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A PLAN FOR THE BIOLOGICAL INVESTIGATION OF THE WATER AREAS OF ONTARIO

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During the past two years a considerable amount of attention has been given to the organization within the Department of Biology of the University of Toronto of a research branch to be devoted to the investigation of the water areas of Ontario with reference to existing biological conditions and economic problems. It has been proposed to carry on the work of this branch under the title "Ontario Fisheries Research Laboratory", some distinction being necessary to indicate its scope and outlook, as also to draw a line of demarcation between this and other interests of the Department, and being especially advisable in view of the work now conducted in marine biology. Moreover a special name is advisable in order to establish a basis for the better classification of publications which in this instance may be expected to appeal for the most part to those interested in general limnology or in conservation and fishery problems. Apart from the provision of apparatus and equipment the initial step in the formation of the new organization was the appointment of Professor W. A. Clemens as Limnobiologist, an arrangement which renders possible full time service and supervision of field operations at any part of the year, and also provides for continuous investigation of the collected material and data. The first reports of a technical nature are now in course of publication. They refer principally to some special fisheries work on Lake Erie, but will be followed by a series of papers dealing with Lake Nipigon. The latter will be in a sense the products of the first field party, consisting of Professor Clemens and other members of the university and museum staffs who spent the greater part of the summer of 1921 in practical operations on the lake.

The study of the scientific aspects of fishery questions is one for which the University Biological Laboratory is

especially fitted. Its position as part of the provincial educational system identifies its interest in matters touching the natural resources with that of the province at large. Nearly thirty years ago the desirability of a systematic biological survey of the provincial waters was urged by Professor Ramsay Wright ('92), and in the interval the need of a thorough investigation of the factors underlying the distribution of aquatic organisms has become increasingly evident. Neither individual efforts nor the collective participation of members of the university staff in the work of the Georgian Bay Biological Station, which was maintained for some years in that region, led to the consideration of any measures upon which the hope of a continuous if not permanent organization for the biological investigation of provincial waters could be based. That the latter now appears within the range of possibility is therefore a matter of some satisfaction.

The following pages are devoted to a general discussion of the proposed line of investigation. This is mainly a matter of the relation of limnology at large to local conditions as represented by the waters of the Province of Ontario, with particular reference to general and economic problems. The principal topics considered are (a) the relation of the proposed investigation to the practical and administrative aspects of conservation, (b) the foundations of limnology, (c) the extent of the local fish fauna, and (d) the chief physical features of the provincial water areas, including, first, the provincial portions of the Great Lakes and, second, the land-enclosed areas, from the point of view of their limnological study and the nature of economic questions. Except in the case of the fishes, which occupy a central position in respect of the economic outlook, no reference will be made to particular groups of organisms.

The distinction often made between theoretical and applied or economic considerations is generally recognized as purely a matter of convenience in description. Its value, if any, consists in denoting the purpose or outlook implied. There is, however, a relation between investigation of an

economic kind or purpose and practical or administrative measures. In Canada, as elsewhere, various questions, partly of revenue, partly of control of exploitation of natural resources, wastefulness and many other matters having to do with natural wealth, gave rise long ago to regulative measures, and more recently to a public movement in the direction of conservation. More intricate perhaps than in other fields, because of the elusiveness of wild life and the obscure factors upon which its success depends, the problems of conservation as applied to living organisms were early recognized as involving scientific knowledge of an exact kind. On the other hand, the desire to arrive at what would usually be considered expert information has, in a great many instances, painfully evident in the literature of conservation, given rise to confusion as to the extent and method of its application, resulting in the concealment of many sound practical ideas in a mass of information relating to general natural history. Measures of conservation as applied to the fisheries, including under the term also regulatory legislation, which has or ought to have a similar effect, consist broadly in striking a reasonable balance between forces of utilization and those of natural and artificial replacement. In this process the administrative function is the first necessity; technical practice, as, for example, fish breeding and economic industrial processes, is next in order of urgency, while scientific investigation is accessory or contributory. Its value consists in the analysis of all factors physical, chemical and biological, and in drawing attention to particular factors the neglect of which may result in ineffective practice or futile legislation.

The early development of fresh water biology in Europe, in many respects the foundation of similar work in America, established first of all the identity and distribution of the various species of aquatic organisms, and, second, the association of these organisms with environmental conditions; to a certain extent also it carried out the classification of these conditions on the basis of their mutual associations. After nearly one hundred years of individual, and for the

most part isolated, effort on the part of early biologists, among whom will be found some whose names are foremost in the records of biological science, it gave rise, mainly through the efforts of Forel, Apstein, Zacharias, Zschokke and others, to an attempt at correlation of limnological results, best expressed by Zacharias ('91) and his co-workers in their compilation dealing with the fauna and flora of fresh water. The extensions of this earlier work not only resulted in a more thorough enumeration of species in local European areas, but also gave rise to the study of physical and chemical factors, environmental communities, plankton determination, and the formal and institutional recognition of limnology, as best exemplified by the complete limnological study of Lake Geneva by Forel ('92) and the establishment through Zacharias ('93) of the Biological Station of Plön after the pattern of the marine institution at Naples.

