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A Survey of the Bottom Fauna of Streams in the Scottish Highlands

Part II. The relationship of the fauna to the chemical and geological conditions

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INTRODUCTION

A survey of the bottom fauna of 52 streams in the Scottish Highlands was carried out in 1960, samples being taken from the 'salmonid region' (ILLIES, 1952) of each stream, in both spring and summer. The survey extended over the Highland area of the mainland and included the main geological strata. Details concerning the streams sampled, the composition of the bottom fauna and the distribution of species have already been published (MORGAN & EGGLISHAW, 1965). The present paper relates the amount and composition of the bottom fauna to the chemical richness (i.e. the ionic concentration) of the streams and to the geology of their substrates.

Although the sampling sites were selected to avoid polluted conditions three streams (one on basalt and two on sandstone) were included which were found to be mildly polluted with organic matter and household refuse. The bottom fauna of these streams was markedly different from the fauna of the other streams (MORGAN & EGGLISHAW, l.c.). The three streams have been excluded from the

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present analysis of the relationship of the bottom fauna to chemical and geological conditions.

In the following account the reference numbers given for streams are those used in the brief descriptions of the streams given in MORGAN & EGGLISHAW (l.c.).

All the streams included in the survey were chosen so that upstream from the sampling site each flowed over only one kind of rock as far as could be discerned from the Geological Maps prepared by the Ordnance Survey. Of the 49 unpolluted streams examined, 16 occurred on schist and 13 on granite, the two commonest rock types in Highland Scotland; six were on basalt, seven on limestone and five on sandstone, the other important types of rock. There was also one stream flowing over gneiss and one over quartzite.

When the survey was planned, the geology of the substrate was used as the basis for the selection of streams to be studied, because this seemed likely to have a controlling effect on the fauna of the streams. The geology of a region influences the surface texture and size of the component parts of the substrate of a stream, the nature of the surrounding land and thus the rate of flow of the water. Further, since the kinds of rock over which the streams flow have different constituents of various solubilities they may affect the chemistry of the water to different degrees. There are, of course, many other factors such as surroundings, local agricultural practices and amount and composition of the rain which can greatly modify the chemical composition of the stream water.

The chemical analysis of water samples taken during the survey showed there was great variation in the total cationic concentration from stream to stream (MORGAN & EGGLISHAW, 1965, Appendix 2a). An account of the results of the chemical analyses of the water samples is being published by HOLDEN. Here it is necessary to give details of the chemistry of the stream waters, only in so far as they might indicate possible correlations with the amount and kind of bottom fauna present.

The ranges of the total cation concentration (as micro-equivalents/l) and certain ions and pH of the samples from streams occurring on each kind of rock are given in Table I. Only on granite and schist were there streams with water having less than 400 micro-equivalents of total cations/l and these streams have been classified separately.

The extensive range of the total cation concentration/l of samples from the streams on sandstone is due to three streams which had a high concentration of sodium (644, 1140 and 1705 μ eNa^{+}/l), presumably because of their proximity to the sea.

TABLE I

The range in certain chemical properties of water samples from streams on different types of rock.

	Number of streams	Total cations	Ca^{++}	Mg^{++}	HCO_3^-	pH
Granite	8	224– 375	40– 95	50–100	26– 100	6.12–6.75
	5	412–1005	138– 361	74–210	100– 296	6.60–7.23
Schist	5	266– 374	56– 115	53– 89	54– 136	6.22–6.75
	11	424–1662	84– 936	29–364	20– 828	5.98–7.40
Basalt	6	730–1061	180– 476	171–315	330– 644	7.13–7.50
Limestone	7	415–1785	195–1457	44–502	100–1108	6.48–7.82
Sandstone	5	1383–3608	656–1063	206–790	328–1232	7.12–7.61

THE RELATIONSHIP BETWEEN THE STANDING STOCK OF BOTTOM FAUNA AND THE CHEMICAL RICHNESS OF THE STREAMS

The mean catches of bottom fauna from streams of five ranges of total cation concentration are given in Table II.

