

CRUSTACEANS AND MITES (ACARI) FROM HYPORHEIC AND OTHER UNDERGROUND WATERS IN SOUTHEASTERN NEW YORK

BY

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SUMMARY

The meiofauna of hyporheic and other shallow groundwaters in southeastern New York is dominated by microannelids, copepods, insects, nematodes, and various mites. Ostracods, cladocerans, and amphipods are represented by relatively few species and individuals. The copepod fauna includes 33 species, chiefly from *Diacyclops*, *Bryocamptus*, *Attheyella*, and *Parastenocaris*. Most species of copepods are most abundant during the summer, but *Phyllognathopus* and *Parastenocaris* reach peak densities during the winter. The life cycles of 4 species of copepods and a halacarid mite are described. Three of the copepods have a strongly seasonal life cycle, with recruitment of copepodites in the spring. The fourth species of copepod and the halacarid do not have clearly seasonal life cycles. The mite fauna contains 5 species of halacarids, 13 genera of parasitengones (= "Hydrachnellae"), and an undetermined number of other species.

RÉSUMÉ

La méiofaune de l'hyporheal et d'autres eaux souterraines peu profondes du sud-est de l'Etat de New York est dominée par des Microannelides, Copépodes, Insectes, Nématodes et Acariens variés. Les Ostracodes, Cladocères et Amphipodes sont représentés par un nombre relativement restreint d'espèces et d'individus. La faune de Copépodes comprend 33 espèces appartenant principalement aux genres *Diacyclops*, *Bryocamptus*, *Attheyella* et *Parastenocaris*. La plupart des espèces de Copépodes sont plus abondantes pendant l'été, mais les densités maximales pour *Phyllognathopus* et *Parastenocaris* sont atteintes pendant l'hiver. On décrit le cycle vital pour 4 espèces de Copépodes et pour une espèce d'Halacaride; trois des Copépodes ont un cycle vital clairement saisonnier, les copépodites étant produits au printemps; la 4^{ème} espèce de Copépodes, ainsi que l'Halacaride, ne présentent pas de cycle vital saisonnier distinct. La faune d'Acariens se compose de 5 espèces d'Halacarides, 13 genres de Parasitengona ("Hydrachnellae") et d'un nombre indéterminé d'autres formes.

INTRODUCTION

North American biologists have been slow in following the lead of European workers in exploring the biota of underground waters. Despite the demonstration by Europeans (e.g., Delamare Deboutteville, 1960; Botosaneanu, 1986) that these waters often contain an abundant, diverse, and specialized invertebrate fauna, research in North America has been largely confined to

studies of the cave fauna (Culver, 1982), the psammon of lake beaches (Pennak, 1940, 1988), and the macroinvertebrates of hyporheic waters (Williams, 1984). The first detailed study of the meiofauna of hyporheic and phreatic waters in North America (Colorado) appeared only recently (Pennak & Ward, 1986).

I report here some of the results of an intensive survey of the interstitial meiofauna of various habitats, especially the hyporheic zone, in southeastern New York. My goals are to describe the invertebrate community, compare the composition of this fauna to those found in similar habitats elsewhere in the world, and outline the life histories of the more common species of invertebrates. The present paper is concerned chiefly with the crustaceans and mites; previous papers have covered the flatworms (Kolasa et al., 1987), oligochaetes (Strayer & Bannon-O'Donnell, 1988), and tardigrades (Strayer et al., 1988) found during this study. A companion paper (Strayer, 1988) provides taxonomic notes on some copepods found during this study.

THE STUDY AREA

Samples were taken at various sites in southeastern New York, along with a single site in northwestern Connecticut (fig. 1). Most of the study area is underlain by Ordovician shales, although there are extensive outcrops of sandstones, quartzites, and limestones as well, some of which are Devonian or Silurian in age. The entire study area was overrun by glaciers of Wisconsin age, and surface deposits include glacial deposits of highly varied character. Much of the region is gently rolling, but the Shawangunk, Catskill, and Taconic Mountains include areas of great local relief (>300 m/km), and rise to >1000 m a. s. l. Most surface waters in the area are hard (pH = ca. 8, $Ca^{++} = 0.2-1$ mM) and fertile, but streams running on the Shawangunk quartzite conglomerate are much more dilute (pH = 4-6, $Ca^{++} = 0.02-0.2$ mM).

