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A Survey of the Bottom Fauna of Streams in the Scottish Highlands Part III Seasonal Changes in the Fauna of Three Streams

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INTRODUCTION

Part I (MORGAN & EGGLISHAW, 1965) and Part II (EGGLISHAW & MORGAN, 1965) of this survey dealt with the composition of collections of bottom fauna, and their quantitative and qualitative relationship to the chemical and geological conditions of 52 streams from which they were taken. Since February 1962 the seasonal changes in the bottom fauna of three streams in the Scottish Highlands have been investigated and it seems appropriate to extend the original scope of the survey to include this further descriptive study as Part III.

The most detailed investigation of seasonal changes in the bottom fauna of a stream in Great Britain is that by HYNES (1961) on a hill stream in Wales. The invertebrate community of this stream is in many ways similar to that encountered by the present writers in the Scottish Highlands. A less detailed study of seasonal changes in bottom fauna has been made by FROST (1942) on an Irish stream. Both of these workers deal with seasonal changes in the numbers, but not the weights, of benthic organisms, and also with seasonal changes in the length frequency distribution of individual species. Information on the life-cycles of certain groups of benthic organisms is given by HARKER (1952), HYNES (1941) and MACAN (1957 a, 1957b). The present work deals with seasonal changes in the composition and amount, by number and weight, of benthic organisms in riffles of three streams of different character.

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The streams studied

The main observations were made on the Shelligan Burn, a tributary of the River Almond (Perthshire), and other observations were made on the headwaters of the River Almond and on Allt dos Mhuicarain (Ross-shire). In each of the three streams studies of the salmon and trout populations were being carried out or were about to commence (Egglishaw 1967; Mills, 1964).

The Shelligan Burn rises at an altitude of about 550 m and flows southeastwards for 3.2 km, then east for a further 2.4 km to join the River Almond. The site studied (Nat. Grid ref. 27/951290) is 4 km from the stream's source. Here the Shelligan Burn flows through cultivated land and sheep and cattle pasture at an altitude of 183 m. There are deciduous trees, chiefly oak and beech, on the west bank of the stream and along the margins of neighbouring fields. Upstream from the site studied there is a conifer plantation on the west bank and beyond this is heather moorland. At the site studied the stream has a uniform width of 4 m. Before reaching the site the Shelligan Burn flows over sandstone and quartzite.

The headwaters of the River Almond (subsequently termed the River Almond) rise at about 820 m and flow eastward. The site studied (Nat. Grid ref. 27/798334) lies about 10 km from the source and 18 km upstream from its junction with the Shelligan Burn. The stream, 16 m wide, is four times wider than the Shelligan Burn. The site is at an altitude of 290 m and is surrounded by treeless heather moor and rough sheep-grazing land. Approximately 200 m from the river bank and 500 m upstream from the site there is a plantation of 10—12 years old mixed larch and spruce trees. The surroundings are noticeably much poorer in vegetation than the surroundings of the site on the Shelligan Burn. Upstream of the site studied the River Almond flows over quartzite and mica schist.

Allt dos Mhuicarain rises at an altitude of 300 m and flows southeastwards for 2.4 km to join the River Bran. The site studied (Nat. Grid ref. 28/210606) which is 100 m before this confluence is at an altitude of 125 m. The stream flows through rough sheep pasture and heather moorland devoid of deciduous trees – surroundings that are similar to those of the River Almond headwaters. The width of the stream at the site studied is 4 m. Situated at the head of Allt dos Mhuicarain is a small loch, Loch na Moine Beag.

The substrates of the areas of the Shelligan Burn and River Almond studied consist of stones mainly less than 30 cm in diameter lying on stones embedded in gravel and sand. The areas are chiefly riffle with a depth, under normal water conditions, mainly between 10 cm and 18 cm but up to 25 cm in places. Within 40 m of the areas studied in

both streams there are pools which reach depths of 60 cm.

The bed of Allt dos Mhuicarain consists of firmly packed angular stones and boulders. About 80% of these are 18 cm to 35 cm in diameter and gravel less than 5 cm diameter forms less than 5% of the visible substrate. At intervals the stream flows over exposed bedrock and among boulders up to 1.5 m across. The depth of the stream varies greatly with rainfall but is generally between 15 cm and 30 cm.

Among the stones and gravel in the Shelligan Burn and Allt dos Mhuicarain there are quantities of disintegrating fragments of leaves, stems and seed cases, but there is much less of such allochthonic plant material in the River Almond. In 1962 each bottom fauna sample from the Shelligan Burn yielded an average of 5.4 ml (wet volume) of plant detritus in April, 7.6 ml in June, 15.6 ml in July, 11.1 ml in August and about 7 ml in September, October and November. In Allt dos Mhuicarain the average volumes were 15.0 ml in March, 12.2 ml in May, 10.3 ml in August and 8.5 ml in November. In the River Almond the amounts were 5.0 ml in April and between 2.2 ml and 4.4 ml in May to December (EGGLISHAW, 1964).

There are submerged mosses attached to stones in the faster-flowing parts of the riffle stretches in the Shelligan Burn and Allt dos Mhuicarain but there are no submerged mosses in the River Almond.

Water samples were taken from the three streams and their analyses appear in Table I. The Shelligan Burn and River Almond are both much richer in calcium and bicarbonate ions than Allt dos Mhuicarain, the Shelligan Burn being richer than the River Almond. Allt dos Mhuicarain is nearer to the sea than the other two streams and this is shown in the greater concentration of sodium and chloride ions.

METHODS

There is no known sampling method that takes a truly representative collection of the bottom fauna of flowing waters. Techniques using coarse nets fail to retain the smaller organisms, and larger animals escape nets with fine meshes because of the slow water flow through them (MACAN, 1958; HYNES, 1961). It is difficult to sample with equal accuracy benthic species that are free-swimming and those that attach themselves to stones.

Bottom fauna samples were taken by the method described in Part I (MORGAN & EGGLISHAW, 1965). The technique depends on allowing the current to wash into a handnet the animals from an area disturbed by the investigator kicking into the stream substrate. The handnet

TABLE I

The chemical analysis of water samples from the Shelligan Burn, River Almond and Allt dos Mhuicarain. All quantities of ions are in microequivalents per litre.