American limnology, which naturally had a later origin, has the same foundation and in some respects a similar development. That it may be said to have only recently arrived at the stage of collective recognition is due to a variety of circumstances, including no doubt the great area to be covered in the classificatory study of the various groups, and the fact that the accumulation of information bearing in one way or another upon general limnology, as, for example, in the fisheries, natural resources in general, conservation and the like, has been almost from the beginning the particular interest of government bureaus, and of surveys and commissions under state or national auspices. Though the study of the water areas as entities, or complete physical-biological complexes, has not yet arrived at a stage of development commensurate with its great importance, its recognition is at least assured. As long ago as 1887 the principle was advocated by Professor Forbes ('87) and its application is observable in his later work ('08) in association with Richardson, Kofoid ('03) and others on the Illinois river system. The same principle is exemplified in the work of others, some of whom owe their inspiration to the example of Professor Forbes, including that of Reighard ('94) on

Lake St. Clair, Ward ('96, also '18) on Lake Michigan, Birge and Juday ('11) on the inland lakes of Wisconsin, the study of physical factors and their association by Needham and Lloyd ('16), Shelford ('13) and Adams ('13), and finally the recent work of Evermann and Clark ('20) on Lake Maxinkuckee, Indiana, in some respects the most complete study of an individual lake yet available in America. Not a small part in the collection of data bearing upon limnology has been taken by state organizations, by the establishment of temporary or permanent biological field stations (Ward '98, Needham and Lloyd '16) and the recognition of the state university as the natural centre of such investigation. On the other hand, while the results of investigation wherever conducted have at least some measure of general applicability, it is unfortunate that the study of limnology has not proceeded along more uniform and better organized lines. The paucity of information concerning the water conditions of all the Canadian Provinces and certain of the States is in marked contrast to the extensive information available in respect of certain States, notably Illinois and Wisconsin. What is chiefly significant, however, is the contrast between European and American efforts in general in view of the opportunities offered. If there is any one single outstanding fact concerning the importance of American water areas, it is the fact of the existence of a mid-continental area of some 80,000 square miles represented by the Great Lakes of the St. Lawrence basin. Parts of a great international waterway, locally shared by one Canadian province, and eight states of the Union, the centre of an old established fishery, the Great Lakes constitute in all respects the outstanding fresh water area of the world. Had the example of Forel and of Zacharias been followed we should have had available on the Great Lakes either an extensively equipped limnological institution or at least some specific organization devoted to the study of the area in all its aspects. The question is not one of simply local concern, though it is evident from geographical considerations

that it is one in which the Province of Ontario is vitally interested.

While various groups of aquatic organisms are directly or indirectly involved in questions of an economic kind, it is obvious that the fishes are the ones chiefly concerned. To what extent are they represented in Ontario? The commercially recognized fishes, including the more desirable species, lake trout, whitefish, ciscoes, tullibee, doré and sturgeon, as well as the coarser species, pike, carp, mullets and catfish, and the game fishes, principally speckled trout, small and large mouthed bass and maskinonge, are collectively a small, though very important part of the local fauna. The number of fish species, fresh water and marine, occurring in Canadian and Newfoundland waters, is stated by Halkett ('13) to be 569. Evermann and Goldsborough ('07) place the number of fresh water species occurring in Canada as a whole at 145, representing 67 genera and 25 families. In the first computation of the number occurring in Ontario (Wright '92) reference is made to forty or fifty species, but the local records were at that time very incomplete, and the computation was doubtless based to some extent on the earlier reference compilation of Jordan and Gilbert ('83) later greatly extended and revised by Jordan and Evermann ('96). The most complete index of Ontario fishes is that of Nash ('08), based partly on the foregoing compilation checked against collections from various points in the province. The total number is placed at 112, representing 69 genera and 26 families. Though this computation precedes some other taxonomic work, notably that of Jordan and Evermann ('11), and though much is yet to be done in the matter of critical diagnosis of species from individual areas, it is probable that the number of species occurring in Ontario is in the neighbourhood of 125. While this representation is fairly large as to species and apparently very inclusive as to families and genera as compared with Canada as a whole, it is probable that the number of species occurring at any one point is less than half the total. The number reported by Nash ('13) for the Toronto region is 49 and