Intensive studies were made on the hyporheic fauna of two sites: the East Branch of Wappinger Creek near Millbrook ($41^{\circ}47' N 73^{\circ}45' W$) and the Coxing Kill near New Paltz ($41^{\circ}46' N 74^{\circ}12' W$). Some characteristics of these two sites are given in table I. The other samples taken came from the hyporheic zones of local streams (habitat type L1 of Botosaneanu, 1986), seeps (habitat N, the "hypotelminorheic" of Botosaneanu, 1986), springs (habitat S), lake psammon (habitat M), and wells and shallow phreatic waters (habitat K). In addition, a few samples were taken from some small streams (habitat L3) in the Ellenville Ice Caves ($41^{\circ}41' N 74^{\circ}20' W$), a series of crevices formed by breakage and mass-wasting of enormous pieces of the Shawangunk conglomerate.

Most of the study area was covered by oak and northern hardwood forests prior to European settlement. However, almost all of these original forests

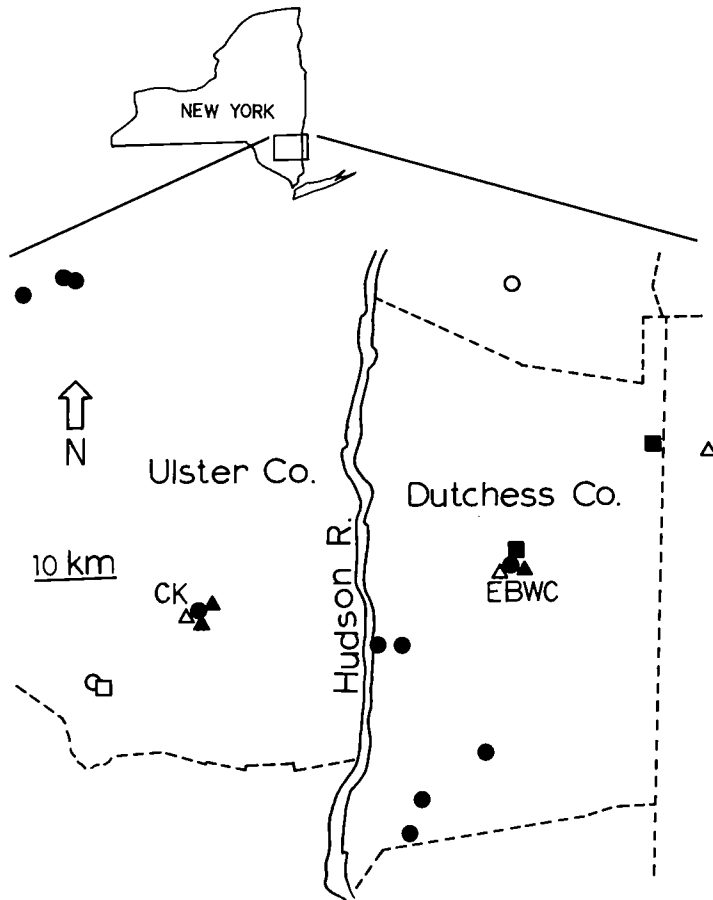


Fig. 1. The study area and sampling sites in southeastern New York. Sites of intensive study are the East Branch of Wappinger Creek (EBWC) and the Coxing Kill (CK). Other sampling sites include hyporheic zones (●), lake psammon (○), springs (△), seeps (▲), phreatic waters (■), and cave streams (□). Modified from Kolasa et al. (1987).

have been cut, and the area is now a mix of second-growth forests, pastures, orchards, plowed fields, suburban areas, and small cities.

METHODS

Depending on the habitat being sampled, I used the Karaman-Chappuis method (Delamare Deboutteville, 1960), a Bou-Rouch pump (Bou, 1974) or various smaller pumps, a modified Cvetkov net (Danielopol, 1978), or a fine (100 μm mesh) net through which suspended sediments were strained. All samples were sieved through a 100 μm mesh net and stored under refrigeration until the living animals could be picked out under 12X magnification under

TABLE I

Some environmental characteristics of the two intensively studied sites. Taken in part from Kolasa et al. (1987) and Strayer & Bannon-O'Donnell (1988).

	Coxing Kill East Branch	
elevation (m)	198	91
drainage area (km ²)	8.8	78
gradient (m/km)	32	2.7
pH	6.6	8.0
Ca ⁺⁺ (μM)	110	880
Mg ⁺⁺ (μM)	49	380
K ⁺ (μM)	8	31
Na ⁺ (μM)	140	410
SO ₄ ⁻ (μM)	110	230
Cl ⁻ (μM)	160	560
sediment loss on ignition (%)	2.6	2.2
sediment particle size (% of total weight)		
<0.25 mm	6	5
0.25-1 mm	22	26
1-4 mm	28	26
4-16 mm	28	29
>16 mm	16	15

TABLE II

Comparison of numbers of animals taken by the Karaman-Chappuis technique (K-C) and a Bou-Rouch pump (B-R), hyporheic zone of the East Branch of Wappinger Creek.

