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ACID RAIN AND SNOW AT KEJIMKUJIK, N.S. DURING 1985

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Scientific Services Division
Atmospheric Environment Service
Bedford, N.S.

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1. Introduction

The Atmospheric Environment Service of Environment Canada has operated a daily precipitation sampling station in Kejimkujik National Park in southwestern Nova Scotia since May 1979. Daily precipitation samples are collected at the station and sent for analysis for pH and the concentration of various chemical constituents, such as sulphates and nitrates. In addition, the pH of precipitation has been determined on-site since December 1983. Environment Canada issues a weekly bulletin (The Acid Rain Report) which summarizes the information gathered on-site during the past week and includes a brief description of the areas over which each weather system originated and/or passed on its path to the site. This information highlights the variability of precipitation pH from event to event and the relationship between pH and the levels of emission of acid-forming compounds from areas upwind of the site.

The pH value is a measure of the acidity (hydrogen ion concentration) of the precipitation. The pH scale ranges from 0 (extremely acidic) to 14 (extremely alkaline). A pH value of 7 is neutral. The scale is logarithmic, so there is a ten-fold difference between integers. For example, a pH of 5 is ten times more acidic than a pH of 6.

Clean precipitation, which is not contaminated by pollutants, is slightly acidic with a pH of approximately 5.6. Most of eastern Canada receives acid precipitation, with average pH values ranging from 4.2 to 4.5.

Environmental damage to lakes and streams is usually observed in acid sensitive areas that regularly receive precipitation with pH less than 4.7. Readings of 4.2 and below are considered strongly acidic and are not uncommon at Kejimkujik. Although they do not constitute an immediate danger to human health or property, readings of less than 4.0 are considered to be serious events. The effects of acid rain and snow are generally cumulative over time, although fish kills have been observed after low pH events and after the melting of acidic snow.

2. Analysis of Data

2.1 Annual Summary

The variability of precipitation pH at Kejimkujik, N.S. during 1985 is clearly shown in Figures 1-3, which are plots of the pH value of the precipitation against the day of the year for January to April, May to August and September to December, respectively. The different types of precipitation are indicated using different symbols. Also included in each graph are lines that represent three different levels of pH:

1. normal precipitation (pH = 5.6)
2. damaging pH level (pH = 4.7)
3. seriously acidic level (pH = 4.0)

An examination of the Figures shows that none of the precipitation events at Kejimkujik in 1985 were in the normal pH range and that most of the precipitation events were within the damaging or seriously acidic pH ranges. Table 1 summarizes these events.

Table 1: Summary of Precipitation Events at Kejimkujik, N.S. During 1985

Level of pH	pH Range	Number of Occurrences	Percentage
Normal	pH > 5.6	0	0.0%
Slightly Acidic	4.7 < pH <= 5.6	40	28.8%
Damaging	4.0 < pH <= 4.7	69	49.6%
Seriously Acidic	pH <= 4.0	30	21.6%

Generally, very low pH values (high acidity) are associated with events that produce only small amounts of precipitation. Thus, the total deposition of acid may not be as large as for other events with higher pH but more precipitation. The deposition of acid (in mg/m^2) during each precipitation event is calculated by converting the precipitation pH into a hydrogen ion concentration (in mg/l) and multiplying by the amount of precipitation in millimetres. In the case of snow, the water equivalent in millimetres is used by assuming that 1 cm of snow is equivalent to 1 mm of water. When calculating an average pH value for a number of events, precipitation-weighted averages are determined by summing the hydrogen ion depositions for the events and dividing by the total precipitation during the events. This precipitation-weighted average hydrogen ion concentration is then converted into an average precipitation-weighted pH value.

The overall average precipitation-weighted pH for precipitation at Kejimkujik for 1985 was 4.4. This value was calculated from the 139 days of precipitation during the year. Average pH values were also calculated for the different types of

precipitation. The average value was 4.4 for rain, 4.3 for snow, and 4.4 for mixed precipitation (rain and snow on the same day).

The precipitation events were then categorized by their pH value (pH <= 4.0, 4.0 < pH <= 4.7, and pH > 4.7) and by the main source region. This was the region that was considered to be the main source of precipitation pH, as determined by the meteorologist who prepared the Acid Rain Report. The regions are shown in Figure 4 and defined as:

GL: Great Lakes States and Southern Ontario
MID: U.S. Midwest
ONT: North and Central Ontario
QUE: Quebec and Labrador
E.CST: U.S. East Coast
MRT: Maritimes and Newfoundland
ATL: Atlantic Ocean and New England

The results are plotted in Figure 5. The number printed after each region is the number of days when it was the main source region for precipitation pH in the range indicated. The percentage that this represents is printed next and also plotted in the adjacent pie chart.

It can be seen that, for precipitation with a pH <= 4.0, the U.S. East Coast, Midwest, and the Great Lakes/Southern Ontario regions account for nearly three-quarters of all events. These areas are the largest sources of air pollution in North America. It can also be seen by comparing the three pie graphs that these three main source regions become less important with the increasing pH ranges. For the pH > 4.7 range, they are the main source regions for only 5% of the events.

In contrast, the Atlantic Ocean/New England region, which was the main source region for 10% of the events with pH <= 4.0, becomes the most important main source region for pH > 4.7. The Maritimes/Newfoundland region also becomes a more important main source region with increasing pH as does, to a lesser extent, the Quebec/Labrador region. The contribution from the North/Central Ontario region is always very small and decreases with increasing pH.

2.2 Seasonal Summary

The data were grouped into the four-month periods January to April, May to August and September to December. The average precipitation-weighted pH for January - April was 4.3; for May-August, 4.4; and for September - December, 4.4.

Figures 6, 7, and 8 show the frequency of occurrence of the main source regions of precipitation pH broken down into pH ranges, as well as into four-month periods. To a large extent there is no significant deviation from the pattern shown in the graphs for the entire year (Fig 5). In many of the cases there is only a very small number of days for which there were data.

