Benthic Invertebrates of the Westfield River (Nova Scotia, Canada)

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BENTHIC INVERTEBRATES OF THE WESTFIELD RIVER (NOVA SCOTIA, CANADA)

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ABSTRACT

Peterson, R. H., L. Van Eeckhaute, and S. B. Eddy. 1987. Benthic invertebrates of the Westfield River (Nova Scotia, Canada). Can. Tech. Rep. Fish. Aquat. Sci. 1561: iii + 12 p.

Mayflies (Ephemeroptera), caddisflies (Trichoptera) and stoneflies (Plecoptera) inhabiting the Westfield River study area (SW Nova Scotia) were identified to the lowest possible taxa. Filter feeders were the dominant feeding guild in the study area, represented most abundantly by Brachycentrus appalachia, the Hydropsyche species sparna and betteni, Cheumatopsyche spp. and Chimarra socia. The most abundant mayfly was Stenonema modestum, while Leuctra tenuis and Paracapnia sp. were the most abundant Plecoptera. Brachycentrus appalachia was univoltine with adults emerging in early May. The Cheumatopsyche sp., Hydropsyche sparna and H. betteni were probably univoltine with considerable asynchrony in emergence and egg hatching, so that a wide range of instars was present at most times. Chimarra socia was either univoltine with considerable asynchrony, or multivoltine. Rhyacophila carolina was univoltine with adults emerging in May and new instars in late June to early July. Stenonema modestum was probably multivoltine.

RÉSUMÉ

Peterson, R. H., L. Van Eeckhaute, and S. B. Eddy. 1987. Benthic invertebrates of the Westfield River (Nova Scotia, Canada). Can. Tech. Rep. Fish. Aquat. Sci. 1561: iii + 12 p.

Dans le présent document, on a identifié au plus bas taxon possible les éphémères (éphéméroptères), les phryganes (trichoptères) et les perles (plécoptères) habitant la région de la rivière Westfield qui fait l'objet de la présente étude (sud-ouest de la Nouvelle-Écosse). Les filtreurs constituent la guilde dominante du secteur à l'étude, les espèces les plus abondantes étant le Brachycentrus appalachia, les espèces sparna et betteni de la famille Hydropsyche, les espèces de la famille Cheumatopsyche et le Chimarra socia. L'éphémère la plus abondante était la Stenonema modestum, tandis que les espèces Leuctra tenuis et Paracapnia étaient les plus abondants représentants des plécoptères. On a découvert que le Brachyocentrus appalachia est univoltin, l'éclosion de l'adulte se faisant au début de mai. Le Cheumatopsyche, le Hydropsyche sparna et le H. betteni sont problement univoltins mais l'éclosion imaginale et l'éclosion de l'oeuf sont asynchrones ce qui explique la présence d'insectes de plusieurs stades larvaires en même temps. Le Chimarra socia est soit univoltin avec asynchronisme pronouncé ou polyvoltin. On a déterminé que le Rhyacophila carolina est univoltin; l'éclosion des adultes se fait en mai et les nouveaux stades larvaires apparaissent à la fin de juin ou au début de juillet. Le Stenonema modestum est probablement polyvoltin.

INTRODUCTION

In 1980 an intensive stream ecology study was initiated on the Westfield River, N.S., an acidic tributary of the Medway River, with a mean annual pH of 4.9-5.2. Quantitative estimates of juvenile salmon production in a stream of near lethal pH quality was the primary objective. A study of the benthic invertebrate community was performed to provide background information which might be useful in interpreting some of the fisheries studies.

The benthic communities inhabiting riffle habitat in the study area were specifically selected for investigation. Riffles were a major habitat in the study area and are the primary habitat for juvenile Atlantic salmon. They are also typically the most important source of food organisms for juvenile salmon (Peterson and Martin-Robichaud 1986).

The type of benthic community inhabiting riffle areas depends primarily upon the water chemistry of the stream, the stream size, temperature and on the nature of the energy sources supplying the aquatic ecosystem (autochthonous vs allochthonous sources) (e.g. Cushing et al. 1983; Minshall 1968). The pH of the Westfield River is sufficiently acidic to restrict the diversity of some groups of benthic insects, such as mayflies (Peterson et al. 1985; Sutcliffe and Carrick 1973; Friberg et al. 1980). Peterson et al. (1985) found the genera Epeorus, Heptagenia, Baetis, Isonychia and Tricorythodes to possibly be intolerant of the pH levels which occur in the Westfield River. Other groups, such as Eurylophella and the stonefly genus, Leuctra, may be more tolerant (Mackay and Kersey 1985; Hall et al. 1980).

Approximately 8% of the Westfield drainage area is occupied by lakes (DeGraeve and Peterson 1982) and some stillwater areas lie 1-2 km upstream of the study area. It is probable that primary and secondary production in these lakes and stillwater areas provide important energy sources for invertebrates and fish of the study area. Accordingly, the species composition of this community will be influenced as well. For example, filter-feeding organisms, such as Hydropsyche, frequently occur in greater abundance at the outfalls of lakes (e.g. Williams and Hynes 1973; Benke and Wallace 1980). In this report, the species composition for three orders of benthic invertebrates (Ephemeroptera, Trichoptera and Plecoptera) inhabiting the Westfield River study site is presented, as well as the life histories of several of the more abundant species.

STUDY AREA

The study area consisted of a 450-m reach, 6-10 m wide (Knox and Dadswell 1982) in a third order stream, the Westfield River (44°24'N, 64°59'W), a tributary to the Medway River in western Nova Scotia. The study area was partially canopied, principally with red maple (Acer rubrum), balsam fir (Abies balsamea), white spruce (Picea glaucens) and yellow birch (Betula lutea). The water chemistry has been described (Lacroix et al. 1983, 1985). Mean annual stream discharge was estimated to be 3.2 m^3/s with low monthly flows ca. 1.2 m^3/s in August and maximal mean monthly flows of 8.2 m^3/s in April (DeGraeve and Peterson 1982).

