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A survey of the invertebrates of four streams in The Moor House National Nature Reserve in Northern England

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Summary

The Moor House Nature Reserve, Westmorland, is situated in typical north Pennine moorland and experiences a rigorous climate. Three of the streams arise between 700 and 750 m O.D. and the fourth at 590 m O.D. The sampling sites lie between 570 and 540 m O.D. and conditions in the streams range from slow-flowing peaty-bottomed reaches to typical fast-flowing stony streams. Samples were taken in riffles and pools in May, August and October using the kick method. 111 taxa were recorded from the four streams, 90 of which were identified to the species level. The most abundant and widespread taxa were *Leuctra inermis*, *L. fusca*, *Rhithrogena semicolorata*, *Elmis aenea* and Chironomidae. Seasonal and annual variation in abundance of several species was marked with *L. inermis* most numerous in May, *E. aenea* and Chironomidae in August and *R. semicolorata* most abundant in October. The total number of animals caught was generally higher in riffles than in pools and the mean number per 60-sec kick for riffles and pools, based on May, August and October samples between 1967 and 1970, ranged from 110 to 128 in the four streams. *Capnia bifrons*, *Paraleptophlebia submarginata*, *P. cincta*, *Leptophlebia marginata*, *Centroptilum pennulatum*, *Plectrocnemia geniculata*, *Cyrnus trimaculatus*, *Lepidostoma hirtum*, Hydropsychidae (larvae indet.) and Philopotamidae (larvae indet.), are all additions to the lists of previously studied groups on the Reserve. All the species of Tricladida, Annelida, Coleoptera, Hydrachnellae and *Pisidium* are here recorded for the first time for the Reserve.

Great Dodgen Pot Sike supported the largest number of species and species groups (88) and was characterized by having water with the lowest pH (6·75) of all the streams and by having the most gentle gradient and a relatively stable bottom. The fauna is discussed and compared with that of the adjacent Cow Green area. Some of the differences between these areas may be attributable to the slightly greater variation in flow-conditions and water chemistry in the Cow Green basin. Comparison with other areas in the British Isles are made briefly and it is suggested that habitat diversity may account for the species richness of the Moor House streams.

Introduction

A Freshwater Biological Association programme to study fish populations within the

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proposed Cow Green reservoir basin and in the Tees downstream of the dam began in 1967 (Crisp, Mann & McCormack, 1974a). A supporting study was made on the aquatic invertebrates and is described in Armitage, MacHale & Crisp (1974). Concurrent investigations were also made of four streams in the Moor House National Nature Reserve, which is situated about 3·5 km upstream of the Cow Green basin.

Surveys of the Plecoptera (Brown, Cragg & Crisp, 1964), Ephemeroptera (Crisp & Nelson, 1965), Simuliidae (Phillipson, 1957; Davies & Smith, 1958), Tipulidae (Coulson, 1959) and some other aquatic invertebrates (Nelson, 1965, 1971) have been made on the Reserve but none concerns complete faunas of particular streams. This paper describes the annual and seasonal changes in the composition and relative abundance of the fauna in this area between 1967 and 1970.

Study area

The Moor House Nature Reserve, Westmorland, described in general terms by Conway (1955) consists of typical north Pennine moorland situated on carboniferous limestone and glacial drift. The climate described by Miller (1964) is characterized by high wind speeds, low temperatures and high rainfall, the respective average annual values being 24 km/h, 5 °C and 1800 mm.

Four streams were studied each, arising above 550 m O.D. Their profiles and the location of the sampling sites are given in Figs. 1 and 2. The sampling reach of each stream is described briefly below.

Troutbeck (TB)

The sampling station has a large stony pool 40–60 cm deep and 5 m long with a bottom consisting of stones up to about 30 cm in diameter mixed with smaller stones and coarse gravel. At the downstream end of the pool there is 10 m of riffle generally not exceeding 20 cm in depth with a similar substratum to the pool but with generally larger stones up to about 60 cm in diameter. The final stretch downstream of the riffle consists of a shallow run (generally not exceeding 15–20 cm in depth) over bare limestone, which may be partly covered by moss and algae under low-flow conditions. The width of stream in the sample reach varies from 4 to 8 m.

Nether Hearth Sike (NHS)

The sampling area contains pools up to 40 cm in depth either with bare rock bottoms or with a scant cover of stones up to 15–20 cm in diameter. These pools alternate with riffles up to 20 cm deep with a substratum consisting of medium-sized stones (10–15 cm in diameter) grading to coarse gravel and sand. Other areas of the reach consist of shallow runs about 5 cm deep over bare limestone which again may support a temporarily dense growth of moss and algae under low flow conditions. The width of NHS at the sampling site varies from 2 to 4 m

Moss Burn (MB)

The stream is small with rather uniform characters in the sampling area. Shallow pools and riffles (about 10–15 cm deep) alternate with each other and the substratum consists of coarse gravel with stone up to 30 cm in diameter. The width of the stream varies from 1·5 to 1·75 m and the banks are more or less parallel.

