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Influence of Water pH on Frequency of Collection of Certain Invertebrates During Lake and Stream Surveys in New Brunswick and Nova Scotia

R. H. Peterson

Biological Station,
St. Andrews, N. B., E0G2X0

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INFLUENCE OF WATER pH ON FREQUENCY OF COLLECTION OF CERTAIN INVERTEBRATES DURING LAKE AND STREAM SURVEYS IN NEW BRUNSWICK AND NOVA SCOTIA

R. H. Peterson
Fisheries and Environmental Sciences Division
Biological Sciences Branch
Department of Fisheries and Oceans
Biological Station
St. Andrews, N.B. E0G 2X0
Canada

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ABSTRACT

Peterson, R. H. 1987. Influence of water pH on frequency of collection of certain invertebrates during lake and stream surveys in New Brunswick and Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 1523: iii + 7 p.

Gastropods were not collected from lakes or streams in New Brunswick or Nova Scotia with a water pH less than 5.0, while sphaeriid clams were collected from lakes with pH as low as 4.6. Unionidae were encountered infrequently and not at all in lakes of pH less than 6.0. The frequency with which Hyalella was sampled was graded with decreasing numbers correlated with decreasing lake pH. Hexagenia sp. is tolerant of low pH and was sampled most frequently from lakes of pH 4.3-6.5.

RÉSUMÉ

Peterson, R. H. 1987. Influence of water pH on frequency of collection of certain invertebrates during lake and stream surveys in New Brunswick and Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 1523: iii + 7 p.

Aucun gastéropode n'a été recueilli dans les lacs ou les cours d'eau du Nouveau-Brunswick ou de la Nouvelle-Écosse dont le pH était inférieur à 5,0 tandis qu'on a recueilli des sphaeriidés dans des lacs dont le pH était aussi bas que 4,6. On y a trouvé assez peu d'unionidae et il n'y en avait pas du tout dans les lacs dont le pH était moins de 6,0. Pour ce qui est de l'Hyalella, on a noté que la fréquence des prélèvements établie en ordre décroissant coïncidait avec le pH décroissant des eaux des lacs. Quant à Hexagenia sp. il tolère bien les lacs au pH bas et il a été prélevé les plus souvent dans des lacs ayant un pH de 4,3-6,5.

INTRODUCTION

The ways in which various environmental factors act in concert to limit temporal and spatial distributions of living organisms has been a major field of endeavor for biologists for many years. Several generalizations have resulted, such as Blackman's principle of limiting factors, Liebig's law of minimum, and Shelford's law of tolerance (e.g. Odum 1959). With the increasing concern over anthropogenic acidification of water bodies over the last two decades, the limitations imposed upon distributions of various aquatic organisms by low pH and low pH-calcium interactions have been frequently investigated.

Considerable literature is accumulating which describes the trends in abundance of various freshwater invertebrates with correlated trends in lake and stream pH. The most completely documented surveys have been performed in Norway. Økland has been mapping the distributions of Gastropoda in Norway for 20 yr (J. Økland 1969, 1980), and has concluded that both water pH and Ca^{2+} are important in determining the presence of snails in lakes. Altitude, amount of macrophytic vegetation, and water color seemed important also. The mean number of species for lakes with pH of 7.0 or above was about 20. A prominent decrease in species numbers occurred near pH 6.0 and no snails were found at pH levels lower than 5.1. Freshwater sphaeriid mussels, as a group, appear slightly more tolerant than snails with numbers of species declining from a mean of 17 at pH $\geq$7.0 to 4 at pH 5.7 and none at pH 4.6. The amphipod Gammarus lacustris was not found below a pH of 6.0 and Asellus was not found below pH 5.2. Conversely, Rooke and Mackie (1984) concluded from a survey of six lakes, with a rather restricted alkalinity range of 0.2-3.2 $mg \cdot L^{-1}$ (pH was not given), that there were no consistent differences in number of molluscan species across the limited range. They suggested that other factors, such as mean lake depth, influenced ease of collection and, hence, conclusions as to presence or absence. They did find that some species were more tolerant than others. The sphaeriid clam, Pisidium, was more resistant to low alkalinity than was the snail, Amnicola. They suggested that this difference might be related to differing reproductive strategies or two differing life habits -- Pisidium burrows, while Amnicola does not.

