champlain led a band of Huron warriors across the narrows between Lake Simcoe and Lake Couchiching and on into the territory of the Iroquois. In his journal for that date, he mentions an Indian fishing station at the outlet of the lake where the village of Atherley now stands. In 1891, Wallace, of Orillia, records the discovery of the remains of a Huron fish weir in the Narrows and suggests that it was the one referred to by Champlain in his journal.

In 1687, Lahontan's "La Grande Voyage" tells of Iroquois hunting and fishing trips in the direction of Lake Taranto (Simcoe), a district in which they were free to wander, having massacred its Huron population in the years 1649-50. In the next hundred years there is very little record of fishing in the lake, although the Algonquins were known to encamp along its northern and western shores, while the Ojibways who followed them in occupying the Simcoe district were expert fishermen.

Sir Geo. Head spent the spring of 1814 on Kempenfelt bay, and in his "Forest Scenes in Canada," (pub. 1838) he describes in detail the fish and fishing methods of the locality. With the sum of nine dollars and a quantity of whiskey he was able to buy from an Indian a complete fishing outfit, consisting of a bark canoe and a fifteen-foot spear with two barbed iron spikes. During his stay he speared numbers of salmon (lake trout), carp (suckers), perch, bass, freshwater herring and a large catfish. He confessed that "like all their freshwater brethren," the fish of Lake Simcoe were inferior in quality to those of the salt water.

Smith's Canadian Gazetteer in 1846 testifies to the excellence of Lake Simcoe maskinonge and whitefish, and in

1852, after a trip to the Orillia district, Mrs. Jameson praises the quality of the bass. A description of the Northern Lakes of Canada, by Barlow, 1886, tells of bass, trout and maskinonge fishing, all of which indicate that Lake Simcoe received early recognition as a fishing ground.

In 1868 we have the first statistical record of fishing in Lake Simcoe, when trout, whitefish and ciscoes were taken to the value of $2,450. An analysis of the fishing records for the last 60 years will be found on page 165.

Statements made to the Dominion Fisheries Commission (1893) by residents of the district indicate that the numbers of whitefish and trout had become considerably reduced at that time.

Angling for bass in Lake Simcoe became more intensive as large numbers of summer homes sprang up around its shores. Residents around the lake say that the peak of this fishing was about 1905, after which the numbers of bass fell off rapidly. At the present time the bass are not heavily fished due to their scarcity. The maskinonge have practically disappeared and the trout, although present in moderate numbers, are difficult to catch. The causes of this depletion, including the introduction of carp, will be discussed in the following pages.

FISHING METHODS IN LAKE SIMCOE

In Lake Simcoe, several unusual methods are employed in angling and in commercial fishing, in addition to those in common use in other lakes.

ANGLING FOR CISCOES IN THE MAYFLY SEASON

During the swarming of the Ephemeridae* in Lake Simcoe, it is found that the cisco, *Leucichthys artedi*, becomes a surface-feeder for a ten-day period. The common species of *Ephemera*, *E. simulans*, swarms about June 27-30, while

*The Ephemeridae or mayflies are known to the fishermen as shadflies, bass flies and fish flies. Anglers use the less familiar terms of "Duns" for the subimago and "Spinners" for the adults.

the large *Hexagenia*, *H. occulata*, reaches its maximum emergence about July 1st. At the latter date, ciscoes can be taken in great numbers in certain parts of the lake, notably in the Narrows at Atherley. Plate IV, fig. 1, shows a "fleet" of boats on the bay at Atherley on July 1, 1928, the occupants being engaged in this sport. The newly emerged adult or subimago of the large mayfly, Hexagenia, are the chief bait, although the fish are readily taken on a suitable artificial fly. A catch of 60 ciscoes, (plate IV, fig. 2), in two hours is not an unusual record for a fisherman on this area or even from the dock at Atherley. The fish continue to rise for about ten days although the fishing is usually best during the first three days in July.

ANGLING FOR WHITEFISH WITH MINNOWS AS BAIT

Whitefish in other waters are occasionally taken on a hook, usually when fishing for some other species. In Lake Simcoe the method is so widespread and successful that it has become a commercial practice in certain seasons.

Most of this fishing is carried on in depths of 15 to 75 feet of water through holes cut in the ice. Each fisherman is provided with a lightly-constructed fish-house, Plate V, fig. 1, about 3 ft. by 5 ft. by 4½ ft. high, which can be easily moved over the ice on a hand-sleigh. The houses are windproof and each is provided with a small stove so that the fisherman may sit comfortably inside. Catches of 50 to 75 whitefish in a day are considered good fishing. The modern fisherman uses his automobile to reach the fish-house, which may be three to five miles from shore.

The minnows which are used for bait are chiefly the lake shiner, *Notropis atherinoides*, about two inches long. They are kept alive all winter by confining them in a cage which is sunk in ten feet of water at the end of a convenient dock. Salted minnows of the same species are used for prebaiting, *i.e.* a small pailful is scattered over the bottom where the fisherman places his house. If live minnows are scarce, salted ones are used for bait, and for prebaiting, chopped ling flesh, cooked rice, wheat and other grains are considered equally good. The prospective fisherman usually spares himself any such expense by salting down in the previous autumn as much as one or two hundred pounds of minnows, caught with a dip net usually at the entrance to a boathouse.