TAXON	K-C	B-R
Cyclopoida	125	41
Harpacticoida	44	1
Oligochaeta	29	2
Nematoda	26	0
Tardigrada	19	0
Turbellaria	18	0
Ostracoda	15	0
Others	8	2

a dissecting microscope. I had initially planned to use the Bou-Rouch pump more extensively, but preliminary tests showed that samples taken with this pump lacked many kinds of invertebrates that were present in Karaman-Chappuis samples taken from the same site (table II). The results shown in table II are disturbing, and suggest a need for a careful study to evaluate the selectivity of the Bou-Rouch pump, as well as other interstitial sampling methods. As a result of this preliminary comparison, I chose to take most of my samples by the Karaman-Chappuis technique.

At the two sites of intensive study (the Coxing Kill and the East Branch), I took monthly Karaman-Chappuis samples. At each site, I visited three or four gravel bars each month, taking a 3 l sample from each gravel bar and filtering it through a 100 μ m mesh net.

Animals were slide-mounted, either whole or dissected (copepods and amphipods), and identified to the species level wherever possible. Because copepod dissections and identifications were so time-consuming, I dissected and identified subsamples of only 20 cyclopoids and 20 harpacticoids per sample in samples that contained many copepods. In total, I dissected and identified 2328 copepods. Taxonomic sources included Lang (1948), Wilson & Yeatman (1959), Yeatman (1959), Dussart (1967, 1969), Pennak (1978), Dussart & Defaye (1985), and Reid (1988), as well as original descriptions and the kind help of Drs. Ilse Bartsch, David Frey, J. R. Holsinger and Ian Smith. Voucher specimens of cladocerans, copepods, and halacarid mites have been deposited in the National Museum of Natural History in Washington, D.C. (catalog numbers 235357 through 235395), parasitengone mites are in the collection of the Biosystematics Research Unit of Agriculture Canada in Ottawa, and amphipod specimens are in the collection of Dr. J. R. Holsinger.

RESULTS AND DISCUSSION

Overall composition of the fauna

The interstitial fauna of shallow groundwater in southeastern New York is dominated by microannelids (chiefly naidids, *Aeolosoma*, and enchytraeids — see Strayer & Bannon-O'Donnell, 1988), copepods, insects (primarily chironomids and first-instar mayflies and stoneflies), nematodes, and various mites (table III). Many other taxa are present as well, but usually in low numbers. Even though not all of the taxa have been studied in detail, it is clear that this fauna contains well over 100 species. Conspicuous by their absence or rarity in table III are the archiannelids, syncarids, isopods, and amphipods, which frequently are important members of the interstitial community, both in Europe (e.g., Botosaneanu, 1986) and North America (Pennak & Ward, 1986). Hypogean amphipods and isopods are found regularly in North America in karstic regions south of the glacial border, so the absence of these and other groups from the immediate study area may be due to the influence of glaciation, the scarcity of karstic terrain, and the lack of extensive post-glacial drainage connections between the Hudson River basin of southeastern New York and the great interior drainages of North America.

Cladocera

Cladocerans are a minor component of the local interstitial fauna, constituting only 1.3% of the animals collected. In only three of 147 samples did they con-

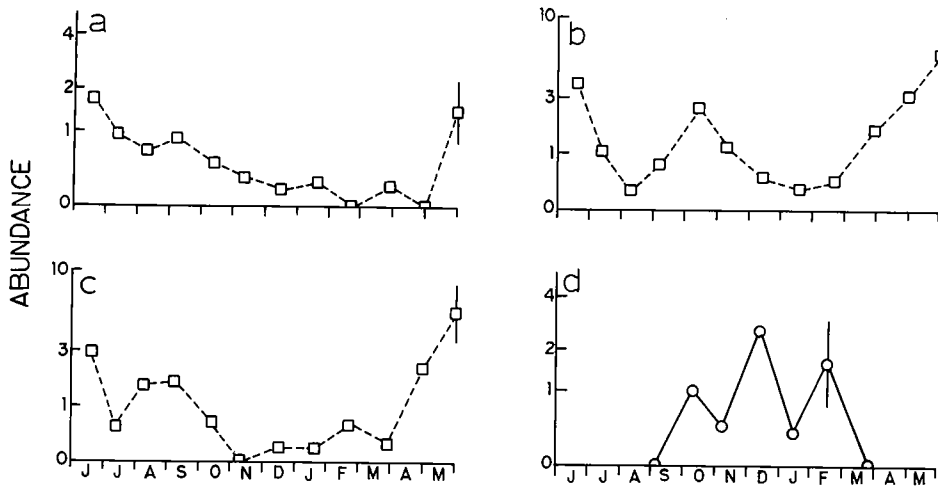


Fig. 2. Seasonal abundance of a) cladocerans, b) ostracods, c) *Loboalacarus weberi*, and d) *Phyllognathopus* sp. from the East Branch (○—○) or from data from the East Branch and Coxing Kill combined (□---□). Plotted points are the means of numbers of animals per 3 l sample, after transformation by $\ln(x + 1)$. The vertical lines around the last sampling point show the average standard error of the data.