Surveys of stream invertebrates have emphasized the influence of pH on insect communities. Sutcliffe and Carrick (1973), in a survey of mountain streams in the English lake district, found Ephemeroptera to be absent from streams with pH less than 5.7 as were the Trichoptera genera Wormaldia and Hydropsyche, and the amphipod Gammarus. They concluded that Ca^{2+} was less important than pH in limiting distribution. Townsend et al. (1983), in a study of southern English streams, found that, while stream discharge was the most important factor determining numbers of organisms sampled, stream pH was the most important factor in determining species numbers -- low pH streams had fewer species.

In a survey of 20 Maritime streams, Peterson et al. (1985) found that more genera of Ephemeroptera were present in streams of high pH ($\geq$5.5) than in medium (4.7-5.4) or low (<4.7) pH streams. Similarly, a study of streams near Dorset, Ontario (MacKay and Kersey 1985) found that streams of pH 4.3-4.8 were devoid of Ephemeroptera while streams of pH 5.0-6.3 had 3-4 genera. Shredders (e.g. Eurylophella and the caddisfly Frenesia) appeared more tolerant of low pH than were collectors or grazers, possibly relating to the adaptation of shredders to foraging in acidic leaf packs. In a study of three first-order Adirondack streams (two at pH 4.4-5.0, one at pH 5.8-7.2), the less acidic stream had a more diverse fauna with Ephemerella funeralis and the beetle O. latiusculus being dominant. In the more acid tributaries, the plecopteran shredders Leuctra fenugina and Isoperla sp. were dominant. A study of two southwestern Pennsylvania streams (Kimmel et al. 1985) indicated that many taxa were lost from the more acid tributary during the spring acid snow-melt (e.g. Cambarus, Epeorus, Ephemerella, Heptagenia). Species richness increased again through the summer months. Leuctra, Chironomidae and Asellus were the only taxa in the acid tributary all year.

Experimental acidification of both natural and artificial streams have also demonstrated the sensitivity of various stream invertebrates to low pH. For example, Burton et al. (1985) observed increased mortality of Lepidostoma liba, Asellus intermedius, Physa heterostropha and Pycnopsyche sp. upon acidifying an artificial stream from pH 7.2 to 4.0 with H_2SO_4. Egg masses of the snail, Physa were killed upon transfer from high to low pH; although no mortality of large individuals was noted. Hall et al. (1980) found that experimental acidification of a brook in the Hubbard Brook watershed reduced emergence of Ephemeroptera, some Plecoptera and some Diptera. Both diversity and density were reduced. Stream acidification also eliminated recruitment of the mayfly species, Eurylophella funeralis.

The Canadian Maritime provinces, particularly Nova Scotia, have extensive areas characterized by waters of low pH (e.g. Watt et al. 1979; Wiltshire and Machell 1981; Peterson et al. 1986; Underwood et al. 1986). In July-August of 1981-82, a survey of 145 head-water lakes in New Brunswick and Nova Scotia included the sampling of benthic invertebrates (five grab samples per lake). An analysis of the water chemistry of these lakes is in press (Peterson et al. 1986). One must exercise caution in interpreting the results of such a limited sampling effort. However, the survey of a large number of lakes provides some redundancy so that reduced occurrence of some taxa may be reflected in the data. Obviously, one cannot be sure any given taxa is absent from a given lake, due to the limited sampling effort, but in some cases one may be able to postulate reduced abundance. In addition to the lake survey, some data on organisms from 20 Maritime streams which were not included in Peterson et al. (1985) are included here.

