Proceedings of a Symposium

Man's Impact on the Canadian Flora

Edited by J. K. Morton

Canadian Botanical Association
Association Botanique du Canada

Bulletin
Supplement to Vol. 9, No. 1
Jan. 1976

ISSN 0008-3046

MAN'S IMPACT ON THE CANADIAN FLORA

Proceedings of a Symposium organized by the CANADIAN BOTANICAL ASSOCIATION on the occasion of its 8th Annual Meeting held at the University of Western Ontario, London, Ontario, Canada, June 3-7, 1973.

Edited by J.K. Morton

Published by the Canadian Botanical Association/ Association Botanique du Canada as a supplement to the CBA/ABC Bulletin, Vol. 9, no. 1. January 1976.

Supplied free to members of the Association. Price to non-members $10 post free from Department of Biology, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada (payable to Canadian Botanical Association).

Preface

On the occasion of the 1973 Annual Meetings of the Canadian Botanical Association a symposium was held to deal with the subject of the impact which man has had on the flora and vegetation of Canada. The symposium sessions were organized by Dr. D.G. Wilson and chaired by Drs. M. Steeves, and R.L. Peterson. They were attended by about 170 botanists from many parts of Canada. The symposium was designed to bring together a broad spectrum of expertise and was followed by a lengthy and lively panel discussion in which the audience participated freely. The symposium marks a milestone in the development of concern by Canadian botanists for the continued existence of many components of our flora and the habitats in which they grow, under the ever increasing pressures of human activity. Because of this it was considered desirable to publish the proceedings of the symposium so that they should be available as a permanent record to a wider audience.

Contents

PAGE

The Fossil History of Man's Impact on the Canadian Flora by J.H. McAndrews 1

The Canadian Flora Since Colonization by R.L. Taylor 7

Recent Changes in the Canadian Flora by J.K. Morton 13

The Ecology of Weeds by P.B. Cavers 17

The Impact of Urbanization by N. Pearson 21

The Impact of Pollution by T.C. Hutchinson 25

Acknowledgements 30

FOSSIL HISTORY OF MAN'S IMPACT ON THE CANADIAN FLORA: AN EXAMPLE FROM SOUTHERN ONTARIO

John H. McAndrews,
Department of Botany,
University of Toronto
and
Department of Mineralogy and Geology,
Royal Ontario Museum,
Toronto, Ontario.

In 1941 the late J. Iversen published his famous "landnam" (land settlement) paper describing the fossil record of neolithic farmers in Denmark. In several pollen diagrams from peat deposits he found a relative increase of the pioneering trees Betula, Alnus and Corylus. Pollen of the weeds Plantago and Rumex appeared simultaneously with cereal-type Gramineae pollen. Subsequent more detailed pollen analyses in western Europe show that forest clearance, grazing and cultivation by these early agriculturists is radiocarbon dated to about 3,000 B.C. (Pilcher et al. 1971).

In Canada a good place to study the fossil history of man's impact on the flora is in an area such as southern Ontario (fig. 1) where the original forests have been largely destroyed and replaced by introduced species adapted to agriculture and urban settlement. In addition this is the only area of Canada that supported prehistoric Indian agriculture (Moodie and Kaye 1969). Pollen analyses of sediments of two lakes yield a record of both historic and prehistoric agriculture.

Van Nostrand Lake lies in an ice block depression or kettle hole about 20 miles north of Toronto. It is surrounded by cultivated fields (fig. 2). The pollen diagram (fig. 3) from this lake is zoned largely on tree pollen (McAndrews 1973). The only indication of abundant weed pollen is zone 8 which is dominated by Ambrosia and Gramineae with small amounts of Rumex and Plantago. Zone 8 must represent modern agricultural disturbance because the weed pollen extends to the surface of the accumulating sediment and the plants are abundant in the surrounding fields. Zone 8 also contains abundant Pinus strobus pollen, but Pinus rises in abundance just before Ambrosia and this defines the base of zone 7. Zone 8, the Ambrosia zone, dates from sometime after European contact in the 17th century, but radiocarbon dating is too imprecise for such young, carbonate-rich sediments (McAndrews 1969). Recent reports of lakes depositing annual laminations or varves (Tippett 1964, Ludlam 1969, Craig 1970) led to the discovery of such varves in Crawford Lake where a detailed chronology of pollen zones 6, 7 and 8 was developed.

Crawford Lake lies in a collapse basin in the dolomite bedrock of the Niagara Escarpment about 35 miles west of Toronto. It has a surface area of 2.5 ha and a maximum depth of 24 m. This morphometry accounts for the meromixis of the lake and the consequent oxygen-poor bottom water that excludes sediment-disturbing bottom fauna. Carbonate precipitated during the summer forms white lamina that alternates with black lamina of winter deposited organic matter. The lake is surrounded with farmland and a mixed forest dominated by sugar maple (Acer saccharum), with beech (Fagus grandifolia), birch (Betula papyrifera, B. lutea), oak (Quercus spp.), hemlock (Tsuga canadensis), cedar (Thuja occidentalis), ironwood (Ostrya virginiana) and white pine (Pinus strobus) (fig. 4). Cut pine stumps are common in the forest around the lake and pine stump fences border nearby fields.

Sampling the sediments of Crawford Lake with a piston sampler caused the upper loose varves to mix together and consequently a freezing sampler was adapted (Swain 1973). The freezing sampler ("frigid finger") is a closed pipe filled with dry ice. The pipe is lowered with a rope into the upper meter of sediment and left for 20 minutes before being pulled up. Varved sediment together with the overlying 20 cm of water adhere as a 3 cm thick frozen rind to the outside of the tube. The sediment is slipped from the tube after thawing the inner surface of the rind by pouring hot water into the pipe. The varves were compact downward to less than 1 mm thick. Pollen analyses were done at contiguous intervals of 5, 10 or 25 years. Figure 5 shows a pollen diagram summarizing 125 analyses. The varve count is precise to 1300 A.D. (Boyko 1973) but less certain back to 200 A.D. The diagram contains the pollen zones 6, 7 and 8 of Van Nostrand Lake. Zone 6 represents a forest dominated by maple and beech with lesser amounts of other deciduous trees and cedar and hemlock. In zone 7 Fagus and especially Acer decline and are succeeded at first by Quercus and then by Pinus to form a mixed conifer-deciduous forest. In zone 8 there is a marked decrease in Pinus and a relative increase in Betula, Ulmus and Thuja reflecting the logging of pine, and forest succession by disturbance adapted tree species. Zone 8 is dominated by Ambrosia and Gramineae with small amounts of Rumex, Plantago and other weed pollen. The bottom of zone 8, placed where Ambrosia pollen rises above 1%, is in the interval 1846-1851 A.D. and dates European impact in the area surrounding the lake. This date corresponds with forest clearance immediately around the lake as inferred from colonial patent records (Boyko 1973). Pinus does not show a decrease until the 1870's, a date that corresponds with the operation of a sawmill on the shore of the lake. Pollen of European introduced weeds such as Plantago lanceolata, P. major, Melilotus and Echium vulgare are confined to post-1846 levels, although Rumex acetosella appears as early as 1820. The Gramineae peak dating from 1300 to

1500 A.D. contains several large grains that can only be those of Zea mays. Portulaca oleracea pollen and seeds are also present during this interval. This weed, together with maize pollen, suggests nearby prehistoric Indian maize fields (Byrne and McAndrews 1975).

The maize and Portulaca fossils led to the discovery of an Iroquoian Indian village 150 m north of the lake and subsequent excavation yielded charred maize kernels as well as pottery that indicates a village date of about 1380 A.D. (Finlayson et al. 1973). Because the longevity of the village was perhaps only 20 years, it is probable that the maize, weedy grass and Portulaca pollen came from other fields in the vicinity of Crawford Lake rather than only from the fields of the excavated village. Although Indians practised agriculture in southern Ontario before 1300 A.D. (Wright 1972) there is no pollen record of it in Crawford Lake. Indian agriculture around Crawford Lake involved forest clearance and forest succession on abandoned fields. The Indian agricultural period corresponds with the pollen zone 6-7 transition that is interpreted as a succession from maple and beech to oak and pine. Maple and beech form a slow-growing, stable forest community in contrast to oak, particularly Quercus rubra, and white pine that are fast-growing trees which pioneer succession in forest clearings. Thus zone 7 is interpreted as reflecting forest succession following the impact of Indian agriculture. On the other hand, white pine has its main distribution northward and the succession to pine forest could be interpreted as due to southward migration caused by climatic cooling. However, a little pine charcoal was present in the Crawford Lake archaeological site indicating that pine was present in the vicinity of Crawford Lake before zone 7 and thus the increase of pine pollen was probably not related to southward migration.

One of the striking differences between the European and Indian agricultural periods is the virtual absence of Ambrosia pollen during the Indian period. Calculation of Ambrosia influx during the European period is about 1,000 per square cm per year in contrast to less than 10 per square cm per year for the preceding time even though Indian fields would have been a suitable habitat for ragweed. Ambrosia influx in Minnesota for immediate pre-European time is about 1,500 per square cm per year (Waddington 1969). Ragweed species are adapted to floodplain and prairy communities in Minnesota and adjacent states and seeds occur in mid-Holocene sediments of Kansas (Gruger 1973) and South Dakota (Watts and Bright 1969). No such high pollen values, or seeds, have been reported from Ontario and the occasional occurrence of the pollen can most easily be explained as wind carriage from the west. Bassett and Terasmae (1962) regard ragweed as native to Ontario but its failure to colonize Indian fields indicates that the species dates from 19th century introduction from the west.

In summary, southern Ontario has proved to be ideal for the detailed study of plant fossils related to human impact on the flora. Maize and Portulaca were introduced by prehistoric Indian agriculturists whose forest clearance activities initiated a succession from maple and beech to oak and pine. Our studies also indicate that European forest clearance, agriculture and logging did not make an impact until the mid-19th century and that ragweed was introduced at this time.

REFERENCES CITED

Bassett, I.J. and Terasmae, J. 1962. Ragweeds, Ambrosia species, in Canada and their history in postglacial time. Can. J. Bot. 40: 141-150.

Boyko, M. 1973. European impact on the vegetation around Crawford Lake in southern Ontario. M.Sc. Thesis, Department of Botany, University of Toronto. 115 p.

Byrne, A.R. and McAndrews, J.H. 1975. Pre-Columbian purslane (Portulaca oleracea L.) in the New World. Nature 253: 726-727.

Craig, A.J. 1970. Pollen influx to laminated sediments: a pollen diagram from northeast Minnesota. Ecology 53: 46-57.

Finlayson, W.D., Byrne, A.R. and McAndrews, J.H. 1973. Iroquoian settlement and subsistance patterns near Crawford Lake, Ontario. Bull. Can. Archaeological Assoc. 5: 134-136.

Gruger, J. 1973. Studies on the late Quaternary vegetation history of north-eastern Kansas. Geol. Soc. Amer. Bull. 84: 239-250.

Iversen, J. 1941. Land occupation in Denmark's stone age. Danmarks Geol. Unders. 2 Rk. Nr. 66, 68 p.

Ludlam, S.D. 1969. Fayetteville Green Lake, New York. III. The laminated sediments. Limnol. Oceanog. 14: 848-857.

McAndrews, J.H. 1973. Pollen analysis of the sediments of the Great Lakes of North America. In Holocene Palynology and Marine Palynology; Proc. III Internat. Palynol. Congr., Moskow: Acad. Sci. USSR. pp. 76-80.

______________. 1969. Paleobotany of a wild rice lake in Minnesota. Can. J. Bot. 47: 1671-1679.

Moodie, D.W. and Kaye, B. 1969. The northern limit of Indian agriculture in North America. Geogr. Rev. 59: 513-529.

Pilcher, J.R., Smith, A.G., Pearson, G.W. and Crowder, A. 1971. Land clearance in the Irish neolithic: new evidence and interpretation. Science 172: 560-562.

Rowe, J. 1972. Forest regions of Canada. Dept. Environment, Can. Forestry Serv. Publ. No. 1300. 172 p.

Swain, A.M. 1973. A history of fire and vegetation in northwestern Minnesota as recorded in lake sediments. Quaternary Res. 3: 383-396.

Tippett, R. 1964. An investigation into the nature of the layering of deep-water sediments in two eastern Ontario lakes. Can. J. Bot. 42: 1693-1709.

Waddington, J.C.B. 1969. A stratigraphic record of the pollen influx to a lake in the Big Woods of Minnesota. Geol. Soc. Amer. Spec. Paper 123. 263-282.

Watts, W.A. and Bright, R.C. 1968. Pollen, seed and mollusk analysis of a sediment core from Pickeral Lake, northeastern South Dakota. Geol. Soc. Amer. Bull. 79: 855-876.

Wright, J.V. 1972. Ontario prehistory. National Mus. Canada. 120 p.

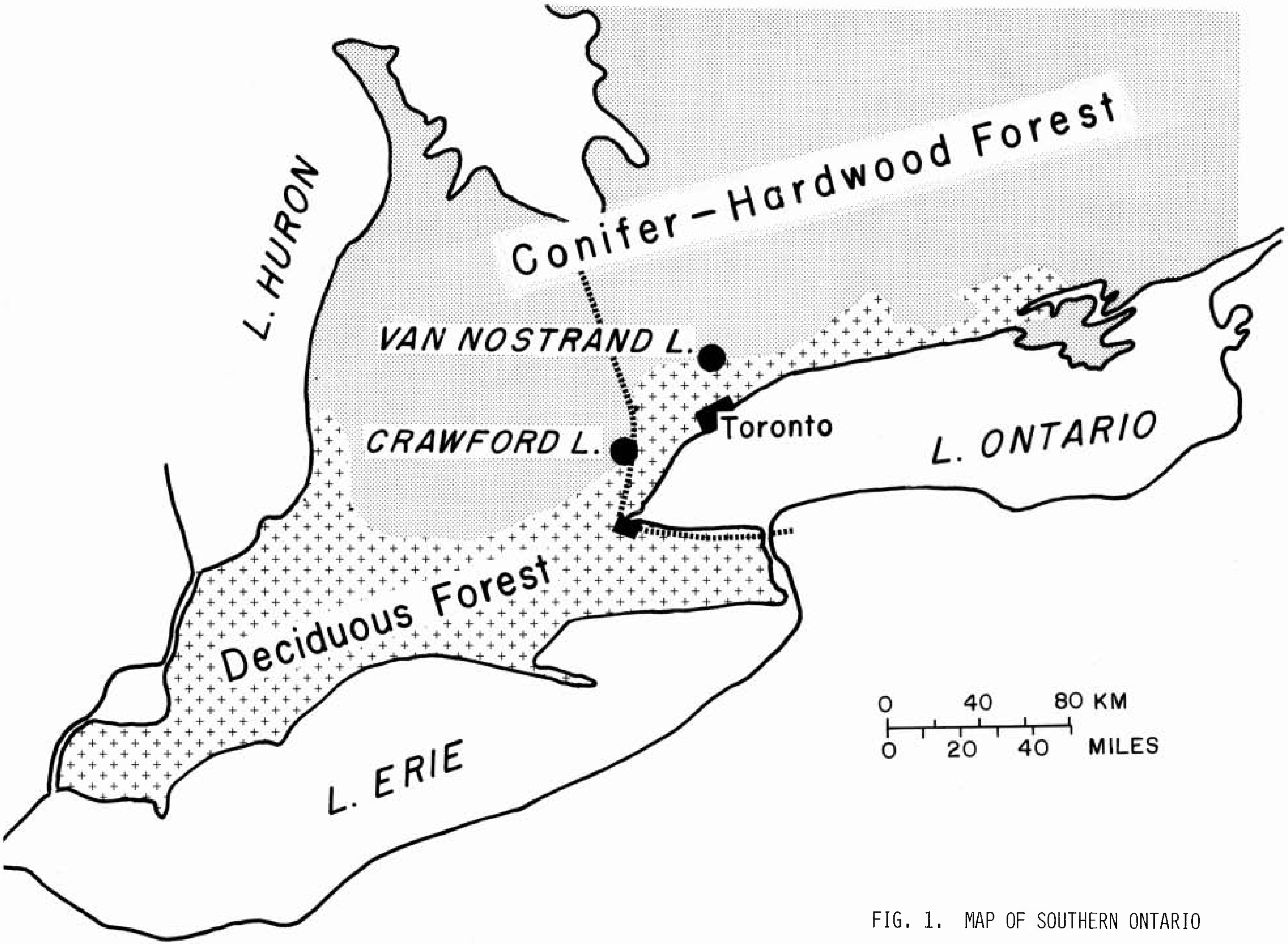


FIG. 1. MAP OF SOUTHERN ONTARIO

SHOWING NATURAL FOREST REGIONS (AFTER ROWE 1972)
THE DASHED LINE IS THE NIAGARA ESCARPMENT.