SAMPLING METHODS

Four sampling methods were utilized: Surber benthic samplers (1000-µm mesh size), which sampled 0.09 m^2 of substrate to a depth of 4-8 cm; Coleman-Hynes pot samplers (10 cm diameter, 2 cm deep), filled with sieved and washed stream rubble and buried in the rubble of the study area (6 wk colonization time); adult emergence cages (Ide 1957), 0.9 m^2 x 1.5 m high; and drift samplers, 25 x 2.5 cm tall opening, mesh size of 600 µm (Peterson and Martin-Robichaud 1986). Most samples were washed through 1000-µm sieves prior to sorting.

All methods were used from August 1982 until July 1983, with samples being collected every 6 wk. At each sampling period, two pot samples and five pooled Surber samples were taken from each of four transects (Knox and Dadswell 1982). Three drift nets were set 300 m upstream from the benthic sampling areas for either two 12-h sampling periods or one 24-h period. For the purposes of this report, not all samples were examined to identify species of the study area, but at least one sample was examined from each sampling method at each sampling date. Stream samples were preserved in 10% formalin, and sorted insects were stored in 70% ethanol. Numbers of all taxa identified were counted from each sample studied.

During the 1982-83 sampling period, two adult emergence traps were situated between the benthic sampling area and the drift sampling area. However, the traps were not cleared of insects with sufficient frequency (every 6 wk) to provide useful information on adult emergence times. Many individuals were undoubtedly lost between sampling periods. To provide additional adult material, an adult emergence trap was installed in the study area May 30-Sept. 15, 1986 (except for July 12-Aug. 21, when it was washed out by high water) and cleared of adults five times weekly.

Trichoptera, Ephemeroptera and Plecoptera were identified to the lowest possible taxon. Keys from many sources were used, notably: Hitchcock (1974), Stark and Gaufin (1976), Morihara and McCafferty (1979), Allen and Edmunds (1961, 1962, 1963a, b, 1965), Bednarik and McCafferty (1979), Burks (1953), Flowers and Hilsenhoff (1978), Ross (1941, 1944, 1947), Ross and Wallace (1974), Flint (1962), Neves (1977), Morse (1972), Resh (1976), Schuster and Etnier (1978), Rutherford (1985), Gordon (1974), Schmid (1982), and Flint (1984). Plecoptera in this study were identified only from adults; however, Knox and Davidson (1982) identified the nymphs in the collection.

RESULTS AND DISCUSSION

A total of 40 Trichopteran taxa were identified in the study area, of which 29 were identifiable to species (Table 1). Sixteen Ephemeropteran taxa (9 to species), and 4 Plecopteran taxa (3 to species) were also identified. An additional 6 Plecopteran taxa were identified by Knox and Davidson (1982).

Nine taxa account for about 80% of the total numbers of the three orders identified; in order of abundance, these are: Brachycentrus appalachia, Cheumatopsyche spp., Hydropsyche sparna, Chimarra socia, Stenonoma modestum, Rhyacophila carolina, Eurylophella spp., Hydropsyche betteni and Glossasoma nigrior (Table 2). We have placed the most confidence in the Surber sample data in making this assessment because we feel that these samples give the best representation of natural relative abundances of the various taxa. The data from the drift samples are biased toward those taxa exhibiting a propensity to drift, while the pot samples utilized a defined substrate which probably biases the relative colonization rates of the various taxa. Of the nine most abundant taxa, the four most numerous are either obligate or facultative filter feeders, suggesting that the lakes and deadwaters upstream of the study area do indeed influence the composition of the benthic community. Two additional important Plecopteran shredders, Leuctra tenuis and Paracapnia sp. were also present. Mean numbers of filter feeders collected in the surber samples were 337/sample, while scrapers, detritivore gatherers, herbivorous shredders, carnivores, detritivore shredders and piercers occurred at 267, 37, 15.5, 19, 3, and 1.7/sample, respectively.

PLECOPTERA

L. tenuis adults were collected in the Westfield from early June to late August, with most specimens from mid-June to mid-August. In southern Ontario, L. tenuis has been shown to be univoltine (Harper 1973). Eggs laid by adults in Westfield or Ontario in July-late August (some females as late as October) hatch in December-January, the 4-5 mo diopause requiring cold temperature for termination. Most nymphal growth occurred in May-July. Emergence in the Westfield thus begins somewhat earlier than it did in the population studied in southern Ontario. Ernst and Stewart (1985) elucidated a somewhat different univoltine life cycle for a L. tenuis population in Oklahoma, where the eggs hatched in early March, grew until mid-September and adults emerged in September-October. It would appear that adults emerge earlier from more northern streams. Paracapnia sp. is a "winter" stonefly, and hence was missed in the adult collections.

TRICHOPTERA

The life history of Brachycentrus appalachia (Fig. 1) in the Westfield River is similar to that described for the species in the St. Croix River (Peterson and Martin-Robichaud 1986). The species is univoltine with late instars overwintering and adults probably emerging in early to mid-May. We collected a female adult Brachycentrus, presumably of this species, on May 18, probably a late straggler. The earliest instars appeared about 2 wk earlier in the Westfield River than they did in the St. Croix, suggesting that the former stream warms more quickly in the spring. The life histories of two other Brachycentrus species, americanus and occidentalis, have been reported in the literature (Gallepp 1974; Krueger and Cook 1984). These species are also univoltine with the life cycle of occidentalis resembling that of appalachia very closely (Krueger and Cook 1984). New instars of B. americanus, on the other hand, do not appear until August from eggs laid in June. The larvae of americanus overwinter as stage III or IV instars.