Great Dodgen Pot Sike (GDP)
The area sampled consists of a slow-flowing meandering upstream reach characterized by deep (40 cm) peaty-bottomed pools with vertical peat banks up to 1·5 m high alternating with shallower parts with fine gravel and study bottoms. Some of these shallower regions support patches of *Potamogeton* sp. and *Callitriche* sp. The downstream reach contains more riffles with silty gravel-bottoms and stones up to 20 cm in diameter which alternate with stony-bottomed pools 20–30 cm deep. The width of GDP varies from 2·5 to 0·5 m in the sampling reach.

Methods

Samples were taken in May, August and October, between 1967 and 1970. The main sampling method used throughout the study was the 'kick' method (Hynes, 1961). The operator kicked and stirred up the stream bed for a total of 60 sec immediately upstream of a square-framed net, 25 cm in diameter with a mesh of ten threads per cm, and collected the animals washed into it. Two main types of habitat were sampled at each site. These were classified as 'riffles'—shallow fast-flowing water over gravel and stones, and 'pools'—deeper slow-flowing water. This classification was fairly arbitrary because during spates the flow of water through pools was quite rapid.

The method was found to be simple and effective for a wide size-range of substratum particles and despite three changes of operator between 1967 and 1970 gave very consistent results. This agrees with Morgan & Egglishaw's (1965) observations on the method. A means of expressing the results per unit area is described and discussed in Armitage *et al.* (1974) when it was found that 8½ to 13 kicks gave a catch equivalent to 1 m^2.

Results and discussion

A total of 111 taxa were represented in samples from the four streams, ninety of which were identified to species level. The abundance and distribution of these taxa amongst the streams are shown in Table 1.

Table 1. The mean number of invertebrates per 60-sec kick × 10, for Troutbeck (TB), Nether Hearth Sike (NHS), Moss Burn (MB), and Great Dodgen Pot (GDP), based on collections made between 1967 and 1970 in May, August and October.

Species	TB	NHS	MB	GDP
PLATYHELMINTHES				
Crenobia alpina (Dana)	2	7	1	–
Polycelis felina (Mull.)	–	10	–	–
Tricladida indet.	+	15	–	+
ANNELIDA				
Nais alpina Sperber	1	1	–	–
Nais pardalis Piguet	+	–	–	–
Nais elinguis (Mull.)	–	+	–	–
Naididae	–	–	–	+
Peloscolex ferox (Eisen)	–	+	1	+
Tubifex ignotus (Stolc.)	–	–	–	3
Tubifex tubifex (Mull.)	6	23	11	19
Limnodrilus sp.	–	–	1	–
Rhyacodrilus coccineus (Vejd.)	–	+	–	+
Tubificidae	–	–	–	+

Table 1 cont.

Species	TB	NHS	MB	GDP
Stylodrilus heringianus (Clap.)	–	+	2	10
Lumbriculus variegatus (Mull.)	+	–	–	4
Lumbriculidae	+	+	+	+
Enchytraeidae	3	2	2	16
Eiseniella tetraedra (Savigny)	2	1	1	1
Lumbricidae	7	5	2	6
CRUSTACEA				
Gammarus pulex (L.)	3	7	196	1
Ostracoda	–	–	5	–
PLECOPTERA				
Taeniopteryx nebulosa (L.)	7	23	10	12
Brachyptera risi (Morton)	1	1	–	1
Protonemura meyeri (Pictet)	5	12	3	1
Protonemura praecox (Morton)	5	1	1	+
Protonemura sp.	1	1	+	–
Amphinemura sulcicollis (Stephens)	9	10	9	52
Amphinemura standfussi Ris	1	2	1	14
Amphinemura spp.	2	15	8	60
Nemoura cambrica (Stephens)	1	8	32	20
Nemoura erratica Claassen	+	+	5	5
Nemoura cambrica/erratica	–	–	4	2
Nemoura avicularis Morton	+	–	–	23
Nemoura cinerea (Retz.)	–	+	–	2
Nemoura spp.	+	3	4	12
Leuctra nigra (Olivier)	3	2	3	9
Leuctra fusca (L.)	51	58	16	20
Leuctra inermis Kempny	252	238	72	203
Leuctra hippopus (Kempny)	4	13	12	34
Leuctra moselyi Morton	40	20	19	14
Leuctra spp.	1	2	2	3
Capnia bifrons (Newman)	–	+	–	–
Capnia vidua Klapalek	1	3	–	1
Capnia spp.	1	+	+	2
Perlodes microcephala (Pictet)	3	3	3	3
Isoperla grammatica (Poda)	+	4	1	3
Diura bicaudata (L.)	2	2	7	–
Dinocras cephalotes (Curtis)	+	1	–	–
Chloroperla torrentium (Pictet)	28	21	25	11
EPHEMEROPTERA				
Caenis sp.	+	–	–	–
Ephemerella ignita (Poda)	+	2	–	–
Ecdyonurus dispar (Curt.)	49	13	33	1
Ecdyonurus torrentis Kimmins	15	12	21	1
Ecdyonurus venosus (Fabr.)	6	2	7	+
Ecdyonurus spp.	10	5	36	–
Rhithrogena semicolorata (Cuert.)	202	134	190	19
Heptagenia lateralis (Curt.)	73	19	13	1
Leptophelbia marginata (L.)	–	–	–	11
Paraleptophlebia submarginata (Steph.)	–	+	1	2
Paraleptophlebia cincta (Retz.)	+	–	–	+
Ameletus inopinatus Eaton	8	19	42	9
Siphlonurus lacustris Eaton	–	1	2	1
Centroptilum pennulatum Eaton	+	–	+	–
Baetis muticus (Burm.)	1	1	2	–

Table 1 cont.

