# Acid Rain: a further Estimate of the Risk to Ontario's Inland Fisheries.

C.K. Minns

Great Lakes Fisheries Research Branch
Canada Centre for Inland Waters
867 Lakeshore Road, P.O. Box 5050.
Burlington, Ontario. L7R 4A6

June 1986



**Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1874.**



Fisheries and Oceans | Pêches et Océans

Canada

## Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901-1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426-1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

## Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report

of Fisheries and Aquatic Sciences 1874

June 1986

# ACID RAIN: A FURTHER ESTIMATE OF THE RISK TO ONTARIO'S INLAND FISHERIES

by

C. K. Minns

Great Lakes Fisheries Research Branch
Canada Centre for Inland Waters
867 Lakeshore Rd., P.O. Box 5050
Burlington, Ontario L7R 4A6

Cat. No. Fs 97-4/1874 ISSN 0706-6473

Correct citation for this publication:
Minns, C.K. 1986. Acid rain: A further estimate of the risk to Ontario's inland fisheries. Can. MS Rep. Fish. Aquat. Sci., 1874:vi+17p.

# TABLE OF CONTENTS

## ABSTRACT

Minns, C.K. 1986. Acid rain: A further estimate of the risk to Ontario's inland fisheries. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1874.

The databases of lake inventory and chemistry have substantially increased from Minns (1981). There has also been progress in evaluating the biases in the databases. A methodology is presented for extrapolating from a comprehensive database of inventory and chemistry data via the larger lake inventory database, to the total resource of lakes in the province of Ontario. This "scaling-up" is done for lakes regardless of fish species and for the lakes containing one of four gamefish species - brook trout, lake trout, smallmouth bass and walleye.

The results suggest there are more than 3200 lakes in Ontario with an alkalinity less than zero and nearly 16000 lakes with an alkalinity between 0 and 50 $\mu eq.l^{-1}$. There are few gamefish lakes with alkalinities less than zero but large portions of gamefish resources are found in lakes with alkalinities less than 50 $\mu eq.l^{-1}$. Most of the lakes with alkalinities less than 50 $\mu eq.l^{-1}$ are located in watersheds bordering the upper Great Lakes (2B, 2C, 2D and 2F) where acid deposition is greatest.

The results obtained here do not differ substantially from results reported by Minns (1981).

# RESUME

Minns, C.K. 1986. Acid rain: A further estimate of the risk to Ontario's inland fisheries. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1874.

Les bases de données sur le contenu et la composition chimique des lacs se sont considérablement étoffées depuis l'étude de Minns (1981). De plus, des progrès ont été faits dans l'évaluation des biais. On présente ici une méthode d'extrapolation des ressources globales dans les lacs de l'Ontario à partir d'une base de données exhaustive sur le contenu et la composition chimique de certains grands lacs. Pour certains cours d'eau, l'extrapolation englobe indifféremment diverses espèces de poissons alors que pour d'autres, elle porte sur une des quatre espèces suivantes destinées à la pêche sportive: truite mouchetée, truite grise, achigan à petite bouche et doré.

Selon les résultats, il semble y avoir plus de 3 200 lacs en Ontario où l'alcalinité est supérieure à zéro et près de 16 000 lacs où l'alcalinité varie entre 0 et 50 $\mu eq\ l^{-1}$. Il existe peu de lacs de pêche sportive où l'alcalinité est inférieure à zéro; par contre on trouve des poissons de sport en abondance dans les lacs dont l'alcalinité est inférieure à 50 $\mu eq\ l^{-1}$. La majorité des lacs dont l'alcalinité est inférieure à 50 $\mu eq\ l^{-1}$ se trouvent dans les bassins versants en bordure du cours supérieur des Grands Lacs (2B, 2C, 2D et 2F), là où les dépôts acides sont les plus élevés.

Les résultats de cette étude ne diffèrent pas tellement de ceux qu'a obtenus Minns (1981).

## INTRODUCTION

Minns (1981) published an analysis of the Ontario Ministry of Natural Resources lake inventory database. The database includes lake morphometry, a fish species list, and limited chemistry including conductivity and a crude field pH. Since that time, the Lake Inventory database has grown substantially and considerable effort has been put into compiling recent and reliable lake chemistry data including laboratory pH and alkalinity measures into a sensitivity database. In addition, the means of extrapolation from the database samples to the total lake population has been refined. This report provides an up-to-date estimate of the aquatic resources at risk, overall, and for particular game fish species.

