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ESTIMATES OF THE NUMBERS AND AREAS OF ACIDIC LAKES IN NOVA SCOTIA

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There are 6674 lakes larger than 1 hectare in Nova Scotia covering an area of 2255 km^2. Geological and pH isopleth maps were consulted to estimate acidified and acid sensitive lakes. Assuming that granitic or metamorphic bedrock only very slowly produce acid neutralizing ions, we estimate that 78% of the lakes (85% of lake area) would, in the absence of moderating influences of surficial geology and marine aerosols, be susceptible to acidification. When all sources of acid neutralizing capacity are indirectly considered via examination of pH isopleths drawn from lake chemistry, we estimate that 16% of the lakes (26% of lake area) have zero alkalinity, and that 69% of the lakes (80% of lake area) have $< 50\ \mu eq\ L^{-1}$ alkalinity.

En Nouvelle-Ecosse il y a 6674 lacs ayant une superficie au delà d'un hectare, avec une superficie totale de 2255 km^2. On a consulté des cartes géologiques ainsi que des cartes d'isoplèthes de pH, en but d'obtenir une estimation des lacs acidifiés ainsi que des lacs sensibles à l'acide. Supposant que le fond de roche granitique ou métamorphique libère des ions qui neutralisent l'acide très lentement, nous estimons que 78% des lacs (85% des superficies) seraient predisposés à l'acidification, dans l'absence d'influences modérantes de la geologie superficielle. Quand on donne leurs poids à toutes les sources démontrant la capacité de neutraliser l'acide, par le biais d'inspection des isoplèthes de pH des lacs, nous estimons que 16% des lacs (26% de la superficie totale) ont nulle alcalinité, et que 68% des lacs (80% de la superficie totale) ont une mesure d'alcalinité de $50\ \mu eq\ L^{-1}$.

Introduction

The Dominion Water Power Branch of the Canada Department of the Interior initiated hydrometric surveys in Nova Scotia in 1915 and prepared a drainage index map which divided the 55.5×10^3 km^2 province into 44 basins (Fig 1). In 1980 a series of 1:50000 Watershed Area maps of the province was compiled by Maritime Resource Management Survey. From these maps the areas of all lakes over 1 hectare (the smallest size for which statistics were available on the maps) were tabulated for each of the 44 drainage areas by B. Sabean, Nova Scotia Department of Lands and Forests (unpubl. data). We have used Sabean's data, geological data (Anon. 1986), and water chemistry information (Clair *et al.* 1982, Alexander *et al.* 1986 and Underwood *et al.* 1987) in order to provide estimates of the numbers and areas of acidic lakes in Nova Scotia.

Nova Scotia lakes are sensitive to acidic precipitation (Kerekes *et al.* 1982; Watt *et al.* 1983; Underwood *et al.* 1987) and while estimates of the proportions of lakes in various classes of acidity have been published (Jeffries *et al.* 1986; Kelso *et al.* 1986; Underwood *et al.* 1986), none have had the advantage of working with information about the actual number of lakes in the province as is the case in this study.

Methods

Lakes were subdivided into pH classes by superimposing a lake pH isopleth map (Underwood *et al.* 1987; Fig 2) and calculating isopleth areas by planimeter. The total number of lakes within one drainage unit was assumed to be evenly distributed throughout the unit.

