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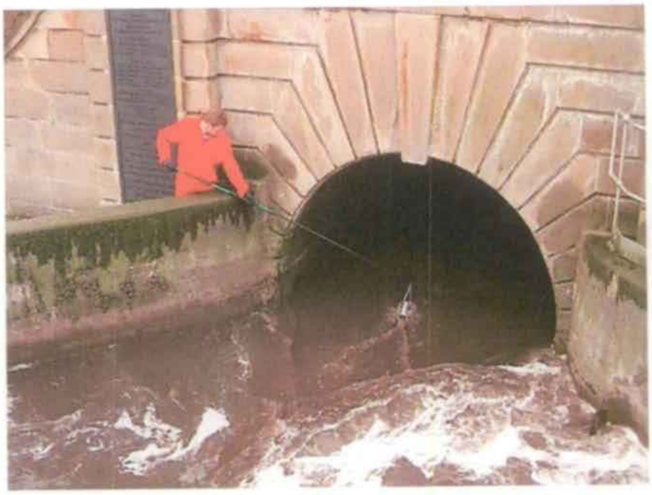

INTRODUCTION – JOHN GOOD

Effects of urban land cover on diversity of plant species in Britain

Report to Centre for Ecology and Hydrology Integrating Fund

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Abstract

Regression models were used to quantify the relationship between the amount of urban land and composition of local species pools. There was no evidence that urban land cover increases the richness of plant species, based on a survey of 785 2-km squares of which 157 had more than 10% urban land cover. However, the number of alien plants is significantly higher in urban areas. Complete urbanization approximately doubles the proportion of alien species, and the proportion of aliens is twice as high in southern Britain as in the north. The flora of urban tetrads consists of ubiquitous native species and introduced species characteristic of waste ground, but woodland species are poorly represented. At the tetrad scale, enhanced dispersal by man is not the main factor for maintaining the urban flora; availability of urban habitats and high levels of disturbance are more important. The planned housing expansion to greenfield sites in Britain will increase the proportion of alien species, yet the majority of native species should persist in urban areas if existing woodland is preserved.

Aims

We aim to quantify the effects of urbanization on the flora for Britain, particularly how urban land cover is related to the proportion of alien species and total number of plant species in the local flora. A secondary aim is to identify the plant species that are most strongly associated with urban land, and to discuss the ecological factors determining their success in urban habitats.

Data and methods

We use two datasets covering the British Isles, the BSBI Monitoring Scheme and the ITE Land Cover Map, collected over approximately the same time period.

BSBI Monitoring Scheme

The Botanical Society of the British Isles Monitoring Scheme (Monitoring Scheme) was a botanical survey carried out in 1987 and 1988 (Palmer and Bratton 1995). The survey was based on a nested sampling structure of three 2-km squares (tetrads) within larger 10-km squares. A sample set of one in nine 10-km squares was selected from the British and Irish National Grids. Within these selected 10-km squares, presence of plant species was recorded in each of three systematically positioned 2-km squares. At the present time, only the baseline survey has been made.

The 785 Monitoring Scheme tetrads in Britain (excluding the Isle of Man) were used to derive summary measures of the flora. The total number of species and the number of alien and native species per tetrad were calculated. Figure 1 shows the proportion of alien species within tetrads. For the purposes of this report, the regional species pool is defined as the flora of a 10-km grid square and the local species pool as the flora of a 2-km grid square.

Land Cover Map

The Land Cover Map of Great Britain (LCMGB) is a classification of Britain derived from satellite images (Fuller, Groom and Jones 1994). The map, based on a 25m grid, records 25 cover types, comprising sea, inland water, beaches, bare ground, developed and arable land,

and 18 types of permanent vegetation, mostly semi-natural. The baseline data to create the map were collected in 1990, but satellite imagery from 1988-1992 was used to fill gaps, eg due to cloud cover.

The LCMGB identifies two types of urban land cover, suburban/rural and urban development. The suburban/rural category is defined as land where there is a mixture of built-up land and permanent vegetation. The urban development category comprises land where buildings and hard surfaces are large enough to fill individual 25m pixels. Figure 2 shows the most urban areas of Britain. The proportion of these two categories taken together was used as a measure of urban land within each tetrad surveyed by the Monitoring Scheme.

Statistical procedures

The nested sampling structure of the Monitoring Scheme allows local effects of urbanization to be separated from broad geographical variation. Generalized linear models (McCullagh and Nelder 1989, Crawley 1993) were applied to quantify variation between tetrads within 10-km squares.

Results

In Britain, urban areas tend to occur in the south and in the lowlands. Most tetrads with more than 10% cover of urban land have mean altitude less than 100 m and occur in England and Wales – i.e. south of the northing 600 (Table 1). The tetrads with the highest number of alien species (30 or more species), also tend to be the most urban. Tetrads rich in native species do not show the same trend (Table 1).

The estimated effects of urbanization apparently result in a decrease in the total number of species caused by a reduction of the native flora, but the effect is not statistically significant. Urban areas have a significantly higher richness of alien species. There is therefore an increase in the proportion of alien species in the flora of urban areas compared to more rural areas nearby (Table 2).

The proportion of alien species predicted by regression is illustrated for four tetrads in different regions of Britain (Figure 2). With an increase of 40 hectares (+10%) in urban land, a typical tetrad in rural Cambridgeshire, which currently has little urban land (4%), is predicted to lose 7 native species and gain 4 aliens, an increase in the proportion of alien species of 2%. For a region of Britain with a lower regional species pool of introduced species the impacts of urbanization are less marked. The flora of a relatively urban tetrad (52%) on the edge of Glasgow (South-central Scotland) is predicted to become only 1% less native with an increase of 10% in the cover of urban land to 62%. A heavily urban tetrad such as central Leeds (West Yorkshire, 91% urban) would be expected to have half the proportion of alien species in its flora if it were completely non-urban.

Individual species distribution

Species vary in their response to the effects of urbanization. Table 3 identifies sets of species which have a strongly negative or strongly positive relationship with urban land cover. About half the species with a strong positive relationship are alien to Britain, whereas all species with a negative relationship are native. The two sets of species are also distinct in their habitat preferences. Species characteristic of urban areas tend to occur in habitats such as waste ground, walls and waysides. Examples include butterfly bush *Buddleja davidii* and common goldenrod *Solidago canadensis*.

Most species that have a strongly negative association with urban land are characteristic of woods and hedgerows.

Conclusions

The effects of urbanization on the distribution of plant species are clearly detectable at the relatively coarse scale of the 2-km square, though with large geographical differences reflecting the larger regional species pool in the south. The increase in alien species within urban areas is a marked effect, as is the loss of woodland species. At this scale, there is no overall gain in the number of plant species with increasing urbanization. This result is opposite to findings of related studies in Central European towns and cities, but may reflect a difference of sampling technique rather than a genuine difference between these geographical areas. Although propagule pressure through introduction and dispersal by humans is important in urban ecosystems, it has little effect at the tetrad scale.

The planned increase in housing over the next twenty years will surely increase the proportion of alien species where greenfield sites are developed. However, if existing woodland is preserved, there may be relatively little loss of native species.

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Table 1. Number of tetrads in urban land-cover categories in relation to bands of mean altitude, northing (distance north on Ordinance Survey national grid), number of native species and number of non-native species.

		Percent urban land-cover category					
		0-1	1-5	5-10	10-20	20+	Total
Mean altitude	0-100	96	96	64	59	60	375
(m)	100-200	79	52	39	22	14	206
	200-400	105	28	6	1	1	141
	400+	59	4	0	0	0	63
Northing	0-300	52	88	68	38	39	285
(km)	300-600	83	60	31	37	31	242
	600-900	164	29	10	7	5	215
	900+	40	3	0	0	0	43
Native species	0-100	65	9	5	3	6	88
(n)	100-200	162	72	44	31	27	336
	200-300	104	84	52	41	31	312
	300+	8	15	8	7	11	49
Alien species	0-10	240	61	24	15	6	346
(n)	10-20	75	77	43	28	22	245
	20-30	19	29	28	24	18	118
	30+	5	13	14	15	29	76
	Total	339	180	109	82	75	785

Table 2. Effects of urban land cover and altitude on species richness. Regression coefficients and significance values (*, $p < 0.05$; ns, not significant) were calculated from generalised linear models.

	Regression coefficients	
	Urban land cover (km^2/km^2)	Mean altitude (km^{-1})
Number of alien species (Model 1)	0.73 *	-4.27 *
Number of native species (Model 1)	-0.19 ns	-1.64 *
Total number of species (Model 1)	-0.08 ns	-1.75 *
Proportion of alien species (Model 2)	0.89 *	-2.80 *

Table 3. Species with a strong negative or positive association with urban land cover and their status (alien – A or native – N). Nomenclature follows Stace (1997). N_{tet} is number of tetrads where the species was found out of a total of 785 and N_{urb} is number of urban tetrads from which the species was recorded out of a total 157. Regression coefficients were calculated for a generalised linear model.

Species	Status	N_{tet}	N_{urb}	Regression coefficients	
				Urban land cover (km^2/km^2)	Mean altitude (km^{-1})
Canadian goldenrod	A	42	29	9.62	-4
Horse radish	A	178	87	9.40	-16
Slender speedwell	A	190	57	9.35	-15
Lesser swine-cress	A	82	32	8.20	-18
Wall barley	N	173	88	8.17	-24
Common reed	N	167	57	8.12	-23
Oxford ragwort	A	125	76	7.89	-3
Butterfly bush	A	78	40	7.09	-10
Square-stalked willowherb	N	106	43	6.61	-10
Procumbent pearlwort	N	536	108	5.89	-5
Three-nearved sandwort	N	268	58	-7.45	17
Primrose	N	385	55	-7.69	1
Common spotted orchid	N	170	38	-8.07	-7
Field-rose	N	228	62	-8.14	-24
Honeysuckle	N	462	88	-8.77	11
Creeping soft-grass	N	450	83	-9.44	6
Wood-sorrel	N	400	45	-10.35	0
Sharp-flowered rush	N	300	28	-10.53	3
Germander speedwell	N	606	121	-10.81	20
Wood sage	N	311	40	-12.45	10

Table 4. Species occurring in 95% or more of urban (>10% urban land cover) tetrads and their status (alien – A or native – N). N_{tet} and N_{urb} are as defined for Table 3.

Species	Status	N_{tet}	N_{urb}
Annual meadow-	N	713	155
Cock's foot	N	645	155
Creeping buttercup	N	729	155
Common nettle	N	695	154
Elder	N	584	154
Cleavers	N	610	154
Spear thistle	N	692	154
Creeping thistle	N	669	153
Ribwort plantain	N	734	153
White clover	N	733	153
Hawthorn	N	612	153
Greater plantain	N	668	152
Hogweed	N	634	152
Common ragwort	N	600	151
Daisey	N	693	151
Dandelion	N	715	150
Shepherd's-purse	N	557	150
Cow parsley	N	570	150

Fig. 1. Percentage of alien species in the flora of 2-km squares (tetrads) recorded by the Botanical Society of the British Isles Monitoring Scheme in Britain. Tetrads are in groups of three within a regular grid of 10-km squares.

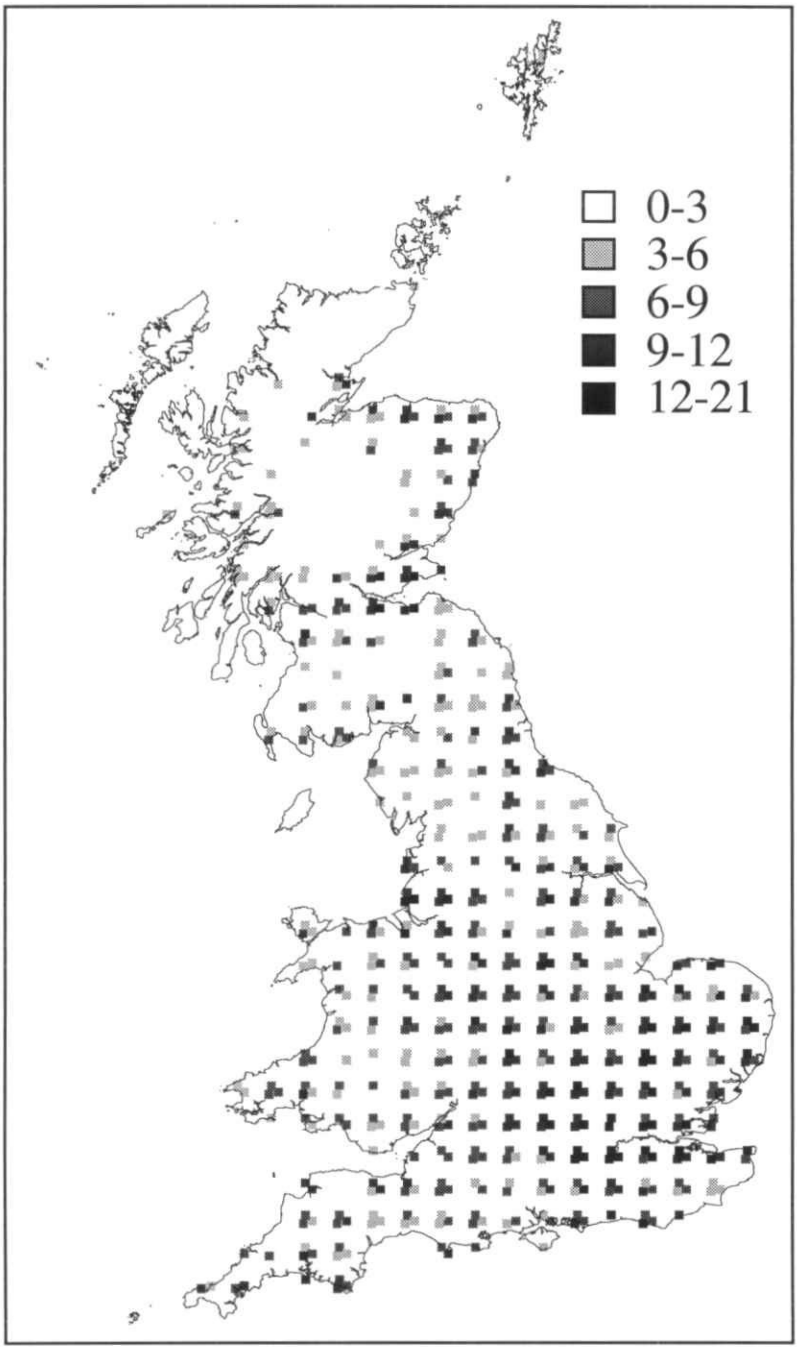


Fig. 2. Urban land cover in Britain - 1km squares with greater than 40% cover of urban land. Date is derived from the ITE Land Cover Map.