MATERIALS AND METHODS

Five replicate benthic samples were collected with a Birge-Ekman dredge from each of the 145 lakes (76 in Nova Scotia, 69 in New Brunswick). The sampling was performed from a helicopter in only one part of each lake. In most cases, this was near the deepest position of each lake, hence taxa that occur preferentially in littoral areas would be underrepresented or absent in the samples. Only data for five taxa; Hexagenia sp., Gastropoda, Sphaeriidae, Hyalella sp., and Unionidae will be presented as only these five were sampled frequently enough to permit any conclusions about trends as related to lake pH.

The streams were sampled more intensively with 6 to 10 Surber samples (methods described in Peterson et al. (1985)) taken in both June and August from each stream. Sampling was in stoney riffle areas at depths of 16 to 38 cm where the velocities ranged from 19-56 cm/s.

The distribution of lakes and streams sampled are presented in Peterson et al. (1986) and Peterson et al. (1985).

RESULTS AND DISCUSSION

Gastropods have frequently been cited as sensitive organisms to low pH and low calcium in the ambient water (J. Økland 1980). The results of the lake surveys in New Brunswick and Nova Scotia tend to support this generalization (Fig. 1, map 1). Snails were obtained from 35% of the sampled lakes which had a pH greater than 7.0 with a mean of just over 0.5 per sample. Both the frequency with which snails were encountered and the mean number per sample declined for lakes in progressively lower pH categories, and no snails were collected from lakes with a pH below or equal to 5.0. This is nearly identical to the pH level of 5.1 cited by Økland as the lowest pH at which he collected gastropods. Most of the very acidic lakes (≤5.0) sampled are in southwestern Nova Scotia, and snails were sampled in only two lakes from a total of 56 sampled. Lakes in Cape Breton all had pH levels in the 6.5-8.0 range, yet snails were collected from only one of these lakes. Snails would have been sampled more frequently if littoral areas with macrophytic vegetation had been sampled. The low pH lakes in southwestern Nova Scotia tended to be shallower than lakes sampled elsewhere (Peterson et al. 1986), so that the absence of snails in samples from these lakes cannot be ascribed to physical differences among the lakes. All things being equal, snails should be sampled more frequently from shallow lakes.

While snails are probably generally less abundant in lotic than lentic habitats, snails were sampled from a greater percentage of streams than lakes (Fig. 2), due no doubt, to the more intensive stream sampling. As with the lake data and in line with Økland's conclusions, no snails were sampled in streams of pH less than pH 5.0.

Sphaeriid clams are reportedly more tolerant of low pH than gastropods (K. A. Økland 1980; Rooke and Mackie 1984); nevertheless, no Sphaeriidae were sampled from lakes ≤pH 5.0 (Fig. 3, map 2). They were, however, collected in small numbers from three of six streams in the 4.6-5.0 pH range. (Fig. 4). Numbers of sphaeriid clams in lotic areas tend to increase in the out-falls of lakes or where there are high suspended nutrient loads, thus the fluctuations in mean numbers for streams of various pH categories (Fig. 3, lower panel) may reflect differences in these parameters. Sphaeriidae are also usually found in sandy sediments. Most of the acidic lakes of southwestern Nova Scotia occur in heath-like areas and may have a lot of organic floc sediments, which may not be suitable habitat for Sphaeriidae. This may explain their absence from samples taken from lakes in the 4.6-5.0 range. Clifford (1984) sampled Sphaeriidae from a Nova Scotia lake of pH 4.7.

Large mussels of the family Unionidae were encountered infrequently in lakes with pH levels above 6.0 (Fig. 5, map 3). Rooke and Mackie (1984), in their survey of six lakes in the Dorset area, suggested that Unionidae might be particularly sensitive to low pH. Kerekes (1975) reported that Unionidae were found only in Kejimkujik Park lakes of pH >6.0. While the data obtained in this lake survey are suggestive of extreme sensitivity, they are too scanty to be conclusive. The frequency with which they were sampled were very low from lakes of all pH categories. Unionidae are encountered only occasionally in stream samples and none were recorded in this survey.

