Chemical Characteristics of Selected Rivers in Nova Scotia During 1982

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March, 1988

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1961

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Canadian Manuscript Report of
Fisheries and Aquatic Sciences No. 1961

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CHEMICAL CHARACTERISTICS OF SELECTED RIVERS IN NOVA SCOTIA DURING 1982.

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Cat. No. Fs 97-4/1961 ISSN 0706-6473

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ABSTRACT

Farmer, G.J., D.K. MacPhail and D. Ashfield. 1988. Chemical characteristics of selected rivers in Nova Scotia during 1982. Can. MS Rep. Fish. Aquat. Sci. No. 1961. ix + 44 p.

On two occasions during 1982, chemical characteristics of the larger tributaries to 15 rivers which drain to the Atlantic coast of mainland Nova Scotia were measured. On one occasion during March of that year, nine smaller rivers along the same coast were sampled to determine their chemical characteristics. The results of the analyses were examined to: (1) determine the sensitivity of the various river systems to acidic precipitation, (2) facilitate planning of Atlantic salmon enhancement programs and (3) facilitate selection of suitable release sites for hatchery-reared juvenile salmon.

Key words: Atlantic salmon rivers, Nova Scotia, precipitation, water chemistry, salmon enhancement, geology, soils, river discharge.

RÉSUMÉ

Farmer, G.J., D.K. MacPhail and D. Ashfield. 1988. Chemical characteristics of selected rivers in Nova Scotia during 1982. Can. MS Rep. Fish. Aquat. Sci. No. 1961. ix + 44 p.

On a mesuré, à deux reprises en 1982, les paramètres chimiques de gros tributaires de quinze cours d'eau qui s'écoulent vers la côte atlantique de la partie continentale de la Nouvelle-Écosse. Au mois de mars de cette année-là, on a prélevé une fois des échantillons dans neuf petits cours d'eau sur la même côte pour déterminer leurs caractéristiques chimiques. On a examiné les résultats des analyses: pour (1) déterminer la sensibilité de divers réseaux hydrographiques aux précipitations acides, (2) faciliter la planification des programmes de mise en valeur du saumon de l'Atlantique et (3) faciliter le choix d'emplacements appropriés pour la remise à l'eau de jeunes saumons élevés en piscifacture.

Mots-clés: cours d'eau à saumon de l'Atlantique, Nouvelle-Écosse, précipitations, chimie de l'eau, mise en valeur du saumon, géologie, sols, débit des cours d'eau.

INTRODUCTION

A number of Atlantic coast rivers in mainland Nova Scotia have become more acidic during at least the past 30 years in response to increased acid loading by precipitation (Watt et al. 1983). Concomitant with this increase in acidity has been a decline in bicarbonate and increases in aluminum and sulfate concentrations. The most seriously acidified rivers are those found in areas where the bedrock consists of granite and/or greywacke, and the native populations of Atlantic salmon once found in some of these rivers have become extinct. Rivers which lie on slate have higher pH values and the highest values are found for rivers which drain areas of Carboniferous sediments.

Watt et al. (1983) demonstrated that the pHs of these rivers were inversely correlated with their discharge rates. Thus, river pH is maximum during the late-summer when discharge is lowest, and minimum during the winter when discharge is relatively great. Studies of Nova Scotia rivers (Farmer et al. 1980 and Watt et al. 1983) contain results of chemical analyses of water samples collected from each river, usually at one or two sites situated just above the head of tide. Although this is indicative of the chemical characteristics of a river's entire discharge, it does not provide information on the characteristics of its various tributaries.

Hatchery-reared juveniles are currently released in a number of Atlantic coast rivers of mainland Nova Scotia to enhance existing salmon stocks, while other rivers in this area are potential sites for stock-enhancement effort. For this reason, it was necessary to collect information on the chemical characteristics of the major tributaries to these river systems to facilitate enhancement planning and to enable the selection of suitable salmon release sites. The chemical characteristics of the various river systems were related to their associated bedrock geology and soil types and to the abundance of native Atlantic salmon as indicated by angling catch and effort information.

MATERIALS AND METHODS

Water samples were collected from 15 river systems during the late-winter to early-spring period of 1982 and again during the following summer to early-fall period. (Fig. 1) Since pH is inversely correlated with rate of discharge (Watt et al. 1983), selection of the two sampling periods was made to gain insight into the range of pH which occurs in the rivers. In addition, nine smaller rivers which once supported salmon populations (Smith 1981), but for which recent chemical analyses were not available, were also included in the sampling program (Fig. 1). Samples were collected during March of 1982 at a site located just above the head of tide of each river.

Water samples were collected in 500-mL polyethylene containers which had first been washed and then rinsed with deionized water. Within 24 hours of sampling, the pH at all sites was determined with a Metrohm Herisau pH meter. Techniques outlined by Environment Canada (1981) were used to measure total hardness, total alkalinity, chloride and sulfate levels. Total hardness was determined by EDTA titration to Eriochrome Black T colour change; total alkalinity[1], by potentiometric titration with H_2SO_4 to pH end points of 4.5 and 4.2; chloride, by the automated thiocyanate method; and sulfate, by titration with barium chloride and use of thorin indicator. Specific conductance was determined at 25°C with a Metrohm Herisau conductivity meter and apparent colour was measured with a Helige Aqua Tester. Samples taken for the analysis of calcium, magnesium and aluminum were collected in 250-mL polyethylene containers which had first been washed in a 50% HNO_3 solution and then rinsed with deionized water. These samples were preserved by adding one mL of 50% HNO_3 solution. Concentrations of calcium and magnesium were determined by emission spectrophotometer (Jarrel-Ash, AtomComp) and concentrations of aluminum by a Perkin-Elmer atomic absorption spectrophotometer (Anon 1973).

Watt et al. (1983) demonstrated that the chemical characteristics of rivers in Nova Scotia are related to their bedrock geology and that seasonal pH variation is correlated with rate of river discharge. Thus, we have attempted to relate the results of our chemical analyses to the geology of the various drainage areas, to the soil types in these areas and to river discharge rates at the time of sampling. When a gauging station was not present on a particular river, an estimate of its relative rate of discharge on a sampling date was made by examining the discharge of nearby rivers on the same date. Finally, by examining trends in angling catch and effort which have occurred since 1951 (Smith 1981), an attempt was made to relate the chemical characteristics of each river system to the abundance of Atlantic salmon in that river.

1. Not accurate for concentrations <0.05 mg/L. Alkalinity would have been detected for samples which had a pH as low as about 5.2 if titrations had been continued to pH 3.5 and a Gran function analysis performed. Below pH 5.1, "negative" alkalinities are usually obtained.

List of rivers

1. Salmon
2. Carleton
3. Tusket
4. Clyde
5. Mersey*
6. Medway
7. Petite Rivière
8. LaHave
9. Mushamush
10. Martins Brook
11. Gold
12. Ingram*
13. Little Salmon
14. Salmon (Lawrencetown Lake)
15. Chezzetcook
16. Musquodoboit
17. Ship Harbour*
18. Taylor Bay Brook
19. West River Sheet Harbour
20. East River Sheet Harbour
21. Quoddy*
22. Moser
23. Necum Teuch (Smith Brook)
24. Liscomb
25. Gegogan Brook
26. St. Mary's
27. Sherbrooke Lake Outflow*
28. Indian Harbour Lakes
29. Indian River

* Water samples not collected.

FIG. 1. Location of rivers included in the sampling program.

RESULTS AND DISCUSSION

SALMON RIVER

The Salmon River drains a 284-km^2 area of Digby and Yarmouth counties and flows in a southwesterly direction to meet the Gulf of Maine at the community of Salmon River. A yearly average of 40 Atlantic salmon were angled in this river during the 1951-59 period, from a mean annual effort of about 1,615 rod days (Smith 1981). From that time, both catch and effort appear to have declined and only one salmon was reported to have been angled during the 1975-79 period. It is not known whether this decline in catch and effort reflects a decrease in the surveillance and reporting by fisheries officers or if there was an actual decrease in the salmon population. During the 1980-82 period, an average of 56 salmon were angled per year from an average annual effort of 1,227 rod days. This increase coincides with the beginning of salmon culture at the Yarmouth Hatchery located at the head of the Indian River tributary.

Water samples were first collected from eight sites (Fig. 2) on the Salmon River during April 29, 1982 when discharge of the nearby Tusket River (at Wilsons Bridge) was 71.3 m^3/s (Environment Canada 1983). That discharge was greater than the April mean of 51.6 m^3/s observed at that site (Environment Canada 1980). Assuming discharge of the Salmon River was also relatively great on April 29, pH of that river may have shown only a small increase from the minimal values which, for most Nova Scotia rivers, occur during the mid-winter period (Watt et al. 1983). The pH at Site A1, located just above the head of tide, was 4.87 on April 29 (Table 1). Water at that location was very soft, as indicated by the value of 6.9 mg/L recorded for total hardness. The pH below Salmon River Lake (A7), near the headwaters of the system, was slightly greater (5.10) on that date than observed near the head of tide. This may be attributed to some acid-neutralizing capacity provided by water from Clearwater Lake. The pH values of Dean Brook (A6), Blackwater Brook (A5) and Felix Mill Brook (A2) ranged from 4.67 to 4.88 on this date. The highest pH values on the Salmon River system were recorded at Site A4, located below George Lake (pH 5.36), and at Site A3 on the Indian River (pH 5.40). Despite the higher values of pH, alkalinity was <0.5 mg/L.

Water samples were again collected at all eight sites on July 27, 1982, when discharge at Wilsons Bridge on the nearby Tusket River was 7.3 m^3/s. That discharge was considerably lower than the July mean of 16.1 m^3/s at that site during the 1930-78 period (Environment Canada 1980, 1983). Under such July conditions, river pH can be expected to approach the maximum (Watt et al. 1983). However, pH at Site A1 had increased to only 5.10 on this date and alkalinity was <0.5 mg/L. Colour measured 120 relative units and was indicative of the substantial inputs of humic materials to the system. The aluminum concentration of 440 µg/L was relatively high (Baker 1982) and probably reflects leaching of this metal from the drainage area. However, most aluminum is probably bound to organic ligands and therefore not toxic to fish. The pH at Site A7, located below Salmon River Lake, was only 5.23 and alkalinity <0.5 mg/L. The pH's of most tributary brooks (Felix Mill, Blackwater, Dean and Swallow Lake brooks) ranged from 4.72 - 4.88 on this date and their colours from 75 to 260 relative units. In contrast, pH's of samples collected at the two sites on the Indian River tributary were 5.55 (A3) and 5.86 (A4) and alkalinity was detected at both locations. Colour at these sites measured <30 relative units and was considerably less than observed for other sites on the Salmon River system.

The chemical data indicate that most tributaries of the Salmon River may be unsuitable for natural reproduction of Atlantic salmon because pH values are < 5.0. Although natural recruitment of Atlantic salmon still occurs in the main section of the river, alkalinity was <0.5 mg/L on both dates and pH values were within the 4.87-5.23 range. This suggests that some mortality may be occurring in the river among newly feeding fry (Farmer et al. 1980). The data also indicate that the Indian River tributary is the most suitable for natural reproduction of salmon and that fry mortality attributable to acidity is not occurring in that stream.

Most of the Salmon River lies on the Goldenville Formation which consist of greywacke. Smaller bands of slate are also found within the drainage (Keppie 1979). Because greywacke is relatively resistant to chemical weathering, it provides little acid-neutralizing capacity to the river. In addition, the soils associated with the Goldenville Formation in this area are thin, stoney, poorly suited to agriculture (Hilchey et al. 1960, 1962) and not effective in reducing acid inputs to the river. The Indian River tributary originates at Lake George, which lies on the Halifax and Whiterock formations. The former is composed of slate, silt and some limestone. These materials weather to a greater extent than does greywacke and can provide some acid-neutralizing capacity. The Whiterock Formation is composed of rhyolite, mafic and felsic tuff and basalt. The latter material is a basic igneous rock which contains high concentrations of calcium and magnesium. Soils of the Yarmouth, Deerfield and Bridgewater series, which are judged to be from fair to good for crops, are found in the area of Lake George (Hilchey et al. 1960) and probably provide some alkalinity to the Indian River.

Table 1. Some chemical characteristics of the Salmon River system during April and July of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (µS/cm)	Apparent colour (relative units)	Ca	Mg	Cl	SO_4	Al[1] (µg/L)
							(mg/L)				
April 29											
A1	Above head of tide	4.87	<0.5	6.9	56	75	1.3	1.0	10.8	4.2	
A2	Felix Mill Brook	4.88	<0.5	7.5	56	60					
A3	Indian River	5.40	<0.5	7.4	56	25					
A4	Below Lake George	5.36	<0.5	6.5	53	20					
A5	Blackwater Brook	4.67	<0.5	6.7	56	75					
A6	Dean Brook	4.74	<0.5	6.1	48	70					
A7	Below Salmon River Lake	5.10	<0.5	6.1	47	55					
A8	Swallow Lake Brook	4.57	<0.5	5.6	50	75					
July 27											
A1	Above head of tide	5.10	<0.5	7.8	54	120			11.0	4.8	440
A2	Felix Mill Brook	4.72	<0.5	6.9	54	75					
A3	Indian River	5.55	0.7	7.0	55	30					
A4	Below Lake George	5.86	1.1	6.5	51	15					
A5	Blackwater Brook	4.83	<0.5	6.4	61	260					
A6	Dean Brook	4.88	<0.5	6.8	52	220					
A7	Below Salmon River Lake	5.23	<0.5	6.0	45	40					
A8	Swallow Lake Brook	4.80	<0.5	6.9	48	140					

1. The water sample for aluminum determination was collected on August 15, 1983.

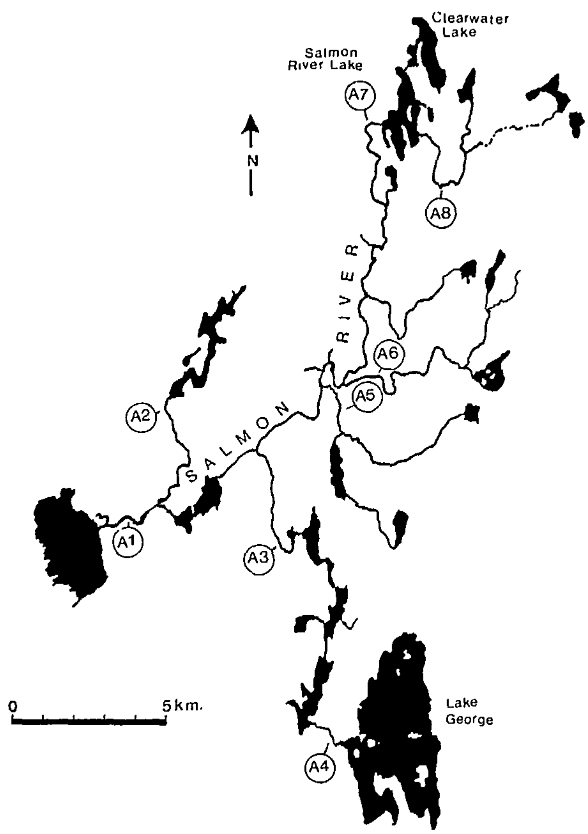

Fig. 2. Water sampling sites on Salmon River

CARLETON RIVER

The Carleton River originates in Digby County and flows in a southerly direction before it enters Yarmouth County and joins with the Tusket River near its entry to the Gulf of Maine (Fig. 3). Glaciation interrupted the Carleton River which is now characterized by chains of lakes along the former river valley (Roland 1982). The river continues to support a small population of native Atlantic salmon whose favoured spawning habitat is located within the area extending from the bottom of Wentworth Lake to the Digby-Yarmouth County line (Smith 1960). Salmon catch statistics are available for the Tusket River system and include fish caught in the Carleton River. The mean annual catch of 91 salmon in these rivers during the 1936-59 period declined to 24 during the 1960-79 period (Smith 1981). The decline was probably attributable to the loss of natural recruitment in the Tusket River because of acidification (Farmer et al. 1980; Watt et al. 1983) and the salmon angled during the latter period probably originated in the Carleton River tributary. The mean angling catch on the Tusket system has recently (1980-82) increased to 126 salmon per year. The increased catch was partly a result of the release of juvenile Atlantic salmon produced at the Yarmouth Hatchery.

Water samples were first collected at the Carleton River sites on February 25, 1982, when discharge at Wilsons Bridge on the Tusket River was 25.2 m^3/s (Environment Canada 1983). That discharge was lower than the mean of 41.9 m^3/s recorded at that site during February of the 1930-79 period (Environment Canada 1980). Samples collected at Richfield (B7) showed that pH was only 4.75 (Table 2). Water at that site can be further characterized as very soft, judging from the low concentrations of calcium (1.3 mg/L) and magnesium (0.9 mg/L). The samples were moderately coloured (65 relative units). Water chemistry at the other sites located below Wentworth Lake (B1,B2,B4,B6,B8) was markedly similar. In contrast, pHs of samples collected at three sites (B14,B15,B16) on Wentworth River, which discharges into Wentworth Lake, ranged from 5.23 to 5.38, and alkalinity was detectable at two of the locations. The most acidic tributary of the Carleton River was Seven Pence Halfpenny Brook (B13), which had a pH of 4.22. The pH of 4.65 measured for Sullivans Brook (B10) was greater than that of Seven Pence Halfpenny Brook despite their close proximity.

Water samples were again collected at the various Carleton River sites on July 8, 1982, when discharge at Wilsons Bridge was 23.2 m^3/s (Environment Canada 1983). Mean discharge for that month was 16.1 m^3/s during the 1930-78 period (Environment Canada 1980). The pH values at most Carleton River sites on this date were greater than had been measured the previous February. For example, the pH at Richfield (B7) was 5.48 and alkalinity was detectable. The aluminum concentration of 400 µg/L was relatively great (Baker 1982) suggesting that this metal has been leached from the river's drainage area. Values of pH at other sites on the Carleton River located below Richfield (B1,B2,B4) were similar and ranged from 5.56 to 5.81. As observed during February, values of pH and alkalinity were greater at sites on the Wentworth River (B14,B15,B16) than at other sites on the Carleton system. For example, pH at the Wentworth River sites ranged from 5.67 to 5.89 and alkalinity from 1.6 to 2.1 mg/L. The lowest pH values (4.31,4.27) were again observed at two sites on Seven Pence Halfpenny Brook (B12,B13). Total hardness at those locations was only 4.9 and 3.0 mg/L and apparent colour measured 220 and 150 relative units. The substantial input of humates to this brook apparently acts to lower pH below that of precipitation. The pH at Site B9 located on the lower section of Seven Pence Halfpenny Brook was greater (4.68) than at sites B12 and B13 because that section receives the discharge of Sullivans Brook (Site B10; pH 5.38).