Since *Simulium* spp. larvae feed by extracting particles from the current (SMART, 1944) the factors affecting their distribution in a stream are very different from those affecting the distribution of the majority of bottom fauna organisms, which feed on the food present at a site (EGGLISHAW 1964). *Simulium* spp. can occur at very high densities where conditions suit their method of feeding, and high numbers were recorded from a few streams where a sample was taken at a site where the larvae were aggregated. In the table *Simulium* spp. have not been included in the mean catches of bottom fauna and their numbers have been given separately.

In waters having a concentration of less than 400 μe of total cations/l the bottom fauna was severely limited in amount. The samples from streams with water containing between 401 and 800 μe of total cations/l contained a significantly higher mean number and weight of animals in spring and in summer than samples from streams in the lowest category of chemical richness. With increasing total cation concentration above 800 μe/l the mean catches and weights of bottom fauna showed no significant increase in the spring, and although there was an increase in summer, the increase is of doubtful significance for the numbers of animals, and for the weight of the catches it is non-significant. The values suggest a possible non-linear relationship between the amount of bottom fauna and the chemical richness of the streams. From streams with a total cation concentration of above 400 μe/l there was a wide range in the amount of

TABLE II

The catch of bottom fauna from streams of different concentrations of cations

	I	II	III	IV	V	
Total cations $\mu e/1$	224–400	401–800	801–1200	1201–1600	over 1600	
Ca^{++}	40–115	94–394	186– 667	656–1067	492–1457	
HCO_3^-	26–136	20–404	204– 748	328–1076	340–1232	
No. of streams	13	14[1])	9	4	7	
Spring fauna						
mean catch	66	234	217	234	267	66 < 234 t = 3.546, P < .01
mean *Simulium* spp.	13	27	22	26	6	
mean wt. (mg) of catches[2])	158	588	524	585	716	158 < 588 t = 3.712, P < .01
mean wt. per animal[2])	2.00	2.25	2.19	2.25	2.62	
Summer fauna						
mean catch	185	539	596	735	1151	185 < 539 t = 2.958, P < .01 539 < 1151 t = 1.909, P = .1–.05
mean *Simulium* spp.	23[3])	21	14	13	39	
mean wt. of catches[2])	226[3])	611	734	693	1106	226 < 611 t = 2.208 P = .05–.02 611 < 1106 t = 1.687 P = .2–.1
mean wt. per animal[2])	1.09	1.09	1.20	0.93	0.93	

[1]) 13 streams in summer, one (no. 32) having dried up.
[2]) including *Simulium* spp.
[3]) excluding one stream (no. 6) from which there was caught a large number (733, 82% of the bottom fauna) of *Simulium* spp.

TABLE III

The spring fauna of chemically poor and richer streams on granite and on schist

	GRANITE				SCHIST			
	Poor streams (8) mean catch	%	Richer streams (4) mean catch	%	Poor streams (5) mean catch	%	Richer streams (7) mean catch	%
PLATYHELMINTHES	1	2	5	1	1	1	3	1
OLIGOCHAETA	+		11	3	1	1	3	1
Gammarus pulex (L.)	—		—		—		7	3
PLECOPTERA	26	49	171	47	29	33	103	46
Brachyptera risi (MORT)	9		5		9		9	
Amphinemura sulcicollis (STEPH.)	5		29		5		33	
Protonemura meyeri (PICT)	2		12		+		2	
Leuctra inermis KEMPNY	4		86		8		29	
L. hippopus (KEMPNY)	1		9		+		9	
Chloroperla torrentium (PICT.)	1		10		2		5	
Isoperla grammatica (PODA)	3		19		2		7	
EPHEMEROPTERA	18	34	84	23	47	54	76	34
Baetis rhodani (PICT)	12		54		28		22	
Rhithrogena sp.	4		20		7		26	
TRICHOPTERA	1	2	34	9	1	1	13	6
Polycentropidae	+		13		—		2	
COLEOPTERA	+		18	5	+		3	1
CHIRONOMIDAE	5	9	39	10	6	7	11	5
OTHER DIPTERA	+		3	1	1	1	4	2
HYDRACARINA	—		1		+		—	
MOLLUSCA	—		1		—		+	
mean total catch	53		366		87		225	
	53 <366 t=5.00, P <.01				87 <225 t=2.43, P=.05–.02			
mean *Simulium* spp.	16		21		8		17	
mean wt. (mg) of catches	128		693		205		603	
mean minimum no. of species	11		32		16		26	
	11 <32 t=7.29, P <.01				16 <26 t=2.67, P=.05–.02			
Taxa occurring only in the class under which they appear with the number of streams in which they were found.	3 spp. each occurred in one stream only		*Polycelis felina* 2 *Protonemura praecox* 2 Lepidostomatinae 4 *Oxyethira* sp. 2 *Esolus parallelopipedus* 4 Other Tipulidae 2 Tanypodinae 3 Hydracarina 3 *Ancylastrum fluviatile* 3 7 spp. each occurred in only one stream		3 spp. each occurred in only one stream		*Polycelis felina* 2 *Gammarus pulex* 3 *Nemoura erratica* 2 *Leuctra nigra* 2 *Caenis rivulorum* 2 *Baetis niger* 2 *Heptagenia* sp. 2 Limnephilidae 3 *Hydraena gracilis* 2 *Helodes* sp. 2 *Latelmis volkmari* 3 *Corynoneura* sp. 3 19 spp. each occurred in one stream only	

