THE RESPONSE OF CHIRONOMIDS TO WATER AND SEDIMENT CHEMISTRY IN URBAN CANALS (UK)

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With 2 figures and 2 tables

ABSTRACT. Forty-six sites on canals in the English Midlands were sampled using the Chironomid Pupal Exuviae Technique (CPET). Species data were associated with water and sediment chemistry at each site. Separate CCA analyses were carried on (i) all species and all chemical variables, (ii) epibenthic species and water chemistry (iii) inbenthic species and sediment chemistry. Dissolved lead, chromium and Total Oxidised Nitrogen, together with sediment lead and fines were the best variables discriminating between sites for (i) Dissolved chromium, lead and Chlorophyll a were best discriminating sites for (ii). Sediment fines, lead and nitrogen were the best discriminating variables for (iii). Biological classifications constrained by each of the significant variables were used to calculate indicator species scores and reveal species assemblages. CPET was effective at determining water and sediment quality within urban canals.

RESUMO. Comparamos a eficiência de detecção com o número de géneros exclusivamente recolhidos para exuviae de superfície- pupas flutuantes e métodos de rede de mão, entre dois gradientes de perturbação. O método mais eficiente foi a colheita exuviae, realizada mensalmente. Efectuando a comparação exclusivamente com o mês de Junho, o método tipo rede de mão foi o mais eficiente em todos os locais de amostragem, mas em locais com perturbação não se verificou significância estatística entre os dois métodos. O método de exuviae exclusivamente, coleccionou duas vezes mais géneros, tal como o método tipo rede de mão.

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INTRODUCTION

The recent implementation of the European Commission legislation, the Water Framework Directive (WFD; COUNCIL OF THE EUROPEAN COMMUNITIES, 1999) requires that member states protect and enhance surface waters and groundwater. Good ecological status should be achieved by 2015. The Directive provides additional designations, for Artificial (AWB) and Heavily Modified Water Bodies (HMWB), with canals included as AWB. Unlike all other surface waters, which have to achieve good ecological status, AWB will be required to reach an objective of "Good Ecological Potential" (GEP) for sustainable use of the water body. Canals are difficult for obtaining representative biological samples. Biological assessment of urban canals is further complicated by the variety of impacts from metals, nutrients and organic compounds. An effective WFD-compliant classification tool is required to assess GEP of canals.

In order to develop a tool for the monitoring of urban canals, the aims of this study were therefore to (1) investigate which chemical parameters influence the variation in chironomid taxa composition and (2) determine indicator chironomid taxa for significant chemical variables.

MATERIAL AND METHODS

Forty-six urban canal sites were chosen from approximately 1000 km of classified canals within the English Midlands and these were predominately urban in nature. The sites were chosen in order to represent as wide a range of water and sediment chemical characteristics as possible, especially metals (Table 1).

Chironomid data were collected over four years (2001-2004). Each site was sampled three times between April and September each year, to cover the different emerging periods of the adults. A 250 µm mesh net on a light extendable pole was used to collect floating debris on the water surface. In the laboratory subsamples from each sample was taken and sorted in a small tray, removing all exuviae. This was done until a random collection of 200 individuals was made (WILSON & MCGILL 1979; RUSE 1993; RUSE 2002). The exuviae were then identified to species level using the keys of LANGTON (1991), WILSON (1996) AND LANGTON & VISSER (2003). Chemical data were obtained from the Environment Agency (Environment Agency 2005) for the twelve month period ending on the month of the final pupal collection. At each site, a one-off sediment sample was obtained.