stitute more than 10% of the animals collected. Seven species were found (table IV), of which only *Alonella* cf. *excisa* and *Alona rustica* were encountered at all frequently. The seven species listed in table IV are common and widespread in surface waters, although “*Alonella* cf. *excisa*” differs from the typical *A. excisa* by its small eye and ocellus. Peak densities of cladocerans occur in late spring and summer (fig. 2a).

My observations lend support to the notion that the Cladocera generally form a more or less incidental part of the invertebrate communities of the hyporheic zone and other shallow groundwaters. Cladocerans are only rarely abundant in such habitats (but see Sabater, 1987), and the species found usually are surface-dwelling generalists or very closely related to such species (e.g., Dumont, 1983; Sabater, 1987). However, at least a few species of Cladocera (notably the European *Alona protzi* group) appear to be true groundwater specialists (Dumont, 1987).

Copepoda

The copepods were among the most abundant and speciose of the invertebrates encountered in this study. Thirty-three species of copepods (1 calanoid, 20 harpacticoids, and 12 cyclopoids) were found in my samples (table IV). Three species were especially abundant and widespread: *Bryocamptus zschokkei*, *Diacyclops* cf. *languidus*, and *D. nearcticus*. *B. zschokkei* is widely distributed in many habitats in both surface and underground waters (e.g., Lang, 1948;

Wilson & Yeatman, 1959), but the species of *Diacyclops* are much less well known in North America. *D. languidus* is known from this continent only from temporary ponds in Quebec (Leblanc et al., 1981a, b). In Europe, it is typically regarded as a troglaxene (e.g., Lescher-Moutoué, 1973), although it may be a dominant species in some interstitial habitats (Šterba & Holzer, 1977; Amoros & Mathieu, 1984). *D. nearcticus* is a poorly known species reported from only a few scattered sites, chiefly from wells (Yeatman, 1943, 1959). It probably is a true stygophile. Several of the copepods listed in table IV apparently are undescribed or poorly known and are treated in an accompanying paper (Strayer, 1988). The occurrence of small numbers of the planktonic species *Eurytemora affinis* and *Mesocyclops edax* in my samples (from the psammon of the Hudson River and an upland lake, respectively) probably is accidental; these are not interstitial species.

Although numbers of all harpacticoids combined and all cyclopoids combined both show a clear seasonal pattern with a minimum during the winter (fig. 3), seasonal trends for individual species are varied. Of the species for which I have sufficient data to analyze, most have peaks in numbers in late spring and early summer (*Attheyella nordenskioldi*, fig. 4a; *Bryocamptus zschokkei*, fig. 4b; *Diacyclops* spp., figs. 5b-d). However, *Phyllognathopus* sp. (fig. 2d) and perhaps *Parastenocaris* spp. (fig. 4d) show a very different pattern, with peak numbers in midwinter. Because I do not have data on copepod numbers in the

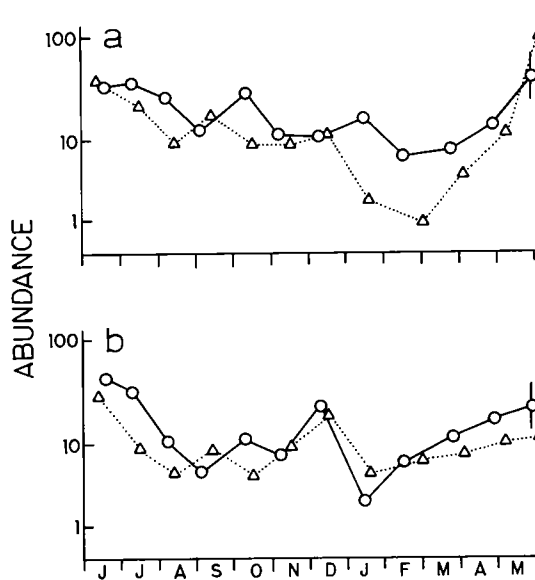


Fig. 3. Seasonal abundance of a) cyclopoids and b) harpacticoids at the East Branch (○—○) and the Coxing Kill (△.....△). Plotted points are the means of numbers of animals per 3 l sample, after transformation by $\ln(x+1)$. The vertical lines around the last sampling point show the average standard error of the data.