Cheumatopsyche species in the Westfield River consisted of individuals with and without a frontoclypeal notch. We measured head capsule widths of those with no notch as those appeared to be a single species (1st instars were not measured as the notch was then indistinguishable). Adults of C. sordida and miniscula were collected from mid-June to late July, suggesting univoltine life histories. A range of Cheumatopsyche instars were usually present (Fig. 2). Egg hatching of many Hydropsychidae species is notably asynchronous, as will be discussed more completely with the Hydropsyche life histories. This asynchrony frequently leads to the presence of a range of instars at any given time. The data of Fig. 2 suggest that only late instars occur in early June, at which time adult emergence begins, and most early instars were collected in August.

The two common Hydropsyche species of the Westfield River, sparna and betteni, also show considerable asynchrony in life cycles (Fig. 3, 4). H. sparna was the more abundant of the two, and adults of this species were collected from late May until mid-September (Fig. 3). All instars are present from late June to early November. No Hydropsyche larvae were collected from the latter half of December until late March, although they must have been present. Fuller and Mackay (1980) found that food habits of H. sparna changed from filter feeding to scraping of diatoms from rocks during the winter. Perhaps such dietary changes in the Westfield population are correlated to behavioral and distributional changes, so that they no longer were present at sites normally sampled. It is probable that the Westfield population of H. sparna is univoltine with considerable asynchrony of adult emergence and egg hatching, with a possibility of some partial bivoltinism. Benke and Wallace (1980) found a population of H. sparna in a southern Appalachian stream to be primarily univoltine. Fuller and Mackay (1980) found the species to be univoltine in the upper Humber River (Ontario) but bivoltine in the lower Humber. H. betteni was more distinctly univoltine than H. sparna in the Westfield (Fig. 4). Adults were collected from early May to late August, and recruitment of new instars occurred predominantly in early August to mid-September. As with H. sparna, no H. betteni was sampled during the winter months. H. betteni has been reported to shift from filter feeding on detritus to carnivory of diptera larvae in winter (Fuller and Mackay 1980). As with H. sparna, one may speculate that such dietary shifts may lead to concomitant changes in distribution.

It is customary to find more than one species of Hydropsychidae coexisting in a given locality (Benke and Wallace 1980). In such instances, the available food resources may be partitioned on the basis of differential mesh sizes in the nets constructed, on the basis of occupancy of differing microhabitats or on the basis of different life histories. H. sparna appears to be adapted to more rapid, turbulent water velocities than H. betteni (Fuller and Mackay 1980). H. sparna constructs filtering nets of larger mesh size, and the nets are set at a slight angle to the substrate, as compared to the more perpendicular orientation of the net of H. betteni. The nets of H. sparna are also more protected in that they are set further back from the opening to the larval retreat. The characteristics of Cheumatopsyche spp. microhabitats and net-building characteristics which may separate them from Hydropsyche species are not yet known.

Chimarra socia, another filter-feeding caddisfly of the family Philopotamidae, was also abundant at the Westfield study site. Its life history is similar to the Hydrospychidae life histories described above in that several instars are usually present throughout most of the year (Fig. 5). Adults were obtained only in July; however, we have collected them throughout the summer until early September in other stream systems (Peterson and Martin-Robichaud 1986), so the species may be multivoltine. Most recruitment of early instars in the Westfield River appears to be late August-early November. C. socia spins filtering nets of much smaller mesh sizes than do the Hydropsychidae (e.g. 60 µm vs 2000-3000 µm for H. sparna; Wallace et al. 1977). Food particle sizes of C. socia are also much smaller than those of the Hydropsychidae. Generally speaking, members of the Philopotamidae are adapted to slower water velocities than the Hydropsychidae. If members of the two families inhabit the same rock, the Philopotamid will be in a more sheltered location - frequently on the under surface (Williams and Hynes 1973; Benke and Wallace 1980). Chimarra species are also more prone to inhabit areas of lower velocity along banks and under submerged roots.

Rhyacophila carolina was the invertebrate predator sampled in largest numbers in the Westfield study area. It has a straightforward univoltine life cycle with the adults flying in May and new instars in late June-early July (Fig. 6). The larvae grew principally in July-October and over-winter in instar IV or V. This life cycle is very similar to that reported for R. melita (Martin 1985). R. fuscula, probably the commonest species of the genus, occasionally sampled in the Westfield, has a quite different life cycle. The adults fly from June to August and the eggs may hatch anywhere from June to October. Thus, although univoltine, a wide range of larval instars may be present at any given time, similar to the life cycles described here for the Hydropsyche spp.

EPHEMEROPTERA

Of the Ephemeroptera present in the Westfield study area, Stenonoma modestum is the most abundant, and is easily identifiable. Unlike caddisflies, which uniformly have five instars, Ephemeroptera may have as many as 30 or more, and the full range of S. modestum instars seem present in the Westfield at all times (Fig. 7). Kondratieff and Voshell (1980) found this species to have a multivoltine life cycle in a Virginia stream. Adults of the overwintering brood in Virginia emerged mainly in April with stragglers as late as June-July. These adults gave rise to a summer brood with highly variable and prolonged period of egg hatching, resulting in a wide variety of instars, the most mature of which would emerge in August-October. Such asynchrony in development results in a wide range of larval sizes present at any time, and could account for much of the variability depicted in Fig. 6. We collected adults only in late August, and many more collections would have to be made to determine whether multivoltinism occurs in the Westfield population. The data suggest that most recruitment occurs in July-September and that the population is mainly univoltine. S. modestum feeds mainly on diatoms and detritus, with large instars particularly including larval Chironomidae in their diets.

