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A survey of the zinc-polluted River Nent (Cumbria) and the East and West Allen (Northumberland), England, using chironomid pupal exuviae

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Abstract

Collections of chironomid pupal exuviae from zinc-enriched sites on the Rivers Nent, and East and West Allen in the English Pennines, showed consistently lower diversities than those from low-zinc sites. The dominant species found at zinc-enriched sites differ between the Nent and the Allens, being *Krenosmittia camptophleps* in the Nent, and *Eukiefferiella clypeata* and *Tvetenia calvescens* in the West Allen. The low-zinc sites may contain chironomid communities close to those which would live in normal unpolluted rivers of similar types to those investigated. These communities will vary as conditions change between different sites or rivers, but will form the basic set of species from which a zinc-tolerant sub-set will be selected in each case.

Introduction

The area of the North Pennine orefield in Britain, is notable for the extensive mining operations that were carried out principally during the eighteenth century (Dunham, 1949). Currently there is very little mining activity in the area, but previous workings and accumulations of mine spoil have left a legacy of acid and heavy metal enriched streams. The Rivers Nent and the East and West Allen, rise in the high moors near Alston, at the intersection of the three counties, Cumbria, Durham and Northumberland. This paper reports an investigation carried out in 1983, into the chironomid fauna of the zinc-enriched Nent and the Allens, using collections of chironomid pupal exuviae. It was hoped to gain some understanding of the distribution of the chironomid fauna in relation to the stream conditions, and in particular to the concentration of zinc in the water.

The rivers are affected by acid mine drainage from old mine workings, and are particularly rich in zinc. Certain locations also receive organic effluents of domestic and agricultural origin. Armitage (1980), studied the macroinvertebrates of an extensive series of sites on the Nent and its tributaries, and has related their distribution and abundance to broad categories of zinc concentrations. He also gives figures for certain chemical measurements related to organic and metal concentrations in the water. Abel & Green (1981) have reported on the ecology and distribution of macroinvertebrates on the Allens in relation to the zinc concentrations, which are significantly higher in the West, as opposed to the East, Allen.

In the Nent, Armitage (1980) showed that there was a significant negative correlation between the zinc level and the number of taxa per site, although the situation was complicated by localised inflows of calcium-rich water. Summer growths of *Stigeoclonium tenue* may also have affected the faunal distribution. Abel & Green (1981) showed that the fauna in the zinc-enriched West Allen was quantitatively and qualitatively restricted as compared to that in the East Allen, and suggest that this is directly due to the toxic effects of the zinc. They also showed a significant negative correlation between numbers of species of macroinvertebrate and the concentration of zinc in the water.

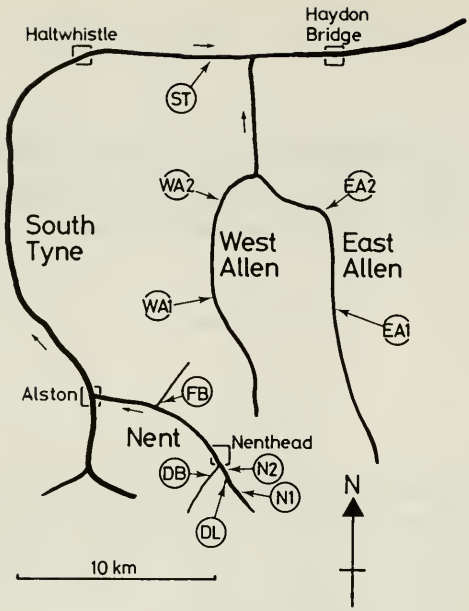

Fig. 1: Diagrammatic sketch-map of the section of the River South Tyne and its tributaries the River Nent and the East and West Allen. Sampling sites are shown in circles.

Other work on the effects of heavy metals on river invertebrates includes the classical studies on the Rivers Ystwyth and Rheidol in North Wales (see eg. Carpenter, 1924; Jones, 1940), and on the Willow Brook by Solbé (1977), while a general discussion may be found in Whitton (1975). Little of the data refers in detail to the Chironomidae, however, and the work reported in this paper is an attempt to remedy this omission by examining data from a series of collections of chironomid pupal exuviae made in July 1983 in the same area as worked by Armitage (1980), and by Abel & Green (1981).