Species data at each site were combined and abundance recorded as a percentage of the total number of exuviae collected. Separate CCA analyses were carried on (i) all species and all chemical variables, (ii) water chemistry and epibenthic species and (iii) sediment chemistry with inbenthic species. To improve the signal to noise ratio species data were square-root transformed (PRENTICE 1980). All environmental data were tested for normality by a Ryan-Joiner correlation test and transformations were performed when necessary. Detrended Correspondence Analysis (DCA) was carried out to determine whether there was a unimodal relationship apparent in the species data within the sampling sites (HILL 1980). Environmental variables and biological data were directly related by Canonical Correspondence Analysis (CCA). Biplot-scaling with emphasis on inter-species distances was used. Forward stepwise regression was used to select the minimal number of variables that could significantly explain the species data. Significance was tested by 999 Monte Carlo permutations (probability of randon association, $p< 0.05$). To avoid spatial autocorrelation, a covariable file was used to restrict permutations so that sites on the same canal were not in the same block. This restricted permutation was also used to test the significance of the first and second axes. Redundant variables were excluded by reference to Bonferroni-adjustment (MANLY 1991) of probability with p= á/n, where á= 0.05 and n is the variable rank.

COINSPAN classification (CARLETON *et al*., 1996) of sites was constrained by significant environmental variables. COINSPAN classes were analysed using INDVAL (DUFRENE & LEGENDRE 1997) to determine significant indicator assemblages. INDVAL can test for the significance of the association of each species with a particular COINSPAN class and only the indicator with the class at which it reaches its maximum score should be assessed. Indicator values were calculated for each species within each group produced at every level of the classification. Significance of the highest INDVAL score by each species was assessed from 999 random permutations based on there being less than 5% probability of the observed indval score occurring randomly and a one-tailed t-test. Species passing one (*) or both (**) significance tests were listed. The INDVAL method combines measures of *specificity* (relative abundance) and *fidelity* (frequency of occurrence in a group of sites). Indicators with maximum scores at the top levels of a COINSPAN classification will be more generalist, as opposed to indicators with maximum values at the end groups, which will be regarded as more specialist. The species assemblages have defined mean and variance of the variable under consideration, determined by their associated COINSPAN group.

RESULTS

A total of 28, 772 chironomid pupal exuviae were identified to 88 taxa from 46 sites. The species data set had a gradient length of 2.32 SD units along the primary axis of a DCA. Accordingly, CCA was deemed appropriate as a unimodal model of species distribution (TER BRAAK 1988). After stepwise regression, 5 chemical variables were selected. These were sediment fines, total oxidised nitrogen (TON), lead (dissolved and sediment) and chromium (Fig. 1a). The first two axes explained 17% of the variation seen in the species data and both axes were significant in a restricted permutation test ($p< 0.001$). The eigenvalue for CCA axis 1 was 0.269 and this axis was highly correlated with water chemistry (TON and lead). Axis 2, with an eigenvalue of 0.196 was highly correlated with sediment characteristics (sediment lead and sediment fines) and was significant (*p*< 0.05*)*. All canonical axes were significant (*p*< 0.05) with an F-ratio of 1.576.

After removing species associated with sediment, this left 52 epibenthic species. Three variables were significantly related to epibenthic species variance, when using water chemistry data: chlorophyll a, lead and chromium (Fig. 1b). There were 36 inbenthic species and three variables were significantly related to species variance: sediment fines, lead and nitrogen (Fig. 1c).

