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THE ECOLOGY OF A LOWLAND SANDSTONE RIVER: THE RIVER PERRY, SHROPSHIRE

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ABSTRACT

A preliminary description of the ecology of a lowland sandstone river, the River Perry, Shropshire is given in terms of flow patterns, water chemistry, aquatic plants and benthic macroinvertebrates. Distribution patterns of plants and macroinvertebrates, together with pollution indices derived from them, indicate the river's response to input of organic effluents and downstream recovery. Discontinuous distribution of some species of invertebrates is a reflection of substrate type. Suggestions are made for further experimental observations to test hypotheses arising from this preliminary study.

INTRODUCTION

ECOLOGICAL FIELD studies of rivers and streams in the United Kingdom have covered a wide range of physical types. Proportionally more studies have been carried out on upland watercourses (e.g. Hynes, 1961; Morgan & Egglishaw, 1965; Maitland, 1966; Arnold & Macan, 1969; Armitage, 1976; Boon, 1979; Brooker & Morris, 1980) with relatively few in the lowlands (e.g. Langford & Bray, 1969; Bryce, Caffoor, Dale & Jarrett, 1978; Wright, Hiley, Cameron, Wigham & Berrie, 1983; Berrie & Wright, 1984). One reason for this is the focus of many studies on the effects of reservoirs, which are commoner in the uplands (e.g. Brooker, 1981; Boon, 1987). Another is that fewer lowland studies are published. Many are focussed upon the effects of organic pollution (e.g. Brinkhurst, 1965; Hawkes & Davies, 1970). They are carried out by water industry scientists and remain in internal reports. A major project to classify rivers throughout the United Kingdom has, to some extent, redressed the balance (Furse, Moss, Wright & Armitage, 1974) although, until very recently, lowland rivers were still under-represented.

Streams and (smaller) rivers are attractive sites for ecological education and all Field Studies Council Centres, as well as numerous Schools and Colleges, utilise catchments local to them. There are five good reasons for this:

1. Streams are widespread, accessible, semi-natural habitats.
2. Most are available throughout the year and, for invertebrates at least, can be studied in the winter months when other habitats and organisms are dormant.
3. Different stream types within short distances of each other, or sites in a downstream sequence, enable useful comparisons to be made of biological with physical characteristics (Hawkes, 1975; Hildrew & Edington, 1979).
4. The effects of organic pollution from industrial premises or sewage treatment works are commonplace in the more populated areas of Britain; ecological studies are important in monitoring the health and guiding the improvements of such rivers (Harper, Hancock & Davies, 1979) and provide a model for teaching about the effects of pollution, the sequence of recovery and the development of monitoring techniques (Hellawell, 1977; Hellawell, 1984).

5. In the last decade the interest of conservation ecologists has focussed upon rivers and their associated riparian communities as important "corridors" of semi-natural habitats in larger areas of intensively-farmed countryside (Brooker, 1982, 1983).

In Shropshire, ecological studies have been carried out on a number of rivers. The ecology and zonation of invertebrates in a small hillstream on the Long Mynd was reported as a consequence of the educational work of Preston Montford Field Centre (Arnold & Macan, 1969; Redfern, 1969, 1975). Most work has been done on the River Severn, and its upper tributaries, as part of the feasibility assessment of the Craig Goch water transfer scheme (Anon., 1977). Pollution monitoring and fisheries surveys are carried out, on all the streams in the area, by Severn Trent Water (now Severn-Trent Region of the National Rivers Authority). More detailed studies were carried out on the River Perry for a period of five years as part of the impact analysis for the Shropshire Groundwater augmentation scheme (Anon., 1978) the principles of which have been published (Bryan, Harper & Hellawell, 1980). The Perry has also been the subject of one of the few studies in the U.K. of the ecological effects of river canalisation, with emphasis on fish (Swales, 1982; Swales & O'Hara, 1983). It formed part of the nationwide classification of river plant communities by Haslam (1982) but no studies have been carried out on the overall ecology of this, or of any other, lowland sandstone river.

The River Perry is the closest tributary of the Severn to Preston Montford Field Centre. It has been used as a teaching site for many years because it has a number of interesting features, both natural and as a result of human influence. This paper is based on work carried out by adult students on courses in May and August between 1980 and 1985, supplemented by personal visits at different times of the year. It reports on the basic ecology of the river and discusses its unique features.

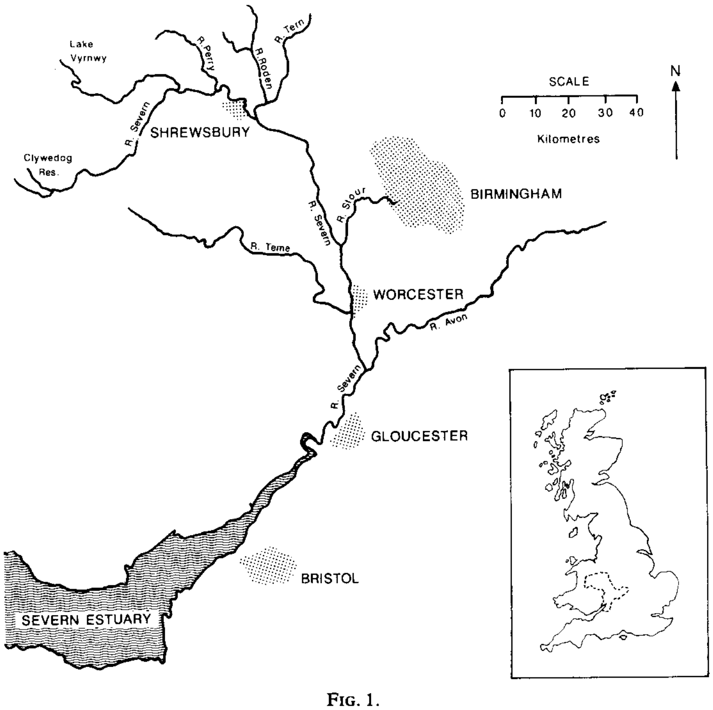

FIG. 1.
Location of the River Perry in the catchment of the Severn, West Midlands, England.