Date	pH	SO_4^{--}	Cl^-	NO_3^-	HCO_3^-	NH_4^+	Na^+	K^+	Mg^{++}	Ca^{++}
SHELLIGAN BURN										
20 Sept 1962	7.29	106	133	2	432	7	150	4	132	380
17 Oct 1962	7.36	108	134	3	460	7	150	4	133	411
15 Nov 1962	6.99	110	142	9	352	5	142	6	130	330
21 Mar 1963	6.73	268	157	?	112	?	158	10	99	270
25 Feb 1964	7.03	171	171	?	196	?	146	8	94	290
RIVER ALMOND										
20 Sept 1962	7.26	84	104	?	336	?	101	4	120	299
17 Oct 1962	7.46	91	102	?	356	?	102	6	117	324
21 Mar 1963	6.79	109	123	?	124	?	110	8	99	199
27 Feb 1964	7.05	124	140	?	160	?	112	4	115	193
ALLT DOS MHUICARAIN										
7 Nov 1962	5.73	51	274	?	28	?	232	6	53	60
14 Mar 1963	5.45	133	217	?	16	?	232	18	51	65
10 Mar 1964	6.45	77	353	?	48	?	294	16	74	94

? = not calculated

The samples from the Shelligan Burn and River Almond in March 1963 and February 1964 were taken in moderate flood which accounts for the lower values for HCO_3^-, Mg^{++} and Ca^{++} when compared with previous samples.

used is pyramid-shaped and made of grit-gauze, 12 meshes per cm, attached to a square frame with 24 cm sides.. Each sample was taken in a depth of water up to about 20 cm and at a site where the stones were 8—25 cm in diameter. The current speed at all sites was the same as far as could be observed.

This sampling method was compared with that used by SURBER (described in WELCH, 1948), a method that has been frequently employed by other workers and which has been used to compare the fauna of riffles and pools in this work. The gravel and stones enclosed by a horizontal square frame with 30.5 cm sides were stirred thoroughly by hand until it was considered that all animals had been washed into the net. In addition, the stones were scrubbed with a small brush to obtain the closely attached animals and those living among the algal covering. These 'stone scrubbings' were kept separately. Five Surber samples were taken using a box-shaped net with an opening 35 cm wide by 40 cm high and a depth of 60 cm, made from grit-gauze having 12 meshes per cm. Another five samples were taken with a net of the same dimensions but made of grit-gauze having 24 meshes per cm. The animals collected were measured to the nearest mm, and weighed after being surface dried on absorbent paper.

The tests were carried out in a stretch of the River Almond selected for the uniformity of the stream bed. The site chosen was a 45 m long straight riffle of depth 23 cm, with a current speed of about 50 cm/sec., 10 cm above the substrate, which was composed of 20—30 cm angular stones.

The results of the comparison are given in Table II. Because of the large size of *Eiseniella* spp. compared with other benthic organisms the weight of those over 20 mm in length in the samples are given separately. The Surber technique, using a net with 12 meshes per cm, collected 1.4 times the number and 2.7 times the weight of animals less *Eiseniella* spp. collected by the sampling method used for most of the present work. This collecting of relatively larger animals in the Surber net results from its greater surface area (60 cm deep compared with 30 cm), allowing the water current to pass more easily through it. It can be seen that the net with 24 meshes per cm retains many more organisms than the net with 12 meshes per cm, but most of these are very small and the weight of animals caught increased by only 24%. MAITLAND (1962) has pointed out that at certain times of the year up to 57% of the invertebrates retained by a 180 meshes per in. (70 meshes per cm) sieve pass through a 40 meshes per in. (16 meshes per cm) sieve but that these animals represent less than 1% of the total weight of the fauna of a sample. In none of the size groups shown (Table II) was any species of

TABLE II

A comparison of the sampling technique used in this work with the Surber technique. Figures given are median values except where stated otherwise.

	Method used in this work	Surber	Surber	Stone scrubbings
Meshes/cm	12	12	24	
Number of samples	10	5	5	10
Wet Weight less *Eiseniella* (g)	.156	.420	.522	.037
Mean wt of *Eiseniella*/sample	.021	.235	.280	.000
Number of organisms/sample	271	377	948	115
Naididae	24	25	75	8
Amphinemura sulcicollis (Stephens)	37	4	78	1
Leuctra spp.	11	21	75	0
Isoperla grammatica (Poda)	3	2	22	0
Caenis rivulorum Eaton	2	2	4	0
Baetis spp.	2	4	25	0
Ecdyonuridae	23	17	57	0
Hydroptilidae	4	22	15	5
Other Trichoptera	4	5	17	4
**Helmis maugei* Bedel 1.	2	3	6	1
**Esolus parallelopipedus* Müller 1.	43	107	220	9
**E. parallelopipedus* a.	18	4	23	0
**Latelmis volkmari* Panzer 1.	17	50	57	1
Chironomidae 1.	26	51	234	80
The size composition of the animals per median total				
Less than 4 mm	211	277	764	91
4—6 mm	43	66	124	17
7—9 mm	11	22	30	7
10 mm or larger	6	12	20	0

*Helmidae = Elmidae, *(H)Elmis maugei* = *Elmis aenea* (Müller), *Latelmis volkmari* = *Limnius volkmari*. *Limnius tuberculatus* = *Oulimnius tuberculatus*.

bottom fauna (other than Hydroptilidae) represented more in the Surber samples using net with 12 meshes per cm than they were in the samples using net with 24 meshes per cm, showing that the finer net did not restrict the flow of water enough to allow the larger organisms to escape. The increase in the number of animals longer than 4 mm caught by the finer net was due mainly to the net retaining more of the slender organisms, such as the larvae of Chironomidae (53% of the increase), Naididae (12%) and Tipulidae (8%), which were able to wriggle through the meshes of the coarse net.

The shortcomings of the method used in the present work compared with the Surber technique are compensated for by the larger number of samples it is possible to take and examine. Altogether 430 samples, containing a total of almost 80,000 animals, were examined in the present survey.

Ten samples were taken each month from both the Shelligan Burn and the River Almond from March 1962 until April 1963, except in January and February 1963 when the River Almond was inaccessible due to snow. The samples from these two streams were taken within 50 m lengths of riffles. Twenty samples were taken from Allt dos Mhuicarain at about three-monthly intervals. These samples were taken within a 200 m length of the stream. After April 1963 samples were taken from the streams at infrequent intervals.

The lengths of all of the animals in some samples (to a total of at least 1000 animals) taken each month from the Shelligan Burn were measured. Additional collections of bottom fauna provided the material for calculating the dry weight (24 hours at 100°C) of certain species.

The total fauna

The median dry weight and number of animals, less *Simulium* spp. in the samples from the three streams from March 1962 to April 1963 are given in Fig. 1. This figure also shows the proportion of animals in three length groups in the samples from the Shelligan Burn. *Simulium* spp. have not been included for the reasons given in Part II (Egglishaw & Morgan, 1965).