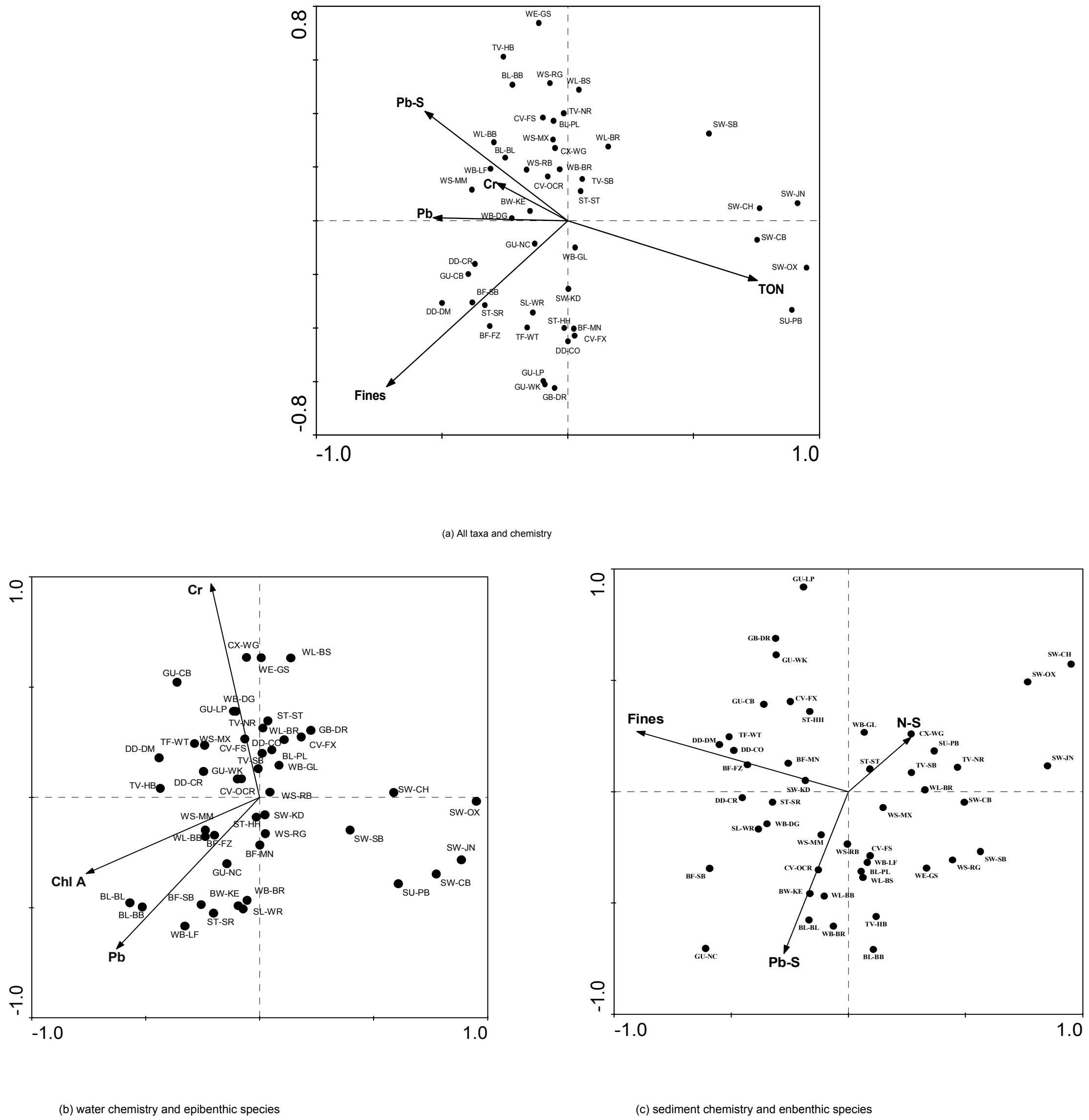

Figure 1. CCA ordination plots (sites and environmental variables): a) water and sediment chemistry and all benthic taxa; b) water chemistry and epibenthic taxa; c) sediment chemistry and inbenthic taxa.