The Westfield River is probably sufficiently acidic that the species diversity of its benthic insect fauna is reduced (Peterson et al. 1985). Mayfly genera which would usually be represented in similar habitats of higher pH are Baetis, Isonychia, Ephemerella, subgenera Drunella and Serratella. Any possible decrease in species diversity of caddisflies and stoneflies is conjectural at present. Mackay and Kersey (1985) have suggested that insects in the guild of leaf shredders may be tolerant of low pH due to their adaptation to foraging in leaf packs, the interstitial water of which may be acidic. The Eurylophella subgenus and the Paraleptophlebia species in the Westfield River are shredders. The filter-feeding Hydropsychidae and Philopotamidae are also sufficiently tolerant to thrive in the Westfield River. Ephemeroptera scrapers or algal grazers, such as Baetis, Drunella, Heptagenia and Epeorus appear particularly sensitive. Lack of algal grazers may in part be the reason why blooms of algae, such as filamentous diatoms, seem more frequent in acidic streams (personal observation).

The other insect order, Diptera, which is abundantly represented in the Westfield River, was not studied. The families Chironomidae and Simuliidae were both abundant in the study area. The Simuliidae larvae are filter feeders, and Chironomidae are primarily shredders and gatherers - thus, neither of these groups would compensate for the lack of Ephemeropteran grazers.

The Baetis genus, when present, are prominent members of the stream drift and, as such, are major components of the diets of juvenile Atlantic salmon (e.g. Peterson and Martin-Robichaud 1986). Such abundant caddisflies as Brachycentrus, Hydropsyche and Chimarra, on the other hand, are not characteristically part of the drift. The results reported by Knox and Dadswell (1982) on diets of juvenile salmon indicate that larval Chironomidae are particularly important as they are tolerant to low pH and prone to drift, as are Simuliidae. Drift of zooplankon from the upstream lakes are also ingested. Abundance of these three taxa may be sufficient to maintain excellent growth rates of juvenile salmon at the low salmon population densities occurring in the Westfield (Lacroix et al. 1985).

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Table 1. Trichoptera, Ephemeroptera and Plecoptera species list for the Westfield River, Nova Scotia. L = larva; P = pupa; A = adult; *: collected; - not collected; ? = identification uncertain.

	L	P	A
Trichoptera			
Brachycentridae			
Brachycentrus appalachia	*	-	*(?)
Micrasema sp.	*	-	*
Glossosomatidae			
Glossosoma nigrior	*	*	*
Helicopsychidae			
Helicopsyche borealis	*	-	-
Hydropsychidae			
Cheumatopsyche miniscula	?	-	*
Cheumatopsyche sordida	?	-	*
Hydropsyche betteni	*	-	*
Hydropsyche morosa	*	-	-
Hydropsyche sparna	*	-	*
Hydroptilidae			
Hydroptila delineatus	?	-	*
Oxyethira rivicola	*	-	*
Lepidostomatidae			
Lepidostoma sp.	*	-	-
Leptoceridae			
Ceraclea arielles	*	-	-
Ceraclea sp.	*	-	-
Mystacides sepulchralis	?	*	*
Nectopsyche sp.	*	-	-
Oecetis avara	*	-	-
Oecetis sp.	*	-	*
Triaenodes sp.	*	-	-
Limnephilidae			
Apatania sp.	*	-	-
Hydatophylax sp.	*	-	-
Limnephilus sp.	-	-	*
Pycnopsyche guttifer	-	-	*
Pycnopsyche lepida	-	-	*
Odontoceridae			
Psilotreta indecisa	*	-	*
Philopotamidae			
Chimarra aterrima	*	*	*
Chimarra socia	*	?	*
Dolophiloides distinctus	*	-	-
Phryganeidae			
Ptilostomis sp.	*	-	-
Polycentropodidae			
Neureclipsis crepuscularis	?	-	*
Nyctiophylax celta	?	-	*
Phylocentropus placidus?	-	-	*
Polycentropus cinereus	?	-	*
Polycentropus remotus	?	-	*
Rhyacophilidae			
Rhyacophila carolina	*	-	-
Rhyacophila fuscula	*	-	*
Rhyacophila manistee	?	-	*
Sericostomatidae			
Agarodes sp.	*	-	-

Table 1. (cont'd)

	L	P	A
Ephemeroptera			
Baetidae			
Baetis sp.	*	-	-
Cloeon sp.	*	-	-
Pseudocloeon punctiventris	*	-	-
Ephemerellidae			
Eurylophella bicolor/minimella(?)	*	-	-
Eurylophella prudentalis	-	-	*
Heptageniidae			
Heptagenia sp.	*(?)	-	-
Stenacron interpunctatum	*	-	-
Stenonema femoratum	*	-	-
Stenonema modestum	*	-	*
Stenonema vicarium	*	-	-
Leptophlebidae			
Habrophlebia vibrans	*	-	-
Leptophlebia sp.	*	-	-
Paraleptophlebia mollis	*	-	-
Paraleptophlebia volitans	*	-	-
Siphlonuridae			
Siphlonurus sp.	*	-	-
Plecoptera			
Chloroperlidae			
Alloperla sp.	*		
Leuctridae			
Leuctra tenuis	*?		*
Perlidae			
Perlinella drymo	*		
Acroneuria abnormis	*?		*
Perlodidae			
Isoperla bilineata?	?		*
Isoperla sp.	*		
Nemouridae			
Taeniopteryx sp.	*		
Nemoura sp.	*		
Paracapnia sp.	*		

Table 2. Trophic status and abundances of various mayfly and caddisfly species in the Westfield River study area. P = piercers; Shr = shredders; Scr = scrapers; Filt = filter feeders; Gath = gatherers.