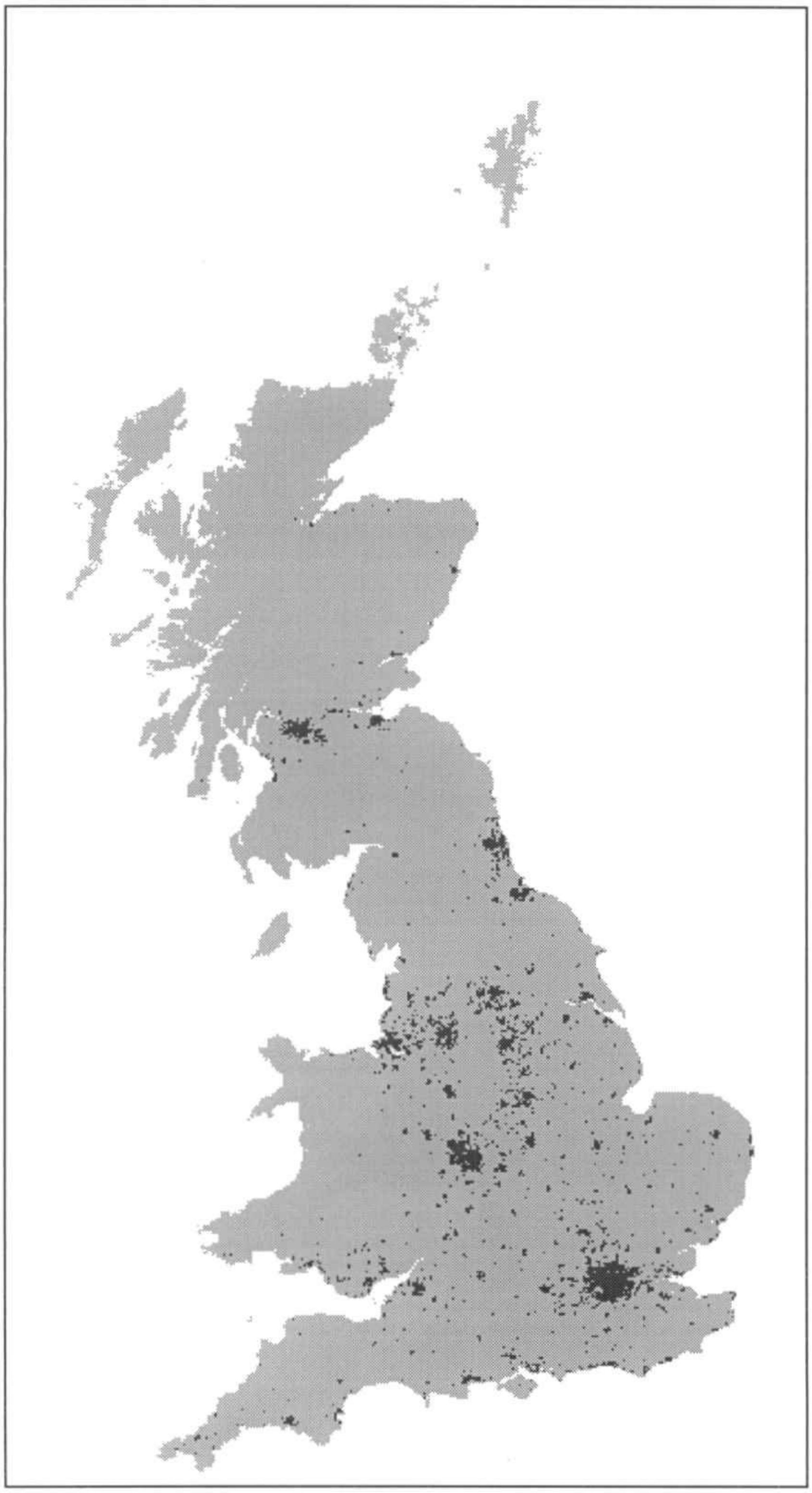


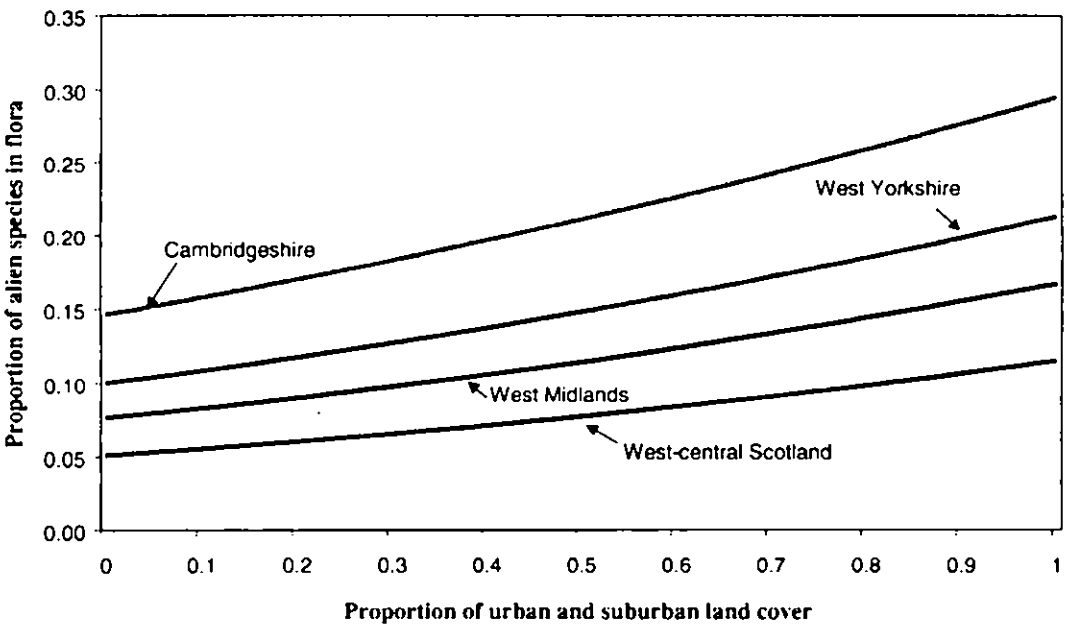
Fig. 3. The predicted effect of urban land cover on the proportion of alien species within four regions of Britain: Cambridgeshire – a rural tetrad in the same 10-km square as Cambridge (mean altitude 23 m; 4% urban land cover); West Yorkshire – a heavily urban tetrad within the city of Leeds (mean altitude 34 m; 91% urban land cover); West Midlands – a tetrad on the south-east edge of Birmingham (mean altitude 178 m, 38% urban land cover); West-central Scotland – an urban tetrad on the north-west edge of Glasgow (mean altitude 81 m, 52% urban land cover).

Effects of urbanisation on the River Cam and its associated waters in Cambridge

Changes in the aquatic flora, 1660-1998

Introduction

An accurate assessment of impact of urbanisation or other land-use changes on the flora of an area must be based on reliable historical records of plant species. The long and continuous history of botanical study in England from the late 16th century has left us such records for many areas, at least for the more conspicuous terrestrial vascular plant species. These have been used in numerous detailed studies of the changes in the vascular plant flora of particular



regions (e.g. Dony 1977, James 1997, Preston in press).

It is less easy to trace reliable historical records of aquatic species than of terrestrial species. There are two main reasons for this. The first is that many of the important aquatic genera are taxonomically difficult. Taxonomic treatments have varied from one generation to another, to such an extent that written records for some species are worthless and the only reliable historical records are those which are based on expertly determined herbarium specimens. This obviously limits the number of records available. Secondly, these taxonomic difficulties and the relatively inaccessibility of the aquatic habitat to land-based botanists have discouraged many botanists from studying water plants. In each generation the aquatic species have tended to be the preserve of a few specialists. The combination these two factors means that there are few areas where it is possible to obtain a long sequence of reliable records of water plants.

One area from which there a sequence of historical records of aquatic macrophytes is the city of Cambridge. The River Cam and its associated streams and ditches have been studied by many botanists from the University of Cambridge from the mid 17th century onwards. In this report the available records have been used to outline the history of the aquatic macrophytes from the 17th century.

The study area

Available data for aquatic macrophytes have been extracted for the River Cam and its adjacent floodplain from in Cambridge, from the loop of the river just upstream of the University Bathing Sheds at TL 439567 downstream to the railway bridge at Chesterton, TL 473601. This includes the northern part of Grantchester Meadows, Coe Fen, Sheep's Green, The Backs, Jesus Green, Midsummer Common and Stourbridge Common, but excludes Hobson's Brook, Coldham's Brook, Coldham's Common and the historical site known as the Paper Mills.

Definition of aquatic plants

The definition of aquatic plants is inevitably somewhat arbitrary. I have included those species which were treated as aquatic plants by Preston & Croft (1997), i.e. species which characteristically grow in water throughout the year.

Sources of plant records

The first reliable records date from John Ray's pioneering work, the 'Cambridge Catalogue' of 1660. Ray taught himself botany while living in Cambridge, and he was subsequently to become the leading plant taxonomist of his generation. It is clear that Ray was interested in aquatic plants, and several of the aquatic species he described were either completely new to science or at least accurately described for the first time in this book (e.g. *Ceratophyllum demersum, Potamogeton compressus*). Although there are some relevant records in Relhan's *Flora Cantabrigiensis* (1785, 1802, 1820), it was not until the revival of botany in the university inspired by Professor J.S. Henslow from the 1820s onwards that numerous detailed records are available. Thereafter records are available more or less continuously to the present day.

The historical records have been extracted from a wide range of published sources and unpublished manusscripts, and from specimens in the major herbaria. It should be emphasied that, except for the period from 1985 onwards, none of these sources represent a comprehensive survey of the study area. They represent records made because they were thought to be significant in the context of the county as a whole, or were notable to the compiler of the record for personal reasons. The availability of records in copies of Babington's *Flora of Cambridgeshire* in the Department of Plant Sciences, University of Cambridge, which have been annotated by undergraduates and others is particularly significant, as these records provide localities records of common species which would not have been thought worthy of note by more experienced botanists, and which never merited publication.

For the sake of analysis, records have been considered from five date periods. The first are the records published by Ray (1660). Three periods of 40 years have then been chosen, 1821-1860, 1861-1900 and 1921-1960. These have been selected as well-documented periods of equal length. The final period is that from 1985 onwards. CDP has surveyed the study area for aquatic plants from 1985 onwards, and plants are regarded as still present if they were recorded during this period.

Extinction of native plants in the study area

The native aquatic plants recorded from the study area are listed in Table 1 (species still present) and Table 2 (species which are apparently extinct). Most of the 35 aquatic species present in the study area today have a long and continuous history in this area. There are 25 extinct species represent 42% of the native species recorded in the study area, a proportion which greatly exceeds the proportion of aquatic species which have become extinct in the county as a whole (21%).

The date of the last record of the extinct species is compared to that for the extinct aquatic species of Cambridgeshire, and all species extinct in Cambridgeshire, in Table 3. Almost all the extinct aquatic species were last recorded in the study area in the period 1840-1959. The losses in the period 1930-59 were particularly great, being twice as great as in any of the other 30-year periods. The pattern for the aquatic plants in the county as a whole shows that extinctions occurred slightly later, with most species becoming extinct in the period 1870-1989. A striking feature of these results is the fact that no aquatic species has been lost from the study area since 1960, a striking contrast with the results for aquatic species and all species in Cambridgeshire.

Detailed records are available for the River Cam itself, and for two of the adjacent commons, Sheep's Green and Coe Fen. There are also localised records from the ditches along The Backs. The aquatic species recorded from each of these sites are listed in Table 4, with the date of last record for extinct species. For the river itself most of the last records of extinct species were made the period between 1939 and 1954. Most of the aquatic plants of Sheep's Green were last recorded in the between 1860 and 1910, especially in the 1860s and the 1900s. By contrast there has been a more gradual loss of species from Coe Fen. Few of the species recorded from The Backs have been lost, but the records may be less comprehensive for this area (if there are few records from an area it is not easy to say whether the area was species-poor or under-recorded).

The relationship of extinction to the trophic requirements of species is investigated in Table 5. There is a clear relationship between the Trophic Ranking Score allocated by Palmer *et al.* (1992) and extinction, with the majority of extinct species having scores below 9.0 whereas the majority of extant species have scores in excess of 9.0. There has, therefore, been a disproportionate number of extinctions in the species characteristic of the less nutrient-rich habitats.

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Table 1. Native species still present in the study area.

Species	Date period				
	1660	1821-60	1861-1900	1921-60	1985-98
Alisma plantago-aquatica	E	+	+	+	+
Apium nodiflorum	E	+	C	+	+
Berula erecta	-	C		+	+
Butomus umbellatus	+	+	+		+
Callitriche agg.	-	C	C	+	+
Carex acuta					+
Carex acutiformis		C	+	+	+
Carex riparia	-	C	+	+	+
Catabrosa aquatica		C		+	+
Ceratophyllum demersum	E		+	+	+
Glyceria fluitans	E	C	C		+
Glyceria maxima	-	C	+	+	+
Glyceria notata		C	C	+	+?
Iris pseudacorus	Cam	+	+	+	+
Lemna gibba		+	+	+	+
Lemna minor	-	C	+	+	+
Lamna trisulca	Cam	+	+		+
Myosotis scorpioides	E	C	+	+	+
Myriophyllum spicatum		+	+		+
Nuphar lutea	Cam	+	+	+	+
Persicaria amphibia	-	+	+		+
Phalaris arundinacea	Cam	C		+	+
Potamogeton crispus	-	+	+	+	+
Potamogeton pectinatus	Cam	+	+	+	+
Potamogeton perfoliatus	Cam	+	+	+	+
Potamogeton pusillus					+
Rorippa nasturtium-aquaticum agg.	-	+	+	+	+
Rumex hydrolapathum	-	+	+	+	+
Sagittaria sagittifolia	-	+	+	+	+
Sparganium emersum	-		+		+
Sparganium erectum	E	+			+
Spirodela polyrhiza		C	+	+	+
Veronica anagallis-aquatica	-	+		+	+
Veronica beccabunga	-	C	+	+	+
Zannichellia palustris	-	+		+	+
Total		30	26	24	34

Key to abbreviations:
- \+ Present
- C Recorded from 'Cambridge' but not explicitly from the study area
- Cam Listed by Ray (1660) from the River Cam, but without specific locality
- E Regarded by Ray (1660) as so frequent in Cambs. that localised records were not published
- \- Other species listed by Ray (1660) for Cambs. but without any indication of distribution

Table 2. Native species no longer present in the study area.

Species	1660	1821-60	Date period 1861-1900	1921-60	1985-98	Last recorc
Carex vesicaria						1820P
Potamogeton compressus	Cam	+				1848
Ranunculus hederaceus		+				pre-1860
Baldellia ranunculoides		+				1860P
Menyanthes trifoliata	E	+				1860P
Typha latifolia		+				1860P
Carex lasiocarpa			+			1878
Equisetum fluviatile	-		+			1890
Hippuris vulgaris	+	C	+			1892-6
Oenanthe aquatica	E	+	+			1892-6
Ranunculus aquatilis	-	+	+			1898
Ranunculus fluitans		+	+			post-1900
Hydrocharis morsus-ranae	+	+	+			1905
Ranunculus trichophyllus	E	+	+			1905
Oenanthe fistulosa	E	+	+			1907
Carex elata	-	C		+		1932
Hottonia palustris	E	+	+	+		1938
Oenanthe fluviatilis		+	+	+		1939
Potamogeton lucens	-	+	+	+		1940
Potamogeton natans	-	+	+	+		1940
Potamogeton trichoides				+		1946
Eleocharis palustris	-			+		1949
Ranunculus circinatus		+	+	+		1951
Potamogeton praelongus		+	+	+		1954
Groenlandia densa	-	+	+	+		1958

Key to abbreviations:
+ Present
C Recorded from 'Cambridge' but not explicitly from the study area
Cam Listed by Ray (1660) from the River Cam, but without specific locality
E Regarded by Ray (1660) as so frequent in Cambs. that localised records were not published
- Other species listed by Ray (1660) for Cambs. but without any indication of distribution
P Date of publication of undated records

Table 3. Date of last record of extinct species in the study area (see Table 2), compared to date of extinction of species in Cambridgeshire as a whole (taken from Preston, in press).