Each set of graphs shows a similar pattern emerging. The Great Lakes States/Southern Ontario, U.S. East Coast and Midwest regions account for the largest fraction of events with pH <= 4.0, and these regions become less important with the increasing pH ranges. Again, the Atlantic Ocean/New England region is the predominant main source region for pH > 4.7. Also, as before, the Maritimes/Newfoundland and Quebec/Labrador regions become more important with increasing pH.

2.3 Main Source Regions

The data for the precipitation events were then sorted by the main source region. The average precipitation-weighted pH for each main source region was calculated for the whole year as well as for the four-month periods. The results are plotted in Figure 9, with the main source regions ordered by increasing average annual precipitation-weighted pH. The main source region of the most acidic precipitation (average annual pH of 3.9) was the U.S. Midwest and of the least acidic precipitation (average annual pH of 4.6) was the Atlantic Ocean/New England States region. As can be observed in the graph, the average pH is usually lowest in January - April and highest in September - December.

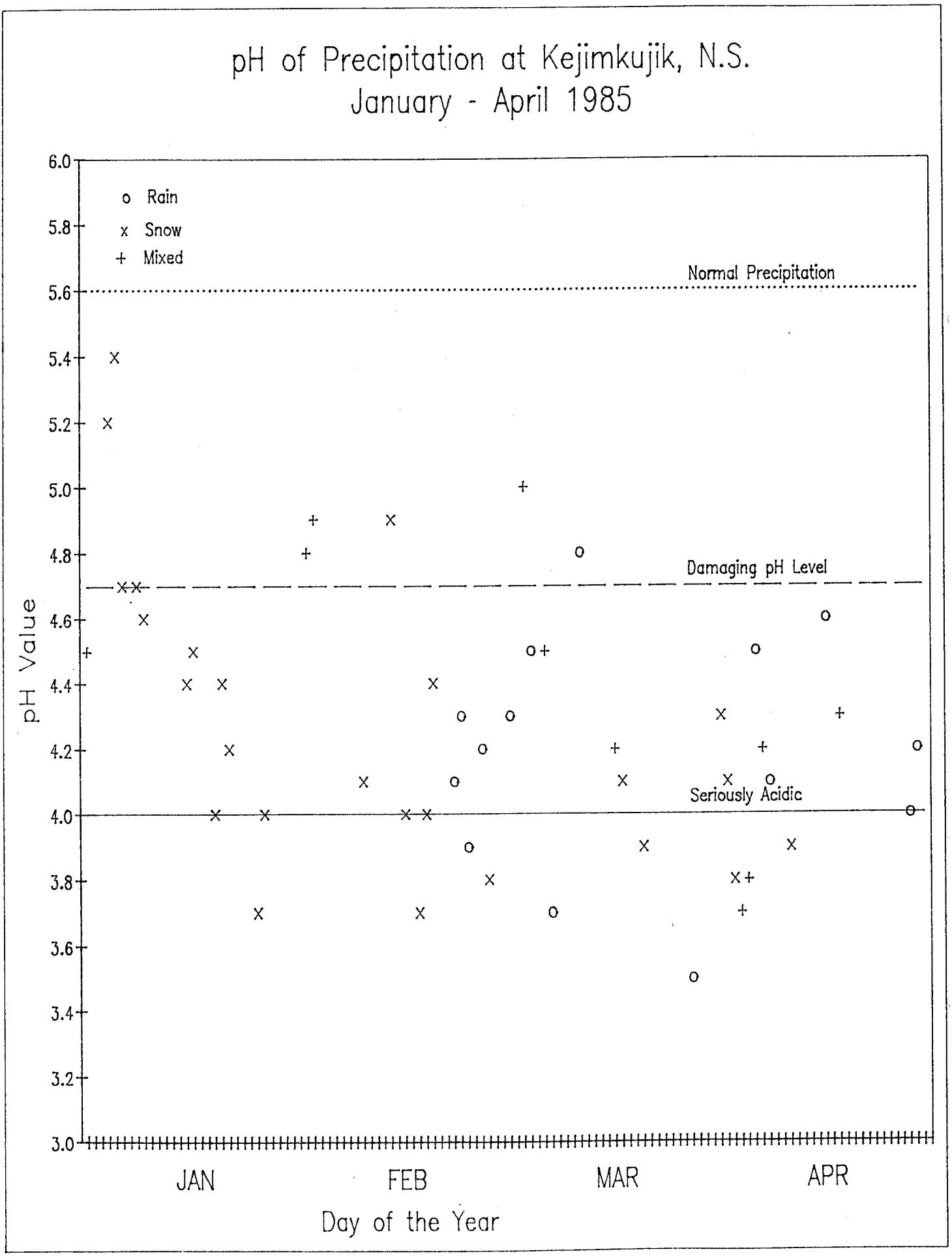
The number of occurrences of pH values attributed to each main source region are plotted in Figure 10, again in order of increasing average annual precipitation-weighted pH. These seven plots give an indication of how the pH values are distributed for each main source region. However, they should not be used to determine average pH values. Precipitation-weighted values must be used for this, not the arithmetic average. Note that North/Central Ontario and Maritimes/Newfoundland regions have small amounts of data, and that the scale for Figure 10g is not the same as for the other figures. Table 2 provides some sample statistics for each main source region.