In each of the 14 series of ten samples taken from the Shelligan Burn between March 1962 and April 1963 the number of animals in the sample containing the largest number of animals was 2.1 to 4.9 times the number in the samples containing the least number of animals. Similar variation was found in the samples from the River Almond. The largest number of animals in a sample from the twenty

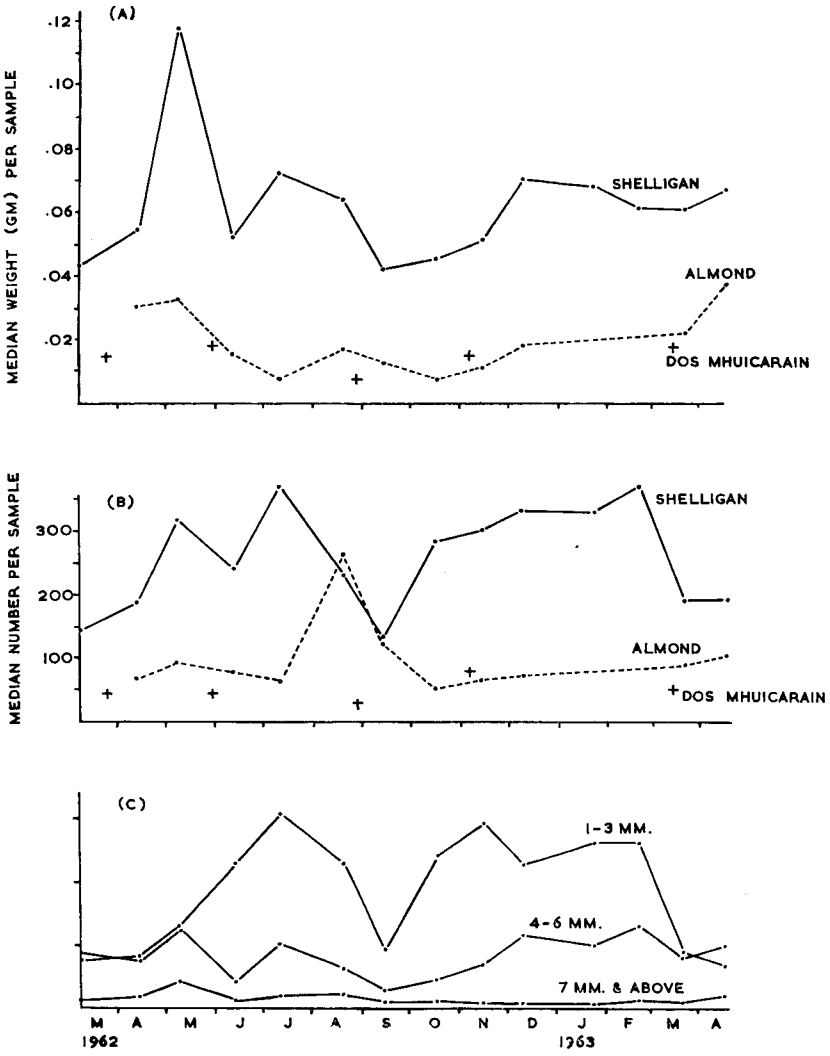


Fig. 1. Seasonal changes in (A) the dry weight and (B) the number of animals from the three streams and (C) changes in the proportion of animals in three size groups in the Shelligan Burn.

taken on each occasion from Allt dos Mhuicarain was about ten times greater than the smallest. The variation in the weight of bottom fauna in each series of samples from all three streams was, with one exception, greater than the variation in the number of animals present in the samples.

Most of this variation in the number and weight of bottom fauna

present in samples could be attributed to the amounts of plant detritus present at the sampling sites, there being a close distributional relationship between the bottom fauna and the detritus, the chief source of food (EGGLISHAW, 1964).

The frequency distributions of quantities of plant detritus and bottom fauna in stream riffles require further investigation but from present data they are known to be positively skewed. For this reason median, rather than mean, quantities of benthic fauna have been given in Fig. 1 and elsewhere in this paper. Of the 25 median weight values given in Fig. 1 for the Shelligan Burn and the River Almond all but one are less than the respective mean values. The mean weight is between 9% and 25% greater than the median weight on 13 of these 24 occasions.

It can be seen from Fig. 1 that the Shelligan Burn is fairly consistently richer in number and weight of bottom fauna than the other two streams. The exception provided by the greater number of animals in the River Almond in August was due to a large population of Naididae. In the eleven months in which samples were obtained from both the Shelligan Burn and River Almond there were 28,314 animals (weighing 7.96 g dry weight) in those from the Shelligan Burn and 11,655 animals (2.58 g dry weight) in those from the River Almond. There is a greater density of numbers of animals in the River Almond than Allt dos Mhuicarain but the weights of bottom fauna are more equal.

This greater density of bottom fauna in the Shelligan Burn compared with the other two streams probably results from its being chemically richer than Allt dos Mhuicarain, and containing a greater amount of allochthonic plant material than the River Almond. It has been shown (EGGLISHAW, 1965) that the regression (coefficient b) of bottom fauna on plant detritus increases with increase in the concentration of calcium ions in streams. A large proportion of the bottom fauna consumes plant detritus, probably only when it has been partially decomposed, and it is thought that bacterial decomposition is accelerated by a high concentration of calcium ions.

The greatest weight of bottom fauna in the Shelligan Burn occurred in May and in the River Almond in April and May (Fig. 1). In May five of every seven animals collected from the Shelligan Burn were 4 mm or longer and one in seven was 7 mm or longer. Most of these larger animals were Plecoptera and Ephemeroptera near emergence. By June most had emerged, the numbers of animals present then having fallen by one-quarter from the May value but the weight of animals present having fallen by more than one-half. The largest numbers of animals in the Shelligan Burn occurred in July and February. In July there were large numbers of small nymphs of

species that grow during the summer emerging in August and September.

During the fortnight before the date of the September samples, 11.0 cm of rain were recorded in a gauge on the bank and animals were therefore probably washed out of the area being sampled. There was much less plant detritus present in September than the amount present in August (EGGLISHAW, 1964) and both the weight and number of animals particularly those under 4 mm, were much less in September than in August. By October the numbers of animals had returned to the level for August but the increase in total weight of animals was slight. The increase in numbers was caused mainly by the hatching of eggs of *Baetis* spp., *Rhithrogena semicolorata* (CURTIS) and *Amphinemura sulcicollis*.

Other than those given for the River Endrick by MAITLAND (1964) no gravimetric values of bottom fauna densities in flowing waters in Scotland have, as far as is known, been published. Using the ratio between the weight of animals caught by the sampling method used in the present work and the weight of animals caught by the Surber sampler (Table II) it is possible to calculate the mean standing stocks of bottom fauna in the three streams studied; these are given in Table III. From work on the feeding biology of salmon and trout (EGGLISHAW, 1967), in which the wet and dry weights of 25 of the commonest benthic organisms at several lengths were determined, it is considered that the wet weights of bottom fauna collections from the Shelligan Burn are 5.5 times greater than the dry weights. (Wet weight/dry weight ratios for individual species ranged from 2.3 for *Latelmis volkmari* adults, through 4.3 for *Dinocras cephalotes* (CURTIS) 12—20 mm in length, 5.2 for Chironomidae larvae, 5.3 for *Baetis* spp., 5.5 for *Rhithrogena semicolorata*, 6.1 for *Rhyacophila* spp., 6.4 for *Leuctra* spp. to 6.6 for *Ephemerella ignita* (PODA) (unpublished data)). The additional values included in Table III were obtained by using this figure of 5.5 to convert to dry weight densities, the wet weight results obtained during the present study and the figures given by MAITLAND (1964) for the River Endrick.