THE STUDY RIVER

The Perry is the most westerly of the rivers which rise in low hills on the boundary of the North Shropshire sandstone plain and flow south to the Severn at Shrewsbury (Fig. 1). The underlying geology of almost all the catchment, except the western headwater streams, is Bunter Sandstone (Toghill & Chell, 1984), but with a complex mixture of glacial deposits and soils (Burnham & Mackney, 1964) which have modified the river drainage and created the depressions which, in post-glacial times, became filled with water to form the Meres and Mosses (Sinker, 1962). Most of these are in the adjacent catchment of the River Roden but several important Meres around Baschurch and Ellesmere drain westward into the Perry (Fig. 2).

In its western headwaters, the Perry is a stony-bottomed small stream (Elton & Miller, 1954) with a gradient falling from 30 to 15m.km^{-1} (Fig. 3). South-east of Gobowen, it flows through alluvial silts and clays with a reduced gradient of between 5 and 7m.km^{-1}. After about a third of its length, it receives the first of its two major tributaries, the Tetchill Brook, from the north. This rises as Newnes Brook, draining sandstone-derived soils in the Ellesmere area. It begins life as the artificial outflow from the Mere at Ellesmere, created in Victorian times to regulate the lake level. Immediately after its confluence with the Tetchill Brook, the Perry enters the large depression of basin peat known as Baggy Moor and here the gradient falls to 1m.km^{-1} or less. After Baggy Moor, it enters a narrow valley, cutting a broad meander under sandstone cliffs at Ruyton. Downstream of Ruyton, the character of the river changes markedly as it follows its final course to the River Severn. Flowing over boulder clay with glacial debris, the gradient increases to 2m.km^{-1} as it enters the post-glacial valley. Its channel bed becomes predominantly stony, but with large rocks and boulders (originally derived from the Welsh hills). This is now the only stretch of the river below Gobowen left with its natural meander patterns and riffle-pool sequences.

The river has been heavily modified. Many areas in the upper part of the catchment, the largest being Baggy Moor, which were formerly peat-filled depressions, have been drained for agriculture. The Water Authority and its predecessors have extensively canalised the main and tributary channels above Ruyton XI Towns; the most recent scheme carried out between 1985 and 1988 has lowered the river bed by about a metre between Ruyton and Rednal, to increase the drainage of Baggy Moor and intensify adjacent agricultural land use.

The upper reaches, between Perry Farm and Rednal, are also to be subject to flow regulation during dry conditions (at some future date) by pumping from the underlying sandstone aquifer. The increased flow will regulate the lower Severn where abstractions for water supply are a substantial proportion of low flows (Anon., 1978).

Throughout its length, the Perry is the recipient of continuous treated organic effluents (of moderate to good quality) and discontinuous untreated ones. Treated discharges come primarily from sewage works (Water Reclamation Works) with some dairy factory effluents. Untreated discharges come from careless agricultural practices. In 1983, waste from an intensive pig unit at Hengoed (detected by a summer field course) was polluting the upper reaches to Gobowen. The most recent and serious of several major pollution incidences was a discharge of 50,000 gallons of pig slurry in September 1985 which caused almost total loss of fish life down to the confluence with the River Severn (Anon., 1985).

PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE RIVER

During the feasibility studies for the groundwater regulation scheme (Anon., 1978), intensive flow and chemical investigations were carried out by Severn-Trent Water in the

FIG. 2.
Catchment of the River Perry.

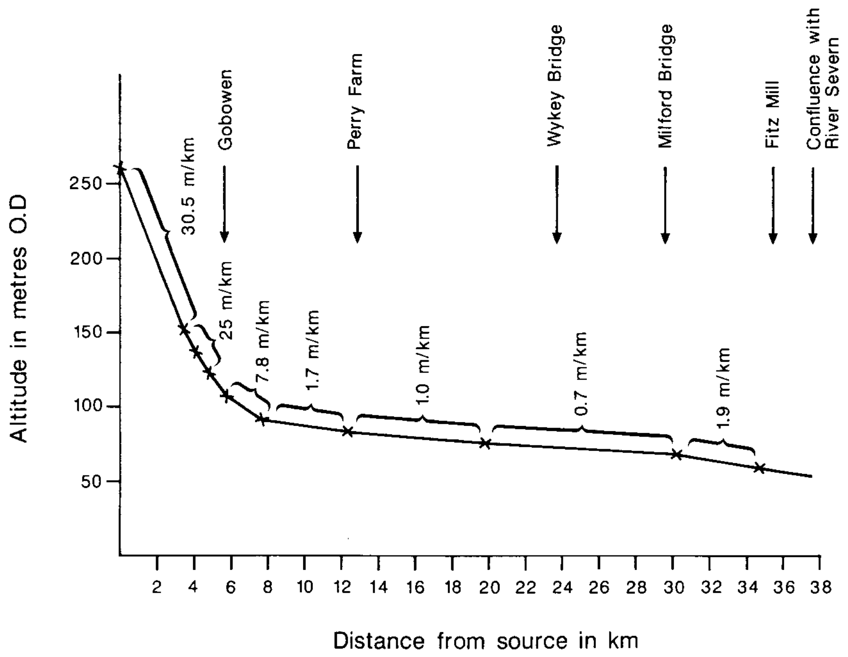

FIG. 3.
Cross-section of the river showing gradient changes.

upper reaches of the river. Normally, flow and quality monitoring is confined to a site close to the confluence with the Severn. The flow data show clearly the natural effect of the sandstone aquifer (Fig. 4). At Perry Farm, the river drains about 25% of the catchment at Yeaton but its dry weather flow is about 50% of the total. The difference between normal

