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Article abstract

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FISHERIES AND FUNDAMENTAL SCIENCE: DONALD RAWSON'S STUDIES OF LAKE PRODUCTIVITY

Stephen Bocking[1]

ABSTRACT

Between 1930 and 1960 Donald Rawson was the leading limnologist in Western Canada. His work in the Fisheries Laboratory of the University of Saskatchewan between 1948 and 1960 is of particular interest. Through his surveys of lakes in his province he was able to contribute to development of theoretical concepts of lake productivity, while providing results useful to the provincial fisheries management agency.

RESUME

Entre 1930 et 1960 Donald Rawson était le plus grand limnologue de l'ouest du Canada. Ses travaux au laboratoire des pêcheries de l'Université de la Saskatchewan entre 1948 et 1960 ont été d'un intérêt tout particulier. Ses analyses des lacs de la province lui ont permis de contribuer au développement des concepts théoriques sur la productivité lacustre tout en fournissant des données utiles à l'agence de gestion des pêcheries de la province.

For generations, scientists have ranged across Canada, seeking to understand the 'cool curving worlds' within our lakes and rivers.[2] Interestingly, this study of limnology has often been pursued at institutions dedicated to fisheries research. At the University of Toronto, for example, limnology was supported from 1921 to

1 Institute for History & Philosophy of Science and Technology, University of Toronto.

2 This phrase is from Richard Miller's autobiography, **A Cool Curving World** (Don Mills, 1962).

1956 through the Ontario Fisheries Research Laboratory (OFRL). At the federal level, the Fisheries Research Board and its predecessor, the Biological Board, supported research on Georgian Bay between 1903 and 1912, studies on several lakes in Western Canada from the 1920s to 1940s, and more recently, research at the Freshwater Institute at Winnipeg and the Canada Centre for Inland Waters at Burlington.[3] Because of this situation, the history of limnology in Canada provides an opportunity to explore the relations between the research requirements of the fisheries, and the scientific priorities of limnologists.[4]

This support by fisheries institutions has been a distinctive feature of Canadian limnology. In the United States, in contrast, fisheries agencies supported little basic limnological research. From about 1870 to the 1930s American fish commissions, both state and federal, responded to declining fisheries by expanding their efforts in fish culture, and they saw little need for scientific study of the freshwater environment. When limnology did develop in the United States, it did so through the work of scientists like Edward Birge and Chancey Juday of the University of Wisconsin, and Stephen Forbes of the University of Illinois. None of these scientists had significant ties to fish commissions.[5]

I will discuss the relation of fisheries and limnological research by examining the work of Donald Rawson. Rawson graduated from the University of Toronto with a PhD in 1929. In his thesis, the research for which was supervised by some

3 E. Horne Craigie, **A History of the Department of Zoology of the University of Toronto up to 1962** (Toronto, 1967); Kenneth Johnstone, **The Aquatic Explorers: A History of the Fisheries Research Board of Canada** (Toronto, 1977).

4 Canadian limnological research remains almost unexamined by historians. The best introduction are several chapters in David G. Frey, ed., **Limnology in North America** (Madison, 1963), including T.G. Northcote and P.A. Larkin, 'Western Canada,' 451-85; F.E.J. Fry and V. Legendre, 'Ontario and Quebec,' 487-519; M.W. Smith, 'The Atlantic Provinces of Canada,' 521-34; A.M. Beeton and D.C. Chandler, 'The St Lawrence Great Lakes,' 559-74; D.A. Livingston, 'Alaska, Yukon, Northwest Territories and Greenland,' 683-90. Frank Egerton discusses American studies of the Great Lakes and surveys Canadian studies of lake productivity in 'Missed Opportunities: US Fishery Biologists and Productivity of Fish in Green Bay, Saginaw Bay and Western Lake Erie,' **Environmental Review** 13:2 (1989), 33-63.