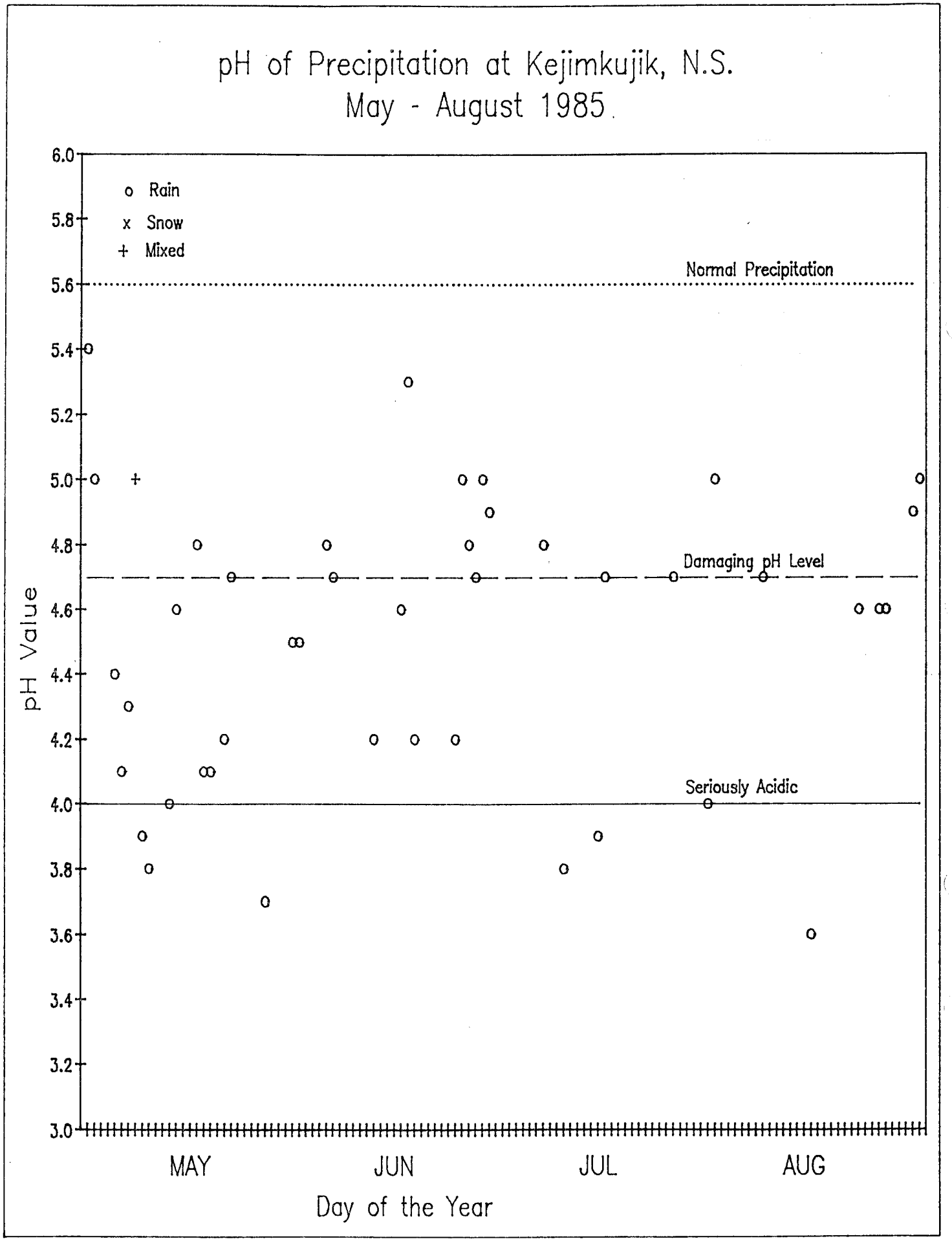
Table 2: Sample Statistics of Precipitation pH Received at Kejimkujik, N.S. from Seven Main Source Regions During 1985

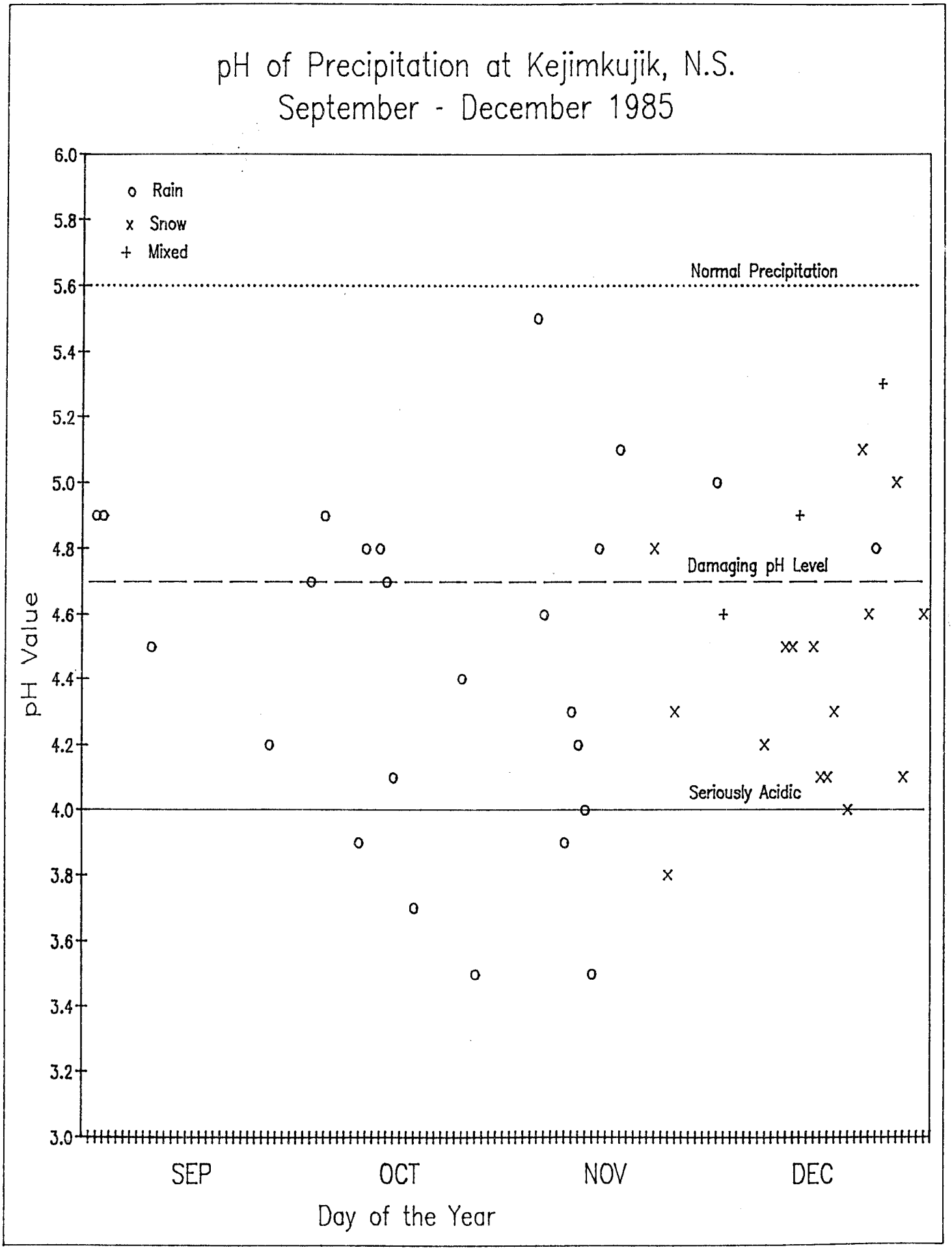
Main Source Region	Number of Occurrences	Minimum pH	Maximum pH	Average pH
MID	15	3.5	4.4	3.9
ONT	3	3.9	4.2	4.1
GL	16	3.5	4.8	4.1
E.CST	18	3.5	4.8	4.1
QUE	20	3.8	5.0	4.4
MRT	9	4.0	5.0	4.6
ATL	58	3.7	5.5	4.6