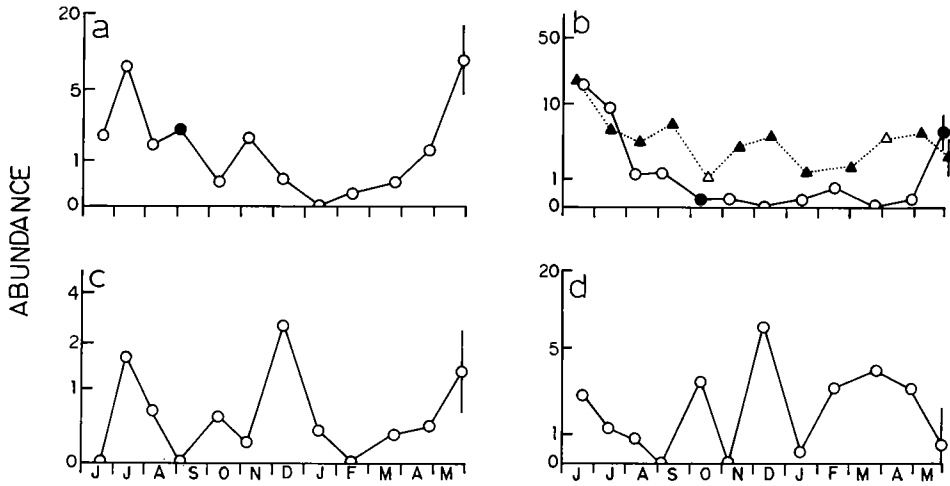


Fig. 4. Seasonal abundance of a) *Attheyella nordenskioldii*, b) *Bryocamptus zschokkei*, c) *Epactophanes richardi*, and d) *Parastenocaris* spp. in the East Branch (○—○) and the Coxing Kill (△...△). Plotted points are the means of numbers of animals per 3 l sample, after transformation by $\ln(x + 1)$. The vertical lines around the last sampling point show the average standard error of the data. Blackened symbols indicate months in which ovigerous females were observed.

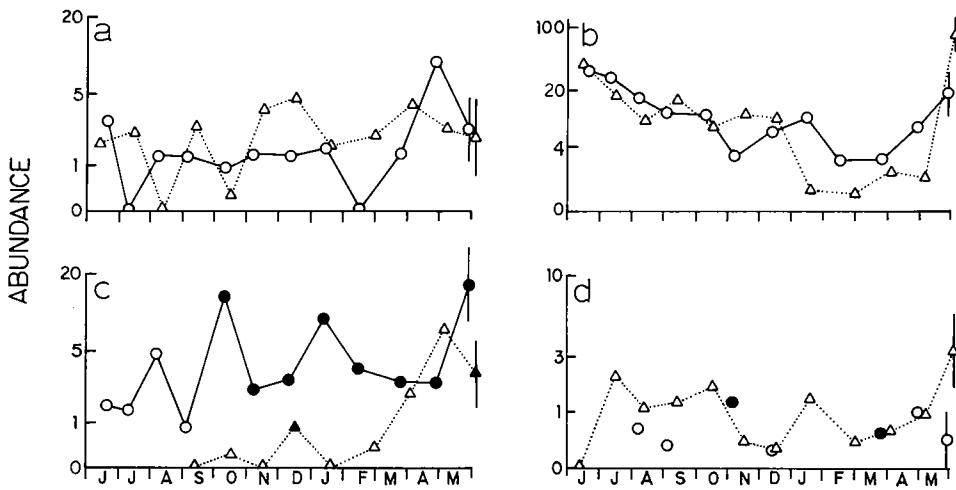


Fig. 5. Seasonal abundance of a) harpacticoid copepodites, b) *Diacyclops* copepodites, c) *Diacyclops* cf. *languidus*, and d) *Diacyclops nearcticus* in the East Branch (○—○) and the Coxing Kill (△...△). Plotted points are the means of numbers of animals per 3 l sample, after transformation by $\ln(x + 1)$. The vertical lines around the last sampling point show the average standard error of the data. Blackened symbols indicate months in which ovigerous females were observed.

TABLE III

Species richness and percent composition of the invertebrate fauna in monthly samples from the hyporheic zone of the East Branch of Wappinger Creek (EBWC), monthly samples from the hyporheic zone of the Coxing Kill (CK), and all other samples + = < 0.05%.