COMPOSITION OF THE FAUNA

The animals collected from the three streams were separated into 67 taxonomic categories not including categories containing larvae of undetermined species. Of the 67 categories 37 were species and 13 genera some (e.g. *Baetis*, *Rhyacophila*, *Hydropsyche*) of which were known to include more than one species. Fifty-three categories were represented in the Shelligan Burn, 45 in the River Almond and 49 in

TABLE III

The standing stock of bottom fauna in streams

	Standing stock dry weight g/m²	Date
Shelligan Burn	2.88	Mean of monthly samples Apr 1962-Apr 1963 excluding Jan and Feb.
	2.04	Apr 1964
	1.96	Oct 1964
R. Almond site where techniques were examined	1.27	Sept 1964
R. Almond headwaters	0.93	Mean of monthly samples Apr 1962-Apr 1963 excluding Jan and Feb.
Allt dos Mhuicarain	0.70	Five sets of samples Mar 1962-Mar 1963
R. Endrick stony site	2.91	Nov 1959-Jan 1961.
sandy site	1.45	Nov 1959-Jan 1961.

TABLE IV

Seasonal changes in the composition of the bottom fauna of the Shelligan Burn.
The figures given are the means of ten samples. + = present but less than 0.5

	1962 Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1963 Jan	Feb	Mar	Apr
Crenobia alpina (Dana)	2	+	5	1	1	4	4	12	9	12	6	4	4	4
Naididae	–	+	–	4	13	21	6	17	10	1	1	1	1	1
Other Oligochaeta	+	+	3	1	1	2	–	+	–	+	+	+	+	+
Gammarus pulex (L)	–	+	+	+	1	1	1	+	1	+	+	+	+	–
PLECOPTERA														
Amphinemura sulcicollis	11	12	18	1	–	+	16	49	54	25	35	35	15	11
Protonemura spp.[1])	1	+	+	–	–	1	5	1	4	2	4	2	+	+
Leuctra inermis Kempny	31	27	42	3	–	+	3	12	44	61	53	58	47	66
L. hippopus (Kempny)	2	1	–	–	–	–	+	3	4	3	2	3	1	1
L. fusca (L.)	–	–	1	18	36	19	+	–	–	–	–	–	–	–
Dinocras cephalotes	1	+	2	7	10	7	3	3	2	1	3	2	3	1
Perla bipunctata (Pictet)	1	1	1	1	1	1	2	1	+	1	+	+	1	+
Chloroperla torrentium (Pictet)	12	12	22	8	1	3	4	11	12	18	16	18	10	14
C. tripunctata (Scopoli)	1	1	–	–	–	–	–	+	2	2	1	1	1	2
Isoperla grammatica	7	10	7	+	–	–	1	8	13	16	28	29	11	7
EPHEMEROPTERA														
Ephemerella ignita	–	–	–	35	28	5	+	–	+	–	–	–	–	–
Caenis rivulorum	1	3	7	2	+	+	+	–	–	–	–	+	–	1
Baetis spp. [2])	44	34	62	21	8	46	14	90	115	124	105	98	30	27
Ecdyonurus spp. [3])	1	1	2	4	8	7	2	4	4	3	2	2	2	1
Rhithrogena semicolorata	24	22	12	2	+	–	5	26	31	28	28	22	16	10
Ecdyonuridae indet.	+	2	1	3	3	1	7	4	2	1	2	–	1	+
TRICHOPTERA														
Limnephilidae	2	3	2	+	6	11	7	9	8	4	3	5	6	6
Hydropsyche spp.	2	2	5	3	+	1	+	1	2	1	2	3	1	1
Polycentropidae	+	1	–	+	–	–	–	+	1	1	+	1	1	1
Rhyacophila spp.	3	1	8	5	3	5	7	6	3	5	5	5	3	3
Hydroptilidae	+	1	1	8	1	–	–	–	+	–	–	+	+	–

TABLE IV (Continued)

	1962 Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1963 Jan	Feb	Mar	Apr
COLEOPTERA														
Oreodytes rivalis (Gyllenhal) 1	–	–	–	+	2	+	–	–	–	–	–	–	–	–
O. rivalis a	–	–	+	2	–	–	–	–	–	–	–	–	–	–
Hydraena gracilis Germar a	+	+	2	1	3	2	1	2	1	1	1	1	+	+
Helmis maugei 1	+	1	1	4	9	9	5	4	2	1	1	2	–	1
H. maugei a	+	–	+	1	1	1	1	+	+	–	+	+	+	+
Esolus parallelopipedus 1	1	5	14	20	14	10	5	3	+	+	1	+	4	5
E. parallelopipedus a	–	2	9	9	6	+	+	1	+	+	–	–	+	+
Limnius tuberculatus Müller 1	–	+	3	3	+	–	–	–	–	–	–	–	–	–
L. tuberculatus a	–	–	1	+	+	–	–	–	–	–	–	+	–	–
Latelmis volkmari 1	–	1	2	1	1	2	+	1	+	–	+	–	+	1
L. volkmari a	+	–	+	–	+	+	+	–	–	–	–	–	–	–
DIPTERA														
Dicranota spp.	1	2	5	2	9	8	5	6	4	1	2	2	2	1
Chironomidae 1	7	30	43	101	250	89	22	17	17	13	36	95	3	8
Chironomidae p	–	+	4	4	6	3	1	2	+	–	+	–	–	–
Simulium spp.	24	1	2	1	1	3	1	4	17	23	25	10	7	4
HYDRACARINA	+	2	7	5	8	2	1	+	+	+	1	1	+	1
TOTAL less *Simulium*	156	178	294	285	427	261	129	294	348	326	338	390	163	176

[1]) *Protonemura praecox* (Morton) and *P. meyeri* (Pictet)
[2]) In winter and spring *Baetis rhodani* (Pictet) with a small proportion of *B. pumilus* (Burmeister)
[3]) *Ecdyonurus venosus* (Fabricius) & *E. torrentis* Kimmins

TABLE V

Seasonal changes in the composition of the bottom fauna of the River Almond headwaters.
The figures are the means of ten samples. + = present but less than 0.5

	1962 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1963 Mar	Apr
Crenobia alpina	2	2	1	+	1	1	2	1	1	3	4
Naididae	1	4	4	8	164	46	1	1	–	+	–
Other Oligochaeta	1	1	2	1	1	+	–	+	–	–	–
Gammarus pulex	–	+	–	+	–	–	–	–	+	–	–
PLECOPTERA											
Amphinemura sulcicollis	3	4	–	–	–	2	3	5	5	3	4
Protonemura spp.[1])	+	2	+	–	–	+	+	+	1	+	+
Leuctra inermis	19	18	2	–	4	13	15	22	28	52	79
L. hippopus	+	–	–	–	–	1	1	2	+	2	1
L. fusca	–	+	7	4	–	–	–	–	–	–	–
Dinocras cephalotes	+	+	+	+	+	–	–	+	+	+	–
Perla bipunctata	–	–	1	1	1	3	+	–	+	1	+
Chloroperla torrentium	2	1	+	–	–	+	1	2	1	3	7
Isoperla grammatica	+	+	–	+	+	4	3	4	5	2	7
Brachyptera risi (Morton)	1	1	–	–	–	–	–	1	5	4	1
EPHEMEROPTERA											
Ephemerella ignita	–	–	1	2	+	+	–	–	–	–	–
Caenis rivulorum	2	6	11	+	1	1	+	–	–	–	1
Baetis spp.[2])	14	44	15	16	6	11	14	23	18	20	21
Ecdyonurus spp.[3])	+	+	+	1	3	1	+	+	+	+	–
Rhithrogena semicolorata	6	3	1	+	1	6	4	13	9	9	12
Ecdyonuridae indet.	+	+	2	1	2	1	3	1	2	1	1