Date of last record	Aquatic plants in study area	Aquatic plants in Cambs.	All plants in Cambs.
pre-1750	0	0	2
1750-1779	0	0	3
1780-1809	0	1	6
1810-1839	1	1	24
1840-1869	5	0	10
1870-1899	5	4	9
1900-1929	3	3	18
1930-1959	10	3	27
1960-1989	0	4	21
Date unknown	1	0	0
Total	25	16	120

Table 4. Native species recorded from the River Cam itself, and from Coe Fen, Sheep's Green and ditches on the Backs, with the date of last record for extinct species.

Species	Area			
	River Cam	Sheep's Green	Coe Fen	The Backs
Alisma plantago-aquatica		1863	+	
Apium nodiflorum	1940	+	+	+
Baldellia ranunculoides		1860P		
Berula erecta		1938	+	
Butomus umbellatus	+	+	1885	+
Callitriche agg.	+	+	+	+
Carex acutiformis		+	+	
Carex elata		1932		
Carex lasiocarpa		1878		
Carex riparia	+	+	+	+
Catabrosa aquatica		1941	+	
Ceratophyllum demersum	+	+	1955	
Eleocharis palustris			1949	
Equisetum fluviatile		*c.*1880		
Glyceria fluitans		1905	+	
Glyceria maxima	+	+	+	+
Glyceria notata			1959	
Groenlandia densa	1909	1860P	1899	
Hippuris vulgaris			C19	
Hottonia palustris		1905	1900	1938
Hydrocharis morsus-ranae		1905	*c.*1880	
Iris pseudacorus	+	+	1939	+
Lemna gibba	+	+	+	
Lemna minor	+	+	+	+
Lemna trisulca			+	+
Menyanthes trifoliata		1860P	1860P	
Myosotis scorpioides		+	+	+
Myriophyllum spicatum		1882		+
Nuphar lutea	+	+	*c.*1900	
Oenanthe aquatica	1892-6	1892-6		
Oenanthe fistulosa		1901	1907	
Oenanthe fluviatilis	1939	1905	1930	1893
Persicaria amphibia	+	*c.*1880	+	
Phalaris arundinacea	+	+	+	+
Potamogeton compressus	1848			1843
Potamogeton crispus	+	1892-96	1938	+
Potamogeton lucens	1940			1860P
Potamogeton natans		1892-96	1940	
Potamogeton pectinatus	+	+		+
Potamogeton perfoliatus	+	+		
Potamogeton praelongus	1954	1849		
Potamogeton pusillus				+
Potamogeton trichoides	1946			

Table 4 cont.

	River Cam	Sheep's Green	Coe Fen	The Backs
Ranunculus aquatilis		*c.* 1880		
Ranunculus circinatus	1866	1905	1920	1951
Ranunculus fluitans	1860P	1892-96		
Ranunculus trichophyllus		1905	*c.* 1900	
Rorippa nasturtium-aquaticum agg.	+	1944	+	+
Rumex hydrolapathum	1939	+	+	
Sagittaria sagittifolia	+	1938	1939	
Sparganium emersum	+	+	1900	+
Sparganium erectum		+		
Spirodela polyrhiza	1892-6	1938	+	
Typha latifolia		1860P	1860P	
Veronica anagallis-aquatica agg.	*c.* 1909	1860P	+	
Veronica beccabunga	+	+	+	
Zannichellia palustris	+		1859	
No. extinct species	13	29	21	5
Total no. species	32	48	41	21

Key to abbreviations:

+ Present

P Date of publication of undated records

Table 5. Relationship of extinction to trophic requirements of aquatic plant species. Trophic ranking scores (TRS) are taken from Palmer *et al.* (1992); they are not given for 8 extinct and 5 extant species. Low trophic ranking scores are allocated to species which characteristically grow in nutrient-poor water.

Trophic ranking score	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0
No. extinct species	1	2	1	5	4	0	4
No. extant species	0	0	1	1	9	2	17

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Environmental Characterisation of Urban Freshwater Sites in Great Britain

(Environmental characteristics of urban environments: second year report)

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Michael Gravelle

Internal Report

CEH Project Number: T04071Y2
Report Date: April 1999
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ACKNOWLEDGEMENTS

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Contents

Executive Summary

The first year of work towards this project has already been detailed in a previous progress report (Armitage et al. 1997). This report describes the second 18 months of work:

1. Further to the recommendations made at the end of the first year of the project, (to concentrate effort on representative rivers/towns) an examination has been made of 39 urban areas which fall into 3 town types (type 1 - resorts, administrative and commercial, type 2 - industrial and type 3 - suburbs and suburban type towns). Multivariate analysis showed no relationship between town type and benthic macroinvertebrate assemblages and physical characteristics of the rivers were the main controlling features of faunal composition.

2. A case study of the River Cam in Cambridgeshire has been undertaken to obtain a historical perspective for the effects increasing urbanisation on a River. This is a collaborative project between CEH staff at IFE (Wareham) and ITE (Monk's Wood). The extent to which data has been collected is described.

3. Work to prepare the 1990 and 1995 Environment Agency survey data for analysis is now complete. Analysis of faunas from a large number of urban areas in 1990 and 1995 should now be possible. A file has been forwarded to the Institute of Hydrology for the next stage (isolating the urban sites from the non-urban sites and working out their orientation with respect to urban areas).

4 A brief account is given of the very small amount of freshwater biological monitoring which takes place in lentic (standing water) urban environments compared to lentic (running water) environments.

5 River Habitat Survey data was examined to assess its use in characterising the urban river environment. Urban sites were generally heavily modified particularly with regard to straightening, re-sectioning and reinforcement of the channel. Riparian characteristics also show less diversity than non-urban sites. However instream channel vegetation and predominant channel substrata show few differences between urban and non-urban sites.

Introduction

This second progress report continues to address two key objectives identified in the CEH Programme 3 core/strategic document - The Urban Environment:

1 To develop understanding of the key environmental patterns and processes in urban situations and their responses to change, especially that resulting from man's activities.
2 To develop and extend, through survey, monitoring and modelling the inter-disciplinary knowledge base to plan and achieve more sustainable urban developments.

This work is funded by the Urban Integrating Fund which requires that component sites within the Centre for Ecology and Hydrology collaborate in order to increase the level of integration within the CEH. To date staff from the Institutes of Terrestrial Ecology, Freshwater Ecology, and Hydrology have contributed to the project and the degree of data integration and communication achieved in the execution of this project reflect the original aims behind the establishment of the integrating fund.

The objectives of this report are to describe progress in areas identified as needing more work in the previous report (Armitage et al 1997) and to outline new initiatives.
Five aspects are covered including:-

- the collation and validation of data from large-scale national surveys,
- a preliminary report on lentic monitoring in urban areas,
- the use of the River Habitat Survey in urban environments
- an analysis of the relationship between town type and macroinvertebrate assemblages
- an historical analysis of the urbanisation of the Cam

1.0 Progress Report 1. A case study of the River Cam

A collaborative project between:

Patrick Armitage	(PA)	IFE, River Laboratory
John Davy-Bowker	(JDB)	IFE, River Laboratory
Chris Preston	(CP)	ITE, Monk's Wood
John Sheail	(JS)	ITE, Monk's Wood

This is a collaborative project between the IFE and the ITE examining a variety of data sets from the River Cam in Cambridgeshire with the aim of distinguishing whether urban and rural environments are distinct from each other. Because part of the data held by ITE was of a historical nature (macrophyte data extending back to 1660), it was decided to focus on long term data sets for this project so that the effects of increasing levels of urbanisation over time could be examined.

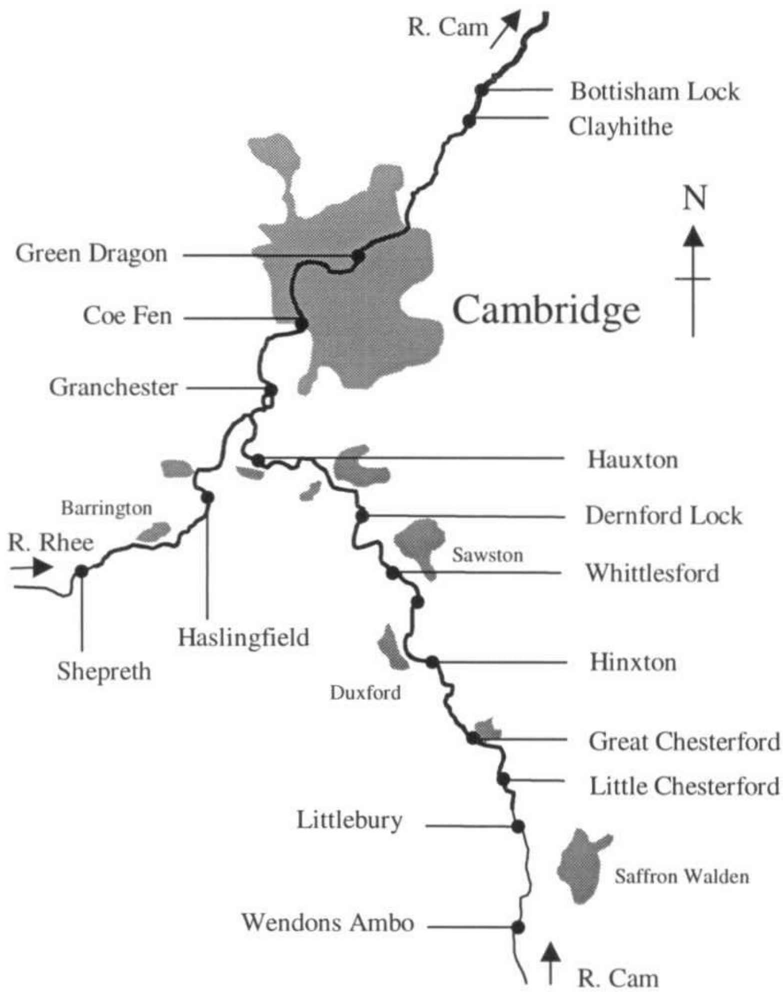

Figure 1. The River Cam study area .

Work at IFE began in February 1998 when initial information requests for contemporary data were sent out to the Environment Agency in Peterborough. Contemporary information on freshwater macroinvertebrates, chemical water quality and abstractions from the River Cam in the vicinity of Cambridge was gathered and entered into a data-base.

On the 18th August 1998 a meeting was held at ITE Monk's Wood in order to clarify the direction of the project (JBD, CP and JS present) and plan the eventual publication of the data under the working title *'Urban Impacts on Rivers: a study of the physical and biological attributes of the River Cam since 1660'*.

It was decided that historical data would be gathered largely by John Sheail from the Cambridge records office and that JDB would organise the contemporary data for chemical water quality and macroinvertebrates while CP would do the same for the macrophyte data. It was proposed that JDB would attempt to use RIVPACS to predict the biological quality of the River Cam system back in time using historical notes about the substratum obtained by JS. This idea was later dropped in favour of matching up broad bands of contemporary biological quality with historical comments about the ecology of the River Cam system.

This approach was taken so that actual BMWP scores (contemporary and recent data) could be compared with older descriptive accounts of various reaches of the river. Biological quality was ascribed to one of 4 categories as below:

Category	**BMWP score**
Very Good	150+
Good	**100-149**
Moderate	50-99
Poor	0-49

Over the next few months more data were gathered and worked up both at IFE and ITE. As of March 1999, JDB had gathered data on chemical water quality from 1998 back to 1970 and freshwater macroinvertebrate data from 1998 to 1980. This is presented in Figures 2 and 3.

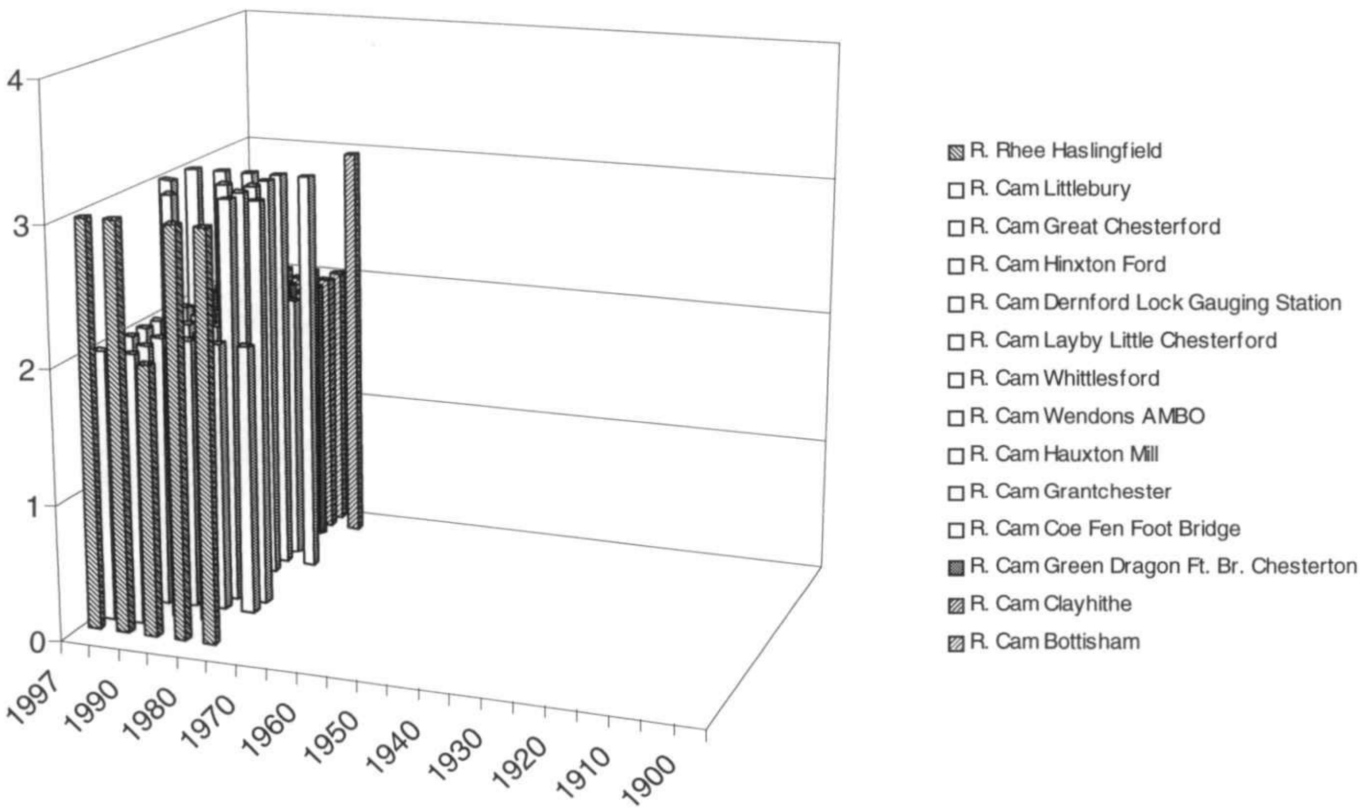

Figure 2. The macroinvertebrate biological quality of the River Cam in the vicinity of Cambridge (Bands 1 to 4 represent poor, moderate, good and very good BMWP quality respectively)