The headwaters of the Carleton system lie on the Halifax Formation which is primarily comprised of slate (Keppie 1979). Soils of the Bridgewater Series found in this area are considered to be from good to fair for agriculture (Hilchey et al. 1962). These soils provide some acid-neutralizing capacity to the river and may be responsible for the higher values of pH and alkalinity that were recorded. The headwaters of Seven Pence Halfpenny Brook lie on granitic rock associated with soils judged to be unsuitable for agricultural purposes (Hilchey et al. 1962). This partly accounts for the chemical characteristics of the brook which is more acidic than precipitation in this area of the province. Soils of the Bridgewater Series, found in the area of Sullivans Brook, appear to be responsible for its slightly higher pH. The area of the Carleton River from Parr Lake to Lake Vaughan (Fig. 3) lies on the Goldenville Formation comprised of greywacke. This type of bedrock and the soils associated with it (Hilchey et al. 1960) provide little acid-neutralizing capacity to the river. Accordingly, chemistry of water in this portion of the river is similar to that observed at the outflow of Wentworth Lake, which receives the discharge of both the Wentworth River and Seven Pence Halfpenny Brook.

Our chemical analyses indicate that Seven Pence Halfpenny Brook is unsuitable for the natural reproduction of Atlantic salmon and that the area of the Carleton River located below Wentworth Lake is extremely sensitive to further inputs of acidic precipitaiton. The acidic flow of Seven Pence Halfpenny Brook lowers the pH of Wentworth Lake and hence the area of the Carleton River below this lake. Electrofishing surveys conducted by us during the summer of 1982 in this area demonstrated the presence of naturally produced underyearling Atlantic salmon.

Table 2. Some chemical characteristics of the Carleton River system during February and July of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)	Ca	Mg	Cl	SO_4	Al[1] (μg/L)
							(mg/L)				
February 25											
B1	Below Reynards Lake	5.04	<0.5	6.6	46	65					
B2	Below Lake Fanning	4.92	<0.5	6.9	48	65					
B4	Below Parr Lake	4.75	<0.5	6.9	50	60					
B6	Below Briar Lakes	4.65	<0.5	6.3	50	70					
B7	At Richfield	4.75	<0.5	7.0	52	65	1.3	0.9	11.3	3.7	
B8	Below Wentworth Lake	4.70	<0.5	6.9	52	60					
B10	Below Sullivans Lake	4.65	<0.5	6.7	49	65					
B13	Seven Pence Halfpenny Brook	4.22	<0.5	4.0	54	75	0.7	0.6		3.5	
B14	Above Wentworth Lake	5.23	<0.5	8.7	55	60					
B15	Below Porcupine Lake	5.38	0.6	7.5	52	60					
B16	At Havelock	5.35	0.5	9.0	54	60					
July 8											
B1	Below Reynards Lake	5.81	0.9	6.0	43	25					
B2	Below Lake Fanning	5.68	0.5	6.2	42	30					
B4	Below Parr Lake	5.56	0.6	6.0	41	60					
B5	Salmon Lake Brook	5.70	1.3	5.0	38	20					
B6	Below Briar Lakes	5.13	<0.5	6.3	43	75					
B7	At Richfield	5.48	0.6	5.5	40	75			8.8	4.1	400
B8	Below Wentworth Lake	5.41	<0.5	6.3	41	75					
B9	Seven Pence Halfpenny Brook	4.68	<0.5	5.0	40	220					
B10	Below Sullivans Lake	5.38	<0.5	6.0	38	75					
B11	Bear Lake Brook	5.28	<0.5	4.5	37	40					
B12	Seven Pence Halfpenny Brook	4.31	<0.5	4.9	42	220					
B13	Seven Pence Halfpenny Brook	4.27	<0.5	3.0	43	150					
B14	Above Wentworth Lake	5.67	1.6	8.4	45	110					
B15	Below Porcupine Lake	5.87	2.0	7.5	46	70					
B16	At Havelock	5.89	2.1	8.4	47	110					

1. The water sample for aluminum determination was collected on August 3, 1983.

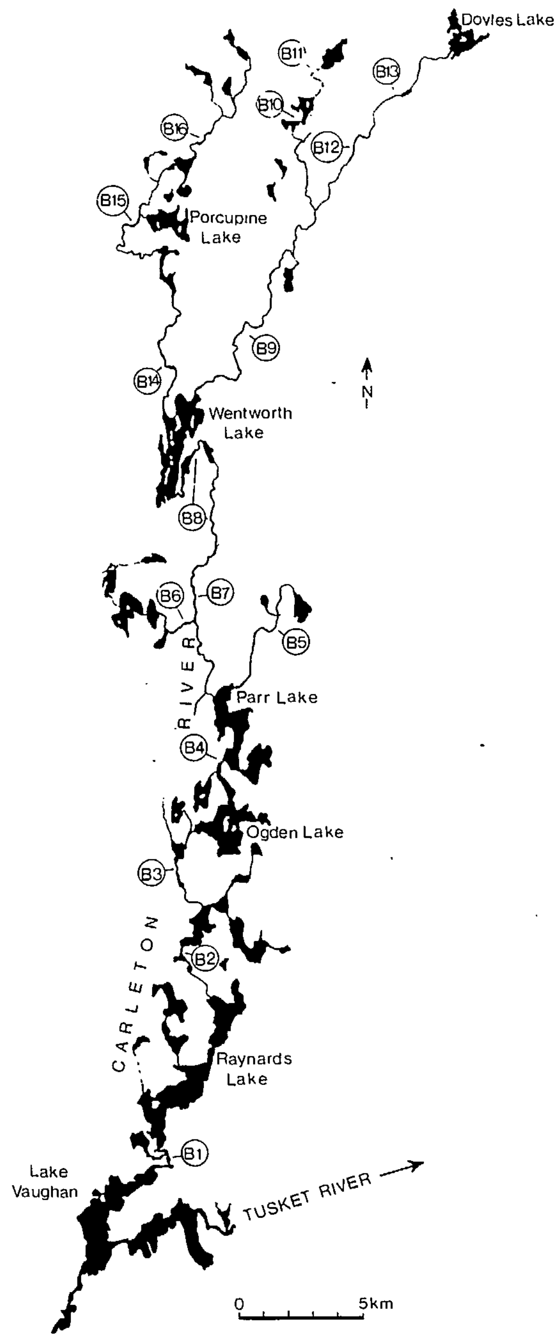

Fig. 3. Water sampling sites on Carleton River

TUSKET RIVER

The Tusket River originates in Digby and Yarmouth counties and flows in a southerly direction before joining the Carleton River near their entry to the Gulf of Maine (Fig. 4). The Tusket River (excluding the Carleton tributary) has a drainage area of 1,072 km^2 and the annual mean discharge at Wilsons Bridge during the 1930-78 period has been 32.6 m^3/s (Environment Canada 1980). Angling catch on the Tusket system (including the Carleton River) averaged about 91 salmon/year during the 1936-60 period but declined to an average of 24 salmon/year during the 1961-79 interval (Smith 1981). The decline in catch was probably attributable to the loss of natural recruitment in the Tusket River because of increased acidity (Watt et al. 1983). The small number of salmon angled during the 1961-79 period probably originated in the Carleton River where water quality remains acceptable for natural reproduction.

Water samples were collected from the Tusket River on April 29, 1982, when discharge at Wilsons Bridge was 71.3 m^3/s which is considerably greater than the mean of 51.6 m^3/s which has been recorded for that month (Environment Canada 1980, 1983). Values of river pH measured during the spring are usually slightly higher than the minimal values which occur during January and February (Watt et al. 1983). The 17 sampling sites on the Tusket River were selected to reflect the water quality of the rivers entire drainage. Included in the survey were the following major tributaries: Quinan River, Mespark Brook, East Branch of the Tusket River, Napier River, Silver River and the Caribou River (Fig. 4).

Water collected from the Tusket River below its confluence with the Quinan River (Site C4) on April 29, 1982, indicated that pH was only 4.58 (Table 3). Water at that location can be further characterized as very soft, judging from the low concentrations of calcium (0.7 mg/L) and magnesium (0.5 mg/L). Of the 17 sites on the Tusket system sampled on April 29, none had detectable alkalinity, and only two small brooks (Somes Lake Brook, Mill Lake Brook) had pH values $\geq$5.0. The pH at the remaining sites ranged from 4.30 to 4.64. For example, the pH of some of the major tributaries were: Quinan River 4.60; Mespark Brook 4.50; East Branch Tusket River 4.43; Napier River 4.45; Silver River 4.40 and Caribou River 4.31. The pH at Tusket Falls (C1) located below the confluence of the Tusket and Carleton rivers, was 4.80 which reflects the higher pH of the Carleton River.

Water samples were again collected from the various sites on the Tusket system on October 27, 1982, when discharge at Wilsons Bridge was 5.55 m^3/s (Environment Canada 1983). In comparison, the mean discharge at that site during October of the 1929-78 period has been 22.6 m^3/s (Environment Canada 1980). Judging from the discharge measured on October 27, 1982, river pH was expected to have been maximal (Watt et al. 1983). However, samples collected below the confluence of the Quinan and Tusket rivers (C4) on that date indicated pH had increased to only 4.95. Total hardness measured 5.0 mg/L at that site and apparent colour 120 relative units. The elevated aluminum concentration of 550 µg/L indicates that this metal is being leached from the drainage area. In comparison, the pH measured at site C4 on August 25, 1954, by Thomas (1960) was 5.7. The difference in pH is not attributable to differences in discharge because the discharge of 17 m^3/s recorded on August 25, 1954, was greater than that measured on October 27, 1982.

The pH values recorded at most other sites on October 27, 1982, ranged from 4.50 to 5.20 and are probably representative of the maximum values which now occur (Table 3. Apparent colour ranged from 75 to 260 units at these locations reflecting the considerable input of humic materials to the system. Exceptions were Somes Lake Brook and Mill Lake Brook where pH values of 5.90 and 6.18 were recorded. Thus, of 17 sites on the Tusket River that were sampled, the water quality of only two small brooks was judged to be acceptable for the natural reproduction of Atlantic salmon. The water chemistry of the remainder of the Tusket system is greatly influenced by the chemistry of precipitation and by inputs of humic materials.

The Tusket River originates in Digby and Yarmouth counties in an area of granitoid rock (Keppie 1979). As the river flows in a southerly direction, it drains an area where the predominant bedrock is greywacke. The Quinan River tributary lies on gneiss, migmatite and greywacke. These types of bedrock are characterized as hard, resistant to chemical weathering and deficient in acid-neutralizing materials. In addition, the associated soils are generally thin, stoney and either poor or unsuitable for agricultural purposes (Hilchey et al. 1960; Hilchey et al. 1962). Neither the soils nor the bedrock in the Tusket River drainage area have provided sufficient acid-neutralizing capacity to prevent the acidification of this river.

Table 3. Some chemical characteristics of the Tusket River system during April and October of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)	Ca	Mg	Cl	SO_4	Al[1] (μg/L)
							(mg/L)				
April 29											
C1	Tusket Falls	4.80	<0.5	5.0	42	55					
C2	Somes Lake Brook	4.99	<0.5	5.1	40	60					
C3	Mill Lake Brook	5.37	<0.5	6.9	44	30					
C4	Below Quinan River	4.58	<0.5	4.0	41	65	0.7	0.5	7.6	3.5	
C5	Quinan River	4.58	<0.5	4.5	42	100					
C6	Quinan River	4.60	<0.5	4.0	41	100					
C7	Mespark Brook	4.50	<0.5	4.2	45	100					
C8	Below Kegeshook Lake	4.64	<0.5	4.0	40	55					
C9	Above Pearl Lake	4.54	<0.5	3.4	38	75					
C10	East Branch Tusket River	4.43	<0.5	2.7	38	100					
C11	Big Meadow Brook	4.37	<0.5	2.5	40	110					
C12	Bear Lakes Brook	4.30	<0.5	2.0	40	100					
C13	Napier River	4.45	<0.5	2.5	37	100					
C14	Whistler Brook	4.52	<0.5	3.0	38	100					
C15	Below Barrios Lake	4.50	<0.5	3.4	39	100					
C16	Silver River	4.40	<0.5	3.3	40	100					
C17	Caribou River	4.31	<0.5	2.4	40	120					
October 27											
C1	Tusket Falls	5.30	<0.5	5.5	40	80					
C2	Somes Lake Brook	5.90	2.3	8.3	45	45					
C3	Mill Lake Brook	6.18	3.2	8.9	51	15					
C4	Below Quinan River	4.95	<0.5	5.0	38	120			7.0	3.5	550
C5	Quinan River	5.02	<0.5	5.0	41	100					
C6	Quinan River	5.00	<0.5	4.5	40	100					
C7	Mespark Brook	5.06	<0.5	5.4	45	75					
C8	Below Kegeshook Lake	5.05	<0.5	4.4	35	110					
C9	Above Pearl Lake	4.90	<0.5	5.2	38	220					
C10	East Branch Tusket River	4.80	<0.5	3.6	37	220					
C11	Big Meadow Brook	4.69	<0.5	3.7	41	200					
C12	Bear Lakes Brook	4.50	<0.5	2.1	36	150					
C13	Napier River	4.60	<0.5	3.1	40	220					
C14	Whistler Brook	4.72	<0.5	5.1	45	260					
C16	Silver River	4.88	<0.5	5.0	39	110					
C17	Caribou River	4.56	<0.5	3.6	43	220					

1. The water sample for aluminum determination was collected on August 2, 1983.

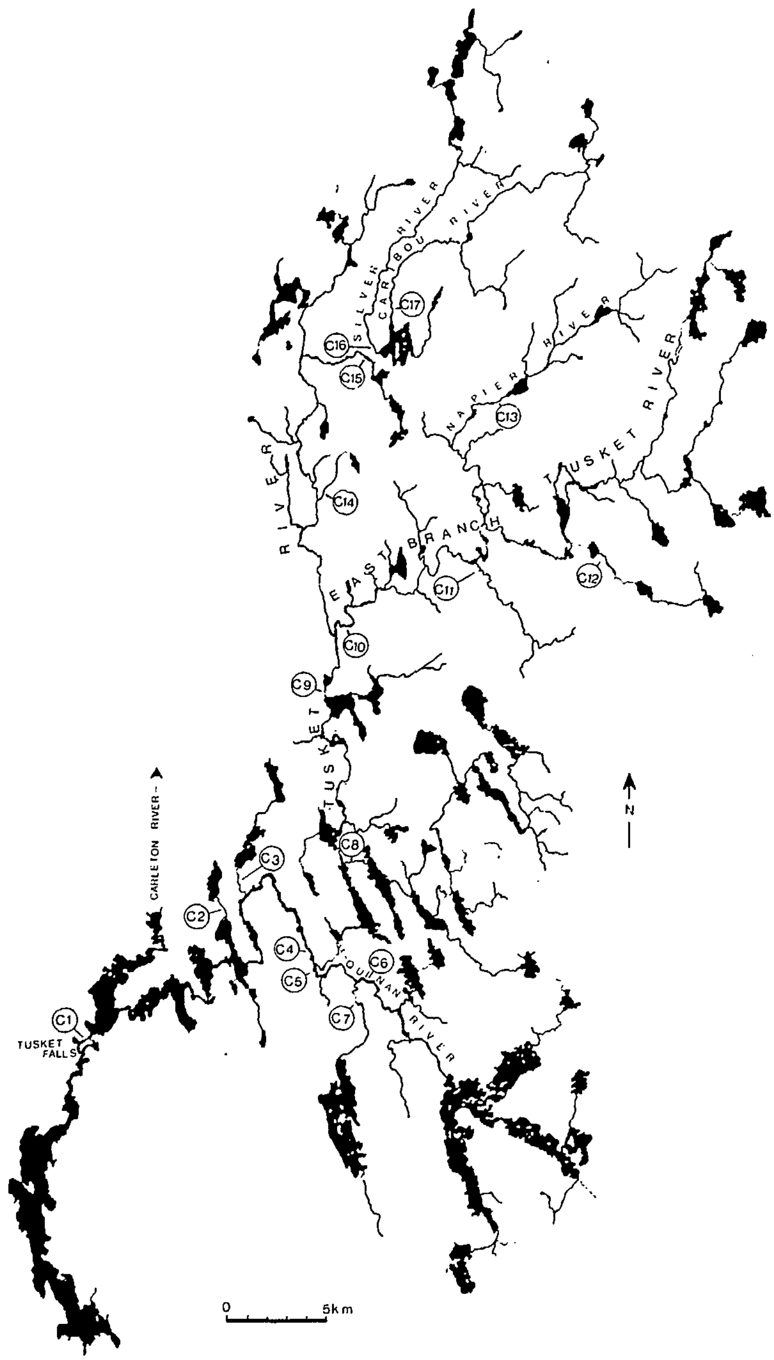

Fig. 4. Water sampling sites on Tusket River

CLYDE RIVER

The Clyde River originates in Yarmouth County and flows in a southerly direction through Shelburne County to meet the Atlantic Ocean at Negro Harbour (Fig. 5). The river has a drainage area of 774 km^2 and an annual mean discharge of about 24.3 m^3/s (Anon. 1969). Numbers of Atlantic salmon angled in the Clyde River showed a marked decline during the 1936-70 period (Farmer et al. 1980). Catch for successive five-year intervals remained relatively constant from 1936 to 1955 and then decreased until no salmon were angled after 1969. Partial recruitment failure, attributable to increased acidity of the river, appears to have occurred during the 1951-55 period. In this regard, Thomas (1960) found that the pH of the river was 5.0 during August of 1954. Angling catch during the 1936-55 period averaged 37 salmon/year (Smith 1981). Although records of effort have been collected only since 1951, this variable averaged 1,078 rod days/year during the 1951-54 period when salmon were captured in appreciable numbers.

Water samples were collected from the Clyde River on March 15, 1982, when discharge at Lower Ohio on the nearby Roseway River was 34.3 m^3/s. That discharge was greater than the March mean of 24.1 m^3/s (Environment Canada 1980, 1983). Judging from the sampling date and assuming that the rate of discharge on the Clyde River was also high, pH of the water samples collected on March 15 were expected to be minimal (Watt et al. 1983). Thus, pH at Site D1, located just above the head of tide, was 4.30 (Table 4). Concentrations of calcium and magnesium both measured 0.5 mg/L at the site, indicating that the bedrock in the drainage area is resistant to chemical weathering. Apparent colour was 60 relative units. The chemical characteristics of some of the larger tributaries of the Clyde River (Bloody Creek; Hamilton Branch; Hemlock Creek; Davis River) were markedly similar to those measured at site D1. For example, the pH of these tributaries ranged from 4.21 to 4.43 and their total hardness from 1.5 to 3.5 mg/L.