Species	Abundance (no./sample)			Herbivore			Detritivore			Carnivore
	Surber	Pot	Drift	P	Shr	Scr	Shr	Filt	Gath	
Brachycentrus appalachia	224.0	25.8	9.8			X		X		
Cheumatopsyche spp.	58.5	11.6	2.0					X		
Hydropsyche sparna	23.5	0.6	4.0					X		
Chimarra socia	20.8	0.7	0.6					X		
Stenonema modestum	18.0	4.6	0.4			X			X	
Rhyacophila carolina	17.2	1.3	0.0							X
Eurylophella spp.	14.7	2.5	0.6		X	X			X	
Hydropsyche betteni	8.7	0.0	0.4					X		
Glossosoma nigrior	7.0	0.0	0.6			X				
Leptophlebia sp.	2.8	4.6	0.5						X	
Polycentropus spp.	1.8	4.6	0.6		X			X		X
Hydroptila sp.	1.5	0.8	0.8	X		X				
Paraleptophlebia sp.	1.3	4.7	0.4				X		X	
Lepidostoma sp.	1.3	0.1	0.0				X			
Chimarra aterrima	1.0	0.70	0.20					X		
Stenonema femoratum(?)	0.74	0.09	0.0			X			X	
Stenonema vicarium	0.70	0.30	0.0			X			X	
Psilotreta indecisa	0.69	0.0	0.0			X			X	
Neureclipsis sp.	0.38	1.2	0.20		X			X		
Hydatophylax sp.	0.38	0.30	0.0				X			
Oecetis sp.	0.23	1.0	1.0		X					X
Oxyethira sp.	0.23	1.3	0.60	X		X			X	
Micrasema sp.	0.23	0.0	0.80		X				X	

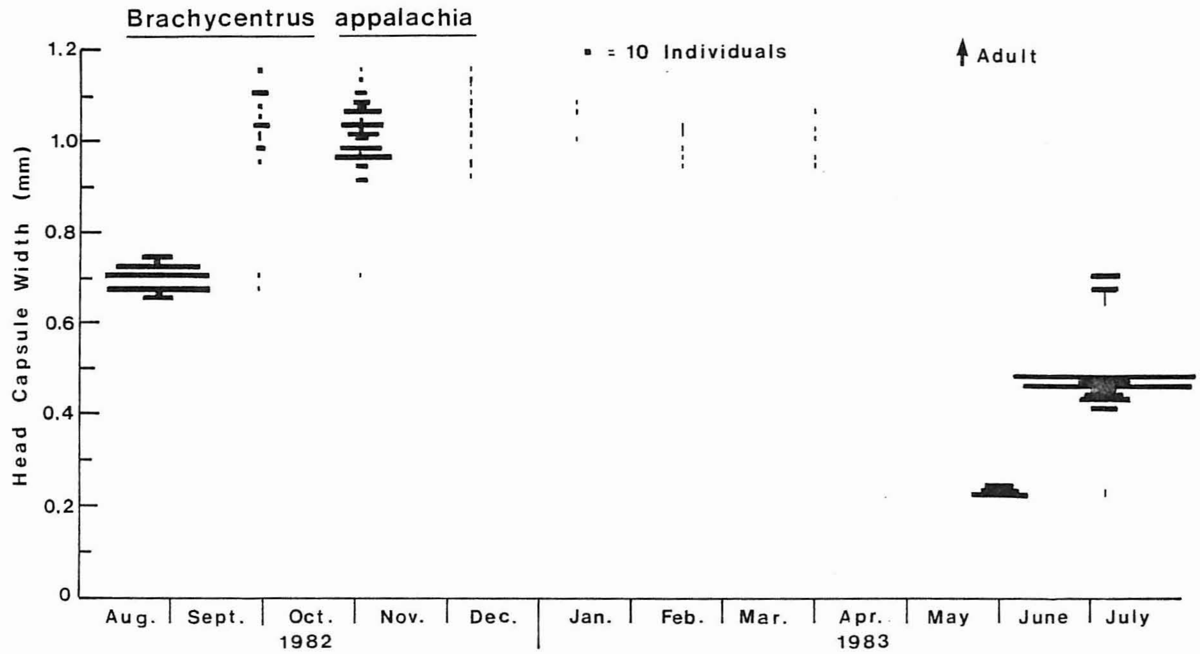

Fig. 1. Size distributions of Brachycentrus appalachia larvae in the Westfield River, Nova Scotia, at various times of the year. Width of the horizontal bars are proportional to the number of individuals measured in each size-class (calibration bar included in the figure). Arrow indicates capture of adults at the corresponding time of the year.