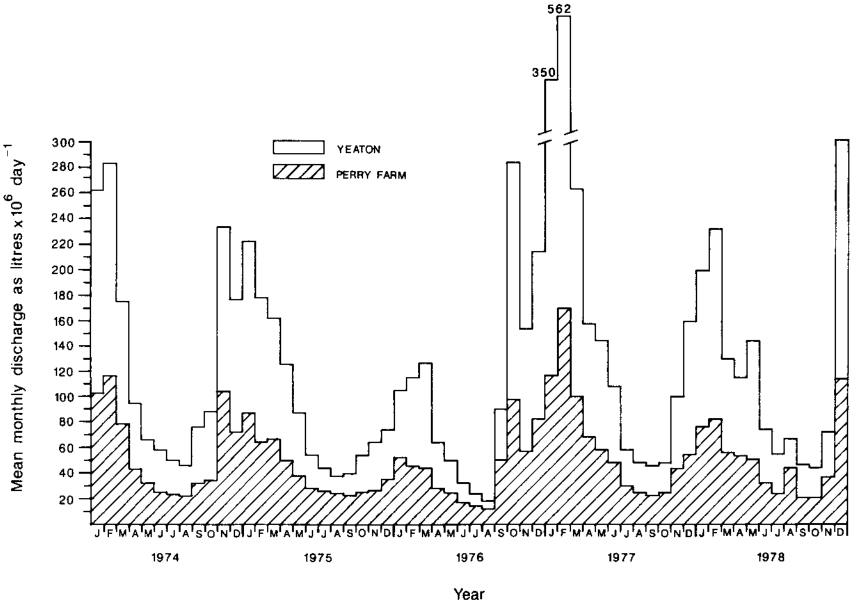

FIG. 4.
Flow characteristics of the Perry at upper (Perry Farm) and lower (Yeaton) sites between 1974 and 1978.

TABLE 1.
Ionic composition of waters in the River Perry.
The figures are mean milliequivalents per litre, plus or minus the standard deviation, with the number of samples in brackets. Source : Severn-Trent Water Authority.

SITE			CATIONS			
	calcium	magnesium	sodium	potassium	iron	TOTAL
Rednal	4.5:0.1	1.3:0.1	0.9:0.1	0.1	0.01	6.8:0.4
	(3)	(3)	(3)	(3)	(3)	
Wykey	5.1:0.9	1.3:0.6	0.8:0.2	0.1	0.2	7.5:1.7
	(31)	(31)	(32)	(32)	(33)	
Milford	4.7:2.3	1.5:0.4	0.9:0.1	0.2:0.1	0.01	7.3:3.0
	(2)	(7)	(7)	(7)	(7)	
Mytton	4.8:1.2	1.2:0.4	0.9:0.3	0.1	0.02	6.8:1.0
	(36)	(36)	(35)	(35)	(53)	

SITE			ANIONS				
	bicarbonate	carbonate	chloride	nitrate	silica	TOTAL	pH
Rednal	3.4:0.6	0.9:0.5	0.6:0.1	0.4:0.1	0.3	5.7:1.3	7.9
	(33)	(4)	(33)	(24)	(3)		(33)
Wykey	3.3:0.6	1.8:0.8	0.9:0.1	0.5:0.1	0.1	6.5:1.6	7.8
	(61)	(33)	(61)	(25)	(32)		(61)
Milford	3.4:0.6	1.7:0.2	0.8:0.1	0.5:0.1	0.06	6.4:1.0	8.0
	(34)	(7)	(34)	(25)	(7)		(35)
Mytton	3.3:0.2	1.8:0.7	0.9:0.1	0.5:0.1	0.08	6.6:1.1	8.0
	(159)	(64)	(159)	(89)	(67)		(159)

low and high flows in any year at Yeaton is about 6 or 7-fold; this is similar to (groundwater regulated) chalk catchments and contrasts with the 10-fold differences or higher between lowland clay or upland hard-rock catchments (Ward, 1981).

Chemically, the river is fairly uniform throughout its length below Rednal Mill (Table 1). Its character is dominated by calcium and magnesium (68% and 17% respectively of cations) with bicarbonate and sulphate (51% and 27% respectively of anions).

This is the commonest chemical category of water type in the U.K. (Rodda, Downing & Law, 1966), typical of the drainage waters of triassic geological deposits (Walling & Webb, 1981). Comparison of the percentage composition of the three main anions and cations (Fig. 5) shows clearly how the river's chemical composition is intermediate between those of the other main lowland waters, chalk and clay. Upland granite is shown for comparison.

The major water quality parameters measured in the river (Table 2) indicate that it is slightly polluted and nutrient enriched throughout its length below Rednal Mill. Its official classification is 1B on the U.K. quality scale of 1–4, with two upper tributaries receiving sewage effluent, the Tetchill Brook and Common Brook, placed in Class 2 (Anon., 1983).

METHODS

The studies were confined to the qualitative identification and distribution of plants and invertebrates throughout the river and an interpretation of the patterns revealed. Aquatic plants (those associated with the river channel) were identified, whenever a site was visited between May and October, using the keys of Clapham, Tutin & Warburg (1964) and of Haslam, Sinker & Wolseley (1975). Total frequency of occurrence was calculated for the

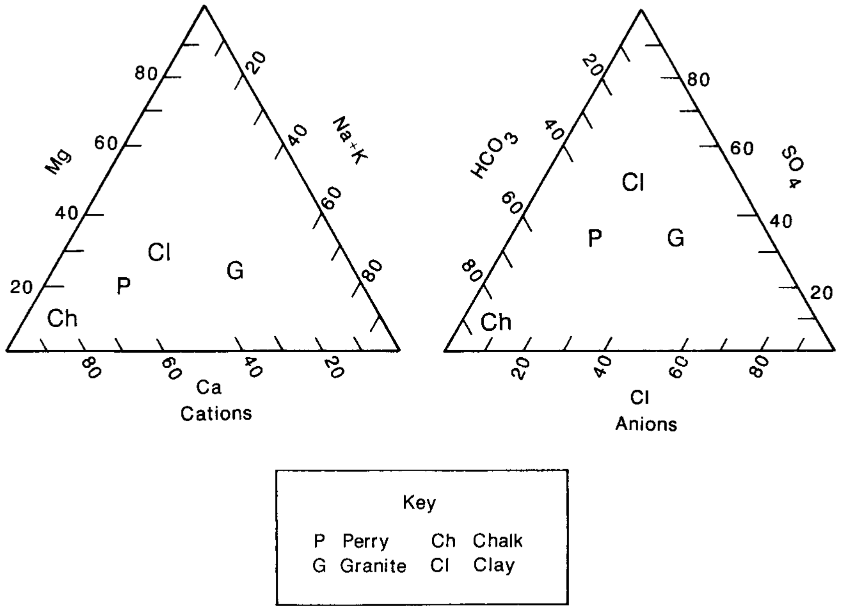

FIG. 5.
Characteristics of the major ion composition, in relation to other water types.

river as a whole. The "damage rating" of (Haslam & Wolseley, 1981) was calculated during one field course in 1983.