5 Stephen Bocking, 'Stephen Forbes, Jacob Reighard and the Emergence of Aquatic Ecology in the Great Lakes Region,' **Journal of the History of Biology** (forthcoming).

members of the OFRL, he discussed the limnology of Lake Simcoe. In 1928, Rawson became a professor in the Department of Biology of the University of Saskatchewan, and in 1949, chairman of the department. He there conducted thirty years of research on the lakes of Western Canada, before his death in 1961 at the age of fifty-six. Both through his own research, and through his training of numerous students, Rawson became the most influential Canadian limnologist of his generation.[6]

Rawson was one of several limnologists and fisheries biologists from the University of Toronto to study in the west between the 1920s and 1940s. The first was A. G. Huntsman, professor of marine biology from 1927 to 1954. While known primarily as a marine expert, in the early 1920s he surveyed the fisheries potential of the Quill Lakes in Saskatchewan.[7] Somewhat later came Richard Miller, like Rawson a graduate of the University of Toronto and the OFRL. He came to the University of Alberta in 1940, and devoted many years in that province and the North West Territories to the study of fish parasites, the survey of the fisheries potential of its lakes and streams and the development of an Alberta provincial fisheries branch. A third was William Kennedy, during the 1930s a fellow student with Miller at the OFRL. Kennedy and Miller worked together in the 1940s on a fisheries survey of Great Bear Lake, before Kennedy returned to Ontario, eventually to become Director of the Biological Station of the Fisheries Research Board in London.[8]

Rawson received research assistance from several federal agencies between the late 1920s and 1940s. The Biological Board supported, briefly, his studies begin-

6 Two notices briefly describing Rawson's life and work are: J.G. Rempel, **Transactions of the Royal Society of Canada**, 3rd series, 55 (1961), 149-51, and Anonymous, **Journal of the Fisheries Research Board of Canada** 18 (1961), 480-82.

7 Northcote and Larkin, **op. cit.**, 459.

8 Miller, **op. cit.**

ning in 1928 of lakes in Prince Albert National Park. This ended in 1931, when jurisdiction over natural resources, including the fisheries, passed from the federal government to the Prairie provinces.[9] The Biological Board continued, however, to support his research in 1931 and 1935 on several lakes in the Kamloops region of British Columbia, including a detailed study of Paul Lake.[10] During the 1930s he studied several lakes in the Rocky Mountain national parks, with the assistance of the National Parks Bureau of the Department of Mines and Resources.[11] From 1943 to 1948 the Fisheries Research Board supported his surveys of Great Slave Lake and Lake Athabaska. His Great Slave Lake study is perhaps the best known of these surveys, as his conclusions regarding the abundance of the fish and their food justified establishment of a commercial fishery.[12]

It was beginning in the late 1940s, however, that Rawson's research at home in Saskatchewan really began to expand. As with most of his earlier work for the federal government, his support came from agencies responsible for fisheries research or management. In 1944 the provincial CCF government of Tommy Douglas took office. This government believed strongly that the University of Saskatchewan had a special responsibility to apply its intellectual expertise to the promotion of the social and economic progress of the province. Woodrow Lloyd, the Minister of Education, went so far as to refer to the University as a 'public service corporation.' W. P. Thompson, university president from 1949 to 1959,

9 Johnstone, **op. cit.**, 134.

10 Donald S. Rawson, 'Productivity Studies in Lakes in the Kamloops Region, British Columbia,' Biological Board of Canada, **Bulletin** 42 (1934).

11 Rawson, 'A Comparison of Some Large Alpine Lakes in Western Canada,' **Ecology** 23 (1942), 143-61.

12 Rawson reported on this study in: 'Estimating the Fish Production of Great Slave Lake,' **Trans. Amer. Fish. Soc.** 77 (1947), 81-92; 'Great Slave Lake,' in 'North West Canadian Fisheries Surveys in 1944-1945,' Fisheries Research Board of Canada, **Bulletin No 72** (1947), 45-68; 'The Physical Limnology of Great Slave Lake,' **Journal of the Fisheries Research Board of Canada** 8 (1950), 3-66; and 'Studies of the Fish of Great Slave Lake,' ibid., 8 (1951), 207-40.

was sympathetic towards these ideals, as he himself wished to promote a return to the university's tradition of extension and public service.[13]

Among the government's priorities was provincial control, development and conservation of natural resources. Joint promotion by university and government of soil and water conservation had already started by 1935, in response to the devastating drought. By 1946, the new CCF government had begun, through the Department of Natural Resources and Industrial Development, to expand its role in natural resource development and conservation, including, for example, forest conservation.[14] These policies were also extended to the province's aquatic resources. Following the suggestions of a Saskatchewan Royal Commission on the Fisheries of Saskatchewan (1946-47), on which Rawson served, the department's Fisheries Branch designed more effective regulations and began technical research on such topics as fish canning.[15]

The Fisheries Branch took its most significant step, however, when it established in 1948 a Fisheries Laboratory in the university's Department of Biology. While officially a government laboratory and under the administration of the Fisheries Branch, it was to be directed by Rawson. Its purpose was to contribute to the government's overall plans for conservation by conducting research and surveying lakes to evaluate their fisheries potential. Rawson himself was already active in conservation efforts. In 1942-43 he directed a survey of the natural resources of the Big River area of central Saskatchewan.[16] He continued this personal interest in conservation, serving during the 1950s as vice-president of the Canadian Conservation Association and he also helped found the Canadian Society of Wildlife and Fishery Biologists.