The extent of this winter-fishing is indicated by the observation that 70 fish-houses were located within a two-mile radius of Jackson's point in March, 1928. During January, February and March of the same year, one dealer bought more than nine tons of whitefish (16,000 fish) from about 15 men engaged in this kind of fishing.

It has been found that whitefish can be caught with minnow bait on certain shoals, 20 feet to 30 feet deep, from November 5 until the ice forms on the lake and in the same places in the early part of May. One enterprising fisherman at Beaverton finds that by prebaiting and marking the spot with a buoy, he is able to catch whitefish all summer, using live minnows for bait.

While this method is used primarily for whitefish, an occasional ling, cisco, perch and sucker is caught with the same tackle.

Spearing Trout Through the Ice

Making use of the fish-houses described above, the fishermen are able to spear trout throughout most of the winter. The house is light proof and banked with snow around its edges, so that the fisherman is able to see 25 to 40 feet into the water, depending on its turbidity and on the amount of snow covering the ice. A cleverly-constructed decoy (Plate V, fig. 2) is made of white wood with bright metal fins, the appearance and size of the device being that of the cisco. The decoy is so balanced and the fins so turned that by an intermittent pulling on the line the imitation cisco is made to travel in a circle about 10 feet in diameter. Following the decoy, the trout is lured upwards into striking distance of the fisherman's 16-foot spear. A less common method makes use of a similar decoy with hooks attached, Plate V, fig. 2, in which case the trout is allowed to strike the lure in deep water.

During the past four years, trout-fishing through the ice has been so unsuccessful that many of the fishermen have given it up and now confine their attention to the whitefish.

The fishermen are allowed to sell their catch of whitefish or trout though it is necessary to obtain a licence before using a spear. The bulk of the commercial fishing in the lake is provided by the carp. Carp are taken in the weedy bays with heavy seines, 200 to 400 yards in length and 15 to 20 feet deep at the centre. The only legal gill netting in the lake is carried on by the Indians of the Georgina island reserve, who are allowed the special privilege of using a gill net for their personal needs.

THE FISHES OF LAKE SIMCOE

The following annotated list of fishes includes those forms taken in the lake during the course of the survey, with the addition of three species recorded by Meek (1902) and the rainbow trout. The list includes 31 species and is probably incomplete since the systematic study of the fish was accessory to the main investigation. The identification of the specimens has been verified by Professor J. R. Dymond of the University of Toronto.

The food of the larger fishes of Lake Simcoe has been dealt with in Part II, pages 125-133.

1. *Coregonus clupeaformis* (Mitch.)

The common whitefish of Lake Simcoe is abundant but of small size. The average weight of several thousand taken in 1928 was 1 lb. 2 oz., while a fish of 2½ lbs. weight is quite unusual. Spawning occurs between November 5 and 25, on stony shoals from 6 to 15 ft. deep.

2. *Leucichthys artedi* (Le Sueur)

The cisco of Lake Simcoe differs in a number of respects from the typical *artedi* of the Great Lakes. The fishermen of the lake distinguish a small slender form, ½ to ¾ lb., as "trout herring," in contrast with the larger specimens, "blue backs," ¾ to 1 lb., although specimens of an intermediate character are to be found. They are said to spawn in mid-November along with the whitefish.

3. *Salmo gairdneri* Rich.

The rainbow trout was planted in the lake in 1918 (20,000) and again in 1922 (5,300). There is at least one authentic record of a 5-lb. rainbow trout caught near Orillia in the summer of 1924. Several other reports were probably reliable, but not thoroughly substantiated.

4. *Cristivomer namaycush* (Walb.)

The lake trout is still numerous in Lake Simcoe but during the past five years there has been a noticeable decrease in the numbers taken by trolling. The average size of those taken is about 5 lbs. with occasional specimens of 12 to 14 lbs., and the largest known record a 28-lb. trout taken in 1909. It has been observed that trout taken on the west side of the lake, mostly in the vicinity of Eight Mile point, average 2½ to 3 lbs., while those taken in the east, off Thorah and Georgina islands, are larger, averaging 6 to 7 lbs. Spawning is said to extend from October 15 to November 1, spawn being deposited among the larger stones on shoals in from 10 to 25 ft. of water. The food of the trout is practically all made up of ciscoes, with only an occasional whitefish or young sucker.

5. *Catostomus commersonii* (Lac.)

The common sucker is both large and numerous in the lake. The average weight of specimens taken during the experimental work was 2¾ lbs., but many were as large as 3½ lbs.

6. *Cyprinus carpio* L.

The carp is now one of the most abundant fish in the lake and supports the only commercial fishery of importance. It reaches a large size, many of those taken by the seine weighing as much as 12 lbs., while a 20-lb. carp is not unusual.

The carp is thought to have been introduced into Lake Simcoe through the Holland river into which it had escaped when a mill dam near Newmarket broke about 1896. Fishery overseer Terry of Lake Simcoe district, in his report for 1899, states that "Great numbers of carp have made their appearance in the Holland river and in the marshes of Cook's bay." The spread of carp in the lake was very rapid and in 1911, when the first intense fishing was begun, fishermen using two 400-yard seines were able to take 462,400 lbs. of carp in one year. In 1927, an epidemic of an unknown nature among the carp of the lake killed off a considerable number of all sizes. The reports of the mortality were greatly exaggerated for there was no observed decrease of carp in the following season.