+ = present but less than 0.5.

Table IV

The summer fauna of chemically poor and richer streams on granite and on schist

	GRANITE				SCHIST			
	Poor streams (8) mean catch	%	Richer streams (4) mean catch	%	Poor streams (5) mean catch	%	Richer streams (7) mean catch	%
PLATYHELMINTHES	3	1	60	5	2	1	5	1
OLIGOCHAETA	59	27	86	8	19	13	90	16
AMPHIPODA	—		—		—		11	2
PLECOPTERA	11	5	45	4	13	9	39	7
Leuctra fusca (L.)	8		31		6		29	
EPHEMEROPTERA	62	29	181	17	58	38	175	31
Baetis rhodani	22		34		19		39	
TRICHOPTERA	10	5	86	8	4	3	47	8
COLEOPTERA	9	4	193	18	5	3	20	4
TIPULIDAE	2	1	12	1	3	2	6	1
CHIRONOMIDAE	59	27	394	36	44	29	157	28
HYDRACARINA	2	1	22	2	1	1	2	
MOLLUSCA	—		4		—		—	
mean total catch	217		1094		151		560	
	217 <1094 t=8.34 p <.01				151 <560 t=3.28, p <.01			
mean *Simulium* spp.	7[1]		18		7[2]		37	
mean wt. (mg) of catches	196[1]		1329		184[2]		731	
mean minimum no. of species	20		38		22		30	
	20 <38, t=7.70, P <.01				22 <30 t=2.10, P=.1–.05			
Taxa occurring only in the class under which they appear with the number of streams in which they were found	4 spp. each occurred in only one stream.		*Polycelis felina* 2 *Perlodes microcephala* 2 *Ecdyonurus torrentis* 3 Limnephilidae 4 *Oxyethira* sp. 2 Dytiscidae 1. 2 *Pericoma* sp. 2 *Hemerodromia* sp. 3 *Limnophora* sp. 2 *Ancylastrum fluviatile* 3 14 spp. each occurred in only one stream.		3 spp. each occurred in only one stream		*Polycelis felina* 2 Nematoda 2 *Gammarus pulex* 3 *Perlodes microcephala* 2 *Caenis rivulorum* 2 *Baetis pumilus* 6 *Oxyethira* sp. 3 *Oreodytes rivalis* 2 *Helophorus brevipalpis* 2 14 spp. each occurred in only one stream.	

[1]) excluding one stream (no. 6), having 733 *Simulium* spp.
[2]) excluding one stream (no. 15) having 195 *Simulium* spp.

bottom fauna caught, both poor (< 180 animals less *Simulium* spp. in spring, and < 330 animals less *Simulium* spp. in summer) and rich faunas being found, (see MORGAN & EGGLISHAW, 1965, Appendix 2) whereas in streams with a total cation concentration below 400 μe/l the fauna was always poor.