Water samples were again collected from the various sites on the Clyde River on August 3, 1982, when discharge of the nearby Roseway River at Lower Ohio was 7.03 m^3/s (Environment Canada 1983). The low rate of discharge on that day is similar to the mean of 5.62 m^3/s recorded at that site during August of the 1916-79 period (Environment Canada 1980). Assuming discharge of the Clyde River was also relatively low on that day, values of pH were expected to be maximal (Watt et al. 1983). However, pH, just above the head of tide (D1), was only 4.35. Colour had increased to 240 relative units at that site and the aluminum concentration was 410 µg/L. The pH values measured at sites D2 to D7 ranged from 4.12 to 4.45. Apparent colour at these locations ranged from 130 to 440 relative units, indicative of substantial inputs of humic materials.

The data indicate the pH of the Clyde River is lower than that of the precipitaton in southwest Nova Scotia. Judging from the measurements of pH, none of the areas in the Clyde River drainage appear to be suitable for the natural recruitment of Atlantic salmon. Electrofishing surveys conducted by us and by Watt et al. (1983) in the Clyde River during the 1979-82 period have failed to detect any juvenile Atlantic salmon although brook trout (Salvelinus fontinalis) were reported by local residents to be present. Judging from these surveys and from the chemistry of water collected from the Clyde River, Watt et al. (1983) presumed that the run of native salmon to the river was extinct.

Bedrock in the Clyde River drainage area consists of igneous and hard metamorphic rocks which are associated with surface waters of low pH and alkalinity (Gorham 1957; Watt et al. 1983). These include granitic rocks and metamorphic rocks belonging to the Goldenville Formation (Keppie 1979). In addition, the associated soils are thin, stoney and classified as either poor or unsuitable for agricultural purposes (Hilchey et al. 1960; MacDougall et al. 1961). Neither the soils nor the bedrock in the Clyde River drainage area possess sufficient acid-neutralizing capacity to prevent the acidification of the river which has occurred during at least the past 30 years.

Table 4. Some chemical characteristics of the Clyde River system during March and August of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Al [1] (μg/L)
March 15											
D1	Above head of tide	4.30	<0.5	3.4	46	60	0.5	0.5	8.0	2.3	
D2	Bloody Creek	4.28	<0.5	3.5	51	70					
D3	Hamilton Branch	4.23	<0.5	3.1	46	70					
D4	Salmon Creek	4.33	<0.5	3.5	46	70					
D5	Hemlock Creek	4.21	<0.5	3.0	44	70					
D6	Clyde River at Briar Hill	4.30	<0.5	2.6	43	60					
D8	Davis River at Big Falls	4.43	<0.5	1.5	33	75					
August 3											
D1	Above head of tide	4.35	<0.5	3.0	43	240			6.2	2.0	410
D2	Bloody Creek	4.35	<0.5	3.0	45	240					
D3	Hamilton Branch	4.32	<0.5	2.9	44	240					
D4	Salmon Creek	4.30	<0.5	2.3	46	280					
D5	Hemlock Creek	4.12	<0.5	2.0	52	440					
D6	Clyde River at Briar Hill	4.45	<0.5	2.5	35	130					
D7	Rory Lake, Davis River	4.45	<0.5	2.7	37	150					

1. The water sample for aluminum determination was collected on August 3, 1983.

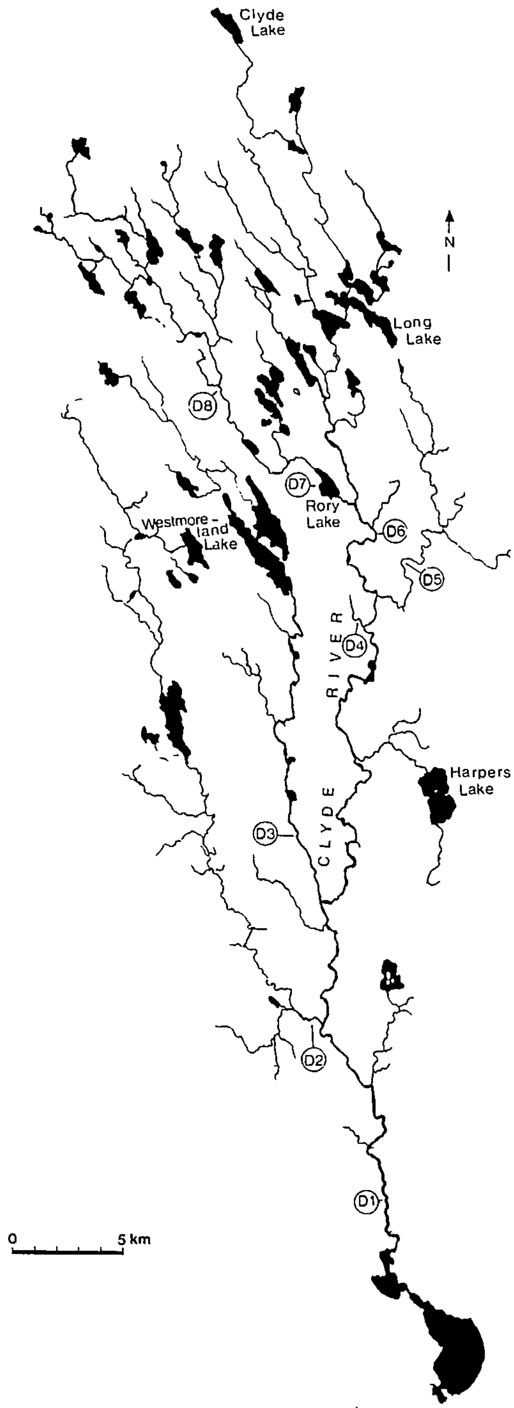

Fig. 5. Water sampling sites on Clyde River

MEDWAY RIVER

The Medway River originates in Annapolis County and drains in a southeasterly direction through Queens County to meet the Atlantic Ocean at Medway Harbour (Fig. 6). The river has a drainage area of 1,390 km^2 and the annual discharge at Charleston, near the head of tide, has averaged 41.6 m^3/s (Environment Canada 1980). The river lies on granitic rock in Annapolis County and on slate and greywacke in Queens County (Keppie 1979). Although some farming occurs on the drumlin soils associated with the areas of slate, the industry of significance in the river's drainage area is forest products. The river continues to support a native population of Atlantic salmon whose numbers are augmented by the release of hatchery-reared parr and smolts. The mean angling catch on the Medway River during the 1951-79 period has been 530 salmon per year and the mean effort, 4,195 rod days per year (Smith 1981).

Water samples were collected on May 26, 1982, from 20 sites on the Medway system. Discharge on that day at Charleston was 23.3 m^3/s which is less than the May mean of 51.0 m^3/s (Environment Canada 1980, 1983). Farmer et al. (1980) indicated that Atlantic salmon are especially sensitive to acidic water during the first month of feeding after completion of yolk-sac absorption. This stage usually occurs during late-May in southwest Nova Scotia when river pH has begun to increase from the minimal values recorded during the winter (Watt et al. 1983).

Samples collected at Charleston (E1) on May 26 indicated that pH was only 5.27 and that alkalinity was <0.5 mg/L (Table 5). The river can be classified as very soft and moderately coloured judging from the measurements of total hardness (4.2 mg/L) and apparent colour (55 relative units). These values of pH, alkalinity, hardness and colour are markedly similar to values measured at most other sites on the lower section of the river (below Harmony Mills fishway). Some acid-neutralizing capacity is provided by the drumlin soils in this area, so that pH values are greater than 5.0 and natural recruitment of juvenile Atlantic salmon continues to occur. The soils found in these drumlins are classified as Bridgewater loam drumlin phase, considered good for crops; or Halifax sandy loam drumlin phase, judged to be fair for crops (Cann and Hilchey 1959). However, this salmon population can be considered threatened by acidic precipitation as pH ranged from 5.1 to 5.4 at the various sites and measurements of alkalinity were <0.5 mg/L. One exception was Harmony Lake Brook (E13) which had a pH of 6.02 and detectable alkalinity, suggesting that additional acid-neutralizing capacity is provided by groundwater in the immediate area.

Values of pH were lower in the upper section of the Medway system (above Harmony Mills fishway) and in tributaries which lie on granitic rock but join the Medway River below the fishway. For example, the Pleasant River (E8) and one of its tributaries, Dexter Brook (E9), had pH values of 4.77 and 4.38 respectively. Similarly, the pH of the Westfield River (E11) was 4.89 and mortalities occurred among salmon fry held in the river water to determine the effects of acidity (G. Lacroix, pers. comm.). The pH at a site (E16) located just below the confluence of the East and West branches of the Medway River was 5.10. Measurements of pH at two sites on the West Branch (E17; E18) were 4.82 and 5.0 and at two sites on the East Branch (E19; E20) 5.07 and 4.93. These values suggest that some mortality of naturally-produced salmon fry could occur in these areas after completion of yolk-sac absorption. An examination of soil maps (MacDougall et al. 1969) indicates that the upper areas of the Medway system lack the drumlin soils found in the lower sections of the river.

The various sites on the Medway system were again sampled on August 10, 1982, when discharge at Charleston was 13.6 m^3/s and similar to the August mean of 11.4 m^3/s (Environment Canada 1980, 1983). Despite the lower rate of discharge on this date compared to that measured during May when the initial samples were collected, values of pH measured on the two occasions were markedly similar (Table 5). Importantly, total alkalinity was <0.5 mg/L at 18 of the 19 sites sampled on August 10.

Our data suggest that, in some sections of the Medway system, particularly those lying on granitic rock, a partial mortality of salmon fry may occur after completion of yolk-sac absorption. Thomas (1960) found that the pH of the Medway River near Charleston was 6.4 during August of 1954 and that considerable bicarbonate alkalinity was present. Discharge on that date was 9.0 m^3/s. In contrast, pH was 5.44 and alkalinity <0.5 mg/L at that site during August of 1982.

1. G. Lacroix, Department of Fisheries and Oceans, St. Andrews Biological Station, St. Andrews, New Brunswick, E0G 2X0.

Table 5. Some chemical characteristics of the Medway River system during May and August of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)	Ca	Mg	Cl	SO_4	Al[1] (μg/L)
							(mg/L)				
May 26											
E1	At Charleston	5.27	<0.5	4.2	21	55	0.9	0.4	5.2	2.7	
E2	Petite Brook	5.28	<0.5	5.0	37	65					
E3	Salter Brook	5.37	<0.5	4.2	29	55					
E4	Fifteen Mile Brook	5.13	<0.5	3.5	28	120					
E5	At Greenfield	5.21	<0.5	3.9	26	50					
E6	Below Christopher Lakes	5.20	<0.5	4.0	27	60					
E7	Wildcat River	5.29	<0.5	3.9	24	50					
E8	Pleasant River	4.77	<0.5	2.7	25	110					
E9	Dexter Brook	4.38	<0.5	3.5	36	60					
E10	At South Brookfield	5.18	<0.5	4.0	27	60					
E11	Westfield River	4.89	<0.5	3.0	26	60					
E12	Halfway Brook	4.63	<0.5	3.5	27	75					
E13	Harmony Lake Brook	6.02	0.7	3.8	24	10					
E14	Mount Merrit Brook	5.21	<0.5	2.5	37	140					
E15	Perch Lake Brook	4.86	<0.5	2.6	26	70					
E16	Below East and West branches	5.10	<0.5	4.0	27	65					
E17	West Branch	5.00	<0.5	3.5	27	75					
E18	Below Long Lake	4.82	<0.5	3.5	28	55					
E19	Below Alma Lake	5.07	<0.5	4.1	27	60					
E20	Randolph Stream	4.93	<0.5	3.8	27	60					
August 10											
E1	At Charleston	5.44	<0.5	3.0	28	50			5.2	2.6	210
E2	Petite Brook	5.10	<0.5	4.2	44	150					
E3	Salter Brook	5.39	<0.5	4.5	33	110					
E4	Fifteen Mile Brook	5.42	<0.5	3.5	27	75					
E5	At Greenfield	5.40	<0.5	3.5	32	55					
E6	Below Christopher Lakes	5.40	<0.5	2.8	27	55					
E7	Wildcat River	5.39	<0.5	2.6	24	30					
E8	Pleasant River	4.66	<0.5	2.7	28	150					
E9	Dexter Brook	4.39	<0.5	3.7	32	200					
E10	At South Brookfield	5.30	<0.5	3.0	36	70					
E11	Westfield River	5.0	<0.5	3.8	27	70					
E13	Harmony Lake Brook	5.97	2.1	3.6	29	15					
E14	Mount Merrit Brook	5.03	<0.5	3.8	42	260					
E15	Perch Lake Brook	4.86	<0.5	2.6	26	70					
E16	Below East and West branches	5.10	<0.5	3.5	27	100					
E17	West Branch	5.22	<0.5	3.5	26	100					
E18	Below Long Lake	4.98	<0.5	2.2	26	50					
E19	Below Alma Lake	4.91	<0.5	3.6	27	110					
E20	Randolph Stream	4.92	<0.5	4.0	27	70					

1. The water sample for aluminum determination was collected on August 3, 1983.

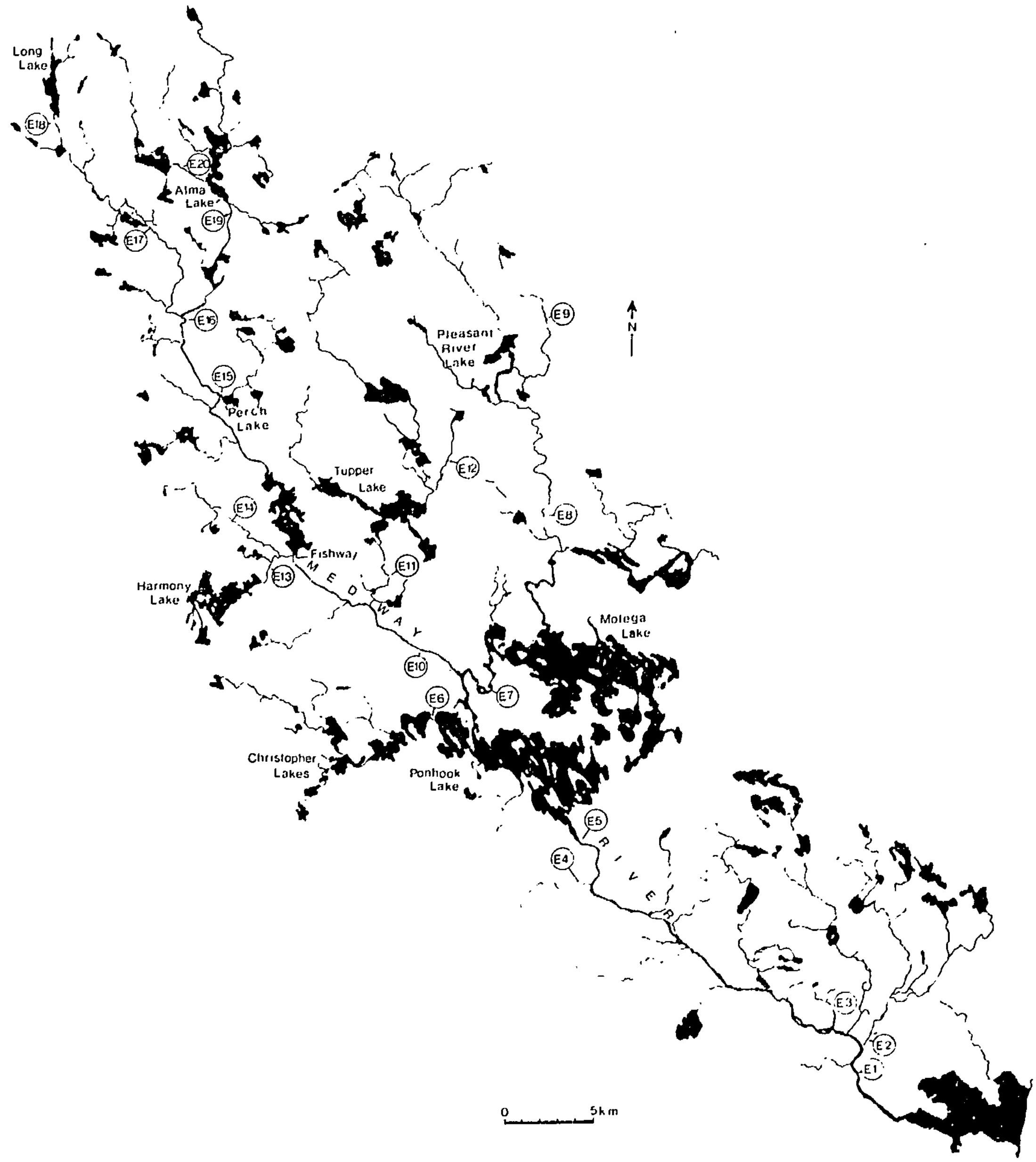

Fig. 6. Water sampling sites on Medway River

PETITE RIVIÈRE

The Petite Rivière is located in Lunenburg County and has a drainage area of 218 km^2 and meander length of 92.8 km (Anon. 1969). However, only the area below Hebb Lake is presently accessible to anadromous species of fish (Fig. 7). The predominant bedrock in the rivers drainage area consists of greywacke and slate (Keppie 1979). The salmon angling catch in Petite Rivière averaged 69 fish/year during the 1951-79 period (Smith 1981) and Watt et al. (1983) demonstrated that no significant decline in catch has occurred during the past 45 years. The latter authors found that the mean pH of the river during the 1980-81 period was 5.6.

Three sites on the Petite Rivière were chosen for sampling during 1982: just above the head of tide (F1), Brown Branch Brook (F2), and at the outlet of Fancy Lake (F3). Samples were first collected on March 2 when discharge of the nearby LaHave River at West Northfield was 14.6 m^3/s and considerably lower than the March, 1916-79 mean of 51.6 m^3/s (Environment Canada 1980, 1983). This indicates that little runoff from precipitation or snowmelt was occurring in Petite Rivière when the samples were collected. The pH of the river below Fancy Lake (F3) was 5.34 on March 2 and alkalinity <0.5 mg/L (Table 6). The water at that site was moderately coloured (50 relative units) and very soft (total hardness 5.5 mg/L). Analysis of water collected just above the head of tide (F1) on that date gave similar results. The pH of Brown Branch Brook (F2) which enters the Petite Rivière near the head of tide was only 4.88.