Amphipoda are usually abundant organisms in lake sediments, and several authors have published data on their distributions in relation to lake pH. They were frequently sampled in lakes with pH levels above 7.0 (80% of the lakes with a mean of 4.5 per sample; Fig. 6, map 4). The abundance of *Hyalella* exhibited a graded decrease with decreasing lake pH and only one specimen was collected from the 15 surveyed lakes with a pH of less than 4.6. *Hyalella* appears to exhibit greater tolerance to low pH than has been reported in the literature for *Gammarus* sp. Meinel et al. (1985) found *Gammarus fossarum* to be very sensitive to low pH with physiological damage occurring at pH levels less than 6.0. Loss of sodium was implicated as a possible mechanism. Similarly, *Gammarus lacustris* was not found in Norwegian lakes of pH less than 6.0 (K. A. Økland 1980). *Hyalella* was not sampled with sufficient frequency in the stream sampling to provide any useful information.

The burrowing mayfly, *Hexagenia* sp., appears to be very tolerant of low pH (Fig. 7, map 5). It was sampled from only 15% of the lakes with pH greater than 6.5, but from 25-50% of lakes with lower pH. There were no obvious trends in either percent of lakes from which it was sampled or in mean numbers per sample for lakes of pH 6.5 or less. The tolerance of *Hexagenia* to low pH appears not to have been discussed in the literature. It requires a soft organic mud or ooze to burrow in. Many of the low pH lakes are peaty, and probably have an organic floc superficial sediment which would be suitable habitat. MacKay and Kersey (1985) postulated that certain bog species, such as *Frenesia difficilis*, were more acid tolerant. *Hexagenia* sp. may fit into this category as well. Rooke and Mackie (1984) postulated that forms, such as *Pisidium* which burrow in the sediments may be protected, by the sediment buffering capacity, from exposure to low ambient pH. As *Hexagenia* is a burrower, that sort of reasoning may be applicable to this species as well.

CONCLUSIONS

The pH levels of lakes from which no *Gastropoda*, *Sphaeriidae*, and *Unionidae* were collected are similar to those reported for these taxa from other geographic areas. Thus, the data may reveal true sensitivities despite sampling inadequacies.

Hyalella sp. in Maritime lakes appears to be somewhat more tolerant of low ambient pH when compared with reported tolerances of other Amphipoda, such as Gammarus sp.

Hexagenia sp. appears to be pH tolerant possibly due to its burrowing habit or to adaptation to living in organic sediments in bog habitats.

Many natural waters in southwestern Nova Scotia have an impoverished benthic invertebrate fauna, lacking typical Maritime molluscan, amphipod, and ephemeropteran (Peterson et al. 1985) representatives.

ACKNOWLEDGMENTS

The lake sampling was performed by Washburn and Gillis Associates Ltd. Identification of lake invertebrates was performed by the staff of Washburn and Gillis Associates Ltd. and of Hardy Associates Ltd. D. J. Gordon, D. J. Johnston and the staff of Marine Research Associates Ltd. sampled and identified stream benthos. J. Kerekes and D. J. Wildish reviewed the manuscript and D. Warren proofread it. B. Fawkes typed the manuscript and F. Cunningham prepared the figures.