7. *Rhinichthys atronasus lunatus* (Cope)

The black-nosed dace was not taken during the survey but Meek (1902) records it as common at Hawkestone.

8. *Rhinichthys cataractae* (Cuv. & Val.)

The long-nosed dace was common at Beaverton and at the Narrows, Atherley.

9. *Semotilis atromaculatus* (Mitch.)

Creek chub are not common in the open lake but are found in large numbers in the mouths of streams.

10. *Pfrille neogaeus* (Cope)

A number of small specimens of this minnow were taken in a seine haul in the Narrows at Atherley.

11. *Notropis heterolepis* Eig. & Eig.

The black-nosed shiner, or Muskoka minnow, was taken in comparatively small numbers. Meek (1902) records it at Hawkestone.

12. *Notropis hudsonius* (Clinton)

The spot-tailed minnow is moderately abundant and reaches a fair size, 3 to 4 inches, in Lake Simcoe. Several of the specimens taken had the larva of a large cestode, *Ligula sp.*, in the visceral cavity.

13. *Notropis atherinoides* Raf.

The lake shiner is the most abundant minnow of the lake although it is comparatively small, averaging about 2 inches in length. It supplies the major part of the whitefish bait for which purpose it is salted away in great quantities every autumn. Other minnows occasionally found in this bait material are *N. hudsonius*, *N. cornutus*, *Chrosomus erythrogaster* and *Hyborhynchus notatus*.

14. *Notropis cornutus* (Mitch.)

Small specimens of the common shiner were taken in moderate numbers in shallow water.

15. *Hybognathus nuchalis* Agassiz

The silvery minnow is recorded by Meek as abundant at Hawkestone.

16. *Chrosomus erythrogaster* Raf.

The red-bellied dace was taken in large numbers at Beaverton and scattered specimens were taken along the south and western shores of the lake. Most of the specimens were not more than 1½ inches long.

17. *Hyborhynchus notatus* (Raf.)

The blunt-nosed minnow occurred in moderate numbers at Beaverton and Atherley.

18. *Pimephales promelas* Raf.

Although the fathead was taken only in small numbers, Meek has recorded it as abundant at Hawkestone.

19. *Ameiurus nebulosus* (Le Sueur)

This is the common bullhead or catfish of the lake. In certain features the specimens tend to resemble *A. melas*. Hubbs, in a recent paper, suggests that in the northern part of its range *A. nebulosus* varies towards *A. melas*.

There are several records of very large catfish caught in Kempenfelt bay, Jackson's point, and at Gamebridge. A 19¾-lb. specimen was speared by A. Grew off the dock at Jackson's point in 1923, this being, to my knowledge, the largest authentic record. It is unlikely that these specimens were *A. nebulosus* since the largest recorded size for this species is only 19 inches.

20. *Esox masquinongy* Mitch.

The maskinonge was at one time abundant in Lake Simcoe. At present a few specimens are taken each year in Cook's bay and in the Holland river, while at infrequent intervals specimens are reported from the Black and Talbot rivers.

The absence of the pike, *E. lucius*, is a remarkable and as yet unexplained feature of the fish fauna of Lake Simcoe. It occurs in other waters of the Trent canal system, both above and below Lake Simcoe, a few specimens being taken as near as the north end of Lake Couchiching.

21. *Fundulus diaphanus menona* (Jord. & Copeland)

Meek records this species at Orillia.

22. *Percopsis omisco-maycus* (Walb.)

Trout perch were taken in several parts of the lake.

23. *Perca flavescens* (Mitch.)

The yellow perch is by far the most abundant of the spiny-rayed fishes in the lake. In the shallow water great numbers of small perch are to be seen and in the deeper water large specimens, more than 1 lb. in weight, are taken in gill nets or with bass tackle.

24. *Stizostedion vitreum* (Mitch.)

The pickerel is exceedingly rare in the lake, most of the inhabitants denying its presence. A few specimens were taken in the north-eastern part of the lake ten to fifteen years ago. The absence of this species is as inexplicable as that of the pike, since like the latter, the pickerel is found in Lake Couchiching and the Severn river, with no barriers between these waters and Lake Simcoe. One and one-half million pickerel fry were planted in Lake Simcoe in 1922-24 with no apparent effect on the fauna of the lake.

25. *Percina caprodes* (Raf.)

Large numbers of log perch were taken in seine hauls in various parts of the lake.

26. *Poecilichthys exilis* (Girard)

The Iowa darter was the only other representative of the darter group taken during the survey. It was most common in the vicinity of Beaverton.

27. *Micropterus dolomieu* Lac.

The small-mouthed black bass is the important game fish of the lake. Its average weight is about 2 lbs., with occasional specimens of 4 or 4½ lbs. in weight.

28. *Eupomotis gibbosus* (L.)

The pumpkin seed, or sunfish as it is locally termed, is widespread but not numerous in Lake Simcoe.