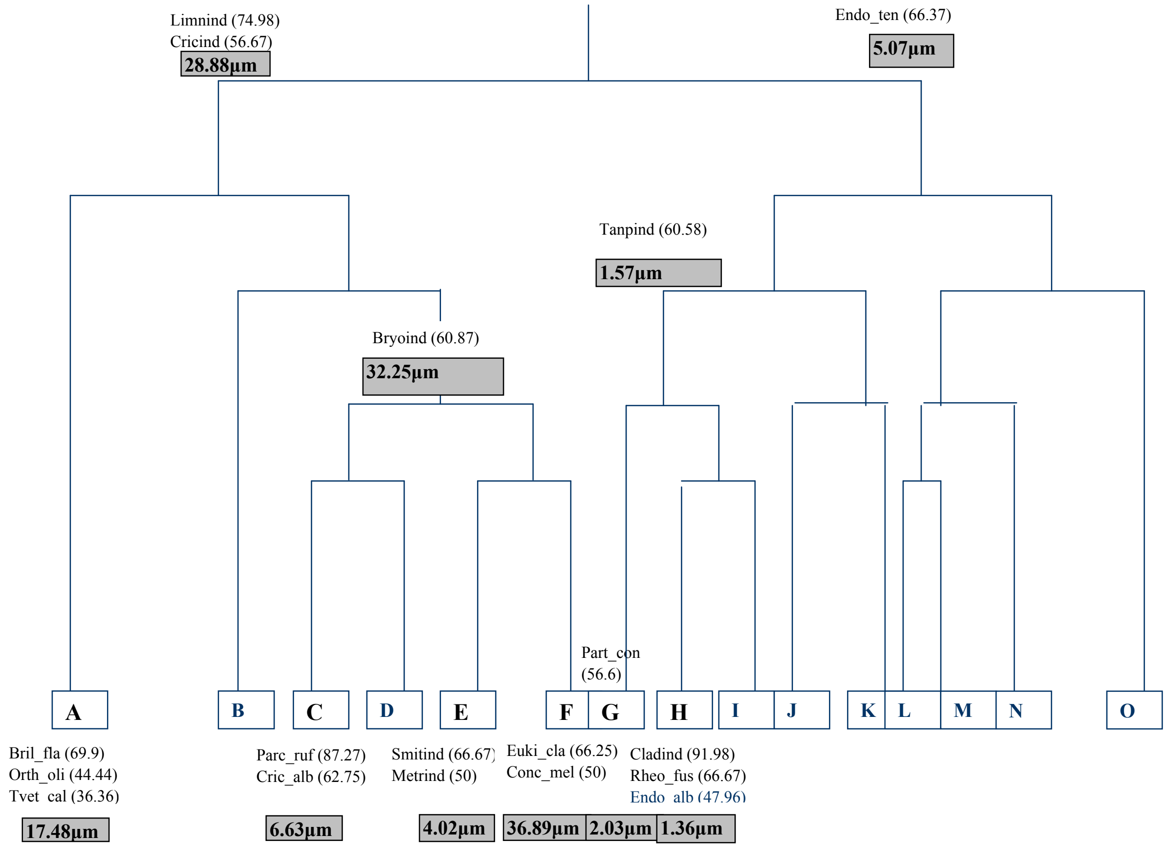

Figure. 2: COINSPAN classification of chironomid data constrained by chromium.

Each significant variable was used to constrain site classifications. Fig. 2 and Table 2 illustrate the COINSPAN classification for chromium and a list of species passing the significance tests for one or more COINSPAN groups. There were *generalist* taxa assemblages, such as *Limnophyes* sp. and *Cricotopus* sp. and *specialist* assemblages such as *Brillia flavifrons* (Johannsen, 1905) to *Tvetenia calvescens* (Edwards, 1929). Each assemblage had a defined mean of chromium, determined by their associated COINSPAN group.

DISCUSSION AND CONCLUSIONS

This survey has demonstrated that the CPET method is an effective method by which to monitor the biodiversity of canals. A collection of pupal skins integrates both marginal and deep-water habitats from a wide area, which also integrates pupal emergence. Many taxa that were found inhabit the sediment, a habitat normally difficult to sample. Chironomid taxa assemblages were able to differentiate between canal sites of different chemistry. Indicator species assemblages could be identified that could be associated with different COINSPAN groups constrained by each of the significant variables determined by CCA analysis. The importance of metals in canal systems was also revealed by ordination techniques.