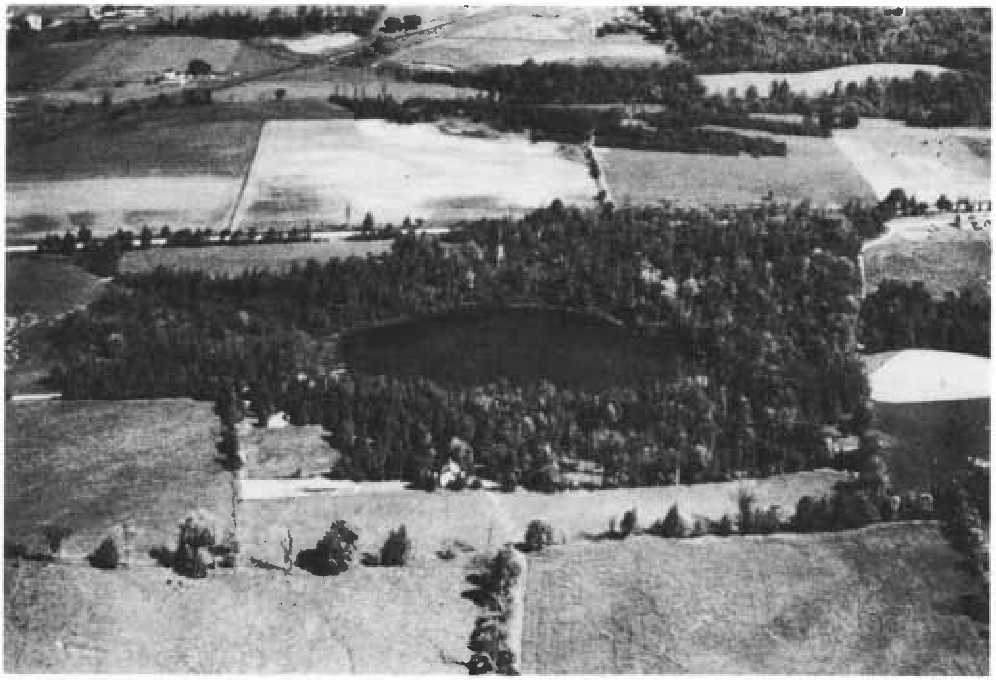


FIG. 2. AERIAL VIEW OF VAN NOSTRAND LAKE
TAKEN IN 1969.

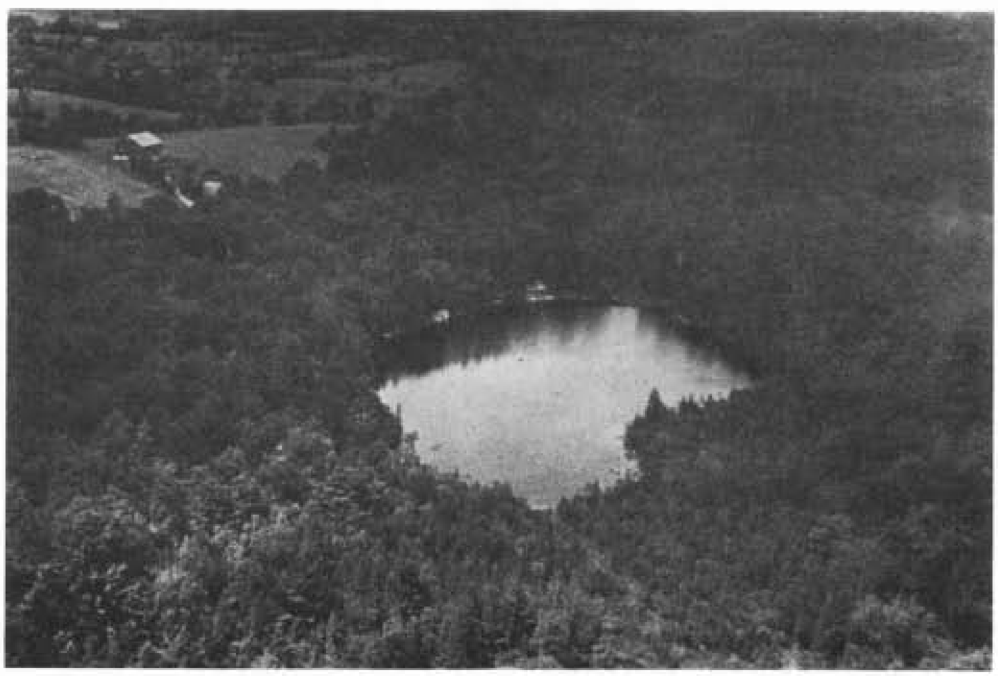


FIG. 4. AERIAL VIEW OF CRAWFORD LAKE
TAKEN IN 1972. THE FARM BUILDING IN THE UPPER LEFT IS ON THE SITE OF THE 14TH CENTURY INDIAN VILLAGE.

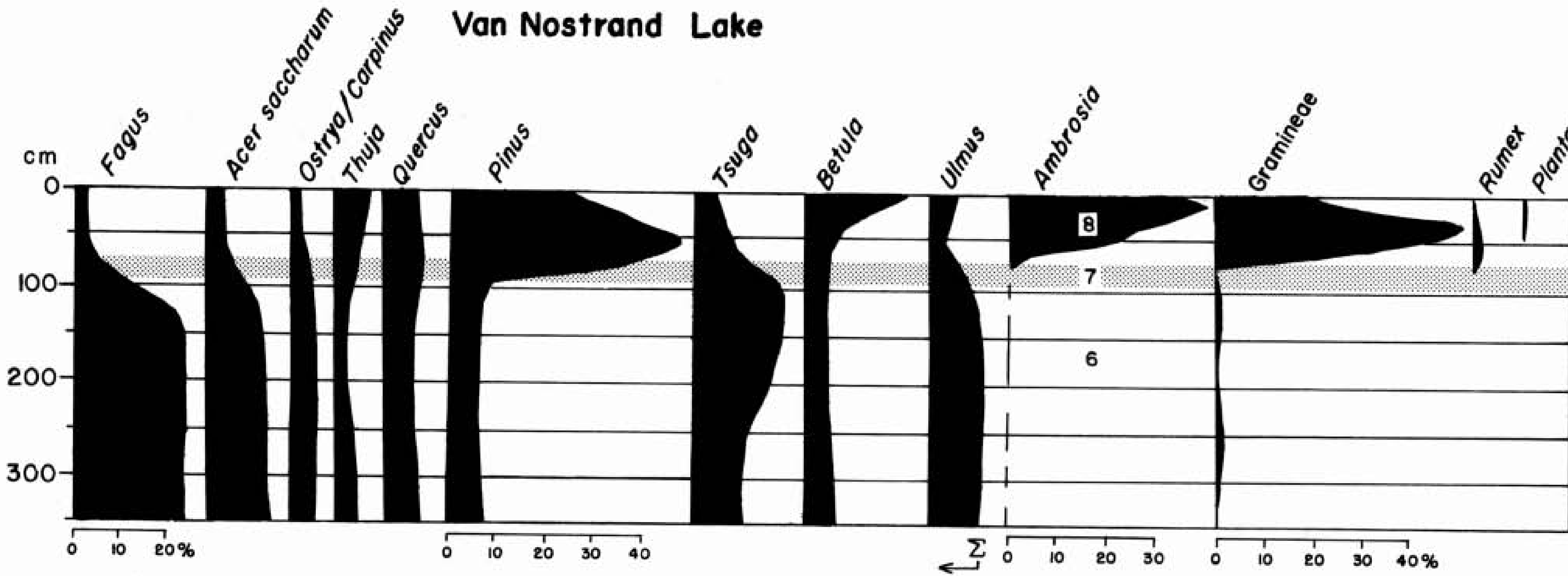


FIG. 3. POLLEN DIAGRAM FROM VAN NOSTRAND LAKE

ONLY THE MORE IMPORTANT TAXA ARE SHOWN. THE POLLEN SUM USED FOR PERCENTAGE CALCULATION INCLUDES ONLY POLLEN OF WOODY PLANTS. ZONE 8 IS THE PERIOD OF EUROPEAN SETTLEMENT.

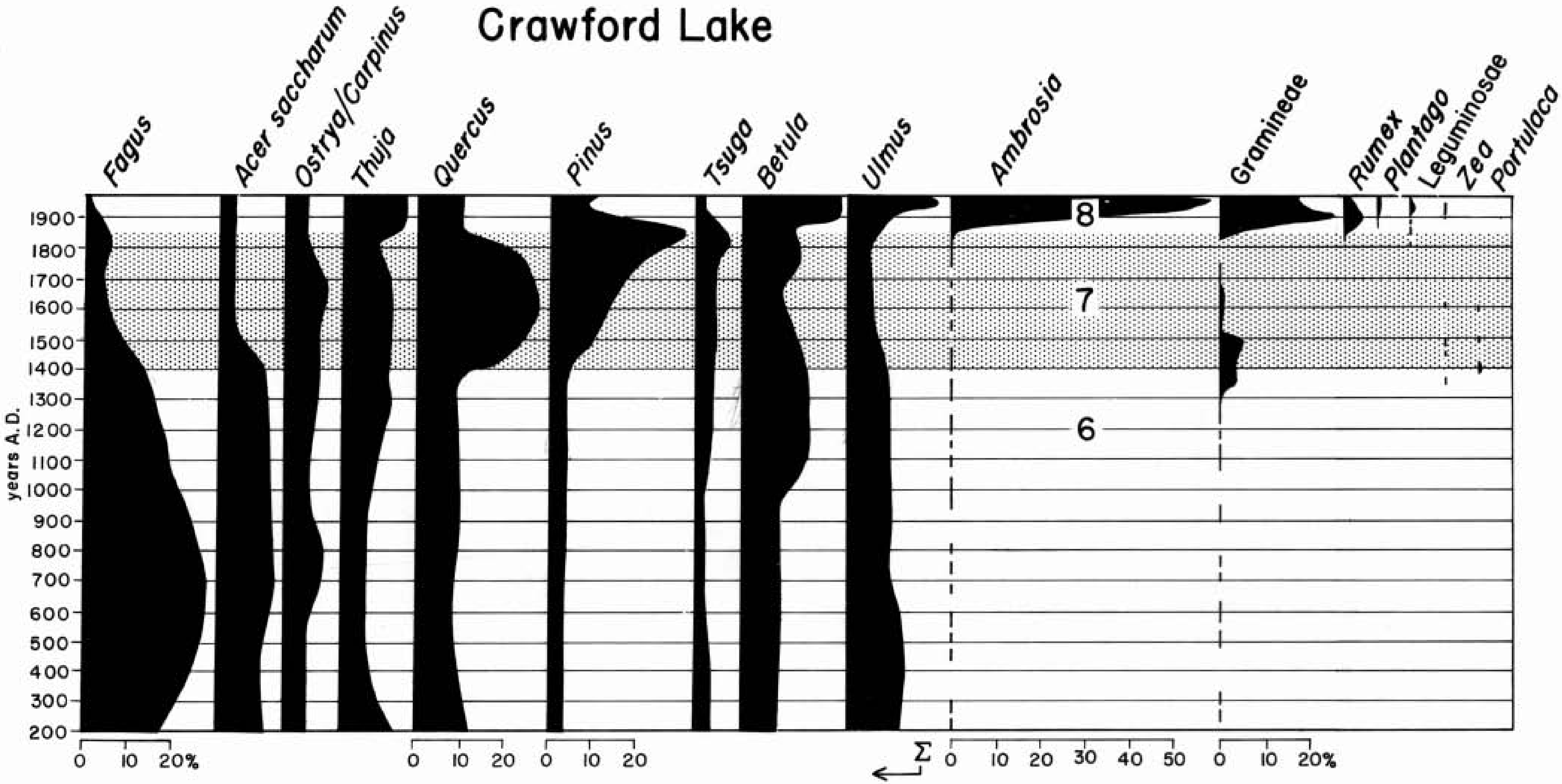


FIG. 5. POLLEN DIAGRAM FROM CRAWFORD LAKE

Drawn in the same format as that of van Nostrand Lake except that the vertical axis representing 83 cm. of sediment is given in years A.D.

THE CANADIAN FLORA 1534-1900

Roy L. Taylor,
Director of the Botanical Garden,
University of British Columbia,
Vancouver, B.C.

The growth and development of our knowledge and understanding of the plants of Canada is directly related to the activities of the people concerned with the plant resources. The number of individuals possessing, or simply taking the necessary time to study, our natural resources was bound to be few during the early stages of the development of our country. However, without the dogged persistence of these few naturalist pioneers we would be much poorer in our appreciation of the dynamic nature of the living plants that today comprise our flora. I think it appropriate to discuss in some detail the accounting for and evaluation of the Canadian flora after the initial advent of European contact. Such a review will provide a minimum background to the discussions concerning our contemporary flora. Suggestions re future directions for research on the Canadian flora conclude this paper as such topics are elaborated in other papers in this symposium.

Any review of the collection, documentation and discussion of the historical aspects of the Canadian flora must rely heavily on the two-part historical review of Canadian Botany by D.P. Penhallow published in 1887 and 1897 respectively (Penhallow 1887, 1897). These two papers were originally presented to Section IV (Geological and Biological Sciences) of The Royal Society of Canada.

The general time span in Canadian history that is covered in this report involves nearly three and a half centuries; namely the period 1534-1892. The growth and development of the botanical knowledge of our flora during this period of time was accomplished by many people of different backgrounds. The contributors can be categorized into three general groups: 1) explorers, 2) early missionaries, 3) professional naturalists. Penhallow (1887) indicates there were probably not more than 24 contributors to the flora or connected with botanical work in Canada between the time Jacques Cartier arrived in 1534 and 1800. Three were missionaries, 8 were explorers, and 13 were naturalists, the latter including administrative officials with a passing interest in botanical matters. Twenty of these people dealt directly with the Canadian flora.

Jacques Cartier, like most of the early explorers, was a far better navigator than a naturalist. His journals were practically devoid of botanical information. We can only surmise the interesting view of the virgin landscape that he saw and, in many ways, it is unfortunate that an accurate journal of the plants he encountered is not available for comparison with our current flora.

Champlain (1613, 1632) in the early 1600's did provide some information concerning the flora and undoubtedly some of the collections of plants made about this time provided contributions. Hennepin, a Franciscan, who accompanied LaSalle, made excellent notes concerning the flora of the St. Lawrence and Great Lakes (Hennepin 1698). Charlevoix, a Jesuit, besides translating Cornut's _Canadensium Plantarum Historia_, described many of the forest trees and made notations concerning introduced species in the St. Lawrence Valley (Charlevoix 1744, 1761). He described the method for utilization of maple sap as a source of sugar (1761). A contemporary of Charlevoix's, Lafitau, discovered ginseng on the St. Lawrence in 1716 (Lafitau 1718). This discovery led to a short but flourishing industry which nearly resulted in the extinction of _Panax quinquefolium_.