Invertebrates were collected at irregular intervals covering all seasons of the year. A standard F.B.A.-type hand net, with 1mm mesh size and frame dimensions 23 × 25 cm (S. M. Davies, Malvern, Worcs.), was used to obtain a "kick-sample" (Furse, Wright, Armitage & Moss, 1981) of 1 minute duration. Additional collecting techniques were sometimes used. In areas of deeper water the net was swept along the bottom and under

TABLE 2.
Concentrations (mg l^{-1}) of oxidised nitrogen, ammonia-nitrogen, phosphate-phosphorus and Biochemical Oxygen Demand in waters of the River Perry, 1974-78. The figures given are means, plus or minus the standard deviation, with the number of samples in brackets.
Source : Severn-Trent Water Authority

SITE	oxidised nitrogen	ammonia nitrogen	phosphate phosphorous	Biological Oxygen Demand
Rednal	6.0:1.5	0.2:0.1	0.3:0.4	2.2:1.0
	(24)	(33)	(6)	(24)
Wykey	6.5:2.4	0.4:0.3	0.3:0.2	3.8:9.7
	(31)	(61)	(32)	(52)
Platt Bridge	6.7:2.0	0.2:0.2	0.3:0.1	2.5:1.1
	(24)	(27)	(3)	(18)
Milford	6.8:2.0	0.2:0.3	0.4:0.1	2.7:1.8
	(25)	(35)	(10)	(26)
Mytton	6.4:3.1	0.2:0.4	0.4:0.3	2.6:1.5
	(89)	(159)	(89)	(143)

overhanging banks. In stony areas, individual large stones and rocks were washed by hand directly into the net. The results of each collection were taken back to the laboratory in plastic buckets for identification.

Identification to family level was carried out on all samples using the keys of Macan (1959) and the early versions of Croft (1986). Species identification was carried out on most taxa except bivalvia, diptera, oligochaeta and hydracarina and a list prepared for the whole river. From samples at each site in 1983 and 1984, family lists were prepared. These enabled sites to be compared on the basis of family richness, the presence/absence of certain families or species, and the BMWP water quality assessment system (Armitage, Moss, Wright & Furse, 1983).

Physical characteristics of each frequently visited site were recorded on a prepared proforma. Data were recorded for depth range, substrate types, channel width, flow, plant cover, bank characteristics and land uses.

RESULTS

Physical characteristics of the river

The river can be divided into discrete sections on the basis of its physical characteristics. The upper tributaries to the west of Gobowen are small and stony, but with flow often reduced to a trickle between successive semi-stagnant pools in the summer months. Between Gobowen and Perry Farm, agricultural drainage schemes have created straight channels with uniform slow flow and sandy substrates dominated by emergent plants such as *Sparganium erectum* in the summer months. Between Perry Farm and a mile below the confluence with the Tetchill Brook, the channel, although straightened in the past, carried discharges with sufficient erosive power to re-create riffle-pool sequences. Such sequences had been characteristic of this stretch until the most recent Severn-Trent drainage scheme eliminated them in 1986/7. From here down to Ruyton, the channel is uniformly silty, deep

TABLE 3.

Species of Aquatic and Riparian Plants recorded in the River Perry

BRYOPHYTA
- *Fontinalis antipyretica* Hedw.
- *Leptodictylum riparium* (Hedw.) Warnst.

ANGIOSPERMAE

Dicotyledones
- *Ranunculus sceleratus* L.
- *R. aquaticus* L.
- *R. fluitans* Lam.
- *Nuphar lutea* (L.) Sm
- *Nasturtium officinale* R.Br.
- *N. microphyllum* (Boenn.) Reichenb.
- *Myriophyllum spicatum* L.
- *M. alterniflorum* DC.
- *Callitriche stagnalis* Scop.
- *C. platycarpa* Kütz
- *Apium nodiflorum* (L.) Lag.
- *Mysotis scorpoides* L.
- *Mimulus guttatus* DC.
- *Veronica beccabunga* L.

Monocotyledones
- *Mentha aquatica* L.
- *Bidens cernua* L.
- *Alisma plantago-aquatica* L.
- *Butomus umbellatus* L.
- *Elodea canadensis* Michx.
- *Potamogeton natans* L.
- *P. perfoliatus* L.
- *P. pusillus* L.
- *P. crispus* L.
- *P. pectinatus* L.
- *Zannichellia palustris* L.
- *Juncus effusus* L.
- *Lemna minor* L.
- *L. trisulca* L.
- *Sparganium erectum* L.
- *S. emersum* Rehmann
- *Schoenoplectrus lacustris* (L.) Palla
- *Glyceria fluitans* (L.) Ribr.
- *G. maxima* (Hartm.) Holmberg
- *Agrostis stolonifera* L.
- *Phalaris arundinacea* L.
- *Phragmites australis* (Cav.) Trin. ex Steidel