29. *Ambloplites rupestris* (Raf.)

The rock bass although more numerous than the pumpkin seed, is very much less abundant than the perch. It seldom exceeds a weight of one-half a pound.

30. *Eucalia inconstans* (Kirt.)

The brook stickleback is widely distributed around the shores of Lake Simcoe, though its numbers are small.

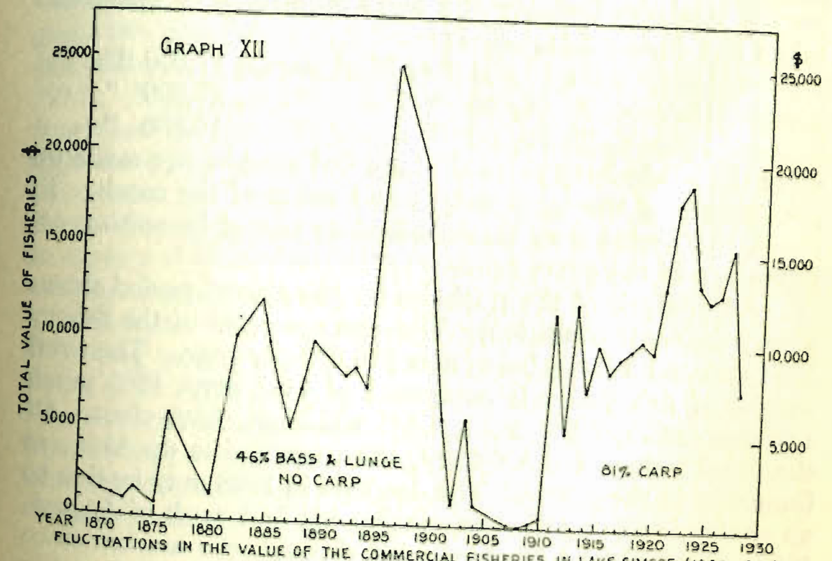
31. *Lota maculosa* (Le Sueur.)

The ling is abundant in the lake and reaches an average weight of 4 to 5 lbs. Living in the deep water and feeding on the cisco, it is an important competitor of the lake trout.

STATISTICS OF THE LAKE SIMCOE FISHERY

Records of the commercial fishing in Lake Simcoe have been obtained for the early years from the annual reports of the Dominion Department of Marine and Fisheries and for the later period from the annual reports of the Ontario Department of Game and Fisheries.

To indicate the fluctuation in the fishery of Lake Simcoe, Graph XII has been constructed, showing the value of the



GRAPH XII. Fluctuations in the value of the commercial fishery in Lake Simcoe (1868-1928).

commercial fishery over the last sixty years. The minor annual fluctuations are largely the result of variation in the number of fishermen and in the amount of equipment and as such they may be disregarded in our general consideration. The curve shows in general an increase in the fishery from 1870 to 1896, after which time it fell off rapidly till in 1908 the fish taken were so few as to be practically valueless, $91.00. This decrease was in part due to the prohibition of the sale of game fish brought about by an order-in-council in the year 1903. From 1910 to the present time, the fishery varies about a mean value of $10,000 per year. The minimum fishery in 1908 separates two fairly distinct periods, which will be considered separately.

The period of forty years, 1868 to 1908, had an average fishery valued at $9,000. The total weight of the catch was made up of 28% lake trout, 27% bass, 19% maskinonge, 15% whitefish, and 11% ciscoes and coarse fish. The following statistics indicate the large quantities of game fish taken out during this period:

1896—Bass	78,000 lbs.,	Maskinonge	17,800 lbs.
1899—	" 43,000 "	"	27,000 "
1900—	" 70,200 "	"	16,800 "

Over the whole forty years the bass and maskinonge made up about 46% of the total weight and value of the catch. In short, the period may be described as one of increasing exploitation of the game fish.

An analysis of the statistics for the second period shows a very different condition. The average value of the fishery has increased a little, being now $10,000 per year. The total weight of fish taken is composed of 71% carp, 18% perch and coarse fish, 7.1% trout, 2.6% whitefish, 0.8% cisco. Of the total value of the fishery, the carp makes up 81%, as indicated in the graph. The decrease in 1928 may be due to an epidemic among the carp during the first week of August, 1927. The effect was chiefly felt through the market since the carp did not appear to have suffered any appreciable decrease in numbers.

The graph, in illustrating the fluctuation in value of the fishery, tells only a part of the story. During the first forty years the total weight of fish caught was roughly 2,200,000 lbs., an average of 55,000 lbs. per year, and the annual value was $9,000. During the last twenty years the total catch has been about 4,679,000 lbs., an average of 233,950 lbs. per year and the average annual value has been $10,000. It is seen that even with the quantity of the catch increased to four times what it was in the first period, and with the value of

fish slightly increased, the decrease in the quality of the fish fauna was so great that the resultant value of the fishery increased only 10 per cent. In other words, the market value of the carp, 81 per cent. of the present catch, is less than one-quarter that of the bass, maskinonge and trout which made up the catch between 1868-1908.