Locality and Methods

The River Nent rises south-west of Nenthead (NGR NY 801421) at an altitude of 656 m and flows north-westward into the River South Tyne at Alston after a course of only 16 km. The East and West Allens are a pair of very

Table 1: Sampling sites and physical and chemical data.

Site code	River and site	National Grid Ref.	Altitude m	Gradient o/oo	Width range	Chemical ranges* - pH	Ca mg/l	Zn mg/l	Pb mg/l
N1	Nent, u/s Dowgang Level	NY782434	433	33	4–5	6–7	5–10	0.5–1	<0.05
N2	Nent, d/s Dowgang Level	NY781435	432	33	4–5	7–8	10–20	1–2	<0.05
DL	Dowgang Level adit	NY782435	433	-	1	7–8	50–100	5–10	<0.05
DB	Dowgang Burn	NY780435	428	125	2–3	3–4	5–10	0.1–0.5	0.1–0.2
FB	Foreshield Burn	NY750467	338	50	2–3	7–8	20–50	<0.1	<0.05
ST	South Tyne, Bardon Mill	NY781643	90	3	80–100	7–8	10–20	<0.1	<0.05
WA1	West Allen, Corryhill Br.	NY782524	245	16	10–20	7–8	20–50	1–2	trace
WA2	West Allen, Whitfield Weir	NY782570	175	14	10–20	7–8	20–50	1–2	trace
EA1	East Allen, Rye Close Ford	NY842509	294	11	10–20	7–8	20–50	<0.2	trace
EA2	East Allen, Thornley Gate Br.	NY831567	193	10	10–20	7–8	20–50	<0.2	trace

* data modified from ARMITAGE (1980), ABEL & GREEN (1981)

Table 2: List of samples from the River Nent, West and East Allen, and South Tyne, showing numbers of exuviae and taxa, and certain exuvial and diversity indices. Percentages to the nearest whole percent. KEY: N1 and N2, Nent; DL, Dowgang Level adit; DB, Dowgang Burn; FB, Foreshield Burn; ST, South Tyne; WA, West Allen; EA, East Allen; %It, %Intolerant taxa; %Ii, % Intolerant individuals; %Sedt, % Sediment-dwelling taxa; %Sedi, % Sediment-dwelling individuals; Men D, Menhinick Diversity; S-W D, Shannon-Weaver Diversity.

			Taxa indices			Exuvial indices		
Station	No. of exuviae	No. of taxa	%It	%Sedt	Men D	%Ii	%Sedi	S-W D
N1	303	13	69	31	.7	17	6	.9
N2	477	18	56	39	.8	21	11	1.3
DL	1	1	–	–	–	–	–	–
DB	51	4	0	25	.6	0	2	.4
FB	118	23	52	17	2.1	36	11	2.4
ST	225	31	71	45	2.1	74	70	2.7
WA	45	13	69	15	1.9	73	11	2.1
EA	315	37	62	22	2.1	70	24	2.6

similar rivers which rise im mediately east of the Nent (NGR: NY802442, NY860432), and flow northwards parallel to each other for 30–40 km, before joining and entering the South Tyne approximately 33 km downstream from the Nent junction.

Fig. 1 is a diagrammatic sketch-map of the area, showing the rivers and the sampling stations. The two sites on the Nent were both near the village of Nenthead, N1 approximately 200 m above and N2 300 m below the zinc-rich output from an old mine adit, the Dowgang Level; DL was on the outflow from the Dowgang Level, which flows for only about 3 m before entering the Nent; DB was on the Dowgang Burn tributary which is highly acidic (pH c.4) with effluent from an old coal mine; FB was on the Foreshield Burn tributary, which is organically enriched from a local farm but has few heavy metals; and ST was on the South Tyne. Two samples were taken from both the East (EA1, EA2) and West Allen (WA1, WA2).