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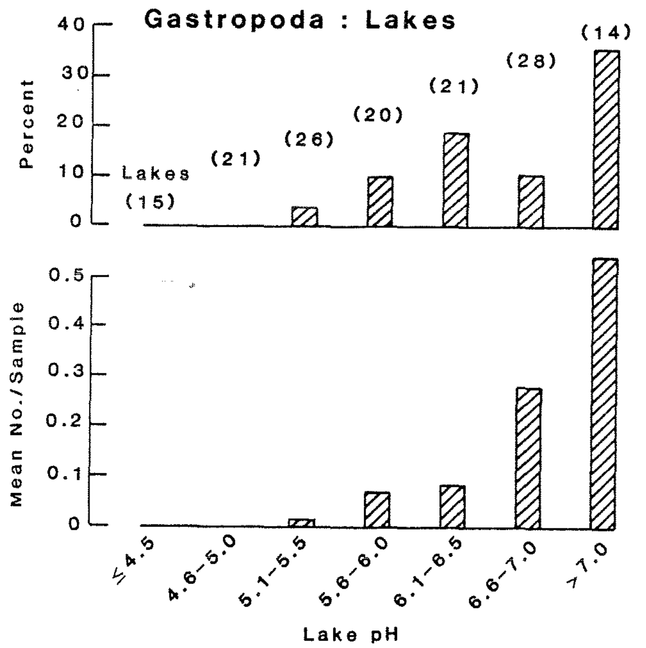


Fig. 1. The frequency with which Gastropoda were collected from lakes of seven pH categories. The top panel illustrates the percentage of lakes from which Gastropoda were collected. Lakes sampled in New Brunswick and Nova Scotia are combined. Numbers of lakes in each pH category are in parentheses.

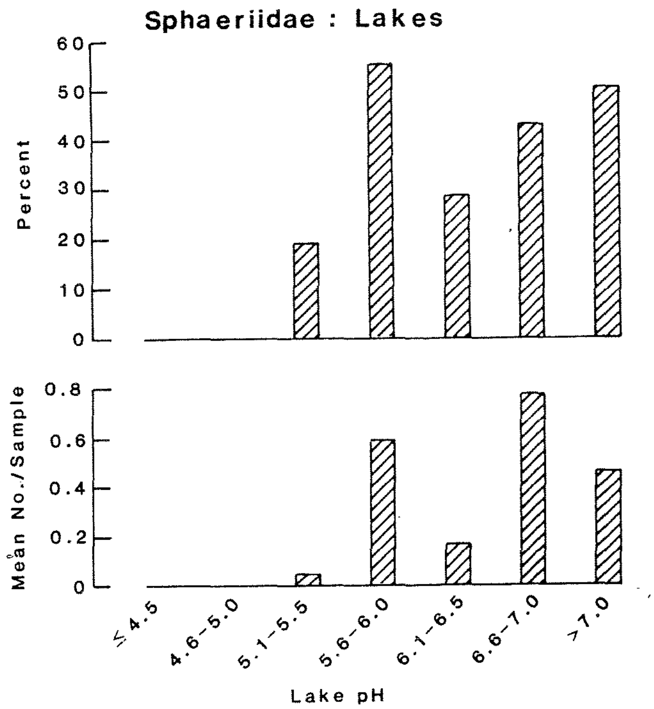


Fig. 3. The frequency with which Sphaeriidae were collected from various lakes in New Brunswick and Nova Scotia. Numbers of lakes in each category are given in Fig. 1.

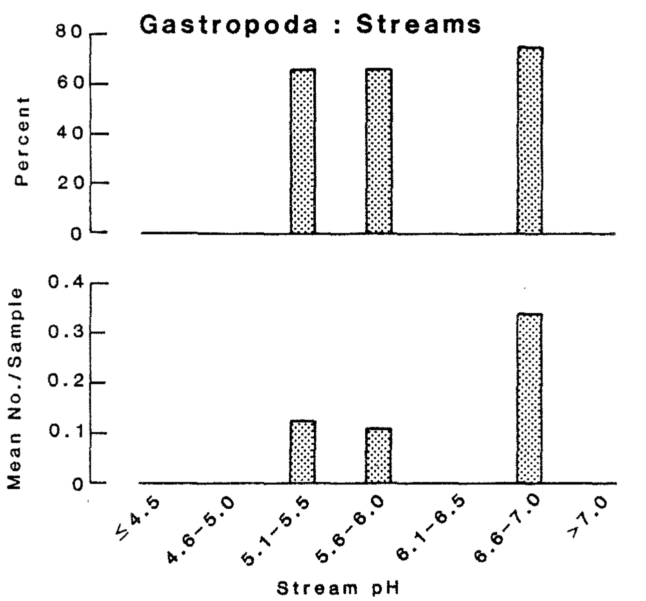


Fig. 2. The frequency with which Gastropoda were collected fom various streams in New Brunswick and Nova Scotia. The number of streams sampled in each pH category is given in Fig. 4 (top panel).