Rawson directed the laboratory from 1948 to 1960. During that period, more than 80 per cent of the support for his research, and that of his students, was provided by the fisheries branch for the operation of this laboratory.[17] Rawson's

13 Michael Hayden, **Seeking a Balance: The University of Saskatchewan, 1907-1982** (Vancouver, 1983), 208-9.

14 James F.C. Wright, **Saskatchewan, The History of a Province** (Toronto, 1955), 238-9, 262; John Richards and Larry Pratt, **Prairie Capitalism: Power and Influence in the New West** (Toronto, 1979), 93-147.

15 Saskatchewan Department of Natural Resources and Industrial Development, **Annual Report, 1947-48**, 88-9.

16 D.S. Rawson, E.C. Hope, J. Mitchell and E.W. Tisdale, **The Big River Survey: A Comprehensive Study of Natural Resources as an Aid to Improved Utilization** (Saskatoon, 1943).

17 Financial data from University of Saskatchewan, **Annual Reports**.

research for the fisheries branch consisted mostly of extensive surveys of some of the major lakes of the province, to determine their potential productivity. These surveys included study of a wide range of characteristics, including area, mean and maximum depths, shore development, temperature at various depths throughout the course of the year (thereby enabling calculation of a heat budget), dissolved oxygen, pH, plankton and bottom fauna, and abundance, growth rate and feeding behaviour of the fish. These surveys, in as much as they were directed at estimating productivity, were, in the government's eyes, highly relevant to fisheries management. As a fisheries branch report noted in 1950,

> In order to properly manage our fisheries resources we must have more knowledge of the productive capacities of various water areas, as well as the amount and kind of harvesting which should be undertaken. A body of water is like a pasture. It will support only as many living animals as the food supply will permit. It is relatively easy for agriculturalists to determine the productivity of a pasture, an entirely different matter for a biologist to determine the productivity of a lake.[18]

Rawson's aim was not simply to determine the productivity of each lake, but to identify those factors most significant in determining any lake's productivity. He had prepared in 1939 a chart illustrating the operation of these characteristics (Figure one).[19] Much of his research over the following twenty years was then devoted to determining the relative importance of the three major kinds of factors, apart from human factors, that he noted on this chart; that is, the edaphic conditions (mineral content) of the lake basin, the shape of the basin, and the climate. By 1952 he had accumulated enough data on these characteristics, both from his own surveys of Western Canadian lakes, and from other scientists' studies of the Great Lakes, to show that for large lakes the shape of the basin was the dominant factor determining fish production. In particular, he found that the mean depth of a lake provided a useful indication of its potential fish production.[20] The importance of depth, however, could be modified by the other

18 Saskatchewan Department of Natural Resources and Industrial Development, **Annual Report, 1949-1950**, 75.

19 Donald S. Rawson, 'Some Physical and Chemical Factors in the Metabolism of Lakes,' in F.R. Moulton, ed., **Problems of Lake Biology: Symposium on Problems of Lake Biology, Richmond, 1938** (Lancaster, PA, 1939), 10.