REYNOLDSON (1958) has shown that the calcium content of lake waters is an important factor in determining the size of triclad populations. As the calcium content of lakes increases the number of species and their abundance generally increases. REYNOLDSON (l.c.) pointed out that there are groups of lakes at the lowest calcium levels which support relatively smaller triclad populations than would be expected if the relationship between triclad numbers and calcium was linear. From REYNOLDSON's regression diagrams these lowest levels correspond with the lower levels of calcium found in the stream survey (i.e. less than about 200 μe Ca^{++}/l).

STREAMS ON GRANITE AND SCHIST

Granite and schist were the only types of rock having streams with water containing less than 400 μe of total cations/l. In Tables III and IV the fauna of these chemically poor streams is contrasted with that of the richer streams, having over 700 μe total cations/l on the same type of rock.

There was little difference between the range of altitudes at which the chemically poor streams were sampled and the range at which the chemically richer streams were sampled. The sites of the chemically poor streams were from 15 m to 270 m altitude with six of the 13 sites below 110 m and the sites in the chemically richer streams were from 15 m to 200 m with seven of the 11 sites below 110 m.

The two chemically richest streams on granite and the richest on schist were running through arable land at the sampling area and fertiliser leaching from this land may have contributed to the chemical richness of the streams. None of the chemically poor streams ran through arable land.

Tables III and IV show that in both spring and summer the chemically richer streams, have, with but few exceptions, a greater mean number of all groups and main species of animals than the poor streams, many of the differences being of the order of five times and more. The differences between the mean total catches are very significant.

The variety of animals is also much greater in the samples from the chemically richer streams than in those from the chemically poor ones, three of the four increases in the number of species present being significant. The increase in the fourth case is of doubtful significance. In the lower part of Tables III and IV there are listed the animals which occurred in only one of the two classes of stream. Only those species or other taxa that were present in at least two streams of the class are entered by name.

It should be emphasised that although there were many species occurring in the samples from the chemically richer streams only, their numbers were usually few and they comprised only a small proportion of the total animals collected. This can be seen from figures given in Table V.

The summed samples from the eleven chemically richer streams contained 11,341 animals less *Simulium* spp. and the summed samples from the chemically poor streams contained 3,347 animals less *Simulium* spp. Of the difference of 7,994 animals between the two classes of streams only 963 animals or 12% were of species or other taxa not present in the samples from the chemically poor streams.

Polycelis felina (DALYELL) was the only animal identified to species present in the chemically richer streams on granite and schist, in both spring and summer which did not occur in the chemically poor streams.

It might be argued that the lower standing stock of bottom fauna in chemically poor streams is possibly due to these streams having a steeper gradient, and consequently a quicker flow, than the chemically richer streams. It might be expected that a steep gradient would greatly affect the amount of stream fauna particularly during and after spates and that the higher rate of flow would exceed the limits of tolerance of many species to this factor. During the stream survey the gradient of each stream at the sampling area was classed as gentle, moderate or steep.

The gradient of five (all on granite) of the thirteen chemically poor streams was steep and the gradient of five (three on granite, two on schist) was gentle. The streams on a steep gradient had a mean catch of 68 animals less *Simulium* spp. in spring and 207 in summer and those on a gentle gradient had a mean catch of 45 animals less *Simulium* spp. in spring and 193 in summer, which suggests that a steep gradient has not restricted the standing stock of bottom fauna in these streams. The composition of the bottom fauna of the streams on the two gradients was similar, less than 3% of the total catch belonging to species or other taxa that were present in streams of only one or other of the categories.

TABLE V

The proportion of animals which occurred in the chemically poor streams only or in the richer streams only, on granite and schist

	GRANITE				SCHIST			
	Poor streams		Richer streams		Poor streams		Richer streams	
Number of streams	8		4		5		7	
	spring	summer	spring	summer	spring	summer	spring	summer
Total number of animals less. *Simulium* spp. from these streams	421	1737	1466	4374	435	754	1578	3923
Simulium spp.	130	783	83	73	40	221	121	262
Total number of animals in species which occurred in only one class of stream	3	6	111	417	5	3	178	257
As a percentage of total less *Simulium* spp.	0.7	0.3	7.6	9.5	1.1	0.4	11.3	6.6

THE BOTTOM FAUNA OF STREAMS ON DIFFERENT GEOLOGICAL SUBSTRATES

The mean catch of bottom fauna from streams on each type of rock is given in Table VI. As several streams on granite and schist were poor chemically and such streams have been shown carlier to have less bottom fauna than chemically richer streams, it is to be expected that the mean catches from streams on granite and schist would be lower than those for the other types of rock. The granite and schist formations whilst containing the streams with the least dense bottom fauna, 11 of the 12 poorest in spring and 15 of the poorest 17 in summer, also had some streams rich in bottom fauna.