Two medical doctors should be mentioned as providing important collections of material in the mid-1700's. Sarrasin, resident physician at the Court of Quebec, made collections of plants that were forwarded to Europe. His material provided documentation for a number of the species with the specific epiphet _canadensis_. He was commemorated by Tournefort in the genus _Sarracenia_. The next resident physician at the Court of Quebec, Gaultier, was an enthusiastic botanist and a great friend of Kalm. The genus _Gaultheria_ was named in his honour.

In the mid-1700's, the 'father of Canadian Botany' arrived on the scene (Kalm 1770-1771). Professor Peter Kalm, a pupil of Linnaeus, came to Canada in 1748 for a period of five months. A hardly respectable gestation period! He was the _first botanist_ to study the Canadian flora and gathered the first major plant collection in Canada. He was accompanied by one of his gardeners and had come to the New World to specifically collect plants that might be useful in the development of economically important plants for the Swedish environment. He cultivated many of his collections in what was the first important botanical garden in Northern Europe. The herbarium material collected by Kalm served to provide a major source of documentation for scientific studies on North American plants.

Kalm's work was followed by an equally important study by André Michaux. Michaux was commissioned by the French government to travel to the New World to collect trees and seeds for important information for the first work on Canadian botany. This work, entitled '_Canadensium Plantarum Historia_', was written by Jacques Philippe Cornut and published in 1635 (Cornut 1635). It was during this early period that the first naturalist to accompany an expedition came to Canada. Dr. Archibald Menzies accompanied Captain Vancouver on his voyages to the Pacific from 1790 to 1795 (Piper 1906, p. 11). The Western North American ericaceous shrub _Menziesia_ was named in his honour. The general lack of significant botanical contributions by early explorers such as Cartier, Champlain, LaSalle, and Mackenzie was in part related to the relative immaturity of the botanical sciences. It should be remembered we are discussing events that took place prior to 1700.

The best information about the young Canadian flora came as a result of the efforts of the early French missionaries. Three missionaries made important early France and to collect shrubs and plants that might serve to ornament the King's garden. Michaux also wanted to study the distribution of trees in North America to determine their original centers of distribution. This later project led to the widespread travel of Michaux in eastern North America. The results of his travels provided the first substantial information on the northern limit of many of our forest species, particularly forest tree species such as oaks (Michaux 1801). Michaux's collections and notes provided the basis for the subsequent publication in 1803 of Flora Boreali-Americana by C.L. Richard (Michaux 1803). In addition, Francois-André Michaux used his father's notes as a basis to produce several important scientific publications concerning the woody flora of Canada. The most important publication being the 'Histoire des Arbres forestiers de l'Amérique septentrionale', a three-volume work first published in 1810 (Michaux 1810-1813). It was later translated to English and published as the first three volumes of The North American Sylva (Michaux 1819). The notes and collections of Kalm and Michaux represent the most significant contributions to the understanding of our flora during the 1700's.

The 19th Century opened with the continuation of both Kalm's and Michaux's work by Frederick Pursh. He was motivated because[1]:

"Among the numerous useful and interesting objects of natural history discovered on the vast extent of the new continent, none claim our attention in a higher degree than the vegetable productions of North America. Her forests produce an endless variety of useful and stately timber trees; her woods and hedges the most ornamental flowering shrubs, so much admired in our pleasure grounds; and her fields and meadows a number of exceedingly handsome and singular flowers (many of them possessing valuable medicinal virtues), different from those of other countries. All these are more or less capable of being adapted to an European climate, and the greater part of easy cultivation and quick growth; which circumstances have given them, with much propriety, the first rank in ornamental gardening.

A country so highly abundant in all the objects of my favourite pursuits, excited in me, at an early period of life, a strong desire to visit it, and to observe in their natural soil and climate the plants which I then knew; and to make such discoveries as circumstances might throw in my way."

Pursh walked for 12 years in the United States of America, returned to England, and completed Flora Americae Septentrionalis (Pursh 1814). He then journeyed to Canada and spent the rest of his life in Canada in an effort to produce a flora of Canada. He lost his material in a fire and died in Montreal in 1820 - destitute. In 1857, the Botanical Society of Montreal made an effort to transfer the remains to the Mount Royal Cemetery; however, it was only accomplished in part as the remains were transferred to a vault. In 1877, the Natural History Society of Montreal took up the cause and in 1878, Pursh was finally laid to rest in the Mount Royal Cemetery and a monument was erected in his memory.[2]

During this same period of time, the arctic explorations of Franklin, Ross, Richardson, Parry, Beechey and others took place. Much of this new information appeared in Hooker's Flora Boreali Americana, published in 1840 (Hooker, W.J. 1833-1840). In a sense, this work represented a flora of Canada and was the precursor of Macoun's later work.

The first half of the 19th Century saw the first description of the flora of Newfoundland and adjacent islands by Pylaie (Pylaie 1825). It was also the period when collectors such as David Douglas made known the rich flora of the pacific slope of Canada (Hooker 1836).

The development of a checklist flora of Montreal was initiated by Professor A.F. Holmes of McGill. His avid occupation with collection of the plants of the Montreal region provided the basis for the catalogue of Canadian plants, including the most comprehensive list of plants then published from Montreal (Barnston 1849). Some 520 species of vascular plants were recorded. It would be most interesting to compare this list with the present flora of Montreal!

Two other important Quebec botanists were also active in this period. Abbé Brunet founded the first botanical museum in Canada in 1860 at Laval University and was a leading scholar in the flora of eastern Canada. Brunet published a catalogue of woody plants (Brunet 1867) and a catalogue of the Canadian plants deposited in the Laval University herbarium (Brunet 1865). Abbé Provancher provided the first distinctly Canadian work on the vegetation of eastern Canada - Flora Canadienne (Provancher 1862). Abbé Provancher continued to work for the advancement of botany in Canada and was instrumental in developing the journal Le Naturaliste Canadien (Holland 1966).

The close of the last half of the 19th Century saw the completion of a catalogue of Canadian plants by John Macoun. This catalogue was published in six parts over a period of 14 years and was the most ambitious and complete record of the flora of Canada produced prior to the present century (Macoun 1883-1902).

No review of conscientious and dedicated botanists of this period would be complete without reference to George Lawson. He was the first professional botanist appointed in Canada and is credited with founding the first botanical society and the first botanical garden in Upper Canada at Queen's College [University], Kingston. A review of some of his botanical papers shows he was truly interested in floristics and attempted to develop an understanding of specific species by conducting monographic studies on such species

[1]Page v, volume I, Frederick T. Pursh. 1814. Flora Americae Septentrionalis. London.

[2]A full account of the problems surrounding the death and burial of Frederick Pursh was found in Penhallow [p. 3-6, Transactions of Section IV (Geological and Biological Sciences) Royal Society of Canada. 1897].

as: Myosotis (1869), the family Ericaceae (1870), Canadian Ranunculaceae (1884), the family Nymphaeaceae (1888), and wild grapes (1884). Lawson even tackled the very difficult genus Rubus (1872). His floristic efforts included the publication of a fern flora of Canada (1889) and notes for a flora of Nova Scotia (1863). Lawson was a great catylst of botanical activity in Canada and only recently have his activities been recorded (see Rousseau and Dore 1966). Today, Professor Lawson is commemorated by the George Lawson Medal in Botany - an award established and given by the Canadian Botanical Association 'To provide a collective, formal expression of the admiration and respect of botanists in Canada for excellence of the contribution of an individual to Canadian botany'[3].

It is clear from the foregoing historical review of the documentation concerning the Canadian flora, that the nearly 350 years following Jacques Cartier's voyage to the New World was concerned with the descriptive floristic stage of our understanding of the flora. Towards the end of the 19th century monographic studies were undertaken on a few groups. General treatments of specific plant groups such as Tuckerman's (1845) ennumeration of North American lichens and Sullivant's (1847, 1864) review of North American bryophytes were published. At the same time studies were undertaken concerning the algae of both the Atlantic and Pacific Coasts of North America by Harvey of the Smithsonian Institute at Washington (1852-1858). The age of specialization involving biosystematic studies would soon become part of botanical research of the Canadian flora. The impact of the work conducted in the 18th and 19th centuries, however, would provide important stepping stones toward contemporary botanical research.

The change of the composition of the flora of Canada is mirrored by the gradual development of publications resulting from information garnered by the explorers, missionaries and professional naturalists. Agriculture became an important component of the Canadian economy and resulted in numerous introductions of plants. Man was providing direct influence on the composition of the flora. The percentage of the introduced flora present in relation to the indigenous flora steadily increased from the first contact of the European with the New World. The question as to whether the plant is an introduction or not is not always easy to answer as exemplified by the discussion of Portulaca oleraceae by Byrnes and McAndrews in another paper in this symposium. It is evident, however, that such problems as exemplified by P. oleraceae do present very interesting challenges.

There are many such challenges waiting to be resolved in the flora of Canada. We have not, as systematists, answered the question - what is the origin of our flora? Little research has been conducted on the significant segment of our flora we call introduced. Vast numbers of our introduced species represent excellent large-scale biological experiments that have not been analyzed. The information obtained from study of our introduced flora could have important ramifications to our understanding of the processes of the evolution of plants - particularly those that are weedy by nature. Too often, systematists have not attempted to evaluate and understand the biology of our weedy species, in spite of the fact that both experimental and control samples are available. The research on our naturalized flora must involve a thorough knowledge of the total range and distribution of the species. Such research may often involve painstaking study of the plant in its native and introduced habitat, but surely such a program would provide results which would allow us to better understand the intrinsic characteristics of the biological behavior of the species. Such information is vital if we are to really understand the composition and dynamics of our flora. The many contributors to our knowledge of the Canadian flora during the 350 years prior to 1900 would expect us to carry on developing our knowledge of the biology of our flora. They provided us with many hard-earned cornerstones, surely we should attempt to build the house that people like Kalm, Michaux, Provancher and Macoun so ably started.

[3]For full details of award see Bulletin of the Canadian Botanical Association, Vol. 2(3): 9, 11. 1969.

ACKNOWLEDGEMENTS

I wish to thank my research assistant Mrs. Sylvia Taylor for her assistance in the preparation of this manuscript. Financial assistance was in part provided by the National Research Council of Canada (Grant A-5705).

REFERENCES

Barnston, James. 1859. Catalogue of Canadian Plants in the Holmes' Herbarium, in the Cabinet of the University of McGill College, Can. Nat. 4: 100-116.

Brunet, l'Abbé Louis Ovide. 1865. Catalogues des plantes Canadiennes, contenuers dans l'herbier de l'Université Laval. Quebec. 200 pp.

______. 1867. Catalogue des végétaux lignaux du Canada pour servir a l'intelligence des collections de bois economiques envoyées a l'Exposition universelle de Paris. C. Darveau, Quebec. 64 pp.

Champlain, Samuel de. 1613. Les Voyages du Sieur de Champlain. Paris. March of America Fascimile Series Number 20 by Ann Arbor University Microfilms, Inc.

______. 1632. Voyages de la Nouvelle-France Occidentale, dite Canada. Paris. Reprinted in The Works of Samuel de Champlain vols. I-VI. The Champlain Society, Toronto. 1936.

Charlevoix, Pierre François-Xavier de. 1744. Description des Plantes principales de l'Amerique septentrionnale. Supplément au Tome IV de l'Histoire et description generale de la Nouvelle-France. Paris. pp. 299-388.

______. 1761. Journal of a Voyage to North America. R. & J. Dodsley, London. Translated from the French of P. de Charlevoix.

Cornut, Jacques Philippe. 1635. Canadensium Plantarum Historia. One vol. Paris. Reprinted 1966. Johnson Reprint Corp., New York.

Harvey, William Henry. 1852-1858. Nereis boreali-americana: or, Contributions to the History of the Marine Algae of North America. Pt. 1. Melanospermeae. 1852. Preprinted from Smithson. Contrib. III (art. 4) and bound separately. 150 pp. + 12 pl.; pt. 2. Rhodospermeae. 1853. Smithson. Contrib. V (art. 2): 1-258 + 36 pl.; pt. 3. Chlorospermeae. 1858. Smithson. Contrib. X (art. 2): 1-140 + 14 pl.

Hennepin, Louis. 1698. A New Discovery of a Vast Country in America, Extending above Four Thousand Miles, Between New France and New Mexico; with a description of the Great Lakes, Cataracts Rivers, Plants and Animals. London.

Holland, G.P. 1966. L'Abbé Leon Provancher, 1820-1892. Pages 44-53 in G.F.G. Stanely, ed. Pioneers of Canadian Science. Published for The Royal Society of Canada by University of Toronto Press, Toronto.

Hooker, W.J. 1833-1840. Flora boreali-americana; or, the Botany of the Northern Part of British America. 2 vols. Henry G. Bohn, London. Reprinted 1966. Historiae Naturalis Classica Series, J. Cramer, Weinheim.

__________. 1836. A brief memoir of the life of Mr. David Douglas with extracts from his letters. Companion to Botanical Magazine 2: 79-182.

Kalm, Peter [Pehr]. 1770-71. Travels into North America. 3 vols. London. Translated into English by John Reinold.

Lafitau, Joseph Francois. 1718. Mémoire présenté a son altesse royale Mgr. le duc d'Orléans régent de France, concernant la precieuse plante due gin-seng de Tartarie, Découverte en Amérique par le père Joseph-Francois Lafitau. Paris.

Lawson, George. 1863. Notes for a Flora of Nova Scotia. Trans. N.S. Inst. Nat. Sc. 1: 84.

__________. 1869. Description of the Canadian Species of Myosotis, or "Forget-me-not", with notes on other plants of the Natural Order Boraginaceae. Can. Nat. N. Ser. IV: 398-407.

__________. 1870. Monograph of Ericaceae of the Dominion of Canada and adjacent parts of British America. Trans. N. S. Inst. Nat. Sc. III: 74.

__________. 1872. On the Geographical Range of the Species and Varieties of Canadian Rubi on the Continents of America, Asia and Europe, as indicating possible regions of primitive distribution. Trans. N. S. Inst. Nat. Sc. III: 364.

__________. 1884. Revision of the Canadian Ranunculaceae. Trans. Roy. Soc. Can. II sect. 4: 15-90.

__________. 1884. On the northern limit of Wild Grape Vines. Trans. N. S. Inst. Nat. Sc. VI(2): 101-109.

__________. 1888. On the Nymphaeaceae. Trans. Roy. Soc. Can. VI sect. 4: 97-125.

__________. 1889. The Fern Flora of Canada. Halifax.

Macoun, John. 1883-1902. Catalogue of Canadian Plants. 7 pts. in 4 vols. Ottawa: Geol. Survey of Canada.

Michaux, André. 1801. Histoire des chênes de l'Amérique, ou descriptions et figures de toutes les especes et varietes de chenes de l'Amérique septentrionale, considerees sous les rapports de la Botanique, de leur culture et de leur usage. Paris.

__________. 1803. Flora boreali-americana, sistens Caracteres Plantarum quas in America septentrionale collegit et detexit Andreas Michaux. 2 vols. Paris, Strasbourg.

Michaux, Francois-André. 1810-1813. Histoire des Arbres forestiers de l'Amerique septentrionale. 3 vols. Paris.

__________. 1819. The North American Sylva. 3 vols. Philadelphia.

Penhallow, D.P. 1887. A review of Canadian Botany from the First Settlement of New France to the Nineteenth Century. Part I. Trans. Roy. Soc. Can. V part 4: 45-62.

__________. 1897. A review of Canadian Botany from 1800 to 1895. Part II. Trans. Roy. Soc. Can. sec. 2 3 part 4: 3-56.

Piper, Charles V. 1906. Flora of the State of Washington Contrib. U.S. Nat. Herb. XI: 1-636.

Provancher, León. 1862. Flore Canadienne. 2 vols. Joseph Darveau, Quebec.