Samples were collected from the same three sites on June 24, when discharge of the LaHave River at West Northfield was 13.9 m^3/s and less than the June, 1916-79, mean of 20.5 m^3/s (Environment Canada 1980, 1983). The pH below Fancy Lake on June 24 was 5.70 and alkalinity measured 0.6 mg/L. The total hardness of 5.0 mg/L at that site was similar to the value measured during March, but the apparent colour of 15 relative units was markedly lower. The apparent colour of the river just above the head of tide was 75 relative units and pH measured 5.15. The values recorded at that location reflect inputs of highly coloured water (200 relative units) from Brown Branch Brook where pH was only 4.68.

The bedrock in the area from Fancy Lake to the head of tide consists of slate (Keppie 1979). Associated with the slate are numerous drumlins composed of Bridgewater loam, considered good for crops (Cann and Hilchey 1958) and which provides some acid-neutralizing capacity to the river. Brown Branch Brook and the headwaters of the river, including Minamkeak, Milipsigate and Hebb Lakes, lie on greywacke. Fewer drumlins are associated with this resistant type of rock, which explains why alkalinity sometimes measured <0.5 mg/L. In addition, Brown Branch Brook receives considerable inputs of humic materials which can reduce pH.

Although pH of most accessible areas of the river continues to be suitable for the natural reproduction of Atlantic salmon, the river is sensitive to further inputs of acidic precipitation because total alkalinity was minimal. In comparison, Thomas (1960) found that the pH of Hebb Lake on September 4, 1958, was 6.1 and that alkalinity was detectable.

Table 6. Some chemical characteristics of the Petite Rivière system during March and June of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Al[1] (μg/L)
March 2											
F1	Above head of tide	5.39	<0.5	6.0	36	50					
F2	Brown Branch Brook	4.88	<0.5	6.3	47	65					
F3	Below Fancy Lake	5.34	<0.5	5.5	33	50	1.2	0.6	6.2	3.8	
June 24											
F1	Above head of tide	5.15	<0.5	5.5	37	75					
F2	Brown Branch Brook	4.68	<0.5	6.0	39	200					
F3	Below Fancy Lake	5.70	0.6	5.0	35	15			6.8	3.8	64

1. The water sample for the determination of aluminum was collected on August 3, 1983.

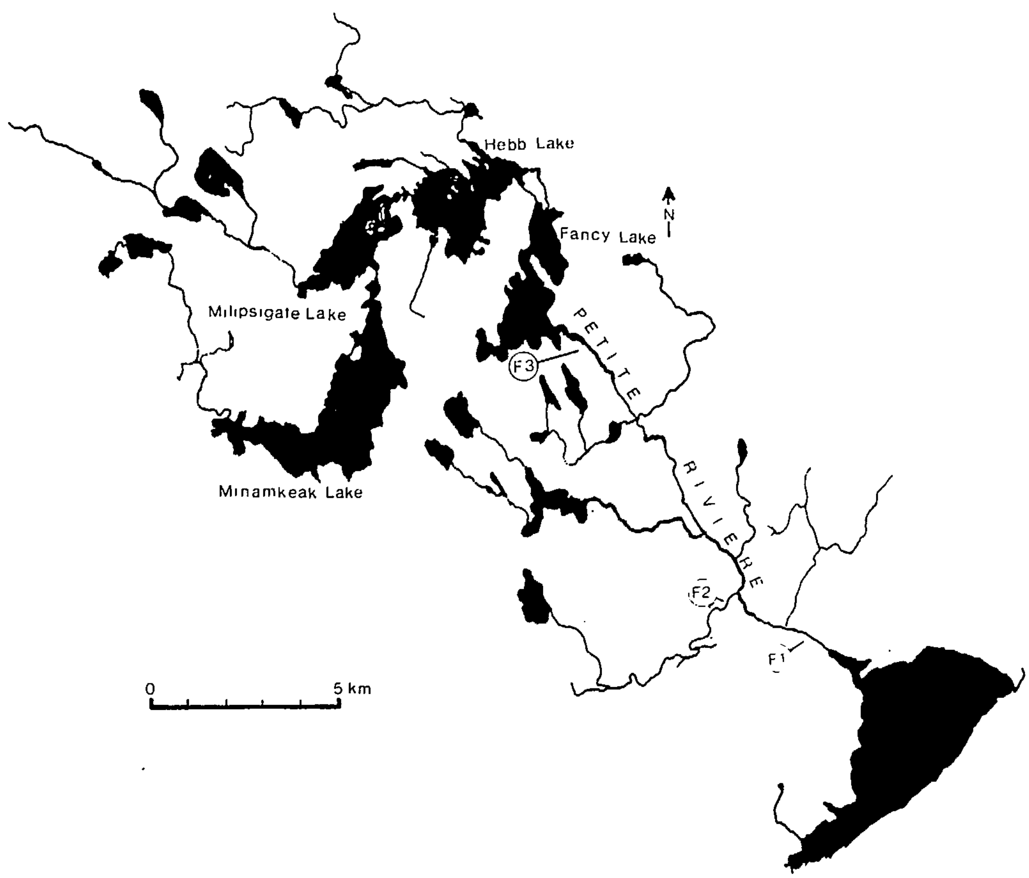

Fig. 7. Water sampling sites on Petite Rivière

LAHAVE RIVER

The LaHave River, which has a drainage area of 1,536 km^2, originates in Annapolis and Kings counties, then flows in a southerly direction through Lunenburg County before it meets the Atlantic Ocean near the community of Bridgewater (Fig. 8). The river has received hatchery-reared, juvenile, Atlantic salmon each year since the early 1970s (Gray and Cameron 1980) to increase the spawning escapement and provide angling opportunities. The release of hatchery juveniles and construction of the Morgan Falls fishway resulted in an angling catch of 2,079 adult salmon during 1981 and a spawning escapement of 3,563. These numbers were the maximum that had been recorded to that time. The predominant bedrock in the LaHave drainage basin consists of granitic rock in the headwater areas and slate in the lower sections (Keppie 1979).

Water samples were collected at seventeen sites which included the larger tributaries of the LaHave River system. The first sampling date was March 16, 1982, when discharge at West Northfield was 99.4 m^3/s, which is greater than the March, 1916-79, mean of 51.6 m^3/s (Environment Canada 1980; 1983). This indicates that considerable runoff from precipitation or snowmelt occurred when the samples were collected. The pH at Site G1, located just above head of tide, was 5.39 and alkalinity was <0.5 mg/L (Table 7). The water was moderately coloured (50 relative units) at that site and very soft (total hardness 5.5 mg/L). In comparison, Thomas (1960) found pH at that location was 5.7 on March 29, 1955, when discharge was 83 m^3/s. The pH values at the 16 other sites sampled on March 16 ranged from 4.43 to 5.39 and pH at 10 sites was <5.0. The highest pH was recorded in the North Branch of the LaHave River at Pinehurst. Most importantly, this was the only site on the LaHave system where alkalinity was detectable by our method (0.8 mg/L). Values of pH which measured <5.0 were recorded at the following sites: below Smith Lake (G4), the West LaHave River below Hirtle Lake (G5), Forties River (G8), Sherbrooke River (G10), Gully River(G9), Little River (G13), West River below West Lake (G12), Mason Meadow Brook (G15) and Sixty Brook (G16).

Water samples were again collected on July 20, 1982, when discharge at West Northfield was 4.75 m^3/s which was considerably lower than the June, 1916-79, mean of 11.5 m^3/s (Environment Canada 1980, 1983). Low discharge at that time of year usually results in values of pH which approach the yearly maximum (Watt et al. 1983). Thus, pH just above the head of tide, was 6.10 on that date and alkalinity measured 1.1 mg/L. Values for hardness and colour were similar to those measured during March, 1982. Thomas (1960) collected samples at a similar location on July 27, 1954, when discharge at West Northfield was 13.2 m^3/s and observed that pH was 6.7.

The pH values recorded at other LaHave River sites on July 20, 1982, ranged from 4.95 to 6.10 and had increased from the values observed during March. The Little River (G13), which had the lowest pH during March, was not sampled on this occasion. Alkalinity was < 0.5 mg/L at four sites during July: the Gully River (G9), the West River below West Lake (G12), the West River above New Germany Lake (G11), and the West LaHave River below Smith Lake (G4). The low pH values are related to the type of bedrock in the immediate drainage areas and to the absence of drumlins. Thus, Smith Lake lies on greywacke and the West River, Little River and Gully River on granitic rock. Drumlins, composed of Wolfville sandy loam, Bridgewater loam or Farmville sandy loam, are found near the lower section of the West River (Cann and Hilchey, 1958) and are probably responsible for the small increase in pH which occurs in that area (G11). The remaining sites on the LaHave system sampled during July had detectable alkalinity (0.5 - 1.6 mg/L) and pH values which ranged from 5.58 to 6.10.

Most sites which had higher values of pH and detectable alkalinity are located on slate. Associated with the slate areas in the LaHave drainage are drumlins which contain Wolfville loam or the three soil types listed above (Cann and Hilchey 1958). Drumlins provide some acid-neutralizing capacity to the North Branch of the LaHave, to the West LaHave and to the main section of the LaHave River below its confluence with the North River. Although, other tributaries of the LaHave River such as the North, Sherbrooke and Forties rivers originate in areas of granitic rock, they also have relatively high values of pH during the summer and detectable alkalinity. Deposits of Wolfville and Bridgetown loam associated with those tributaries (Cann and Hilchey 1958) are considered fair to good for crops and probably provide some acid-neutralizing capacity. Similarly, Wolfville loam found in the area of Sixty Brook may be responsible for its alkalinity. Examination of soil and geological maps for the LaHave River above its confluence with Sixty Brook does not reveal what materials contribute to the alkalinity observed in that area.

The low pH values observed at most sites on the LaHave River during March, 1982, indicate that it is sensitive to inputs of acidic precipitation. Alkalinity remains low in many tributaries even during the summer when discharge is low. A comparison of 1982 pH values for the LaHave and those collected 28 years earlier by Thomas (1960) indicates that this parameter has declined. A similar trend was observed by Watt et al. (1983) after comparison of present and past chemical characteristics of the LaHave River.

Table 7. Some chemical characteristics of the LaHave River system during March and July of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (µS/cm)	Apparent colour (relative units)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Al[1] (µg/L)
March 16											
G1	Above head of tide	5.39	<0.5	5.5	31	50	0.8	0.4	5.8	3.4	
G2	West LaHave River	5.19	<0.5	5.0	29	55					
G3	Below Seven Mile Lake	5.18	<0.5	4.4	27	60	0.8	0.5	4.8	2.3	
G4	Below Smith Lake	4.60	<0.5	3.7	29	70					
G5	Below Hirtle Lake	4.95	<0.5	4.9	29	55					
G6	North LaHave River	5.39	0.8	6.3	31	50					
G7	Below Sherbrooke Lake	5.16	<0.5	5.0	27	55					
G8	Forties River	4.88	<0.5	5.1	33	50					
G9	Gully River	4.55	<0.5	4.5	36	50					
G10	Sherbrooke River	4.68	<0.5	4.8	37	50					
G11	West River	4.76	<0.5	4.0	31	55	0.6	0.4	5.3	2.6	
G12	Below West Lake	4.56	<0.5	3.9	33	60					
G13	Little River	4.43	<0.5	3.0	33	60					
G14	North River	5.10	<0.5	5.5	34	55					
G15	Mason Meadow Brook	4.92	<0.5	7.4	56	50					
G16	Sixty Brook	4.85	<0.5	4.8	33	50					
G17	Upper LaHave River	5.08	<0.5	5.0	33	50					
July 20											
G1	Above head of tide	6.10	1.1	4.5	29	55			4.9	3.4	210
G2	West LaHave River	6.00	0.6	3.5	28	25					
G3	Below Seven Mile Lake	5.85	0.5	3.4	25	25			4.2	2.8	
G4	Below Smith Lake	5.17	<0.5	2.5	21	55					
G5	Below Hirtle Lake	5.68	0.9	3.4	25	50					
G6	North LaHave River	6.00	0.8	5.0	29	25					
G7	Below Sherbrooke Lake	5.70	0.6	3.7	27	45					
G8	Forties River	5.58	1.5	5.7	31	170					
G9	Gully River	4.95	<0.5	2.1	24	90					
G10	Sherbrooke River	5.80	1.3	5.3	29	110					
G11	West River	5.40	<0.5	3.0	26	100			5.0	2.0	
G12	Below West Lake	5.08	<0.5	3.2	26	75					
G14	North River	5.82	0.9	3.6	26	40					
G15	Mason Meadow Brook	5.80	0.7	5.1	40	75					
G16	Sixty Brook	5.92	0.8	3.5	24	55					
G17	Upper LaHave River	6.10	1.6	3.5	27	60					

1. The water sample for the determination of aluminum was collected on August 3, 1983.

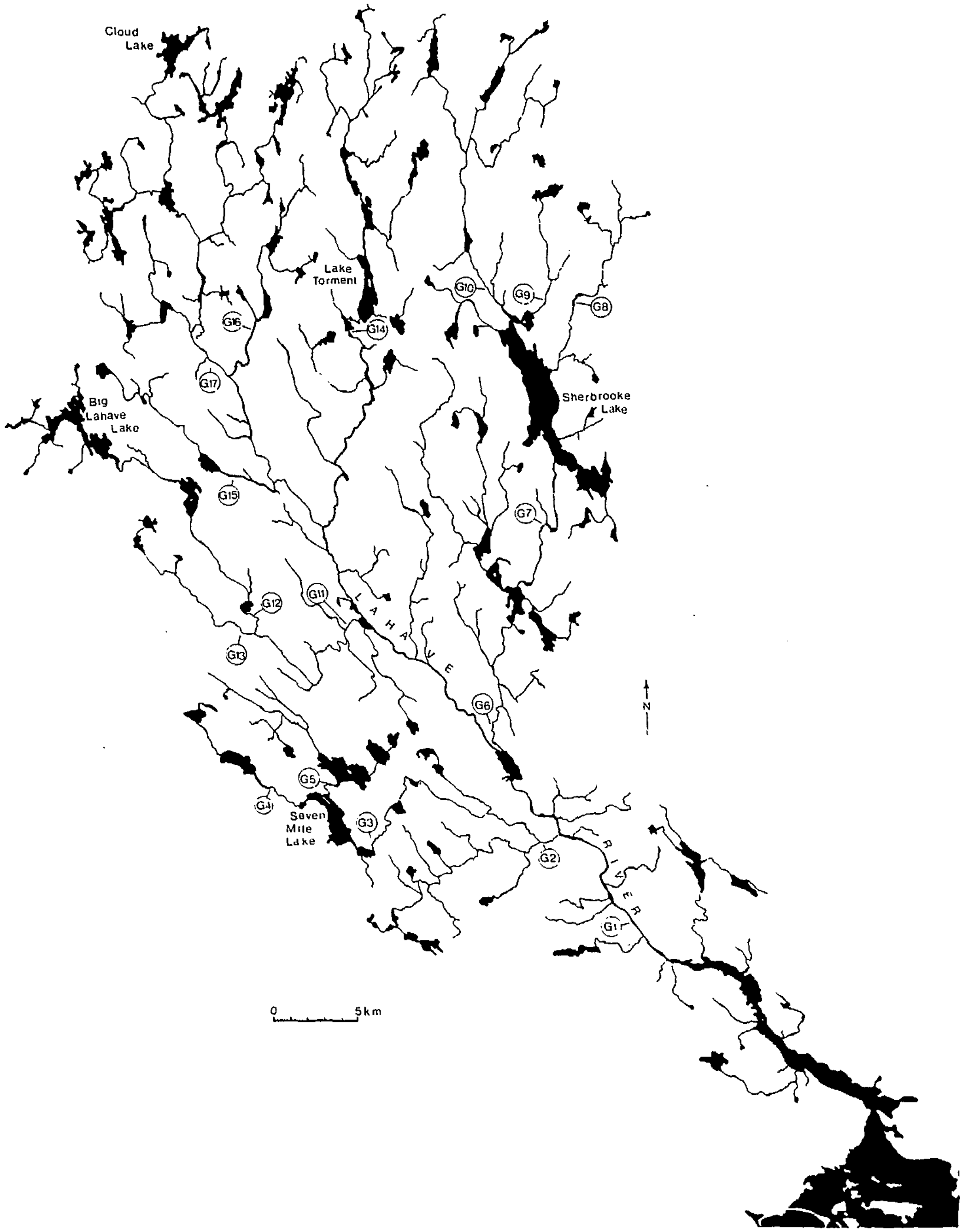

Fig. 8. Water sampling sites on LaHave River

MUSHAMUSH RIVER

The Mushamush River has a drainage area of 158 km^2 (MacPhail et al. 1983) and is located in Lunenburg County in close proximity to the LaHave River system. Five lakes, named Big Mushamush, Caribou, West Whale, Whale and Little Mushamush, form the headwaters of the system (Fig. 9). The main section of the river drains from Little Mushamush Lake and flows for a distance of about 11 km in a southeasterly direction to meet the Atlantic Ocean at Mahone Bay. When MacEachern (1955) surveyed this section of the river, he observed six barriers to fish migration and an additional barrier on Blockhouse Mill Brook (H3). Only the first barrier had a fishway and it did not function efficiently at the time of the survey. Two salmon passed through a counting fence installed at the mouth of the river that year (MacEachern 1955). Local residents claimed that "Before the barriers were built on the river, it was one of the best salmon angling rivers along the coast". Since the time of MacEachern's (1955) survey, all barriers to fish migration have been removed and the river has been recolonized by either a small remnant population of salmon which survived below the first barrier or by stray salmon originating from nearby rivers (MacPhail et al. 1983). West Whale and Whale lakes are found in an area of granitic rock, Caribou Lake is located in an area of greywacke, while Big and Little Mushamush lakes and the lower section of the river lie on slate (Keppie 1979).

Water samples were first collected from the Mushamush system on March 24, 1982, when discharge of the nearby LaHave River at West Northfield was 43.5 m^3/s (Environment Canada 1983). The discharge was slightly lower than the March, 1916-79, mean of 51.6 m^3/s (Environment Canada 1980). If the discharge of the Mushamush River was also typical for March, then the pH of that system could be expected to have been minimal at the time of sampling. The pH at Site H1, just above the head of tide, was 5.99 and alkalinity measured 1.7 mg/L (Table 8). The water was very soft and only slightly coloured, as indicated by measurements of total hardness (5.6 mg/L) and apparent colour (20 relative units). Total alkalinity and pH were greater in Caribou Brook (H7) and in the outflow from Big Mushamush Lake (H8). For example, pH in these brooks measured 6.20 and 6.31 respectively and alkalinity 1.9 and 2.4 mg/L. Water from North Brook (H5), which drains Whale Lake, had lower pH (5.40) and alkalinity (0.7 mg/L) but was considered acceptable for the reproduction of Atlantic salmon. Although the quality of the water in Blockhouse Mill Brook (H3) was also found to be acceptable, the pH of Lantz Brook (H2) was only 4.88.