The streams on basalt had less variation in the quantity of bottom fauna than the streams on the other types of rock. This is probably because the streams on basalt were in the same region (Argyll) and were more similar with regard to stratigraphy, climate and che-

TABLE VI

The catch of bottom fauna from streams on different kinds of rock

	Granite (13)	Schist (16)	Basalt (6)[1]	Limestone (7)	Sandstone (5)
Mean catch of animals less *Simulium* spp.					
in spring	150	162	222	222	290
in summer	484	356	531	749	1191

[1]) 5 in summer.

mistry of water than streams on the other formations which were not so geographically restricted.

To discover if the geological substrate had any appreciable effect on the quality and amount of bottom fauna in streams other than through affecting the chemistry of the water, streams on the same kind of rock and containing a concentration of more than 400 μe of total cations/l were grouped and the mean catches of the chief taxa calculated. This analysis appears in Table VII where the spring fauna is dealt with fully and the three common species that occurred only in the summer have been included.

Table VII shows that the amount and composition of the bottom fauna from streams having a concentration of more than 400 μe of total cations/l but on different rocks is very similar. Even the large differences in the mean number of particular species or groups are not significant, and are shown at the bottom of the table to be due to peculiarities in the catches from individual streams.

The gastropod molluscs were more abundant in the streams on sandstone than in streams on the other rocks. In the summer samples there was a mean of 29 grastropod molluscs from the streams on sandstone. This catch was significantly greater than the catch from the streams on schist ($29 > 0$, $P < .01$). Their greater abundance in streams on sandstone compared with streams on limestone ($29 > 5$) and basalt ($29 > 1.4$) was of doubtful significance ($P = .1$—$.05$) and compared with those on granite ($29 > 2.8$) was not significant.

Large numbers of *Pisidium* sp. (68 in the spring samples and 24 in the summer ones) forming 28% and 7% of the fauna in spring and summer were collected from a stream in North West Sutherland which flowed over gneiss. The highest number collected from any other stream was seven (stream no. 31). The stream on gneiss was also the only one from which the caddis *Chimarrha marginata* (*L.*) was recorded.

SUMMARY

1. A survey of the bottom fauna of 52 streams in the Scottish Highlands was carried out in 1960. The survey included streams on granite (13), schist (16), basalt (6), limestone (7) and sandstone (5).
2. The bottom fauna was much poorer in amount in streams having a concentration of less than 400 μe of total cations/l than in streams having 401—800 μe of total cations/l. In the spring, streams having a concentration of more than 800 μe of total cations/l were not richer in number of animals than streams with 401—800 μe of total cations/l, and although in the summer the mean number of animals in the streams with more than 800 μe/l was greater than

TABLE VII

The bottom fauna of streams on different rocks and having a concentration of over 400 μe of total cations/1.