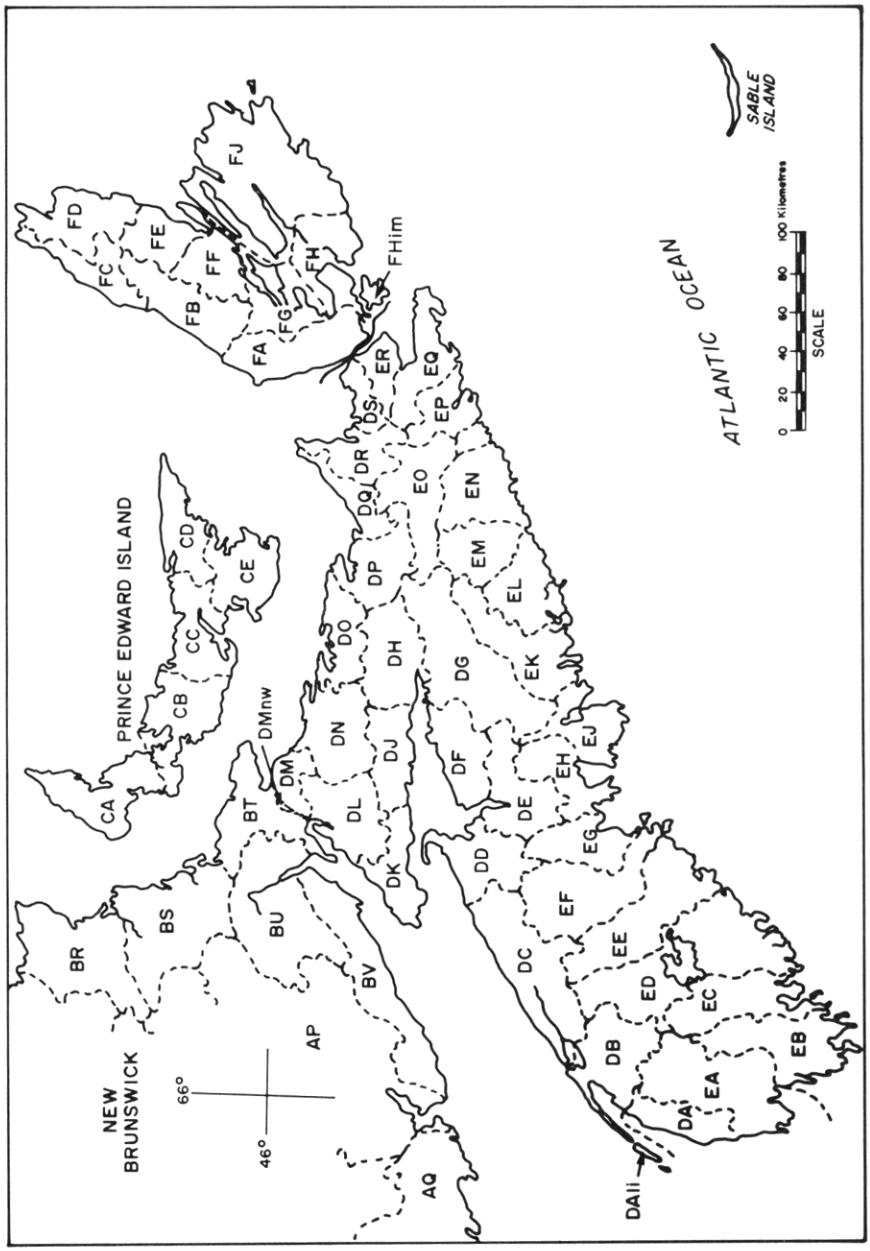

Fig 1 Map of 44 drainage basins in Nova Scotia plus several in New Brunswick and Prince Edward Island. The nomenclature designating each Nova Scotian drainage basin is used in Table II.