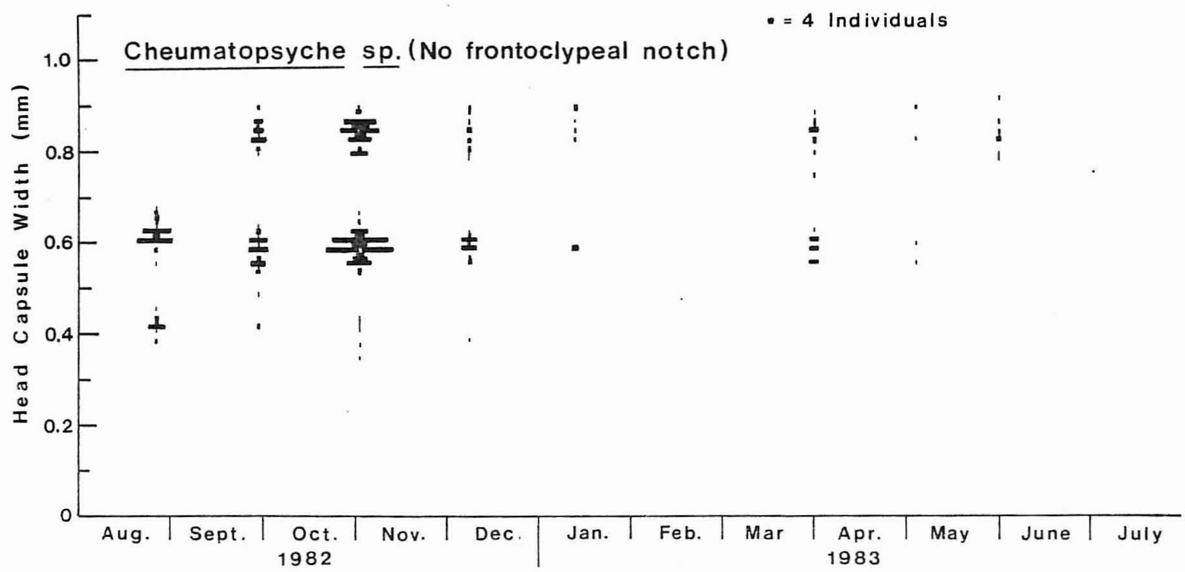

Fig. 2. Size distributions of larvae of the Cheumatopsyche species in the Westfield River, lacking a frontoclypeal notch, at various times of the year. Width of the horizontal bars are proportional to the number of individuals of a particular size-class measured (calibration bar on figure).

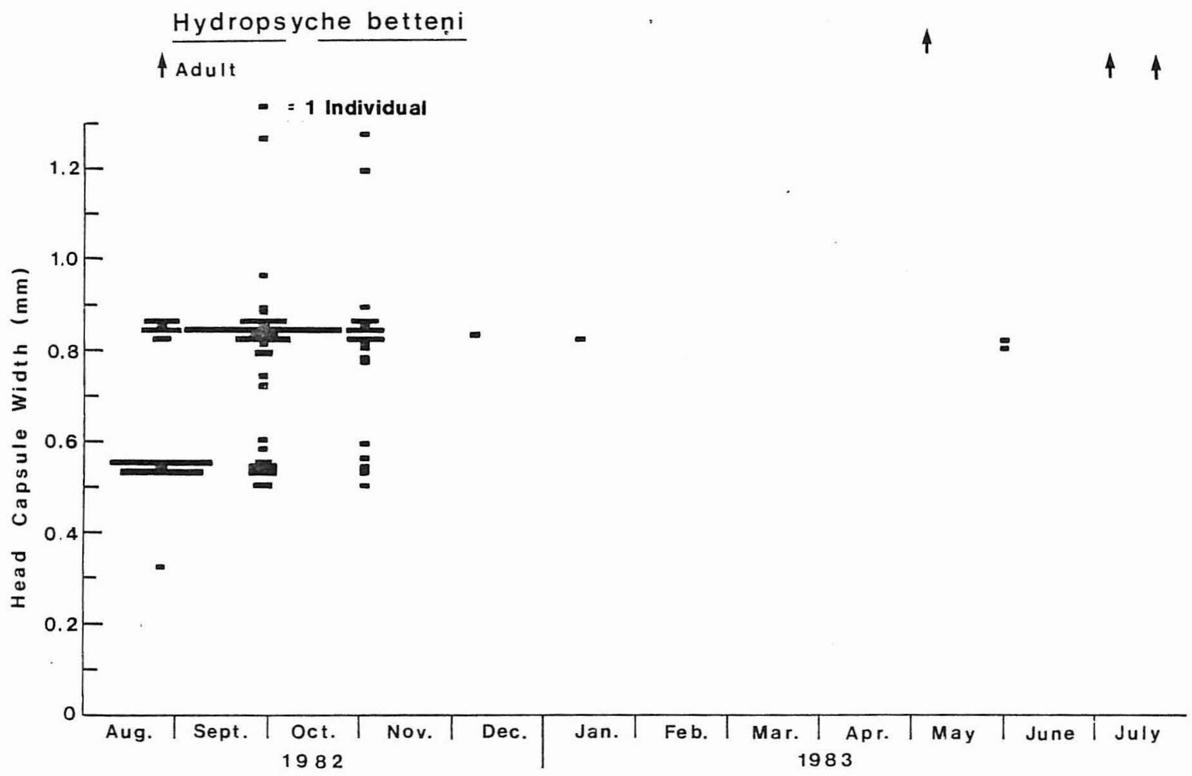

Fig. 3. Size distributions of Hydropsyche betteni larvae in the Westfield River at various times of the year. Width of the horizontal bars are proportional to the numbers of individuals measured (calibration in figure). Upwardly directed arrows indicate capture of adults at the corresponding time of year.