	Granite	Schist	Basalt	Limestone	Sandstone
Number of streams	5	11	6[1])	7	5
SPRING FAUNA					
PLATYHELMINTHES	4	2	3	4	3
OLIGOCHAETA	9	3	3	4	16[2])
PLECOPTERA					
Brachyptera risi	4	9	25[3])	6	2
Amphinemura sulcicollis	24	25	10	25	32
Protonemura meyeri	10[4])	1	1	2	1
Leuctra inermis	69[5])	33	18	22	25
L. hippopus	8	7	3	3	+
Chloroperla torrentium	9	5	4	5	11
Isoperla grammatica	16[6])	6	3	6	3
EPHEMEROPTERA					
Baetis rhodani	45	23	66	49	31
B. pumilus (BURM.)	6	7	12	6	5
Baetis spp. total	53	41	85	59	52
Rhithrogena sp.	16	20	25	20	46
TRICHOPTERA	27	10	7	18	20
Hydropsychidae	3	3	4	5	5
Polycentropidae	9	1	2	5	7
COLEOPTERA	15	3	2	12	26[7])
DIPTERA					
Tanypodinae	7	+	1	2	2
Tanytarsini	5	2	1	2	13
Other Chironomidae	21	7	15	19	14
MOLLUSCA	1	+	+	1	5
Mean total catch less *Simulium* spp.	309	198	222	222	290
Mean weight (mg) of catches	601	525	577	569	814
SUMMER FAUNA					
Leuctra fusca	25	27	31	24	34
Ephemerella ignita (PODA)	51[8])	12	14	22	22
Baetis scambus/bioculatus	20	13	5	8	11
MOLLUSCA-GASTROPODA	3	0	1	5	29
Mean total catch less *Simulium* spp.	910	447	565	749	1191
Mean weight (mg) of catches	1091	578	508	826	987

[1]) Five streams in summer
[2]) 55 from stream no. 46
[3]) 129 from stream no. 33
[4]) 38 from stream no. 11
[5]) 185 from stream no. 12
[6]) 45 from stream no. 12
[7]) 87 from stream no. 49
[8]) 200 from stream no. 12

the mean number in streams in the 401—800 μe/l range the increase was of doubtful significance.

3. Granite and schist were the only types of rock having streams with water containing less than 400 μe of total cations/l. The bottom fauna of these chemically poor streams is compared with the fauna from the richer streams (700—1662 μe of total cations/l) on the same rock types. The summed samples from eleven chemically richer streams contained 11,341 animals and the summed samples from the chemically poor streams contained 3,347 animals. Of the difference of 7,995 animals only 963 or 12% were of species or other taxa not present in the samples from the chemically poor streams.
4. The amount and composition of the bottom fauna from streams on different types of rock and having a concentration of over 400 μe of total cations/l was very similar.

Zusammenfassung

1. Die in 52 Bächen des Schottischen Hochlands befindliche Bodenfauna wurde im Jahre 1960 untersucht, wobei Bäche, die auf Granit (13), Schiefer (16) Basalt (6), Kalkstein (7) und Sandstein (5) flossen, in Betracht gezogen wurden.
2. In Bächen mit einer Gesamtkationenkonzentration von weniger als 400 μe/l kamen viel geringere Mengen Bodenfauna vor, als in Bächen mit 401—800 μe Gesamtkationen/l. Im Frühling waren die Bäche mit mehr als 800 μe Gesamtkationen/l zahlenmässig nicht reicher an Tieren, als diejenigen mit 401—800 μe Gesamtkationen/l. Obgleich im Sommer die Durchschnittszahl der in Bächen mit mehr als 800 μe/l vorhandenen Tiere grösser war, als die Durchschnittszahl bei Bächen mit 401—800 μe/l, liess sich dennoch diese Zunahme als von zweifelhafter Bedeutung betrachten.
3. Ausschliesslich beim Granit und beim Schiefer kamen Bäche mit einem Gesamtkationeninhalt im Wasser von weniger als 400 μe/l vor. Die Bodenfauna dieser chemische armen Bäche wird mit der Fauna aus den reicheren Bächen (700—1662 μe Gesamtkationen/1) verglichen, die über dieselben Steinarten fliessen. Die Gesamtproben aus elf chemisch reicheren Bächen enthielten 11.341 Tiere, während diejenigen aus den chemisch armen Bächen 3.347 Tiere ergaben, d.h., 7.994 Stück weniger, wovon nur 963, d.h., 12%, zu Arten oder anderen systematischen Gruppen gehörten, die in den aus den chemische ärmeren Bächen entnommenen Proben nicht vertreten waren.
4. Sowohl die Anzahl als auch die Zusammensetzung der Boden-

fauna aus Bächen, die über verschiedene Steinarten flossen und eine Gesamtkationenkonzentration von mehr als 400 μe/l aufwiesen, waren sehr ähnlich.

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