TABLE V (Continued)

	1962 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1963 Mar	Apr
TRICHOPTERA											
Limnephilidae	–	–	–	–	+	+	–	+	+	–	–
Hydropsyche spp.	+	1	+	+	+	1	+	+	+	+	–
Polycentropidae	+	2	1	+	3	2	+	+	–	–	1
Rhyacophila spp.	1	1	1	–	+	+	+	+	–	1	+
Hydroptilidae	1	3	+	+	4	1	1	+	–	+	+
COLEOPTERA											
Helmis maugei 1	+	1	+	1	+	+	–	+	–	–	–
Esolus parallelopipedus 1	–	2	2	1	2	+	+	–	–	1	4
E. parallelopipedus a	–	–	1	+	+	–	–	–	–	–	+
Latelmis volkmari 1	+	2	+	1	+	1	–	–	–	–	+
DIPTERA											
Dicranota spp.	+	1	1	1	1	1	1	1	+	+	1
Chironomidae 1	9	16	13	24	48	35	2	6	3	1	4
Chironomidae p	–	1	1	2	3	1	–	–	–	–	–
Simulium spp.	3	52	1	14	1	+	–	1	4	6	+
Clinocerinae	1	+	+	+	+	1	–	–	–	–	–
HYDRACARINA	+	+	+	1	1	+	+	–	–	–	–
Total less *Simulium*	65	119	72	64	246	133	53	84	80	102	148

[1]) *P. praecox* and *P. meyeri*
[2]) In winter and spring *B. rhodani* plus a small proportion of *B. pumilus*
[3]) *E. venosus* and *E. torrentis*

TABLE VI

The composition of the bottom fauna of Allt dos Mhuicarain
The figures given are the means of 20 samples. + = present but less than 0.5.

	1962 Mar	May	Aug	Nov	1963 Mar	Aug	1964 Jan	Nov
Naididae	–	+	4	3	–	14	–	36
Other Oligochaeta	1	3	6	3	+	3	+	2
PLECOPTERA								
Amphinemura sulcicollis	20	8	–	52	28	+	67	45
Protonemura spp.	1	–	+	2	1	1	1	2
Leuctra inermis	2	–	1	1	2	+	1	9
L. hippopus	3	–	2	3	2	–	4	+
L. fusca	–	2	10	–	–	19	–	–
Chloroperla torrentium	2	1	+	1	1	–	6	1
Isoperla grammatica	4	2	+	5	3	1	4	11
Brachyptera risi	3	–	–	5	5	–	5	2
Taeniopteryx nebulosa (L)	+	–	1	1	+	4	1	1
EPHEMEROPTERA								
Baetis spp.	+	10	4	2	+	12	+	2
Heptagenia lateralis (Curtis)	5	5	1	1	2	+	1	1
Leptophlebia marginata (L)	–	+	–	+	+	1	1	1
TRICHOPTERA								
Limnephilidae	+	+	+	+	+	+	+	+
Hydropsyche spp.	+	+	–	1	–	+	+	1
Polycentropidae	1	1	1	+	+	1	+	4
Rhyacophila spp.	+	+	+	+	+	1	+	3
Hydroptilidae	+	–	1	+	+	+	+	+
COLEOPTERA								
Esolus parallelopipedus 1	–	+	–	–	–	+	+	1
Latelmis volkmari 1	+	+	+	+	+	+	+	–
Limnius tuberculatus 1	+	+	+	+	+	–	+	–
Helodidae 1	+	+	1	+	+	+	–	+
DIPTERA								
Dicranota spp.	+	+	+	+	+	1	+	+
Chironomidae 1	9	7	7	5	5	27	10	16
Chironomidae p	–	1	1	–	–	2	–	–
Simulium spp.	1	2	10	8	1	30	3	1
Clinocerinae	+	+	+	1	–	7	1	4
HYDRACARINA	+	+	+	–	–	+	–	–
Total less *Simulium*	53	43	42	90	51	97	105	146

TABLE VII

Taxa present in or absent from only one of the three streams

TAXA PRESENT IN ONE STREAM ONLY

Present in Shelligan Burn	Present in R. Almond	Present in Allt dos Mhuicarain
**Leutra nigra* (Olivier)	None	*Polycelis felina* (Dayell)
Oreodytes rivalis		**Dryops luridus* Erichson adult
**Helophorus* sp. adult		Helodidae
**Ochthebius* sp. adult		**Cordulegaster boltonii* (Donovan)
Odontocerum albicorne (Scopoli)		*Taeniopteryx nebulosa*
Agapetus sp.		*Leptophlebia marginata*
*Psychomyidae		*Ameletus inopinatus* Eaton
Ancylastrum fluviatile (Müller)		**Sialis fuliginosa* Pictet
Pisidium sp.		**Hemerodroma* sp.

TAXA ABSENT FROM ONE STREAM ONLY

Absent from Shelligan Burn	Absent from R. Almond	Absent from Allt dos Mhuicarain
Riolus cupreus (Müller)	Psychodidae	*Crenobia alpina*
Heptagenia lateralis		*Gammarus pulex*
Wormaldia sp.		*Dinocras cephalotes*
		Perla bipunctata
		Chloroperla tripunctata
		Ephemerella ignita
		Caenis rivulorum
		Ceratopogonidae

*Inclusion based on less than five specimens

Allt dos Mhuicarain. Thirty-four categories, of which 17 were species, were common to all three streams.

The bottom fauna in the three streams is given in Tables IV, V and VI. Species present in or absent from only one of the three streams are listed in Table VII. As expected there are differences among the three streams in both the population density and kind of species present. Compared with the fauna of the Shelligan Burn that from the River Almond is very similar in species composition, but most of the species are less dense in the River Almond. Thus all of the fourteen species of Plecoptera which occurred in the River Almond were found in greater quantity in the Shelligan Burn. Allt dos Mhuicarain usually has less dense populations of the species present in the Shelligan Burn and River Almond. Of the 11 species of Plecoptera common to Allt dos Mhuicarain and the Shelligan Burn nine were more abundant in the Shelligan Burn and one *(Amphinemura sulcicollis)* occurred in about equal numbers in both streams.

Some of the differences between the species composition of the fauna in the three streams can be attributed to the differences in the chemical composition of the streams and special features of Allt dos Mhuicarain.