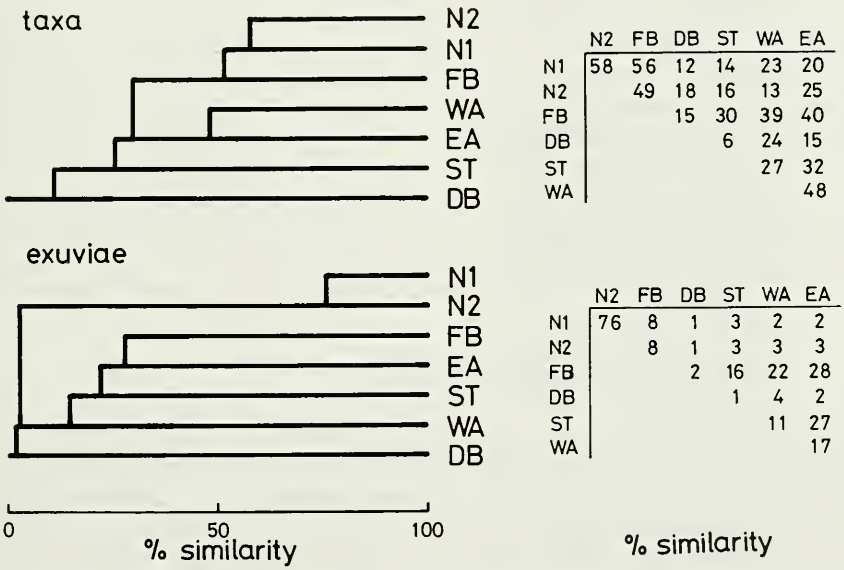

Fig. 2: Dendrograms of percentage similarity derived from average linkage clustering of Sorensen's and Czekanowski's coefficients of similarity; A. taxa presence/absence; B. number of exuviae. The matrices of similarity from which the dendrograms are derived are also shown.

Sets of exuvial collections were made at each site over a two day period (18th and 19th July 1983) by both hand-net and surface drift-nets (similar to Brundin nets but with lateral floats, BRUNDIN, 1956; WILSON & McGILL, 1977), and all collections were lumped for each site. On the Nent and its tributaries, small drift-nets were set out overnight so as to increase the numbers of exuviae collected.

Table 3. List of species and percentage abundance found in chironomid exuvial collections from rivers in the North Pennine orefield in July 1983. Figures are whole percentages; + = <0.5%; . = absent from sample.
KEY TO SITES: N1,N2, Nent; DL, Dowgang Level adit; DB, Dowgang Burn; FB, Foreshield Burn; ST, South Tyne; WA, West Allen; EA, East Allen.