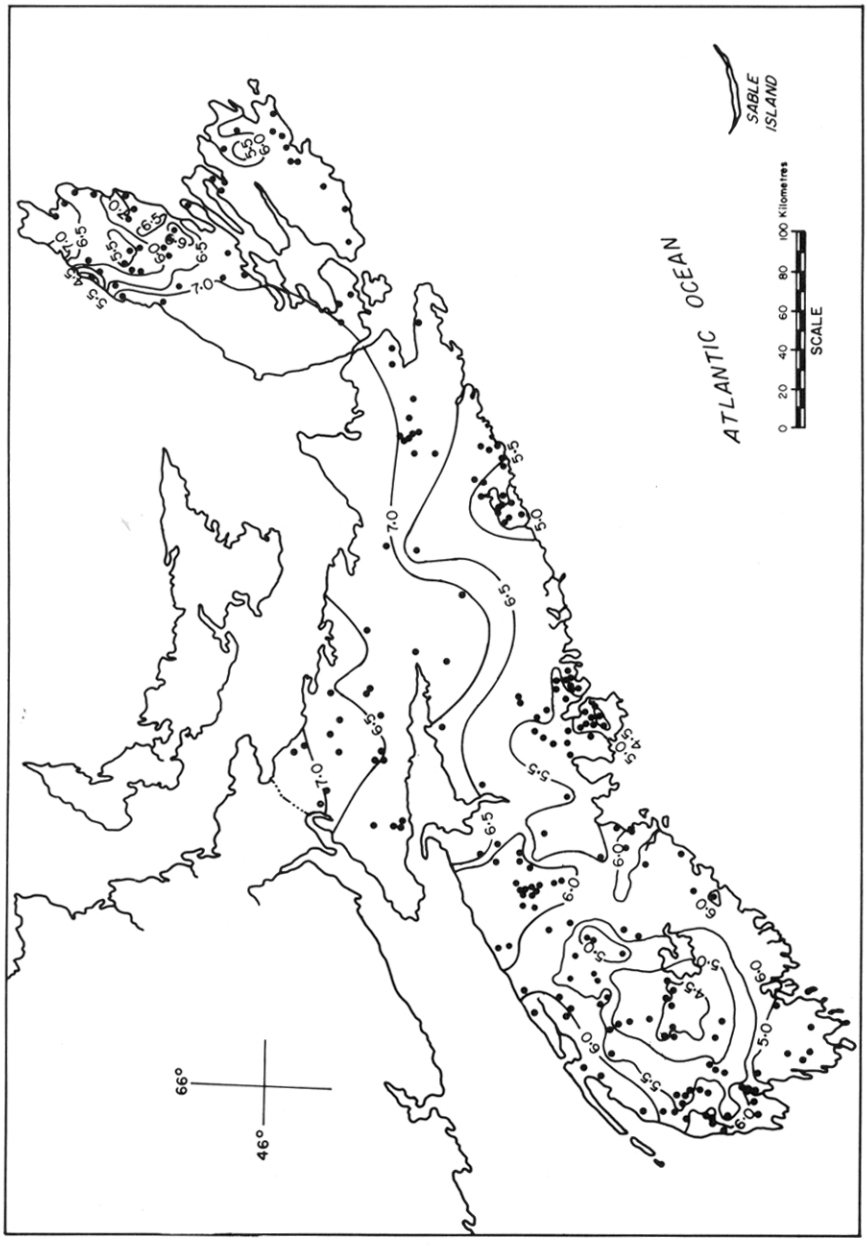

Fig 2 pH Isopleths for lake waters in Nova Scotia.

Kelso *et al.* (1986) classify lakes by both pH and alkalinity with one group for example listed as alkalinity $< 50\,\mu eq\ L^{-1}$. Underwood (1984) developed an equation for determination of HCO_3^- from pH measurements in precipitation:

$$HCO_3^- (\mu eq\ L^{-1}) = 11.35/H^+ (\mu eq\ L^{-1}) \quad (1)$$

where $H^+ = 10^6 \cdot 10^{-pH}$

Using this equation we have calculated that $50\,\mu eq$ Alk L^{-1} (as HCO_3^-) is equivalent to pH 6.6 which was interpolated on the pH isopleth map of Underwood *et al.* (1987) to provide estimates for lakes with alkalinity $< 50\,\mu eq\ L^{-1}$. A value of 6.6 is mid point of lakewater pH as predicted by Wiltshire and Machell (1981) for CO_2 saturated and supersaturated conditions and $50\,\mu eq\ L^{-1}$ alkalinity.

Results

Table I shows total numbers and percentages of several categories of lakes with surface areas > 1 hectare. The lake number is lower than estimates of Smith (1963) who reported 2580 lakes over 10 hectares in area, and about 6800 smaller lakes (no further size classes were given). The numbers for the 5 smallest categories on Table I are similar, averaging 1254 ± 140 per group, although the combined surface areas of the 5 groups account for only 40% of the total surface area. Thus while the two largest categories make up only 6% of the total number of lakes, they account for 60% of the total surface area.

Table I Numbers and areas of size classes of lakes in Nova Scotia.

Size class (ha)	Number	%	Total area (ha)	%
1-2	1339	20.1	2159	1.0
2-5	1436	21.5	5375	2.4
5-10	1163	17.4	8912	4.0
10-25	1249	18.7	20593	9.1
25-100	1081	16.2	53084	23.5
100-500	367	5.5	71781	31.8
over 500*	39	0.6	63591	28.2
Total	6674	100	225495	100

*The largest is Lake Rossignol (15470 ha).

Table II lists the number of lakes in the 44 drainage basins that are greater than 1 hectare in area. The total area of these lakes and the proportion underlain by granites or metamorphics is also given in Table II. This Table indicates that of the 6674 lakes in the province (2255 km^2), 5213 (1915 km^2) are likely to be found on granite or metamorphic rocks. Thus 78% of the total number and 85% of the total area of Nova Scotian lakes would, in absence of moderating influences of surficial geology, be susceptible to acidification. Granitic and metamorphic influences are extensive in the province, and these resistant rocks form the bedrock geology of 65% of the province.

Data for the lake pH classes (Kelso *et al.* (1986), are shown in Table III with an additional class ($pH < 5$) as a further indicator of acidified lakes (cf. Watt 1981). Our estimates for both total number and area of lakes in various pH classes are provided in the upper rows. Estimates of numbers only were all that were available in sub-classes of the 3 other references. Kelso *et al.* (1986) estimated that 47.3% of the lakes in this

Table II Number and area of lakes in each of 44 drainage basins, and the percentage of land area on granite or metamorphic bedrock.