With all chemical variables and species combined it was seen that the first axis of the CCA ordination reflected nutrient enrichment (Fig. 1a). A grouping of sites to the right of the ordination graph (on the Staffordshire & Worcester Canal) shows that there is a nutrient effect from a large sewage works. Nitrogen seems to be the limiting nutrient, with the dominant effect coming via sediment bound nitrogen. This can be seen in Fig. 1c, where sediment nitrogen is the primary variable, whereas chlorophyll a is seen to be dominant when only the water variables are considered.

This study revealed significant chemical variables that influenced the chironomid taxa assemblages across the 46 study sites. The identification of indicator taxa using INDVAL proved to be useful as a tool in the possible future determination of the ecological potential of artificial water bodies. The use of chironomids as bioindicators was shown to be an easy to use and cost effective method by which to ecologically assess canals. The importance of metals revealed by ordination and the identification of indicator taxa could prove to be useful in the ecological assessment of urban canals across the UK. If chironomids are ignored by the WFD, artificial water bodies such as canals will not be adequately monitored.

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TABLE 1. Site Locations and chemical characteristics (metals) of canal sites.

Canal	Site	Grid Ref		Zn (ug/l)	Cr (ug/l)	Ni (ug/l)	Pb (ug/l)	Cu (ug/l)	Fe (ug/l)	Cd (ug/l)
Tame Valley	Holloway Bank	SO 990 939	**TV-HB**	86,04	1,77	24,70	15,21	3,34	568	0,25
	Newton Rd	SP 036 940	**TV-NR**	23,20	1,16	9,11	4,15	3,92	357	0,19
	Salford Br	SP 096 901	**TV-SB**	104,60	2,09	12,50	10,00	5,51	269	0,16
Coventry	Foxford	SP 351 839	**CV-FX**	33,10	1,54	7,90	5,00	3,00	676	0,04
	Old Church Rd	SP 348 821	**CV-OCR**	41,20	2,40	7,80	14,00	4,10	610	0,17
	Foleshill Rd	SP 338 806	**CV-FS**	27,60	1,39	6,18	7,70	2,03	285	0,15
Wyrley & Essington	Ryders Green Rd	SO 983 917	**WS-RG**	122,53	3,86	15,44	6,76	5,93	1052	0,45
Cannock Extn	Moors Mill Lane	SO 977 932	**WS-MM**	66,84	3,47	13,25	12,00	1,96	1583	0,515
Walsall	Moxley	SO 969 955	**WS-MX**	32,49	1,06	7,05	4,36	3,00	481	0,17
	Rayboulds Br	SO 985 977	**WS-RB**	64,49	2,54	15,43	7,48	3,46	448	0,367
	Goscot	SK 016 020	**WE-GS**	34,16	0,72	16,3	3,82	3.88	150,5	0,09
	Wyrley Grove Br	SK 019 054	**CX-WG**	36,29	0,683	13,59	3,70	5,28	221	5,14
Staffs & Worc	Kidderminster	SO 828 758	**SW-KD**	75,54	4,73	20,4	16,76	3,93	281,78	0,21
	Swindon Br	SO 862 906	**SW-SB**	99,7	8,33	14,97	7,93	4,84	224,9	0,29
	Compton Br	SO 883 988	**SW-CB**	105,76	120,47	10,19	5,34	4,36	206,18	0,3
	Junction	SJ 902 011	**SW-JN**	92,46	44,89	8,94	3,39	4,67	149,9	0,199
	Oxley	SJ 902 017	**SW-OX**	104,44	6,17	10,15	1,73	4,96	82,46	0,15
	Coven Heath	SJ 914 054	**SW-CH**	42,92	3,23	7,14	2,14	6,59	178,9	0,186
Shropshire Union	Pendeford Br	SJ 888 034	**SU-PB**	126,95	38,27	11,39	4,06	5,08	193,1	0,31
Worc & B'ham	Bath Row Br	SP 061 860	**WB-BR**	237,00	33,83	40,78	21,82	12,30	355	0,46
	Grange Lane	SP 019 712	**WB-GL**	27,18	1,84	6,84	5,58	4,48	527	0,12
	Worcester	SO 849 539	**WB-DG**	27,62	1,12	4,99	8,51	2,78	322	0,09
Stratford	Lifford	SP 054 803	**WB-LF**	317,83	75,33	54,37	42,96	12,87	761	1,20
	Stirchley	SP 059 796	**ST-SR**	284,00	69,91	42,40	38,38	8,21	799	1,06
	Hockley Heath	SP 152 725	**ST-HH**	103,35	2,94	15,73	6,63	4,93	422	0,09
B'ham Level	Stratford	SP 199 555	**ST-ST**	34,33	1,10	6,81	3,85	2,86	980	0,09
	Bromford Lane	SP 995 903	**BL-BL**	155,05	11,01	11,40	40,20	4,29	1739	1,80
W'ton Level	Park Lane East	SP 966 919	**BL-PL**	18,80	1,57	6,98	6,06	2,54	138	0,29
	Brasshouse Br	SP 019 889	**BL-BB**	83,90	18,75	12,00	52,89	3,68	1857	2,12
B'ham & W'ton	Brades Rd	SO 982 900	**WL-BR**	87,77	1,36	6,33	3,93	3,64	283	0,17
B'ham Level	Baker St, Tipton	SO 954 917	**WL-BS**	157,88	0,73	6,15	2,63	3,21	224	0,12