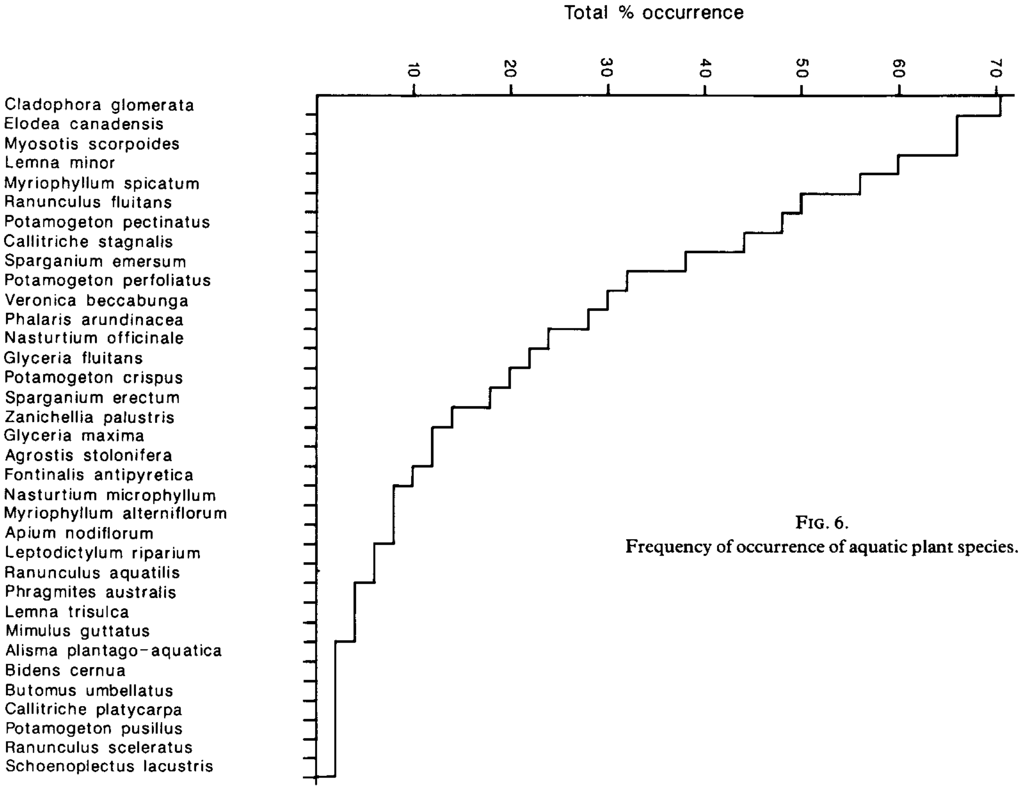

FIG. 6.
Frequency of occurrence of aquatic plant species.

(> 1m) and slow-flowing. Between Ruyton and Milford, it remains slow-flowing and deep, but the substrate becomes more sand-dominated with some accumulations of gravel/ stones; however there is no true riffle-pool sequence. Riffles are apparent at Milford where the gradient begins to increase and the channel hereon down to the confluence shows a "semi-natural" riffle-pool sequence interrupted by the effects of disused mills and associated structures.

Aquatic Plants

The species of plants recorded are listed in Table 3 and their frequency of occurrence in Fig. 6. The submerged plant community is dominated by the alga *Cladophora glomerata*, and the angiosperms *Elodea canadensis, Myriophyllum spicatum, Ranunculus fluitans* and *Potamogeton pectinatus* in the faster-flowing riffle and run stretches; *Callitriche stagnalis, Sparganium emersum* and *Potamogeton perfoliatus* in the slower-flowing runs and pools. Dominant emergents around the edges are *Myosotis scorpoides, Veronica beccabunga, Phalaris arundinacea* and *Nasturtium officinale*. Still water surfaces were almost always colonised by floating *Lemna minor*.

The "damage assessment" (which is based on observations of plant species abundance from bridges) showed the river to be of moderately high quality for most of its length. The most damaged communities were those influenced by organic effluents coming into

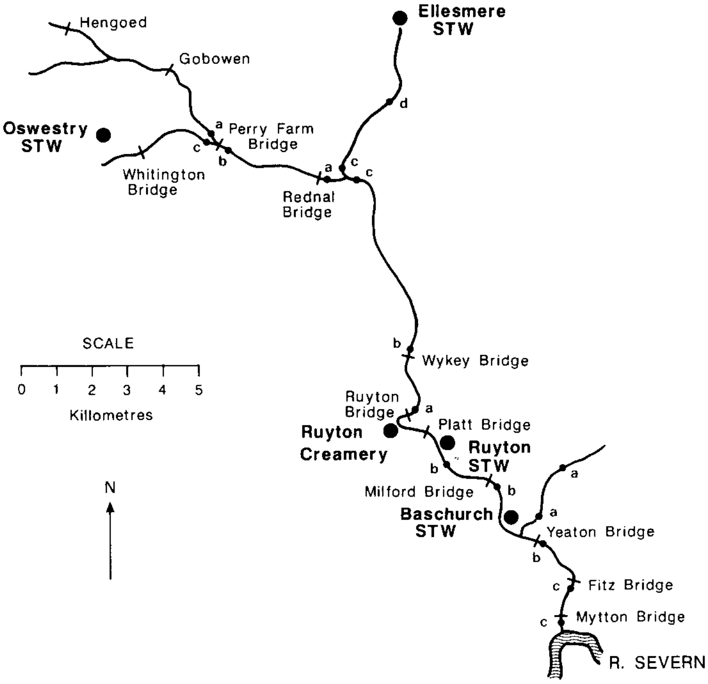

FIG. 7.
Plant "damage rating" assessment at sites throughout the river.

tributaries (Fig. 7). By comparison, the three domestic and industrial discharges in the middle reaches had only a minor detectable effect on the river. The lowest sites showed deterioration which was probably due to nutrient enrichment from farms.

Invertebrates

The current taxonomic list of invertebrates for the river is given in Table 4, but it is undoubtedly incomplete. One would expect, for example, many more beetles and bugs in a lowland river. Nevertheless, the river is rich in species of many groups; 104 species in 60 families so far recorded. The distribution of 53 of these families, which contribute individual scores to the BMWP biological water quality assessment system at 27 sites in the river catchment, is shown in Table 5. A wide range of site characteristics is apparent and from this it is possible to interpret the water quality changes in the river (Fig. 8). Four known sources of effluent in the upper reaches suppress water quality in their tributary brooks and the effects of Ellesmere. The source of the brook is contaminated with septic tank drainage and then effluent from the town's sewage treatment works and a creamery which enter the river almost side by side; these are apparent downstream to Ruyton. Conversely the effects of the three effluents at Ruyton and Baschurch were almost undectectable and the possible farm pollution indicated by the botanical damage rating in the lowest sites was not very obvious.

DISCUSSION

The river shows a straightforward but multiple series of pollution effects followed by recoveries whose extent depends upon the severity of the original input. The way in which

TABLE 4.
The Invertebrate taxa recorded from the River Perry

- PLATYHELMINTHES
  - TURBELLARIA :TRICLADIDA
    - Planariidae
      - *Dugesia lugubris* (Schmidt)
      - *Polycelis nigra* (Muller) / *tenuis* (Ijima)
      - *Planaria torva* (Muller)
    - Dendrocoelidae
      - *Dendrocoelum lacteum* (Muller)

- NEMATODA

- MOLLUSCA
  - GASTROPODA : PROSOBRANCHIA
    - Valvatidae
      - *Valvata piscinalis* (Muller)
    - Hydrobiidae
      - *Bithynia tentaculata* (L.)
      - *Potamopyrgus jenkinsi* (Smith)
  - GASTROPODA : PULMONATA
    - Lymnaeidae
      - *Lymnaea peregra* (Muller)
    - Physidae
      - *Physa fontinalis* (L.)
    - Planorbidae
      - *Planorbis albus* Muller
      - *Planorbis carinatus* Muller
      - *Planorbis contortus* (L.)
      - *Planorbis planorbis* (L.)
      - *Planorbis vortex* (L.)
    - Ancylidae
      - *Ancylus fluviatilis* Muller
  - BIVALVIA
    - Unionidae
      - *Anodonta* sp.
    - Sphaeridae
      - *Sphaerium* sp.
      - *Pisidium* sp.