## METHODOLOGY

Lake selection for the Inventory database is biased toward larger lakes (Minns, 1984) and especially toward lakes containing one or more of four important gamefish species: brook trout (Salvelinus fontinalis), lake trout (Salvelinus namaycush), smallmouth bass (Micropterus dolomieui), and walleye (Stizostedion vitreum vitreum). These species are the top predators in the province's main fish communities (Minns 1985). Because of the biases, estimates of aquatic resource conditions based on the lake inventory database, for any one of the game species, is more likely to be an accurate than an extrapolation for the whole lake resource using the inventory database.

The inventory and sensitivity databases were crossmatched to provide a comprehensive database of lake inventory data (lake morphometry, fish species list, etc.) and recent lake sensitivity data including pH and alkalinity. In the analyses presented here, the inventory and comprehensive databases were used, along with Cox's (1978) estimates of the number and area of lakes in Ontario, to assess the current status of Ontario's inland freshwater resources with respect to acidic deposition.

The resources at risk for the four gamefish species were estimated using three Ontario Ministry of Natural Resources databases. The first (MINNSDAT (COXCAM)) was the counts and measures database compiled by Cox (1978). These data were summarized at the secondary watershed level by lake-size category (order of magnitude in hectares). The second database (EALINV) was a data file derived from the lake inventory database, containing nearly 9000 lake records (Aug. 1, 1985). The variables used from that database were secondary watershed code, lake area (hectares), and the fish species list. The third database (EACOMP) contained comprehensive data sets, crossmatched between the lake inventory database and a sensitivity database. The variables used from the comprehensive database were secondary watershed code, lake area, alkalinity and pH. There are more alkalinity data than pH data. All lakes greater than 100,000 ha and less than one ha were excluded from the analyses. Lakes less than one ha in area are only a small proportion of the total resource and the inclusion of the Great Lakes was considered (>100000 ha) unnecessary.

The analysis of each gamefish species started with the assumption that the total number of lakes containing that species in the province was known (Table 1) (after Minns, 1986). The lake inventory database was summarized by secondary watershed and lake size category (Table 1), both for all lakes and for all lakes with the game species present. The comprehensive database was summarized by secondary watershed and lake size category, and by five alkalinity classes, four pH classes (Table 1) and by fish species present, either each gamefish species alone or with one of the other three gamefish species. Lakes lacking the gamefish species were ignored. The rationale for the alkalinity and pH classes was the same as that in Minns (1981) though the pH classes are less stringent than those used previously. Results of Kelso et al. (1986) suggest that biological effects may be expected with pH's less than 6.0. However, a pH of 5.5 was selected as a compromise with Minns (1981).

The extrapolation, or "scaling-up" from the comprehensive database to the total aquatic resource, overall, or for a particular gamefish species, was done in two stages. The frequency distributions of alkalinity and pH values by lake size range, and secondary watershed in the comprehensive database, were assumed to be representative. So the comprehensive database resource quantities, numbers and areas of lakes, and alkalinity-pH distributions were scaled-up to equal the lake inventory resource quantities by lake size range and secondary watershed. If within a secondary watershed, there were inventory data, but no comprehensive data, the frequency distributions for all watersheds in the same acid deposition region (Table 2) were combined and used. Secondary watersheds were designated approximately as having high, moderate, or low acid deposition, according to the results presented by Barrie and Hales (1984) for wet sulphate deposition. If there were no comprehensive data within the deposition region, a province-wide combination was used for scaling-up. This final option was only invoked once for a small amount of brook trout resource in the low deposition region and any error here would have minimal impact on the results.