3. Summary

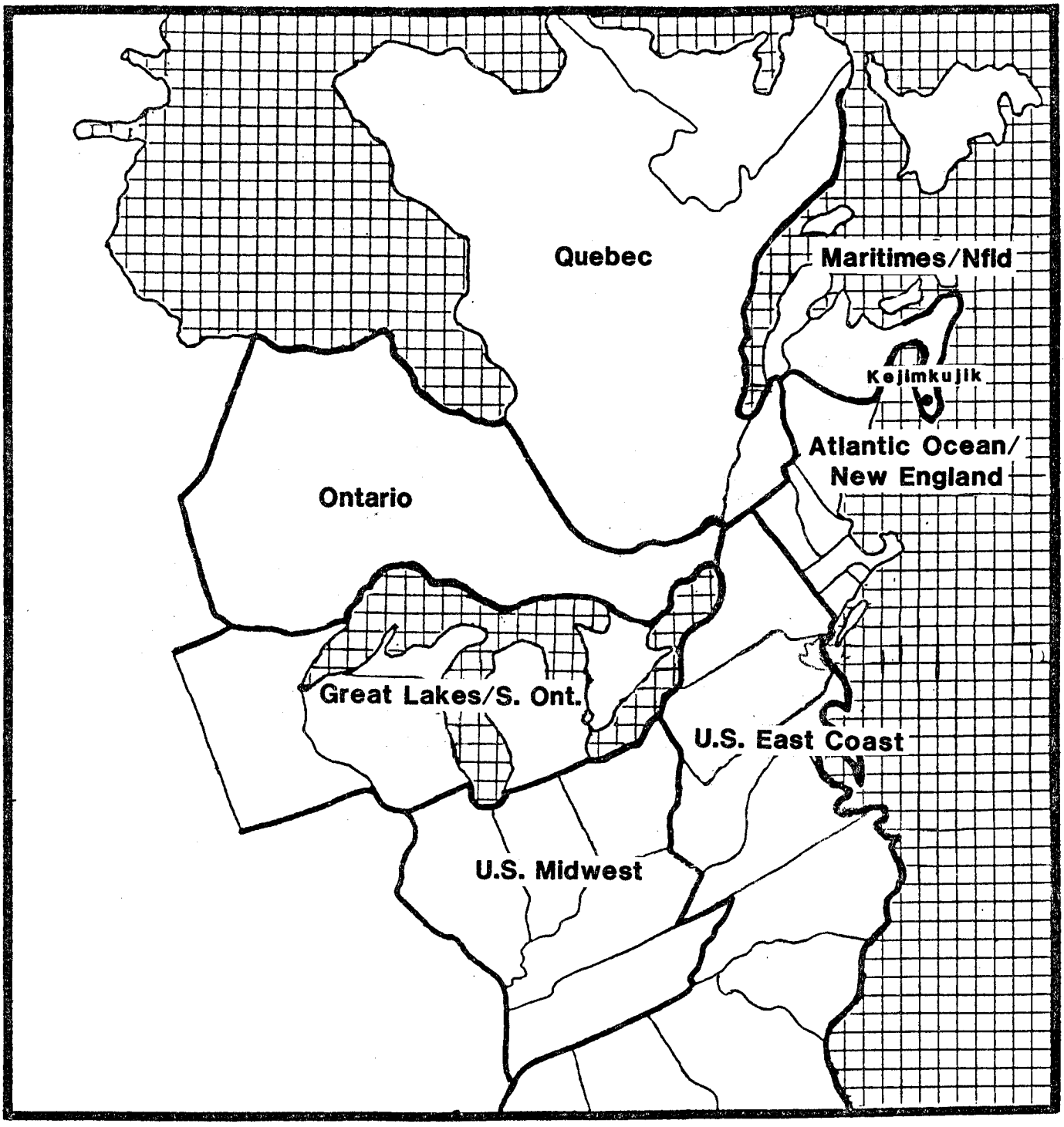
The average precipitation - weighted pH for 1985 at Kejimkujik National Park in southwestern Nova Scotia was 4.4, with the lowest four-month average in January - April and the highest in September - December. The most acidic events of the year, with a pH of 3.5, were one hundred times more acidic than the least acidic events (pH of 5.5). The largest proportion of seriously acidic precipitation events (pH <= 4.0) during the year had acquired acidifying pollutants from the U.S. East Coast, U.S. Midwest, or the Great Lakes States and Southern Ontario regions. That is, the main source of acidifying pollutants acquired by the air mass that had resulted in precipitation of pH 4.0 or less at Kejimkujik was one of these three regions. In contrast, the largest percentage of precipitation with a pH greater than 4.7 had as its main source region the Atlantic Ocean, Quebec and Labrador or the Maritimes.