The graph should not be interpreted as indicating a cessation of bass and maskinonge fishing about 1902, nor a rapid increase in the numbers of carp in 1910. The figures do show, however, that there was a very great drain on the game fish population and that the increase of carp was rapid. Maskinonge fishing in Lake Simcoe has been negligible since 1910. The bass continued to be caught in fair numbers but decreased steadily until at present Lake Simcoe is no longer considered "good bass fishing." Under the lowered demands the present bass population may be expected to last for some time. The carp, from their introduction about 1896, increased so rapidly that in 1911, a catch of 462,000 lbs, was taken out without any effect being observed on their numbers.

In brief, the history of fishing in Lake Simcoe during the last sixty years may be summed up as follows. For forty years after 1868, there was a heavy drain on the game fish, bass and maskinonge and on the lake trout. During the last twenty-five years, the maskinonge have practically disappeared, bass have been much depleted and the carp is now the mainstay of the fishing.

FISH PRODUCTION IN LAKE SIMCOE

The amount of fish taken from a lake is not necessarily representative of its capacity for fish production any more than the crop from a poorly-tilled acre of land is representative of the possibilities of that acre. In agriculture we have fairly accurate data as to how much crop a given soil should produce, but in fish culture such a knowledge is as yet very scanty. In lieu of such information a comparison of the amount of fish taken from lakes of similar size may indicate something of the relation of fish crop to possible productivity. In this connection, the fishery of Rainy lake, Ontario, may be compared with that of Lake Simcoe.

Rainy lake is situated on the boundary between Ontario and Minnesota. Its area of 324 square miles is comparable with that of Lake Simcoe. During the years of 1908-28, the average annual fishery from the Canadian waters, 267 square miles, of Rainy lake was 584,000 lbs. valued at $43,700.00. The composition of this catch has remained fairly constant, being composed of 29% pickerel, 24% pike, 17% whitefish, 16% ciscoes, and 14% mixed and coarse fish. Lake Simcoe, 280 square miles in area, yielded over the past sixty years an average fishery of 148,000 lbs., with an average value of $9,000. For equivalent areas the fishery in Rainy lake is 7.3 times as great and is worth 5.1 times as much as that of Lake Simcoe. It might be said that it is unfair to compare the catch in Lake Simcoe over sixty years with that in Rainy lake over twenty years. We should therefore consider the catch in Lake Simcoe, from 1880-1900, *i.e.*, twenty years at the first of its commercial fishing period, with the fish caught during the first twenty years of fishing in Rainy lake, *i.e.* 1908-28. During these two periods of twenty years, Rainy lake yielded 584,000 lbs. of fish per annum to 100,000 lbs. from Lake Simcoe, representing for equal areas a production of 5 to 1, the same ratio found in the former calculation. It must also be remembered that Rainy lake not only produced five times as much fish over a period of twenty years, but at the end of that time the fish fauna was apparently the same as at the beginning, while the smaller fishery in Lake Simcoe caused a depletion which still exists. The question arises as to whether this greater fish crop is due to the inherent productivity of the lake or to a better utilization of its possibilities.

The outline of Rainy lake is so irregular that the open-water areas are seldom more than four miles in width. The irregular shoreline has a length of about 790* miles, which, for a lake of 324 sq. miles in area, represents the enormous shore development of 12.4 (page 10). By including the shorelines of

*Measured from a map—scale 2 miles = 1 inch.

the numerous islands, the total reaches a length of 1,030 miles, a development of 16.1. The shoreline of Lake Simcoe is 144 miles (including islands), a shore development of only 2.27. A greater shore development indicates a greater proportion of protected bays, a heavier growth of aquatic vegetation and a correspondingly greater production of food organisms. The depth at Rainy lake is less than 15 metres over most of its area and the average depth is probably not more than 10 metres. From the depth and area relation, as stated on page 106, it is obvious that Rainy lake would be much more productive of bottom fauna than Lake Simcoe, both because of its lesser depth and its much greater shore development. It is conceivable that these physical advantages would enable Rainy lake to support an annual fishery worth $42,000, while Lake Simcoe is depleted by a fishery of $9,000. A second possibility has been mentioned above, that the productive capacity of Lake Simcoe may have been less efficiently utilized.

The shallow-water fish in Lake Simcoe, bass and carp have borne the brunt of the game and commercial fishing in the past twenty-five years. During this period the average annual catch of carp was about 68 tons. Over the same period, the average annual catch of trout was 7 tons and of whitefish 2.5 tons. It is obvious that the whitefish is the only desirable fish which utilizes the bottom food in deep water and that the trout is the only useful fish which, by feeding on the ciscoes, makes use of the plankton of the open water. If the carp and bass make use of the water down to a depth of 10 metres, and they rarely go so deep, there still remains a deep-water area of 200 square miles, 71% of the lake being deeper than 10 metres, from which less than ten tons of fish are taken annually. This 9.5 tons of trout and whitefish from 200 square miles of deep water is to be contrasted with 86 tons of carp and an unknown quantity of bass from the remaining 80 square miles. It would seem quite clear that a properly controlled gill net fishery for trout and whitefish would be an advantage in Lake Simcoe.

From the above data, it would seem probable that the small quantity of fish taken from Lake Simcoe as compared with that taken from Rainy lake, is due both to the greater productivity of Rainy lake and to the incomplete utilization of the resources of Lake Simcoe.