The second stage involved scaling-up from the inventory level to the total resource. At this stage, it was necessary to allocate uninventoried gamefish resources to secondary watershed. The uninventoried lakes number for a gamefish species is the difference between the estimated number of lakes containing the species (Table 1) and the total number with that species in the inventory. These uninventoried resources were assumed to inhabit lakes containing only one gamefish species because of selection bias in the inventory database (Minns, 1986). Rather than allocate the remaining uninventoried portion of a gamefish resource according to the remaining uninventoried total resource in each secondary watershed, the remaining uninventoried total resource is weighted by the probability that the species occurs in that secondary watershed. Given the extreme bias toward these gamefish species (Minns 1986), the probability (Pi) that the gamefish species occur was estimated by the ratio of the inventory sample (n*i or a*i) for that species to the total resource (Ni or Ai) by secondary watershed. The separate values for numbers and area were determined and the average taken, as follows:

$$pi = \left( \frac{n^*i}{Ni} + \frac{a^*i}{Ai} \right) /2 \qquad , i=1, \ldots, 28$$

The weighting function determining the distribution of uninventoried lakes containing the gamefish species, is the total uninventoried lakes (numbers, Nu or area Au) times the probability of occurrence of that gamefish species for each secondary watershed divided by the sum of those quantities for all secondary watersheds, as follows:

$$Nai = Nu \cdot \frac{pi(Ni-ni)}{\sum_{i=1} pi(Ni-ni)}$$

The total uninventoried gamefish area is estimated by the number times the average area of singleton gamefish lakes in the comprehensive sample. In each secondary watershed where the species occurs, the scaled-up comprehensive sample for singleton occurrences is scaled-up by the allocation of uninventoried lakes.

$$Aai = Au \cdot \frac{pi(Ai-ai)}{\sum_{i=1} pi(Ai-ai)}$$

where Nai, Aai are the estimated number and area uninventoried lakes containing the gamefish species in watershed i, Nu is the expected total number of uninventoried lakes containing the gamefish species in Ontario. Au is Nu times the average area of lakes containing that gamefish only, in the comprehensive database.

Where Ni,Ai are the total number and area of lakes in watershed i, (Cox, 1978) ni,ai are the number and area of inventoried lakes in watershed i, pi is the probability of encountering the gamefish species in lakes in watershed i, n*i, a*i are the number and area of inventoried lakes in watershed i having the gamefish species present. i = 1 to 28, the number of secondary watershed in Ontario. The average was taken to avoid undue bias to large numbers of small lakes or small numbers of very large lakes.

The results were then summarized by deposition region and overall.

In addition, the comprehensive sample regardless of fish species occurrences is scaled-up to the total resource by secondary watershed to provide an overview of resources at risk, bearing in mind the sample was only one of inventoried lakes. The larger sensitivity database could be used for this extrapolation, but the linkage with the gamefish results was likely to be less clear. Regional or provincial level substitutions were made if there were no secondary watershed level data.

## RESULTS

In the case of brook trout and lake trout lakes, most of the resource has been inventoried (Table 3). With smallmouth bass and walleye, less than half the resource has been inventoried. The probabilities of encountering a gamefish species (inventoried lakes with the species/total resources by secondary watershed) are consistent with known patterns of distribution (Table 3) and the allocation of uninventoried resources is weighted away from areas where a large portion of the resource has already been inventoried. In most cases, there were comprehensive data in the secondary watershed so the scale-up was based on that. In one case a deposition region scale-up was necessary.

The extrapolation from the comprehensive data to the total resource, disregarding fish species, indicates there are 3208 lakes in Ontario where the alkalinity is less than zero and 15,670 lakes with alkalinities between 0 and 50 $\mu eq.l^{-1}$ (Table 4). Of the gamefish resources, the extrapolations indicate that there are 41 brook trout, 51 lake trout, and 26 smallmouth bass lakes with alkalinities less than zero. Large portions of the resources of those three species are in lakes with alkalinities between 0 and 50 $\mu eq.l^{-1}$. Some walleye lakes (142) have alkalinities less than 50 $\mu eq.l^{-1}$. The largest proportion of brook trout resources, 424 lakes, is in the 50-100 $\mu eq.l^{-1}$ class.

Most of the lakes with alkalinities less than zero are in the Sudbury region of Ontario (watersheds 2C, 2D, and 2J) with some in the Algoma region (2B) (Table 5). The lakes with alkalinities between 0 and 50 are also found in a Sudbury-centred region (Table 6), though the number of watersheds involved is greater. The lakes with low or less than zero alkalinities are strongly associated with the areas receiving the highest acid deposition.