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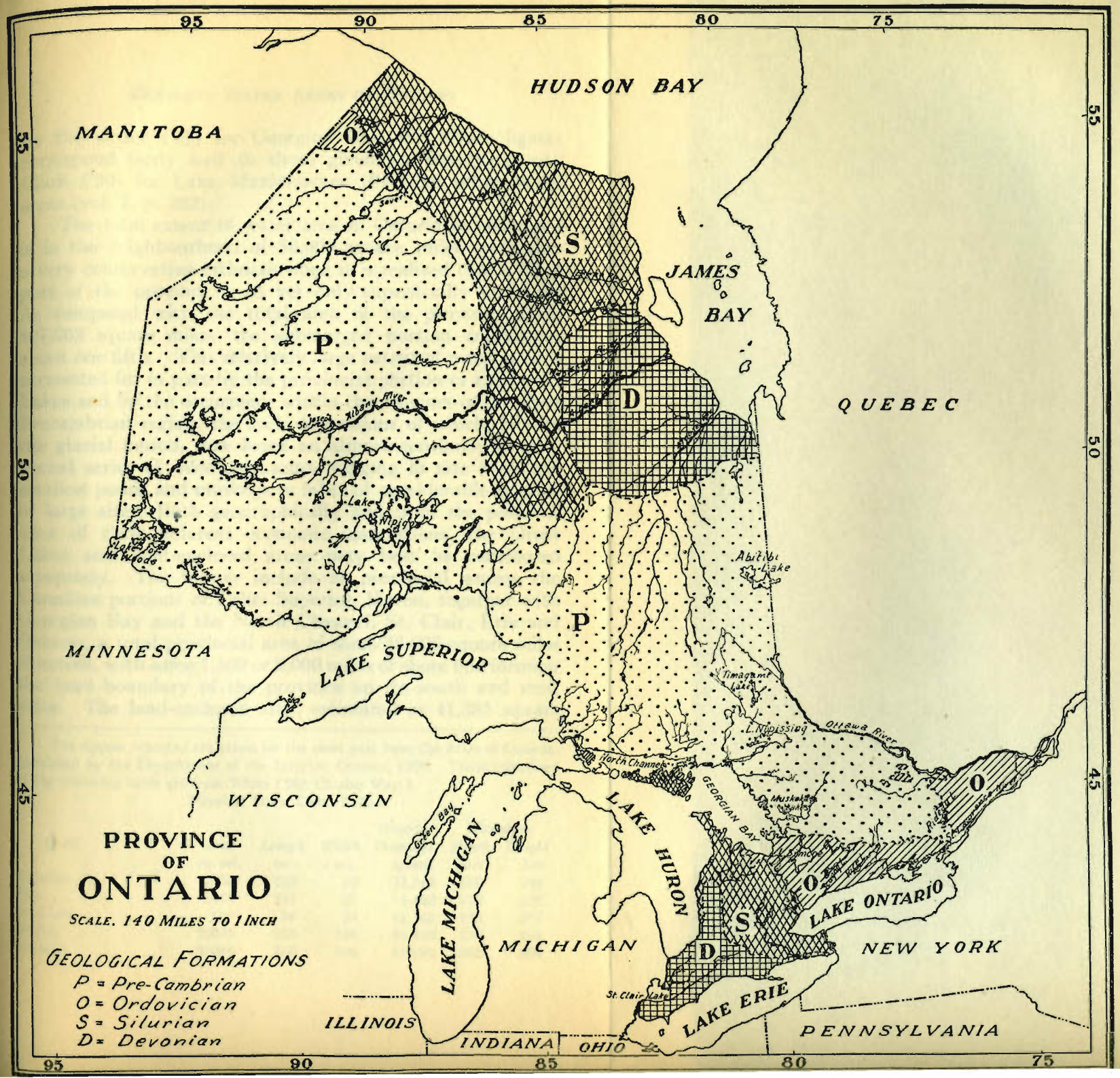
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HUDSON BAY
MANITOBA
JAMES BAY
QUEBEC
MINNESOTA
LAKE SUPERIOR
WISCONSIN
LAKE MICHIGAN
LAKE HURON
MICHIGAN
LAKE ONTARIO
NEW YORK
LAKE ERIE
PENNSYLVANIA
ILLINOIS
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Ottawa River
North Channel
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Green Bay
St. Clair Lake
PROVINCE
OF
ONTARIO
SCALE. 140 MILES TO 1 INCH
GEOLOGICAL FORMATIONS
P = Pre-Cambrian
O = Ordovician
S = Silurian
D = Devonian

by the writer ('15) for Georgian Bay 48. These figures correspond fairly well to those given by Evermann and Clark ('20) for Lake Maxinkuckee (64) and other single areas (vol. I, p. 262).