20 Rawson, 'Mean Depth and the Fish Production of Large Lakes,' **Ecology** 33 (1952), 513-21.

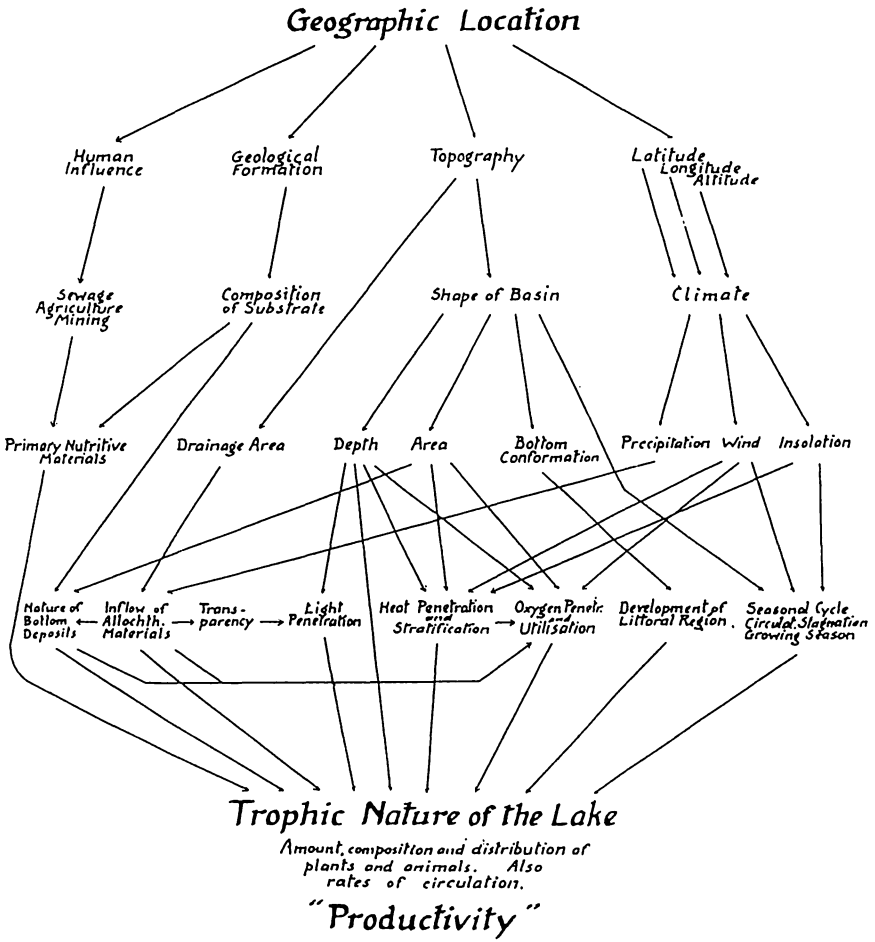

FIG. 1. A chart suggesting the interrelations of factors affecting the metabolism of a lake.

factors. In smaller lakes of the Rocky Mountains and the Prairies, Rawson found that edaphic conditions, as reflected in the mineral content of the lake water, also had a significant impact on lake productivity.[21]

Rawson's work eventually contributed to development of the 'morphoedaphic index,' (MEI) by Richard Ryder of the Ontario Ministry of Nature Resources. According to Ryder, Rawson's work, and the surveys of his colleagues in British Columbia, T. G. Northcote and P. A. Larkin, provided the basis for his index. The MEI, defined as total dissolved solids divided by mean depth, provided a method of predicting productivity that balanced the effects of shape and mineral content of the lake basin. Since Ryder's original formulation of the MEI in 1961, it has been discussed and modified extensively by the fisheries and limnological research community. It has been applied to fisheries in several climatic regions of the world, including Ontario, California, central Africa and Finland.[22] The MEI has provided generally useful predictions of productivity, although in one instance, a study of the potential standing crop of monsters in Loch Ness, there has not yet been an opportunity to test its predictions empirically.[23]

Beyond these theoretical developments, the surveys that Rawson directed provided data on several of the most productive lakes in Saskatchewan that was of use in setting management policy. On several occasions, measurement of lake productivity suggested that the fish production of a lake was less than it could supply on a sustained-yield basis, and hence that catch limits could be safely raised.

When the Fisheries Laboratory was established in 1948, biological surveys to determine lake productivity were almost its sole activity. Over the years, research was gradually enlarged to satisfy some of the more specific needs of fisheries management. By 1956 projects of direct relevance, including examination of the relative effectiveness of nylon and cotton gill nets, creel census studies of recreational anglers, and surveys of reservoirs to determine suitability for stocking, had been started.[24] In summary, the obvious relation of Rawson's research to the fisheries suggests that the government's need for methods of predicting fisheries

21 Rawson, 'The Total Mineral Content of Lake Waters,' ibid., 32 (1951), 669-72.

22 An extensive discussion and bibliography of the MEI is in R.A. Ryder, S.R. Kerr, K.H. Loftus and H.A. Regier, 'The Morphoedaphic Index, a Fish Yield Estimator -- Review and Evaluation,' **Journal of the Fisheries Research Board of Canada** 31 (1974), 663-88.

23 R.W. Sheldon and S.R. Kerr, 'The Population Density of Monsters in Loch Ness,' **Limnology and Oceanography** 17 (1972), 796-8.

24 Saskatchewan Department of Natural Resources, **Annual Report, 1955-56**, 47.

yields had a strong impact on his work. But to test this conclusion further, it is necessary to look more closely at the context of his research; that is, the research being conducted elsewhere in limnology.