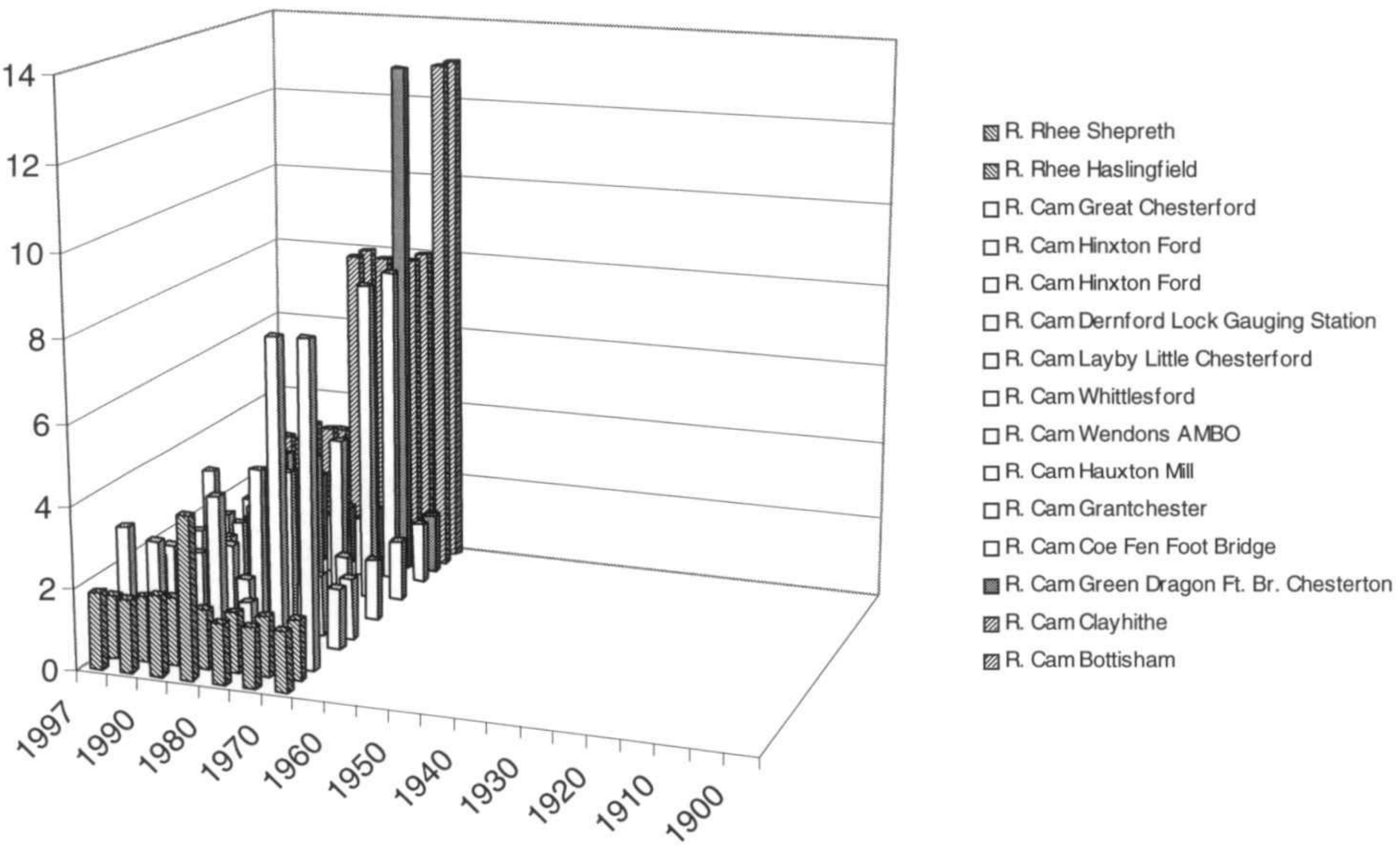

Figure 3. The chemical quality of the River Cam in the vicinity of Cambridge. (as biochemical oxygen demand in mg/l).

In the case of the chemical data, while biochemical oxygen demand (BOD) is presented in figure 3, several alternative parameters were also obtained from the information requests for modern data. These could be substituted if it becomes apparent that extensive historical data exists for a parameter other than BOD.

Attempts to extend the data set further back in time are now focussed on trying to obtain the following documents:

- 1958 National Survey Report - an unpublished report of a survey conducted in 1958
- Annual Reports from the Great Ouse Water Authority (the predecessor body to Anglian Water) for the period ~1960 back to the ~1930's
- British Water Works Association Annual Reports (a series from 1915 to 1968)
- Royal Commissions (and Ministry of Health Commissions)
- Fishery Board Annual Reports

References to information sources.

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2.0 Progress Report 2. The biological quality of urban watercourses in three groups of towns in England and Wales

Patrick Armitage (PA) IFE, River Laboratory
John Davy-Bowker (JDB) IFE, River Laboratory

Introduction

Watercourses flowing through a grossly polluted urban environment will tend to have an impoverished freshwater macroinvertebrate fauna compared with an unpolluted rural setting. Macroinvertebrate faunas of most watercourses can be fitted into several classification schemes that give a good indication of the type of community that a certain river type is likely to support. For example, a chalk stream is likely to support a hard-water fauna rich in gastropods and mayflies while an acidic upland river is likely to have a very different fauna composed of animals tolerant of low pH such as stoneflies and elmid beetles.

However, it is less clear what happens if a moderately polluted watercourse flows through an urban area. Will the type of the river as determined by geological factors in the catchment as a whole continue to determine the composition of the fauna or will the urbanised setting tend to make all urban faunas similar to each other?

Methods and data

In order to address this question, it was first necessary to classify towns. Grove and Roberts (1980) performed principal component analysis on 185 towns in England and Wales based upon data they collected in 1971. They analysed 40 variables from 185 towns with populations exceeding 50,000 to produce a classification with 12 town clusters. They then compared their findings with a similar study performed in 1951 (Moser and Scott, 1961). The two classifications showed general agreement with the three broad categories of towns (Table 1) demonstrated by Moser and Scott in 1951 identifiable in the later classification produced by Grove and Roberts.

Table 1.The three broad categories of town 'type' identified in separate classifications in 1951 and 1971

Town 'type'	1951 Classification	1971 Classification
1) Resorts, administrative and commercial	MS 1-3	Cluster 1,2
2) Industrial	MS 4-8	Cluster 4,5,6,7,8
3) Suburbs and suburban type towns	MS 9-14	Cluster 9,10,11

With this classification of towns established, it was then necessary to find towns within these categories where samples of lotic macroinvertebrates had been taken. The data set used for this project was the Environment Agency 1995 General Quality Assessment (GQA) survey data, which is currently being turned in to a database under an Environment Agency R&D project at the IFE. Towns in each of the three groups above were examined on maps in order to find examples of where biological samples had been taken from sites within the urban area of the town in 1995 (Table 2).

The biological quality assessment method, RIVPACS III++, was also run on the 39 biological sampling sites isolated above, in order determine how far the urban sites deviated from the predicted target value.

Table 2. Towns where urban samples had been taken in 1995

Type 1	Type 2	Type 3
Bath	Birmingham	Cambridege
Blackpool	Blackburn	Cheadle & Gatley
Bournemouth	Bolton	Oxford
Cheltenham	Burnley	Reading
Eastbourne	Cardiff	Sale
Exeter	Carlise	St. Albans
Harrogate	Chesterfield	Staines
Southend	Darlington	Sutton Coldfield
	Dewsbury	Wigan
	Doncaster	
	Halifax	
	Huddersfield	
	Leeds	
	Leicester	
	Lincoln	
	Manchester	
	Merthyr Tydfil	
	Norwich	
	Nottingham	
	Southampton	
	Stockport	
	Swindon	
8	22	9

Results

Samples from sites in the 39 towns in Table 2 (listed in Appendix 1) were analysed using Canonical Correspondence Analysis (CCA, Ter Braak 1988) applied to the taxa/site matrix. CCA attempts to explain the responses of the taxa by ordination axes which are constrained to be linear combinations of in this case, the variables mean annual discharge, distance from source, altitude, slope, width, depth, velocity, alkalinity, and substratum cover. The results are presented in Figure 4 and Table 3 lists the ordination characteristics.

Table 3 Ordination characteristics from CCA analysis of the species/site matrix

Axes		1	2	3	4	Total inertia
Eigenvalues	:	0.21	0.15	0.07	0.1	1.659

Species-environment correlations :	0.95	0.91	0.75	0.8	
Cumulative percentage variance: of species data	12.6	21.3	25.7	29	
of species-environment relation	31.7	53.6	64.5	72	
Sum of all unconstrained eigenvalues					1.659
Sum of all canonical eigenvalues					0.66

The ordination diagram shows a relatively widespread of samples with large lowland streams occurring on the right hand side of the diagram and smaller upland streams on the left.

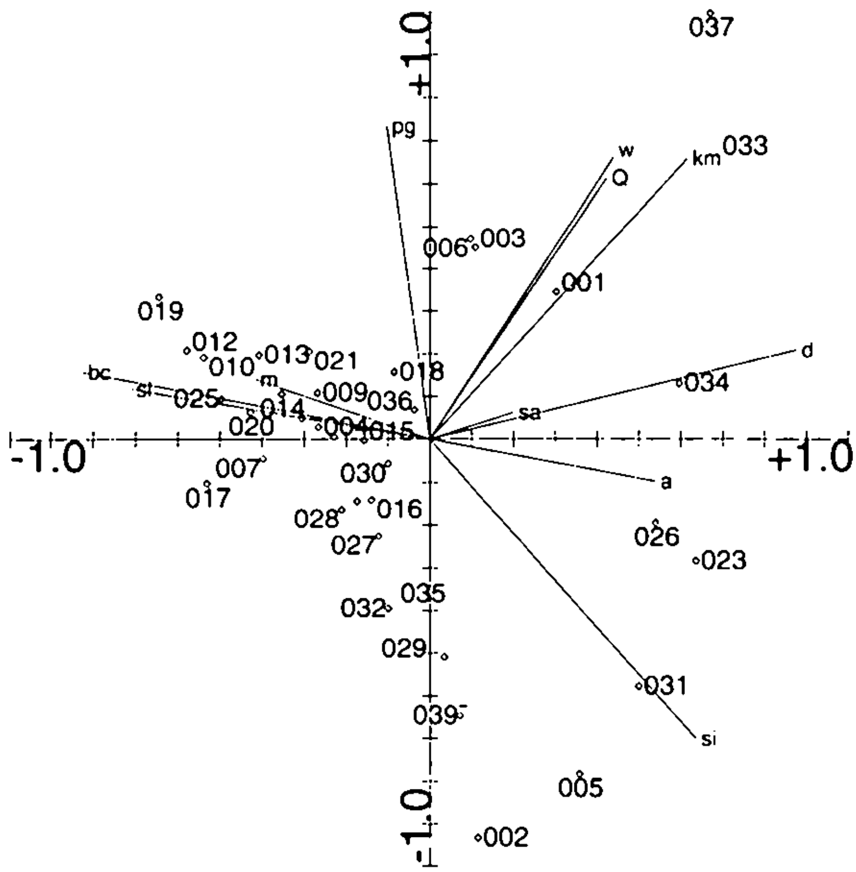

Figure 4 CCA analysis on combined seasonal data from thirty-nine urban sites with environmental variables represented by lines. (mean annual discharge, Q; distance from source, km; altitude, m; slope, sl; width, w; depth, d; alkalinity, a; and substratum cover, boulders/cobbles,bc; pebbles/gravel, pg; sand, sa; silt,si.

The relationship between ordination scores and the environmental variables is shown in Table 4. Most of the environmental variables show a significant relationship with axis scores. This is not surprising given that many of the features used are auto-correlated. Depth is the strongest variable separating sites along axis 1. Axis 2 is defined by distance down stream, width and the proportions of pebble/gravel and silt substrata. The range of values in each of the three categories of town was wide but in general the industrial sites had coarser substrata, steeper slopes and were situated at higher altitudes. Sites from the suburb set were generally wider, and lower down on the river systems and with a high proportion of silt composing the substrata.

Those from the resort/commercial set were intermediate in characteristics but were found at lower altitudes than sites from the other two sets. The environmental variables are listed in Table 5.

Table 4 Product-moment correlation of ordination axis scores with the quantitative environmental variables, mean annual discharge, Q; distance from source, km; altitude, alt; slope, sl; width, w; depth, alkalinity, alk; and substratum cover, boulders/cobbles,bc; pebbles/gravel, pg; sand, sa; silt,si. [Bold type indicates significance at the 1% level]

Axis	Q	km	alt	sl	w	d	alk	bc	pg	sa	si
1	0.378	**0.578**	**-0.419**	**-0.647**	**0.421**	**0.817**	**0.522**	**-0.718**	-0.027	0.094	**0.593**
2	**0.566**	**0.641**	0.139	0.080	**0.661**	0.285	-0.084	0.134	**0.643**	-0.032	**-0.577**

Table 5 The mean and range of values of environmental variables from the three sets of urban category.