	Percentages (nearest whole percent) -								
TAXA	N1	N2	DL	DB	FB	ST	WA	EA	TOTAL
BUCHINOMYINAE									
Buchinomyia thienemanni Fitt	.	.	.	.	.	1	.	+	+
PODONOMINAE									
Paraboreochlus minutissimus (Strobl)	1	1	.	.	.	.	.	.	+
TANYPODINAE									
Macropelopia nebulosa (Mg)	.	.	.	.	.	4	.	.	1
Ablabesmyia longistyla Fitt.	.	+	.	.	.	.	.	.	+
Conchapelopia viator (K)	+	+	.	.	5	9	2	6	3
Rheopelopia maculipennis (Zett)	.	.	.	.	.	1	.	.	+
Thienemannymia laeta (Mg) Pe1/2	.	.	.	.	.	+	.	.	+
Trissopelopia longimana (Staeg)	1	.	.	.	1	.	.	.	+
DIAMESINAE									
Diamesa insignipes K	.	+	.	.	1	+	.	.	+
Diamesa thienemanni K	.	.	.	.	.	.	.	+	+
Potthastia Pe1a	1	1	.	.	.	.	.	.	+
Potthastia longimana K	.	.	.	.	.	+	.	.	+
Potthastia sp.2	.	.	.	.	.	4	.	.	1
PRODIAMESINAE									
Prodiamesa olivacea (Mg)	.	.	.	.	.	.	.	1	+
ORTHOCLADIINAE									
Brillia modesta (Mg)	.	.	.	.	6	.	.	2	1
Cardiocladius fuscus	.	.	.	.	.	.	.	+	+
Chaetocladius Pe2	+	+	100	.	1	.	.	.	+
Corynoneura spp.	.	.	.	.	4	.	.	.	+
Cricotopus (C) Pe2 ?similis Goet	.	.	.	.	.	1	.	.	+
Cricotopus (C) bicinctus (Mg)	.	.	.	.	.	.	.	+	+
Cricotopus (C) pulchripes Verr	4	10	.	.	2	.	.	.	4
Cricotopus (C) spp.	.	.	.	.	.	1	.	.	+
Cricotopus (C) tremulus (L)	.	.	.	.	.	.	.	1	+
Cricotopus (C) trifascia Edw	.	.	.	.	4	.	.	.	+
Cricotopus (I) brevipalpis (K)	.	+	.	.	.	1	.	2	1
Eukiefferiella brevicalcar (K)	.	.	.	.	.	.	.	+	+
Eukiefferiella claripennis (Lund)	+	2	.	2	30	.	13	2	4
Eukiefferiella clypeata (K)	.	.	.	.	.	.	36	1	1
Eukiefferiella coerulescens (K)	+	.	.	.	2	+	2	1	1
Eukiefferiella devonica (Edw)	.	.	.	.	.	1	9	6	2
Eukiefferiella ilkleyensis (Edw)	.	.	.	.	.	.	2	3	1
Eukiefferiella minor (Edw)	.	.	.	.	3	.	.	+	+
Heleniella ornaticollis (Edw)	5	6	.	.	1	.	.	.	3
Krenosmittia camptophleps (Edw)	78	65	.	.	5	.	.	+	36
Limnophyes spp.	.	.	.	92	.	.	.	+	3
Metriocnemus hygropetricus (K) gp.	.	.	.	.	2	.	2	+	+
Nanocladius bicolor (Zett)	.	.	.	.	1	.	.	.	+
Nanocladius rectinervis (K)	.	.	.	.	1	1	.	.	+
Orthocladius (Eudact) obtexens Brund	.	+	.	.	1	.	.	+	+
Orthocladius (Euorth) rivicola K	.	.	.	.	.	.	.	9	2
Orthocladius ?rubicundus Edw	.	.	.	.	.	.	.	1	+
Orthocladius Pe1	.	.	.	.	.	.	.	+	+
Orthocladius rhyacobius K	.	.	.	.	.	1	.	.	+
Orthocladius rubicundus sensu Edward	.	.	.	.	.	4	7	6	2
Orthocladius sp.A Pinder	.	.	.	.	.	1	.	+	+
Paracladius conversus (Walk)	+	.	.	.	.	.	.	.	+
Parametriocnemus stylatus (K)	.	.	.	.	.	+	.	.	+
Paratrichocladius rufiventris (Mg)	.	.	.	.	.	.	2	.	+
Paratrissocladius excerptus Pe1	.	+	.	.	.	.	.	.	+
Pseudorthocladius sp.	.	4	.	.	.	.	.	.	+
Pseudosmittia Pe1	.	+	.	.	.	.	.	+	+

Rheocricotopus chalybeatus (Edw)	.	.	.	.	1	2	.	.	+
Rheocricotopus dispar (Goet)	.	.	.	.	.	.	.	1	+
Rheocricotopus effusus (Walk)	5	4	.	.	2	.	.	+	2
Thienemannia gracilis K	.	.	.	.	.	.	.	+	+
Tvetenia calvescens (Edw)	.	.	.	.	20	4	9	29	8
Tvetenia discoloripes (Goet)	.	.	.	.	.	.	4	3	1
CHIRONOMINAE									
CHIRONOMINI									
Microtendipes spp.	.	.	.	.	.	31	.	.	5
Paratendipes Pe2	.	.	.	.	.	.	.	+	+
Polypedilum Pe2	.	.	.	.	1	.	2	1	+
Polypedilum albicorne (Mg)	4	9	.	.	1	3	.	.	4
Polypedilum cultellatum Goet	.	.	.	.	.	+	.	.	+
Polypedilum laetum (Mg)	.	.	.	.	.	.	.	+	+
TANYTARSINI									
Cladotanytarsus ?nigrovittatus Goet	.	.	.	.	.	1	.	.	+
Micropsectra aristata Pind	.	+	.	2	9	4	9	14	4
Micropsectra atrofasciata K	.	.	.	.	.	4	.	+	1
Micropsectra apposita (Walk)	.	.	.	.	.	11	.	7	3
Parapsectra nana (Mg)	.	+	.	.	.	.	.	.	+
Rheotanytarsus pentapoda K	.	.	.	.	.	+	.	.	+
Tanytarsus brundini Lind	.	.	.	.	.	4	.	.	1
Tanytarsus eminulus (Walk)	.	.	.	.	.	2	.	.	+
Tanytarsus palmeni Lind	.	.	.	.	.	4	.	.	1
TOTAL TAXA IN SAMPLE	13	18	1	4	23	31	13	37	72
TOTAL EXUVIAE IN SAMPLE	303	477	1	51	118	225	45	315	1535
TOTAL PERCENTAGE (nearest whole %)	99	102	100	96	104	100	99	96	96