What we notice immediately in examining this context is that the question of the productivity of lakes, far from being imposed on it by the requirements of fisheries management, was perhaps the central preoccupation of limnology. This was the case not only in Canada, but in the United States and Europe, where many limnologists had no ties to fisheries agencies. Indeed, for some limnology was, in effect, the study of the productivity of lakes. Paul Welch, for example, a University of Michigan limnologist, and author of the most influential limnology textbook of Rawson's generation, defined the field as that branch of science which deals with biological productivity of inland waters and with all the causal influences which determine it.[25]

Between about 1910 and 1945, a particular method of studying lakes persisted as a standard approach for many limnologists. The method began with the patient accumulation of much data on the physics, chemistry and biology of large numbers of lakes. The limnologist would then classify the lakes according to their primary productivity, and through this, would be able to identify the factors responsible for differences between them. This highly empirical, highly inductive technique of classification (known as the *Seetypenlehre*) was, in particular, the most common methodology of European limnologists, who until World War II formed the largest community of lake researchers. August Thienemann and Einar Naumann, who together established the International Association of Limnology in 1922, were among the most influential leaders in this effort. Thienemann established the basic division of lakes still used today by limnologists, of oligotrophic (less productive) and eutrophic (more productive) lakes, identifying lakes of these types on the basis of bottom fauna and bottom oxygen supply; Naumann adhered to these categories, but added a third, the 'dystrophic,' (lakes with low productivity, but that receive much organic matter from terrestrial sources) and assigned lakes to these according to their chemistry and primary productivity.[26]

25 Paul S. Welch, **Limnology** (New York, 1935), 10.

26 H.J. Elster, 'History of Limnology,' **Mitt. Internat. Verein. Limnol.** 20 (1974), 7-30; F.H. Rigler, 'Nutrient Kinetics and the New Typology,' ibid., 19 (1975), 197-210; Welch, **op. cit.**, 308-28; G.E. Hutchinson, 'Eutrophication: the Scientific Background of a Contemporary Practical Problem,' **American Scientist** 61 (1973), 269-79; W. Rodhe, 'Crystallization of Eutrophication Concepts in Northern Europe,' in National Academy of Science, **Eutrophication: Causes, Consequences, Correctives** (Washington, DC, 1969), 50-64.

This development of lake classification schemes reflected a distinctive feature of the limnological research community. Unlike most ecologists, who studied various aspects of nature separately (for example, fisheries biologists would focus on fish populations, plant ecologists on plant populations), limnologists sought to study a lake as a single unit and described each of them in terms of its overall characteristics. And only through classification could the enormous amounts of data describing the complex of relationships existing in each lake be integrated into a single characteristic such as productivity so that different lakes could be compared.

Throughout the period that Rawson was engaged in active research, limnologists continued to be interested in productivity and lake classification. Rawson was himself well aware of this work. This is apparent in his review papers, in which he made frequent mention of the views of various limnologists studying productivity, including Thienemann and Naumann.[27] He also had extensive personal contacts in the field, as is indicated by the offices he held in international limnological organizations. During the 1950s he served as Canadian representative to the Council of the International Association for Theoretical and Applied Limnology, as chair of several sessions at European meetings of the International Congress of Limnology, as an editor of the *Journal of Limnology and Oceanography*, and as president of the Limnological Society of America in 1947.

He was more than just aware of these developments, however. It is apparent that Rawson's research was motivated not simply by the requirements of fisheries management, but by his desire to study productivity as a question of interest to the limnological research community. Several papers indicate this, but of particular note are two that appeared in 1960 and 1961. In these he used the same method of classification that had been used by other limnologists, particularly in Europe, to develop generalizations concerning lake productivity. He brought together a great deal of basic data on the physical, chemical and biological characteristics of Saskatchewan lakes that he and others had gathered over the previous ten years of fisheries laboratory surveys. He then ranked and classified the lakes on the basis of these characteristics, to determine which were most significant in determining overall productivity. He then concluded, in contrast to his earlier generalization for large lakes, that edaphic differences, that is, local

27 See, for example, Rawson, 'A Limnological Comparison of Twelve Large Lakes in Northern Saskatchewan,' **Limnology and Oceanography** 5 (1960), 195-211; 'A Critical Analysis of the Limnological Variables used in Assessing the Productivity of Northern Saskatchewan Lakes,' **Verh. Internat. Verein. Limnol.** 14 (1961), 160-66.

soil conditions, were most significant in determining lake productivity. This result, while useful in identifying lakes as oligotrophic or eutrophic, was only indirectly relevant to determining potential fish production.[28]