## DISCUSSION

The results obtained in this analysis are comparable with the results obtained earlier (Minns, 1981). The number of lakes with alkalinities less than 50 $ueq.l^{-1}$, is less than that estimated by Kelso et al. (1986) for Ontario. They extrapolated results of headwater lake surveys. Their selection of lakes was biased toward small headwater lakes while the inventory lake selection is biased toward non-headwater larger lakes (Minns, 1984). The two approaches likely bound the range of most likely values; e.g., 19,878 to 40,662 lakes with an alkalinity less than 50 $\mu eq.l^{-1}$. Similarly, here it is estimated there are 1344 lakes with a pH <5 while Kelso et al. (1986) estimate there are 2020 lakes with a pH <4.7.

Beggs et al. (1985) carried out a detailed analysis of the lake trout resource in Ontario and estimated that 80 lake trout lakes had an alkalinity less than 0 (compared to 51 here) and 274 lakes with an alkalinity between 0 and 40 $\mu eq.l^{-1}$ (compared to 343 lakes in the 0 to 50 range reported here). Field and laboratory data pointed to an extinction threshold at a low pH 5.2 associated with mortality of early life history stages of lake trout.

With respect to gamefish resources, the estimates of resource at risk are comparable with those of Minns (1981). Large parts of the brook trout, lake trout, and smallmouth bass resources have low alkalinities (<50 $\mu eq.l^{-1}$) and are located in areas receiving high acid deposition (Table 2). Fortunately, so far, only a small percentage (<2 percent) of these resources appear to be acidified; i.e., have alkalinities less than zero.

As the databases grow, so the estimates of the resource at risk can be refined. Further iterations can be expected in the future, but it is unlikely that the estimates will change dramatically.

## ACKNOWLEDGMENTS

I wish to acknowledge the assistance and co-operation of staff at Fisheries Branch, Ontario Ministry of Natural Resources in Toronto, especially Ms. G. Beggs and Ms. D. Wales, in the completion of this work.

REFERENCES

Barrie, L.A. and J.M. Hales. 1984. The spatial distributions of precipitation acidity and major ion wet deposition in North America during 1980. Tellus (1984), 36B:333-355.

Beggs, G.L. J.M. Gunn and C.H. Olver. 1985. The sensitivity of Ontario lake trout (Salvelinus namaycush) and lake trout lakes to acidification. Ont. Fish. Tech. Rept. No. 17, 24p.

Cox, E.T. 1978. Counts and measures of Ontario lakes. Ont. Min. Nat. Res. MS Rept. 114 p.

Kelso, J.R.M., C.K. Minns, J.E. Gray and M.L. Jones. 1986. Acidification of surface waters in eastern Canada and its relationship to aquatic biota. Can. Spec. Publ. Fish Aquat. Sci., No.87, 42p.

Minns, C.K. 1981. Acid rain: a preliminary estimate of the risk to Ontario's inland fisheries. Can. MS Rep. Fish. Aquat. Sci., 1622:36 p.

Minns, C.K. 1984. Analysis of lake and drainage area counts and measures for selected watersheds across Ontario's shield region. Can. MS Rep. Fish. Aquat. Sci., 1748:17 p.

Minns, C.K. 1986. Analyses of the Ontario lake inventory database. I A model of bias in lake selection, and II Fish species community structure in Ontario's lakes. Ontario Fish. Tech. Rept. (in press).

TABLE 1: Input data for the classification and extrapolation of the lake inventory and composite databases.

| Subject | Information | | Source |
|---|---|---|---|
| Fish species occurrences | brook trout<br>lake trout | - 2110<br>- 2220 | Minns (1985) and Olver (OMNR, pers.comm) |
| | smallmouth bass<br>walleye | - 3500<br>- 6000 | |
| Alkalinity categories ($\mu eq.l^{-1}$) | <0, 0-50, 50-100, 100-200, >200 | | Various |
| pH categories | none, <5, 5-5.5, >5.5 | | Various |
| Lake size categories | 1-10, 10-100, 100-1000, 1000-100000 | | |

TABLE 2: Designation of acidic deposition zones by secondary watershed.

| Watershed | Deposition level[1] | $kg SO_4 . ha^{-1} . yr^{-1}$ |
|---|---|---|
| 2B, 2C, 2D, 2E, 2F, 2G, 2H, 2J, 2K, 2L, 2M | High | >20 |
| 2A, 4G, 4J, 4K, 4L, 4M, 4N, 5P, 5Q | Moderate | 10-20 |
| 4A, 4B, 4C, 4D, 4E, 4F, 4H, 5R | Low | <10 |