	Q	km	alt	sl	wid	dep	alk	bc	pg	sa	si
1. RESORTS ETC (n=8)											
Mean	3.38	39.33	20.75	2.59	11.48	53.62	164.50	17.92	40.42	10.83	30.83
Standard Error	1.16	16.82	8.64	0.96	4.33	15.40	20.37	8.11	10.12	3.18	14.52
Median	1.00	8.80	10.00	1.20	4.92	34.78	182.50	13.34	51.67	11.67	11.67
Minimum	1.00	0.50	1.00	0.10	1.33	10.00	60.00	0.00	0.00	0.00	3.33
Maximum	8.00	111.65	70.00	6.70	33.67	121.67	231.00	70.00	81.67	23.33	100.00
Confidence Level(95.0%)	2.75	39.77	20.43	2.27	10.24	36.41	48.16	19.17	23.94	7.52	34.34
2. INDUSTRIAL (n=22)											
Mean	3.23	26.31	46.82	5.09	11.49	36.04	142.95	37.97	30.44	13.23	18.36
Standard Error	0.51	5.77	7.86	1.03	2.20	7.77	17.42	5.64	3.48	2.71	5.34
Median	2.00	13.75	36.50	4.60	6.89	25.83	119.00	37.50	35.00	10.84	7.50
Minimum	1.00	3.00	5.00	0.10	1.07	10.67	31.00	1.67	0.00	0.00	0.00
Maximum	8.00	79.30	120.00	18.00	35.00	150.00	314.00	95.00	63.00	40.00	88.33
Confidence Level(95.0%)	1.06	12.00	16.34	2.14	4.58	16.17	36.22	11.73	7.23	5.64	11.11
3. SUBURBS (n=9)											
Mean	3.78	56.19	40.90	1.65	16.11	78.93	183.89	6.85	31.78	23.78	37.59
Standard Error	1.02	23.54	8.91	0.45	6.73	27.21	19.17	2.97	10.1	6.38	10.20

									6		
Median	3.00	20.56	33.20	1.95	5.17	33.33	207.00	2.33	20.00	13.67	28.33
Minimum	1.00	4.50	10.00	0.10	0.87	5.00	110.00	0.00	0.00	0.00	5.00
Maximum	9.00	219.34	90.00	4.00	51.00	230.00	261.00	26.67	80.00	55.00	100.00
Confidence Level(95.0%)	2.36	54.28	20.56	1.04	15.52	62.74	44.22	6.84	23.44	14.70	23.53

Environmental Quality

RIVPACS (Wright et al 1993)uses site specific environmental variables to predict the community of macroinvertebrates to be expected in the absence of pollution. The analysis of samples from the three types of urban area is illustrated in Figure5 . The ratio of observed and expected values of the number of taxa and Average Score per Taxon (ASPT) at a site are plotted for each location together with 95% confidence levels. There appears to be no general pattern although 'Resorts/Commercial' sites are generally slightly better in quality than the other two categories. With reference to predicted taxa, there is a very wide range of quality in the industrial sites with 50% of them in the fairly good or better categories. The suburban set is intermediate in quality with few top quality sites possibly reflecting their occurrence in mainly lowland regions. ASPT shows a similar picture but only one site attains the top quality.

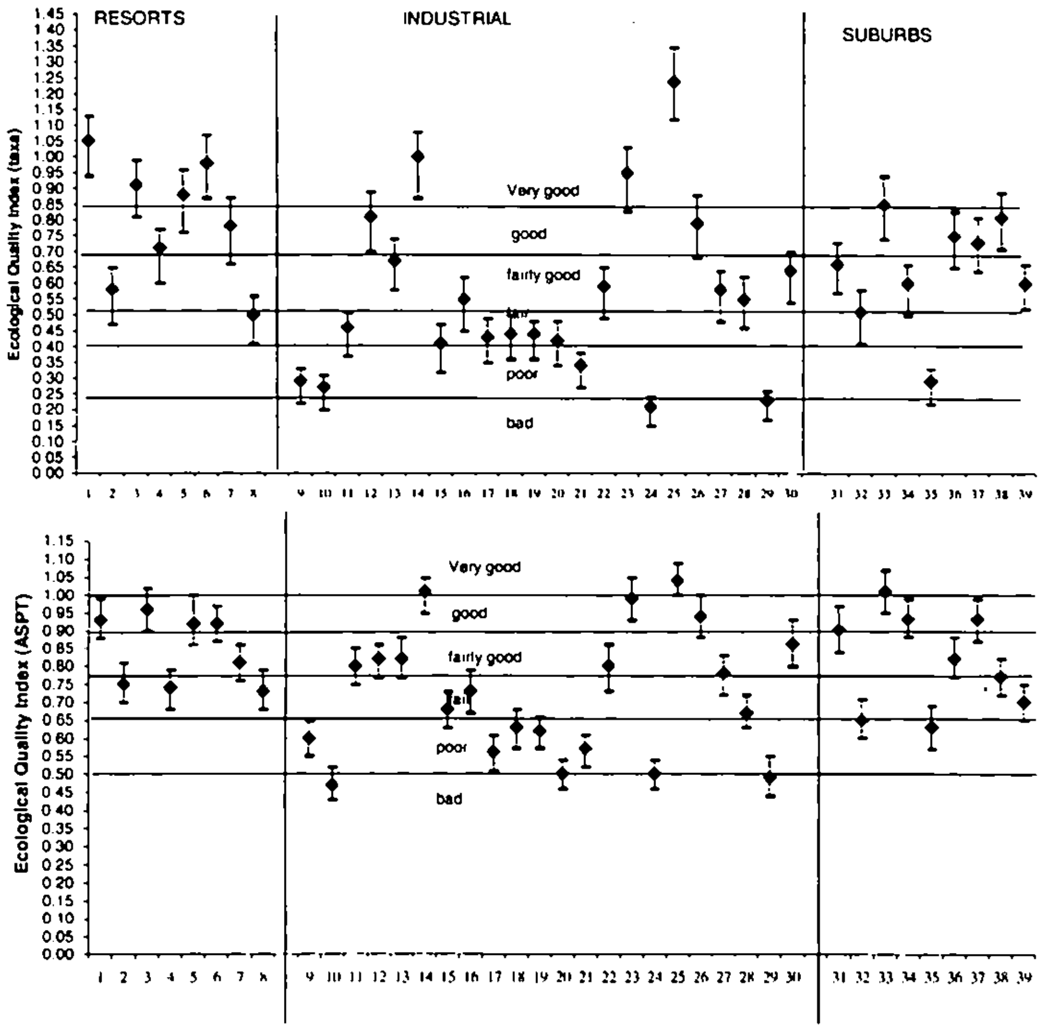

Figure 5 Ecological Quality Indices for taxa and ASPT and grading of index values according to Environment Ageny criteria, for sites in three urban categories ..

Conclusions

The main indications from these analyses support the observations, made in the first progress report (Armitage et al. 1997), that the predominant influences on urban rivers are the geological, geomorphological and hydrological characteristics of the catchment and the location of the site along the river. Socio-economic factors may play a significant role in determining the characteristics of the terrestrial environment but their influence on urban rivers is relatively minor.

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3.0 Progress Report 3. Analysis of urban watercourses: Environment Agency 1990 and 1995 survey data

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John Davy-Bowker (JDB) IFE, River Laboratory
John Packman (JP) IH, Wallingford

This work continues with the classification and ordination performed on the 1990 River Quality Survey (RQS) data survey data as detailed in the first progress report (Armitage et al 1997). As detailed in the first report, the next stage of the analysis should involve bringing in the 1995 General Quality Assessment (GQA) data to allow a comparison to be made between the two years.

Since the original report was written, the 1995 survey data has been validated and brought in to the database. This has been a long process due to the need to check the data from many angles in order to tease out errors in most parts of the time invariant measurements (altitude, distance from source and discharge category). These errors were isolated by querying out the most extreme or unusual combinations of measurements (e.g. high discharge category rivers which were close to their source). These odd combinations were then manually checked on maps and any errors were amended.

The time variant data (substratum composition, width, depth, hardness) have also needed extensive checking. For example, all substratum values not totalling 100% have been amended. Significant problems were encountered with the chemical measure of alkalinity/hardness/calcium/conductivity associated with each site in each sampling year. It was not noticed that two chemical data columns in one of the data files originally received from the Environment Agency were mislabelled. Also, many data items were missing and had to be requested from the Environment Agency regions to complete the data set.

Once the 1995 data had been validated, it was then possible to work out how many sites in 1990 and 1995 had the correct number of samples (with respect to the GQA survey). In 1990, sites should have been kick sampled three times and three sets of time variant environmental data should have been gathered, while in 1995 sites should have been kick sampled two times and but three sets of time variant environmental data should still have been gathered. Once sites with the correct number of samples had been isolated, it was then possible to generate a list of sites which had been sampled in both 1990 and 1995 (3018 sites) so that a comparison between the two years could be performed.

The next stage of analysis required each site to be classed as either urban or non-urban. In the analysis of the 1990 (GQA) data (Armitage et al 1997) this was achieved by the use the Geographical Information System programme ARCInfo which was accessed on a Sun work station. The urban areas were identified from a Bartholomews Geographical Information System (GIS) urban layer. This layer was buffered to 1km, 1.5km and 5km (this creates additional outlines around the urban areas at these distances). The sites were then plotted onto the urban areas and buffers in ARCInfo to determine which (if any) of the urban layer or its buffers the sites occupied.

In addition to this automated process the 821 sites identified were checked manually on maps to ensure that the river on which each site as located actually flowed through the urban area and not just the buffer zone. It was also necessary to manually eliminate sites below tidal limits. The remaining sites were then manually checked to find groups of sites in the same river system flowing through the same urban area.

This process provided a set of 134 sites from the 5000 or so 1990 sites with complete three season combined freshwater macroinvertebrate faunal lists (at the RIVPACS family level) and averaged time variant and time invariant environmental data. This set of 134 sites was then used to examine the relationship between faunal assemblages and the urban/non urban property.

The 1990 analysis then went on to use TWINSPAN (two-way indicator species analysis) to classify the sites in terms of their macroinvertebrate faunal lists. The analysis produced 15 groups with a variety of relationships between time variant and time invariant data. The 134 sites were also analysed using correspondence analysis (Hill 1973) in the computer programme

CANOCO version 2.1 (Ter Braak, 1988). This analysis revealed that alkalinity, depth, slope and substratum features were the most powerful factors in determining the freshwater macroinvertebrate fauna which occurred at each site. Whether the site was in an urban area or not was judged to be of little importance in determining the fauna found at each site.

An examination of the macroinvertebrate quality of the 134 sites was also performed using RIVPACS III (Wright et al 1996). Environmental Quality Indicies (EQI) were calculated for BMWP score, number of taxa and ASPT. Sites upstream of urban areas and within urban areas were found to be of better quality than sites downstream of urban areas (it had been expected that the sites within urban areas would be of lower biological quality than both upstream and downstream sites). It was thought that this was due to the effects of urbanisation being transposed to downstream areas (discharges being further downstream than the area of urbanisation from which they arose) in combination with the supply of higher quality macroinvertebrates into urban areas from sites upstream. A confounding factor could have been the size of the buffers used which were thought to have been too small (thereby exacerbating the effect above).

For the comparison of the 1990 RQS and 1995 GQA survey data effort has been concentrated on the 3018 sites which were known to have complete and validated data for both years and which were sampled in both 1990 and 1995. These 3018 sites were also put through RIVPACS III++ (Clarke et al 1997) twice in order to calculate the EQIs for all of the sites in both 1990 and 1995.

NB The time invariant environmental data used for these RIVPACS runs was the average of the 1990 and 1995 values so that the RIVPACS environmental file was the same for 1990 and 1995.

The next stage was to identify the sites which lay in urban areas and in buffers around these urban areas. This GIS work was carried out in the ARCView software which can be run on a personal computer unlike the less accessible ARCInfo software. The original buffer layers used in the analysis of the 1990 data were extracted from the Sun work station and compared to a Bartholomews urban layer to assess the accuracy of the buffers. It was realised that the buffers were either less precise than had been hoped or that the process of moving them between the two packages had resulted in a loss of precision. This problem is illustrated in Figure 6 below.

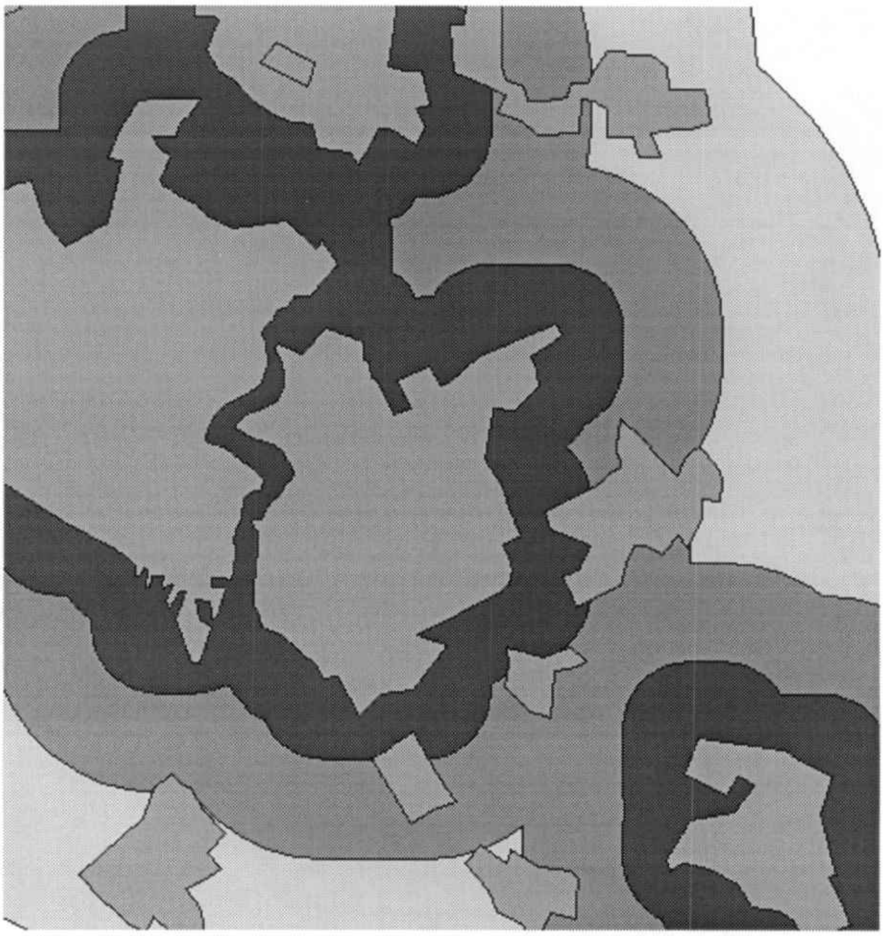

Figure 6. The buffers used in urban the analysis of the 1990 RQS data compared to a Bartholomews urban layer.

It is as yet undecided whether to use the original buffers or to try to generate new ones based upon the Bartholomews urban layer. Given that this problem can be overcome it should be possible to arrive at lists of sites which fall in each of the or the urban layer itself. It would also be useful to try some larger buffering distances than those used in the 1990 analysis (as was recommended in the future work section of the first report).It will then be necessary to reapply the set of checks made manually in the previous study of the 1990 data. These were:

- To check that the river on which each site is found actually flows though the urban area rather than just through one of the buffer zones.
- To note for each site whether it is either upstream or down stream of an urban area
- Tidal sites should not need to be eliminated as none of the 3018 sites used in both 1990 and 1995 should have been tidal.

- Sites should be grouped on the same river system flowing though the same urban area (in the 1990 analysis groups of sites were limited to those which included a site incident with an urban area and either a site upstream or downstream (both where possible)

Figure 7 is included in order to illustrate the problems above. Figure 5 shows a river which has sites in an urban buffer but the river does not actually pass through an urban area. Figure 8 illustrates sites in urban areas or buffers where there are too few sites on the river system to allow their inclusion in the data set under the previously applied criteria. It may be decided that these criteria should be dropped in order to avoid restricting the size of the data set too greatly.