MORGAN & EGGLISHAW (1965) pointed out that *Gammarus pulex* only occurs in the chemically richer streams in the Scottish Highlands, being absent particularly from those streams with a concentration of less than about 200 microequivalents of calcium ions/l. It occurred more frequently in the Shelligan Burn than the River Almond, and was absent from Allt dos Mhuicarain. Even in the Shelligan Burn *G. pulex* was still relatively uncommon. Ten Surber-type samples showed there was less than ten *G. pulex* per m^2 in February 1964, whereas there were 230 per m^2 in Fincastle Burn (stream number 43 in Part I, with a concentration of 1686 Ca^{++}/l) at this time. *Ancylastrum fluviatile* and *Pisidium* spp. are other organisms known to be present only in the streams which are richer chemically. They occurred in the Shelligan Burn but were absent from the River Almond headwaters and Allt dos Mhuicarain.

Because Allt dos Mhuicarain is on a steeper gradient and its watershed has a higher rainfall than those of the Shelligan Burn and River Almond, it suffers from more severe spates. This may account for the absence of *Dinocras cephaloies* and *Perla bipunctata* from Allt dos Mhuicarain. These two species live in riffles and rarely in pools (see later) and as their life history is known to take three years (HYNES, 1941) there is a high probability of the larvae having to survive several large spates, each of which would reduce the population. *Dinocras cephalotes* and *P. bipunctata* are both present in the Shelligan Burn and River Almond. *Cordulegaster boltonii* (Odonata), which occurs in Allt dos Mhuicarain but is absent from the Shelligan Burn and River Almond, spends at least two years in the larval stage. This species occurs most frequently under the large stones of the pools in Allt dos Mhuicarain, which, during spates, is presumably a more sheltered habitat than the riffles. The heavy spates in Allt dos Mhuicarain may also account for the unusually low population of *Baetis rhodani* and *B. pumilus* in the winter and spring in this stream. *B. rhodani* is one of the commonest organisms in both the Shelligan Burn and River Almond, and is known usually to be common in streams throughout the Scottish Highlands. From a stream only 4 km distant from Allt dos Mhuicarain, and flowing from the same hillside, but subject to less severe spates because of its smaller watershed, fifteen Surber-type samples (12 meshes/cm) taken in February 1964 contained a total of 798 *Baetis rhodani* and *B. pumilus* (range 17—110 with eight samples containing 42—55). Fifteen samples taken in Allt dos Mhuicarain on the same day contained only two *Baetis* sp. It is shown later, from samples taken in the Shelligan Burn, that *Baetis* spp. live in riffles and are rare in slow-flowing water, and so the population of these species in Allt dos Mhuicarain will be regulated by the frequency and severity of the spates. In summer when the water

conditions are lower and Allt dos Mhuicarain is not so susceptible to spates *Baetis* spp. are much more frequent.

Another factor which may have affected the fauna in Allt dos Mhuicarain is the discharge into the stream from a septic tank of a house which, previously empty, became occupied in April 1962. Naididae, which feed on fine organic matter, increased in number and *Polycelis felina*, which had previously been absent, were first found in November 1964. MACAN (1961) reported that, following the overloading of a septic tank which discharged into a stream, the numbers of *P. felina* present increased. *P. felina* never occurred in the Shelligan Burn or River Almond.

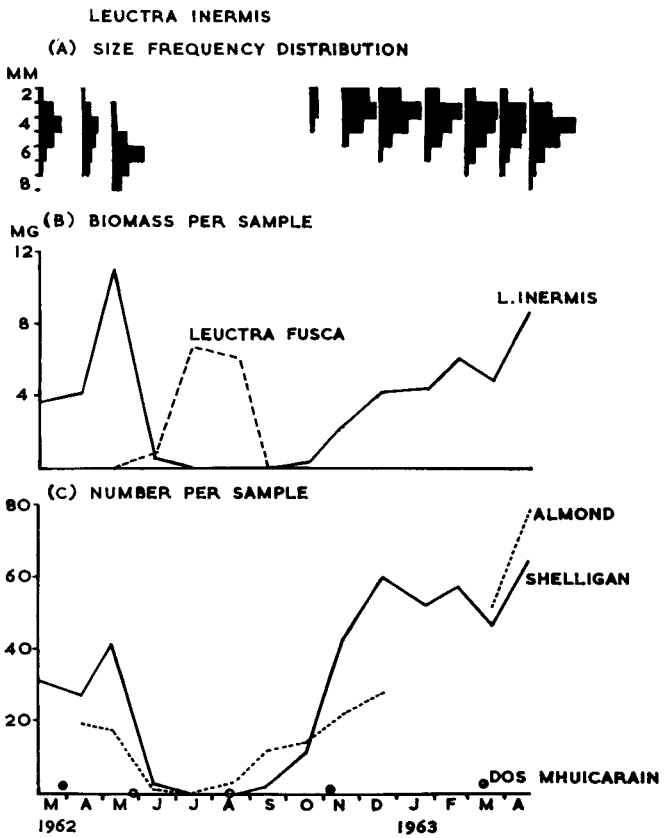
Oreodytes rivalis is present in the Shelligan Burn and absent from the River Almond and Allt dos Mhuicarain. It is shown later (Table VIII) that this species occurs chiefly in the slow flowing water rather than the riffles of the Shelligan Burn so could well be present in pools in the River Almond and Allt dos Mhuicarain.

Not enough of their ecology is known to suggest why *Taeniopteryx nebulosa*, *Leptophlebia marginata* and *Ameletus inopinatus* are relatively common in Allt dos Mhuicarain but absent from the Shelligan Burn and River Almond, nor why *Ephemerella ignita* and *Caenis rivulorum* are absent from Allt dos Mhuicarain.

SEASONAL CHANGES IN CERTAIN TAXA

The rate of growth and development of animals in streams is very varied. There is no growing season common to all groups, and many closely related species develop in succession throughout the year. Other animals may make little growth for many months then increase greatly in size during a relatively short period. In Scottish Highland streams generally, including the Shelligan Burn and the River Almond, the chief species of *Leuctra* present are *L. inermis* during the winter and spring and *L. fusca* during the summer, with smaller numbers of *L. hippopus* in winter and spring, and *L. moselyi* in summer. The seasonal succession in emergence, first *L. hippopus* in early spring, followed by *L. inermis*, *L. moselyi* and finally *L. fusca* in late summer, is similar to that found by HYNES (1961) for a mountain stream in Wales. Details of the seasonal changes in the numbers of *L. inermis* caught in the three streams and the seasonal changes in the biomass and size-frequency distribution of the species in the Shelligan Burn are given in Fig. 2, which also includes the seasonal changes in the biomass of *L. fusca* in the Shelligan Burn.