The total extent of water area in Ontario as estimated is in the neighbourhood of 80,000 square miles,[1] probably a very conservative estimate when it is realized that a large part of the province is as yet only superficially surveyed. As compared with the total area of the province itself, 407,262 square miles, the submerged portion constitutes about one fifth. This relatively large extent of water area is accounted for in part by the provincial portion of the Great Lakes and by the occurrence within the province of the great Precambrian region, the rock depressions of which, left by the glacial period, now lodge an almost continuously connected series of overflow basins, ranging in size from the smallest ponds and muskegs to lakes of considerable or even of large size. Both geographically and from the point of view of their different economic associations, the Great Lakes and land-enclosed areas may best be considered separately. The former include as provincial waters the Canadian portions of Lakes Superior, Huron, together with Georgian Bay and the North Channel, St. Clair, Erie and Ontario, a total provincial area of some 38,000 square miles in extent, with some 1,500 or 2,000 miles of shore line forming the land boundary of the province on its south and west sides. The land-enclosed area, estimated at 41,385 square

[1]The figures reported are taken for the most part from the Atlas of Canada; published by the Department of the Interior, Ottawa, 1906. Those contained in the following table are from White ('05). Cf. also Map I.

Physical Data, Great Lakes

Lake	*Area*	*Length*	*Width*	*Ontario Drainage*	*Maximum Depth*	*Height*
	sq. mi.	*mi.*	*mi.*	*sq. mi.*	*feet*	*feet*
Ontario	7053	193	53	11,342	738	246
Erie	9968	241	57	5,480	210	572
St. Clair	503	26	24	41,160	180	575
Huron	22978	206	101	35,400	750	581
Superior	32060	350	160	30,780	1012	602

miles, includes lakes and rivers distributed unequally over a land area which for convenience may be divided into five portions, each having a more or less definite facies, depending originally no doubt upon the geological foundation and the final effects of glacial action. These portions are:—

(*a*) The south western peninsula, or that portion lying to the west of a line connecting the south end of Georgian Bay with the north shore of Lake Ontario to the west of Toronto. This portion comprises the older agricultural part of the province, is noteworthy for the paucity of water areas, and is underlain by strata of Silurian and Devonian age (cf. Map II)* covered by glacial soil deposits of considerable thickness. It is also that portion of the province having the principal frontage on the Great Lakes.

(*b*) A portion lying to the south of a line connecting the southern end of Georgian Bay with Lake Ontario in the region of Kingston. It forms the north shore of the larger part of Lake Ontario, contains some characteristic lakes, including Simcoe (300 square miles), Rice (27 square miles) and Scugog (39 square miles), is underlain by Cambrian and Ordovician strata, and is transitional in many ways between the portion already described and the Precambrian area to the north.

(*c*) The northern Precambrian area of relatively great extent, including the Laurentian Highlands, and characterized by its exposed igneous and metamorphic rocks with innumerable lakes distributed over its surface. The larger lakes include Nipissing (330 square miles) and Nipigon (1,730 square miles).

(*d*) A north west portion containing the Lake of the Woods (1,851 square miles) and similar water areas lying beyond the height of land, and related both in aspect and origin (Lake Agassiz) to Lake Winnipeg and other lakes with the drainage system of which they are connected, though underlain by rock formations similar to the foregoing.

*Prepared under the supervision of Professor W. A. Parks, University of Toronto.

(*e*) The Hudson Bay drainage area, a region characterized by the broad coastal plain, and on the whole moderately inclined river basins of the Severn, Moose and Albany Rivers, and underlain in part with strata of Devonian age, an area hitherto, on account of its inaccessibility, only superficially considered in its relations to the province, but presenting as a matter of fact some 600 miles of provincial marine coast line.

From the point of view of limnological investigation the Great Lakes offer almost unlimited opportunity. Except for the identification of aquatic organisms and, at least to some extent, their distribution, the most detailed information concerning the lake area refers to soundings and levels,[1] of importance in navigation, water supply and sewage disposal, of interest to municipalities, and practical matters relating to the fisheries.[2] Information is desirable concerning a great variety of physical factors, depth and seasonal variation of water temperatures, suspended materials, dissolved substances and absorbed gases, light penetration, substratum, as well as dynamic forces concerned in transportation of materials, water currents and circulation. Of especial importance are also environmental or ecological associations, in respect of which there are not only great local variations entering into the life cycle of organisms, but also marked general contrasts between individual lakes as complete environmental entities on a large scale. Thus even a superficial comparison of Lake Superior with Lake Erie in respect of their geographical position and physical characteristics reveals contrasts of geological formation, depth, transparency and temperature, the last-named

[1]Admiralty, Dominion and United States Charts, listed Department of Naval Service, Catalogue of Official Canadian Government Publications of Use to Mariners, Ottawa, 1920. Cf. Report of the International Waterways Commission, same reference; also Russell ('93), White ('15).