Species	TB	NHS	MB	GDP
Baetis scambus Eaton	8	2	1	–
Baetis rhodani (Pict.)	88	52	31	2
Baetis tenax/vernus Eaton/Curt.	8	12	40	2
Baetis spp.	4	2	4	1
MEGALOPTERA				
Sialis sp.	–	1	1	2
HEMIPTERA				
Callicorixa wollastoni (D. & S.)	–	–	+	–
TRICHOPTERA				
Rhyacophila dorsalis (Curt.)	8	9	4	5
Rhyacophila obliterata McLachlan	2	1	–	+
Rhyacophila spp.	1	1	–	+
Hydropsychidae	–	–	+	–
Philopotamidae	+	–	–	–
Polycentropus flavomaculatus (Pict.)	6	8	–	9
Plectrocnemia geniculata (McLachlan)	3	4	3	3
Plectrocnemia conspersa (Curt.)	2	5	13	6
Plectrocnemia spp.	–	3	1	4
Cyrnus trimaculatus (Curt.)	–	–	–	+
Polycentropidae	–	+	–	–
Hydroptila sp.	13	33	11	45
Glossosoma sp.	+	–	–	1
Drusus annulatus (Steph.)	23	32	7	26
Ecclisopteryx guttulata (Pict.)	5	41	4	6
D. annulatus/E. guttulata	5	52	8	17
Chaetopteryx villosa (Fabr.)	–	–	–	2
Potamophylax sp.	–	–	+	–
Halesus radiatus (Curt.)	–	–	1	1
Anabolia nervosa (Curt.)	–	–	–	+
Limnephilidae	+	4	1	23
Lepidostoma hirtum (Fabr.)	–	1	1	2
Brachycentrus subnubilus (Curt.)	7	9	–	+
COLEOPTERA				
Hydraena gracilis Germ.	2	2	15	2
Oreodytes rivalis Gyllenhal	–	–	–	•
Oreodytes borealis davisii Curt.	–	–	–	•
Oreodytes spp.	3	5	2	29
Deronectes spp.	6	17	2	1
Dytiscidae	–	–	–	1
Elmis aenea (Mull.)	11	64	46	77
Limnius volckmari Panz.	5	14	20	25
Esolus parallelepipedus (Mull.)	2	1	3	+
Oulimnius ruberculatus (Mull.)	–	+	1	30
Helodes marginata F.	–	+	2	–
DIPTERA				
Dicranota sp.	21	43	9	33
Pedicia sp.	+	1	2	10
Tipulidae	–	1	1	1
Pericoma sp.	–	2	–	–
Chironomidae	21	72	44	103
Ceratopogonidae	–	–	–	+
Prosimulium hirtipes Fries.	•	–	–	–
Simulium brevicaule Dorier & Grenier	•	•	•	•
Simulium ? dunfellense Davies	–	–	–	•

Table 1 cont.

Species	TB	NHS	MB	GDP
Simulium aureum Fries.	–	·	–	–
Simulium monticola Friederichs	·	·	·	–
Simulium latipes Meigen	·	·	·	·
Simulium nitidifrons Edwards	–	–	–	·
Simuliidae	111	16	11	18
Nemotelus sp.	–	3	+	1
Clinocera sp.	2	–	–	1
Hemerodroma sp.	–	–	–	2
Diptera indet.	1	3	1	15
HYDRACARINA				
Sperchon brevirostris Koen.	·	–	·	·
Sperchon glandulosus Koen.	–	–	–	·
Hygrobates foreli (Strom.)	–	·	–	·
Lebertia porosa Thor.	·	·	·	·
Hydrachnellae indet.	8	42	6	18
MOLLUSCA				
Lymnaea peregra (Mull.)	+	–	–	–
Pisidium casertanum (Poli)	+	–	+	8
Pisidium hibernicum (Westerlund)	–	–	–	1
Pisidium personatum Malm.	–	–	+	–
Pisidium obtusale Lamarck	–	–	–	2
Pisidium spp.	+	–	+	3
Total nos. per 60-sec kick	1182	1280	1102	1154
No. of samples, R = Riffles, P = Pools	26 R, 15 P = 41	21 R, 17 P = 38	24 R, 18 P = 42	23 R, 28 P = 51
No. of taxa	73	78	73	88
No. identified to species level	60	65	56	70

+ = < 1 animal per ten kicks.
· = present but data insufficient for quantification.

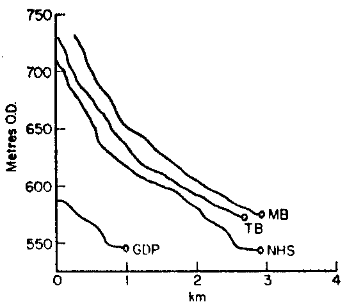

Fig. 1. Stream profiles of Troutbeck (TB), Moss Burn (MB), Nether Hearth Sike (NHS) and Great Dodgen Pot (GDP) showing position of sampling stations.