Pursh, F. 1814. Flora Americae septentrionalis. 2 vols. Londres.

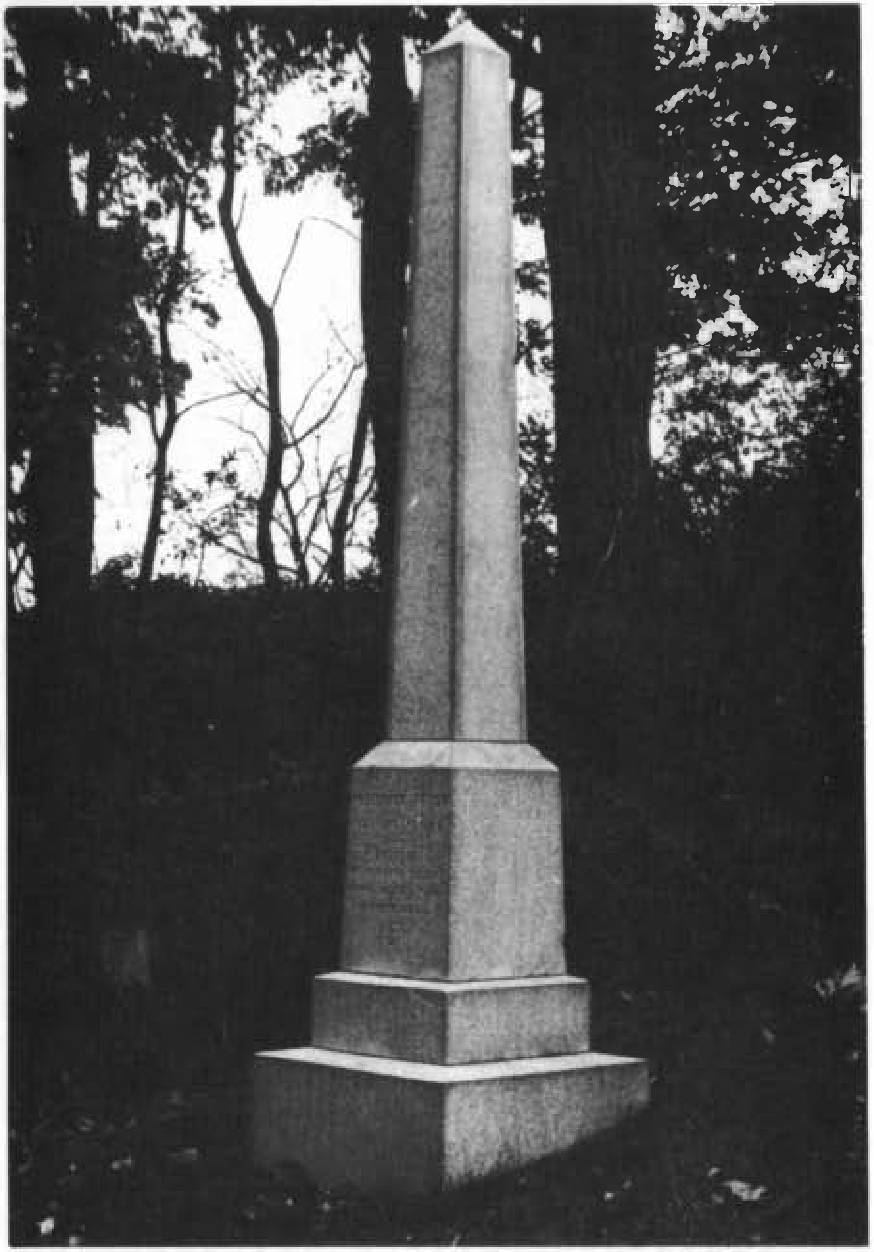
Pylaie, A.J.M. Bachelot de la. 1825. Voyage à l'île de Terre-Neuve, contenant la description des îles voisines et des vues généralis sur leur vegetation. Paris. 131 pp. 1 pl.

Rousseau, Jacques and William G. Dore. 1966. L'oublie de l'Histoire de la science canadienne - George Lawson, 1827-1895. Pages 54-80 in G.F.G. Stanely, ed. Pioneers of Canadian Science. Published for the Royal Society of Canada by University of Toronto Press, Toronto.

Sullivant, William S. 1848. Contributions to the Bryology and Hepaticology of North America - 1. Mem. Am. Acad. Arts & Sc., N. Ser. III: 57-66.

__________. 1864. Icones Muscorum, or Figures and Descriptions of most of those Mosses peculiar to Eastern North America which have not been heretofore figured. Sever and Francis, Cambridge, Mass. and Trübner & Co., London, England. 216 pp. + 129 pl.

Tuckerman, Edward. 1845. An Enumeration of North American Lichenes with a Preliminary View of the Structure and General History of these plants and of the Friesian system: to which is prefixed an Essay on the Natural Systems of Oken, Fries and Endlicher. John Owen, Cambridge, Mass. 59 pp. Reprinted 1964 in: The collected lichenological papers of Edward Tuckerman. Historiae Naturalis Classica series, J. Cramer, Weinheim.



The TOMBSTONE of FREDERICK PURSH

In the Mount Royal Cemetery in Montreal.

PETER (PEHR) KALM

A print from a painting by J.G. Gertel in 1766, housed in the National Museum, Helsinki, Finland (print courtesy of the Hunt Institute for Botanical Documentation).

RECENT CHANGES IN THE CANADIAN FLORA

J.K. Morton,
Department of Biology,
University of Waterloo,
Waterloo, Ontario.

This is an appropriate occasion to take stock of the Canadian flora. How many species does it contain? How many are native and how many are introduced? How many have become extinct or are endangered as a result of man's impact on the environment? And what evolutionary changes are taking place in response to developments? These are the topics I would like us to consider.

Firstly a few statistics. The Canadian flora consists of some 4,000 species of vascular plants. There have been two recent studies - that of Boivin (1966-67), and the more recent one of Scoggan in his Flora of Canada, now in course of publication. I am indebted to Dr. Scoggan for permitting me to consult his manuscript and utilize information from it in compiling this talk. Boivin gives our flora as containing 3,990 species; Scoggan 4,102 species. The differences are due mainly to different treatments of infraspecific variation and of hybrids. Alaska and Greenland, though forming a floristic entity with Canada, have been omitted from these statistics. However between them they only add another 50 species to the native flora - a fact which says little for Canadian identity from a floristic point of view!

We have some 4,000 species in the Canadian flora. This is a small flora for a country so large and diverse as Canada. It reflects our northerly position, for floras become progressively richer as one moves from the poles to the tropics. It also reflects the very recent arrival of our flora in most parts of this country, which have only emerged from the glacial ice sheets within the last 20,000 years.

How does our flora compare in size with other regions? North America, excluding Mexico, is estimated to have between 15,000 and 20,000 species - Canada has but one-quarter of these. Europe has about 16,000 species; Russia a similar number. A small country like Spain with a land area one-half the size of Ontario has 6,000; Britain about 1,500; and a tiny tropical island like Jamaica, about the size of Lake Ontario, has 3,000 species. Hence Canada can hardly claim to have a rich flora. Nor can we boast many endemics. Endemism is usually associated with age; either ancient relics or the products of evolutionary divergence - which is usually a slow process. Because most of the Canadian flora is of such recent arrival in this country, after the receding ice sheets, there has been little time for endemism to develop; whilst few areas remained ice free and could have served as refugia for the survival of species. Amongst our limited list of endemic species are to be included Limnanthes macounii Trel. from Vancouver Island, Senecio newcombei Greene from the Queen Charlotte Islands, and, in the east, Draba peasii Fern. from the tip of the Gaspé peninsula. Any statistics on endemism in the Canadian flora are virtually meaningless because most of our endemics are young endemics which have barely diverged sufficiently to be regarded as species. As a result there is little agreement amongst botanists whether to treat them as species or as infra- specific variation. However, this should in no way detract from the importance of these plants, and there are many of them, or of the habitats in which they occur and are evolving. These centres of endemism are of immense scientific interest for they are open-air laboratories where natural experiments in evolution and speciation are in progress. Many of these areas in Canada are well recognized. Through the efforts of I.B.P. and others many are protected, or efforts are being made for their protection. The lower St. Lawrence is particularly rich in such areas - Mount Albert and its neighbouring mountains, parts of the Gaspé Coast, the Mingan Islands, Anticosti, the west coast of Newfoundland, etc. Other areas of endemism include the sand-dunes of Lake Athabasca, several of the mountainous areas of Alberta and British Columbia, the Queen Charlotte Islands, high ground in the Yukon and flanking the Mackenzie Valley. The preservation of these and similar areas is of immense importance, before their endemic flora becomes endangered due to the encroachment of modern men through agriculture, urbanization, industrialization, the development of transport systems and recreation areas.

The two great changes which have taken place in recent years in the Canadian flora both relate to man's activities. On the one hand the destruction of vast areas of natural vegetation, and with it the decimation, and in some cases extinction of local populations and species. On the other hand the introduction of species from other parts of the world and their dispersal, along with some of our native species, to other areas in this country. How has the Canadian flora stood up to man's impact - how serious have been the results? In terms of destruction of vegetation the situation is all too obvious. Little remains of the once extensive deciduous forest which once covered southern Ontario and Quebec. On the vast prairies it is difficult to find a bit of natural grassland. In the west little remains of the magnificent forests of the coastal regions with their majestic giants of Sitka spruce and Douglas fir. Around many of our lakes, cottage development is destroying the unique and very restricted marsh and rock habitats. Even the endless boreal forests have been ravaged for timber and pulp; and now our mountains are being threatened by ski resorts, and the arctic by the oil industry. This tremendous destruction of natural vegetation has inevitably resulted in the increasing rarity and even extinction of many of the characteristic species of these habitats. Just how great have been the losses we frankly do not, at this time, know. Information on this subject is, for the most part, known only to local naturalists and botanists scattered across Canada, each with a bit of information relating to the area in which he lives or works. We urgently need a centralized index of plants which are very rare or local and liable to extinction through man's interference - a sort of Red Book for the Canadian Flora. The zoologists, at least as far as the birds, mammals, reptiles and fishes are concerned, are far ahead of the botanists in this respect and appear to know fairly precisely the status of each of their species in Canada. I.B.P. has done some very valuable work in identifying and recommending for preservation, important areas of natural vegetation in which many of these rare plants occur. However, many of our most threatened species occur in places where no extensive areas of natural vegetation remain. Only by identifying the endangered species and determining where they still occur can we attempt to set aside areas of land for their conservation. Hence we must have an index, a Red Book, of rare and threatened species. I propose that the Canadian Botanical Association, through its Systematics and Phytogeography section, become actively engaged in the creation of an index of rare, endangered and extinct vascular plants. This information is essential if objectivity is to be a part of our efforts to create conservation areas and save our ever dwindling plant resources.

What is the present position as far as extinctions and endangered species are concerned? Through the co-operation of many members of our Association, and from the literature, I have been able to assemble some of the fragmentary information, but I am sure the results are very incomplete. At least two Canadian species appear to be extinct and occur nowhere else in the world - Pedicularis furbishiae S. Wats. and Mitella prostrata Michx. The former used to occur fairly frequently in the valley of the St. John River but has not been seen since 1943. The latter occurred but rarely in the Lake Champlain area. Also, of course, the North American Chestnut Castanea dentata (Marsh.) Borkh. is probably doomed as a result of disease, and now survives mainly as suckers from old stumps or in cultivation.

These are species not found elsewhere in the world and if extinct are lost for all time. In addition many more species are apparently now extinct in the Canadian part of their range, though surviving elsewhere. I have a list of thirteen such species - all incidentally from southern Ontario, - a region which is rich in species at the northern limit of their range and which has suffered most from man's depredations. My list is doubtless very incomplete but it includes such plants as:

Circis canadensis L. (Norfolk Co.)
Iris brevicaulis Raf. (Pt. Pelee)
Conobea multifida (Michx.) Benth. (Pelee Isl.)
Juncus brachycarpus Engelm. (Essex Co.)
Euphorbia serpens HBK
Stylophorum diphyllum (Michx.) Nutt. (near London)
Agastache scrophulariaefolia (Willd.) Ktze.
Blephilia ciliata (L.) Benth. (Pelee and Walpole Islands)
Silene virginica L.
Silene stellata (L.) Ait. f.
Paronychia canadensis (L.) Wood
Scutellaria nervosa Pursh (Essex Co.)
Stellaria pubera Michx.

Many more species just hang on in one or two localities - very vulnerable to destruction. Amongst such plants can be mentioned the Canadian endemic Limnanthes macounii Trel. which only occurs near Victoria, B.C. and about which Dr. Césta wrote to me recently saying he could only find 2 sites this year, each with 2 to 3 hundred individuals. Plantago cordata Lam. is in a similar situation in southern Ontario with very few individuals remaining; whilst the distinctive native tetraploid race of Cerastium arvense var. oblongifolium (Torr.) Pennell now survives in Canada as a single patch measuring about 2 ft. by 4 ft., by the roadside on Point Pelee.

These examples of plants which are either wholly extinct, or extinct in the Canadian part of their range, or endangered, represent but the tip of the iceberg of our problem. Some concept of the magnitude of the problem can be gained by listing those species which, in Canada are confined to restricted areas in a single province or astride the border of 2 provinces. From an analysis of Dr. Scoggan's manuscript I find that there are 512 such species - one-eighth of our flora that is potentially endangered.

This takes no account of the wealth of infraspecific variation found in our flora - subspecies of varieties, which includes so many of our evolving endemics from places like Newfoundland, the Gaspé, and Lake Athabasca. Nor does it take any account of species with remote isolated populations which are of immense phytogeographic importance and which have probably diverged genically from those in the main centre of distribution. Examples include Schizaea pusilla Pursh which had an outlying population on the Bruce Peninsula, Ontario - now probably extinct, with its main range in the Maritimes; and Cheilanthes siliquosa Maxon with isolated populations in the same area and in Quebec, whilst its main centre of distribution is British Columbia. Or Arenaria humifusa Wahlenb. which was recently discovered by Mr. Garton near Thunder Bay, and also occurs on Mt. Albert, though its main distribution is in the arctic and down into Newfoundland. It turns out that these 2 isolated populations at Thunder Bay and on Mt. Albert both have 44 chromosomes instead of the 40 found throughout the arctic populations.

If we add to the eighth of our flora which, by its restricted range, is potentially endangered, all those species with locally developing endemic races, or which have widely disjunct isolated populations, we begin to see the magnitude of the problem which faces us. For effective measures to be taken to preserve our flora we must know what species and divergent populations are endangered, and what others occur in areas where they may become endangered. Hence the need for our index or Red Book.

The extinctions and the endangered species provide one side of the balance sheet resulting from man's activities in Canada. The other side is represented by the alien species which have been added to our flora and become established in this country. How many aliens have we? What proportion of our 4,000 species are native and what are the results of recent introduction since white man settled this country? Over one-fifth of our flora consists of aliens - nearly 900 species (884-Scoggan;

895-Boivin). Just how effective many of these aliens have been in establishing themselves is apparent along almost any stretch of road or railroad. A typical situation here in southern Ontario is one in which these habitats are dominated by introduced species to the virtual exclusion of native species other than Solidago canadensis L. and Asclepias syriaca L. The situation is similar, but less extreme, along many of our rivers and lake shores where aliens form a major component of the flora.

Where did these aliens come from? From all over the world, but of course particularly the north temperate regions. M. Camille Rousseau (1968) has analysed the introduced flora of Quebec and Ontario, which between them contain about 800 of the 900 Canadian aliens, and found that 76% are species with a European or Eurasian origin and only 16.7% came from the American continent, the residual 7% coming from the rest of the world.