Basin (Fig 1)	# Lakes	Area Lakes ha	% Granite Metamorph.	Basin	# Lakes	Area Lakes ha	% Granite Metamorph.
DMnw	17	144	0	EL	452	9923	100
DM	20	253	0	EK	390	9227	83
DN	41	555	18	EJ	372	7073	100
DO	28	415	11	EH	201	6849	100
DP	48	584	17	EG	137	5738	100
DQ	20	147	62	EF	193	8785	100
DR	45	681	19	EE	273	16155	100
DS	37	637	0	ED	307	32989	100
FA	45	816	11	EC	133	8404	100
FB	27	5873	20	EB	112	8117	100
FC	45	295	83	EA	287	17563	100
FD	197	1539	88	DA	100	4106	100
FE	105	789	81	DAli	2	6	100
FF	33	271	50	DB	118	7891	100
FG	28	117	24	DC	180	5751	75
FJ	467	12655	54	DD	41	5311	66
FH	125	3281	45	DE	174	5849	88
FHim	26	650	0	DF	33	404	12
ER	82	1507	0	DG	203	5792	35
EQ	441	6482	74	DH	78	404	15
EP	124	1855	80	DJ	28	397	45
EO	234	4313	41	DK	19	113	4
EN	283	6409	100	DL	22	457	18
EM	301	7922	100	TOTAL	6674	225494	

DMnw: A small area northwest of DM, which flows into New Brunswick.
FHim: Isle Madame.
DAli: Long Island.
There are 5213 lakes on granite or metamorphic bedrock.

Table III Estimates of acidity in 6674 lakes in Nova Scotia.*

Number of Lakes measured	Number of Lakes with Acidities in the pH ranges				
	> 6.6	6.6-6	6-5	5-4.7	< 4.7
6674 (2255)	2065 (450)	1947 (512)	2103 (970)	364 (223)	195 (100)
6585 (2650)	441	1291	---	---	3115**
	474	727	2870	1135	1468 #
	1768	571	3565	570	200 $

*The sum of the areas (in km²) of the lakes in each pH range are given in parentheses; ** Kelso *et al.* (1986); # estimated from Jeffries *et al.* (1986); $ estimated from Underwood *et al.* (1986).

province have pH < 4.7 but the isopleth maps have led us to conclude that only 3% of lakes may exist in that state. Similar extrapolation of data from the 234 lakes examined by Underwood *et al.* (1986) to the 6674 lakes, gave a value of 3% (Table III). Jeffries *et al.* (1986) had no pH class < 4.7 and the number in Table III was extrapolated from

their estimates for other pH classes giving a value of 22%. We believe that differences in the estimates result from inadvertant selection of varying proportions of lakes on different geological substrata. None of the studies examined included more than 3.5% of the lakes, and Kelso *et al.* (1986) only had at their disposal a data base of 1.1% of the freshwater resources of the province.

Table III shows that 80% of the surface area of lakes in the province has less than 50 μeq L^{-1} of alkalinity, and that there are somewhere between 14% and 57% of total lake area with zero alkalinity. We employ a simplified definition of alkalinity where Alk = HCO_3^- - H^+. When Alk is set to 0, then $H^+ = HCO_3^-$, and based on equation 1, this would occur at pH 5.5. This yielded an estimate that 26% of lake area in the province had no alkalinity (16% of the number of lakes), a condition rendered doubly critical by rapid flushing rates in many lakes, and a resultant tendency for water quality in lakes to resemble precipitation (Underwood *et al.* 1987). If only lakes on granite or metamorphic bedrock are considered, the proportion of zero-alkalinity lakes rises slightly to 21% (based on numbers) and 31% (based on areas). We estimate similarly that 88% of granitic/metamorphic lakes (95% based on areas) have less than 50 μeq L^{-1} alkalinity.

The acid neutralizing capacity in a lake is governed by a variety of internal and external processes (Schindler *et al.* 1986). It is therefore possible to find two lakes very close together which have different levels of acidity (Kerekes *et al.* 1982). Although Nova Scotia is very sensitive to acidic precipitation (Underwood *et al.* 1987), our data imply that there are fewer acidic lakes in the province than estimated by Kelso *et al.* (1986) or Jeffries *et al.* (1986). We encourage more research on watershed processes for there is still uncertainty about relative sources and sinks for acidity in Nova Scotian lakes (Gorham *et al.* 1986).

Acknowledgements

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