- ANNELIDA
  - OLIGOCHAETA
  - HIRUDINEA
    - Piscicolidae
      - *Piscicola geometra* (L.)
    - Glossiphoniidae
      - *Hemiclepsis marginata* (Muller)
      - *Glossiphonia heteroclita* (L.)
      - *Glossiphonia complanata* (L.)
      - *Helobdella stagnalis* (L.)
      - *Theromyzon tessulatum* (Muller)
    - Erpobdellidae
      - *Erpobdella octoculata* (L.)

- ARTHROPODA
  - ARACHNIDA : HYDRACARINA

  - CRUSTACEA : MALACOSTRACA : ISOPODA
    - Asellidae
      - *Asellus aquaticus* (L.)
      - *Asellus meridianus* Racovitza
  - CRUSTACEA : MALACOSTRACA : AMPHIPODA
    - Gammaridae
      - *Crangonyx pseudogracilis* Bousfield
      - *Gammarus pulex* (L.)
  - CRUSTACEA : MALACOSTRACA : DECAPODA
    - Astacidae
      - *Austropotamobius pallipes* (Lereboullet)

- INSECTA : EPHEMEROPTERA
  - Baetidae
    - *Baetis buceratus* Eaton
    - *Baetis muticus* (L.)
    - *Baetis rhodani* Pictet
    - *Baetis scambus* Eaton
    - *Baetis svernus* Curtis
    - *Centroptilum luteolum* (Muller)
    - *Cloeon dipterum* (L.)
  - Heptageniidae
    - *Ecdyonurus dispar* (Curtis)
    - *Ecdyonurus insignis* (Eaton)
    - *Rithrogena semicolorata* (Curtis)
    - *Heptagenia sulphurea* (Muller)
  - Ephemerellidae
    - *Ephemerella ignita* (Poda)
  - Ephemeridae
    - *Ephemera danica* Muller
  - Caenidae
    - *Caenis macrura* Stephens
    - *Caenis moesta* Bengtsson
- INSECTA : PLECOPTERA
  - Nemouridae
    - *Nemoura* sp.
  - Leuctridae
    - *Leuctra fusca* (L.)
  - Perlodidae
    - *Isoperla grammatica* (Poda)
- INSECTA : ODONATA
  - Coenagriidae
    - *Coenagrion puella* (L.)
    - *Ischnura elegans* (van der Linden)
  - Agriidae
    - *Agrion splendens* (Harris)
- INSECTA ; HEMIPTERA, HETEROPTERA
  - Gerridae
    - *Gerris* sp.
  - Nepidae
    - *Nepa cinerea* L.
  - Notonectidae
    - *Notonecta glauca* L.
  - Corixidae
    - *Callicorixa praeusta* (Fieber)
    - *Sigara dorsalis* (Leach)
    - *Sigara falleni* (Fieber)

- INSECTA : COLEOPTERA
  - Haliplidae
    - *Brychius elevatus* (Panzer)
  - Dytiscidae
    - *Deronectes depressus* (Fabricius)
    - *Hydroporus marginatus* (Duftschmid)
  - Gyrinidae
    - *Gyrinus* sp.
  - Elminthidae
    - *Elmis aenea* (Muller)
    - *Esolus parallelepipedus* (Muller)
    - *Limnius volkmari* (Panzer)
    - *Oulimnius tuberculatus* (Muller)
  - Helodidae

- INSECTA : MEGALOPTERA
  - Sialidae
    - *Sialis lutaria* (L.)

TABLE 4.
The Invertebrate taxa recorded from the River Perry (*Continued*)

INSECTA : TRICHOPTERA
Rhyacophilidae
Agapetus fuscipes Curtis
Glossosoma boltoni Curtis
Rhyacophila dorsalis (Curtis)
Polycentropodidae
Plectrocnemia conspersa (Curtis)
Polytropus flavomaculatus (Pictet)
Psychomyiidae
Lype phaeopa (Stephens)
Psychomyia pusilla (Fabricius)
Tinodes waeneri (L.)
Hydropsychidae
Hydropsyche augustipennis (Curtis)
Hydropsyche contubernalis McLachlan
Hydropsyche instabilis (Curtis)
Hydropsyche pellucidula (Curtis)
Hydropsyche siltalai Dohler
Hydroptilidae
Hytroptila tineoides Dalman
Ithytrichida lamellaris Eaton
Limnephilidae
Anabolia nervosa Curtis
Halesus radiatus (Curtis)
Limnephilus decipiens Kolenati
Potamophylax cingulatus (Stephens)
Stenophylax lateralis (Stephens)
Molannidae
Molanna angustata Curtis
Beraeidae
Beraea maurus (Curtis)
Beraeodes minutus (L.)
Leptoceridae
Athripsodes bilineatus (L.)
Athripsodes cinereus (Curtis)
Mystacides azurea (L.)
Mystacides nigra (L.)
Trienodes bicolor (Curtis)
Goeridae
Goera pilosa (Fabricius)
Silo pallipes (Fabricius)
Brachycentridae
Brachycentrus subnubilis Curtis
Sericostomatidae
Sericostoma personatum (Spence)

INSECTA : DIPTERA
Tipulidae
Dicranota sp.
Psychodidae
Pericoma sp.
Culicidae
Anopheles sp.
Ceratopogonidae
Chironomidae
Simuliidae
Stratiomyidae
Nemotelus sp.
Empiididae
Rhagionidae
Atherix ibis (Fabricius)
Tabanidae
Muscidae
Limnophora riparia (Fallen).

plant and invertebrate biotic indices show these events makes an interesting comparison. Haslam & Wolseley, (1981) make the point that the plant assessment technique is an overall damage rating and not just a pollution damage rating. Experienced practitioners in water quality assessment know that the same is true of the invertebrate score system, which is an improvement on previous systems, such as the Trent Index, precisely because it allocates scores to a large number of lentic families such as those in the Coleoptera and Hemiptera. However, it is rarely possible to compare lotic and lentic characteristics directly. The Perry data provide an excellent demonstration of the limitations imposed on water quality assessment by physical characteristics.