If the numerical density and occurrence of the taxa in the four streams are considered together, it is possible to calculate an index of dominance (Ulfstrand, 1968). Taxa forming a certain percentage of the total fauna in each stream were assigned numerical values as follows, 10–30% = 8, 5–10% = 4, 1–5% = 2, and <1% = 1.

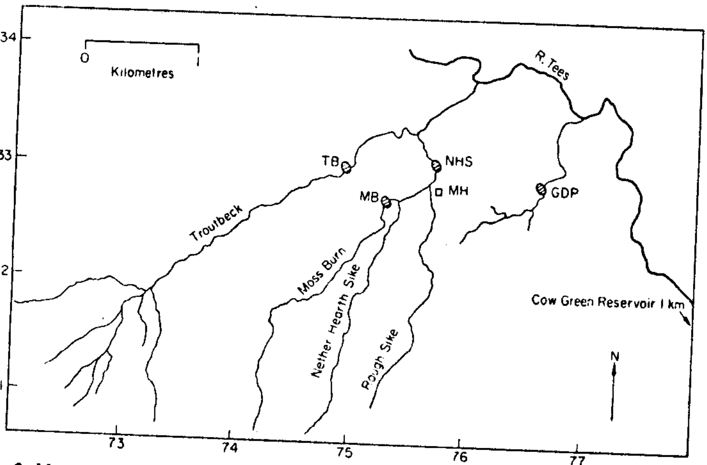

Fig. 2. Map of study area showing position of sampling stations.

Table 2. Grouping of taxa in numerical dominance classes, based on calculated dominance index figures (see text for details)

Index 13–15	16–19	20+
Tricladida		
Tubifex tubifex		
Enchytraeidae		
Taeniopteryx nebulosa	*Gammarus pulex*	
Protonemura meyeri		
Amphinemura standfussi	*Amphinemura sulcicollis*	
Nemoura cambrica	*Leuctra moselyi*	
Leuctra nigra	*Chloroperla torrentium*	*Leuctra inermis*
Leuctra hippopus		*Leuctra fusca*
Ecdyonurus torrentis	*Ecdyonurus dispar*	
Ameletus inopinatus	*Heptagenia lateralis*	*Rhithrogena semicolorata*
Baetis tenax/vernus	*Baetis rhodani*	
Rhyacophila dorsalis	*Hydroptila* spp.	*Elmis aenea*
Plectrocnemia conspersa	Simuliidae	Chironomidae
Drusus annulatus	*Dicranota* sp.	
Ecclisopteryx guttulata		
Limnephilidae indet.	Hydracarina indet.	
Hydraena gracilis		
Deronectes spp.		
Oreodytes spp.		
Limnius volckmari		

Also occurrence in 4, 3, 2 or 1 stream scored 8, 4, 2 and 1 respectively. By using the cumulative total from the four streams for each species it was possible to classify the taxa into groups of numerical dominance for the area as a whole. The results of this analysis are shown in Table 2.

The inter-relationship of the streams was considered by using the Mountford index of similarity, (Mountford, 1962), applied to taxa at the species level. The results (Fig. 3) show the close relationship of NHS, MB and TB and the relative uniqueness of GDP. Also shown in Fig. 3 is the percentage composition of the fauna in each stream in terms of major taxonomic groups, and this shows clearly the larger proportions of Diptera, Trichoptera and Coleoptera and smaller proportion of Ephemeroptera in GDP.

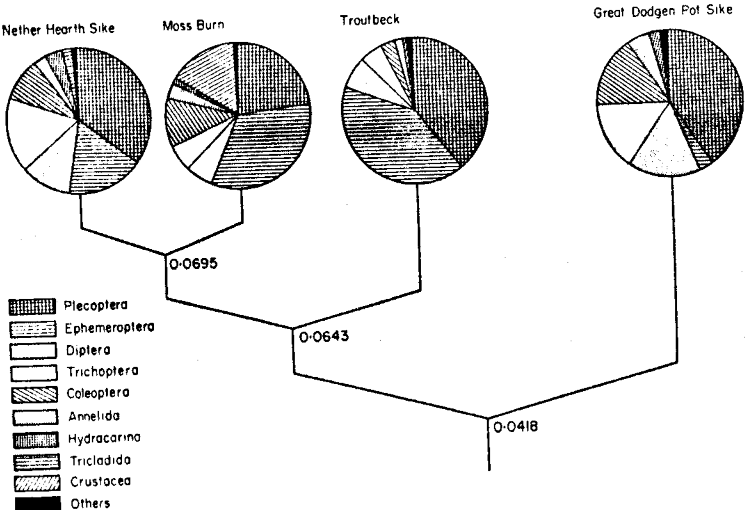

Fig. 3. Percentage composition of faunal groups in the four streams, showing the relationship of one stream with another using similarity indices.