[2]Reports of Dominion Department of Marine and Fisheries, Department of Naval Service, Commission of Conservation, United States Bureau of Fisheries; Ontario Department of Game and Fisheries, Geological, Natural History and Fish Commission publications of individual States.

difference doubtless involving several factors in addition to the more obvious ones of depth and maximum latitude difference amounting to some eight degrees. Furthermore the development of the Great Lakes is one of the most interesting chapters of glacial history, and one which will be found to bear very directly upon the origin and history of the fauna and flora, especially the origin of the northern fishes, their migrations, spawning periods, the effects of natural barriers and of natural and artificial means of communication. The study of the origin of the life of the Great Lakes is in fact one of the most interesting of general scientific questions.

The significance of the provincial great lake area from the point of view of economic research is indicated both by the extent and value of the commercial fisheries and by the measures already adopted by the Dominion and Provincial Governments for the control of fishery operations and of the practical means of restocking. The annual value of the fisheries is subject to considerable variation, and it is necessary to examine the returns over a long period of years in order to form any real conception as to the possible relations to one another of the number of men engaged, gear, poundage of catch and probable supply. Taking the year 1918 as the last one for which figures for all the provinces including Ontario are available,[1] it is found for this year that the total value of the Ontario fisheries amounted to $3,175,111. As compared with the total for Canada of $60,250,544 this is approximately 5 per cent., a very creditable showing when it is realized that the latter figure includes the value of the Atlantic and Pacific marine fisheries, among the richest in the world. In relation also to the total for the fresh water fisheries of the Dominion, amounting in 1918 to $6,019,005, the Province of Ontario produced of this total an amount equal to 52.7 per cent., while the

[1]Fisheries Statistics, 1918, Dominion Bureau of Statistics, Ottawa, 1920. Cf. also Report of the Department of Game and Fisheries, Ontario, 1918; Toronto, 1919.

great lake fishery of the province alone produced 44 per cent. When it is considered that the Great Lakes are the mainstay of the commercial fishery, that this fishery has been cultivated assiduously for very many years, and that it is first to be considered in all measures of Dominion or provincial legislation, it is evident that there should be available not only detailed information concerning the natural occurrence, migration, growth stages and dimensions, time of maturity, local variations of the spawning period, as well as concerning the natural associations and enemies of every species of direct market value, but also full particulars of all species directly or indirectly serving them as food.

The land-enclosed water areas, though they at least equal, and in all probability greatly exceed the combined areas of the provincial portions of the Great Lakes, are so varied and irregularly distributed with reference to the topography of the country otherwise that they can scarcely be treated as having conditions in common. With the exception of the Lake of the Woods and Rainy Lake, which are boundary waters, they lie wholly within the province. They have a certain facies depending on their respective relations to the underlying substratum and rock formation, which in Ontario shows a marked contrast as between igneous and sedimentary, a contrast enhanced in every way by the extremes of soil formation and other effects of the glacial period. Some of the lakes as purely inland waters are of large size, notably the Lake of the Woods (1,851 square miles) and Nipigon (1,730 square miles), others though much smaller are nevertheless bodies of considerable magnitude, such as Rainy Lake (324 square miles), Nipissing (330 square miles) and Simcoe (300 square miles). Of the thousands of smaller lakes of perhaps less than 100 square miles in extent, some such as the Rideau waters are significant in the early development of the province, others are summer resort lakes of long standing, such as the Muskoka Lakes, while still others, like Lake Timagami are newer game fish areas of which hundreds have been made accessible within recent years through improvements of rail transportation.

Apart from any question of the utilization of the lake areas otherwise, as travel routes or for transportation of timber, the economic factors concerned are chiefly two in number, namely, in what way and to what extent are the lakes in general capable of utilization from the point of view of marketable fishes, and second, what restrictions must be made, or practical means adopted, for increased utilization of the areas for game fishing, considering the great revenue to be derived from the presence in the province of the summer resident and sportsman.

No limnological investigation of these collectively immense areas or indeed of any one of them has hitherto been attempted. Unlike the Great Lakes their waters have not been the object of hydrographic surveys even for determination of depth. Except for ordinary geographical information, what is known about the physical character of the inland waters is chiefly a matter of canals and water power. Though there have been a good many individual investigations dealing with particular groups of plants and animals, much more is known about the whole country from the standpoint of the traveller and sportsman than has been arrived at through scientific study. Every area which as a matter of development is subject to human interference, and this involves the extreme of conditions in areas like the Muskoka Lakes, which are relatively of long standing occupation and therefore of game fish depletion, as opposed to others which with the improvement of means of ready access, always the deciding factor, are now beginning to be occupied, should be thoroughly known from the point of view of the factors entering into the conditions of existence within its limits. The limnological study of such areas, on account of their easy transitions from ponds and puddles to lakes of sufficient magnitude to present typical lacustrine conditions, ought also to yield important data concerning the general stages of lake formation in different situations, and the relation to this development of the groups of aquatic organisms.