Water samples were again collected at all Mushamush River sites on September 21, 1982, when discharge at West Northfield on the nearby LaHave River was 2.57 m^3/s (Environment Canada, 1983), less than the September, 1916-79, mean of 9.77 m^3/s (Environment Canada, 1980). Under such low-flow conditions at that time of year, pH and alkalinity of Nova Scotia rivers are usually maximal (Watt et al. 1983). Thus, pH of water collected at Site H1 on that date was 6.50 and alkalinity measured 3.8 mg/L. Hardness had increased to 8.4 mg/L and apparent colour measured 15 relative units. The aluminum concentration of 42 µg/L at that site was the lowest observed in any of the rivers included in the present sampling program. This may be related to higher soil pH in the Mushamush drainage area which acts to decrease aluminum solubility and therefore leaching of this metal. The pH at other sites on the Mushamush system ranged from 5.95 to 6.40 on this date and alkalinity from 0.8 to 4.4 mg/L.

Water which possessed the greatest acid-neutralizing capacity was found at the outflow of Big Mushamush Lake, in Caribou Brook, and in Blockhouse Mill Brook. This can be related to the presence of drumlins in the vicinity of Big Mushamush, Caribou and Langille lakes. The soil type associated with these drumlins is Wolfville loam, which is considered good for the cultivation of crops (Cann and Hilchey 1958). In contrast, few drumlins are found in the area of the Whale Lakes and Zwicker Lake, which explains the relatively low alkalinity and pH of North and Lantz brooks. However, the only area of the Mushamush system where water quality may not be acceptable for the natural reproduction of Atlantic salmon is Lantz Brook. For this reason, 14,600 fingerling salmon of LaHave stock were release in various areas of the river during the fall of 1982 to supplement the small population of salmon in the system. That release of hatchery-reared salmon was followed by the spring liberation of 10,000 salmon smolts of the same genetic stock and by 8,000 smolts during the spring of 1984.

Table 8. Some chemical characteristics of the Mushamush River system during March and September of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (µS/cm)	Apparent colour (relative units)	Ca	Mg	Cl	SO_4	Al[1] (µg/L)
							(mg/L)				
March 24											
H1	At Mahone Bay	5.99	1.7	5.6	31	20					
H2	Lantz Brook	4.88	<0.5	3.0	26	55					
H3	Blockhouse Mill Brook	5.98	2.1	7.2	33	30					
H4	Mushamush River	5.90	1.3	5.5	29	15					
H5	North Brook	5.40	0.7	4.0	24	25					
H6	Above Little Mushamush Lake	6.20	2.1	6.4	31	10					
H7	Caribou Brook	6.20	1.9	5.5	32	10					
H8	Below Big Mushamush Lake	6.31	2.4	6.7	31	10					
September 21											
H1	At Mahone Bay	6.50	3.8	8.4	35	15	2.1	0.8	5.2	3.8	42
H2	Lantz Brook	6.10	1.8	6.4	38	75					
H3	Blockhouse Mill Brook	6.40	6.4	12.9	52	25					
H4	Mushamush River	6.11	1.8	6.1	29	10					
H5	North Brook	5.95	0.8	4.4	22	10					
H6	Above Little Mushamush Lake	6.00	4.1	7.5	37	15					
H7	Caribou Brook	6.21	2.2	6.2	31	10					
H8	Below Big Mushamush Lake	6.30	3.9	8.3	33	15					

1. The sample for the determination of aluminum was collected on August 3, 1983.

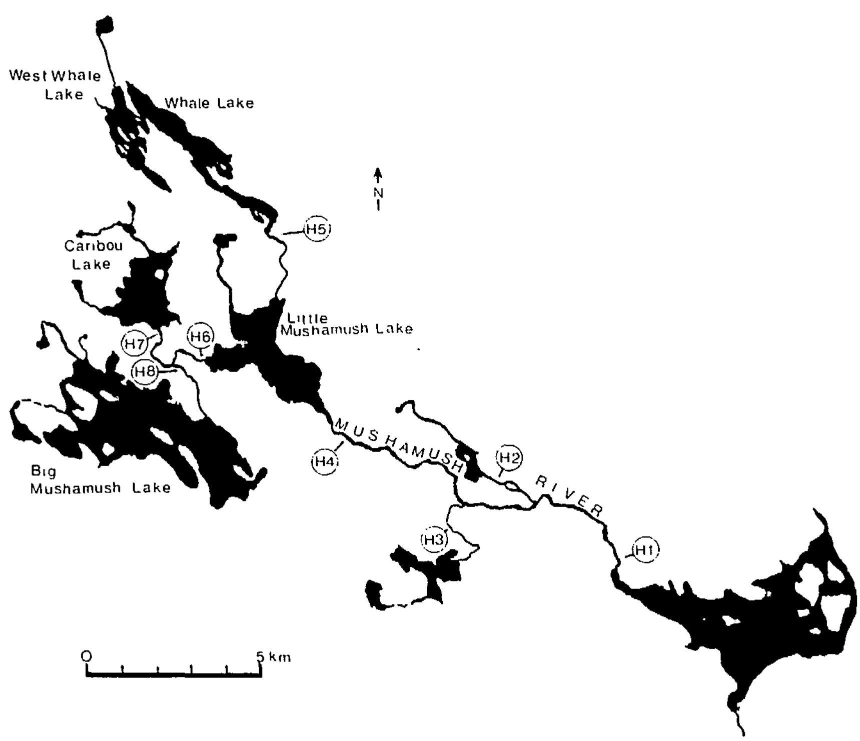

Fig. 9. Water sampling sites on Mushamush River

GOLD RIVER

The Gold River originates near the border of Lunenburg and Kings Counties, and flows in a southeasterly direction through Lunenburg County to meet the Atlantic Ocean at Mahone Bay (Fig. 10). The river has a drainage area of 370 km^2 (MacPhail et al. 1983) most of which lies on granitic rock (Keppie 1979). The mean discharge at Mosher's Falls during the 1966-79 period has been 11.3 m^3/s (Environment Canada 1980). The catch of Atlantic salmon on the Gold River has increased during recent years in response to increased angling effort (Smith 1981). Thus, catch during the 1951-74 period averaged 107 salmon per year and 252 fish per year during the 1975-82 interval. Accordingly, angler effort during the earlier period averaged 503 rod days per year and 851 rod days per year during the more recent interval (Smith 1981).

Water samples were collected from four Gold River sites on March 2, 1982, when discharge at Mosher's Falls was 3.88 m^3/s and less than the March mean of 17.0 m^3/s (Environment Canada 1980; 1983). This indicates that little runoff from snowmelt or precipitation was occurring the day samples were collected. The pH of the Gold River, just above the head of tide (J1), was 5.14 and alkalinity <0.5 mg/L (Table 9). The total hardness of 6.0 mg/L and apparent colour of 60 relative units indicates that the water at that site was very soft and moderately coloured. Similar values were recorded for the Larder River (J2) on that date. Although the alkalinity of a sample collected further upriver at the community of New Ross (J3) measured <0.5 mg/L, pH was 5.46 at that site. Both pH (5.75) and alkalinity (0.6 mg/L) were greatest in Mill Brook (J4), a tributary stream which joints the Gold River near New Ross.

Water samples were collected from five sites on the Gold River system on June 24, 1982, when flow at Mosher's Falls was 5.93 m^3/s and similar to the June mean of 6.65 m^3/s (Environment Canada 1980, 1983). River pH at that time of year in Nova Scotia has usually shown a significant increase from the minimal values which are observed during the winter (Watt et al. 1983). However, pH of the Gold River just above the head of tide (J1) was 5.18 on this date and alkalinity <0.5 mg/L. These values are similar to those recorded at that site during March. Apparent colour had increased to 100 relative units, indicating a significant input of humic materials to the lower section of the river. Values for both pH and total alkalinity were greater upriver at New Ross, above New Ross, in the Larder River and in Mill Brook. For example, pH at these sites ranged from 5.51 to 5.80 and alkalinity from 1.1 to 1.6 mg/L. In addition, water was only moderately coloured at these sites (50-65 relative units) in comparison to the highly coloured water collected just above the head of tide. It is apparent that the acid-neutralizing capacity present in the upper areas of the Gold River system is reduced in the lower areas by inputs of acidic, highly coloured water.

Soil maps of Lunenburg County (Cann and Hilchey 1958) indicate concentrations of drumlins in the area of Lake Ramsay on the Larder River, at New Ross, on the drainage of Mill Brook, and in the area of Hatchard and Sefferns lakes which drain to a tributary stream that enters the Gold River above New Ross. The soil associated with these drumlins is Wolfville sandy loam which is considered good for crops and which appears to be providing some acid-neutralizing capacity to the upper areas of the Gold River system. Drumlins are not found below the confluence of the Gold and Larder rivers. Inputs of highly coloured, acidic water to the lower section of the river which lies on grantic rock appear to be depressing pH and alkalinity and explains the marked difference in water chemistry observed at New Ross and at the head of tide.

Table 9. Some chemical characteristics of the Gold River system during March and June of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)	Ca	Mg	Cl	SO_4	Al[1] (μg/L)
							(mg/L)				
March 2											
J1	Above head of tide	5.14	<0.5	6.0	34	60					
J2	Larder River	5.17	<0.5	7.2	36	60					
J3	At New Ross	5.46	<0.5	6.9	35	55	1.6	0.7	6.8	3.2	
J4	Mill Brook	5.75	0.6	7.4	37	55					
June 24											
J1	Above head of tide	5.18	<0.5	4.1	27	100					
J2	Larder River	5.51	1.4	5.0	29	65					
J3	At New Ross	5.80	1.6	5.0	30	50			5.0	2.9	260
J4	Mill Brook	5.66	1.1	4.4	29	60					
J5	Above New Ross	5.70	1.1	4.0	26	50					

1. The water sample for the determination of aluminum was collected on August 3, 1983.

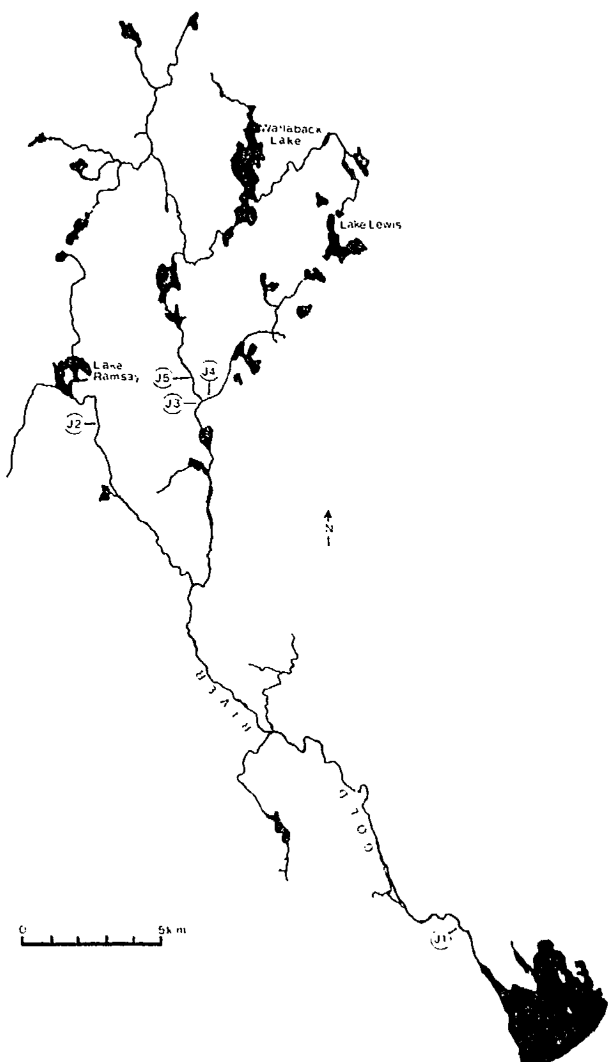

Fig. 10. Water sampling sites on Gold River

MUSQUODOBOIT RIVER

The Musquodoboit River (Fig. 11) drains a 694-km^2 area of Halifax County and meets the Atlantic Ocean at Musquodoboit Harbour located on the eastern shore of Nova Scotia. The annual mean discharge at Crawford Falls has been 19.9 m^3/s (Environment Canada 1980). The predominant bedrock in the upper drainage area (above Lower Meaghers Grant) consists of the Windsor Group of rocks which includes sandstone, limestone, dolostone, anhydrite, halite and gypsum (Keppie 1979). Smaller areas in the upper drainage lie on rocks belonging to the Halifax Formation (slate) or on those belonging to the Goldenville Formation (greywacke). The section of the river located below Lower Meaghers Grant lies on granitic rock. The Musquodoboit River continues to support a sport fishery for salmon which has captured an average of 51 fish per year (1951-82 period) from an average effort of 1,295 rod days per season (Smith 1981).

Water samples were first collected from the Musquodoboit River on May 19, 1982, when the discharge at Crawford Falls was 12.3 m^3/s or about half the mean May discharge of 23.1 m^3/s (Environment Canada 1980, 1983). The pH just above the head of tide (L1) was 6.60 and total alkalinity measured 6.6 mg/L, reflecting the presence of the Windsor Group of rocks in the drainage basin (Table 10). The presence of these rocks was also reflected in the concentrations of sulfate (10.4 mg/L), calcium (6.0 mg/L) and magnesium (1.1 mg/L) which were several times greater than observed in other Nova Scotia rivers which drain to the Atlantic side of the mainland. The pH of the tributaries to the Musquodoboit River (L2-L7) ranged from 6.04 to 6.80 and total alkalinity from 0.7 to 7.7 mg/L. The range of alkalinity observed for the various tributaries is attributable to differences in their bedrock geology. For example, the alkalinity of Kent Brook (L7) was only 0.7 mg/L because most of its drainage lies on slate. Ogilvie Brook (L2) lies on greywacke as well as rocks of the Windsor Group, so that alkalinity of that brook (2.9 mg/L) was less than observed for the Musquodoboit River near the head of tide. The only area of the river included in our survey that appears to be sensitive to acidic precipitation is the South Musquodoboit River (L8) which lies on greywacke. The pH of this river was 5.20 and total alkalinity <0.5 mg/L.

Nine sites on the Musquodoboit River system were sampled on August 12, 1982 when discharge at Crawford Falls was 25.2 m^3/s, which is several times greater than the August mean of 8.31 m^3/s (Environment Canada 1980, 1983). This indicates that a period of precipitation had preceded collection of the water samples. The pH just above the head of tide (L1) on August 12 measured 6.45 and alkalinity was 9.2 mg/L. Total hardness was 24.8 mg/L and sulfate measured 14.2 mg/L. Values of hardness, alkalinity and sulfate were greater than had been measured at this site during May. The pH of the tributaries ranged from 5.75 to 6.52 and alkalinity from 1.1 to 6.7 mg/L. The only section of the Musquodoboit system included in our sampling program that may not be suitable for the reproduction of Atlantic salmon is the South Musquodoboit River (L8). The pH of that river was 4.68 on August 12 and apparent colour measured 110 relative units, indicating that the river receives a considerable input of organic acids from bog soils.

The Windsor Group of rocks has a dominant influence on the water chemistry of the Musquodoboit River. Because of these rocks, most of the river has resisted the gradual acidification which has occurred in other rivers which drain to the Atlantic side of mainland Nova Scotia. Watt et al. (1983) demonstrated that the mean annual pH of the Musquodoboit River during 1980-81 was not significantly different than it was during 1954-55. Because of the rivers considerable acid-neutralizing capacity and because other eastern shore rivers have become more acidic, the Musquodoboit River was selected as the site for a salmon enhancement project. Thus, 52,000 eggs were collected from two-sea-year salmon captured in the river during the fall of 1982. A portion of these eggs were transported to the Mersey Hatchery for the production of one-year smolts for release in the river in 1984 while the remainder were held at the Cobequid Hatchery to produce two-year smolts for release in 1985.