Most of the species show more or less marked seasonal variation in numbers with *Leuctra inermis*, and *Amphinemura* spp. most abundant in May; *Drusus annulatus*/*Ecclisopteryx guttulata*, chironomid larvae and *Elmis aenea* larvae abundant in August and the ecdyonurid *Rhithrogena semicolorata* most abundant in October. Annual variation of particular species and species groups eg. Chironomidae, *Leuctra fusca* and *Baetis rhodani* was quite marked in some streams but as can be seen from Fig. 4 the total numbers of animals caught in riffles and pools in all four streams were relatively constant from year to year. Total catches from riffles were always higher than from pools though some taxa occurred in greater numbers in pools, examples are, oligochaetes, chironomid larvae, *Heptagenia lateralis*, *Ecdyonurus dispar* and *Ameletus inopinatus*. Table 3 gives details of the distribution of the more common animals in riffles and pools in the Troutbeck system (NHS-MB-TB) and GDP.

Table 3. Species and species groups making up 90 or more % of the total fauna in riffles (R) and pools (P) in the Troutbeck system (TB+NHS+MB) and in Great Dodgen Pot (GDP). (+ = 0·5%)

Species	TB+NHS+MB		GDP	
	(R)	(P)	(R)	(P)
Tricladida	1	+	—	—
Oligochaeta	1	5	2	8
Gammarus pulex	4	10	—	—
Taeniopteryx nebulosa	1	1	2	+
Amphinemura spp.	2	—	14	4
Nemoura cambrica	1	1	2	2
Nemoura avicularis	—	—	2	3
Leuctra fusca	3	4	2	1
Leuctra inermis	20	9	24	4
Leuctra hippopus	1	1	4	—
Leuctra moselyi	1	4	1	3
Chloroperla torrentium	2	2	1	1
Ecdyonurus dispar	1	5	—	—
Ecdyonurus torrentis	1	2	—	—
Ecdyonurus spp.	+	3	—	—
Rhithrogena semicolorata	19	7	1	4
Heptagenia lateralis	1	7	—	—
Leptophlebia marginata	—	—	1	2
Ameletus inopinatus	1	5	1	2
Baetis rhodani	6	1	—	—
Baetis tenax/vernus	2	1	—	—
Polycentropus flavomaculatus	—	—	+	2
Plectrocnemia conspersa	+	1	+	1
Hydroptila sp.	1	4	2	10
Drusus annulatus/Ecclisopteryx guttulata	6	3	5	+
Limnephilidae indet.	—	—	1	4
Brachycentrus subnubilus	+	1	—	—
Oreodytes spp.	—	—	1	6
Deronectes spp.	—	—	+	2
Elmis aenea	4	2	7	3
Limnius volckmari	1	1	3	1
Oulimnius tuberculatus	—	—	1	4
Dicranota sp.	2	2	3	3
Pedicia sp.	—	—	+	3
Chironomidae	3	6	6	16
Simuliidae	6	1	2	+
Hydracarina	2	2	2	1
	93	91	90	90

The Fauna

Tricladida. Crenobia alpina and *Polycelis felina* were the two species present but *P. felina* was only recorded at NHS. This stream also contained the highest density of flatworms. NHS receives the overflow from the Moor House septic tank about 50 to 60 m above the sampling reach and this may account for the increased number of these species. Macan (1963) noted a similar association of septic tank outflow and increase in flatworms in a stream in the English Lake District.

Annelida. Great Dodgen Pot supported both the highest number of species and

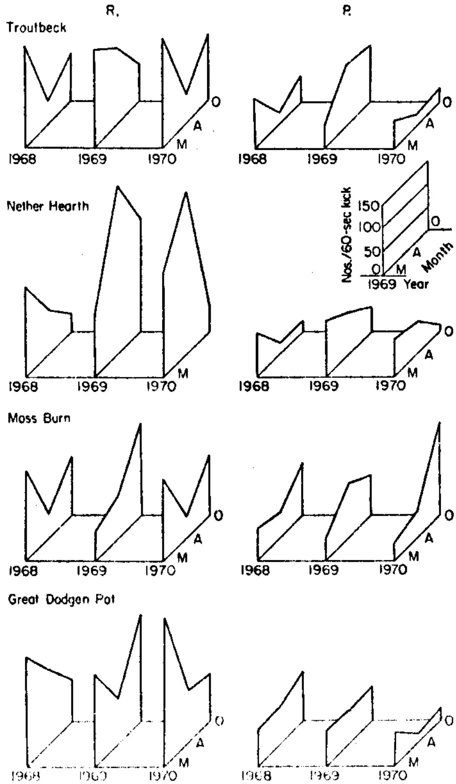

Fig. 4. Annual and seasonal changes in the total fauna of riffles (R) and pools (P) in the four streams, showing mean numbers per 60-sec kick sample (nos/60sk) in 1968, 1969 and 1970 for May, August and October, (M, A, and O).

highest density of worms. Tubificidae occurred commonly in all streams but were most numerous in NHS. Lumbricids were also widespread. Lumbriculidae and Enchytraeidae however were common only in GDP. Peachey (1963) has emphasized the importance of enchytraeids in peaty sites in the Moor House Reserve and their relative abundance in GDP may be linked to the fact that the stream has a peaty bottom and is surrounded by blanket bog and eroding peat areas.