	Richness ^a	EBWC	CK	Other
Cnidaria	1	0.1	0.2	0
Turbellaria	27	1.8	2.3	2.2
Nemertea	na ^b	0.1	0	0.1
Nematoda	na ^b	13.9	8.8	8.6
Tardigrada	6	4.9	0.1	1.6
Aphanoncura	≥ 3	12.5	1.1	7.3
Oligochaeta	≥ 22	24.9	17.5	15.3
Cladocera	7	0.7	0.8	3.9
Copepoda	33	24.2	34.4	40.6
Ostracoda	na ^b	1.8	2.0	4.6
Amphipoda	3	+	+	0.3
Acari	≥ 19	3.5	11.4	4.1
Insecta	na ^b	11.7	21.6	11.0
Mollusca	2	0	0	0.5

^atotal number of species found

^bna = species not identified

TABLE IV

Species list and average abundance (number per 3 l sample) of crustaceans and mites in samples from the East Branch of Wappinger Creek (EBWC), the Coxing Kill (CK) and all other samples. + = < 0.1.

	EBWC	CK	OTHER
CLADOCERA			
<i>Macrothrix laticornis</i> (Jurine)	0	0	0.2
<i>Pleuroxus striatus</i> Schoedler	0	0.1	0
<i>Alonella</i> cf. <i>excisa</i> (Fischer)	0.9	0	3.1
<i>Chydorus</i> cf. <i>brevilabris</i> Frey	0.3	0	0.2
<i>C. piger</i> Sars	0	0	+
<i>Alona quadrangularis</i> (O. F. Müller)	0	0	+
<i>A. rustica</i> Scott	+	0.7	0.1
COPEPODA			
<i>Eurytemora affinis</i> (Poppe)	0	0	0.1
<i>Phyllognathopus</i> sp.	0.8	0	0
<i>Canthocamptus assimilis</i> Kiefer	0	0	0.1
<i>C. staphylinooides</i> Pearse	0.4	0	0.1
<i>Attheyella obotogamensis</i> (Willey)	0	1.0	0
<i>A. illinoisensis</i> (Forbes)	0	0.6	2.2
<i>A. nordenskioldi</i> (Lilljeborg)	3.9	0	0.6
<i>Maraenobiotus brucei</i> (Richard)	0	0	0.1
<i>Epactophanes richardi</i> Mrazek	1.3	+	0
<i>Moraria laurentica</i> Willey	0	0.1	0
<i>M. affinis</i> Chappuis	+	0.1	0.6

	EBWC	CK	OTHER
<i>Bryocamptus zschokkei</i> (Schmeil)	4.2	5.1	8.1
<i>B. vejvodskyi</i> (Mrazek)	1.1	0	0.3
<i>Bryocamptus</i> (<i>Bryocamptus</i>) sp.	+	0	0
<i>B. cuspidatus</i> (Schmeil)	0	0.4	0
<i>B. nivalis</i> (Willey)	0.4	0.2	1.3
<i>Elaphoidella bidens coronata</i> (Sars)	0.3	0	+
<i>E. shawangunkensis</i> Strayer	0.6	1.1	0.1
<i>Parastenocaris</i> spp.	3.8	0.1	0.1
immature Harpacticoida	3.0	3.9	4.8
<i>Macrocyclops albidus</i> (Jurine)	0.2	0	0.1
<i>Eucyclops</i> sp.	+	0	0.1
<i>Paracyclops fimbriatus</i> (Fischer)	0	0.2	0
<i>P. poppei</i> (Rehberg)	0	0.1	0.3
<i>P. smileyi</i> Strayer	0	0.1	0
<i>Acanthocyclops</i> cf. <i>vernalis</i> (Fischer)	0.2	0	0
<i>A. venustoides</i> Coker	1.2	0	0.5
<i>A. parvulus</i> Strayer	0	0	2.6
<i>Diacyclops</i> cf. <i>languidus</i> (Sars)	9.7	1.9	1.7
<i>D. crassicaudis brachycercus</i> Kiefer	0	0	0.3
<i>D. nearcticus</i> Kiefer	0.6	1.9	1.0
<i>Mesocyclops edax</i> (Forbes)	0	0	+
immature Cyclopoida	15.6	18.5	5.4
OSTRACODA (sp. indet.)	1.8	2.0	4.6
AMPHIPODA			
<i>Crangonyx</i> cf. <i>gracilis</i> Smith	+	0	+
<i>Stygobromus allegheniensis</i> (Holsinger)	0	+	0
<i>S.</i> cf. <i>borealis</i> Holsinger	0	0	0.1
ACARI			
<i>Porohalacarus uniscutatus</i> Bartsch	+	0.3	0
<i>Lobohalacarus weberi weberi</i> (Romijn & Viets)	2.0	4.0	0.2
<i>Soldanellonyx monardi</i> Walter	0.2	0.6	0.1
<i>S. visurgis</i> Viets	0	+	0
<i>Porolohmanella violacea</i> Kramer	0.1	+	0
<i>Sperchon</i> sp.	0	0	0.1
<i>Clathrosperchon</i> sp.	+	0	0
<i>Bandakia</i> sp.	0	+	+
<i>Lebertia</i> sp.	+	0	0.1
<i>Torrenticola</i> sp.	1.2	+	0.5
<i>Hygrobates</i> sp.	+	0	0
<i>Atractides</i> sp.	+	0.3	0.2
<i>Feltria</i> sp.	0.2	0	0
<i>Ljanita</i> sp.	0	+	0
<i>Alturus</i> sp.	0.2	0	0
<i>Stygomonomia</i> sp.	0	+	0
<i>Neoacarus</i> sp.	+	0	0
<i>Forelia</i> sp.	+	0	0
Other Acari (not Halacaridae or Parasitengona)	2.7	6.1	1.7