Table 10. Some chemical characteristics of the Musquodoboit River system during May and August of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Al (μg/L)
May 19											
L1	Above head of tide	6.60	6.6	18.6	56	40	6.0	1.1	4.9	10.4	130
L2	Ogilvie Brook	6.22	2.9	7.4	30	55					
L3	Little River	6.45	4.2	18.8	52	65					
L4	McNutt Brook	6.80	7.7	29.2	89	15					
L5	Dickey Brook	6.56	4.2	43.7	115	10					
L6	McCaffrey Brook	6.44	1.8	6.0	26	15					
L7	Kent Brook	6.04	0.7	5.4	24	15					
L8	South Musquodoboit River	5.20	<0.5	3.7	22	55					
August 12											
L1	Above head of tide	6.45	9.2	24.8	73	80			4.9	14.2	119
L2	Ogilvie Brook	6.04	6.1	10.4	36	60					
L3	Little River	6.10	4.3	13.4	40	110					
L4	McNutt Brook	6.52	6.7	21.1	65	55					
L5	Dickey Brook	6.51	4.2	29.2	85	15					
L6	McCaffrey Brook	6.24	1.8	5.0	25	25					
L7	Kent Brook	5.75	1.1	5.0	25	50					
L8	South Musquodoboit River	4.68	<0.5	4.8	28	110					
L9	North Musquodoboit River	6.08	2.4	17.0	57	60					

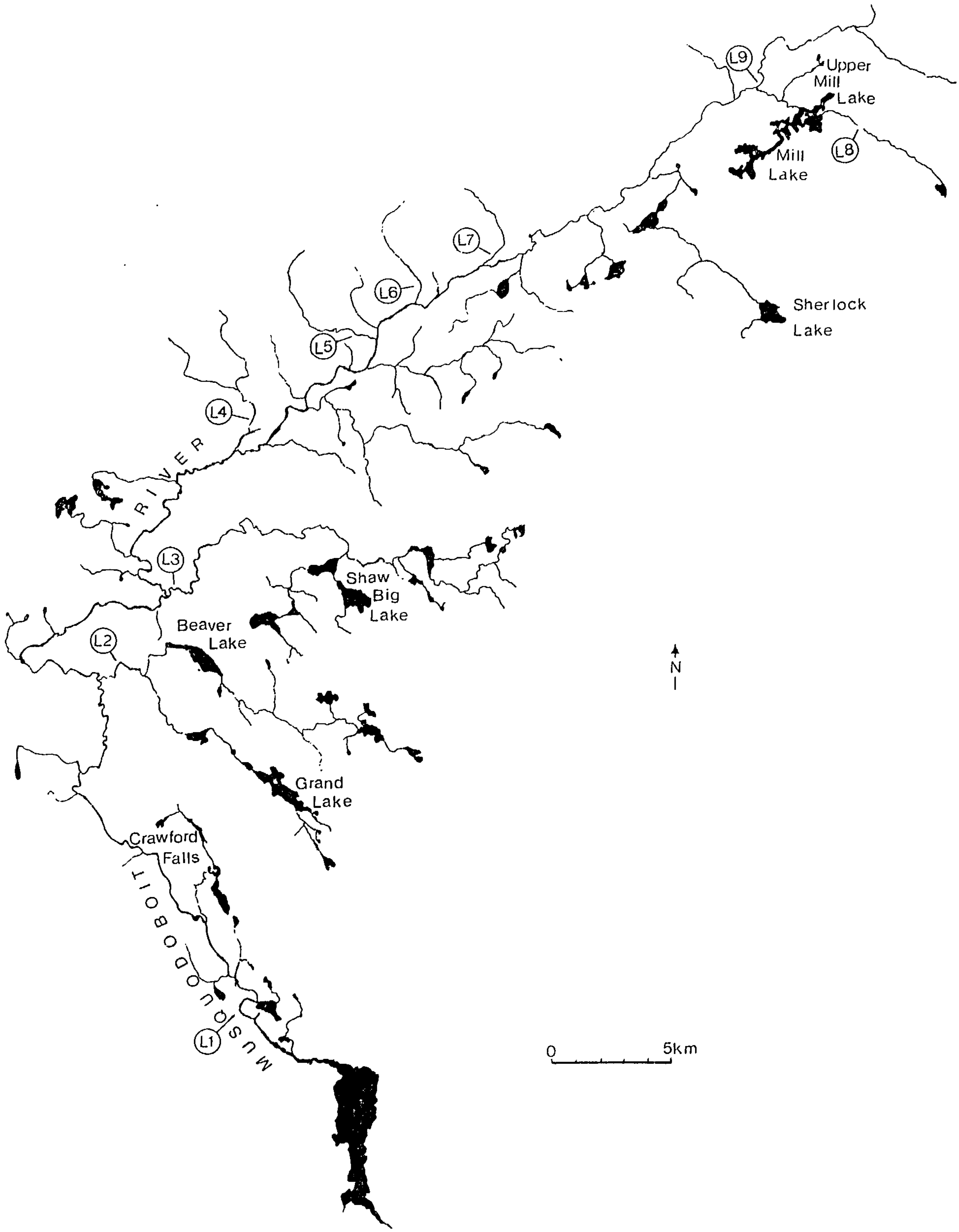

Fig. 11. Water sampling sites on Musquodoboit River

WEST RIVER SHEET HARBOUR

The West River Sheet Harbour is located in Halifax County and meets the Atlantic Ocean at the community of Sheet Harbour on the eastern shore of Nova Scotia (Fig. 12). The river has a drainage area of 290 km^2 and its annual mean discharge is about 9.6 m^3/s (Anon. 1969). The predominant bedrock in the river's drainage area is greywacke (Keppie 1979). Smaller areas of slate and granitic rock are also found within the drainage. The mean annual sport catch on the river during the 1951-82 period has been 232 Atlantic salmon from a mean effort 6,096 rod days per year (Smith 1981). Although catch has shown a decline since the 1951-64 period, angling effort has also declined.

Water samples were first collected at various sites on the West River Sheet Harbour on May 10, 1982. The closest gauging station to that river is located at Liscomb Mills on the lower section of the Liscomb River. Discharge at Liscomb Mills on May 10 was 15.4 m^3/s, less than the mean May discharge of 20.1 m^3/s (Environment Canada 1980, 1983). Assuming that the discharge of the West River on May 10 was also lower than normal, pH of that river was expected to have shown a small increase from the minimal values which usually occur during the winter (Watt et al. 1983). However, pH of the West River near the head of tide (M1) was only 4.76 (Table 11). Water at that site was very soft as indicated by the low concentrations of calcium (0.7 mg/L) and magnesium (0.3 mg/L). Values for pH, alkalinity, hardness, specific conductance and apparent colour at site M3, located below River Lake, and at site M4 on the Killag River were markedly similar to values measured just above the head of tide.

Water samples were again collected at the West River sites on September 3, 1982 when discharge at Liscomb Mills was 7.6 m^3/s and similar to the September mean of 6.6 m^3/s (Environment Canada 1980, 1983). The pH near the head of tide on that date had only increased to 5.10 and alkalinity was not detected. Colour was 90 relative units and aluminum measured 400 µg/L, suggesting that this metal has been leached from the drainage area. Alkalinity was not detectable by our method at the other 3 sites (M2 to M4) sampled on September 3, and pH at these locations ranged from 4.65 to 5.12.

Because of the chemical characteristics of the West River, it is possible that some mortality of salmon fry occurs at the time of first feeding (Farmer et al. 1980). In this context, Gray et al. (1978) have shown from electrofishing surveys that salmon fry and parr densities in the West River decreased during the 1966-77 period. Despite this, sport catch per unit effort during the 1980-82 period has been greater than recorded during the 1950s when river pH and alkalinity were undoubtedly greater. Presumably, recruitment of juveniles continues, because only a partial mortality of salmon fry occurs at the time of first feeding and because other acceptable areas for reproduction that were not detected by our limited sampling program exist in West River. However, if these refuges exist, they are limited in area and the West River is considered to be seriously threatened by inputs of acidic precipitation. A dam, located below River lake, was removed during 1983 to provide salmon with access to the headwater areas of the river. Drumlins, which contain soils of the Wolfville series (MacDougall et al. 1963), are found near Fisher and Rocky Brook Lakes in the headwaters and may provide sufficient acid-neutralizing capacity to this small section of the river to enable successful reproduction by Atlantic salmon.

Table 11. Some chemical characteristics of the West River Sheet Harbour system during May and September of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)	Ca	Mg	Cl	SO_4	Al[1] (μg/L)
							(mg/L)				
May 10											
M1	Above head of tide	4.76	<0.5	3.1	27	55	0.7	0.3	4.6	2.7	
M3	Below River Lake	4.62	<0.5	2.7	29	55					
M4	Killag River	4.76	<0.5	2.6	22	55					
September 3											
M1	Above head of tide	5.10	<0.5	4.0	28	90			5.7	2.8	400
M2	Little River	5.12	<0.5	4.0	24	40					
M3	Below River Lake	4.65	<0.5	3.2	32	110					
M4	Killag River	4.89	<0.5	4.0	23	110					

1. The water sample for the determination of aluminum was collected on August 9, 1983.

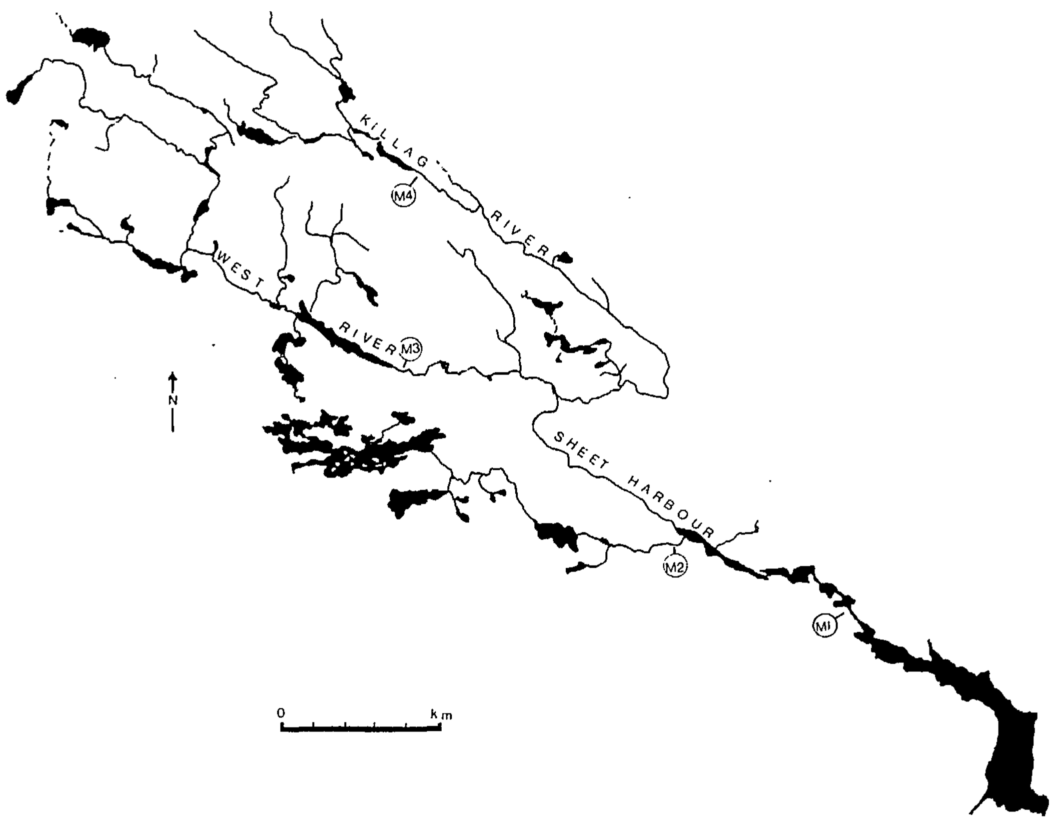

Fig. 12. Water sampling sites on West River Sheet Harbour

EAST RIVER SHEET HARBOUR

The East River system is located within both Halifax and Guysborough counties and drains to the eastern shore of Nova Scotia, where it meets the Atlantic Ocean near the community of Sheet Harbour (Fig. 13). Two hydroelectric dams and five water-storage dams have been constructed on the river by the Nova Scotia Power Corporation. Because of these barriers, upstream fish passage is restricted to a trapping and trucking operation, originating at the Ruth Falls fishway located at the head of tide (N1). The East River has a drainage area of 526 km^2 and an annual mean discharge of approximately 16.7 m^3/s (Anon. 1969). The predominant bedrock in the river's drainage basin consists of greywacke (Keppie 1979). Smaller areas of slate and of granitic rock are also found within the drainage area. Adult Atlantic salmon continue to return to the Ruth Falls fishway but their numbers are largely dependent upon the release of hatchery-reared salmon smolts.

Water samples were collected on May 10, 1982, from six sites which included the five major tributaries (Seven Mile, Ten Mile, Twelve Mile, Fifteen Mile and Seventeen Mile streams). River pH at that time of the year can be expected to have shown a small increase from the minimal values which occur during the winter (See section on the West River Sheet Harbour for river discharge comparisons). The pH of the East River at Ruth Falls fishway (N1) was only 4.96 on May 10 (Table 12). The water was very soft, as indicated by the extremely low concentrations of calcium (0.6 mg/L) and magnesium (0.3 mg/L), and moderately coloured (45 relative units). The chemical characteristics of the five tributary streams (sites N2-N6) were markedly similar to those observed at site N1. Thus, pH of the various tributaries ranged from 4.78 to 5.0. Similar values of pH probably occur during late-May and early-June when salmon fry commence feeding. Under such conditions, a partial mortality of naturally produced salmon fry can be expected (Farmer et al. 1980.

Water samples were again collected at all sites on September 3, 1982, when river pH and alkalinity are usually maximal (Watt et al. 1983). The pH at site N1 on that date had increased to 5.33 but alkalinity was <0.5 Mg/L. The water was moderately coloured (55 units), as observed during May and the aluminum concentration was 270 µg/L. The pH at the other sites on the East River system remained low and ranged from 4.68 to 5.26.

The very soft, acidic water of the East River Sheet Harbour system is partly attributable to the bedrock in the drainage area (Watt et al. 1983) which is predominantly composed of greywacke. The scattered drumlins which contains soils of the Wolfville Series (MacDougall et al. 1963) may provide some acid-neutralizing capacity to localized areas of the river, but these deposits are too few in number to maintain pH values of >5.0 during the critical period when salmon fry initiate feeding. The very soft, acidic water of the river and the man-made barriers to both upstream and downstream fish passage pose a problem to salmon enhancement efforts on this sytem.

Table 12. Some chemical characteristics of the East River Sheet Harbour system during May and September of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (µS/cm)	Apparent colour (relative units)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Al[1] (µg/L)
May 10											
N1	Ruth Falls	4.96	<0.5	3.0	22	45	0.6	0.3	3.4	2.9	
N2	Seven Mile Stream	4.78	<0.5	2.7	21	55					
N3	Ten Mile Stream	5.00	<0.5	2.9	21	45					
N4	Twelve Mile Stream	4.97	<0.5	2.4	21	35					
N5	Fifteen Mile Stream	4.95	<0.5	3.0	22	35					
N6	Seventeen Mile Stream	4.90	<0.5	3.0	22	35					
September 3											
N1	Ruth Falls	5.33	<0.5	4.0	23	55			3.7	2.6	270
N2	Seven Mile Stream	4.68	<0.5	3.8	25	55					
N3	Ten Mile Stream	4.99	<0.5	6.7	33	55					
N4	Twelve Mile Stream	5.11	<0.5	3.0	20	20					
N5	Fifteen Mile Stream	5.26	<0.5	3.5	22	30					
N6	Seventeen Mile Stream	5.20	<0.5	3.6	23	50					

1. The water sample for the determination of aluminum was collected on August 9, 1983.

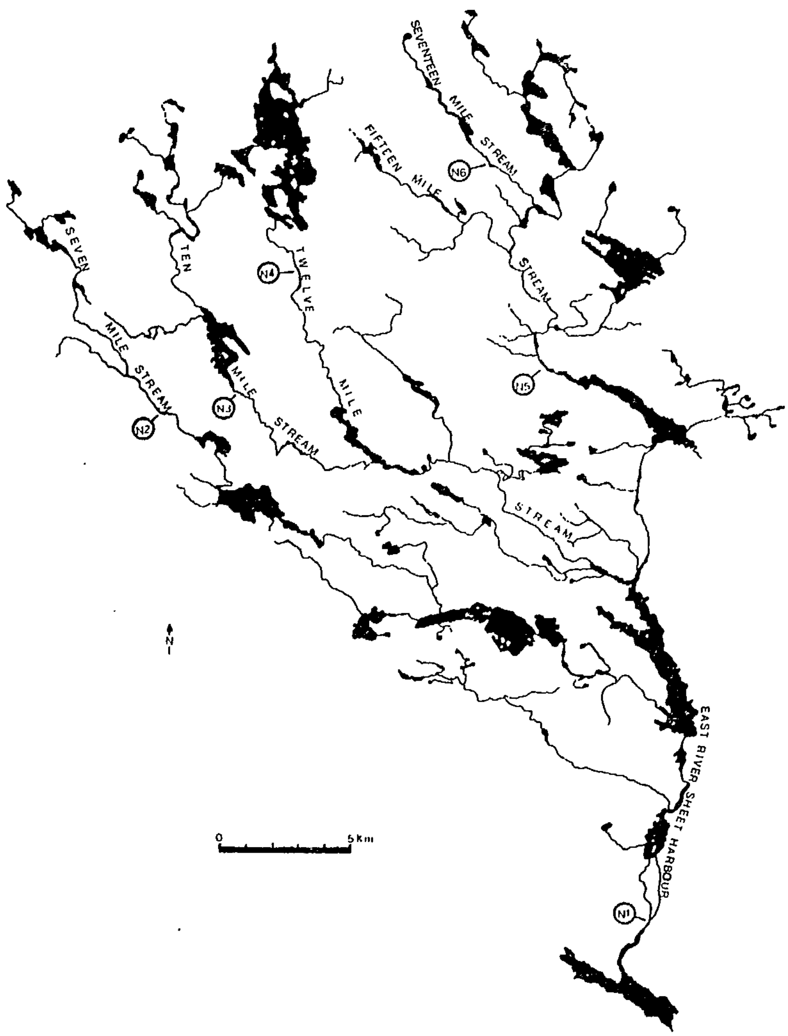

Fig. 13. Water sampling sites on East River Sheet Harbour

MOSER RIVER

The Moser River is located within both Halifax and Guysborough counties and drains to the eastern shore of Nova Scotia where it meets the Atlantic Ocean at Necum Teuch Harbour (Fig. 14). The predominant bedrock in the river's drainage area of 176 km^2 is greywacke (Keppie 1979); smaller areas of slate are also found. The mean sport catch on the Moser River during the 1951-82 period has been 200 Atlantic salmon per season, from an average annual effort of 3,842 rod-days (Smith 1981). Despite a decline in angler effort during that period, catch has remained relatively constant.

Water samples were first collected from three sites on the Moser River on May 13, 1982, when discharge at Liscomb Mills on the nearby Liscomb River was 10.3 m^3/s (Environment Canada 1983). That discharge was considerably lower than the May (1962-79) mean of 20.1 m^3/s at that gauging station (Environment Canada 1980). The pH at site P1, located just above the head of tide, was 5.20 on that date and alkalinity was <0.5 mg/L (Table 13). In accord, concentrations of calcium (0.8 mg/L) and magnesium (0.3 mg/L) were very low. The pH upriver, above Round Lake (P2), was only 4.80. In contrast, pH of the Melopseketch River (P3a) near it confluence with the Moser River was 5.70. Despite the relatively high pH at the latter site, alkalinity was <0.5 mg/L.

The soft, acidic water of the Moser River is, in part, attributable to the drainage area bedrock, which primarily consists of greywacke. However, drumlins, which contain soils of the Wolfville Series, are found in the area of Round and Boggy lakes (MacDougall et al. 1963; Hilchey et al. 1964) and are probably responsible for the higher pH measured in the lower part of the Melopseketch River. In contrast, the portion of the Moser River located above Round Lake drains rock land and soils of the Danesville and Halifax series which are derived from greywacke and which apparently provide little acid-neutralizing capacity to the river. Water from the Melopseketch River and drumlins in the area of Round and Kelly lakes apparently increase the pH of the lower Moser River.