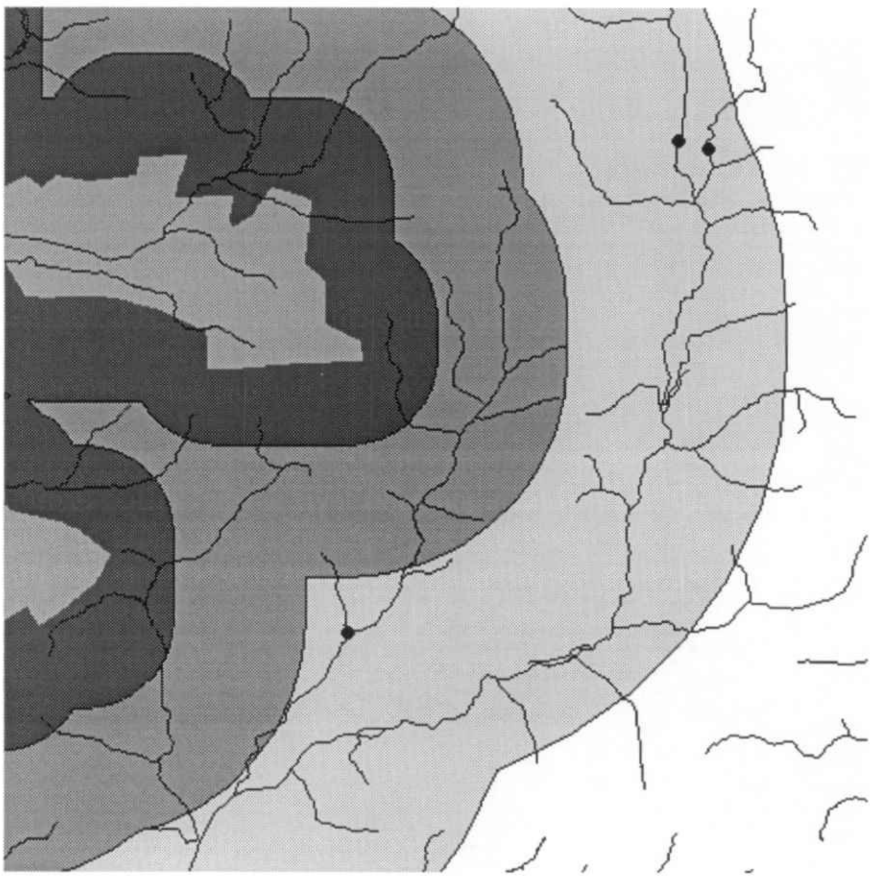

Figure 7. The urban area of Plympton, West Plymouth which has sites in an urban buffer zone but the river does not actually flow though the urban area.

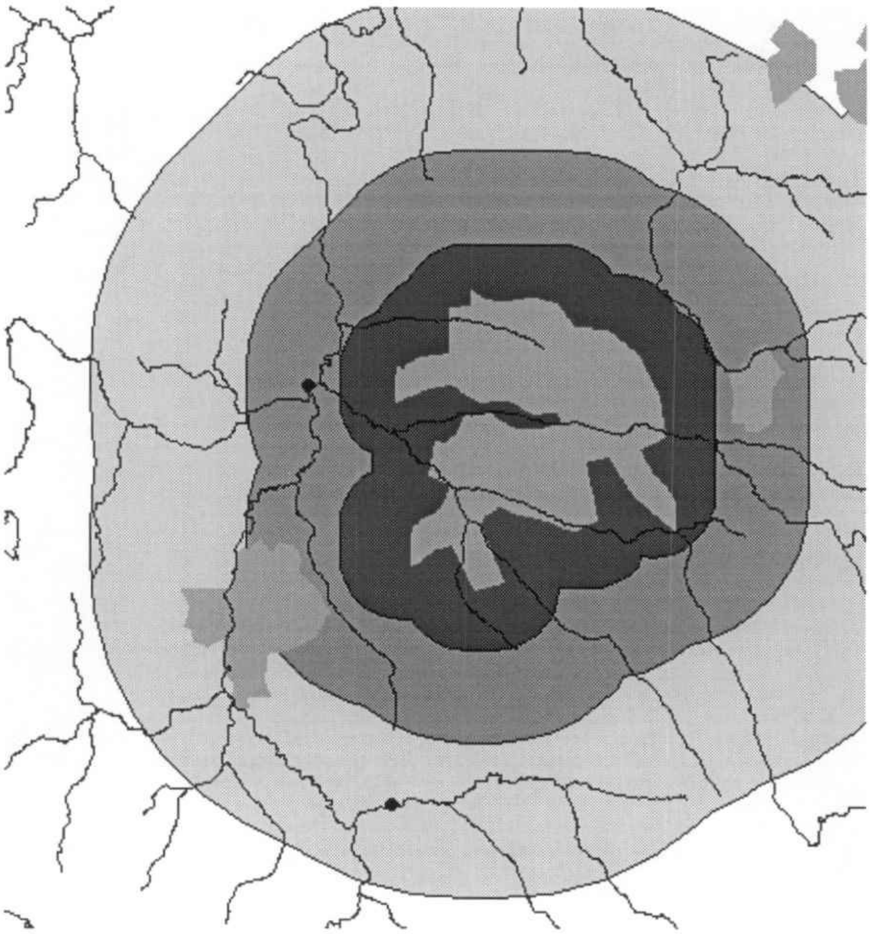

Figure 8. The urban area of Crewe in Cheshire where there are too few sites for inclusion in the urban data set (under the 1990 analysis selection criteria).

It is hoped that rather than the above checks being carried out manually as with the previous analysis of the 1990 data, that this large data set could be checked in an automated way using the expertise of staff at Institute of Hydrology (Wallingford), our contact being John Packman.

In the same way as the 1990 analysis the project could then move on to the use of TWINSPAN and CANOCO to classify the sites in terms of their three season combined freshwater macroinvertebrate faunal lists both in 1990 and 1995. Hopefully this will reveal any grouping of towns based upon their freshwater macroinvertebrate fauna and reveal the most important factors in determining the distribution of animals at these urban sites. It would also be possible to rework the analysis of biological quality at these urban sites and compare 1990 with 1995.

Another option for a way forward for this work could be to abandon the use of GIS layers altogether and use ITE land classification data although this would probably create a similar set of problems to be checked either on maps or in an automated process as in the approach already used.

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4.0 Progress report 4. Lentic (standing water) urban environments

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In the first progress report for this project (Armitage et al 1997) one of the items suggested for future work was to assess the availability of freshwater macroinvertebrate data in lentic (standing water) urban sites. In order to simplify the information request it was decided to use a single urban area as an example. The urban area of Sheffield was chosen, as this was one of the nuclei members of the industrial towns in Grove and Reberts (1979). Sheffield contains a number of park and ornamental standing waters in largely urban settings and was therefore considered suitable as an example.

Contact was made with a variety of individuals and organisations who were thought to possibly hold freshwater macroinvertebrate data. This is summarised below.

Environment Agency (Ridings Area, North East Region)

The Environment Agency has the responsibility to monitor rivers (various legislation applies) but not ponds. Ponds would only be surveyed by the Environment Agency if there had been a specific request, for example, if there had been public concern over weed control, or the status of a fish population. The Environment Agency would also survey a pond if the Local Council had made a request.

The Environment Agency perceived the main problems in Sheffield to centre around industrialised running waters. Sheffield does have canals (e.g. the Sheffield and N. Yorkshire Navigation Canal) and the Environment Agency did hold old data for this. The Environment Agency also thought that canals may come on line for GQA assessment in the year 2000 due to new developments with the RIVPACS software. It was also pointed out that some regions such as Midlands Region may well devote more attention to canals than the North East Region because they have an extensive canal network.

It was thought that biodiversity action plans for various species and habitats may result in an increase in the amount of survey work done on ponds by the Environment Agency (for example surveys for the native crayfish may have included ponds in the urban area of Sheffield).

More recently the Environment Agency has reported phase two of a three phase project to develop biological assessment methods for monitoring the quality of standing waters in England and Wales (Williams et al 1998). The work discusses a wide variety of assessment methods including combinations of metrics and diagnostic techniques to arrive at a preferred assessment method with which the Environment Agency could assess the quality of ponds and canals in England and Wales. While the technical details of these methods are beyond the scope of this document, the work does indicate that in the future the Environment Agency may be performing more monitoring and investigative work on standing waters and that this would be more likely to be carried out with standardised methods.

Sheffield City Council (Environmental Services Department)

Sheffield City Council has no legislation to enforce with respect to ponds but they do have responsibility to ensure that the water quality of ponds, swimming baths, spa pools e.t.c. is satisfactory for its principal use (which is often recreational).

The Council had no programme of routine monitoring of ponds in Sheffield although the Council did undertake monitoring work where public concern had been raised over a pollution incident (e.g. sewage leaks or exessive extractions of water). In these cases the in house team would go out to a site and perform some form of assessment. The council had several hand held meters to perform bankside measurements of chemical parameters in ponds and they would also take samples for chemical and bacteriological analysis. Chemical samples would be sent to Yorkshire Water for analysis (a NAMAS accredited laboratory) while bacteriological samples would be sent to the Public Health Laboratory (which is part of the Local Health Authority). The Council also had a small laboratory of its own which would be used for performing simple chemical tests of water samples.

Another contact in Sheffield City Council was aware of a survey from the 1970's which included many of the standing waters in Sheffield, and it was thought that someone at Sheffield University was looking for a grant to repeat the work.

British Waterways Board

The British Waterways Board did not operate a systematic programme of monitoring for freshwater macroinvertebrates in standing or running waters. Data would only have been collected where canal restoration or conservation projects had been carried out. For example biological data was held for the Montgomery Canal and the Kennet and Avon Canals because major schemes had been undertaken at these sites.

Specifically for Sheffield, the British Waterways Board held some data on the Sheffield and Tinsley Canal and navigable sections of the Rivers Rother and Don in Sheffield although this was thought to be quite old.

Pond Action (Oxford Brookes University)

Nationally Pond Action have done very few surveys on urban standing waters; only half a dozen or so. They have done nothing in Sheffield although they may take some samples this year as they intend to expand their data set in this area (they have more data on the North West of England).

<u>Liverpool John Moores University - The Pond Life Project</u>

Members of the research team knew of local councils who held good data on park ponds:

Manchester a lot of monitoring occurring due Manchester airport 2nd runway
Wigan data held on ponds
Liverpool Lots of park ponds
Warrington Local Council keen on Ponds

Middlesex University

Thought to have conducted surveys on standing waters in Sheffield.

Cardiff University

Thought to hold an extensive but mainly botannical data set from Sheffield.

Sheffield City Museum

Thought to hold a variety of data on the Sheffield urban area

Local Wildlife Trusts

The Sheffield Wildlife Trust and the Yorkshire Wildlife are thought to be possible sources of biological monitoring data.

Yorkshire Naturalists Union

Possibly hold biological monitoring data for Sheffield.

Summary

Various organisations hold or may hold freshwater macroinvertebrate data for the standing water bodies within the urban area of Sheffield. However, only Sheffield City Council had any statutory responsibilities towards urban standing waters and these responsibilities were principally related to public health issues for recreational uses. No organisations had any statutory responsibilites to maintain minimum standards for biological quality at these sites and hence no regular monitoring of this nature was being performed.

While the exact amount of freshwater macroinvertebrate monitoring data available for lentic waters in urban settings will vary between urban areas, it is reasonable to conclude that the responsibilities of the Environment Agency and the Local or City Councils will be the same in all parts of the Country so that the principles observed in Sheffield are probably the same across England and Wales. Particular regions of these organisations may take a greater interest in this type of monitoring (as noted by Liverpool John Moores University, Pond Life Research Group), perhaps to monitor the impact of specific construction schemes or for educational or public relations reasons, but this work will always be patchy and highly variable in both its quality and techniques used.

It is likely that significantly more data on freshwater macroinvertebrates in urban standing waters exists in non-governmental organisations such as Environmental Consultancies, Universities, Museums, Local Wildlife Trusts, and Natural History Societies. This situation could change if current Research and Development work funded by the Environment Agency intended to arrive at standardised methods for monitoring ponds and canals results in an increase in the amount of monitoring that is undertaken.

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5.0 Characteristics of urban rivers using RHS data.

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Patrick Armitage PA (IFE, River Laboratory)

General.

The River Habitat Survey records landuse on each bank in two sections.
1) At each of the ten spot checks the predominant landuse within 5m of the banktop along 10m of banklength is recorded.
2) An overall assessment of the extent of landuse categories within 50m is also made for the full 500m. Each category recorded as absent, present or extensive (>33% of area).

Urban landuse is recorded as Suburban/urban and includes buildings, gardens, roads, tracks, rail and any similar development. This category excludes parkland and other amenity grassland areas which would be recorded as Improved/semi improved grassland.

The data used for this study come from a set of 5613 surveys in England, Wales, Scotland and Northern Ireland completed during the summers of 1994-96. Survey sites were selected on a random basis such that there was one site per year within each 10 kilometre grid square.

Datasets used.

Given the constraints of the data the following criteria were used to classify the urban site.
1) Suburban/urban recorded as extensive on both banks for the overall assessment (total of 317 sites), refered to as Urbanised sites
2) As criteria 1 but an additional condition that the predominant (most frequently recorded) landuse within 5m was suburban/urban (total of 71 sites) refered to as Heavily urbanised sites.

These criteria were selected to ensure that occurences of surban landuse due to isolated houses, tracks or roads were excluded and that only those sites within a suburban/urban area were selected. However a proportion of these sites will still be at least partially rural or fall within a relatively small village. The use of the second criteria was to restrict the data to those sites with development to the banktop as some of the larger dataset will included rivers relatively unaffected by the urban landuse if they are within an undeveloped river corridor.

Preliminary results and conclusions.

The distribution of urbanised sites is shown in Figure 9. There are a number of apparent outliers to this distribution which will be investigated later and removed if they are artefacts of the selection criteria.

Urban sites are more extensively modified than the full set of sites. In both urbanised and heavily urbanised sites resectioning and reinforcement of the channel (Figure 10) and of the banks (Figure 11) occurs at a greater percentage of sites than the full dataset. Heavily urbanised sites have the greatest percentage of modification.

There are relatively few differences between the predominat channel substrates recorded at urbanised and other sites, except that more artificial and fewer bedrock and boulder substrates are recorded at the urban sites (Figure 12). Similarly the predominant bank material is more often artificial (e.g. brick/laid stone, concrete or sheet pilling) and less often earth at the urbanised sites (Figure 13).