Results

Most of the samples contained satisfactory numbers of exuviae, but some were numerically poor. The Dowgang Level mine adit (DL) yielded only a single exuviae, and the acid Dowgang Burn (DB) only 51 exuviae in 24 h drift-netting. The Allens were sampled with hand and drift nets for about an hour at each site, and WA1 and WA2 on the West Allen, yielded only 4 and 41 exuviae respectively; whereas the two East Allen samples EA1 and EA2 on the other hand yielded 65 and 250 exuviae. It was therefore decided to lump EA1 and EA2, and WA1 and WA2, together for analysis, forming a single composite sample for each of the East Allen (EA) and the West Allen (WA).

Table 1 gives some basic parameters such as altitude, slope of site, and grid reference for each site, as well as chemical data derived from the papers by Armitage (1980) and Abel & Green (1981) which illustrate the chemical conditions. Table 2 shows the numbers of exuviae and identified taxa found in each sample together with certain exuvial and diversity indices. Table 3 gives the complete species list found in the samples in taxonomic order, while Table 4 lists only those species which were found making up 5 % or more of the exuviae in any one sample.

Fig. 2 shows the dendrograms plotted from data from average linkage clustering of the species collected from each site, using Sørensen's and Czekanowski's coefficients of similarity for taxa presence/absence and numbers of individual exuviae respectively.

Discussion

The cluster analysis data (see Fig. 2) show that the two Nent sites (N1, N2) are very similar in both taxa and numbers of exuviae (N1:N2 taxa, 58 %; exuviae, 76 %). They are also closely linked to the Foreshield Burn (FB) by taxa presence/absence (N1:N2, 58 %; N1:FB, 56 %; N2:FB, 49 %), but not by numbers of individual exuviae (N1:FB, 8 %; N2:FB, 8 %). Similarly the West Allen and the East Allen are similar in taxa (WA:EA, 48 %) but not in numbers of exuviae (WA:EA, 17 %). The zinc-enriched sites also show a lower diversity of species (N1: Menhinick, 0.7; Shannon, 0.9; N2: Menhinick, 0.8; Shannon, 1.3) in contrast to the higher diversity in the low-zinc sites (FB: Menhinick, 2.1, Shannon, 2.4; EA: Menhinick, 2.1; Shannon, 2.6).

Table 4: Table of principal species (>5% in any sample) in the Nent, East and West Allen, and South Tyne. Figures to the nearest whole percent. KEY: N1 and N2, Nent; DB, Dowgang Burn; FB, Foreshield Burn; ST, South Tyne; WA, West Allen; EA, East Allen; + = <0.5%; . = absent from sample.

Species	Percentages -						
	N1	N2	DB	FB	ST	WA	EA
Krenosmittia camptophleps (Edw)	78	65	.	5	.	.	+
Heleniella ornata (Edw)	5	6	.	1	.	.	.
Cricotopus (C) pulchripes Verr	4	10	.	2	.	.	.
Polypedilum albicorne (Mg)	4	9	.	1	3	.	.
Limnophyes spp.	.	.	92	.	.	.	+
Eukiefferiella claripennis (Lund)	+	2	2	30	.	13	2
Tvetenia calvescens (Edw)	.	.	.	20	4	9	29
Micropsectra aristata Pinder	.	+	2	9	4	9	14
Brillia modesta (Mg)	.	.	.	6	.	.	2
Conchapelopia viator (K)	+	+	.	5	9	2	6
Microtendipes spp.	.	.	.	.	31	.	.
Micropsectra apposita (Walk)	.	.	.	.	11	.	7
Eukiefferiella clypeata (K)	.	.	.	.	.	36	1
Eukiefferiella devonica (Edw)	.	.	.	.	1	9	6
Orthocladius (ss) rubicundus Edw	.	.	.	.	4	7	6
Orthocladius (Euorth) rivicola K	.	.	.	.	.	.	9
Total taxa in sample	13	18	4	23	31	13	37
Total exuviae examined	303	477	51	118	225	45	315

If the taxa composition is similar between comparable zinc-enriched and low-zinc sites, but the abundances of individual species differs, and the diversity is lower at the enriched sites, then it seems possible that the fauna of the zinc-enriched sites (N1, N2 and WA), comprise those species that have higher tolerance of the zinc, and represent subsets of the unpolluted chironomid communities of these rivers. The low-zinc sites (FB and EA) may exemplify the unpolluted fauna.