habitats that border my sampling sites and because my data on the numbers of immatures of various copepod species are so limited, it is impossible to know whether the patterns shown in figs. 2-5 are the result of seasonal changes in population sizes, seasonal migrations to and from nearby habitats, or both.

Seasonal patterns of reproduction are clear for only a few species (cf. figs. 2-5). Ovigerous females of *Diacyclops* spp. were collected only during October through May (figs. 4c, d), and copepodites of this genus appeared in large numbers in May. These observations suggest that the species of *Diacyclops* have a simple annual life cycle, with egg development occurring over the colder months of the year, recruitment into copepodites in spring, and maturity in early winter. The presence of adults throughout the year may indicate that adults live for more than one year or that there is considerable asynchrony in development within the population. The data for *Attheyella nordenskioldi* (fig. 4a) are much sparser than those for *Diacyclops* spp., but suggest a similar life cycle (large numbers of copepodites of *A. nordenskioldi* were collected in April). The life cycle of *Bryocamptus zschokkei* follows another pattern. Although there was a peak in adult numbers in May, ovigerous females were collected in nearly every month, suggesting that reproduction is less strongly seasonal in this species than in the three preceding species. This observation is consistent with O'Doherty's (1985) inference that *B. zschokkei* may reproduce continuously throughout the year, if the water temperature is high enough ($>4^{\circ}\text{C}$), and with prior field studies that found year-round reproductive activity in this species (Lang, 1948).

Females outnumbered males in all common species that I collected (table V). This is typically the case in natural populations of copepods, although exceptions are known (Lescher-Moutoué, 1973; Hicks & Coull, 1983).

TABLE V

Numbers of copepods collected, by species and sex, and sex ratio of common species of copepods. Data from all sites combined.

	Males	Females	% Male
<i>Phyllognathopus</i> sp.	5	19	21
<i>Attheyella obotogamensis</i>	6	25	19
<i>A. illinoisensis</i>	16	26	38
<i>A. nordenskioldi</i>	45	67	40
<i>Epactophanes richardi</i>	5	41	11
<i>Bryocamptus zschokkei</i>	110	162	40
<i>B. vejdoskyi</i>	8	21	28
<i>B. nivalis</i>	10	23	30
<i>Elaphoidella shawangunkensis</i>	17	25	40
<i>Parastenocaris</i> spp.	45	47	49
<i>Acanthocyclops parvulus</i>	6	23	21
<i>Diacyclops</i> cf. <i>languidus</i>	102	169	38
<i>D. nearcticus</i>	29	38	43

The copepod fauna from the study area is broadly similar to that reported from other parts of the world. For example, many previous workers have reported copepod faunas containing ca. 20 species, with both cyclopoids and harpacticoids well represented, and typically dominated by *Diacyclops*, *Acanthocyclops*, *Bryocamptus*, and *Parastenocaris* (e.g., Husmann, 1956; Goubault & Lescher-Moutoué, 1968; Dole, 1983; Amoros & Mathieu, 1984). Such generalizations are not invariably true, of course, and it is common for researchers to find considerably lower species richness (i.e., <10 species) (e.g., Tilzer, 1968; Pennak & Ward, 1986) or a marked dominance of either cyclopoids (e.g., Kiefer, 1981) or harpacticoids (Pennak & Ward, 1986).

It is remarkable that studies in North America (i.e., this study and that of Pennak & Ward, 1986) have not turned up any copepod genera that are endemic to North American ground waters. In Europe, there are several genera of copepods that are more or less restricted to underground waters (e.g., *Speocyclops*, *Graeteriella*, *Nitocrella*, *Antrocamptus*) (e.g., Lescher-Moutoué, 1986; Rouch, 1986). Not only have North America surveys failed to find these European genera but they have not yet uncovered any equivalent genera that are endemic to North America. Instead, the known stygophilic copepods of North America belong to genera such as *Diacyclops*, *Acanthocyclops*, and *Parastenocaris*, genera that are either ecologically or geographically widespread. It will be interesting to see whether surveys of the hypogean copepods of the ancient unglaciated parts of North America (e.g., the Cumberland and Ozark plateaus) uncover any genera endemic to North American ground waters.