FISH CULTURE IN LAKE SIMCOE

Fish culture in its widest and most useful sense is concerned as much with the utilization and conservation of the fish fauna as with the more widely recognized phase, that of rearing and planting fry or fingerlings. The present survey deals with only one phase of the conditions affecting fish life in a thorough manner. This phase, the food supply, is so fundamental in its effects that its investigation leads to a considerable understanding of the "fish condition" of the lake. The following discussion combines this understanding with observations on the limnology and the fish of the lake in an attempt to indicate what has been and may be done in fish culture in Lake Simcoe.

THE SMALL-MOUTHED BLACK BASS

The early abundance of bass in Lake Simcoe is indicated by the average annual catch between the years 1868-1908 of $2,430, or 27% of the total fishery of the lake. At the present time a small number of bass is taken by anglers, their scarcity being demonstrated by the small numbers of anglers now attracted to the lake. This depletion, as has been suggested, is due both to the overfishing in former years and to the inroads of the carp, which appears to have crowded the bass off some of its former feeding and spawning grounds. The extent to which spawning has been interfered with is not known, although some of the better grounds have not been molested.

If restricted spawning is the factor that is suppressing the numbers of bass in Lake Simcoe, we might expect the introduction of fry to have beneficial effects. The following bass fry have been planted in Lake Simcoe:

1916	200,000
1917	100,000
1920	30,000
1921	25,000
1922	5,000
1923	5,000
1924	2,500
1926	500

While we have no means of estimating the result of this planting, it may be significant that many more bass were caught in 1928 than in any of eight years previous, while during the years preceding 1928 planting was at its lowest. Apparently the bass made some recovery of their own accord.

The value of bass fishing in Lake Simcoe is such that it deserves the best of protection. This protection is especially needed during the spawning period and throughout the twenty-day period after spawning, during the first days in which the eggs hatch and the young leave the nest and during the last days in which the male bass protects the young brood.

The Department of Game and Fisheries in 1927 advanced the open season for bass from June 15 to July 1. In 1928, observation of the bass at Beaverton indicated that on July 1 only a small proportion of the adult bass had spawned. This would seem to indicate that for some years at least, July 1st as the opening date is too early for the adequate protection of spawning and immature bass in Lake Simcoe.

THE CARP

The rapid increase in numbers of carp following their introduction about 1896 has already been mentioned, as has the fact that carp make up 81% of the value of the present commercial fishery in the lake. Although the flesh of the carp is of a very inferior quality, the fishermen are able, by marketing them alive, to obtain as much as 10 or 12 cents per pound for their catch.

While the carp interfere little with the fish fauna of the deeper water it is a menace to the bass by crowding the latter off its feeding and spawning grounds. The relative values of the present carp fishery, $8,100 annually, and the bass fishing, the value of which in attracting summer visitors is quite inestimable, is a difficult question. Should we decide that the bass were of more value than the carp, it is doubtful whether it would be possible to exterminate or greatly reduce the numbers of carp. Further, if the carp could be reduced in numbers, it is again doubtful whether the bass fishing could be restored to what it was prior to the inroads of the carp. Due to the fact that it is impossible to seine in much of the grounds inhabited by carp, it is unlikely that it could ever be satisfactorily kept down, although allowing the fishermen to take it during the spawning season would tend to reduce its numbers to some extent. Such a policy could not be recommended at present in view of the doubt as to the possible restoration of the bass.

The carp interfere with the other fishes of the shallow water by stirring up the bottom mud and uprooting the aquatic vegetation. They have destroyed completely the wild-rice beds in Cook's bay and several recent attempts to re-introduce this plant have been frustrated by the rooting tendencies of the carp.

THE LAKE TROUT

While the opinion of residents on the lake is that the trout are very much depleted, experimental gill net settings indicate that they are still present in moderate numbers. The impression of scarcity is derived from the difficulty with which trout are taken on a troll or by spearing through the ice. It is thought that this difficulty is due in part to the moderate numbers of fish and in part to the abundance of their food supply. The number of ciscoes taken from the stomachs of trout supports the latter view. It has been suggested that the moderate population of trout is due to some condition which interferes with the production and development of the young trout up to a size at which they can begin to feed upon the cisco. Although this theory appears to be quite plausible, it cannot be tested till the life-history of the lake trout has been worked out.

In view of the fair numbers of adult trout and the very numerous and suitable spawning grounds, it is doubtful whether stocking with fry is to be recommended. During the past ten years some 2,110,000 lake trout fry have been planted in Lake Simcoe, mostly along the shores. In at least two cases, the fry were "dumped" off the dock and numerous perch were observed to have eaten a large percentage of them in a short time.

THE WHITEFISH

The whitefish are still abundant in the lake and the fishermen turn to them when they find the trout too difficult to capture. The small size attained by whitefish in Lake Simcoe is remarkable, the average weight of adult fish being only 1 lb. 2 oz. Since the larger whitefish in our Great lakes and in Lake Nipigon depend in part on the amphipod, *Pontoporeia hoyi*, for food, the absence of this species in Lake Simcoe may have some effect in limiting the size of the whitefish. It is thought more probable that the small size is due to an overcrowding and a resultant competition for food. Such condition is said to be responsible for the small size of perch in many lakes where that species is numerous (Dymond, 1926). In view of this small average weight it is obvious that the minimum weight limit for whitefish in Lake Simcoe should be not more than one pound instead of the two pound limit as enforced in the Great Lakes.