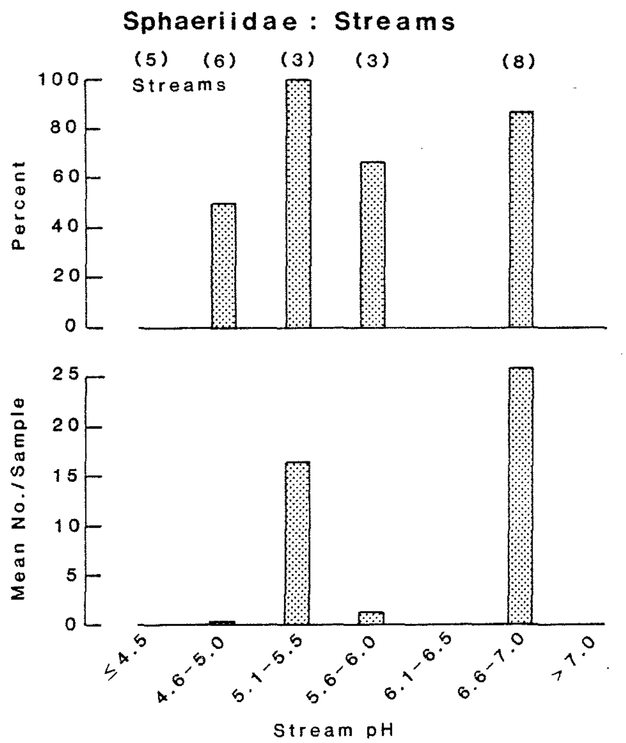


Fig. 4. The frequency with which Sphaeriidae were collected from various streams in New Brunswick and Nova Scotia. Numbers of streams in each pH category are in parentheses.

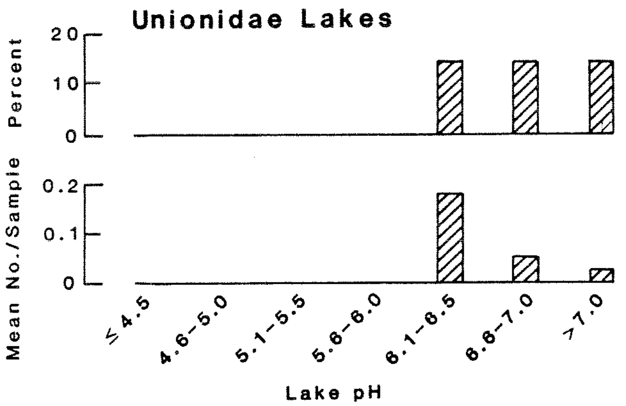
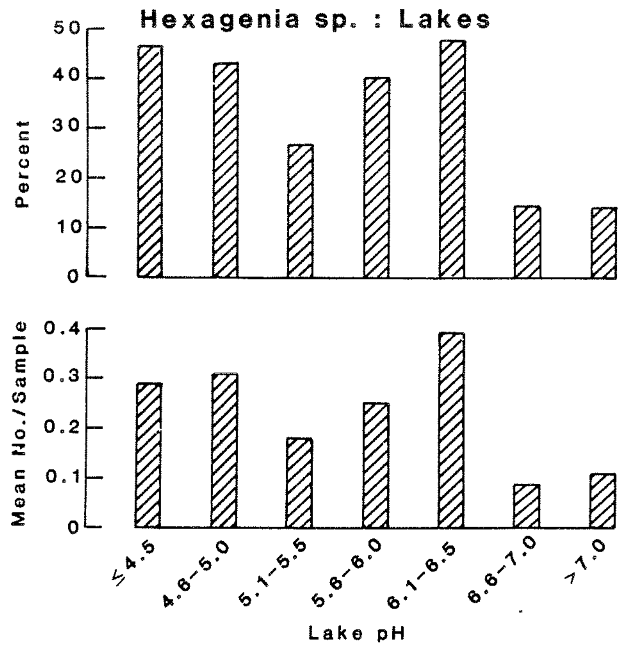