pH of Precipitation at Kejimkujik, N.S.
January - April 1985
o Rain
x Snow
+ Mixed
Normal Precipitation
Damaging pH Level
Seriously Acidic
pH Value
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
JAN
FEB
MAR
APR
Day of the Year


pH of Precipitation at Kejimkujik, N.S.
May - August 1985
o Rain
x Snow
+ Mixed
Normal Precipitation
Damaging pH Level
Seriously Acidic
pH Value
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
MAY
JUN
JUL
AUG
Day of the Year


pH of Precipitation at Kejimkujik, N.S.
September - December 1985
o Rain
x Snow
+ Mixed
Normal Precipitation
Damaging pH Level
Seriously Acidic
pH Value
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
SEP
OCT
NOV
DEC
Day of the Year

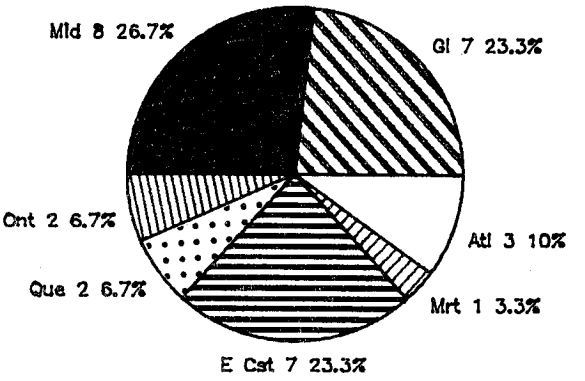
Map Showing Seven Source Regions of Precipitation at Kejimkujik, N.S.



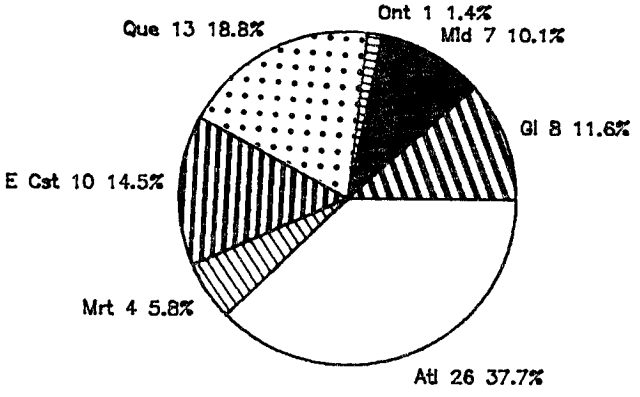
Frequency of Occurrence of Main Source Regions of Precipitation pH at Kejimkujik, N.S. for 1985

LEGEND

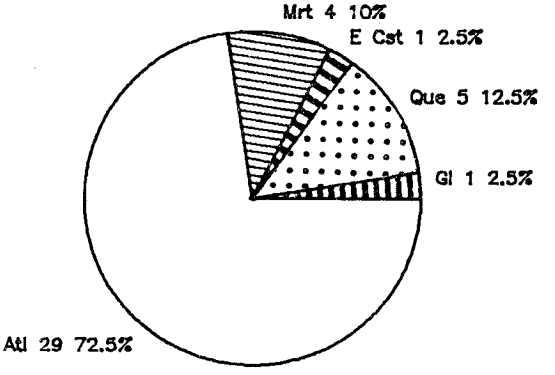
GL: Great Lake States/Southern Ontario
Mid: U.S. Midwest
Ont: North/Central Ontario
Que: Quebec/Labrador
E Cst: U.S. East Coast
Mrt: Maritimes/Newfoundland
Atl: Atlantic Ocean/New England



pH <= 4.0



4.0 < pH <= 4.7

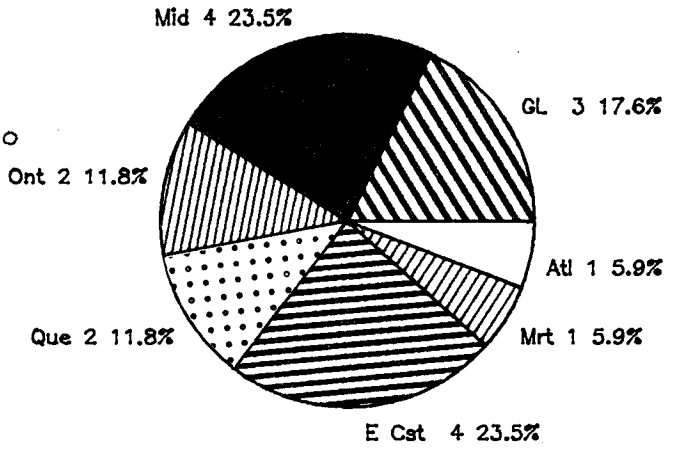


pH > 4.7

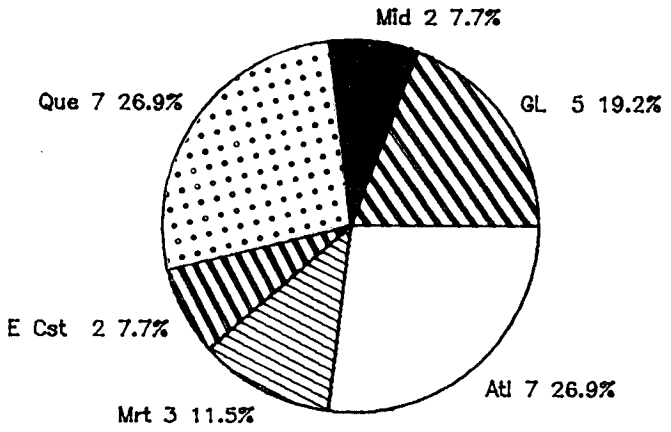
Frequency of Occurrence of Main Source Regions of Precipitation pH at Kejimkujik, N.S. January - April 1985