[1] Approximate after Barrie and Hales 1984

TABLE 3: Allocation of uninventoried resources, probability of encountering a gamefish species, and scaling substitutions by secondary watershed.

| Watershed | Brook trout | | | Lake trout | | | Smallmouth bass | | | Walleye | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Scaling[a] | Prob. | # | Scaling | Prob. | # | Scaling | Prob. | # | Scaling | Prob. | # |
| Uninventoried | | | | | | | | | | | | |
| # | | | 360.0 | | | 587.0 | | | 1902.0 | | | 3662.0 |
| Area (Ha) | | | 13600.7 | | | 218125.6 | | | 270614.6 | | | 3294170.0 |
| 2A | 1 | 0.0077 | 7.4 | 1 | 0.0337 | 15.4 | 1 | .0265 | 54.2 | 1 | .0527 | 80.8 |
| 2B | 1 | 0.0346 | 62.0 | 1 | 0.0907 | 77.4 | 1 | .0206 | 78.8 | 1 | .1383 | 396.2 |
| 2C | 1 | 0.0531 | 74.2 | 1 | 0.1141 | 76.0 | 1 | .0750 | 223.5 | 1 | .0613 | 136.9 |
| 2D | 1 | 0.0100 | 5.1 | 1 | 0.1224 | 29.4 | 1 | .1410 | 151.6 | 1 | .1238 | 99.8 |
| 2E | 1 | 0.1033 | 37.4 | 1 | 0.1684 | 29.1 | 1 | .2862 | 221.0 | 1 | .1503 | 87.0 |
| 2F | 2 | 0.1030 | 1.3 | 2 | 0.0147 | t | 2 | .3857 | 10.6 | 2 | .1252 | 2.6 |
| 2G | 2 | 0.0496 | 2.4 | - | - | - | 2 | .1261 | 12.9 | 2 | .0117 | 0.9 |
| 2H | 1 | 0.0308 | 8.7 | 1 | 0.1261 | 16.9 | 1 | .4060 | 244.1 | 1 | .2387 | 107.6 |
| 2J | 1 | 0.0435 | 20.1 | 1 | 0.2278 | 50.2 | 1 | .2214 | 218.5 | 1 | .2813 | 208.1 |
| 2K | 1 | 0.1524 | 78.8 | 1 | 0.2031 | 50.0 | 1 | .2258 | 249.0 | 1 | .1199 | 99.1 |
| 2L | 2 | 0.0025 | t | 1 | 0.1680 | 1.3 | 1 | .3695 | 12.4 | 1 | .2908 | 7.3 |
| 2M | 2 | 0.0234 | 0.4 | 1 | 0.0846 | 0.8 | 1 | .2511 | 10.1 | 1 | .0465 | 1.4 |
| 4A | - | - | - | 2 | 0.0383 | 4.1 | - | - | - | 2 | .1532 | 55.6 |
| 4B | - | - | - | - | - | - | - | - | - | - | - | - |
| 4C | - | - | - | 2 | 0.0125 | 7.4 | - | - | - | 2 | .0707 | 140.8 |
| 4D | - | - | - | - | - | - | - | - | - | 1 | .0434 | 98.6 |
| 4E | 3 | 0.0086 | 4.9 | 2 | 0.0081 | 2.2 | - | - | - | 2 | .0061 | 5.6 |
| 4F | - | - | - | - | - | - | - | - | - | 1 | .0723 | 58.8 |
| 4G | 2 | 0.0007 | 0.9 | 1 | 0.0383 | 22.0 | 2 | .0005 | 1.2 | 1 | .2109 | 405.3 |
| 4H | - | - | - | - | - | - | - | - | - | 2 | .0199 | 10.7 |
| 4J | 1 | 0.0462 | 42.2 | 1 | 0.0554 | 24.0 | - | - | - | 1 | .2181 | 317.8 |
| 4K | - | - | - | - | - | - | - | - | - | - | - | - |
| 4L | 1 | 0.0055 | 6.0 | 1 | 0.0264 | 13.6 | 1 | .0166 | 38.2 | 1 | .1591 | 275.0 |
| 4M | 1 | 0.0135 | 5.3 | 1 | 0.0148 | 2.8 | 1 | .0004 | 0.3 | 1 | .3272 | 205.4 |
| 4N | 2 | 0.0044 | 0.4 | - | - | - | - | - | - | 1 | .0595 | 9.5 |
| 5P | 2 | 0.0001 | 0.1 | 1 | 0.1317 | 78.2 | 1 | .0823 | 218.5 | 1 | .1515 | 301.7 |
| 5Q | 2 | 0.0020 | 2.2 | 1 | 0.1437 | 73.7 | 1 | .0684 | 157.0 | 1 | .2323 | 400.0 |
| 5R | - | - | - | 1 | 0.0399 | 12.5 | - | - | - | 1 | .1426 | 149.3 |