Water samples were again collected from the Moser River on September 2 when discharge at Liscomb Mills was 3.8 m^3/s and considerably lower than the September mean of 6.6 m^3/s (Environment Canada 1980, 1983). If similar low discharge conditions existed on the Moser River on September 2, river pH was expected to be maximal at that time (Watt et al. 1983). Thus pH at site P1 located just above the head of tide was 5.45 on that day and alkalinity measured 1.1 mg/L. Measurements of both total hardness (6.0 mg/L) and colour (75 units) at that site were greater than recorded during the spring. In contrast, pH of the Moser River above Round Lake (P2) was only 4.90. Apparent colour at that site measured 120 relative units, indicative of a considerable input of humates from peat deposits in the upper watershed. The Melopseketch River was sampled between Boggy and Melopseketch lakes (P3b) on that occasion and pH was only 5.25 and alkalinity <0.5 mg/L. This is probably attributable to the fact that Melopseketch Lake lies on greywacke in an area of rock land and soils of the Halifax Series which provide little acid-neutralizing capacity. The lower section of this river has a higher pH because drumlins, which contain soils of the Wolfville Series, are found in that area.

Chemical analysis of water from the Moser River indicates that water quality in the lower section of the Melopseketch River and in the area of the Moser River located below Round Lake are best suited for the natural reproduction of Atlantic salmon. Acidic conditions observed in the section of river located above Round Lake suggest that mortality may occur among naturally produced Atlantic salmon fry at the time of first feeding (Farmer et al. 1983).

Table 13. Some chemical characteristics of the Moser River system during May and September of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)	Ca	Mg	Cl	SO_4	Al [1] (μg/L)
							(mg/L)				
May 13											
P1	Above head of tide	5.20	<0.5	3.6	23	50	0.8	0.3	3.9	3.4	
P2	Above Round Lake	4.80	<0.5	2.6	22	55					
P3a	Melopseketch River	5.70	<0.5	3.5	22	25					
September 2											
P1	Above head of tide	5.45	1.1	6.0	33	75			6.7	3.2	350
P2	Above Round Lake	4.90	<0.5	3.5	25	120					
P3b	Melopseketch River	5.25	<0.5	3.6	21	15					

1. The water sample for the determination of aluminum was collected on August 9, 1983.

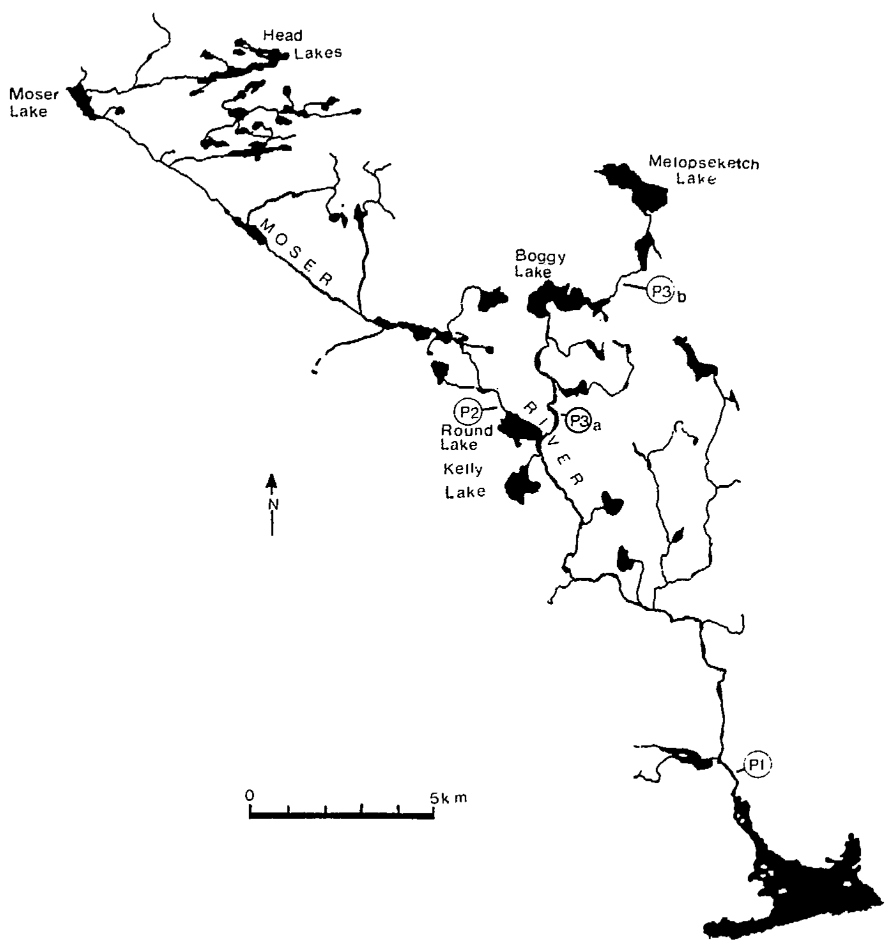

Fig. 14. Water sampling sites on Moser River

LISCOMB RIVER

The Liscomb River is located in Guysborough County and flows to the eastern shore of Nova Scotia where it meets the Atlantic Ocean at Liscomb Harbour (Fig. 15). The river has a drainage area of 389 km^2 and the 1963-79 mean annual discharge at Liscomb Mills located near the head of tide has been 15.9 m^3/s (Environment Canada 1980). The predominant bedrock in the rivers drainage area consists of greywacke (Keppie 1979). Smaller bands of slate are associated with the greywacke in some areas. Prior to 1977, when the Liscomb fishway was completed at a location 3.5 km above the head of tide, the area below the fishway site supported a sport fishery that captured an average of 54 salmon per year from a mean effort of 533 rod days per year (Smith 1981). Since completion of the fishway, salmon have had access to the upper watershed and hatchery-produced smolts have been released in that area each spring since 1977 in an effort to increase the spawning escapement (Gray and Cameron 1980). In this regard, 868 hatchery-return and 262 native salmon passed through the fishway during 1982.

Water samples were first collected from six sites on the Liscomb and Little Liscomb rivers on April 14, 1982, when discharge at Liscomb Mills was 25.6 m^3/s and similar to the mean April discharge of 28.7 m^3/s at that site (Environment Canada 1980, 1983). The pH of the Liscomb River below Ladle Lake (Q4) on that date was 4.80 (Table 14). The low concentrations of calcium (0.6 mg/L) and magnesium (0.3 mg/L) measured at that site reflect the presence in the drainage area of greywacke which is relatively resistant to chemical weathering. The pH of the Little Liscomb River at a site above Yankee Lake (Q3) was 4.70. Values of other chemical parameters at that site were similar to those recorded for the Liscomb River below Ladle Lake. The pH values at other sites sampled on April 14 were <5.0 and therefore alkalinity was not detected at these locations. For example, the pH of Hardwood Lake Brook (Q2) was 4.55, Big Brook (Q5) had a pH of 4.90, and the pH below Rush Lake (Q6), which is located near the headwaters of the Liscomb River, was 4.80.

Water samples for chemical analysis were again collected from the various sites on September 3, 1982, when discharge at Liscomb Mills was 7.9 m^3/s similar to the September mean of 6.6 m^3/s (Environment Canada 1980, 1983). Despite the low discharge on that date, pH of the Liscomb River below Ladle Lake (Q4) was only 4.91. Apparent colour had increased to 110 relative units and aluminum measured 300 µg/L. Chemical parameters of the Little Liscomb River at Site Q3 were generally similar to those measured at Site Q4 on the Liscomb River. However, the aluminum concentration of 420 µg/L at Site Q3 was greater than observed for the Liscomb River. Alkalinity was not detected in any of the samples collected at the remaining sites on September 3 (Q1, Q2, Q5 and Q6) and pH values at those locations were low and ranged from 4.69 to 5.05.

The very soft acidic water of the Liscomb River system can be related to the underlying bedrock of greywacke, to inputs of acidic precipitation (Watt et al. 1983) and to the shallow acidic soils in the drainage basin. Soils in that area primarily belong to the Halifax and Aspotogan series which are unsuitable for agriculture (Hilchey et al. 1964) and provide little acid-neutralizing capacity to the river. The remaining soils in the area are classified as either rock land or as peat deposits. Our analysis of water from the Liscomb River system suggests that a partial mortality among naturally produced salmon fry could occur at the time of first feeding (Farmer et al. 1980). In this context, Semple (pers. comm.[1]) observed that salmon fry densities ranged from 25 to 93/100 m^2 within an area which extended 1.6 km downstream from a limestone gravel bed which had been deposited in the Liscomb River to increase pH. In contrast, fry densities above the limestone or at sites from 32 km to 40 km downstream ranged from 0 to 10/100 m^2. Parr densities were low at all sites and ranged from 0 to 8/100 m^2. No juvenile salmon have been found during electrofishing surveys on the Little Liscomb River.

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1. Semple, J.R. 1982. Biologist. Department of Fisheries and Oceans, Halifax, N.S.

Table 14. Some chemical characteristics of the Liscomb River system during April and September of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (µS/cm)	Apparent colour (relative units)	Ca	Mg	Cl	SO_4	Al[1] (µg/L)
							(mg/L)				
April 14											
Q1	Above head of tide	4.81	<0.5	3.4	28	55					
Q2	Hardwood Lake Brook	4.55	<0.5	2.9	31	55					
Q3	Little Liscomb River	4.70	<0.5	2.7	30	45	0.5	0.4	4.4	2.8	
Q4	Below Ladle Lake	4.80	<0.5	3.0	25	55	0.6	0.3	3.9	2.8	
Q5	Below Big Brook Lake	4.90	<0.5	3.2	26	30					
Q6	Below Rush Lake	4.80	<0.5	2.7	24	30					
September 3											
Q1	Above head of tide	4.78	<0.5	3.8	29	140					
Q2	Hardwood Lake Brook	4.69	<0.5	3.4	26	130					
Q3	Little Liscomb River	4.78	<0.5	3.5	25	120			3.6	1.5	420
Q4	Below Ladle Lake	4.91	<0.5	4.2	23	110			3.3	2.3	300
Q5	Below Big Brook Lake	5.05	<0.5	3.6	21	50					
Q6	Below Rush Lake	4.98	<0.5	3.0	20	25					

1. The water samples for the determination of aluminum were collected on August 9, 1983.

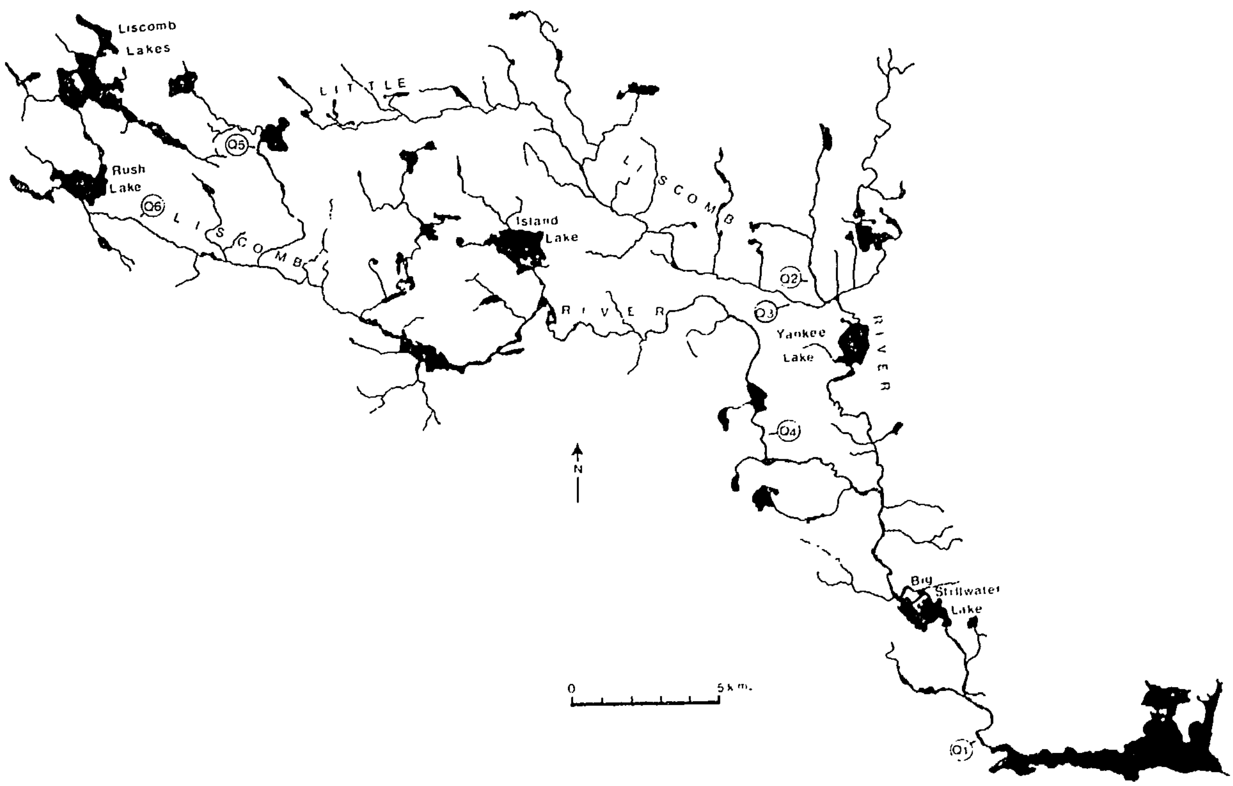

Fig. 15. Water sampling sites on Liscomb River

ST. MARY'S RIVER

The St. Mary's River system drains a 1,350-km^2 area of Guysborough, Antigonish and Pictou Counties, then meets the Atlantic Ocean at Cape St. Mary on the eastern shore of Nova Scotia (Fig. 16). The mean annual river discharge at Stillwater during the 1916-79 period has been 42.8 m^3/s (Environment Canada 1980). Salmon sport catch and effort have remained constant throughout the 1951-82 period, and the St. Mary's River is regarded as one of the best angling rivers in the province. The mean annual catch on the river during that time has been 669 adult salmon from a mean effort of 4,646 rod days (Smith 1981).

Water samples were first collected from the St. Mary's River system on April 13, 1982, when discharge at Stillwater was 49.5 m^3/s and considerably lower than the mean discharge of 90.2 m^3/s recorded at that site during the month of April (Environment Canada 1980, 1983). The pH and alkalinity on that date at Site S1 located just above the head of tide were 6.04 and 1.3 mg/L, respectively (Table 15). These values of pH and alkalinity were intermediate to those measured at sites on the East River St. Mary's, where values were greater and on the West River St. Mary's where values were lower. For example, the pH of the East River St. Mary's below Glenelg Lake (S3) was 6.30 and alkalinity measured 2.8 mg/L. Chemical characteristics of five tributaries (McKeen Brook, Two Mile Brook, below the confluence of Greens and Black brooks, Garden River and Moose River - Site S4 to Site S8) were similar, as pH was observed to range from 5.65 to 6.58 and alkalinity from 0.7 to 4.7 mg/L. Conversely, the pH and alkalinity of the West River St. Mary's at Site S9 (Near Glenelg) were 5.60 and 0.5 mg/L, respectively. The pH of 10 tributaries (Glencross Brook, Indian Man Brook, MacDonald Brook, Sutherland Brook, Barren Brook, Black Brook, Cross Brook, South Lake Brook, Castley Brook and Nelson River - Site S10 to Site S22) to the West River St. Mary's sampled on that date ranged from 5.02 to 5.45. Barren Brook was the only tributary that had detectable alkalinity (0.5 mg/L). Archibald Brook (S2), which enters the St. Mary's River below the confluence of the east and west branches, had a pH of 4.82 on April 13 and the apparent colour was greater than for other tributaries of the St. Mary's system.

The various sites on the St. Mary's system were again sampled on October 14, 1982, when the discharge at Stillwater was 5.21 m^3/s and considerably less than the October mean of 34.2 m^3/s (Environment Canada 1980, 1983). The pH and alkalinity of the East River St. Mary's below Glenelg Lake (S3) measured 6.59 and 5.3 mg/L, respectively, and were greater than observed at that site during April. The pH of the other tributaries to the East River St. Mary's (S4-S8) ranged from 6.30 to 6.92 on October 14 and alkalinity from 1.9 to 10.1 mg/L. Both pH and alkalinity of sites on the West River St. Mary's were again lower than values measured at sites on the east branch of the river. For example, pH and alkalinity at Site S9 near Glenelg Lake were 6.25 and 1.6 mg/L, respectively. The pH of the 13 tributaries to the West River St. Mary's (Sites S10-S22) ranged from 5.70 to 6.35 on that date and alkalinity from 0.5 to 2.8 mg/L. Aluminum concentration was 300 µg/L at Site S3 on the East River St. Mary's and 530 µg/L at Site S9 on the West River St. Mary's, suggesting that there has been some leaching of this metal from the drainage area. Measurements of inorganic aluminum should be made for the more acidic tributaries of the St. Mary's system to determine if toxic concentrations of this metal are present.

The pH of the Archibald Brook (S2) had increased to 5.31 by October 14 but alkalinity was <0.5 mg/L. Values of pH for this brook were lower than observed for other tributaries to the St. Mary's system on both the April and October sampling dates. This is probably attributable to the bedrock in the area of Archibald Brook composed of greywacke and granitic rock (Keppie 1979) which provide little acid-neutralizing capacity.

The pH and alkalinity of sites on the East River St. Mary's system were greater on both sampling dates than observed for sites on the West River St. Mary's system. The bedrock in the East River St. Mary's drainage area is composed of the Horton Group, which includes sandstone, siltstone, shale, conglomerate, dolostone and coal (Keppie 1979). Acid-neutralizing capacity is probably provided to the east branch primarily by dolostone and sandstone. Although the grains of sandstone are usually quartz, they are held together by calcareous (including dolomitic) cement which provides alkalinity to the river. Two Mile Brook originates in an area where the Windsor Group of rocks predominate (sandstone, siltsone, limestone, dolostone, anhydrite, gypsum, salt) and then drains the Knoydart Formation composed of sandstone. These formations provide considerable acid-neutralizing capacity to this brook. The Moose River, Garden River and the Green and Black brooks drain an area where the bedrock is composed of volcanic rocks, wacke and argillite (Keppock Formation; undifferentiated Hadrynian-Cambrian) and of sandstone and limestone (Arisaig Group).

The West River St. Mary's is located near a line dividing rocks of the Goldenville Formation (greywacke, slate and schist) from the Horton Group of rocks (Keppie 1979). Most tributaries lie on the latter group of rocks and receive their acid-neutralizing capacity from sandstone and dolostone. Soils in this area are the Halifax type derived from quartzite and slate and considered unsuitable for crops (Hilchey et al. 1964). These soils apparently provide little acid-neutralizing capacity to the West River St. Mary's and it's tributaries.