Crustacea. Gammarus pulex occurred abundantly in Moss Burn with the down-stream NHS site supporting only a small population. The relative abundance of *G. pulex* at MB may be attributable to a combination of stream size, bottom type and water chemistry. Observations in Rough Sike, and in NHS above the sampling reach, (see Fig. 2) showed that *G. pulex* was absent, or present in very low numbers and that the substrata and general stream-size were similar to those in MB. The catchment of

Rough Sike comprised 11–20% of eroding peat (Crisp, 1966) and that of NHS was very similar. In contrast MB is characterized by having outcrops of limestone and quite extensive areas of limestone grassland (Moor House Reserve Records) near its source. This implies that the water draining this catchment will be richer chemically than that from the catchments of Rough and Nether Hearth Sikes, and this difference may help to account for the relative abundance of *G. pulex* in MB. TB also has much of the same grassland type, Agrosto-Festucetum, but in this case it is growing beside the river on alluvial soil and is less rich in calcium, and besides that, other factors such as river-size and substratum are quite different to those of Rough Sike, NHS and MB. Chemical differences between streams are thought to be a possible explanation for the distribution of *G. pulex* in the English Lake District (Macan & Mackereth, 1957; Macan, 1963). Sutcliffe & Carrick (1973) suggest that pH bicarbonate concentrations are more important than Ca^{++} concentrations in limiting the qualitative distribution of benthic invertebrates. However, all the streams in the present study have a pH in excess of the limiting value of 5·7, put forward by Sutcliffe & Carrick (1973), so it is perhaps an unlikely explanation in this case and more facts are needed to account for the distribution of this species in the Moor House streams.

Plecoptera. All the streams are characterized by having rather a rich plecopteran fauna, with Great Dodgen Pot supporting the highest density of nymphs and greatest variety of species. Most of the species common to stony streams are represented. In addition some less common forms were also found.

Taeniopteryx nebulosa is usually associated with vegetation in sluggish rivers (Hynes, 1941). On the Moor House Reserve it was reported as frequent beneath large stones in most of the streams and in sluggish backwaters, (Brown *et al.*, 1964). In the present study it was found in every stream. At Cow Green (Armitage *et al.*, 1974) *T. nebulosa* was associated with streams with moderately calcareous waters but not with those having the highest calcium concentrations. Langford & Bray (1969) report *T. nebulosa* as being very abundant in chalk streams in Lincolnshire.

Brachyptera risi in the present survey was absent only from Moss Burn, which is the only stream in which nymphs of this species were found by Brown *et al.* (1964). The species always occurred at very low densities. *Nemoura avicularis*, said to be associated with sluggish conditions (Hynes, 1941) was found only rarely by Brown *et al.* (1964) in an almost stagnant pool by the Tees. In the present work the species was most abundant in the relatively slow-flowing GDP. *Capnia bifrons* (a single specimen) was taken in NHS in October. This species was not taken by Brown *et al.*(1964).

The carnivorous Plecoptera are well represented in the area. The inability of *Diura bicaudata* and *Perlodes microcephala* to co-exist (Hynes, 1952), which is discussed by Arnold & Macan (1969), was not borne out in this survey. The species occurred together in similar proportions in all streams except GDP, where *D. bicaudata* was absent. Arnold & Macan (1969) suggest that *D. bicaudata* is unable to compete with other carnivorous Plecoptera. The present work however shows that *D. bicaudata* occurs not only with *P. microcephala* but also with *Isoperla grammatica* and *Dinocras cephalotes*. Both *D. bicaudata* and *P. microcephala* occurred more commonly in riffles than in pools and were rare in May samples. *D. bicaudata* was more abundant in the August samples than *P. microcephala*. This may be a reflection of nymphal size. If *P. microcephala* nymphs were smaller than those of *D. bicaudata* less would be caught by the coarse net used in this study. Much more detailed information on environmental factors and food requirements is needed to explain the distribution of these two species.

Perla bipunctata was taken in the Tees and Troutbeck by Brown *et al.* (1964), and was found to be more numerous and widespread than *D. cephalotes*. In this present survey *D. cephalotes* was the only one of these two large perlids to occur.

Ephemeroptera. All the usual stony stream species are represented. In addition two high level species—*Ameletus inopinatus* and *Baetis tenax* were found in all four streams, but both species occurred less commonly at GDP. *A. inopinatus* was much more abundant in pools whereas *B. tenax* was more or less equally represented in pools and riffles. Both species also occur in all streams of the Cow Green basin (Armitage *et al.*, 1974) though *B. tenax* is much more common in riffles of torrential streams on the Westmorland side of the basin. *A. inopinatus* was most abundant in pools of three streams differing markedly in their physical characteristics, two torrential stony streams and one small stream with little gradient and much moss. These contrasting features make it difficult to explain the distribution of *A. inopinatus*. In the present work the species was most abundant in Moss Burn.

Siphlonurus lacustris and *Centroptilum pennulatum*, both species associated with slow flow were found only in pools and were not very common. *S. lacustris* was reported (Crisp & Nelson, 1965) to be the second most abundant species in their studies on the Moor House Reserve. Their estimate was, however, weighted by large collections in R. Tees and Rough Sike, both areas not sampled in the present study. They also note that 'side pools' (pools and small puddles situated along the stream margins and generally cut off from the main flow except during spates) supported the largest numbers of *S. lacustris*. These areas were not sampled in the present survey. *Centroptilum luteolum* was relatively abundant at one slow-flowing site in the Cow Green basin (Armitage *et al.*, 1974) and it is surprising that it did not occur at GDP in the present study.