In Allt dos Mhuicarain *Leuctra hippopus* is sometimes as common as *L. inermis*, and more *L. moselyi* have been collected from this



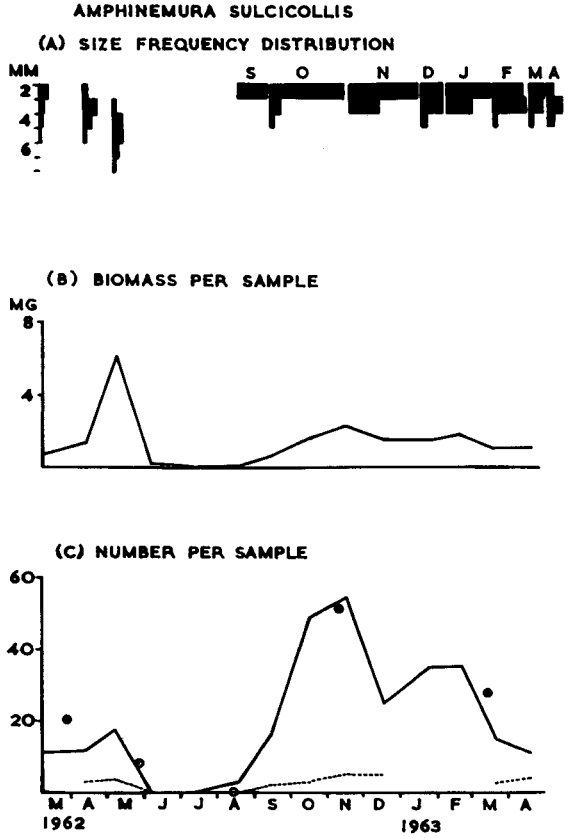


Fig. 2. Seasonal changes in (A) the size-frequency distribution of *Leuctra inermis* in the Shelligan Burn, (B) the mean dry weight of *L. inermis* and *L. fusca* per sample from the Shelligan Burn and (C) the mean numbers of *L. inermis* per sample from the three streams.

Fig. 3. Seasonal changes in (A) the size-frequency distribution of *Amphinemura sulcicollis* in the Shelligan Burn, (B) the mean dry weight of *A. sulcicollis* per sample from the Shelligan Burn and (C) the mean numbers of *A. sulcicollis* per sample from the three streams.

stream than from the Shelligan Burn and the River Almond. In a stream (Buchanty Burn) only 1 km distant from the Shelligan Burn twelve Surber-type samples (12 meshes/cm) taken on 3 March 1964 contained 230 *L. hippopus* compared with 198 *L. inermis*. It is not known what factors common to Allt dos Mhuicarain and the Buchanty Burn favour *L. hippopus*. The streams are very different chemically (e.g. Ca^{++} concentration in Allt dos Mhuicarain is about 70 μe/l compared with 650 μe/l for Buchanty Burn). The Buchanty Burn flows over sandstone and there is a great deal of sand among the gravel and stones of the substrate whereas Allt dos Mhuicarain flows over granite and there is hardly any sand on the substrate.

Chloroperla torrentium is the most abundant species of *Chloroperla* in Scottish Highland streams. In the Shelligan Burn a mean of one or two 5 mm or longer *C. tripunctata* per sample were caught from October to May also, but only two were present in all of the samples taken from the River Almond during this time. *C. tripunctata* was not found in Allt dos Mhuicarain, nor is it listed by MILLS (1964) as being present in other tributaries of the River Bran.

Seasonal changes in the numbers of *Amphinemura sulcicollis* in the three streams studied and changes in the biomass and size-frequency distribution of the species in the Shelligan Burn are given in Fig. 3. *Amphinemura sulcicollis* occurred in about equal densities in the Shelligan Burn and Allt dos Mhuicarain but numbers were much less dense in the River Almond. *A. sulcicollis* feeds on dead leaves and other decomposing plant material (HYNES, 1941; JONES 1950) of which there are large amounts present in the Shelligan Burn and Allt dos Mhuicarain, but much less in the River Almond. However other Plecoptera (e.g. *Leuctra* spp., *Protonemura* spp.) feed on similar plant material and yet have sparser populations in Allt dos Mhuicarain than in the other two streams.

Seasonal changes in *Isoperla grammatica* are given in Fig. 4. In the absence of *Dinocras cephalotes* and *Perla bipunctata* from Allt dos Mhuicarain *I. grammatica* is the main predatory species in this stream.

Brachyptera risi is many times more common in Allt dos Mhuicarain and the River Almond than it is in the Shelligan Burn. A total of only 30 specimens were obtained in the 150 samples taken from the Shelligan Burn from March 1962 to April 1963. HYNES (1961) believes that it is probable that *B. risi* can survive only at low temperatures. This may explain its rarity in the relatively warmer Shelligan Burn. Larvae were present in the River Almond and Allt dos Mhuicarain from November to May.

Taeniopteryx nebulosa is a member of the same family (Taeniopterygidae) as *B. risi*. It is considered 'fairly rare' (HYNES, 1958) and

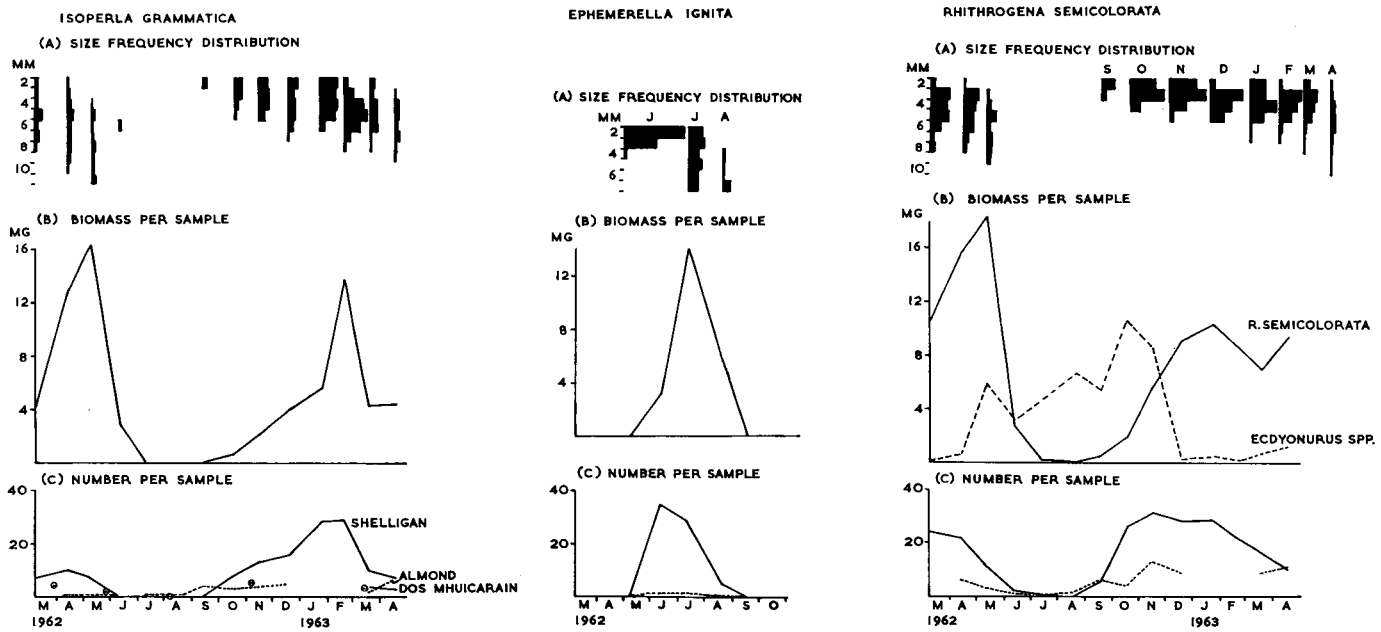


Fig. 4. Seasonal changes in (A) the size-frequency distribution of *Isoperla grammatica* in the Shelligan Burn, (B) the mean dry weight of *I. grammatica* per sample from the Shelligan Burn and (C) the mean numbers of *I. grammatica* per sample from the three streams.