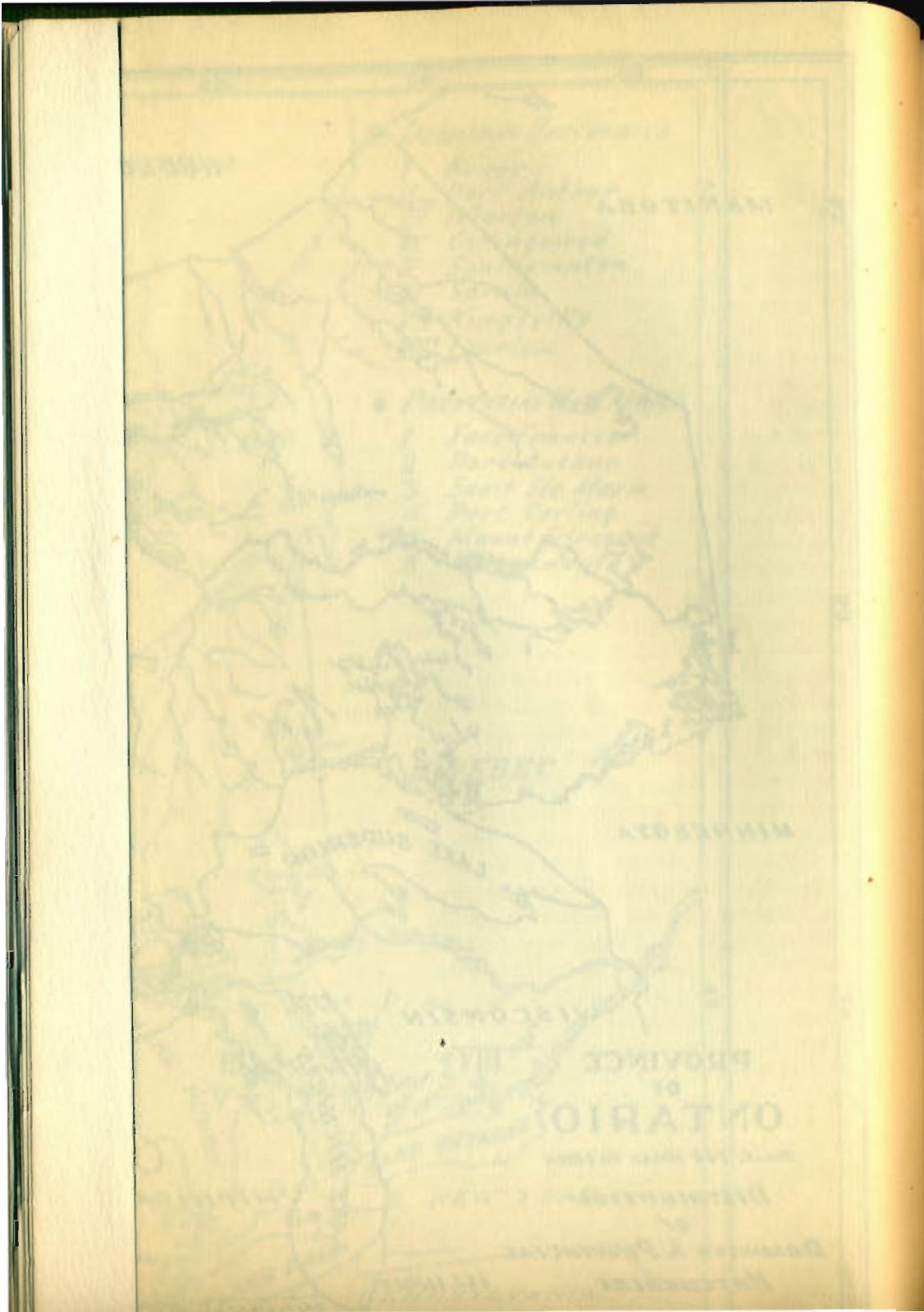
No comparative consideration of the annual yield of

marketable fishes coming from the land-enclosed waters of Ontario is worthy of attention which does not first take into account the principles adhered to in framing legislation which would establish the respective spheres of the sportsman interested in game fish waters and the commercial fisherman. Recognizing the Great Lakes as primarily adapted for commercial fishing, and at least some of the inland northern waters as most attractive and eagerly appreciated by the game fisherman, the principle naturally became established in Ontario of the reservation and protection of inland areas from commercial fishing both in respect of sale and the operation of ordinary types of gear. Fortunately in general this principle has been uniformly supported both in Dominion and provincial legislation. A first and very natural exception was made in the case of the Lake of the Woods and related waters, in part because of the predominance as in the Winnipeg area of fishes of a marketable type. A second exception of more recent origin was made in respect of Lake Nipigon and Lake Nipissing, though in general the inclusion of these areas was recognized as requiring close government supervision. On the whole it will be observable both from the small values presented for the commercial fishes and the evidence of large sums of money brought into the country by summer residents and sportsmen that the element of the commercial fishery is only a small part in the total revenue accruing to the province from the existence of the land-enclosed area.