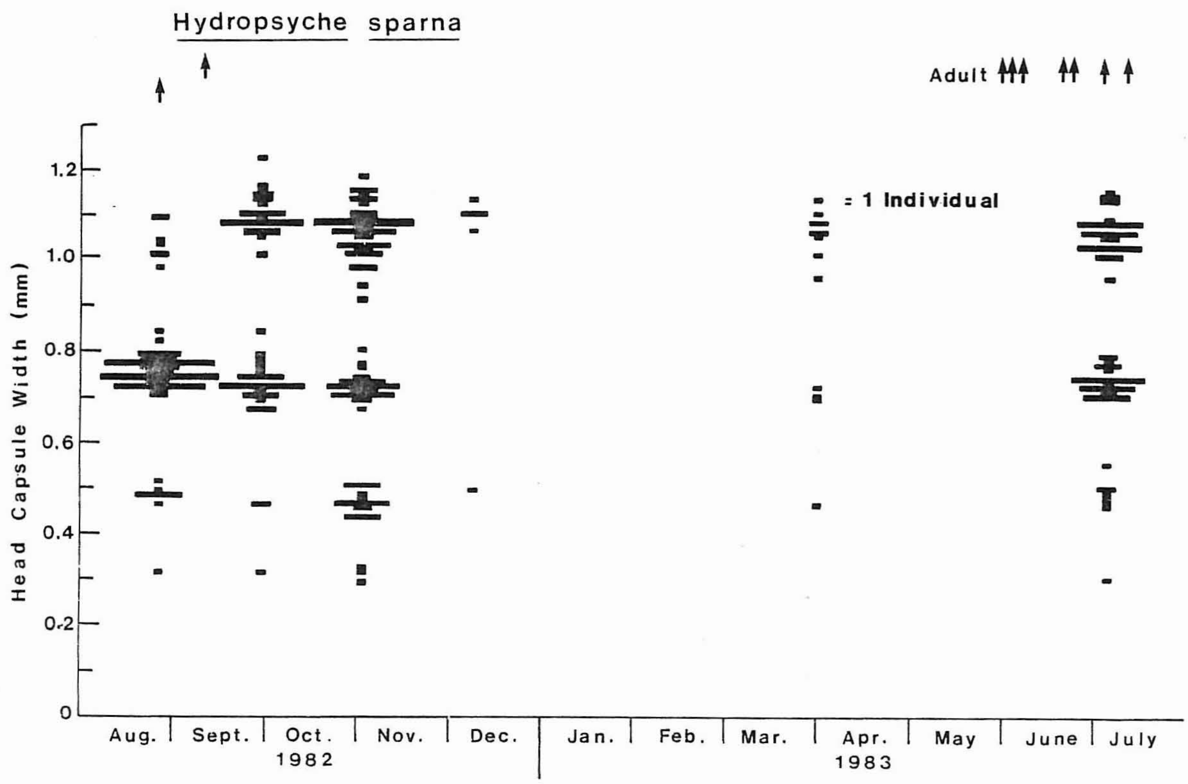

Fig. 4. Size distributions of Hydropsyche sparna larvae in the Westfield River at various times of the year. Width of the horizontal bars are proportional to the numbers of individuals measured (calibration bar in figure). Arrows indicate adult captures.

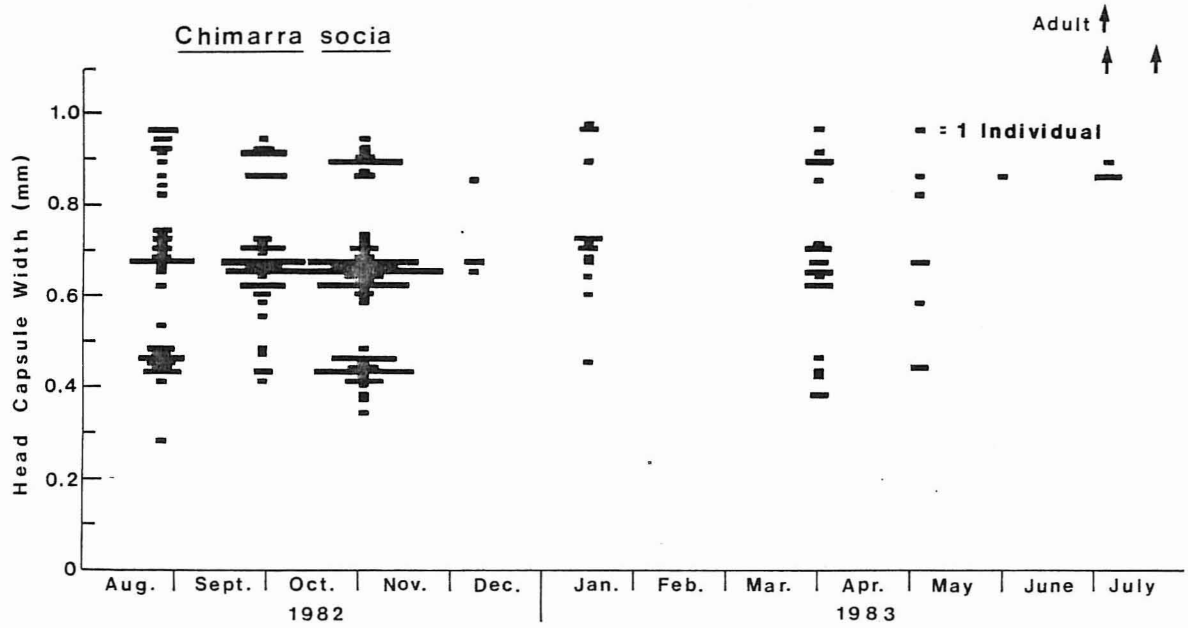

Fig. 5. Size distributions of Chimarra socia larvae in the Westfield River at various times of the year. Width of the horizontal bars are proportional to the numbers of individuals measured (calibration in figure). Arrows indicate adult captures.