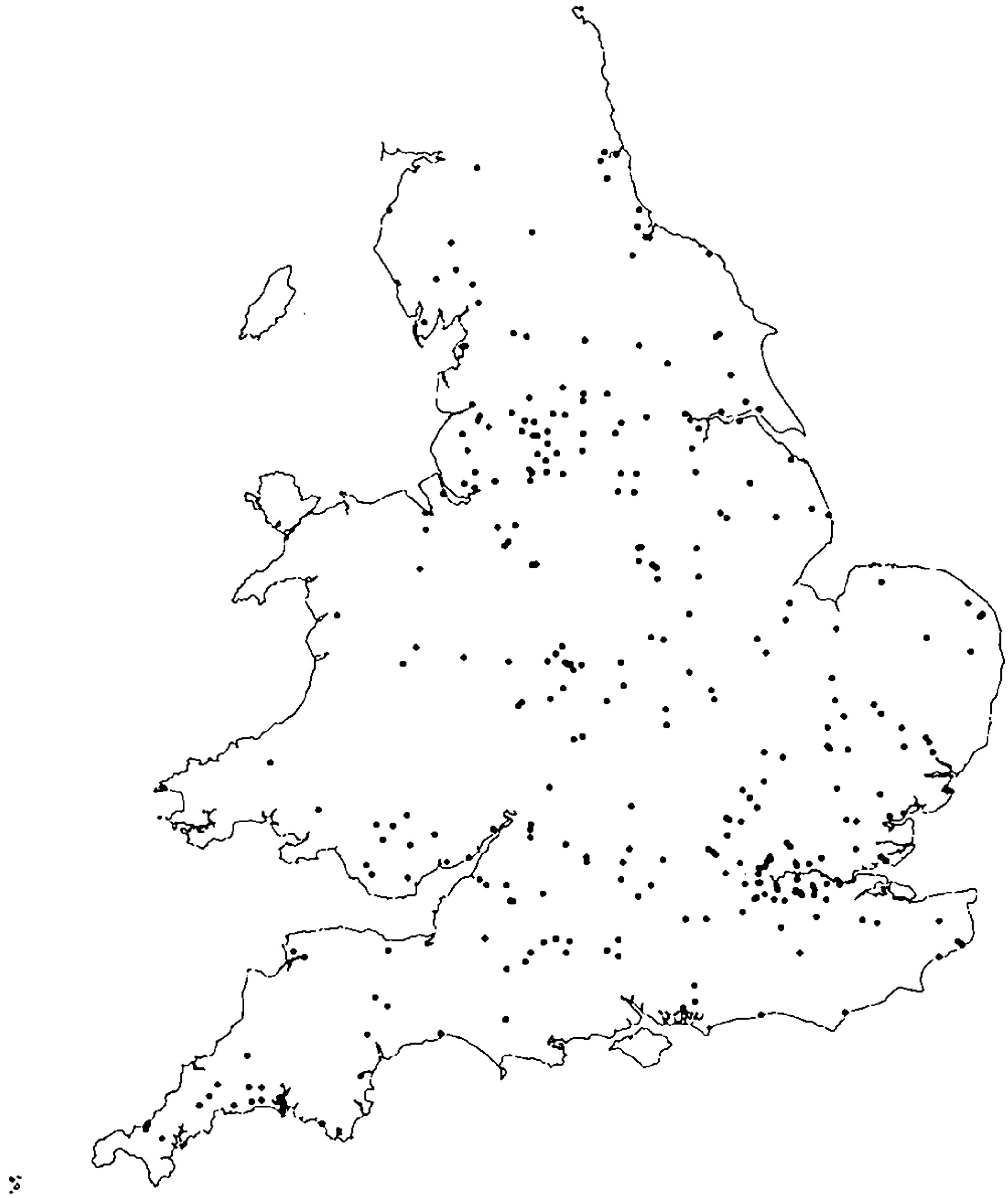
Corresponding to the greater percentage of sites with artificial features is the percentage of sites with artificial or modified bank profiles (Figure). A much greater percentage of urban sites have fully reinforced banks recorded along more than 33% of each bank (extensive) compared to the full data set, and fewer have the natural bank profiles, particularly vertical banks.

Urban sites are generally at lower altitudes than is typical for the full dataset (Figure) as towns are generally built in lowland areas. This will mean that the urban rivers are generally wider and deeper and have more uniform flow types than is typical for the full dataset (**to be tested later**).

There are fewer channel features associated with urban rivers than with those from the national dataset (Figure 16). Features such as mid channel and side bars are likely to be removed during modification and management (e.g. dredging) and exposed bedrock and boulders are typical of high energy upland rivers which urban areas do not occur in, as discussed above.

Bankside trees are slightly more occur frequently at urban sites than at those from the full dataset (Figure), although continuously tree lined banks are less common. This is probably due to the lack of management of vegetation on urban banks which may often be neglegted areas where trees are able to grow without disturbance. In more rural areas agricultural activities often utilise land right up to the bank top, removing trees in favour of greater area for crop production etc. The exception would be in inaccessible or protected areas where woodland is able to grow undisturbed and hence continuous tree cover is more common on the banks whereas there are rarely long sections of wooded banks in urban environments.

There is little difference in the percentage of channel vegetation types recorded at urban and other sites (Figure Figure), although filamentous algae is more often recorded as extensive in urban areas and mosses are less frequently recorded. Algae is commonly abundant at sites with some degree of pollution and nutrient enrichment whereas mosses are pollution intolerant and more associated with upland rivers.



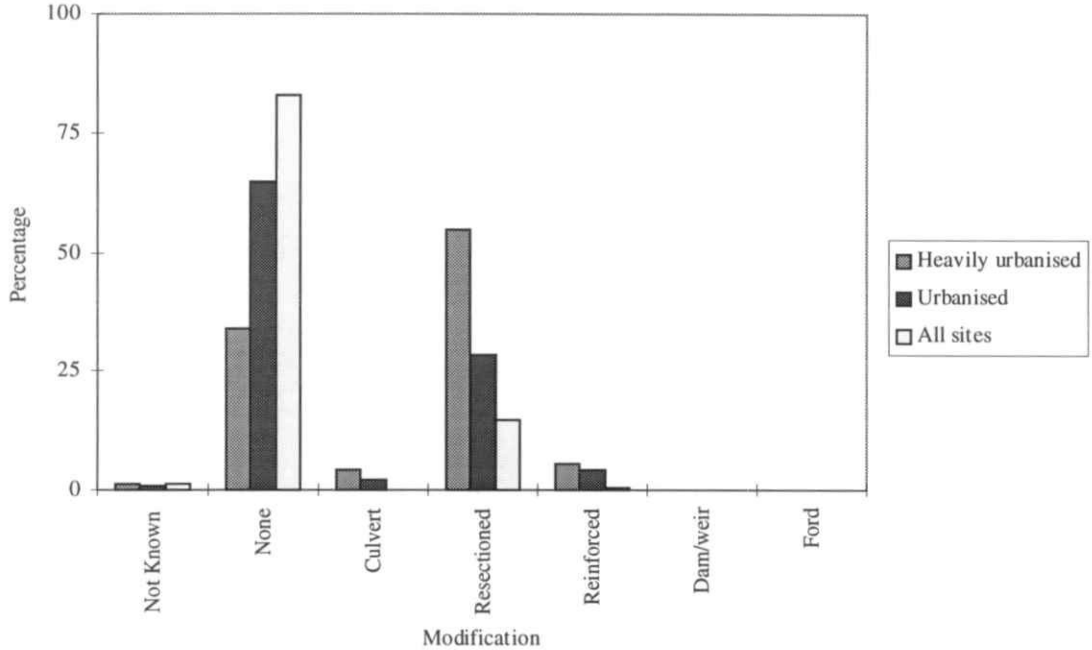


Figure 10. The extent of channel modifications recorded at RHS sites.

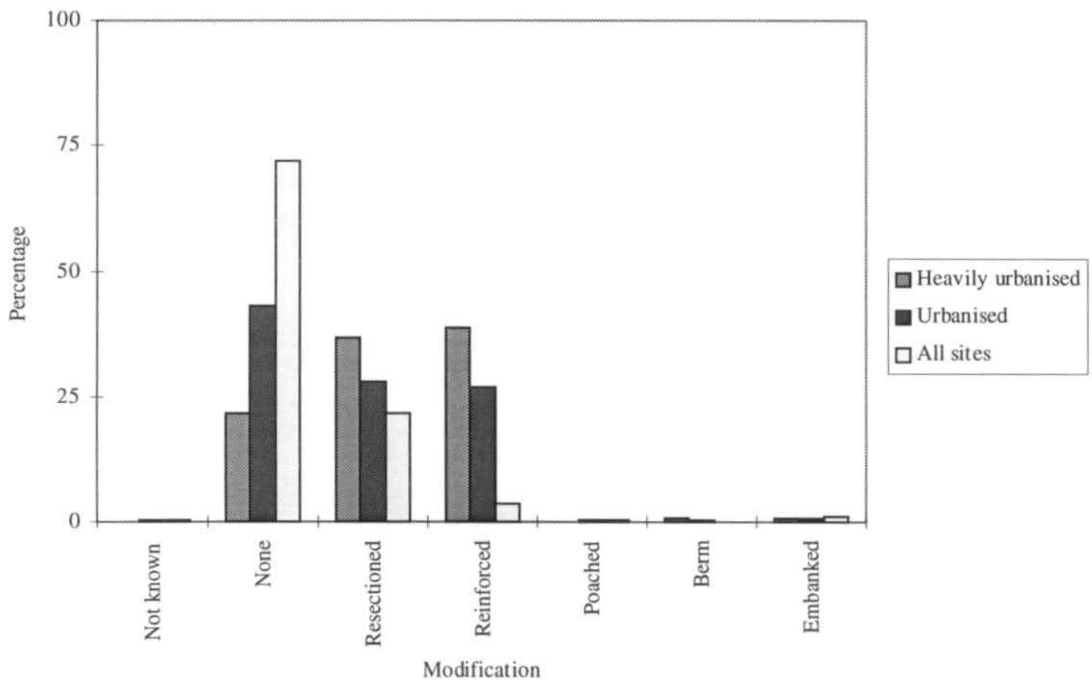


Figure 11. The extent of bank modifications recorded at RHS sites

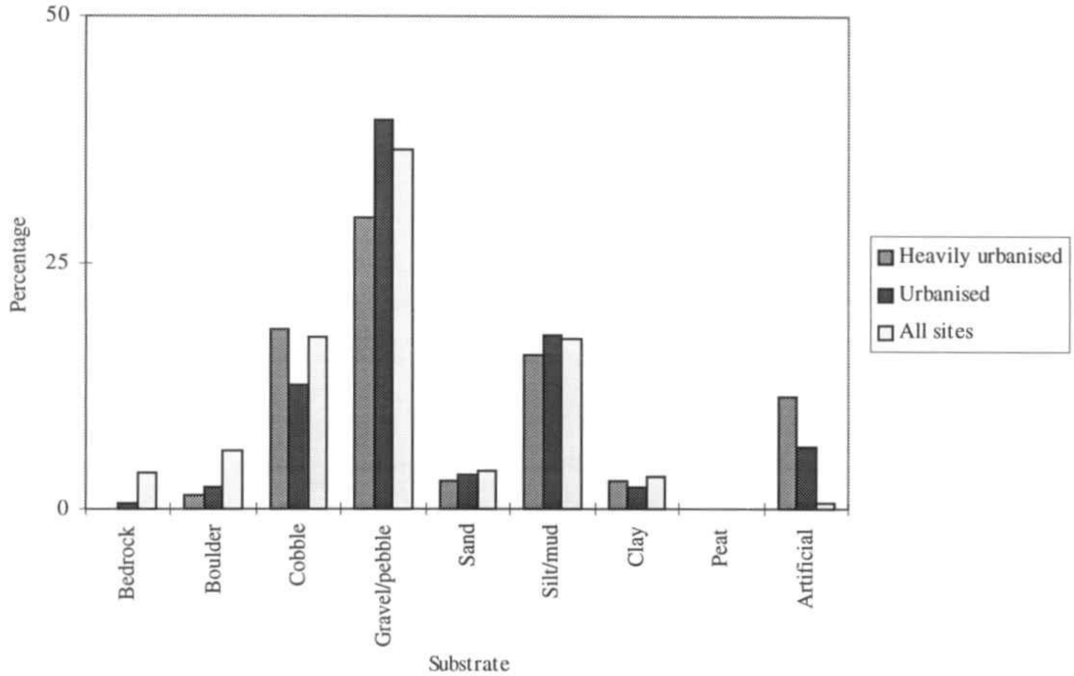


Figure 12. The predominant channel substrate recorded at RHS sites.

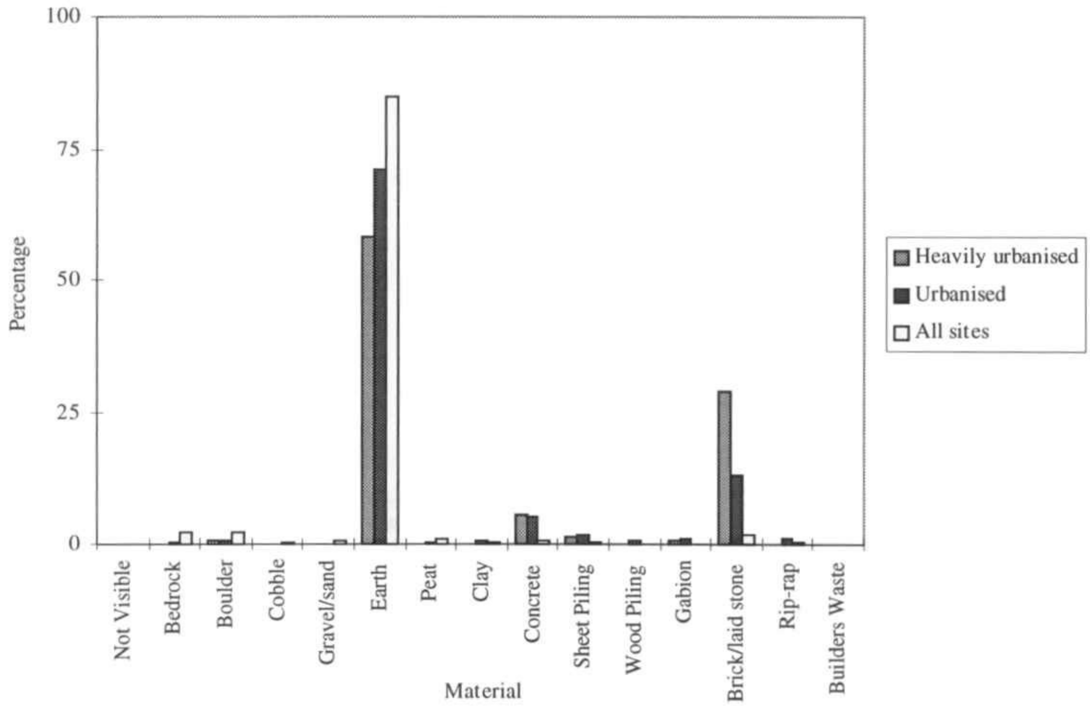


Figure 13. The predominant bank material recorded at RHS sites.