The occurrence of three ecdyonurid species, *Ecdyonurus dispar*, *E. torrentis* and *E. venosus* together in every stream is unusual. *E. dispar* (Macan, 1957) is more often associated with larger streams than those studied in this survey. *E. dispar* is most abundant in TB which is the largest stream studied, but MB has a similar density and it is a much smaller stream. Both *E. torrentis* and *E. venosus* have their highest numbers in MB but are also common in TB. It is not possible with the data available to clarify the reasons for the occurrence of these species together. Crisp & Nelson (1965) recorded *E. torrentis* and *E. venosus* from streams on the Reserve, but did not find *E. dispar*.

The leptophlebiids, *Paraleptophlebia submarginata*, *P. cincta* and *Leptophlebia marginata* were not taken by Crisp & Nelson (1965) and occurred only rarely in the present studies. *P. submarginata* was found only in pools and was absent only from TB, *P. cincta* was found in TB and GDP and *L. marginata* was taken in GDP only, in pools and riffles.

Heptagenia lateralis was most abundant in TB. Harker (1953) states that this species is more affected by floods than any other ecdyonurid. Although floods occur in all streams, it may be that the larger stones and boulders comprising the substratum in TB offer more refuge to *H. lateralis* than the smaller stones common in other streams.

The composition of the substratum may also account for the low numbers of *Baetis muticus*. This species according to Pleskot (1954) inhabits the interstices of the substratum. It is possible that the stream bottoms in the present survey are lacking in suitably sized particles in which the small nymphs may dwell. At Cow Green, (Armitage *et al.*, 1974), this species occurred most commonly in one loose-bottomed torrential stream, a stream with many moss-covered boulders resting on gravel, and a stream where beds of gravel rested on bare rock. Indicating possibly a rather wide tolerance to varying substratum characters.

Ephemeroptera were very common in all streams except Great Dodgen Pot and it remains to discuss their scarcity in that area. The sampling reach has been described and the overall impression is that GDP is more gently flowing, has a greater proportion of pools and a softer bottom made up of generally smaller particles and with more vegetation than in any other stream. The most common species present are *Rhithrogena semicolorata*, *Ameletus inopinatus* and *Leptophlebia marginata*. Of these, the first two are widespread in the other streams and *L. marginata* is a species characteristic of slow-flowing streams where there is vegetation (Macan, 1952). In the Moor House area as whole, most of the species are lithophilous and although some of these can maintain small populations at GDP, the majority find conditions relatively unsuitable in this stream.

Trichoptera. Of the thirty-one species of Trichoptera recorded as adults from light-trap catches by Nelson (1971), ten species and two genera (*Hydroptila* and *Glossosoma*) are recorded as larvae in the present survey. In addition three species, *Plectrocnemia geniculata*, *Cyrnus trimaculatus* and *Lepidostoma hirtum* are recorded from the Moor House Reserve for the first time. Unidentified hydropsychiid and philopotamid larvae were also found but representatives of these families were not taken by Nelson (1971).

Diptera. Of the ten species of Simuliidae known to occur on the Reserve, seven were found in the present study, only *Simulium naturale* Davies *S. variegatum* Meigen and *Prosimulium inflatum* Davies were not represented in the material examined.

Coleoptera. All the species found in this survey are recorded for the first time from flowing-water in Moor House Nature Reserve. Elminthids, particularly *Elmis aenea* and *Limnius volckmari* were widespread and common in all the streams. *Oulimnius tuberculatus* usually associated with large rivers with unstable stony beds (Holland 1972), was most abundant in Great Dodgen Pot, the most stable-bottomed and slowest-flowing stream of all those examined.

Mollusca. This group was generally poorly represented in the streams and was most abundant in GDP. All the species are widespread and common but the *Pisidium* species are new records for the Reserve.

Comparison with the Cow Green streams

Both the Moor House (MH) and Cow Green (CG) (Armitage *et al.*, 1974) streams arise in moorland at similar altitudes and the sampling stations of the CG streams were in general about 40 m lower than those of the MH streams. The gradients (drop in altitude from source to sampling station/length of stream from source to sampling station) showed little difference between the two areas and ranged from 0·075 to 0·05 at CG, and 0·062 to 0·045 at MH. Both areas had a great variety of substrata ranging from almost still water with peaty-mud bottoms through coarser sands and gravels to typical stony streams.

These general similarities between the two areas are reflected by the fact that there was little difference in the actual number of taxa recorded and the total numerical density per kick in the MH and CG streams. 116 taxa were recorded at CG and 111 in the MH streams and the corresponding mean number of animals/kick were 108 and 118 respectively. Inter-stream variation in both parameters was generally greater at

CG (49–81 taxa, 74–207 animals/kick) than at MH (73–88 taxa, 110–128 animals/kick), and this may be due to slightly greater variation in flow conditions and water chemistry in the CG basin. The Ca^{++} content of the waters at CG ranged from 9–23 ppm (Crisp *et al.*, 1974) whereas at MH the range was only from 5–10 ppm (Crisp *et al.*, in press).