Stone-dwelling insects and molluscs are restricted in their distribution by the availability of substrata. Heptageniidae and Ancylidae are found throughout the river but only in stony, riffle-dominated, sites—even at those where pollution is detectable (compare sites 13 with 12). This requirement for stones excludes them from most of the middle reaches and the upper intermittent sites. The species *Ecdyonurus insignis, Isoperla grammatica* and *Tinodes waeneri* are all confined to the lowest sites, restricted by the distribution of continuous flow and large stones. The extent to which the distribution of these species is controlled by substrate and the extent to which it is controlled by flow could be experimentally tested at sites in the lower reaches of the Perry. Many of the large boulders in the channel are relicts of glacial rivers and are not moved by the present-day flows. If some of these downstream species are linked with substrate, comparative measurements of distributions in the Perry and Severn where they also occur could explain their pattern.

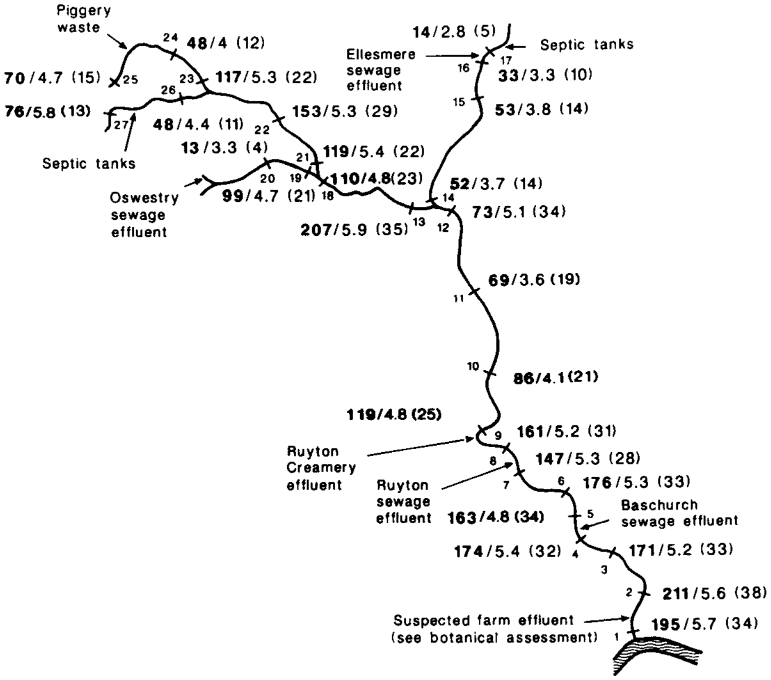

FIG. 8.

Biotic scores (Biological Monitoring Working Party score), average score per taxon and number of scoring families at 27 sites throughout the catchment.

In contrast, the large-bodied bivalve molluscs of the family Unionidae are only found in the silt-dominated sites of Baggy Moor. The families found at Baggy Moor and Wykey are predominantly lentic, which makes comparison between site 12 (which contains the last riffle until Milford, site 6) and 11 (which is deep and silty) difficult.

Extending these studies into the future will also provide some valuable lessons in the limitations of water quality assessment alone. The site at Rednal Mill was canalised in the winter of 1986/7 and all riffles downstream to the confluence with the Tetchill Brook disappeared with the lowering of the river bed. However, the work had started from the confluence with the Tetchill Brook moving upstream and the riffle-pool system which extends for about half a mile downstream of the confluence was undamaged. Here, Biotic scores in the winter of 1987 and spring of 1988 were comparable with those for the site in Fig. 8, whereas in the cleaner water upstream of the confluence (but in a new uniformly fine-particle substratum) they averaged 35 for two visits. Repeated recording of the faunal changes in this newly-canalised section will yield very interesting results. There have been only limited studies on the recovery of streams and rivers from dredging in the U.K. (Crisp & Gledhill, 1970; Pearson & Jones, 1975), and these were both light dredging operations which removed silt and shoals from the existing river bed. The timescale of recovery from river-bed lowering is unknown.

The effects of canalisation on the upper Perry can also be investigated in a wider context of conservation assessment. Methods for river conservation are less well developed than in other areas (Usher, 1986) but comparisons on the Perry could provide a useful experimental ground for developing theory and methods of assessment and re-instatement (Brooker, 1982; Hellawell, 1988; Smith, Harper & Barham, 1990) The Perry at Rednal Mill and the

Table 5.