The value of the fisheries of land-enclosed waters of the province was, in 1918, $503,858. This value amounts to about 16 per cent. of the total for Ontario as compared with 84 per cent. for the Great Lakes. Apart from the latter which give a decided advantage to the province, the total value of the fisheries of all land-enclosed waters of the Dominion amounted in 1918 to $3,347,600, of which the corresponding part of Ontario produced only 15 per cent. as compared with Manitoba's contribution amounting to 55 per cent., while Saskatchewan almost equalled Ontario at 13 per cent. Furthermore, of the total for the land-enclosed

areas of Ontario more than half, or $285,169 was produced by the Lake of the Woods and related waters, which, as indicated above, are in a similar position to the Great Lakes as regards the commercial fishes. Lake Nipigon accounts for $128,647, or roughly one fourth, while the balance, amounting to only $90,042 includes the product of Lake Nipissing, valued at $32,294. The sum of the matter is that, excepting some four or more of the principal lakes, the commercial product for the province as regards the inland areas is negligible; the real significance of these areas lies elsewhere.

So far as the economic aspects of the question are concerned the problems to be investigated in connection with the growth of fishes and related matters are exactly of the kind already outlined for the Great Lakes. But, in addition, the existence of a body of water both isolated in relation to other basins, and, because of its circumscribed boundaries, more naturally accessible to the commercial methods of fishing, gives rise to conditions which make the problem of balance and replacement more immediate. If the Great Lakes escaped total depletion before the advent of corrective measures, it was because the spaces were sufficiently vast in relation to the amount and efficiency of the gear employed to give the fishes most sought after some loop-hole of escape. In an enclosed area, even the size of Lake Nipigon, and the matter is more serious the smaller a lake becomes, it is evident that with continued fishing with modern gear, no large species, valuable or not, would have the least chance for survival, if not through the exercise of moderation, protection of small fish to sexual maturity, and practical propagation. More than this, the maintenance of the natural balance of all organisms is a matter of importance, whether as between predacious species and those feeding upon lower organisms, or as between spawn-destroying coarse fishes and others more desirable, or as between the various species of minnows and similar small species and the larger fishes which depend on them for food. In fact an enclosed lake is a small and complete world in itself. Whatever happens in the way of modification of its living contents, practically



in all cases a matter of human interference, the question of the balance of all organisms, and the balance between the poundage removed and that replaced by natural or artificial means is all important. Doubtless the closer study of conditions would also call into question the advisability of introducing into such area species not adapted either as young or fry to survive, or on the other hand give some point to the introduction of other species whose presence is desirable as marketable or game fishes or even to serve as food for such.

Conservation of the game fishes is quite as much an economic problem as that of the commercial fishes. That it is not usually so recognized is perhaps on the whole a matter of gratification, since it is evident that the protection of game animals and the freedom of the great natural playgrounds are principles which from the beginning have been accepted by legislative authorities. On the other hand no attempt has been made to determine in what respects the invasion of the game country by the tourist and sportsman results in improved circulation of money and prosperity to a larger area, nor to compute what must be a very large amount expended by the non-resident, and contributing to the wealth of the province, if not directly to the provincial treasury through the sale of lands and licenses. It is evident on all hands that the matter of organizing this source of revenue, in a certain sense of capitalizing the natural resources, is one which is being seriously considered elsewhere in America and in Ontario is well worthy of attention. In the game fishes of Ontario we have a wide natural distribution of certain species, notably speckled trout and black bass, and also the occurrence in areas not open to commercial fishing of species, notably lake trout and doré, which deserve to rank as game fishes. The local abundance of these species in the smaller lakes, from most points of view of the game fisherman also the more desirable lakes, is a matter of fundamental importance, since it is the deciding factor, or, if not, a very serious one, in establishing permanency of summer residence. The maintenance of the supply is also immediate

or urgent exactly in proportion as these lakes are frequented. Exact information concerning the complete life histories and the factors bearing upon their success or failure is essential for every occupied area. It is probable too that the communication of such information to the more permanent population would not only contribute to practical sentiment in the matter of conservation but also demonstrate the fact so generally neglected throughout the game country that the protection by the local inhabitants of the game animals is worth to them in money far more than their immediate utilization for food or sale.