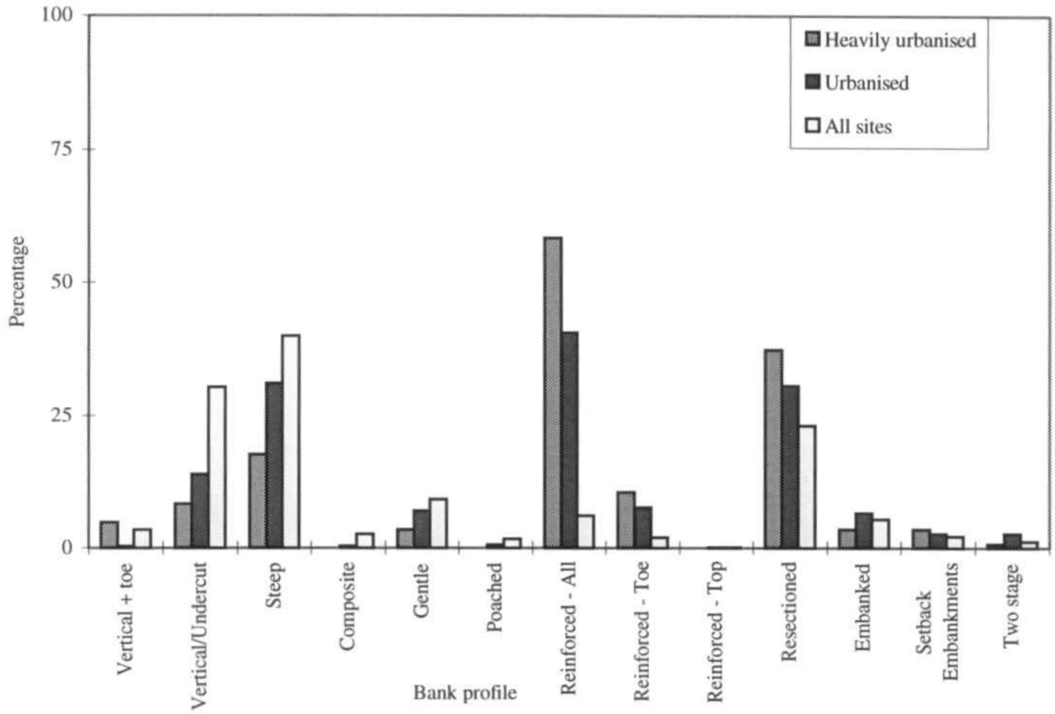


Figure 14. Bank profiles recorded as extensive at RHS sites

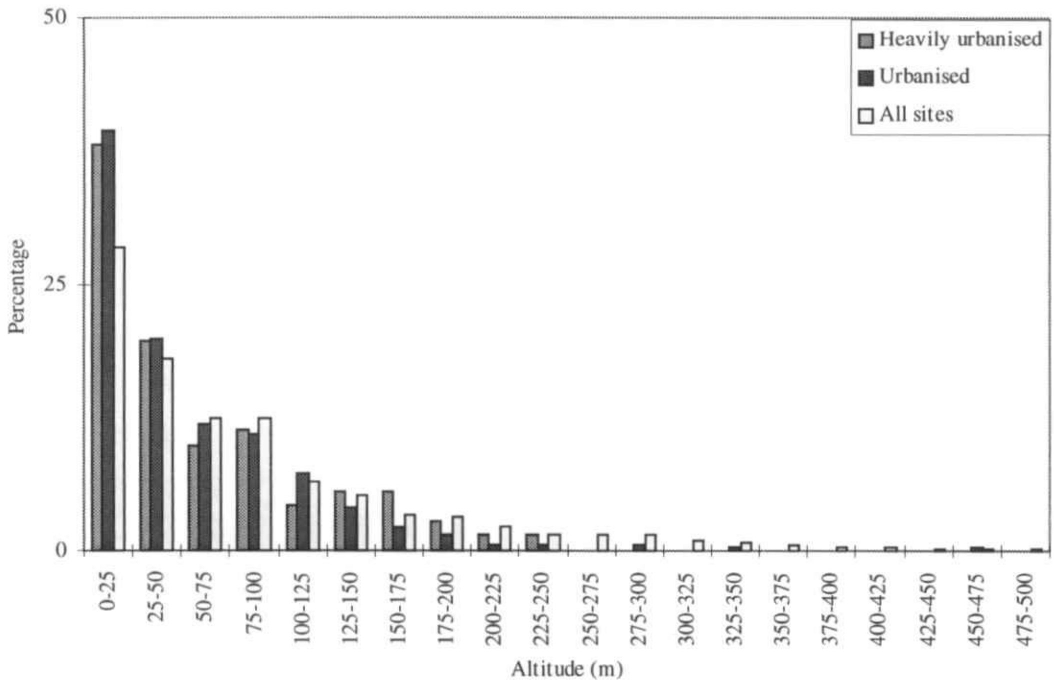


Figure 15. Frequency histogram of site altitude for the RHS sites.

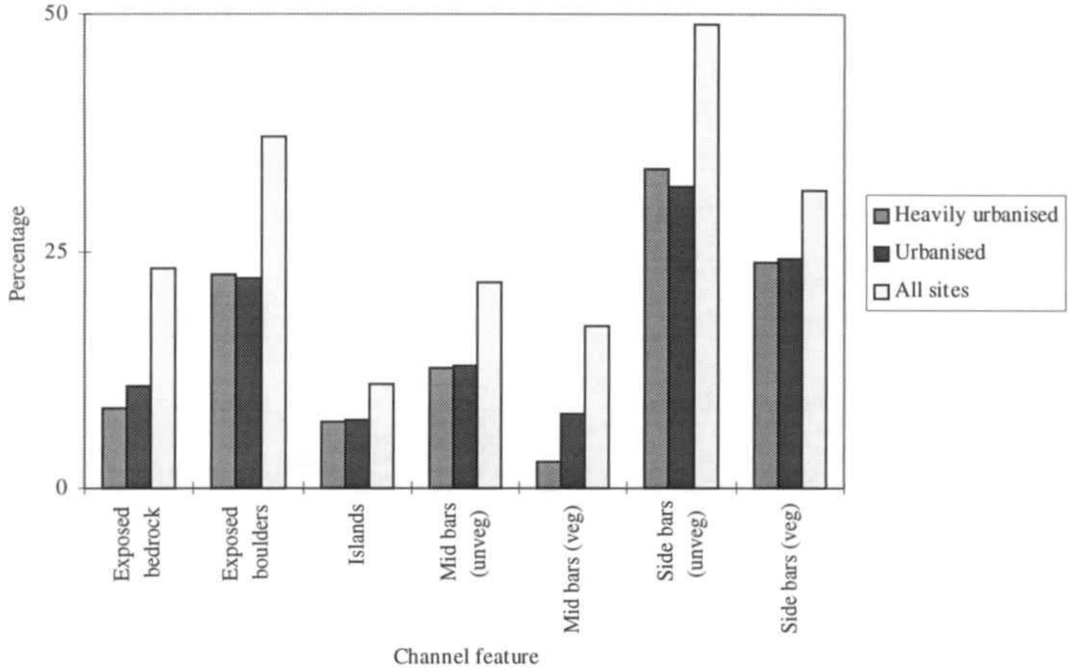


Figure 16. Channel features recorded as present or extensive at RHS sites

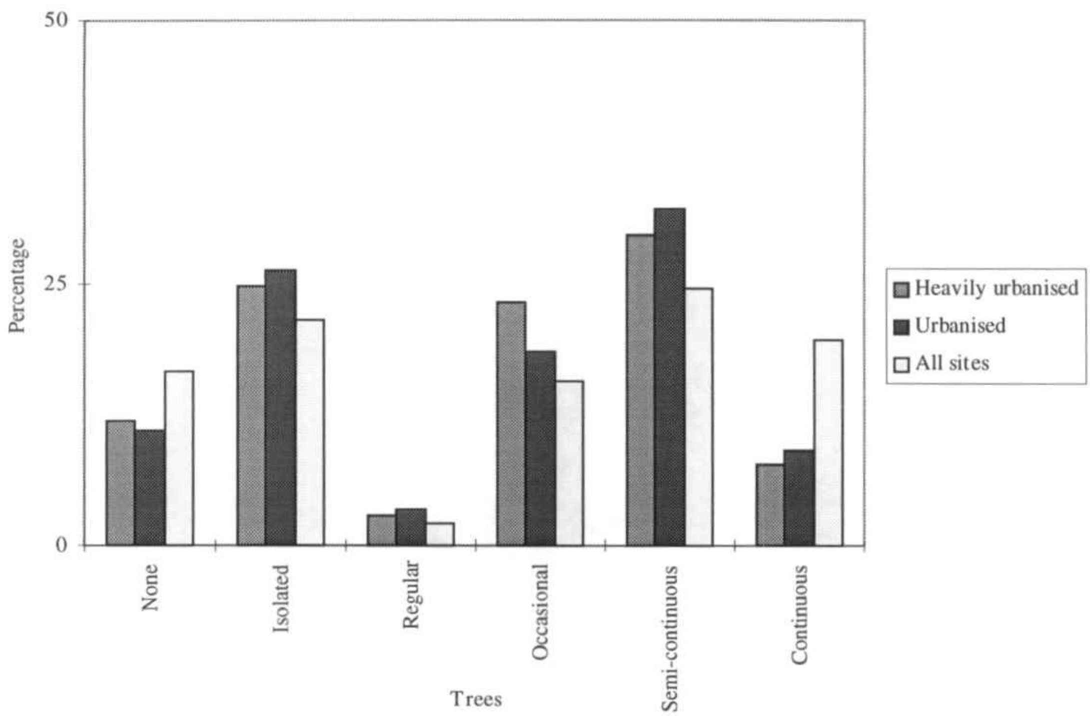


Figure 17. The extent of trees along the river banks at RHS sites.

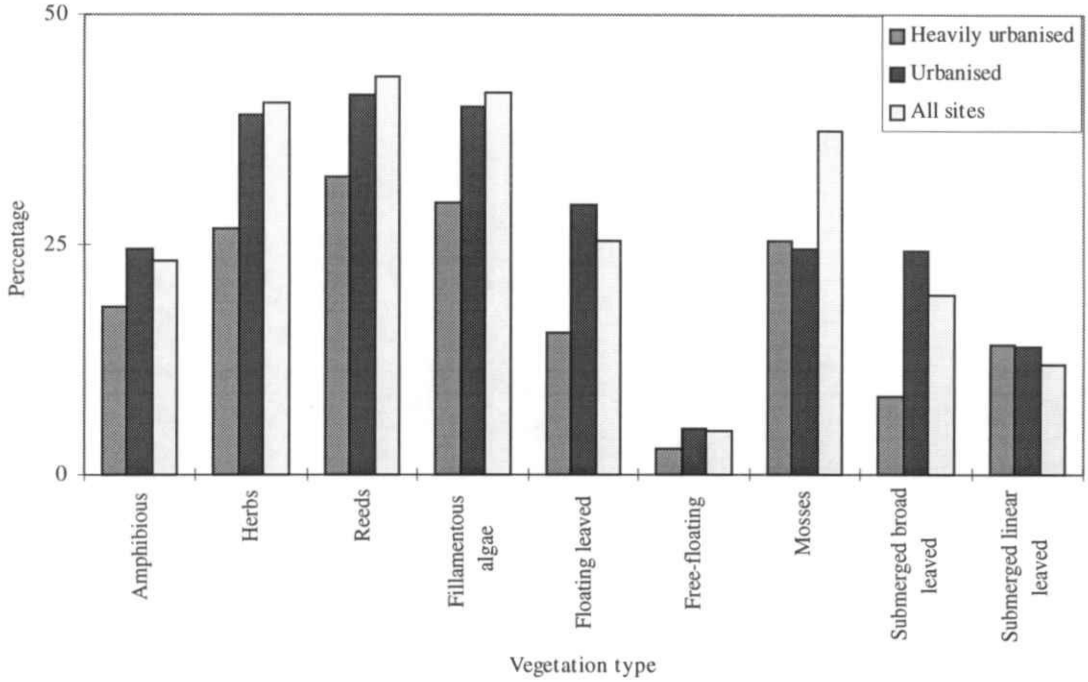


Figure 18. Frequency histogram of channel vegetation types predominantly recorded as present at RHS sites.

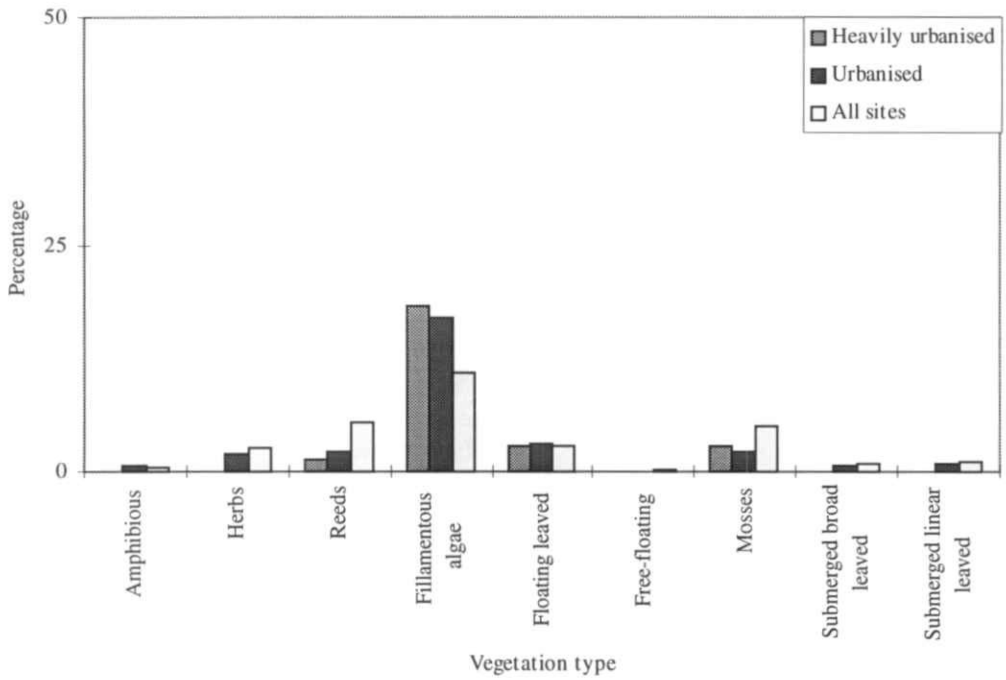


Figure 19. Frequency histogram of channel vegetation types predominantly recorded as extensive at RHS sites.

6.0 Conclusions and Recommendations for Future work

- The River Cam project – a vast amount of data has been gathered and this is currently being collated and prepared for publication. Further details will be available from an ITE report to John Good.

- The analysis of freshwater macroinvertebrates in three different types of urban towns has revealed that the type of town has very little bearing on the freshwater macroinvertebrates community found in a given urban area. The fauna of the river is much more strongly influenced by the upstream nature of the catchment. These findings agree with the analysis of urban sites reported in Armitage et al. (1997). It is hoped to publish these results in an appropriate journal within the next twelve months.

- A wide range of problems with the available data from the Environment Agency 1990 RQS and 1995 GQA surveys, has meant that practically all effort has been used to produce validated data sets which could be used in subsequent analyses. It is likely that IH (Wallingford) will be able to facilitate the screening out of urban sites from these datasets. It is hoped that their assistance will allow some extremely time consuming manual map work to be avoided. There is insufficient time available to proceed further with the analysis of these data but the availability of validated data sets opens up the possibilities of analyses leading to publication in the future.

- The examination of the availability of freshwater macroinvertebrate data for standing water sites in urban environments has demonstrated that information is very patchy with none of the government funded bodies involved in environmental monitoring having any kind responsibilities to carry out such work. It appears that a larger amount of data probably exists in Universities, Consultancies, Museums and Natural History Societies. It is likely that specific survey work would have to undertaken in order to make any progress in this area.