t - trace
a - Scaling - 1-watershed/2-region/3-province

TABLE 4: **Fisheries resources in Ontario allocated by alkalinity and pH classes.**

| Resource | pH class | Alkalinity class <0 | | <50 | | <100 | | <200 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | # | Area[a] | # | Area | # | Area | # | Area | # | Area |
| Total (all lakes) | - | 3,208 | 37,401 | 15,670 | 197,214 | 17,841 | 631,509 | 32,227 | 900,753 | 112,060 | 7,234,031 |
| | <5 | 1,344 | 18,199 | 74 | 882 | - | - | - | - | - | - |
| | 5-<5.5 | 1,336 | 13,340 | 1,569 | 11,058 | - | - | - | - | - | - |
| | >5.5 | 529 | 5,862 | 14,027 | 185,273 | 17,825 | 631,166 | 32,136 | 897,767 | 111,810 | 7,226,604 |
| Brook trout | - | 41 | 3,254 | 527 | 32,023 | 424 | 153,656 | 310 | 36,159 | 610 | 51,109 |
| | <5 | 14 | 712 | - | - | - | - | - | - | - | - |
| | 5-<5.5 | 19 | 668 | 62 | 1,373 | - | - | - | - | - | - |
| | >5.5 | 8 | 1,874 | 465 | 30,650 | 422 | 153,539 | 309 | 35,988 | 607 | 50,997 |
| Lake trout | - | 51 | 11,289 | 346 | 89,084 | 413 | 289,423 | 512 | 315,130 | 766 | 701,521 |
| | <5 | 3 | 414 | - | - | - | - | - | - | - | - |
| | 5-<5.5 | 37 | 6,939 | 5 | 359 | - | - | - | - | - | - |
| | >5.5 | 12 | 3,937 | 341 | 88,724 | 409 | 289,094 | 509 | 314,472 | 760 | 699,881 |
| Smallmouth bass | - | 26 | 3,957 | 644 | 101,172 | 605 | 137,747 | 1,007 | 247,570 | 1,219 | 585,628 |
| | <5 | 3 | 321 | 3 | 190 | - | - | - | - | - | - |
| | 5-<5.5 | 20 | 2,889 | 87 | 10,540 | - | - | - | - | - | - |
| | >5.5 | 3 | 747 | 554 | 90,442 | 604 | 137,624 | 1,006 | 247,390 | 1,219 | 585,628 |
| Walleye | - | - | - | 142 | 93,648 | 185 | 99,672 | 768 | 377,084 | 4,905 | 4,944,566 |
| | <5 | - | - | - | - | - | - | - | - | - | - |
| | 5-<5.5 | - | - | 3 | 156 | - | - | - | - | - | - |
| | >5.5 | - | - | 139 | 93,492 | 185 | 99,672 | 767 | 376,847 | 4,899 | 4,943,993 |

a - hectares

TABLE 5: Resources with alkalinity < zero by secondary watershed.