Family	Site Number 1	2	3	4	5	6	7	8	9	10	11	12	13
Heptageniidae	*	*					*					*	*
Ephemerellidae	*	*	*	*	*	*	*	*				*	*
Ephemeridae	*	*	*	*	*	*						*	*
Leuctridae													*
Perlodidae	*												
Molannidae		*		*	*	*	*	*					
Beraeidae													*
Leptoceridae	*	*	*	*	*	*	*	*	*				*
Goeridae													*
Brachycentridae	*	*	*	*		*		*					*
Sericostomatidae												*	*
Astacidae	*												
Agriidae	*	*		*	*	*	*						
Psychomyidae		*	*	*	*	*	*	*					
Caenidae	*	*	*	*	*			*					
Nemouridae													
Rhyacophilidae													*
Polycentropodidae	*	*											
Limnephilidae	*	*	*	*	*	*	*	*	*	*		*	*
Ancylidae	*	*	*									*	*
Hydroptilidae	*	*	*	*	*	*	*	*				*	*
Unionidae									*	*			
Gammaridae	*	*	*	*	*	*	*	*	*	*	*	*	*
Coenagriidae	*	*	*	*	*	*	*	*					
Mesovelidae													
Gerridae	*	*	*	*	*	*	*	*	*	*			
Nepidae		*	*			*						*	
Notonectidae					*	*		*	*	*		*	
Corixidae		*	*	*	*	*	*	*	*	*	*	*	
Haliplidae	*	*	*	*	*	*	*	*	*	*	*	*	*
Dytiscidae	*	*	*		*	*		*	*	*	*	*	*
Gyrinidae	*											*	*
Hydrophilidae	*			*			*					*	*
Elminthidae	*	*	*	*	*	*		*	*			*	*
Hydropsychidae	*	*	*	*	*	*		*				*	*
Tipulidae	*	*	*	*	*	*	*	*		*		*	*
Simuliidae	*	*	*	*	*	*	*	*	*		*	*	*
Planariidae	*	*	*	*	*	*	*	*	*	*	*	*	*
Dendrocoelidae		*	*	*	*		*	*	*			*	*
Baetidae	*	*	*	*	*	*	*	*	*	*	*	*	*
Sialidae	*	*	*	*	*	*	*	*	*	*	*		
Piscicolidae	*	*	*		*	*							
Valvatidae											*	*	
Hydrobiidae	*	*	*						*	*	*	*	*
Lymnaeidae		*		*	*	*	*	*	*	*	*	*	*
Physidae		*	*	*	*	*	*	*	*	*	*		
Planorbidae		*	*	*	*	*	*	*	*	*	*	*	*
Sphaeriidae	*	*	*	*	*	*	*	*	*	*	*	*	*
Glossiphoniidae	*	*	*	*	*	*	*	*	*		*	*	*
Erpobdellidae	*	*	*	*	*	*	*	*	*	*	*	*	*
Asellidae	*	*	*	*	*	*	*	*	*	*	*	*	*
Chironomidae	*	*	*	*	*	*	*	*	*	*	*	*	*
Oligochaeta	*	*	*	*	*	*	*	*	*	*	*	*	*
Total BMWP score	195	211	171	174	163	176	147	161	119	86	69	173	207
Total Scoring families	34	38	33	32	34	33	28	31	25	21	19	34	35
Average score per taxon	5.7	5.6	5.2	5.4	4.8	5.3	5.3	5.2	4.8	4.1	3.6	5.1	5.9

Table 5. (*Continued*)

Family	Site Number 14	15	16	17	18	19	20	21	22	23	24	25	26	27
Heptageniidae										*				
Ephemerellidae					*	*		*	*	*				
Ephemeridae				*	*		*	*						
Leuctridae														*
Perlodidae														
Molannidae														
Beraeidae								*						
Leptoceridae									*	*		*		
Goeridae														
Brachycentridae														
Sericostomatidae					*			*	*					*
Astacidae														
Agriidae														
Psychomyidae														
Caenidae														
Nemouridae														*
Rhyacophilidae								*	*	*			*	*
Polycentropodidae														
Limnephilidae					*	*		*	*	*		*		*
Ancylidae									*	*		*		
Hydroptilidae								*	*					
Unionidae														
Gammaridae	*	*	*		*	*	*	*	*	*	*	*	*	*
Coenagriidae														
Mesovelidae									*	*		*		
Gerridae				*				*	*				*	
Nepidae														
Notonectidae											*			
Corixidae		*	*		*	*		*	*	*	*	*		*
Haliplidae					*	*		*	*					
Dytiscidae	*	*		*	*	*		*	*	*	*		*	*
Gyrinidae					*							*		
Hydrophilidae	*	*			*	*		*	*		*	*		*
Elminthidae						*			*	*			*	
Hydropsychidae						*				*			*	
Tipulidae	*							*	*	*	*		*	*
Simuliidae	*	*			*	*		*	*	*	*	*	*	
Planariidae						*			*	*				
Dendrocoelidae					*			*	*				*	
Baetidae	*	*	*		*	*		*	*	*		*	*	*
Sialidae	*				*	*								
Piscicolidae									*					
Valvatidae														
Hydrobiidae					*	*			*		*	*		*
Lymnaeidae		*	*		*	*			*			*		
Physidae	*		*	*	*									
Planorbidae														
Sphaeriidae	*	*	*		*		*	*					*	
Glossiphoniidae	*	*	*		*	*		*	*	*		*		
Erpobdellidae	*	*			*	*	*	*	*	*	*			
Asellidae	*	*	*	*	*	*		*	*	*	*			
Chironomidae	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Oligochaeta	*	*	*	*	*	*		*	*	*	*	*	*	
Total BMWP score	52	53	33	14	110	99	13	119	153	117	48	70	48	79
Total Scoring families	14	14	10	5	23	21	4	22	29	22	12	15	11	13
Average score per taxon	3.7	3.8	3.3	2.8	4.8	4.7	3.3	5.4	5.3	5.3	4.0	4.7	4.4	5.8

Perry at Fitz had virtually identical water quality scores during 1983 and 1984. At the present time, Fitz has remained unaltered but Rednal has been severely damaged. Water Authority amelioration of the scheme was confined to the banks, where landscaping and tree planting were carried out. Nothing was done to recreate physical diversity in the new river channel. Measurements of the extent to which this happens naturally, and the relationship between the development of physical diversity and biological diversity, will provide valuable guidelines for reducing the ecological effects of any future schemes below the water line as well as above it.

A preliminary overall comparison may be made with the data presented here and lowland streams on other rock types. Haslam (1982) has already carried out a national classification of aquatic plant communities and her results are similar to these—except that there has been an increase in the frequency of *Cladophora glomerata*, *Myriophyllum spicatum* and *Potamogeton pectinatus* since her field work in the 1970s. The most likely reason for the difference is an increase in the nutrient enrichment of the river from effluents and diffuse agricultural sources.

The invertebrates may be compared with those of limestone and chalk (Mackey, Ham, Cooling & Berrie, 1982; Wright, Hiley, Cameron, Wigham & Berrie, 1983) and clay (Bryce, Caffoor, Dale & Jarrett, 1978). In comparable taxa where all species were identified, such as Trichoptera and Ephemeroptera, species richness in the Perry was similar to that in chalk and limestone streams and considerably higher than that of clay streams. Richness in taxa such as molluscs and leeches may well be due to the high calcium levels common to all three types; but the physical range of sediment particle sizes may also be important. Clay streams are often more uniformly sluggish as a consequence of past drainage schemes and a lack of coarse bedload for re-formation of riffles (Smith, Harper & Barham 1989).

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