Another question with which scientific investigation will ultimately have much to do is that of artificial propagation. Already a hundred years ago, before the settlement of the country was yet solidly established, the better fishes of the Great Lakes were recognized as an important source both of food and profit. By 1850, after a period in which the only restrictions upon the extent of capture were those imposed by primitive means of communication, the effects of excess and wastefulness were already evident. Notwithstanding the better organization of fishing administration from Confederation onwards (cf. Prince '20), by 1880 depletion began to be evident in all the Great Lakes, and questions of replacement became of increasing importance. Artificial propagation owes its inception in Ontario to Samuel Wilmot who began private hatching operations at Newcastle in 1865, and who later as a Dominion officer established the entire hatchery system. The development of this system and the steady increase of the output from year to year[1] has doubtless saved the commercial fishery of the Canadian portions of the Great Lakes from complete destruction. At the present time (cf. Map III) the Dominion system includes eight hatcheries[2] in Ontario, the output of which is supplemented by that of hatcheries established by the

[1]Cf. comparative figures, Fisheries and Game, Report of the Commission of Conservation, Canada, Ottawa, 1911.

[2]Cf. Annual Reports on Fish Culture, Department of Naval Service, Ottawa

Provincial Government to the number of six,[1] while the general supply of the Great Lakes is enormously augmented by the operations of various United States hatcheries under the supervision of the Bureau of Fisheries.

Fish propagation is a technical process, the more difficult because of its aquatic environment, and therefore demanding not only practical ability but also organization of method. The opportunity presented by a spawning period comes only once a year and if lost is irretrievable. The success of a single season's operations depends on controllable elements of precise organization and on uncontrollable factors such as weather, scarcity of spawners, hatchery accidents and the like. If it were possible to effect some organization of scientific work in relation to the hatcheries, an arrangement which would require considerable preparation, a contributory source of information would undoubtedly result which would be analogous in some ways to the usefulness of the agricultural experiment station to the practice of agriculture. Many sides of the hatchery question should be studied by investigators not bound to technical practice, having free time at the proper periods of the year, and provided with equipment adequate to the case; in other words, experimental hatchery work should be carried on with the same kind of equipment as that in regular use, but with additional facilities for scientific study. Bearing in mind that the object of propagation is not simply to make the fisheries hold out a few years longer, but to establish a balance between utilization and replacement, if not indeed an increased output, such as would be the aim of true pisciculture, it is evident that important sources of information are yet unavailable. The case of the hatchery and the commercial fishery is very much that of a mill in which the product is known but the extent or adequacy of the supply is unknown. In order to answer the question it will be necessary to know as nearly as may be practicable the percentage survival of fry and young at different stages and in localities differing both immediately

[1]Cf. Annual Reports, Department of Game and Fisheries, Ontario. Toronto.

and seasonally in respect of their physical characters. It will be necessary to know the true extent of depletion and of artificial increase by corrected figures indicating the poundage of the catch as modified by differences of the total amount of gear and its relative efficiency. There are, however, other considerations.

The recent developments of experimental embryology in relation to the behaviour and growth of aquatic eggs have shown to what extent these features are modified by physical differences in the surrounding medium, the constitution of the medium, absorbed gases and temperature. The investigation of such influences in its bearing upon the development of the eggs of desirable species under hatchery conditions would at least be of great scientific interest and most likely here and there of practical value. The same is true of the study of hybridization, the laws of which, under the influence of the recent work in genetics, are now much more clearly understood. In some of the fresh water fishes, notably *Salmonidae*, there are varietal, racial or environmental modifications which are almost baffling in their complexity, and which should now be thoroughly studied from a genetic point of view under experimental hatchery conditions. Finally the process of re-stocking which involves in part the utilization of young fish or fry, and to which reference has already been made, should be critically examined. While nominally a matter of assisting a natural replacement, the underlying idea is naturally expanded into that of the introduction into depleted waters of the same species from supposedly related waters; in which case it is a question whether the disturbance of the natural balance has not proceeded too far to ensure survival of the introduced stock, also whether as a matter of fact the physical conditions are similar, or if environmental differences are at the moment of introduction beyond the powers of adjustment of the organism. The case is analogous when it is a matter of the introduction of foreign species. Artificial transfer to a hitherto unoccupied area may overcome for the introduced species a natural barrier, permitting it to attain a dominance over

native species perhaps more desirable, or it may readily happen that the desire to introduce a species of recognized merit from elsewhere overcomes the obvious reflection that the new environment is perhaps not suitable in any way, resulting in a process not very different in principle from liberating an infantile south sea islander on the shore of Hudson Bay. One of the recent pronouncements on this point is that of Evermann and Clark ('20, vol. I, p. 279). Concerning Lake Maxinkuckee these authors state:—"Four plants of lake trout aggregating 10,587 fish have been made in this lake. So far as we have been able to learn there is no evidence that any of these survived; there is no authentic record of the capture of a lake trout in this lake. If the physical and biological conditions obtaining in Lake Maxinkuckee had been as well understood before the lake trout were planted, as they are now, those plants would not have been made." The records of failures as well as the sometimes uninformed opposition to hatchery measures should be equally considered and a serious attempt made to bring together all facts and factors, practical and scientific, which bear upon the maintenance of natural balance in every area of economic importance.

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