The present annual catch of 2.5 tons of whitefish is almost negligible when one considers the large area of deep water in Lake Simcoe. It is suggested that a limited amount of gill netting for whitefish in Lake Simcoe would be an advantage in increasing the fish crop of the lake, by removing some of the suckers and ling and possibly by allowing the whitefish, with less competition, to reach a larger average size.

THE PICKEREL

In the years 1921-24, a total of 2,400,000 pickerel fry were planted in Lake Simcoe, the largest lot being 1,000,000 introduced in 1924. This action seems hardly justified in view of the fact that the few pickerel which occurred naturally in the lake some fifteen years ago failed to thrive. Moreover, there is no barrier to prevent the pickerel from Lake Couchiching entering Lake Simcoe should they find the latter a suitable habitat. Apparently none of the fry introduced have been seen since although they have had plenty of time to reach maturity.

THE MASKINONGE

The maskinonge (lunge), abundant thirty years ago, is at present very scarce in the lake, being practically confined to the Holland river and the lower end of Cook's bay. It is doubtful whether this fish could ever be re-established in the lake under present conditions.

THE RAINBOW TROUT

The scattered specimens of the rainbow trout taken near Orillia may be regarded as indicating that at least a few of the fry of this species, planted in the lake, were able to reach maturity. In view of its fine game qualities, a characteristic quite lacking in the larger lake trout, it would seem advisable to make an attempt to establish this or a closely related species in Lake Simcoe.

SUMMARY OF PART III

As a result of the above considerations, the following conclusions have been reached with regard to the fisheries of Lake Simcoe:

1. In the early years, 1868-1908, the game fish, bass and maskinonge, were greatly overfished in Lake Simcoe.

2. This overfishing, combined with the introduction of carp, 1896, has resulted in an almost complete destruction of the maskinonge and a great depletion of the bass.

3. During the last twenty years, the carp has provided 81% of the value of the average annual catch and in doing so has made up in quantity only for the damage it has caused to fishing in the lake.

4. While Lake Simcoe is undoubtedly less productive of fish and fish food than some other lakes of similar area, a second reason for the small annual catch is the failure to utilize the fish supported by the deep water areas.

5. Both the public and the lake itself would benefit by a limited gill-net fishing for whitefish and trout.

6. The planting of most species, especially in the fry stage, in Lake Simcoe is probably not justified, a possible exception being the rainbow trout, which might be a desirable addition to the present fish fauna.

GENERAL SUMMARY

The subject has been treated in three parts. *Part I* deals with the bottom fauna, its composition, distribution and quantity as well as the factors responsible for this composition, distribution and quantity. *Part II* is a discussion of the position of bottom fauna in the ecology of the lake and an application of our knowledge of bottom fauna to some of the problems of nutriment or food circulation in lakes. *Part III* includes certain data as to the fisheries of the lake and combines these data with the results of the bottom fauna survey in explaining the past depletion of the fish fauna in Lake Simcoe and in making certain suggestions as to the future of fish culture in Lake Simcoe.

The results and conclusions of each aspect of the investigation have been summarized at the end of each part on pages 117, 153 and 174, respectively.

The substance of the paper may be suggested as follows: Lake Simcoe is 280 sq. miles in area and has an average depth of 17m. (54 ft.). Its shores are much exposed, due to the broad expanse of open water, and its water is clear, cool and slightly alkaline. A marked thermal stratification occurs in the lake at midsummer with a resultant lowering of the oxygen supply in deep water.

The bottom fauna of the lake comprises a large number of species and groups, the shallow water supporting a much more varied fauna than the deep water. The fauna of deep water in Lake Simcoe is composed of a larger number of species than that of small, more completely stratified lakes, probably due to the oxygen content which, though scanty, is never completely lacking in Lake Simcoe.

The intermediate size, exposure to water movements and the small quantity of oxygen in the deep water are the factors which are chiefly responsible for the nature of bottom fauna in Lake Simcoe and for the differences between its fauna and that of other lakes. The fairly rich bottom fauna and plankton, the low oxygen content of deep water, indicate that Lake Simcoe is an eutrophic lake. The distribution of the bottom fauna as compared with that of typical European eutrophic lakes substantiates this conclusion.

The quantity of bottom fauna over all depths in Lake Simcoe is 12.38 kgm. dry weight per hectare exclusive of mollusc shells. Chironomid larvae make up 65 per cent. of this quantity, Mollusca 18 per cent., and the remainder is composed of ephemerid nymphs, Amphipoda, Oligochaeta and *Corethra* larvae. It has been shown that lakes usually possess a quantity of bottom fauna which is proportional to the product of their depth and area, and that the quantity of bottom fauna in Lake Simcoe is as great as would be expected in a lake of this size. It has been estimated that the annual production of bottom fauna in Lake Simcoe is approximately 30 kgm/ha dry weight as compared with the average fauna of 13.38 kgm/ha throughout the months May to October.