LEGEND

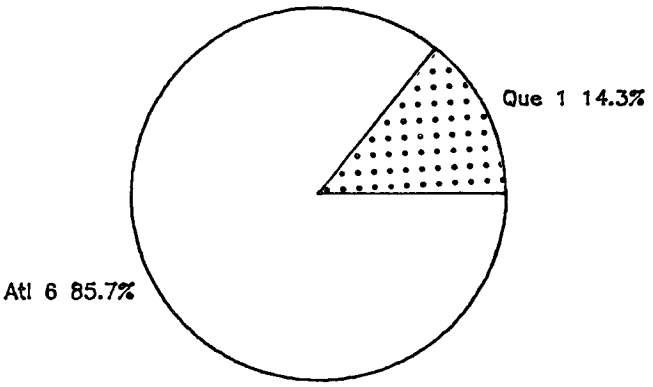
GL: Great Lake States/Southern Ontario
Mid: U.S. Midwest
Ont: North/Central Ontario
Que: Quebec/Labrador
E Cst: U.S. East Coast
Mrt: Maritimes/Newfoundland
Atl: Atlantic Ocean/New England



pH <= 4.0



4.0 < pH <= 4.7

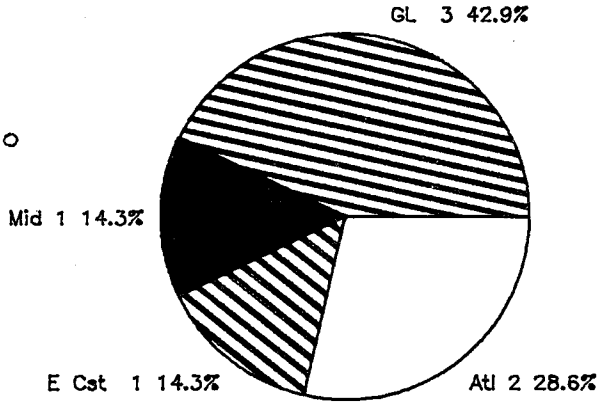


pH > 4.7

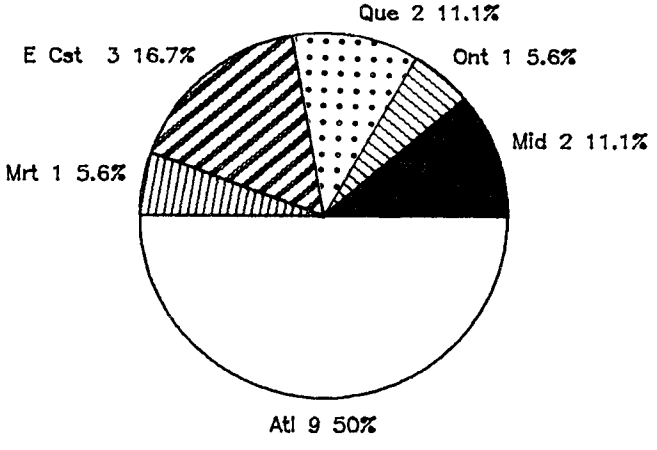
Frequency of Occurrence of Main Source Regions of Precipitation pH at Kejimkujik, N.S. May - August 1985

LEGEND

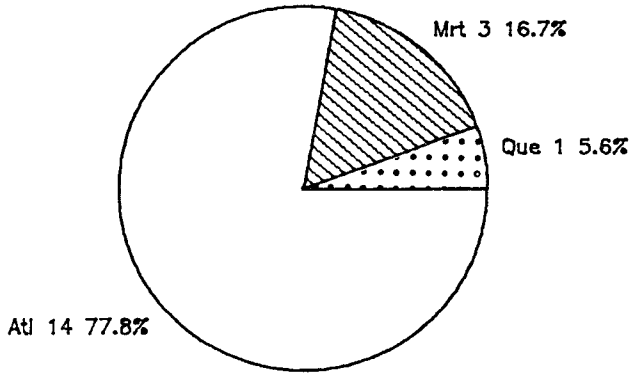
GL: Great Lake States/Southern Ontario
Mid: U.S. Midwest
Ont: North/Central Ontario
Que: Quebec/Labrador
E Cst: U.S. East Coast
Mrt: Maritimes/Newfoundland
Atl: Atlantic Ocean/New England



pH <= 4.0



4.0 < pH <= 4.7

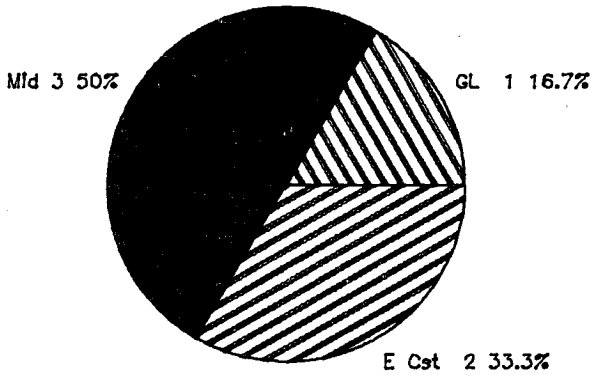


pH > 4.7

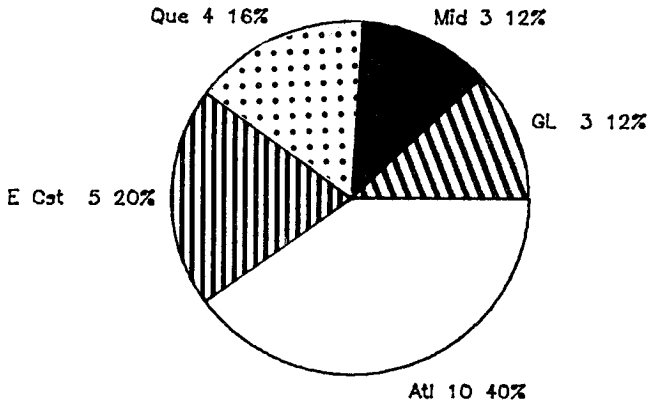
Frequency of Occurrence of Main Source Regions of Precipitation pH at Kejimkujik, N.S. September - December 1985