As Dr. Taylor has pointed out, in the previous paper, this introduced element of our flora presents a vast natural biological experiment which poses many fascinating problems and justifies much greater attention than it has so far received, for these aliens can tell us much about the general biology of plants. As an example of the sort of problem which is posed let me cite the case of Stellaria graminea L. - a persistent and even pernicious weed of grassy places, abundant on the eastern side of North America and occasionally encountered in the west. In North America the species is entirely tetraploid (2n=52) but in Europe, from whence the species was introduced, only the diploid is widely distributed and abundant. The tetraploid appears to be restricted to low lying land in Holland. Why has the tetraploid been able to spread so rapidly and widely in North America whilst the diploid has not even been able to gain a footing? Surely the diploid must have arrived in this continent on many occasions, for it is so common in Europe. There are ample suitable niches for it on this continent and it survives our winters at Waterloo. The problem is one I cannot as yet explain.

Lastly I would like to consider some of the evolutionary changes which are taking place in our flora as a result of man's impact. The results of man's intervention on evolutionary processes have been described from many parts of the world. The effect of the honey bee as an efficient pollinator when introduced into New Zealand, and the resultant hybrid swarms which developed in the native flora were described many years ago by Cockayne. The evolution of a new species of saltmarsh grass - Spartina townsendii H. & J. Groves in the south of England as the result of the introduction of the North American S. alterniflora Lois. appears in many college text-books; as also does the story of the effect on the Iris populations of the draining and clearing of the Mississippi delta, which prompted Edgar Anderson to coin the term introgressive hybridization. These and many other examples of the results of man's activities on evolution are well known. Have there been similar effects in the Canadian flora? It appears that there have.

Crataegus (the hawthorns) is a genus of shrubs with its centre of distribution in eastern North America. Before man destroyed the almost continuous forests, the species were restricted to small and distinct habitats such as river banks, rocky hill tops, and temporary clearings where fire had destroyed the forest. Under such conditions there was little chance for the various species to come into contact, and conditions were thus not favourable for hybridization. Most of the species are interfertile and were thus maintained by ecological isolation. The destruction of the forests by the early settlers opened up vast areas of habitat suitable for these opportunist hawthorns, which came to grow intermixed. Hybrids arose and it appears that many of the species described by early botanists were first generation hybrids which have since died out. Others have persisted and been maintained by apogamy; in yet others some measure of sexuality, with its associated segregation, has produced hybrid swarms. Thus has man's activity given a spurt to the recent evolution of the North American hawthorns producing an array of variation, baffling to the taxonomist, but highly adaptive for the hawthorns, giving them an aggressive competitiveness which has made them amongst the most successful shrubs in the extensive areas of disturbed land in eastern Canada and the United States. It is worth noting that Dr. Jacques Rousseau (1966) attributed the origin of this spurt of evolution in the hawthorns to Iroquois Indians who cleared areas of forest for agriculture and settlement before the advent of the white man. However, the arrival of the latter undoubtedly added a new stimulus to a process already begun. Amelanchier presents a similar situation which accounts for the taxonomic difficulties, great variability and local abundance of these shrubs.

In the asters (Aster) and goldenrods (Solidago) we find a somewhat different situation. Again the species were mostly ecologically isolated, but extensive clearing of the forests gave a tremendous opportunity to some of the species with weedy tendencies. These have increased in abundance at a phenomenal rate and now occupy large areas of disturbed habitat. In both genera most of the species are outbreeders. Hybrids appear to be rare and have contributed little to the recent success of these plants. Instead the result of this great increase in abundance has been to stimulate genotypic and phenotypic variation which, with the breakdown of ecological separation of the species, has made identification of many of the taxa very difficult and has made them more competitive and adaptive, thus enabling them to exploit the opportunities provided by this wealth of new habitats.

Have any of the introduced species become involved in similar processes? Several examples come to mind and there must be more. Firstly the dandelions. The common dandelion (Taraxacum officinale Weber) is introduced from Europe. It is apomictic, probably an obligate apomict, but produces good pollen. In North America, in the arctic and in the mountains of the west, we have a number of native species of dandelion, at least some of which are sexual. When the Alaska Highway and similar roads were constructed the common dandelion moved in and colonized the roadsides, as also did some of the native species which thus came to grow side by side. A few years ago a number of new species of Taraxacum were described from these highways. They appear to be hybrids between the common T. officinale and native species. Whether they are apomictic and will thus be perpetuated as species, or whether they are sexual and will be lost through segregation I do not know. They present a problem worthy of further investigation.

Another case relates to the chickweed Cerastium arvense L. In Canada our common native form is diploid, but in the east the European tetraploid has been introduced and is a common weed. The two are very difficult to hybridize, but it can be done and near Otter lake, southwest of Ottawa, nature has succeeded. Here there grows along the railway line a large clone of a backcross of the F_1 hybrid with the tetraploid parent. It is largely, but not completely sterile and extremely aggressive, occupying 100 yds. or more of the embankment to the exclusion of most other plants. Whether this will give rise to a new fertile type due to further selfing or backcrossing - a plant which will be a new aggressive weed, or whether it is an evolutionary dead-end which will die - out due to sterility, only time will tell; but this is a biological experiment, being undertaken by nature, and one which is still in progress.

In conclusion Canada's flora is changing, and changing rapidly, due largely to the impact of modern man. On the one hand we have the decimation and extinction of some species, but on the other we have gained many new aliens, and coupled with this has been the stimulus to certain opportunist groups of plants such as the hawthorns and dandelions which is leading to evolutionary change through the production of new and better adapted genotypes. What will the future hold? Only time will tell, but of one thing I am sure, the Canadian flora will continue to be a fascinating subject for study!

LITERATURE CITED

Boivin, B. 1966-67. Énumération des plantes du Canada. Provancheria 6, Laval University, Québec.

Rousseau, C. 1971. Une classification de la flore synanthropique du Québec et de l'Ontario I. Caractères Généraux. Naturaliste canadien 98, 529-533.

Rousseau, J. 1966. Movement of plants under the influence of man, in Taylor, R.L. & Ludwig, R.A. The evolution of Canada's flora. Toronto. 137 p.

THE ECOLOGY OF WEEDS - MAN'S IMPACT

P.B. Cavers,
Department of Plant Sciences,
University of Western Ontario,
London, Ontario.

There are obvious and deliberate effects of human activities on populations of weedy plants. If most farmers and gardeners had their way there would be no weed populations! Thus a weed is defined by Frankton and Mulligan (1955) as a plant growing where man does not want it to occur. This term is an anthropic one, it reflects man's priorities. I have alluded already to the concept that I want to stress in this paper. Weedy species exist and spread despite man's best efforts to eliminate them. Much current evidence indicates that a number of weed species could not continue to exist if human manipulation of vegetation were to cease. In some cases the weed control treatment actually encourages or enhances the weed's potential for survival. The plants that we call weeds grow in many kinds of habitat and the criteria for survival in one habitat may be very different from those necessary in a second. I will only have the opportunity to evaluate two types of habitat as potential sites for weeds. These two habitats are (a) arable, cultivated land and (b) lawns.

WEEDS OF ARABLE LAND

In an area which is cultivated more or less continuously any existing plants are liable to be destroyed during tillage. Weedy species possess a variety of ways of overcoming this problem but perhaps the most important is the possession of dormant seeds. An excellent discussion of this subject was provided in 1946 by W.S. Chepil of the Experimental Farms Service of the Canada Department of Agriculture. Chepil (1946) pointed out that seeds of some weeds do not exhibit a marked dormancy, and for this reason alone can be controlled by various cultural treatments. When seeds of these species are ploughed under they will germinate, and most of them will be buried so deeply that they will rot without emerging. On the other hand seeds with a considerable degree of dormancy will be preserved by burial and will remain dormant in the soil until some further cultivation or digging activity brings them back closer to the surface again.

Chepil illustrated these conclusions through a personal study of 58 species at Swift Current, Saskatchewan. Two of these species will serve to illustrate his results. On the one extreme he found a number of species whose seeds had a very short period of dormancy. Typical of these species was *Agrostemma githago* L., the corn cockle or purple cockle. This species was introduced into Canada from Europe where it has had a very long history as a weed of arable land. Thompson (1973) states that it has been inadvertently cultivated by man for 5000 years because its seeds are generally collected with crops such as wheat, oats or barley. The seeds are large and consequently difficult to separate from grain samples so they have been sown with the crop for centuries. Also, in Canada the plant is a winter-annual whose life cycle is closely synchronized with that of a winter grain crop and this makes cultural control difficult. Nevertheless at the time of Chepil's article in 1946, *Agrostemma githago* was no longer a serious weed. Improved methods of seed cleaning and a cropping system which allowed the destruction of small seedlings before a spring crop was sown, were two measures which led to its virtual elimination. I challenge you to find a plant in this area today, yet in the early years of this century it was listed as a noxious weed for all of Canada (Clark, 1906). Here is a species that could be eliminated by man primarily because its seeds had little or no dormancy. It may already be a prime candidate for Dr. Morton's 'Red Book' of endangered species!

In contrast most modern visitors to Canada, and especially this part of Ontario, are impressed with the abundance and widespread distribution of common dandelion, *Taraxacum officinale* Weber. For most newcomers it is our most obvious plant. This species was also studied by Chepil who found that its seeds had "long to very long" dormancy in cultivated soil. Chepil also found that the seeds had no regular or marked periodicity of germination, instead they germinated throughout the growing season in an intermittent fashion. Intermittent germination is a vitally important characteristic for weed species since new seedlings will be continuously appearing to replace others which have been destroyed by man's attempts at weed control, or by natural causes.

If we compare *Agrostemma githago* and *Taraxacum officinale* in other respects we can find additional reasons for the continued success of the latter species. Consider seed dispersal. On arable land a species whose seeds are readily adapted for dispersal may well be dispersed to at least some new arable fields where the pressure of human weed control measures is much less intense. A closer look at dandelion and corn cockle shows us that dandelion is much better adapted for dispersal from the surface of cultivated soil. Each seed has a parachute mechanism which enables the whole structure to be lifted off the plant by convection currents. Warm air from right above the partly-bare soil rises up through the cooler layers above it and carries the dandelion propagule to heights from which it can drift for long distances. If the seed is detached from its parachute it will fit in flatly against a damp lump of soil and can be carried with that soil on clothing, boots, wheels or animal fur. Thus there are many ways in which the dandelion can be dispersed readily in modern habitats.

In contrast seeds of corn cockle are

well-adapted for dispersal with the crop. Chepil noted that the capsule of Agrostemma githago is resistant to shattering and that the seeds tend to be collected with the crop. However, each seed is large and if it remains in the field it will generally drop near the parent plant. Each seed of corn cockle is rounded also and does not stick easily to small lumps of dirt. Thus if it doesn't get collected with the crop its chances for dispersal are not good.

Finally we can compare these two species in terms of their life cycles and the response of the individual plant to cultivation. Agrostemma githago is an annual; it is usually destroyed by cultivation and if occasional plants recover they may not be able to reproduce before they die at the end of the growing season. On the other hand dandelion plants are perennials; cultivation often fragments the root into several pieces each of which can give rise to a new plant. In this way, human activities actually multiply a well-adapted genotype without that genotype being subjected to the dangers of germination and seedling establishment, a stage at which many individuals perish.

This brief introduction to the ecology of weeds of arable land illustrates clearly how two species, that must have been equally abundant at the time of European settlement in this area, have responded in totally different ways to subsequent farming and other human activities.

WEEDS OF LAWNS

Each lawn is a habitat that has been created by man and which requires constant attention in the form of clipping, fertilizing, spraying, rolling etc. if it is to be maintained in a condition acceptable to its creator. The number of species that are really successful as lawn weeds is not great and these species share some obvious attributes:

(a) They are able to survive and reproduce in spite of constant clipping. Many lawn weeds such as plantains and dandelions grow in the form of a flattened rosette. Very little of this structure is removed by close mowing, while at the same time competing plants are cut from above it. Reproduction in dandelions and in some other lawn weeds occurs very quickly; an inflorescence can develop and produce ripe seeds between mowings. With species such as plantains new reproductive structures can be produced more or less continuously throughout the growing season (Hawthorn 1973). If many stalks are cut some will eventually be missed by the mower and will bear ripe seeds. Other species such as black medick (Medicago lupulina L.) produce inflorescences near ground level and these will not be damaged by mowing. Many lawn weeds can survive to reproduce in another year if their inflorescences are removed by clipping during one season.

(b) They are resistant to trampling. Those weeds which are most prevalent on lawns are obviously resistant to trampling and soil compaction. In a recent study at this University Dr. Wayne Hawthorn (1973) showed that plants of common plantain (Plantago major L.) lived much longer when they were growing in roadways and other heavily trampled areas than they did in pastures or other areas where little trampling occurred.

(c) They can compete or at least exist with vigorously growing plants of other species in an area of high fertility. Sometimes weeds are very competitive but in other situations they simply start to grow when other plants have died or are not growing. In a heavily fertilized, well-watered lawn, the lawn grasses grow vigorously throughout the growing season and there are few weeds which can compete directly with them on an even footing. However, there are many ways by which weeds can be maintained in a lawn and then can make rapid growth when the grass is damaged or destroyed. 1) Some plants can grow for long periods in the shade of other plants, suppressed by them but can then grow rapidly when their chance occurs e.g. Glechoma hederacea L. 2) Some clover plants are favoured when the nitrogen supply drops. They then expand at the expense of the grasses which have no rhizobial bacteria associated with their roots. 3) Many weeds exist in the form of dormant seeds until a part of the sward dies or is torn away and bare soil is exposed. Such seeds will not germinate unless exposed to unfiltered sunlight (Roberts 1972). Some recent papers by Wesson and Wareing in Britain (1969a, b) have illustrated the overriding importance of light in causing the germination of many dormant weed seeds.

A recent study by Dr. Surindar Sidhu, formerly of our department, illustrated how a lawn weed can take advantage of divergent conditions. Medicago lupulina (black medick), when it grows in a lawn, produces hard black seeds that are very dormant. They will usually germinate only after two or three years of weathering and then only in a site without a cover of vegetation. However, if the plant is growing on partly bare soil some inflorescences are borne near ground level and if there is a heavy rain storm the whole developing inflorescence may be covered with a thin layer of soil. If this happens all 20 or more seeds in an inflorescence may become essentially viviparous and continue developing until a cluster of seedlings arises near the parent plant. One eventually survives and the others die off. In this way new plants are produced quickly on bare soil and there is rapid colonization by Medicago lupulina. On lawns, in contrast, seed germination is delayed until some grasses die or at least die back, but the stock of dormant seeds ready to grow when a favourable condition arises remains high (Sidhu 1971).

(d) They grow at a time of the year and under conditions when the lawn grasses are not growing well. For example, crabgrass (Digitaria spp.) does well in this area during hot, dry spells in the summer when the desirable grasses are dormant or dying. Plants of crabgrass can grow quickly and reproduce by means of seeds before the regular lawn grasses recover. Other weeds such as Poa annua and Medicago lupulina also have very short life cycles and can succeed in this way.

Species Which Fail as Weeds of Lawns

A number of our roadside and pasture weeds might seem to possess the attributes necessary for success as lawn weeds but they are rarely or never found in well-kept lawns. For example, Harrison and Dale (1966) found that plants of wild carrot (Daucus carota L.) could not survive repeated clipping. Since this species is a biennial which reproduces solely by means of seeds, and since any inflorescences develop relatively slowly in an upright manner, frequent clipping can more or less prevent reproduction.

OTHER INTERRELATIONSHIPS BETWEEN WEEDS AND MAN

1. The Importance of Refuge Areas:

A number of species continue to persist as weeds of agricultural or urban areas because they also occur in large populations in natural or semi-natural habitats where weed control measures cannot be practiced safely or effectively. For example, the common and poisonous "Bouncing Bet" (Saponaria officinalis L.) is a frequent constituent of open woodlands and can be seen in such sites on this campus. Another habitat, possibly more important as a refuge, is the riverbank gravel bar, especially the zone which gets swept clear of vegetation each year and is then recolonized by weedy annuals. We have been studying gravel bars along the Thames River for many years and have found that the most common species of these bars are also common weeds of agriculture.