| Watershed | Total | | Brook trout | | Lake trout | | Smallmouth bass | | Walleye |
|---|---|---|---|---|---|---|---|---|---|
| | # | Area | # | Area | # | Area | # | Area | # |
| 2A | – | – | – | – | – | – | – | – | – |
| 2B | 378 | 2448 | 5 | 469 | 3 | 336 | – | – | – |
| 2C | 1573 | 13002 | 11 | 1862 | 18 | 5624 | 8 | 2931 | – |
| 2D | 820 | 17393 | 7 | 353 | 23 | 4244 | 14 | 296 | – |
| 2E | 120 | 1539 | 8 | 192 | – | – | 3 | 666 | – |
| 2F | 13 | 205 | 1 | 11 | – | 4 | 1 | 45 | – |
| 2G | 21 | 185 | t | 8 | – | – | t | 19 | – |
| 2H | 17 | 178 | – | – | – | – | – | – | – |
| 2J | 224 | 2398 | 6 | 274 | 7 | 900 | – | – | – |
| 2K | – | – | – | – | – | – | – | – | – |
| 2L | – | – | – | t | t | 51 | – | – | – |
| 2M | – | – | t | 11 | – | 131 | – | – | – |
| 4A | – | – | – | – | – | – | – | – | – |
| 4B | – | – | – | – | – | – | – | – | – |
| 4C | – | – | – | – | – | – | – | – | – |
| 4D | – | – | – | – | – | – | – | – | – |
| 4E | – | – | t | 48 | – | – | – | – | – |
| 4F | – | – | – | – | – | – | – | – | – |
| 4G | – | – | – | t | – | – | – | – | – |
| 4H | – | – | – | – | – | – | – | – | – |
| 4J | – | – | – | – | – | – | – | – | – |
| 4K | – | – | – | – | – | – | – | – | – |
| 4L | 41 | 53 | 2 | 21 | – | – | – | – | – |
| 4M | – | – | – | – | – | – | – | – | – |
| 4N | – | – | – | t | – | – | – | – | – |
| 5P | – | – | – | t | – | – | – | – | – |
| 5Q | – | – | t | 3 | – | – | – | – | – |
| 5R | – | – | – | – | – | – | – | – | – |

t - trace

TABLE 6: Resources with alkalinity between zero and 50 µeq $l^{-1}$ by secondary watershed.

| Watershed | Total | | Brook trout | | Lake trout | | Smallmouth bass | | Walleye | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # | Area | # | Area | # | Area | # | Area | # | Area |
| 2A | – | – | – | – | – | – | – | – | – | – |
| 2B | 2949 | 15304 | 85 | 5496 | 37 | 3600 | 87 | 4882 | 10 | 856 |
| 2C | 4545 | 27555 | 46 | 5497 | 58 | 16707 | 117 | 15014 | 14 | 5608 |
| 2D | 1927 | 32218 | 30 | 390 | 47 | 12758 | 89 | 20914 | 30 | 59546 |
| 2E | 2166 | 63540 | 143 | 13819 | 69 | 21557 | 228 | 41381 | 39 | 15742 |
| 2F | 104 | 1059 | 10 | 112 | t | 26 | 16 | 632 | 1 | 99 |
| 2G | 170 | 958 | 2 | 87 | – | – | 8 | 406 | t | 14 |
| 2H | 706 | 18034 | 49 | 2202 | 34 | 5688 | 49 | 9336 | – | – |
| 2J | 894 | 26317 | 23 | 1469 | 53 | 21404 | 10 | 7166 | 26 | 9501 |
| 2K | 1056 | 10211 | 101 | 2269 | 47 | 6162 | 41 | 1441 | – | – |
| 2L | – | – | t | 2 | t | 333 | – | – | 1 | 383 |
| 2M | – | – | 5 | 118 | t | 851 | – | – | t | 311 |
| 4A | – | – | – | – | – | – | – | – | – | – |
| 4B | – | – | – | – | – | – | – | – | – | – |
| 4C | – | – | – | – | – | – | – | – | – | – |
| 4D | – | – | – | – | – | – | – | – | – | – |
| 4E | – | – | 2 | 502 | – | – | – | – | – | – |
| 4F | – | – | – | – | – | – | – | – | – | – |
| 4G | 374 | 1451 | t | 2 | – | – | – | – | 21 | 1587 |
| 4H | – | – | – | – | – | – | – | – | – | – |
| 4J | 89 | 64 | – | – | – | – | – | – | – | – |
| 4K | – | – | – | – | – | – | – | – | – | – |
| 4L | 165 | 101 | 2 | 11 | – | – | – | – | – | – |
| 4M | 373 | 22 | 28 | 43 | – | – | – | – | – | – |
| 4N | – | – | t | 1 | – | – | – | – | – | – |
| 5P | 152 | 380 | t | t | – | – | – | – | – | – |
| 5Q | – | – | 1 | 4 | – | – | – | – | – | – |
| 5R | – | – | – | – | – | – | – | – | – | – |