Fig. 5. The frequency with which Unionidae were collected from various lakes surveyed in New Brunswick and Nova Scotia. Numbers of lakes sampled in each pH category are given in Fig. 1.



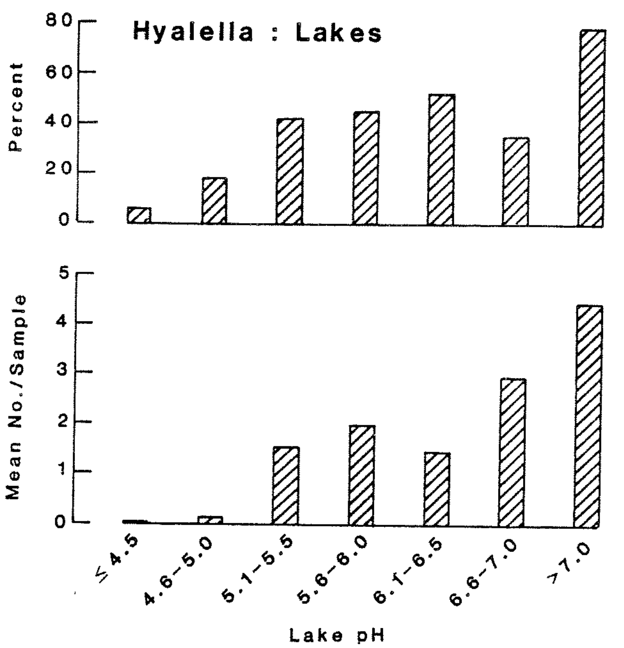
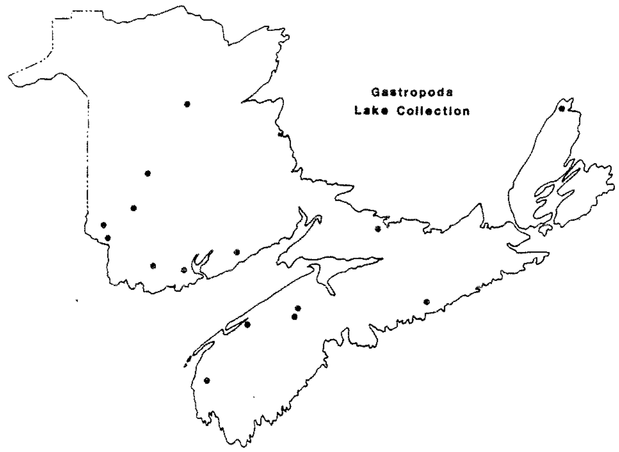
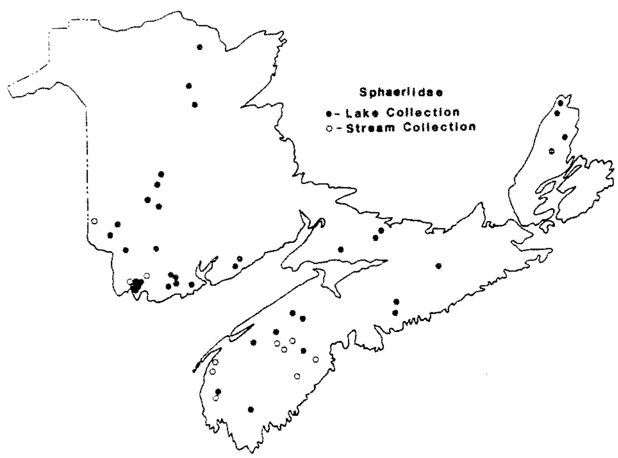


Fig. 6. The frequency with which the amphipod Hyalella was sampled from various lakes in New Brunswick and Nova Scotia. Numbers of lakes sampled in each pH category are given in Fig. 1.