As one example Richard Staniforth has been studying three weedy smartweed species Polygonum lapathifolium L., P. persicaria L. and P. pensylvanicum L. All three of these species are very abundant in riverbank situations and in addition P. lapathifolium and P. persicaria are common weeds in cultivated fields. Richard has been able to establish the following points about these species:

a) the common weedy forms are well-adapted for growth and reproduction on gravel bars.

b) propagules of all three species can be dispersed widely by flood waters.

c) seeds of at least two species (Polygonum persicaria and P. lapathifolium) can be carried from riverbanks to cultivated land by rabbits, which excrete some seeds in a viable state. These rabbits (cottontails) eat large quantities of the seeds of these species.

Another species which is very common on riverside gravel bars in the London area is yellow rocket (Barbarea vulgaris R. Br.). This species is strongly attacked by flea beetles (Psylloides napi) when it grows in farmland; yet it is an abundant and spreading weed in this area. Part of its success may be due to its occurrence on riverbanks, a habitat where the flea beetle seems to be mostly absent (M.A. MacDonald, personal communication). In this situation the riverbank is a refuge against human and insect attack!

2. Large Scale Effects of Herbicides and Resistance to Them:

It is not possible in this paper to discuss thoroughly the major effects of herbicides on the weed flora. I will try to summarize some important ecological effects. (a) First, certain weeds such as wild mustard (Brassica spp.) have been greatly reduced in numbers and quantities over large parts of their area. This effect has been particularly noteworthy on arable land where the most widespread and efficient spraying has been done. Other species, such as certain grass weeds, have been resistant to the most commonly-used herbicides and have increased in quantity. One problem that man has to consider is that the species which increase after herbicide treatment may be worse than those which were present originally. (e.g. if an increasing weed is poisonous to man or farm animals, if it is prickly, or if it causes hay fever or similar problems then it may very well be worse than the original species).

(b) A second important point is that the herbicide is usually quite precise in its effect. It works where it is applied but has little or no effect on weeds in surrounding areas. Thus spraying our lawns to control weeds such as dandelions is a pretty worthless practice since new seeds will undoubtedly be wafted in to the lawn from areas where herbicides cannot be applied for fear of damaging desirable vegetation. However, you are not likely to damage plants beyond the area where you spray if you are careful, thus any damaging effects are limited to the area of application.

(c) A third point is that there is now clear evidence of new forms appearing in certain weed species; forms which are resistant to commonly-used herbicides. You have all heard of the problems with certain insecticides; where the genotype of an insect such as the mosquito will change rapidly because of forced selection of resistant strains through the continued application of one insecticide. This problem has not been considered important in weed control since: 1) weeds generally have one or fewer generations per year whereas many pest insects have 10 to 15 or more generations per year, and 2) in many situations the same herbicide is not sprayed on the same field year after year, rather different crops are grown in rotation and different herbicides are used for each crop. Nevertheless there have been several examples of herbicide resistance in weed species and some of these have been reported from Canada. For example, Whitehead and Switzer (1963) at the University of Guelph found that some strains of wild carrot (Daucus carota L.) are resistant to 2,4D and related herbicides. Walter Saidak and Paul Marriage at Harrow, Ontario (Canada Department of Agriculture) have shown that some ecotypes of Canada Thistle (Cirsium arvense (L.) Scop.) are more resistant than others to 2,4-D and amitrole (a triazole herbicide).

Here in London we have been looking at the biological characteristics of a form of common groundsel (Senecio vulgaris L.) that is resistant to all normal doses of simazine and atrazine under both field and greenhouse conditions. This taxon originated in Washington State on the West Coast of the U.S.A. where groundsel can have six or more generations per year, and thus you could get rapid selection for herbicide resistance (Ryan 1970). Also atrazine and simazine are persistent in the soil so that groundsel would be exposed to continuous selection on land where these herbicides are regularly used. From this brief discussion we can conclude that in the future many weeds may become widely distributed in managed habitats simply because they are naturally resistant to popular herbicides or because resistant genotypes have evolved.

3. The Biological Control of Weeds:

In Canada, biological methods of weed control have not been utilized for many species. Here, every major attempt to control weeds by biological methods has been done by introducing a phytophagous insect to eat the particular weed that one wants to destroy. Excellent control has been obtained for Hypericum perforatum L. (St. John's wort) in some areas of B.C. and promising results have been forthcoming for a few other species (Harris 1971). However, rapid strides are now being made in biological weed control in other parts of the world, and we may expect to see fungi, viruses and other animals as well as insects introduced to control specific weeds within the next few years. Two important points about biological weed control are worth stressing: (a) The biological control agent generally does not eliminate the target weed; it just reduces it to very low levels of density and vigour. Thus biological control is not likely to totally eliminate a particular species unless other factors of the modified habitat become unfavourable with the reduction in weed biomass. (b) A very important aspect of biological control is that the control agent cannot be kept within precise boundaries. Once you introduce a particular insect or disease to North America there is a very good chance that that agent will spread throughout the range of the target weed species. If man makes a mistake and either imports an organism which also damages an important and beneficial plant species, or changes his mind about the merits of the target weed species, he cannot easily eliminate or reverse the biological control that he has established.

ONE FINAL CONSIDERATION

One of the paradoxes of weed control work is that man does change his mind as to the merits or demerits of a given plant species. A species that is a weed in one habitat may well be considered a very desirable plant by other people if it grows in a different part of the country or even in a different habitat within the same area. For example sweet clover is an important forage crop in Western Canada whereas here it is usually just a roadside weed. Many people consider that blueweed (Echium vulgare L.) is a useless prickly plant that should be destroyed, yet it is one of Ontario's most important wild honey plants (G.F. Townsend, personal communication). In Britain, partridge populations have declined in the past few years primarily because farmers have finally obtained a herbicide to kill off the partridges' main food plants; those same smartweeds, Polygonum spp., that were described earlier in this paper (Potts 1970). It is also true that many plants which we consider to be weedy are present in our fields simply because they were once selected to grow there as crop plants. All of the eventual results of man's efforts at weed control have not been apparent when a particular measure was taken. Finally there is good evidence from the foregoing information that the most sweeping and dramatic changes in vegetation wrought by man in Canada have been, and will continue to be, in the weed flora.

REFERENCES CITED

Clark, G.H. and Fletcher, J. 1906. Farm Weeds of Canada. Department of Agriculture Canada. 103 p.

Chepil, W.S. 1946. Germination of weed seeds. I. Longevity, periodicity of germination and vitality of seeds in cultivated soil. Sci. Agric. 26: 307-346.

Frankton, C. and Mulligan, G.A. 1955. Weeds of Canada. Publication 948. Canada Department of Agriculture. 217 p.

Harris, P. 1971. Biological control of weeds in Canada, 1959-1968, pages 67-104 in Biological control programmes against insects and weeds in Canada. Commonwealth Agricultural Bureaux, Farnham Royal, England 266 p.

Harrison, P.J. and Dale, H.M. 1966. The effect of grazing and clipping on the control of wild carrot. Weeds 14: 285-288.

Hawthorn, W.R. 1973. Population dynamics of two weedy perennials, Plantago major L. and P. rugelii Decne. Ph.D. Thesis, University of Western Ontario. 316 p.

Potts, G.R. 1970. Studies on the changing role of weeds of the genus Polygonum in the diet of the partridge Perdix perdix L. J. Appl. Ecol. 567-576.

Roberts, E.H. ed. 1972. Viability of seeds. Chapman and Hall Ltd., London. 448 p.

Ryan, G.F. 1970. Resistance of common groundsel to simazine and atrazine. Weed Sci. 18: 614-616.

Sidhu, S.S. 1971. Some aspects of the ecology of black medick (Medicago lupulina L.). Ph.D. Thesis, University of Western Ontario. 357 p.

Thompson, P.A. 1973. Effects of cultivation on the germination character of the corn cockle (Agrostemma githago L.). Ann. Bot. 37: 133-154.

Wesson, G. and Wareing, P.F. 1969a. The role of light in the germination of naturally occurring populations of buried weed seeds. J. Exp. Bot. 20: 402-413.

__________. 1969b. The induction of light sensitivity in weed seeds by burial. J. Exp. Bot. 20: 414-425.

Whitehead, C.W. and Switzer, C.M. 1963. The differential response of strains of wild carrot to 2,4-D and related herbicides. Can. J. Plant Sci. 43: 255-262.

THE IMPACT OF URBANIZATION

N. Pearson,
Department of Political Science,
University of Western Ontario,
London, Ontario.

URBANIZATION: THE DOMINANT FORCE

Urbanization is, and will continue to be, the dominant force in environmental change in Canada. This impact should not be imagined as simply the built-up area of obvious urban change. We must learn to think of the urban-revolution in terms of all the associated changes which constitute a fundamental transformation. These changes are based on the energy which enabled the agricultural revolution, and which in its turn has started the massive onslaught of resources exploitation to serve the metabolism of the city. In its turn, the city has become metropolis, and the potential reality of the megalopolis, in the Great Lakes Basin and the St. Lawrence Valley, and in the Fraser Valley, shows yet another stage in urban development.

Thus when we speak of urbanization we are also speaking of:

1) The urban area itself, which currently in Canada uses anywhere from 300-1200 acres of land for every 1,000 people added. This includes all the residential, industrial, commercial and associated recreational, cultural, institutional and public utilities land uses.
2) The urban fringe area, of mixed land uses, not yet urbanized, but being affected by urban pressures. Such areas can be from 3 to 5 times the main urban built-up area. It is usually an area where agriculture is in retreat, where there are such uses as hobby farms, horse farms, and where there is a great deal of scattered development, and idle speculative land.
3) The associated "urban field" within a few hours of driving time or travel time, in which public recreational space is provided at about 3 acres per 1,000 people (in the main urban centre), and in which very low density recreational housing (seasonal or permanent) is provided, generally water-oriented. This results in considerable and often quite dramatic variations in environmental loading because of seasonal fluctuations in population.
4) The transport and communications corridors and utility corridors linking the urban centres themselves, and tying them to the power and energy sources on the one hand, and to the resources-production and recreational centres and food supply areas on the other. These form very complex systems including very large areas for airports and railway goods yards.
5) The urban field also is the area which contains the main regional waste disposal areas for urban and industrial solid and liquid wastes.
6) The permanent highly-industrialized production agricultural landscape, which is also tied to areas of water resource conservation and storage and supply; areas of aggregate and surface mineral production; and areas of wildlife conservation and production; and areas for day-use recreation and permanent country homes for the urban population, on land which is now no longer needed for farming.
7) The wilder landscape of resources production; the area of forestry, tree-farming, mining, fisheries production, pulp and paper mills, smelting and mineral processing, and also some of the few remaining areas outside the ecumene, but increasingly drawn into it. This is the area which represents the outer perimeter of the great network of urban-resources demands.

THE INTER-ACTION OF URBAN DEMANDS ON THE ECUMENE AND BEYOND

Thus the impact of urbanization affects, directly or indirectly, the whole ecumene, and beyond to the limits of resource exploitation. There is a constant and increasingly severe and complex set of inter-actions:

1) The urban population is rapidly increasing. Canadian population is expected to increase to about 35,000,000 within the foreseeable future. This is likely to occur by the year 2000, at which time the urban proportion will have increased from 75% to 90%. This urban population of 31.5 million means more than a doubling of the present urban population, and physically, represents the creation of as much development as has occurred in the whole of Canadian history to date. If unguided, it could mean the extinction of Canada's best climatically favoured farmland by 2020 A.D. Even if the trend continues towards "zero population growth", the current demographic structure, and the associated technological, economic and social forces all point to a continuation of a very high rate of urbanization. Over the last 20 years, Canada has urbanized more rapidly than any other country, at a rate of 4% per annum. The next highest rate in the world is 2.7% in the USA.
2) The urbanization is increasingly concentrated. By the year 2000, 75% of the total population (the proportion which is presently urbanized) will live in no more than 12 major urban centres. If we take the threshold level of 500,000 people as evidence of a mature urban centre, Canada has 5 now and will have 7 more by the year 2000. The main concentrations of population will be in metropolitan and megalopolitan areas. Thus, by 2000, the Toronto and Montreal areas are expected to be at the population level of 7,000,000 to 8,000,000 (comparable to Tokyo, New York, Greater London, Chicago or Los Angeles today);

Vancouver will be the equivalent to Toronto today; and Edmonton, Winnipeg, Hamilton, Ottawa, and Quebec City will be about 1,000,000 people each. These megalopolitan areas will be set in larger urban fields and we will begin to see the linking of the Great Lakes conurbation to the Atlantic Seaboard Megalopolis via the St. Lawrence Valley and the Mohawk Gap.

3) The intermediate centres and existing smaller places will only be viable to the extent that they have some vital function or occupy a key role. The direct and indirect resource demands of urban areas, and the attendant technology of connecting links, will empty the countryside (both in the agricultural areas and in the wilder areas) of population. Agricultural population will drop to 2% of the total and will continue to fall. Agriculture will increasingly concentrate on the finest lands and abandon the poorer lands. These in their turn will be released for forestry and for a wide range of urban-oriented uses. There will be high-speed transport corridors and wide swaths of utilities corridors, traversing the landscape. New power developments will probably exist every 40-50 miles along the shoreline of the Great Lakes and perhaps every 100 miles elsewhere, simply to support the urban centres.

4) The metabolism of urban areas will be of increasing concern, including increases in water use and the disposal of urban wastes, both liquid and solid. We will probably move through a difficult decade of attempts to continue large-scale sanitary land fill, while a whole new technology is emerging. Canada will experience so many economic and social demands in handling massive urban change, that the first national objective will be simply "no further environmental deterioration". (While Canada's population increased 1946-1972 by 50%, and its material standard of living increased by 66%, its pollution increased about 500%). In the decade 1962-1972, only 40% of municipal residents were served by sanitary sewers and only 60% of the urban sewage received any form of treatment; only 8 of Canada's 19 largest metropolitan areas treated 100% of all their sewage, but these matters are increasingly given priority. (By 2000, the annual investment in sewage plants will probably reach $350-400,000,000). By the 1980's most urban centres should have a high degree of effluent control, motor vehicles should be relatively pollution-free, and the volume of pollutants in total should be reduced, even though total industrial output is expected to double 1973-1985.

Solid waste disposal represents a major challenge in view of the tendency to use sanitary land fill. Municipal garbage is likely to increase from the present level of 4.5 lbs per capita per day to a level of 7.5 lbs. With the urban trends, this means garbage will triple in quantity by the year 2000. As the composition of such wastes is changing to include more paper, plastics and reclaimable resources, so too the technology must change.

5) The impact of urban growth and transport and power production on air resources will pose air management challenges. Heat islands formed by the greatly expanded urban areas, and by the power stations and utility corridors associated with them will change local microclimates and require very careful controls over the siting of new industries, power plants and new cities. (The Haldimand-Norfolk Environmental Appraisal, Ontario, in a connection with a new heavy-industry park and a new town, illustrates the technique very effectively.)

6) Associated demands for food production, recreation and leisure activities, and urban greenbelts will materially change the landscape around urban areas. The trend will probably be towards dramatic re-organization of the landscape of agricultural production. As a first step, we can expect strict land use controls to preserve the first-class farmland. This will preserve the land-base, allowing agriculture to regroup, by withdrawing from the poorer land. The new agriculture will be increasingly set up as an industrial operation, and the number of farms will be cut to about one-third of the present level. This poses two challenges: (a) If the resident farming population leaves the poorer farmland, how will such areas be managed? (b) If the agricultural areas remodel the landscape, will the ecologists and such experts as the botanists be able to help in preserving essential elements in the landscape, both for the sake of botany and for the sake of a healthy and diverse environment? This also raises great challenges in the tendency to use chemical methods increasingly to maintain what will be highly unstable intensively monocultural areas, and in the impact on wildlife, natural areas and the waterways and lakes.