TABLE 2. Part I. Indicator table of the species indicator power for COINSPAN clustering hierarchy (groups A-F). Species presence is indicated by % abundance. * Species passing one significance test; ** Species passing both significance tests.

	Species	Indval	Mean Cr	A	B	C	D	E	F
F	Euki_cla	66.25**	36.89						**10.17**
	Conc_mel	50*							
C+D+E+F	Bryoind	60.87*	32.25	2.03		1.34	3.08		0.3
(A+B +C+ D+ E+F)	Limnind	74.98**	28.88	**9.63**	1.74				
	Cricind	56.67**		**10.22**	1.36				
A	Bril_fla	69.9**	17.48	0.56	0.09	0.07	0.03		
	Orth_oli	44.44*							
	Tvet_cal	36.36*							
C	Parc_ruf	87.27**	6.63			**0.97**	0.07		
	Cric_alb	62.75**		12.2		**16.59**	0.28		
(G+ H+I+J+K + L+M+N+O)	Endo_ten	66.37**	5.07	0.03	**1.44**				
E	Smitind	66.67**	4.02					**0.52**	
	Metrind	50**				0.24	0.07	**1.29**	0.13
G	Part_con	56.67*	2.03	0.37			0.07		
(G+H+I+J+K)	Tanpind	60.58**	1.57			**1.48**	0.25		
H	Cladind	91.98**	1.36						
	Rheo_fus	66.67*							
	Endo_alb	47.96*							

TABLE 2. Part II. Indicator table showing the species indicator power for COINSPAN clustering hierarchy (groups G - O). Species presence is indicated by % abundance. * Species passing one significance test; ** Species passing both significance tests

	Species	Indval	Mean Cr	G	H	I	J	K	L	M	N	O
F	Euki_cla	66.25**	36,89					0,12				
	Conc_mel	50*										
C+D+E+F	Bryoind	60.87*	32,25	0,08								
(A+B+C +D+E+F)	Limnind	74.98**	28,88									
	Cricind	56.67**										
A	Bril_fla	69.9**	17,48									
	Orth_oli	44.44*										
	Tvet_cal	36.36*										
C	Parc_ruf	87.27**	6,63		0,06							
	Cric_alb	62.75**								2,38		
(G+H+I+J+K												