LEGEND

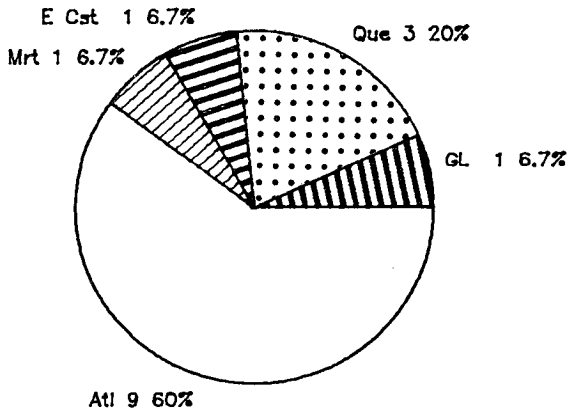
GL: Great Lake States/Southern Ontario
Mid: U.S. Midwest
Ont: North/Central Ontario
Que: Quebec/Labrador
E Cst: U.S. East Coast
Mrt: Maritimes/Newfoundland
Atl: Atlantic Ocean/New England



pH <= 4.0



4.0 < pH <= 4.7



pH > 4.7

Average pH of Precipitation Received at Kejimkujik N.S. from Seven Main Source Regions by Four-Month Periods During 1985

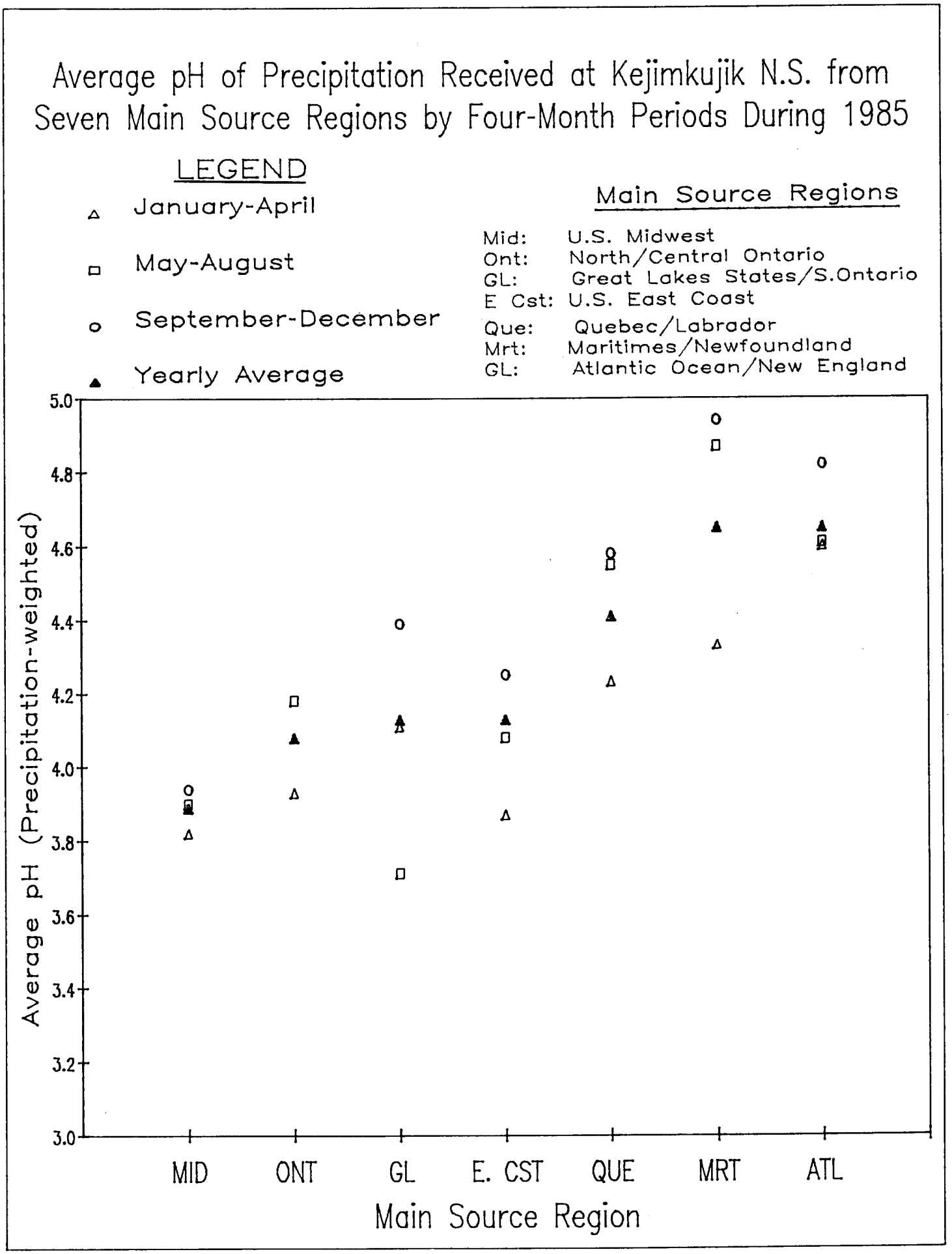


Figure 10

Number of Occurrences of Precipitation pH Received at Kejimkujik, N.S. from Seven Main Source Regions During 1985