Urban greenbelts and associated recreational lands open up the possibility of urban forests, allotments and ecological reserves, using land released by farming. Leisure will be responsible for about 25-30% of time whereas now it is about 20%. This, plus the downward extension of adequate disposable income into lower-income groups, and the great urban concentration, will mean very substantial pressures on all landscapes.

7) The "unfolding" of housing demands and the increasing attractiveness of Canada as a stable country for foreign investment in urban and industrial growth will imply, if Canada is wise enough to safeguard and conserve its energy and water supplies, the creation of very large new towns to cope with some of the urban pressures. The basic axiom behind this is that low-cost housing is absolutely vital and can not be provided on high-cost land. The demand for new housing will vastly increase because of the steady reduction in family size and household size and because, with gradual affluence, in metropolitan circumstances, there is an increasing demand for independent small households. In the same way, to preserve existing housing, new areas must be provided, with a full range of facilities and associated uses.

TASKS FOR BOTANISTS AND PLANNERS

Several urgent tasks emerge from all this, for botanists and planners.

Urban areas will press hard on unique areas. If we are to add about 19,300,000 people to our larger urban centres by 2000 A.D. this means that about 2,000,000 acres of land will be physically built on and some 6,000,000 - 10,000,000 acres will be subjected to the indirect pressures already referred to. Within easy reach of the larger urban centres between 600,000 and 1,200,000 acres will be subjected to intensive recreational pressures, and about 250,000-300,000 acres built on for recreational uses such as private housing, clubs and hotels and resorts. Agriculture will need 10-12,000,000 acres of prime land. Transport and waste disposal may need 1,000,000 acres. There will be very large areas subjected to aggregate production, surface mining, and these will use (and leave for other uses a generally degraded environment) up to 3,000,000 acres. These are only very crude estimates.

They indicate very intense changes on 40,000,000 acres of land for direct and indirect impacts of the main urban thrust. While Canada is an enormous land (3,851,809 sq. miles) the usable part is only about 4% of the total (154,000 sq. m. or about 98,500,000 acres). If we are likely to "re-work" more than 30% of the habitable area or ecumene by the year 2000, it means very drastic changes indeed.

There are so many pressing problems. In every local area, planners and botanists, and those members of the public concerned about the natural environment will every day face tragic battles if each issue is fought piecemeal. What is needed is a thoroughly synoptic biotic inventory of really significant and vital areas, and some scale of priorities by which to judge the environmental stresses. (As an example, when I was Director of Planning in the Hamilton-Wentworth and Burlington areas, 1954-1962, the Planning Board worked with the naturalists to inventory critically important areas. These areas were then protected wherever possible in the Offical Plan and Zoning By-law, or in the process of subdivision approval; and others were noted for acquisition by the Parks Board, the Conservation Authority, or by other naturalist groups.) This process should be given very high priority in areas which will be in the path of direct urban growth, in likely corridor areas, in the potential future resource and power developments, or in areas where new towns and new industries are likely to develop. Planners and botanists have complementary knowledge and skills in this work. It will greatly simplify the tasks of protecting essential areas because it will enable investors and governments to plan around these areas.

The next essential is to have, in the most important growth and change areas, an accurate environmental assessment of the flora and biotic communities, building on the kind of model represented by the Haldimand-Norfolk Environmental Appraisal. These should be interdisciplinary and transdisciplinary, trying to set out the essential factors which can help in the task of environmental management. A further step, which should be a statutory requirement, is the environmental impact study. Hence, for example, botanists will have to familiarize themselves with the process of development and the practice of planners so as to be able to set up guidelines by which impact of proposed measures can be judged. In particular, it will be necessary to set up tests or performance standards or environmental quality guidelines, so that rapid initial assessments can be made before large investment is made abortive. Hopefully this could be carried a step forward, into measures which can become part of the practice of all planners and all developers, steering and guiding development in ways which prevent or avoid conflicts. Here, planners need convenient principles and even rules of thumb, and botanists will need to learn how to make quantitative inputs into terrain analysis. An excellent example of this kind of work is the Hanlon Creek Basin study carried out by the Centre for Resources Development at the University of Guelph, or the "Big Sky" research of Montana State University (Bozeman). Yet another step would be the creation of models for effectively simulating regional environmental-change alternatives. Holling's work in the Greater Vancouver Regional Ecological Model is of great interest in this respect. My own view is that a good number of botanists will need to get themselves involved in regional planning teams.

Botanists and planners should also work together to get stronger regional conservation authorities, a statutory federal-provincial-municipal-regional planning process, and (most important) much greater financial support for the Nature Conservancy, and for special Wilderness, and Nature Reserves categories in parks classifications. These will need much higher priority than they have had. In Ontario the attention of planners should be drawn to such situations as those of the trillium; the fringed gentian; the bottle gentian; the yellow lady's slipper orchid; the showy lady's slipper orchid; the pink lady's slipper orchid; the jack-in-the-pulpit; the cardinal flower; the trailing arbutus; wild lilies; bittersweet; the maidenhair fern; and the walking fern; and the whole development situation between now and 2000 should be assessed to see what others might be imperilled. This task of assessment will be an exercise in being predictive and should be associated with baseline studies in key areas and on-going monitoring so that what is predictive becomes tested and thus aids the next generation of botanists and planners. Planners look forward to a on soil capability, recreational and wildlife capability; perhaps they may have to be content with priority listings of emergency areas, and the botanical task forces to assist in specific assessments.

NEW POSSIBILITIES

But preservation and protection are only part of the situation. New possibilities will emerge as a result of the urban challenge:

1) New planning processes are emerging which involve environmental assessment, impact studies and a concern for environmental quality. These involve much more respect for natural factors than has been common, and there is an associated trend towards much more public involvement, and stronger federal-provincial regional planning, than has been common up to now.
2) There is a good deal of evidence that we will do more than just maintain present pollution levels. In particular, all provinces now have environmental legislation and a great many more control-and-guidance processes are now at work.
3) With the advent of a regional approach, urban planning is improving, and a co-operative federal-provincial-industrial-municipal attack on environmental problems is emerging.

4) There are signs that the Canadian National and Provincial Parks Systems are moving to embrace some of the more extensive characteristic landscapes: we need a major parallel effort closer in to the urban centres.
5) New cities will be established, along with new industrial areas, to meet some of the urban pressures. These will be based on "total energy" concepts, and the industries will be based on the "closed loop" principle, making pollution minimal. By contrast, the scale of the urban, industrial and transport enterprises will tend to increase enormously; but there is also a move to minimize movement by integrating many correlated and complex urban uses into the energy and power source, and making housing areas more imaginative and grouped so as to give room for natural areas within the urban fabric itself. These new cities will likely have far less dependence on the automobile, and will use greenery and urban forests, lakes and pools for control of noise and heat. This gives positive opportunities for preservation.
6) A new city built on migratory bird flightways, for example, could have a height limit of say 6 storeys over-all, and be planned to attract such birds rather than as a hostile environment.
7) Environmental control of large-scale housing, commercial and industrial areas will open up new opportunities for protecting and for introducing flora, and where such growth occurs in natural areas, sensitive urban designers and landscape architects will be trying to work closely with botanists and ecologists.
8) The resource demands in surface mining, and the disposal of solid wastes, offer positive opportunities for sculpturing new land forms and for special environments such as Butchart Gardens in Victoria, or the Rock Gardens in Hamilton.
9) Respect for local microclimatic variations, unique terrain and flora, and special habitat seems to be increasing as a result of constraints on urban form, imposed by the new concern for ecological matters, and the desire for superior urban environments in natural settings.
10) Public awareness of the natural world will rapidly increase as a result of additional leisure-time and wider travelling. The result is also a consequence of better environmental education and nature-interpretation by the media. This means there will be greater public pressure on fragile areas at the same time as there is greater concern for preserving natural areas. The botanists and planners must ensure that while the demand for active recreational areas is met, the really important ecological and nature reserves are well protected from mass onslaught.
11) Urban wastes will increasingly be handled in "environmental industrial parks". While these will be extensive and complex recycling and secondary-materials-handling factories, they will minimize the impact caused by conventional land fill.
12) The retreat from poor farmland will combine with the advance of speculative urban fringes and the creation of substantial transport-and-utility corridors to provide a large area where nature can make a comeback. In Europe, for example, many wild plants and flowers are recovering on the rights-of-way of expressways, railways and powerlines, once the passion for pesticides was stopped. These areas should not be manicured, but rather treated as natural places. We can then manage the succession to achieve some desired effect, or just leave it alone.

In conclusion, botanists should familiarize themselves with the nature of contemporary urban change in order to awaken public interest in flora; planners should build up closer professional working relationships with botanists to protect essential areas, avoid unnecessary losses and land use-conflicts, and seek compatible solutions in change areas, prior to conflict and the loss of vital resources. New kinds of opportunities will arise in the ultimate megalopolitan field, and as such highly complex urban areas are generally better managed than in the initial stages when resources are felt to be finite, then advance planning could well result in advantageous modifica- tion of present trends. The impact of urbanization can be a creative rather than a destructive process.

SELECTED REFERENCES

Chanasyk, V.. and Associates. 1971. Haldimand-Norfolk Study: Environmental Appraisal. (2 Vols), Queen's Printer, Toronto.

Clark, C. 1967. Population Growth and Land Use. Macmillan.

Cullen, G. 1961. Townscape. Arch. Press.

Doxiadis, C.A. 1968. Ekistics. Hutchinson.

Eckbo, G. 1964. Urban Landscape Design. McGraw-Hill.

Johnston, Grayson and Bradley. 1967. Forest Planning. Faber and Faber.

Lewis, R.A. (Ed.). 1973. The Environmental Revolution. Science and Public Affairs, Chicago.

Mandelker, D.R. 1966. Greenbelts and Urban Growth. Wisconsin Press, Milwaukee.

Mayer, A. 1967. The Urgent Future. McGraw-Hill.

Milliken, J.D. (Ed.) et al. 1971-1972. Hanlon Creek Ecological Study, Guelph. (Phase A, 1971, Centre for Resources Development Publ. No. 50; Phase B, 1972, Centre for Resources Development, Publ. No. 51).

Rubenstein. 1968. A Guide to Site and Environmental Planning. Wiley.

Shomon, J.J. 1971. Open Land for Urban America. Johns Hopkins.

Strong, A.L. 1971. Planned Urban Environments. Johns Hopkins.

Tolley, G.S. and Riggs, F.E. 1961. Watershed Planning. Iowa State, Ames, Iowa.

Way, J. 1972. Terrain Analysis. Dowden, Hutchinson & Ross.

Weddle, A. 1967. Techniques of Landscape Architecture. Heinemann.

Weller, J. 1967. Modern Agriculture and Rural Planning. Architectural Press.

THE IMPACT OF POLLUTION

T.C. Hutchinson,
Department of Botany
and
Institute of Environmental Sciences
and Engineering,
University of Toronto,
Toronto, Ontario.

The history of man in Canada over the past two hundred years has been associated particularly with the development of the pulp and paper industry, the mining and extraction industries, the great expansion of agriculture and, more recently, the development of large and expanding urban centres. The inevitable consequence has been the emission of a multitude of pollutants into the atmosphere and the discharge of industrial and domestic wastes into water bodies. Particular concern has been expressed over the past fifteen years for the deterioration of several of the lower Great Lakes, which we share with our southern neighbours. The development of transport networks has increased the mobility of the populace and has hastened the development of cottage country, with its own patterns of recreational use. Particular industries and land uses are associated with their own, often specific, forms of pollutant.

Pollution problems are peculiarly associated with one type of transport - the automobile. The roadways themselves are kept open in winter in most parts of the country by liberal applications of salt. There is a good deal of controversy as to the phytotoxic effects of salt but there seems good evidence, for example that of Hofstra and Hall (1971) working at University of Guelph, that salt damage is a real problem in the spring time to conifers growing along the highways. High sodium and chloride accumulations occur on and in tree foliage and in grasses and soil along road edges (Hutchinson 1972). Interestingly, one of the commonest grass species along the super highways from Quebec to Vancouver is the wild barley Hordeum jubatum, which often forms a narrow strand parallel to the roadway and only a few feet from it. The genus Hordeum is known to be salt tolerant and the closely allied species Hordeum murinum has been shown to occupy a similar position along roads edges with high salt concentrations in Europe (Davison 1971).

Photochemical smog is, of course, the major air pollution problem in western North America and has had profound effects on several sensitive species in the Los Angeles region. Ponderosa pine is one of these species. The evidence for a photochemical smog problem in Canada, however, is unconvincing, although it has a potential in centres such as Vancouver and Toronto. Reducing smogs, on the other hand, have a long history in several cities, notably Montreal, Toronto and Hamilton, and are damaging to several plant species. They are primarily due to a combination of high sulphur dioxide and suspended particulates in a static atmosphere at temperatures from 32-40°F. They are the smoke fogs or smogs and their long history of occurrence is a principal factor in the bryophyte and lichen "deserts" observed in such cities as Montreal (Leblanc and De Sloover 1970).

Some of our problems are apparently imported, such as the oxidant damage to the tobacco crops in the Delhi region of southern Ontario during the 1950's. This was found to be ozone damage, causing weather leaf fleck and was associated with the movement of air masses from Detroit (Macdowall, Mukammal and Cole 1964). We can, however, consider this equalled by the sulphur dioxide damage in the U.S.A. along the valley of the Columbia river caused by emissions from the COMINCO smelter operation at Trail, B.C. in the 1920's and 1930's. The stack gases channeled down the valley and affected orchard crops on the American side. The whole operation of the plant and its effects were very thoroughly studied by the National Research Council, especially by Dr. M. Katz, and their pioneering work led to a better understanding of the phytotoxic effects of sulphur dioxide and to the control of atmospheric pollution from the smelter. Indeed, large quantities of elemental sulphur and sulphuric acid were produced at Trail as highly saleable by-products, largely as the result of the international nature of the problem (National Research Council 1939). It is, perhaps, a little disappointing to have to report a subsequent study by Schmitt et al (1971) on lead poisoning of horses in the vicinity of Trail which occurred in the fall of 1968. This was found to be due to excessive levels of lead in the grass foliage, caused by the presence of lead in surface soils which had accumulated from smelter emissions.

This latter situation takes us on to the very substantial problems in Canada of air and water contamination by the mining and smelting industries. The problems are basically of sulphur dioxide emissions and heavy metal pollution of the air, soil and water. The industries are particularly important to the Canadian economy. The emissions of sulphur dioxide from the Sudbury smelters alone are greater than 2 million tons per year. The discharges have increased markedly over the past 60 years. Over the past 10 years the extent and degree of sulphur dioxide emissions have been recorded in the Sudbury region by the Province of Ontario Government, using Thomas automatic SO_2 recorders. The data have been published in annual reports. Indeed, these studies by, initially, Dreisinger and McGovern, are amongst the most thorough and detailed of any made anywhere in the world. Linzon (1958, 1966) showed that eastern white pine (Pinus strobus) was the most sensitive forest tree to sulphur dioxide damage, and was absent or extensively damaged by sulphur fumes up to 25 miles northeast of Sudbury, and to 15 miles from the nearest smelter source. In contrast red maple (Acer rubrum) and red oak (Quercus rubra) were relatively resistant to this source of pollution, and occurred to within 1 mile of the smelters. Unfortunately, white pine is economically the most important timber tree in Ontario and the economic loss of the forests is considerable. Linzon (1972) has estimated an inner zone of damage around Sudbury of about 720 square miles, where white pine shows severe foliar symptoms, an intermediate zone of 1600 square miles with little damage to white pine showing, and an outer zone with only occasional damage showing. Taller and taller stacks have been built in an effort to dilute the sulphur dioxide fumes. These have served to spread the fumes over a greater area, but at lower concentrations. It is, however, a fundamental rule for most pollutants that there is a time/concentration interaction, such that low concentrations for extended periods, have similar effects to higher concentrations for briefer periods.