Another indication of Rawson's interest in questions apart from those relating to the fisheries is the content of his lake surveys: they included research that had little to do with determining potential fish yield. As I have noted, he would measure such things as the shape of the basin, the lake's heat budget, transparency, plankton and bottom fauna. In the view of some provincial fisheries officials, this kind of information was irrelevant to management. One official asked him,

> Insofar as most of us are largely concerned with the low productivity of reservoirs, why should so much time be spent in the study of plankton, and in other rather dubious analysis. Would it not be more advantageous to spend the majority of time on comparative growth rates of 1 or 2 species of fish that are in the reservoir and thus get a better indication of the productivity of the lakes?[29]

This difference of opinion reflects the disparate perspectives on lake productivity and fish yield held by many limnologists and fisheries biologists. Limnologists (like Rawson) considered primary productivity and the abiotic factors that influence it as the appropriate basis for predictions of fish yield. Such predictions, they argued, should be based on how many fish the environment, and particularly the available food supply, could support. In contrast, fisheries biologists and managers usually estimated fish populations directly, basing their estimates on catch statistics. The environment was placed in the background, in order to focus attention on the population dynamics of the species of interest. In short, while limnologists sought to predict how many fish there *should* be, fisheries biologists tried to measure, using imperfect catch statistics, how many fish there really were.[30]

28 Rawson, 'Limnological Comparisons,' and 'Critical Analysis.'

29 The official was R.G. McMynn. Donald S. Rawson, 'Indices to Lake Productivity and their Significance in Predicting Conditions in Reservoirs and Lakes with Disturbed Water Levels,' in P.A. Larkin, ed., **The Investigation of Fish-Power Problems** [H.R. MacMillan Lectures in Fisheries, University of British Columbia] (Vancouver, 1958), 41.

30 An introduction to the literature and ideas of fisheries management is provided by Peter A. Larkin, 'Fisheries Management -- An Essay for Ecologists,' **Ann. Rev. Ecol. Syst.** 9 (1978), 57-73.

Finally, it is significant that Rawson, even as a student at the University of Toronto, was concerned with lake productivity. In his thesis on Lake Simcoe, which he completed in 1930, he discussed at length the relation between bottom fauna and the shape of the lake basin, and he concluded that lake depth and area were the most significant factors determining its quantity. His interest in this question was, as he noted in his thesis, related to his search for a measure of the richness of the lake (that is, the quantity of nutrients present), that would provide an easily measurable index to potential lake productivity.[31] This indicates that Rawson's interest in productivity began while he was a student, before his research began to be financed by the federal and provincial governments.

It may be concluded, then, that Rawson's research effort, devoted as it was towards determining the productivity of various lakes, was not inspired solely by the needs of fisheries management. To be sure, Rawson stressed the utility of his research to management, both because his research was funded by the provincial government with this end in mind, and because of his own genuine interest in the conservation of natural resources, including the fisheries. However, the nature of his lake surveys, in which he studied characteristics of minimal relevance to the fisheries, but of relevance to limnological studies of productivity elsewhere, his participation in discussions within the limnological research community on lake productivity, and his study of productivity even as a student at the University of Toronto, indicate that his interest in this question was not the consequence simply of the needs of fisheries management. J. R. Nursall, a graduate student under Rawson in the 1940s, recalled recently that Rawson's primary interest was the nature of productivity, and that while he recognized that fisheries questions were important, they were of secondary interest.[32] What Rawson did, in effect, was combine his study of lake productivity, as a question of fundamental interest to the limnological research community, with the provincial government's need for a scientific basis to fisheries management.

The establishment of a fisheries laboratory within the University of Saskatchewan created an opportunity to address both the management priorities of government, and the scientific priorities of the research community. Rawson

31 Rawson, 'The Bottom Fauna of Lake Simcoe and its Role in the Ecology of the Lake,' University of Toronto Studies, **Publications of the Ontario Fisheries Research Laboratory, No 40** (1930).

32 Private communication from J.R. Nursall, 19 December 1989.

took advantage of this situation by developing a research program that provided advice on fisheries management to the government, contributed to scientific discussions within the limnological research community, and trained students who went on to form much of the next generation of limnologists and fisheries biologists of western Canada.

Note: An earlier version of this article was read to the Sixth Kingston Conference, Queen's University, October 1989.

Stephen Bocking is completing his PhD dissertation at the Institute for History and Philosophy of Science and Technology at the University of Toronto.