Table 4 lists the species occurring in only one of the two areas. The available data

Table 4. Lists of species present in only one of the two areas, Moor House and Cow Green. M = present only at Moor House and C = present only at Cow Green. (The Cow Green list includes only species from small streams, not from the Tees itself)

C	M
Glossiphonia complanata (L.)	*Nais alpina*
	Nais pardalis
Centroptilum luteolum (Mull.)	*Nais elinguis*
Ephemera danica Mull.	
	**Halesus radiatus*
Agapetus sp.	†*Potamophylax* spp.
Wormaldia occipitalis (Pict.)	*Glossosoma* sp.
Neureclipsis bimaculata (L.)	
Oxyethirasimplex Ris	Ceratopogonidae
Goera pilosa Fabr.	*Simulium dunfellense*
	Simulium aureum
Riolus subviolaceous (Mull.)	*Prosimulium hirtipes*
Riolus cupreus (Mull.)	
	Pisidium personatum
Psychodidae (larvae)	
Atrichopogon sp.	
Simulium variegatum Meig.	
Hygrobates fluviatilis Strom.	
Atractides nodipalis Thor.	
Lymnaea truncatula (Mull.)	
Lymnaea palustris (Mull.)	

* *Halesus radiatus* present in standing water at Cow Green.
† *Potamophylax latipennis* (Curt.) occurred as adults in light traps at Cow Green.

are insufficient to explain the distribution of most of the species and it is very likely that more collecting would reduce the list of species found in only one area. However, it is possible to suggest why some species are distributed as they are.

Glossiphonia complanata, not present at MH, is said (Mann, 1955) to feed mainly upon molluscs and these are considerably more common at CG than at MH. Molluscs generally prefer hard water and this is found in some of the CG streams. The value 23 ppm of Ca^{++} already mentioned, is near the lower limit of hard water (Boycott, 1936) and most of the CG streams would be considered to be intermediate in hardness since there Ca^{++} content falls between 7 and 24 ppm (Mann, 1955).

Riolus subviolaceous and *R. cupreus* were found only in the most calcareous streams at CG and both species are associated with such conditions (Holland, 1972). This probably excludes them from the MH streams studied here.

In each area more taxa were represented in the streams with the highest Ca^{++} content (Weelhead Sike at CG, and GDP at MH) than in any other, though it should be noted that both these streams have gentle gradients and relatively stable bottoms. So it is likely that these factors work together to create suitable conditions for a large number of taxa.

Comparison with other areas

The fauna of the Cow Green area has been compared with that of other upland regions of the British Isles, (Armitage *et al.*, 1974) and the conclusions which apply to the Moor House area may be summarized as follows.

Despite higher altitudes (up to 570 m O.D.) and a rigorous climate a relatively large number of taxa were recorded compared with studies in similar regions by Hynes (1961), Egglishaw & Mackay (1967), Minshall & Kuehne (1969) and Arnold & Macan (1969).

The present study area is characterized by a wide range of flow-conditions and substrata and a relatively rich inorganic ion content, compared with the upper reaches of some Lake District (Minshall & Kuehne, 1969; Sutcliffe & Carrick, 1973) and Scottish streams (Egglishaw & Mackay, 1967). Egglishaw & Morgan (1965) have shown that chemical richness influences the bottom fauna and Sutcliffe & Carrick (1973) have shown that there is greater faunal diversity in streams with higher Ca^{++} content. They also suggest that Ca^{++} concentration is less important than pH-bicarbonate concentrations in limiting species-richness particularly when the pH is 5·7. pH was not measured at Moor House during this survey but Goreham (1956) found the pH of Troutbeck below the junction with Nether Hearth Sike to range from 6·2 to 7·7 in wet and dry weather respectively, and a recent series of measurements taken in dry weather in November 1973 (Table 5) show a range from 6·75 to 8·00. These values are well above the limiting value of 5·7 and this may be another factor leading to the large number of species found in the Moor House streams.

Table 5. pH measurements at the sample sites in the four streams, taken in dry weather on 23 November 1973

Stream	pH (glass electrode)
Great Dodgen Pot	6·75
Moss Burn	7·55
Nether Hearth Sike	7·60
Troutbeck	8·00

The supply of plant detritus to the streams in the form of peat particles may well be high, since Crisp (1966) has estimated that eroding peat comprised 11–20% of the catchment area of Rough Sike, a stream adjacent to Nether Hearth Sike in the present study area. Although most of this peat would be washed away a certain amount would be trapped under stones thus increasing the organic matter content of the substratum. Egglishaw (1969) demonstrated that an increase in plant detritus was accompanied by an increase in the variety of the bottom fauna.

It is likely that the above features offer a wide range of niches to the bottom fauna and the fact that there is much interlinking of water-systems allows wide distribution of particular species, accounting in part for the relatively species-rich community observed in this work.

The results of this survey have provided information on annual and seasonal changes in the species composition and relative abundance of the fauna of four streams and despite inadequacies, particularly with regard to the identification of Diptera, have helped to describe the communities in the Moor House streams thus augmenting previous studies on single animal groups.

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