The area around Sudbury is visibly devastated. There is extensive loss of vegetation with concomitant loss of the thin soil cover over the bedrock. On a per unit area basis, species diversity, both in the water and on land, is markedly reduced as one approaches the smelters (e.g. Gorham and Gordon 1960, Myslik 1972, Costescu and Hutchinson 1972). Leblanc and Rao (1966) have suggested that the high sulphur dioxide content of the air was responsible for the lack of lichens and mosses near Sudbury. Gordon and Gorham (1963) showed at Wawa, in northern Ontario, in a study of air pollution from an iron sintering plant, that along the paths of the predominant winds forest damage was detectable for at least 20 miles. Species diversity decreased markedly towards the sintering plant. Polygonium cilinode and Sambucus pubens were tolerant of the pollution source (as at Sudbury) whilst white pine, black spruce, white spruce and trembling aspen were not found within 15 miles of the plant.

Perhaps one should, at this juncture, make a point that is often ignored or misunderstood in popular writing and the press; namely, that in no part or province of Canada has even a single species been made extinct as a result of pollution. Even in areas as badly affected as Sudbury, the loss of species is quite local and the devastated areas are surrounded by large centres of inoculum for potential future re-vegetation. Indeed, it is salutary to point out to the Botanical Association that loss of varieties within countries, provinces etc. both in Canada and elsewhere has been very often the result of well informed plant collectors and botanists.

To return to smelter situations, heavy metal fallout as dust on to soil, and metal contamination of streams, lakes, etc. is very common. River pollution by copper and zinc has been well described by Sprague for the Miramichi River, in New Brunswick. The lakes around Sudbury are heavily contaminated by copper and nickel, both of which kill algae. The phytoplankton flora is severely depauperated. The lowered pH, caused ultimately by the sulphur dioxide in the air, enhances the heavy metal problem. However, an interesting evolutionary process has taken place in some of the most contaminated lakes. The very few algal cells which still survive have been shown to be especially tolerant of the normally toxic metals, nickel and copper. This is established for strains of Scenedesmus and Chlorella (e.g. Stokes, Hutchinson and Krauter 1973).

The effects of metal contamination in the Sudbury soils are less clear cut but have been shown to be very extensive. Effects are partially masked by the all pervading sulphur dioxide fumigations, which are directly phytotoxic. The major soil metallic contaminants are nickel, copper, iron and cobalt (Costescu and Hutchinson 1972). For example, in samples of surface soil taken at 0.5 miles from the Coniston stack, nickel levels were 2835 ppm, which had decreased to 83 ppm at 31 miles. Copper at the two sites was 1528 ppm and 31 ppm respectively. The concentrations decreased markedly down the soil profile, suggesting surface contamination (Table 1). The levels found compared with mean "average" soil levels for nickel of 40 ppm and for copper of 20 ppm as quoted by Bowen (1966). In general only the metals smelted showed the pattern of high accumulation in surface soils, with decrease with depth and with distance from the smelters. Dust and rainfall sampling confirm that the metals are air-borne from the smelters, and that large quantities are being emitted to the present day (Hutchinson and Whitby 1973). The levels of metals in the vegetation growing on soils in the area also show highly elevated copper and nickel levels. The metals appear to be present in water soluble forms - and therefore available to plants - at toxic levels over a very large area, an area not less than 400 square miles. The area of elevated metal levels in soils, but not necessarily phytotoxic levels, cannot be much less than that area referred to by Linzon as the intermediate zone of 1600 square miles. The continuing nature of this pollution gives particular cause for concern, since the heavy metals are relatively immobile in the soils, and could affect regeneration and re-vegetation of the area for generations, even should the sulphur dioxide problem be rectified by 1978 as promised by the Province of Ontario. Metal smelting for lead, zinc, cadmium, gold and silver has caused similar but lesser problems in, for example, Flin Flon, Yellowknife and Trail.

The effect of lead additives to gasoline has been clearly shown in high traffic density areas of cities and along main highways where elevated lead levels in vegetation, soil and air have been described. Indeed, Warren and Delavault in British Columbia were among the pioneers in North America in pointing out the environmental hazards of uncontrolled releases of lead from vehicle tailpipes. Theirs was a study of Stanley Park (Warren and Delavault 1962). Hutchinson (1972) and Hutchinson, Cunningham and Czyrska (unpublished) showed that a similar situation regarding lead pollution occurred in Toronto and Hamilton, with soil levels reaching 3000 ppm near major highways in downtown areas. The levels fell off rapidly away from the highways, and the lead was especially concentrated in surface soils. Interestingly, cadmium showed a similar pattern of distribution but at much lower levels. A variety of plant species growing on these soils showed increased lead and cadmium levels. The iron levels were especially high in Hamilton, but a high percentage of the foliar levels were removeable by careful washing and, therefore, probably represented surface contamination (Table 2).

In the Toronto study leaf material was taken from specimens in the University of Toronto herbarium, collected from downtown Toronto over the past 120 years. Several species were studied for their heavy metal content. The pattern of increase for lead and cadmium was especially striking, with lead levels for basswood (Tilia) increasing from a mean of 30 ppm in 1880 to 73 ppm by 1970. A threefold increase occurred for oak and up to a sevenfold increase for pine. Basswood was an especially sensitive accumulator of cadmium and showed changes from a mean of 3.5 ppm in 1890 to up to 22 ppm in 1970 (Hutchinson 1972). These levels suggest gross environmental contamination of our cities and areas bounding highways. The attractive roadside floras are subject to salting, pesticide treatments, fires and heavy metal pollution, as well as being affected by oxidant damage and carbon monoxide fumigations.

Leblanc and De Sloover (1970) have described Montreal as the most polluted Canadian city, with very high concentrations of sulphur dioxide, particulates and automobile fumes. In their study of the epiphytic lichens and mosses of that city they were able to present graphic evidence of the loss and/or absence of many species, such as Physcia millegrana, Parmelia sulcata and Xanthoria fallax from the downtown core, and over extensive areas in the direction of prevailing winds. They noted marked species differences in apparent resistance to air pollutants, and also the occurrence of oasis or refuge areas within the city, such as Mount Royal. Leblanc, Comeau and Rao (1971) also investigated the effects of fluoride emissions from an aluminum factory at Arvida, Quebec. Using lichen and moss-bearing bark discs as transplants they showed that fluoride pollution affected moisture balance, caused chlorophyll damage and caused the death of organisms.

Fluoride emissions around Kitimat, British Columbia, from the aluminum complex, and in Hamilton, Ontario from the steel works, have also been found to create phytotoxic situations. Perhaps the best known case in Canada, however, was that at Dunnville in which fluoride emissions from the ERCO superphosphate plant caused damage to crops and livestock and received great publicity. The technology for controlling fluoride emissions from phosphate plants is well worked out, especially from work in Florida, and one hopes that future incidents can be avoided.

Finally, the potential effects of oil spills and the development of the oil and gas industries in the arctic and sub-arctic regions are of great concern to botanists. Our own studies over the past two years in the Mackenzie valley have indicated that crude oil spills have a direct herbicidal action on most tundra and taiga species, but that dwarf shrubs and black spruce are somewhat better able to survive. Especially badly affected are deciduous species with non-leathery leaves, and most importantly the lichens and bryophytes. Two points need to be made, however; a) that the pipeline routes suggested are nearly all through fairly repetitious taiga and avoid the high ground, alpine meadows and tundra floras of the sub-arctic region, which have the richest flora and b) that the oil, when spilt, is well contained and localized in the soil. The effects of road-building and the environmental and social consequences of large numbers of people invading the north are likely to have a much more profound effect on the flora than are small localized oil spills (Hutchinson and Hellebust 1973).

L. Bliss and his co-workers have carried out extensive experiments on re-vegetation of disturbed areas in the arctic, and this, together with much of the fundamental work done with the IBP programme on Devon Island should allow steps to be taken to ameliorate vegetation damage.

In conclusion, it is apparent from the foregoing that pollution from a variety of sources is having an effect on the Canadian flora, but the government and academics are now deeply involved in tabulating situations and seeking solutions. Urban centres, inevitably, have suffered the greatest loss of local floras, either by being built up directly, by human selective disturbance or by pollution. Local naturalists' groups attempt, sometimes with success, to stem the tide. Conservation areas set aside by local authorities are conservation in name only and are people parks for intensive recreational use - this, in itself, a very necessary addendum to modern city life. We need more involvement from professional botanists at the local level to preserve the urban and roadside floras, and to encourage firm government action on polluters in rural areas no matter how remote.

REFERENCES

Bowen, H.J.M. 1966. Trace Elements in Biochemistry. Acad. Press, New York.

Costescu, L.M. and Hutchinson, T.C. 1972. The ecological consequences of soil pollution by metallic dust from the Sudbury smelters. Proc. Institute Environ. Sci. 18th Ann. Tech. Session. New York, 540-545.

Davison, A.W. 1971. The effects of de-icing salt on roadside verges. I. Soil and plant analysis. J. Appl. Ecol. 8, 555-561.

Gordon, A.G. and Gorham, E. 1963. Ecological aspects of air pollution from an iron-sintering plant at Wawa, Ontario. Can. J. Bot. 41, 1063-1077.

Gorham, E. and Gordon, A.G. 1960. Some effects of smelter pollution northeast of Falconbridge, Ontario. Can. J. Bot. 38, 307-312.

Hofstra, G. and Hall, R. 1971. Injury on roadside trees - leaf injury on pine and white cedar in relation to foliar levels of sodium and chloride. Can. J. Bot. 49, 613-622.

Hutchinson, T.C. 1972. The occurrence of lead, cadmium, nickel, vanadium and chloride in soils and vegetation of Toronto in relation to traffic density. Proc. International Conference on Automobile Pollution 1972. Royal York, Toronto, June 26-28.

__________ and Hellebust, J. 1973. Oil Spills and Vegetation. Final Report, April 1973 for Arctic Land Use Research Program. Can. Dept. Ind. Affairs and Northern Development, Ottawa. Information Canada, Catalogue #R72-10773.

__________ and Whitby, L.M. 1973. A

study of air-borne contamination of vegetation and soils by heavy metals from the Sudbury copper-nickel smelters. Proc. 7th Annual Missouri Conf. "Trace Substances in Environmental Health" Ed. D. Hemphill. June 1973.

Leblanc, F., Comeau, G. and Rao, D.N. 1971. Fluoride injury symptoms in epiphytic lichens and mosses. Can. J. Bot., 49, 1691-1698.

__________ and De Sloover, J. 1970. Relation between industrialization and the distribution and growth of epiphytic lichens and mosses in Montreal. Can. J. Bot., 48, 1485-1496.

__________ and Rao, D.N. 1966. Reaction de quelques lichens et mousses epiphytiques a l'anhydride sulfureux dans la region de Sudbury, Ontario. Bryologist. 69, 338-346.

Linzon, S.N. 1958. The influence of smelter fumes on the growth of white pine in the Sudbury region. Joint Pub. Ont. Dep. Lands and Forests, Ont. Dep. Mines, Toronto, Ontario.

__________. 1966. Damage to eastern white pine by sulphur dioxide, semimature-tissue needle blight, and ozone. J. Air Poll. Control Assoc. 16, 140-144.

__________. 1972. Effects of sulphur oxides on vegetation. Forestry Chronicle. 182-186.

Macdowall, F.D.H., Mukammal, E.I. and Cole, A.F.W. 1964. Direct correlation of air polluting ozone and tobacco weather fleck. Can. J. Plant Sci. 44, 410-417.

Myslik, G. 1972. A study of the effects of heavy metal pollution on the lake phytoplankton flora of the Sudbury region. Unpublished M.Sc. Thesis, Dept. Botany, University of Toronto.

Schmitt, N., Brown, G., Devlin, E.L., Larsen, A.A., McCausland, E.D., and Saville, J.M. 1971. Lead Poisoning in Horses. Arch. Environ. Health 23, 185-195.

Stokes, P.M., Hutchinson, T.C. and Krauter, K. 1973. Heavy metal tolerance in algae isolated from contaminated lakes near Sudbury, Ontario. Can. J. Bot. 51: 2155-2168.

Warren, H.V. and Delavault, R.E. 1962. Lead levels in Stanley Park, Vancouver, B.C. J. Sci. Food Agr. 13, 96-102.

Table 1. The metallic content of Sudbury area soils collected along transects out from the Coniston smelter (3 depths collected). Analyses were on total digests.

Site of Collection Distance	Depth	Copper	Metallic content (ppm) Nickel	Cobalt	Zinc	Lead	Manganese
0.5 mile	surface	1528	2835	127	67	68	232
	2-3"	1238	2510	124	66	64	242
	4-5"	944	1522	82	57	42	202
0.95 mile	surface	2007	1847	72	73	56	207
	2-3"	1864	1611	69	72	47	203
	4-5"	1740	1163	61	69	35	204
1.0 mile	surface	1291	2679	122	75	56	290
	2-3"	1478	1710	88	78	68	276
	4-5"	1630	1097	67	92	47	316
1.2 mile	surface	2071	2161	85	73	58	251
	2-3"	1772	730	34	53	41	252
	4-5"	1578	649	31	51	31	252
2.4 mile	surface	1140	831	42	53	47	161
	2-3"	1104	842	58	57	42	167
	4-5"	1167	732	43	55	38	162
4.6 mile	surface	1425	3309	154	84	52	360
	2-3"	1621	2330	98	80	78	343
	4-5"	944	614	36	64	31	354
6.5 mile	surface	392	356	33	68	28	336
	2-3"	21	69	24	60	14	319
	4-5"	3	79	24	63	9	295
8.4 mile	surface	1177	282	56	78	75	316
	2-3"	568	409	6	72	35	350
	4-5"	191	212	6	72	35	353
12.0 mile	surface	185	306	48	78	47	148
	2-3"	18	114	34	100	28	146
	4-5"	5	79	31	84	28	134
31 mile	surface	31	83	19	46	17	125
	2-3"	27	71	17	51	17	122
	4-5"	23	63	19	50	15	124

TABLE 2. CONCENTRATION OF 6 METALS IN PLANTS COLLECTED FROM 6 SITES AT HAMILTON (mean values)

Plant Species	Cd (ppm) not washed	Cd (ppm) washed	Zn (ppm) not	Zn (ppm) washed	Pbl (ppm) not washed	Pbl (ppm) washed	Cu (ppm) not washed	Cu (ppm) washed	Ni (ppm) not washed	Ni (ppm) washed	Fe (ppm) not washed	Fe (ppm) washed
1. *Poa* (grass)	1.58	1.25	133.3	107.4	145.0	69.2	17.3	15.7	4.6	2.3	1572.5	271.7
2. *Syringa* (lilac)	1.82	1.58	126.8	109.5	76.0	48.7	12.2	9.9	7.8	5.8	490	242.3
3. *Acer saccarinum* (silver maple)	2.15	2.00	139.6	110.2	157.2	96.0	11.4	9.1	6.4	5.5	1351.2	435
4. *Acer negundo* (Manitoba maple)	3.09	3.00	139.8	105.0	209.	149.8	11.2	9.2	5.7	4.9	1000.0	329.2
5. *Picea abies* (Norway spruce 1971 growth)	1.06	0.94	71.5	54.5	120	86	5.3	4.6	2.2	1.6	730	273
6. *Picea abies* (1970 growth)	1.32	1.07	87.5	64.2	158	121	4.9	4.1	3.2	2.4	790	410
Normal plant levels (Bowen)	0.6		100		2.7		14.0		3		140	

Acknowledgements

The photograph of *Trillium grandiflorum* which graces the cover was taken by Dr. J.S. Pringle and is gratefully acknowledged; as also is the assistance of Mrs. Janice Hill and Miss Joan Venn in preparing the manuscript for publication.