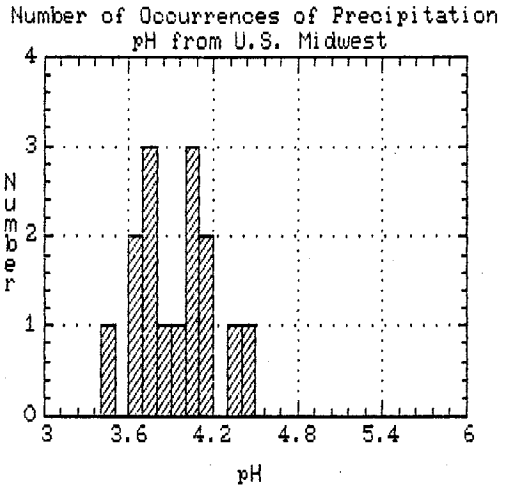


Figure 10a

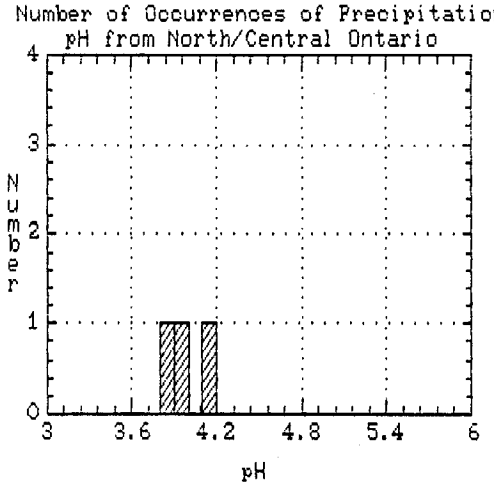


Figure 10b

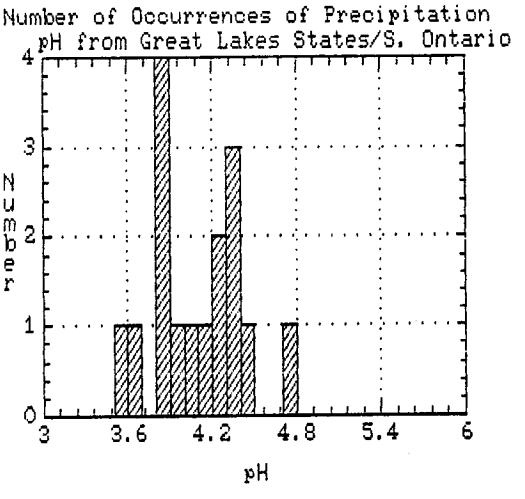


Figure 10c

Number of Occurrences of Precipitation pH Received at Kejimkujik, N.S. from Seven Main Source Regions During 1985

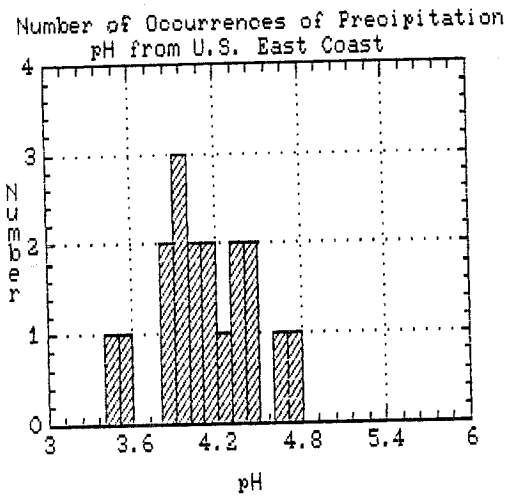


Figure 10d

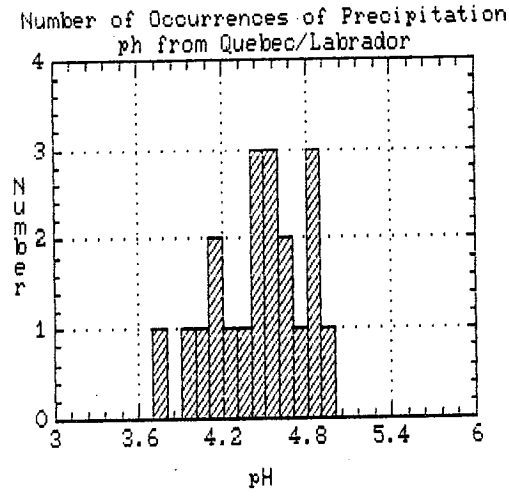


Figure 10e

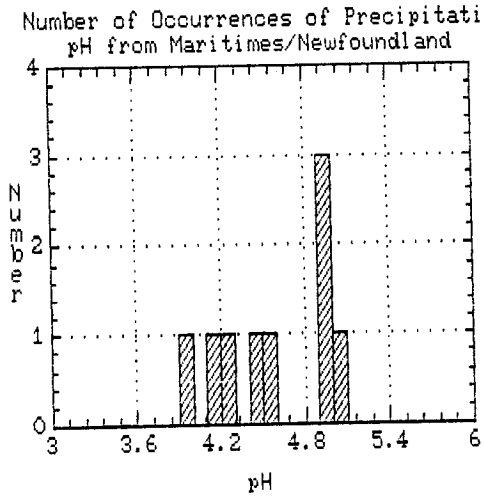


Figure 10f

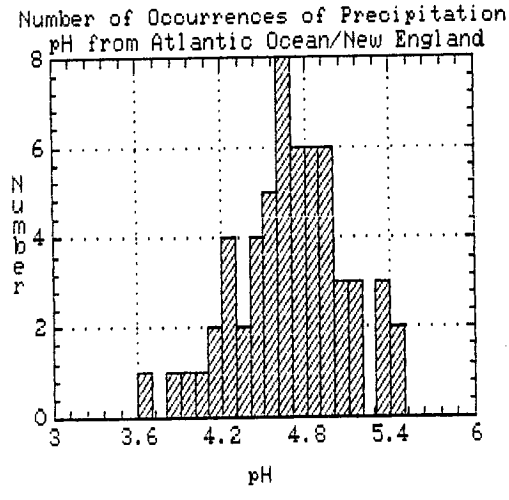


Figure 10g

Environment Canada - Environnement Canada

Acid rain and snow at Kejimkujik, N.S. during 1985
WEBBER, M. A

QC 985.5.M4 M34 86-5 1601585F
NSHW