Athough alkalinity was <0.5 mg/L in most tributaries of the West River St. Mary's on April 13, all measurements of pH exceeded 5.0 suggesting that juvenile salmon mortality attributable to acidity may not be occurring in that branch. However, aluminum should be monitored to determine if toxic concentrations are present. Earlier chemical analyses of tributaries to the West River St. Mary's are not available for comparison with present data, to determine whether alkalinity in that branch of the river has declined as a result of acidic precipitation. The water quality of the East River St. Mary's and its tributaries was found to be suitable for the natural reproduction of Atlantic salmon. However, acidity may be causing mortality among juvenile salmon in Archibald Brook which drains an area composed of greywacke and granitic rock.

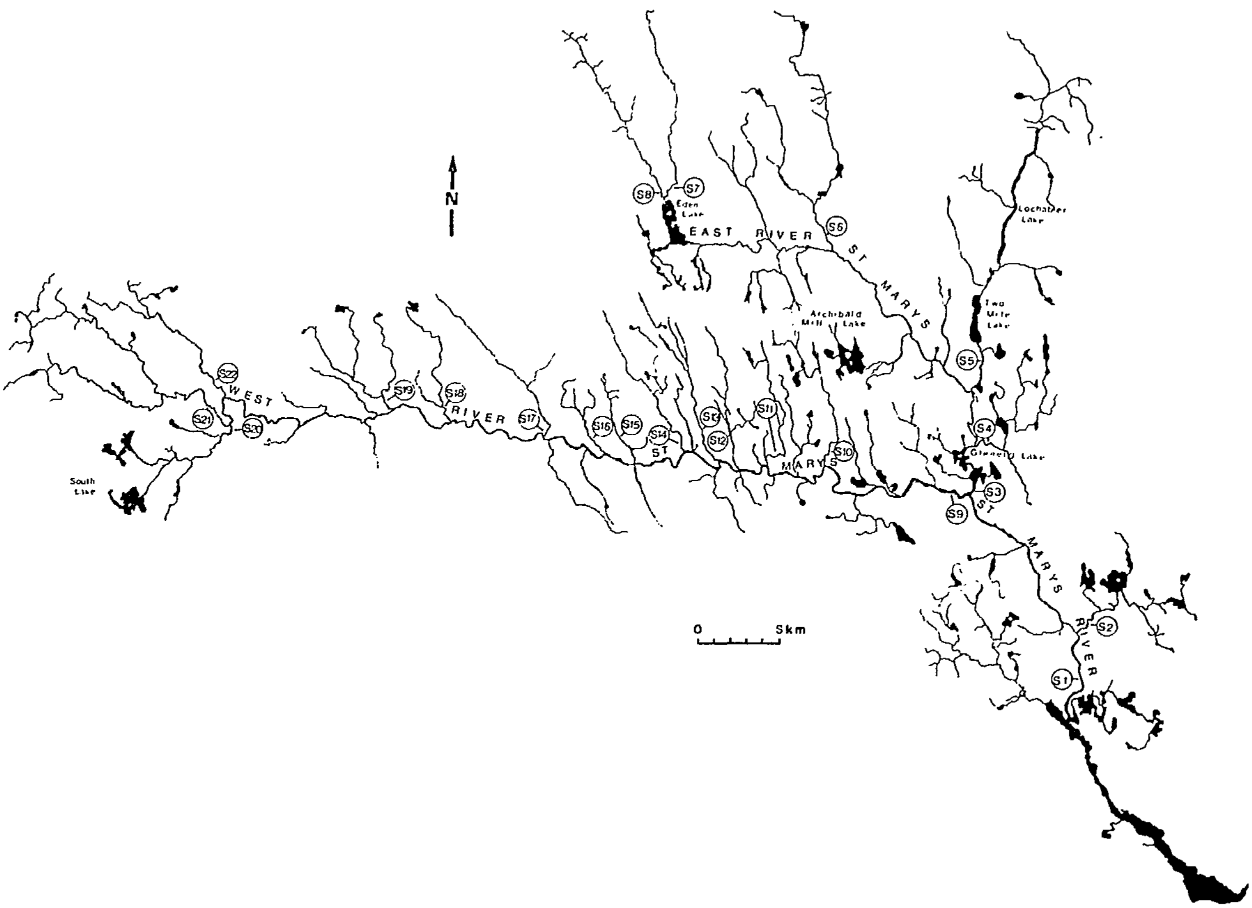

Fig. 16. Water sampling sites on St. Mary's River

Table 15. Some chemical characteristics of the St. Mary's River system during April and October of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)	Ca	Mg	Cl	SO_4	Al[1] (μg/L)
							(mg/L)				
April 13											
S1	Above head of tide	6.04	1.3	5.0	28	20					
S2	Archibald Brook	4.82	<0.5	2.5	25	40					
S3	East River St. Mary's	6.30	2.8	6.6	35	15	1.2	0.6	5.7	2.8	
S4	McKeen Brook	5.65	0.7	4.0	30	15					
S5	Below Two Mile Lake	6.40	4.7	10.7	47	15					
S6	Below Greens and Black brooks	6.58	3.5	6.9	31	15					
S7	Garden River	6.40	2.9	7.5	30	15					
S8	Moose River	6.53	3.9	8.7	45	15					
S9	West River St. Mary's	5.60	0.5	3.5	23	20	0.7	0.5	3.9	2.3	
S10	Glencross Brook	5.45	<0.5	3.6	23	20					
S11	Indian Man Brook	5.05	<0.5	3.0	24	20					
S12	Duncan MacDonald Brook	5.28	<0.5	3.0	24	15					
S13	Sutherland Brook	5.33	<0.5	3.0	21	20					
S14	Barren Brook	5.41	0.5	3.5	23	25					
S15	Black Brook	5.40	<0.5	3.9	23	25					
S17	Cross Brook	5.40	<0.5	4.0	25	20					
S20	South Lake Brook	5.02	<0.5	3.5	26	25					
S21	Nelson River	5.35	<0.5	4.0	22	20					
S22	Castley Brook	5.18	<0.5	2.8	21	20					
October 14											
S1	Above head of tide	6.63	3.4	6.2	34	25					
S2	Archibald Brook	5.31	<0.5	3.5	28	60					
S3	East River St. Mary's	6.59	5.3	9.1	40	25			6.7	3.4	300
S4	McKeen Brook	6.30	1.9	5.0	29	25					
S5	Below Two Mile Lake	6.90	6.7	12.9	49	15					
S6	Below Greens and Black brooks	6.92	8.0	25.8	43	50					
S7	Garden River	6.82	7.7	25.9	41	25					
S8	Moose River	6.85	10.1	15.8	67	15					
S9	West River St. Mary's	6.25	1.6	5.5	26	25			4.7	2.2	530
S10	Glencross Brook	5.70	0.5	4.0	21	70					
S11	Indian Man Brook	5.75	0.9	3.5	21	70					
S12	Duncan MacDonald Brook	6.02	2.1	4.0	22	45					
S13	Sutherland Brook	5.92	1.7	4.0	22	30					
S14	Barren Brook	6.00	1.9	4.6	26	50					
S15	Black Brook	6.00	2.3	5.5	24	75					
S16	Ross Brook	5.87	0.7	3.9	21	20					
S17	Cross Brook	6.07	2.0	5.6	28	20					
S18	Bryden Brook	5.78	1.7	5.0	24	20					
S19	Upper Bryden Brook	6.13	2.4	5.5	25	20					
S20	South Lake Brook	5.79	0.8	4.5	24	45					
S21	Nelson River	6.35	2.8	6.4	27	55					
S22	Castley Brook	5.90	1.5	4.5	24	55					

1. The water samples for the determination of aluminum were collected on August 9, 1983.

Other Atlantic Salmon Rivers

Some smaller rivers thought to support populations of Atlantic salmon (Smith, 1981), but for which recent water chemistry information is not available, were sampled during March of 1982. Water samples were collected just above the head of tide of each river.

Martins Brook (No. 10, Fig. 1)

Martins Brook drains a 98.4-km^2 area of Lunenburg County and meets the Atlantic Ocean at Mahone Bay. Water samples were collected from this brook on March 8, 1982, at a time when river pH has shown little increase from the minimal values which usually occur during January and February (Watt et al. 1983). The pH of Martins Brook on that date was only 4.60 (Table 16). Total hardness was 4.0 mg/L and apparent colour measured 60 relative units. Angling records (Smith 1981) indicate that salmon have not been captured in this brook since 1973. The lack of angling success in Martins Brook may be attributable to its acidity which in turn can be partly explained by the bedrock in the drainage area. The headwaters lie on granitic rock, which provides little acid-neutralizing capacity, while the lower areas lie on slate (Keppie 1979). Drumlins are not associated with the areas of slate. The soil types in the drainage area are Gibraltar sandy loam which is considered poor for agricultural purposes and Bridgewater sandy loam which is only fair for crops (Cann and Hilchey 1958). Apparently these soils do not provide sufficient acid-neutralizing capacity to maintain pH of this brook at values $\geq$5.0.

Little Salmon River (No. 13, Fig. 1)

The Little Salmon River drains a 64.8-km^2 area of Halifax County and meets the Atlantic Ocean at Cole Harbour. Water samples collected near the head of tide on March 8 showed that pH was 5.25 and that total alkalinity measured <0.5 mg/L (Table 16). Total hardness was 7.7 mg/L and apparent colour, 20 relative units. Despite the fact that pH was >5.0, only one salmon was reported to have been angled in the river during the 1951-79 period (Smith 1981). The bedrock in the drainage area consists of granitic rock, greywacke and slate (Keppie 1979) and the associated soil types include the Halifax, Gibraltar and Bridgewater series (MacDougall et al. 1963). The lower section of the river is populated and some agricultural activity is associated with the Bridgewater soils in that area, which may explain why pH was >5.0. Although fish passage to the upper tributaries is provided at Lake Major, water in those areas may be considerably more acidic. Electrofishing near Echo Pool, located below Lake Major, captured underyearling brook trout but no juvenile salmon during July of 1984.

Salmon River (Lawrencetown Lake) (No. 14, Fig. 1)

The Salmon River is located in Halifax County and meets the Atlantic Ocean at Lawrencetown. The pH on March 8 was 4.50 total hardness measured 3.8 mg/L and apparent colour, 50 relative units (Table 16). Watt et al. (1983) demonstrated that a significant decline in the salmon angling catch occurred on this river during the 1936-45 period and Smith (1981) reports that salmon have not been angled since 1953. In accord, juvenile salmon have not been observed by electrofishing during 10 recent site visits (Watt et al. 1983). The loss of the salmon population in this river is apparently attributable to its increased acidity. The river primarily lies on granitic rock and greywacke which provide little acid-neutralizing capacity (Keppie 1979). Smaller areas of slate are located near the river mouth. The soil types associated with the granitic rock and greywacke are the Gibraltar and Halifax series (MacDougall et al. 1963), which do not effectively neutralize acid inputs. Although soils of the Bridgewater and Wolfville series which possess acid-neutralizing capacity are associated with the slate areas, they are located near the mouth of the river which negates their beneficial effects.

Chezzetcook River (No. 15, Fig. 1)

The Chezzetcook River is located in Halifax County and meets the Atlantic Ocean at Chezzetcook Inlet on the eastern shore of Nova Scotia. Water samples collected just above the head of tide on March 8, 1982, showed that pH was only 4.74 (Table 16). Total hardness measured 4.0 mg/L and apparent colour, 50 relative units. There are no reports of salmon having been angled in this river since 1959 (Smith 1981). The acidity of the river is partly related to the drainage basin bedrock which primarily consists of granitic rock and greywacke and a smaller area of slate located in the downstream section (Keppie 1979). Soils of the Gibraltar and Halifax series predominate (MacDougall et al. 1963) and provide little acid-neutralizing capacity to the river. Bridgewater and Wolfville soils, capable of neutralizing acid inputs, are associated with the area of slate in the lower portion of the system. It is possible that pH exceeds 5.0 during fry emergence and that a small population of salmon continues to inhabit the river. However, during July of 1984, neither salmon nor speckled trout were captured by electrofishing in a section of the river between Route 7 and Chezzetcook Lake.

Taylor Bay Brook (No. 18, Fig. 1)

The East and West Taylor Bay brooks are located in Halifax County and meet the Atlantic Ocean at Taylor Bay, located on the eastern shore of Nova Scotia. There are no reports of salmon having been angled in these brooks since 1952 (Smith 1981). The West Taylor Bay Brook is the larger of the two and was sampled on March 9, 1982, at a site located just above the head of tide. The pH on that day was 4.54, total hardness measured 2.4 mg/L and apparent colour, 50 relative units (Table 16). The acidity of the brook can be related to the bedrock in its drainage basin which consists of granitic rock and greywacke (Keppie 1979). In addition, the soils associated with these rocks belong to the Gibraltar and Halifax series (MacDougall et al. 1963), which do not effectively reduce acid inputs to the brook. Despite the low pH of this brook, four salmon parr were captured during July of 1984, by electrofishing in a section of the brook located just above Route 7.

Necum Teuch River (Smith Brook) (No. 23, Fig. 1)

The Necum Teuch River is located in Halifax County and drains to Nova Scotia's eastern shore where it meets the Atlantic Ocean at Necum Teuch Bay. Salmon were reported to have been angled in the river during 1965, 1966 and 1967 but not prior to or following those years (Smith 1981) which suggests there has been a lack of surveillance and reporting by fisheries officers of angling in this river. Water samples collected on March 8, 1982, showed that pH was 4.99 (Table 16). Total hardness measured 3.3 mg/L and apparent colour, 50 relative units. The river lies on greywacke and slate (Keppie 1979) and the soil types associated with these rocks belong to the Halifax, Danesville and Hebert series (MacDougall et al. 1963). Drumlins, composed of soils belonging to the Wolfville series, are found near Smith Lake and provide the headwaters of the river with some acid-neutralizing capacity so that pH remains near 5.0. In this regard, the Wolfville soils are derived from shale and sandstone. During July of 1984, four 0+ and 28 1+ parr were captured by electrofishing in a section of this river located near Route 7.

Gegogan Brook (No. 25, Fig. 1)

Gegogan Brook is located in Guysborough County and drains to the eastern shore of Nova Scotia where it meets the Atlantic Ocean at Gegogan Harbour. During the 1951-79 period, Atlantic salmon were reported to have been angled in the brook only during 1961 and 1962 (Smith 1981). This suggests there has been a lack of surveillance and reporting of catch by fisheries officers responsible for the protection of this small brook. Water samples collected near the head of tide on March 8, 1982, indicated that pH was 5.03 and alkalinity $<$ 0.5 mg/L (Table 16). Total hardness measured 5.0 mg/L and apparent colour was 50 relative units. The acidity of the brook can be related to the bedrock in its drainage basin which primarily consists of greywacke (Keppie 1979). The soil types associated with the brook consist of the Halifax, Aspotogan and Danesville series, which can be characterized as extremely stoney and shallow and unsuitable for agricultural purposes (Hilchey et al. 1964). Although these soils provide only limited acid-neutralizing capacity to the brook, pH was near 5.0 during March, suggesting that it may continue to support a small population of Atlantic salmon. However, during July of 1984, no salmon or speckled trout were captured by electrofishing at two sites on the river located near Route 7.

Indian Harbour Lakes (No. 28, Fig. 1)

Salmon have been observed, by local residents, to spawn in the short runs between these Guysborough County lakes. The lakes drain to the eastern shore of Nova Scotia and meet the Atlantic Ocean at Indian Harbour. Salmon angling statistics for this system are not available (Smith 1981). Water samples collected on March 7, 1982, at a site located just above the head of tide, indicated that pH was 5.41 and that alkalinity was $<$0.5 mg/L (Table 16). Total hardness measured 4.2 mg/L and apparent colour, 25 relative units. The soft, acidic water of the lakes are, in part, related to the bedrock in the area which primarily consists of granitic rock and greywacke (Keppie 1979). In addition, the Halifax and Gibraltar soils in the drainage basin are generally unsuitable for agricultural purposes (Hilchey et al. 1964) and provide little acid-neutralizing capacity. Despite this, pH was 5.41 and suitable for the natural reproduction of Atlantic salmon. This may be attributable to the Hebert soils found in the vicinity of the lakes which are considered fair for agricultural purposes and which may act to neutralize acid inputs to the lakes.

Indian River (No. 29, Fig. 1)

The Indian River originates at the Head Lakes located in Guysborough County and drains to Holland Harbour on the eastern shore of Nova Scotia. Salmon have not been angled in this river since 1961 (Smith 1981). Water samples collect on March 7, 1982, indicated that pH was 4.56 (Table 16). Total hardness measured 3.5 mg/L on that date and apparent colour, 65 relative units. The low pH of the river can be related to the drainage area bedrock which primarily consists of greywacke and to the associated soils (classified as the Halifax and Aspotogan series; peat; rock) neither of which provide sufficient acid-neutralizing capacity to reduce acid inputs to the river (Keppie 1979; Hilchey et al. 1964). Natural recruitment of Atlantic salmon in this river may not be presently possible. In accord, no salmon or speckled trout were captured by electrofishing during July of 1984 at a site on the river near Harpellville.

Table 16. Some chemical characteristics of nine smaller rivers sampled during March of 1982.

Site	Site name	pH	Total alkalinity (mg/L)	Total hardness (mg/L)	Specific conductance (μS/cm)	Apparent colour (relative units)
March 2	Martins Brook	4.60	<0.5	4.0	35	60
March 8	Little Salmon River	5.25	<0.5	7.7	77	20
March 8	Salmon River (Lawrencetown Lake)	4.50	<0.5	3.8	37	50
March 8	Chezzetcook River	4.74	<0.5	4.0	40	50
March 8	Taylor Bay Brook	4.54	<0.5	2.4	34	50
March 8	Necum Teuch River (Smith Brook)	4.99	<0.5	3.3	52	50
March 8	Gegogan Brook	5.03	<0.5	5.0	43	50
March 7	Indian Harbour Lakes	5.41	<0.5	4.2	37	25
March 7	Indian River	4.56	<0.5	3.5	42	65

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ACKNOWLEDGEMENTS

We are indebted to O. Vaidya and S. Ray who conducted the metal analyses and to W. Horne who provided valuable assistance with the chloride determinations. We thank Ms. E.J. McLean, Mrs. K. Newbould and T.R. Goff who assisted with the collection of water samples. Mrs. T. Hart typed the manuscript and K.E.H. Smith provided valuable editorial comments. Drs. R.H. Peterson and J.R.M. Kelso reviewed an earlier draft of the manuscript.