The circulation of food in a lake is a very complex series of cycles, a suggestion of which is given in diagram 3 (page 122). The amount of nutritive material in the form of living plankton and bottom organisms is very small, perhaps 0.5 per cent., as compared to the amount of nitrogeneous organic material dissolved in the water and present in the upper 5 cm. of the bottom ooze. The rate of circulation of nutritive materials depends on a large number of factors, among which

the trophic condition of the lake, the temperature and the length of the growing season are very important. The utilization of successive forms of food material varies greatly in different lakes, resulting in what has been termed a "disharmony of production." The quantity and quality of bottom fauna in a lake is to some extent indicative of the richness or the amount of nutritive material in circulation, but it should be used in combination with other indices.

Fishing in Lake Simcoe has had an unusual history during the past sixty years. During the first forty years the game fish were greatly exploited. Of the annual catch of 55,000 lb., valued at $9,000.00, bass and maskinonge made up 46 per cent. During the last twenty years the annual catch of 234,000 lb., valued at $10,000.00, has been chiefly composed of coarse fish, 81 per cent. carp. Overfishing in the early years and the introduction of carp about 1896, have completely destroyed the maskinonge fishing and depleted the bass and trout to a considerable extent. The present small catch of fish is due in part to a failure to utilize the fish of the deep water so that a limited gill-net fishing for whitefish and trout has been recommended. Planting of fry in the lake is not recommended with the possible exception of the rainbow trout.

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Plate I.

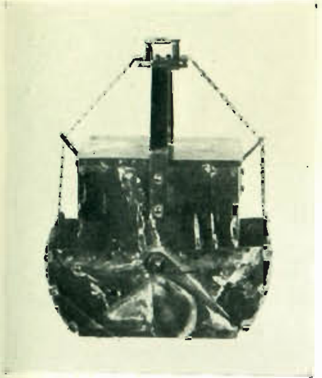


Fig. 1. Ekman dredge open.

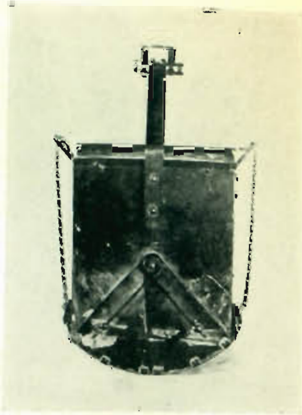


Fig. 2. Ekman dredge closed.

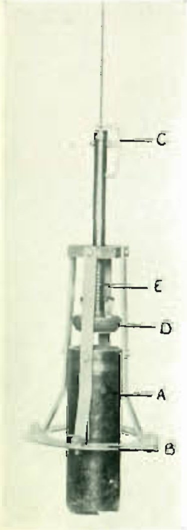
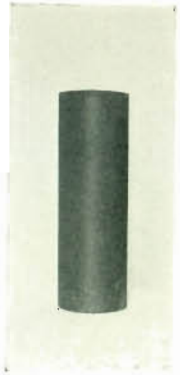


Fig. 3. Heavy sampler "set."



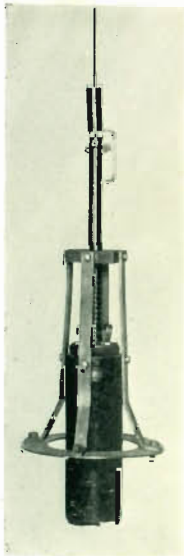


Fig. 4. Heavy sampler released.

Fig. 5. Shell for sampler.

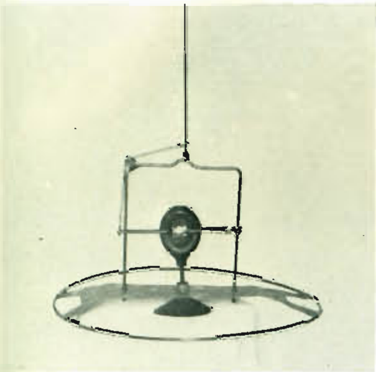


Fig. 1. Ooze sucker "set."

Fig. 2. Ooze sucker released.

Fig. 3. Funnel and bulb of ooze sucker.

Fig. 4. Triangular mouth tow net.

Fig. 5. Bottom net with sheath folded up.

Plate III.

Portion of exposed rocky shore of Lake Simcoe.

PLATE IV

Fig. 1.—Fishing for ciscoes on the bay at Atherley, July 1, 1928.

Fig. 2.—A "catch" of ciscoes.

Plate V

Fig. 1.—A fish-house used for fishing through the ice.

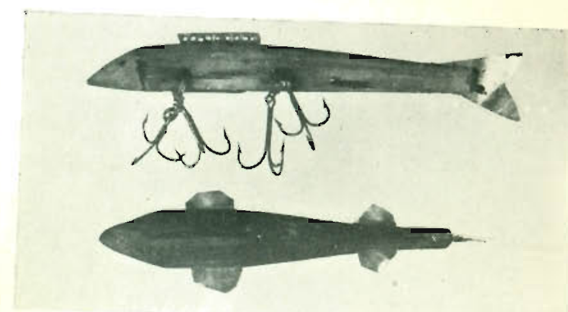


Fig. 2.—Home-made decoys used for trout fishing.