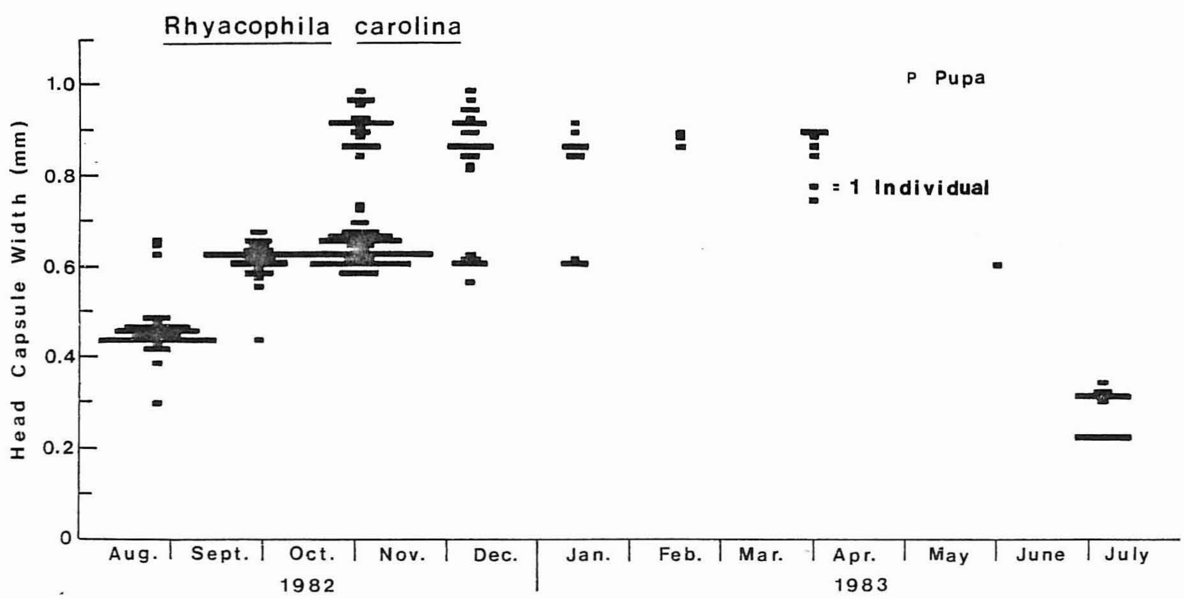

Fig. 6. Size distributions of Rhyacophila carolina larvae in the Westfield River at various times of the year. Widths of the horizontal bars are proportional to the numbers of individuals measured (calibration in figure). Capture of pupae indicated by P.

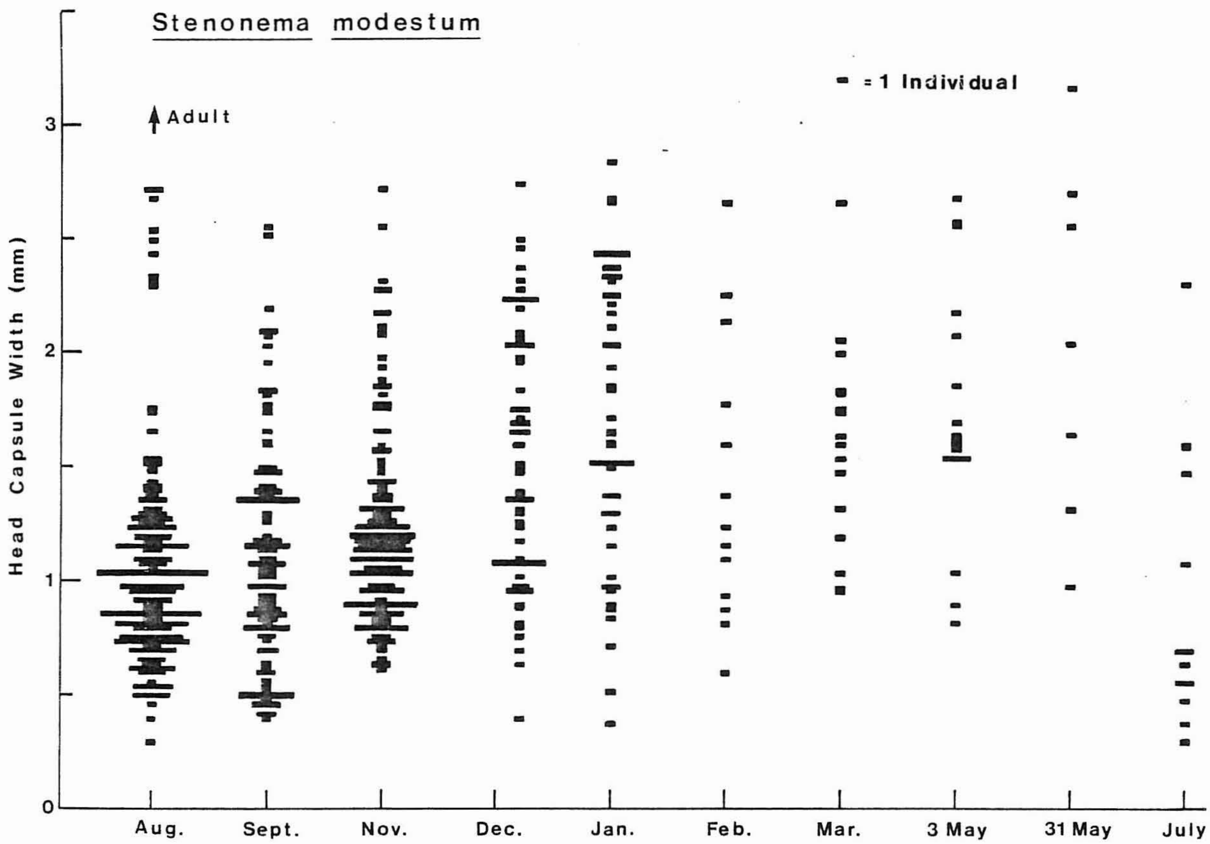

Fig. 7. Size distributions of Stenonema modestum nymphs in the Westfield River at various times of the year. Widths of the horizontal bars are proportional to the numbers of individuals measured (calibration bar in figure). Arrow indicates collection of the imago.