t - trace

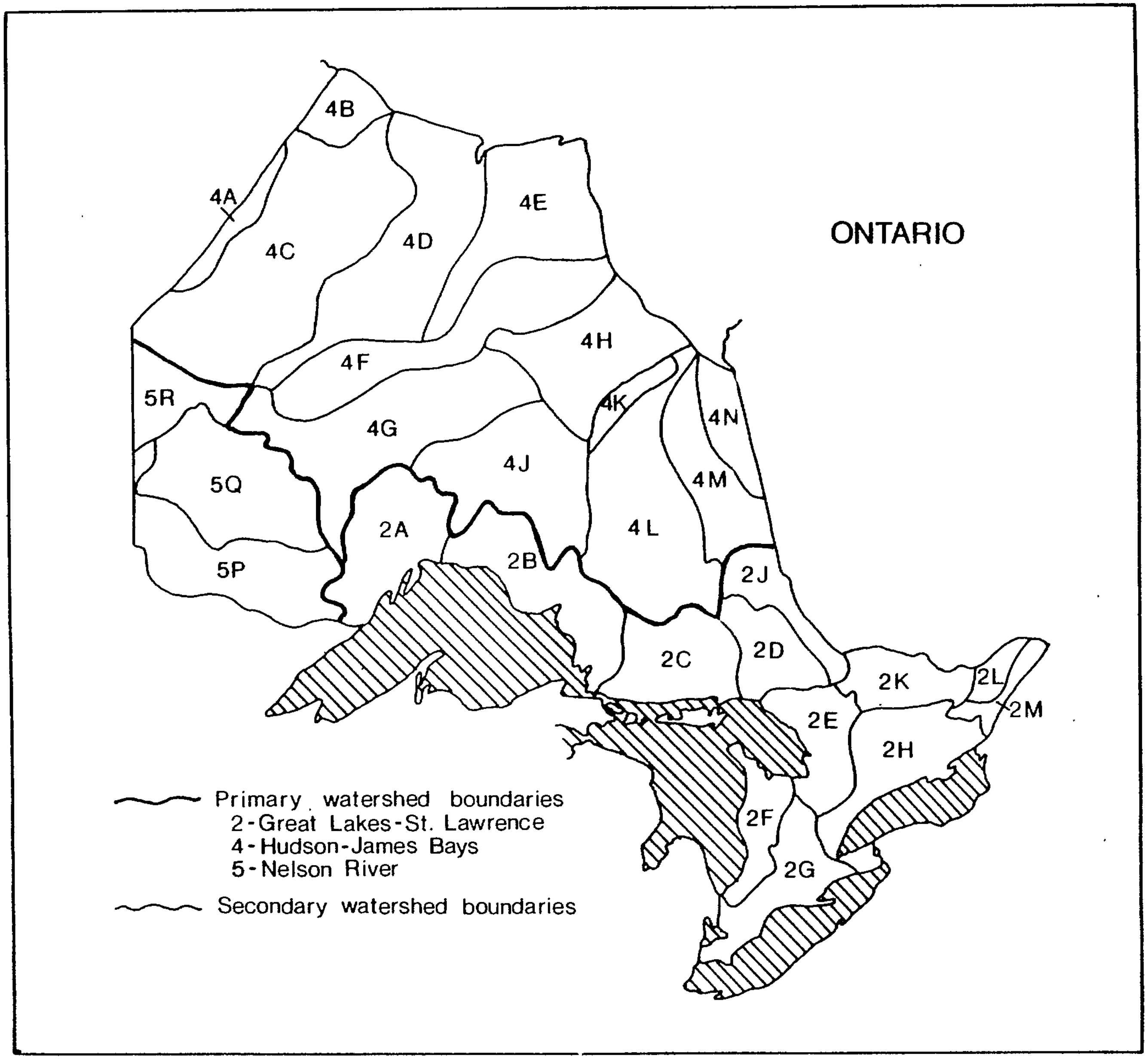


Figure 1. A map of Ontario showing the primary and secondary watershed boundaries.