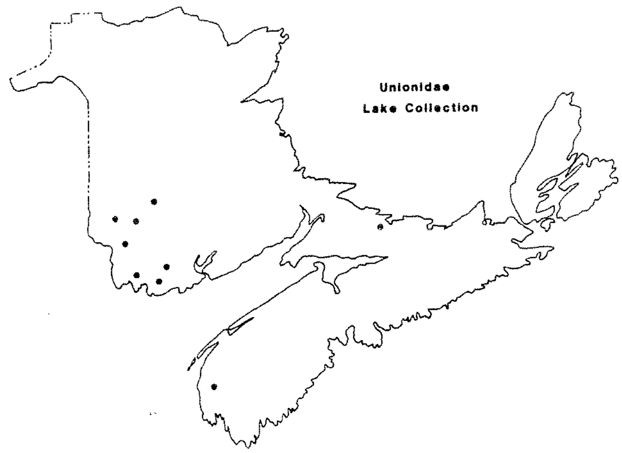
Fig. 7. The frequency with which the burrowing mayfly, Hexagenia, was collected from various lakes in New Brunswick and Nova Scotia. The top panel shows the percentage of lakes sampled from which the taxon was collected. Numbers of lakes in each pH category are given in Fig. 1.



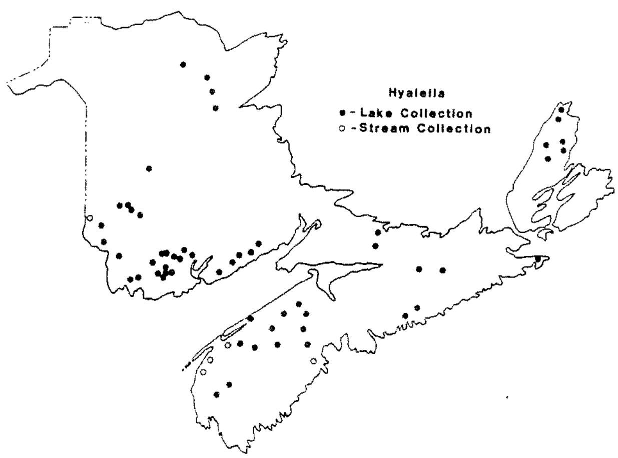
Map 1. Geographic location of each lake from which Gastropoda were collected.



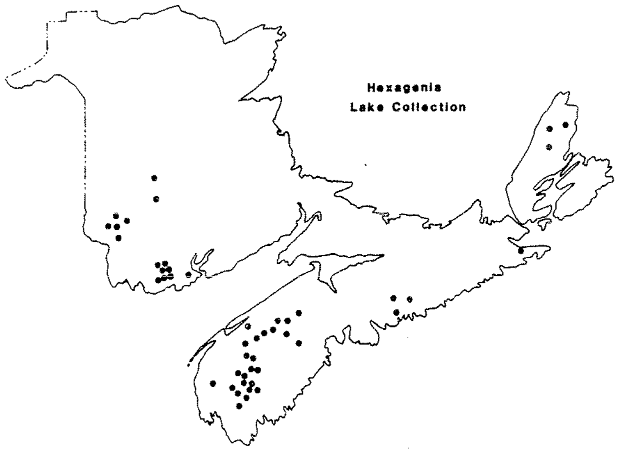
Map 2. Geographic location of each lake and stream from which Sphaeriidae were collected in New Brunswick and Nova Scotia.



Map 3. Geographic location of each lake surveyed from which Unionidae were collected.



Map 4. Geographic location of each lake and stream surveyed from which Hyalella was collected.



Map 5. Geographic location of each lake surveyed from which Hexagenia was collected.