Ostracoda

Ostracods generally constitute a minor part of the interstitial fauna in the study area (tables III and IV). However, they were abundant (> 10% of the fauna) in a few samples taken from springs and gravel bars of headwater brooks. Despite the low density of ostracods, there is a clear seasonal pattern in ostracod numbers, with peak densities in the fall and late spring (fig. 2b). I did not identify the species that I collected, but some specimens belong to the genus *Candona*, a common inhabitant of interstitial waters (Danielopol & Hartmann, 1986).

Amphipoda

Only 10 specimens of amphipods were collected in this study, representing three species: *Stygobromus allegheniensis*, *Stygobromus borealis* or a related undescribed species, and a species of the *Crangonyx gracilis* group. The second species, from the Ellenville ice caves, differs from typical *S. borealis* in that the uropod 3 bears three apical spines (J. R. Holsinger, in litt.), but my material is too scanty to establish the correct systematic placement of this taxon. Both

S. allegheniensis and *S. borealis* have been found at scattered sites in New York and nearby states, although neither is especially widespread or abundant (Holsinger, 1978; Smith, 1985).

Acari

Three groups of mites were present in my samples: Halacaridae, the Parasitengona (= "Hydrachnellae"), and a group of small mites of terrestrial affinities. Although these last mites were abundant (table IV), I did not identify them, and they are not treated further here. Husmann (1956) provided some discussion of the terrestrial mites that sometimes inhabit aquatic interstitial environments.

Halacarids were encountered regularly, but in small numbers (table IV), in interstitial habitats in southeastern New York. Of the five species of halacarids found in my samples, three (*Lobohalacarus weberi weberi*, *Soldanellonyx monardi*, and *Porolohmanella violacea*) are widespread, eurytopic species (Husmann & Teschner, 1970; Paasivirta, 1975; Bartsch, 1982). *Soldanellonyx visurgis* is an uncommon species of hyporheic and bog waters in Europe (Schwoerbel, 1986a); recently, it has been reported from Rhode Island in the United States (Bartsch, 1982). *Porohalacarus uniscutatus* is known previously only from a single animal collected among brown algae in the brackish water of Narragansett Bay, Rhode Island (Bartsch, 1982). Its ecology remains to be determined; however, it is apparent from the great environmental differences between the two known sites of collection — a brackish estuary and the hyporheic zone of two small upland streams — that the species is eurytopic.

Halacarids are most abundant during the spring and summer (fig. 2c). All four life stages of *Lobohalacarus weberi* were found throughout the year in my samples, so no clear pattern of seasonal recruitment is evident from my sparse data. While some workers (e.g., Paasivirta, 1975; Bartsch, 1975; Strayer, 1985) have been unable to discern a clearly seasonal life cycle in freshwater halacarids, at least some populations have a simple annual life cycle (Teschner, 1963; Bartsch, 1987).

Parasitengone mites were scarce in my samples (table IV). Many of the genera from my samples are characteristically found in interstitial waters (e.g., Schwoerbel, 1986b). Parasitengone densities were too low and variable to display any obvious seasonal trends.

CONCLUSIONS

Aquatic interstitial habitats in southeastern New York support an abundant and varied fauna (Kolasa et al., 1987; Strayer & Bannon-O'Donnell, 1988; Strayer et al., 1988; this paper). While some of the species found in these habitats appear to be true interstitial specialists (e.g., the flatworm *Limnoruanis*

romanae, the tardigrade *Thulinia ruffoi*, the copepod *Diacyclops nearcticus*), the great majority are common, eurytopic species of surface waters. The prevalence of eurytopic epigeal species is probably due in part to the proximity of surface waters to the shallow interstitial habitats that were studied here and to the recent glaciation of the study area, but it underlines a point made recently by Rouch & Danielopol (1987) — that many generalist epigeal species actively penetrate into underground waters.

A second point that seems clear from our work in southeastern New York is that it is difficult to generalize about the seasonal patterns of abundance and reproduction of the animals that inhabit shallow ground waters. Most typically, peak densities and reproduction occur during the summer or fall, but there are many exceptions. The apparent differences among species may result from different ecological tolerances of species, different seasonal patterns of migration between shallow ground waters and nearby habitats, or biological interactions (predation, competition) between populations. Until further and much more detailed work is done, we cannot rule out any of these causes.

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