It is important, however, to note that the species found in the zinc-enriched Nent were very different from those in the similarly zinc-enriched West Allen. The Nent samples (N1 and N2) were dominated by *Krenosmittia camptophleps* (Edwards) (78 % and 65 %), but also contained substantial numbers of *Heleniella ornata* (Edwards) (5 % and 6 %), *Cricotopus (C.) pulchripes* Verrall (4 % and 10 %) and *Polypedilum albicorne* (Meigen) (4 % and 9 %): in contrast, the West Allen samples (WA) were dominated by *Eukiefferiella clypeata* (Kieffer) (36 %) and *Eukiefferiella claripennis* (Lundbeck) (13 %), and did not contain any of the four species characteristic of the Nent.

It appears therefore that the Nent and the Allens, although adjacent and similar stony rivers, differ in some way meaningful to the Chironomidae. It is therefore not possible from these samples to designate a characteristic "zinc-tolerant" community of chironomid species, which might be found wherever zinc-enrichment occurs, in the same way that a characteristic "organic-tolerant" community may be defined which is linked to organic enrichment in many different rivers and situations. Zinc-tolerance may develop in a number of different species, selected as appropriate from those available at the particular site.

It is well-known that chironomid communities differ in different sections of a single river, and that different communities are found associated with different gradients and substrates (Thienemann, 1954; Kownacki & Kownacka, 1972). The Nent sites N1, N2 and FS have gradients of from 30–50 ‰, whereas the sites on the Allens have gradients of from 10–16 ‰. It is possible therefore that the chironomid communities found in the Nent are characteristic of higher gradients than those of the Allens, even though the rivers are basically similar.

The dominant species in the Nent in samples N1 and N2, *Krenosmittia camptophleps, Heleniella ornata, Cricotopus (C.) pulchripes* and *Polypedilum albicorne* are all characteristic of upland streams and often associated with hygropetric conditions (Cranston, 1982; Wiederholm, 1983; Langton, 1984). In contrast, *Eukiefferiella* and *Tvetenia* spp., which dominate the samples from the West Allen, are normally more abundant at lower altitudes, and especially where there is increased growth of moss (Humphries & Frost, 1937; Thienemann, 1954; Cranston, 1982; Langton, 1984).

The calcium concentrations in the the Nent were lower than in the Allens (see Table 1). It is widely held that heavy metals are less toxic in calcium-rich water than in acid, low calcium water (Hynes, 1960; Warren, 1971; Whitton & Say, 1975; Mason, 1981), and this effect may influence the response of the chironomids to the river conditions.

The sample from the acid Dowgang Burn (c. pH 4) is quite different from all the other samples, and is dominated by *Limnophyes* spp. (92%). The single exuviae from the very short outfall from the Dowgang Level, which has a high zinc content of 5–10 mg/l, was a *Chaetocladius* sp. (Pe2 in Langton, 1984), also found in low numbers in the Nent and the Foreshield Burn. The River South Tyne at Bardon Mill Ford is a much larger river with more fine sediment, and has a much lower gradient (3 ‰) than the Nent and Allens, and this is reflected in the dominance of sediment-living taxa such as *Microtendipes* spp. and *Micropsectra apposita* (Walker) found in the sample (31% and 11%, respectively). In the cluster analysis, the South Tyne sample (ST) showed closest similarity with the Foreshield Burn (ST:FB taxa, 30%; exuviae, 16%) and with the East Allen (ST:EA taxa, 32%; exuviae, 27%), but the linkage is weak. As the South Tyne has a low zinc content (<0.1 mg/l), it it might be expected to link with the other low-zinc sites.

More data is required before the ideas advanced in this paper can be considered valid, but it is hoped that they will point the way to further, more detailed, work using chironomid pupal exuviae on the effects of heavy metals on chironomid communities.

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