Fig. 5. Seasonal changes in (A) the size-frequency distribution of *Ephemerella ignita* in the Shelligan Burn, (B) the mean dry weight of *E. ignita* per sample from the Shelligan Burn and (C) the mean numbers of *E. ignita* per sample from the three streams.

Fig. 6. Seasonal changes in (A) the size-frequency distribution of *Rhithrogena semicolorata* in the Shelligan Burn, (B) the mean dry weight of *R. semicolorata* and *Ecdyonurus* spp. per sample from the Shelligan Burn and (C) the mean numbers of *R. semicolorata* per sample from the three streams.

was found in only one of the 51 streams in the Scottish Highlands which were sampled in 1960 (MORGAN & EGGLISHAW, 1965). It was absent from the Shelligan Burn and River Almond and the stream in Wales studied by HYNES (1961) but occurred frequently in Allt dos Mhuicarain. Larvae were 2—3 mm long in August and by mid-November were 6—13 mm long with more than half 8—9 mm; by the end of January the larvae were 9—13 mm long, more than half being 11 mm or longer. Adults emerged by about the third week in March only one larva being found on 26 March 1962, two on 14 March 1963 and none on 10 March 1964. Possibly *T. nebulosa* also, can survive at only very low temperatures. As previously nothing was known concerning the food of *Taeniopteryx nebulosa* (HYNES, 1941) the alimentary systems of nine large nymphs found in November and January were dissected. All but one, which was empty, contained small fragments of higher plant tissue plus some fine filamentous algae.

Details of the seasonal changes in *Ephemerella ignita* are given in Fig. 5. This species which occurs during the summer months only was much more abundant in the Shelligan Burn than in the River Almond and was absent from Allt dos Mhuicarain.

Seasonal changes in the numbers of *Rhithrogena semicolorata* in the three streams studied and changes in the biomass and size-frequency distribution of the species in the Shelligan Burn are given in Fig. 6. The biomass of *R. semicolorata* was greatest during the winter and spring from November to May, but the biomass of *Ecdyonurus* spp., members of the same family (Ecdyonuridae), was greatest during June to November. Changes in the biomass of *Ecdyonurus* spp. have been included in Fig. 6.

The sampling programme for this work extended over three winters of differing severity and it is of value to compare the sizes attained in mid-February by species of bottom fauna usually considered to grow during the winter months. The winter of 1961—62 was slightly cooler than average with a mean air temperature between November and February at Perth (altitude 23 m, 18 km from the Shelligan Burn) of 3.0° compared with an average temperature (1921—50) of 3.7°C for this period. The winter of 1962—63 was exceptionally severe. At Perth the mean temperature for November to February inclusive was only 1°C. The following winter was rather mild with a mean temperature of 4.1°C for the November-February period.

The mean January temperature for 1964 was 5.0°C higher than that for 1963 and the mean February temperature was 4.9°C higher. Stream temperatures are very much influenced by air temperatures so that the unusually cold winter of 1962—63 followed by the mild

winter of 1963—64 probably provide as great a contrast in winter water conditions as is likely to occur in the Shelligan Burn.

The size-frequency distribution of the five taxa examined, as shown in Fig. 7, shows little variation from year to year. The variation that does exist could not be ascribed to a slowing of development in the unusually severe winter since certain animals e.g. *Amphinemura sulcicollis* and *Isoperla grammatica* would appear to have grown slightly faster in 1963 than in 1962 or 1964.

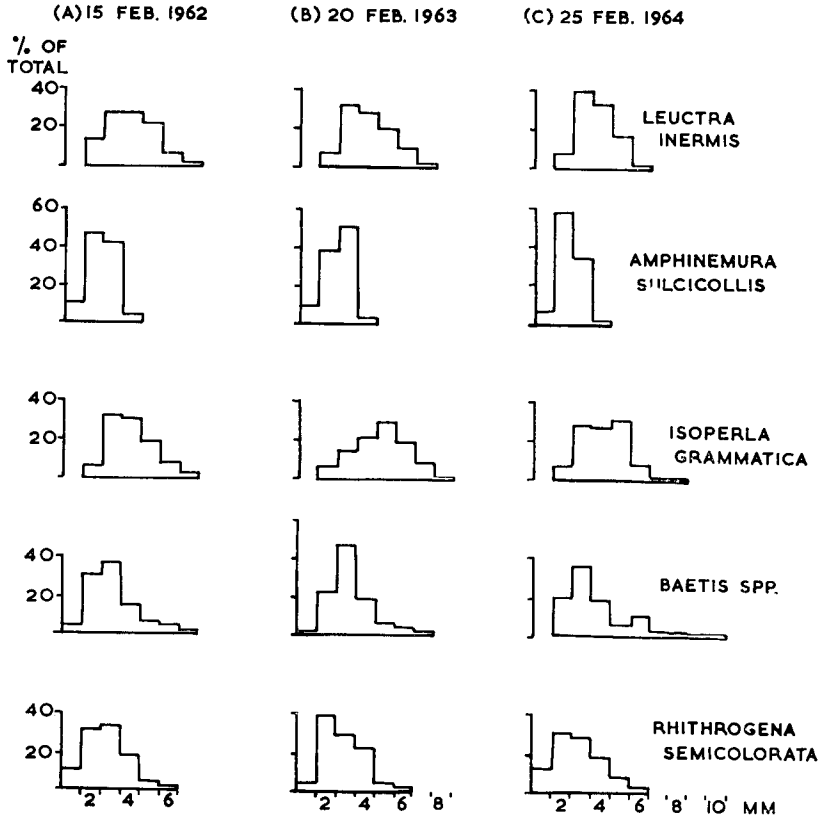


Fig. 7. The size frequency distribution of five species in the Shelligan Burn after three winters of differing severity. (A) November-February slightly cooler than average, (B) severely cold, (C) mild.

Comparison of the bottom fauna of pools and riffles

The investigations previously described have been devoted to the bottom fauna of riffle stretches as these make up the greater part of the

three streams examined. The sites studied in each of the streams also contained areas where the water was at least as deep as in the riffles and the rate of flow much slower. Such pools constitute about 10% of the surface area of the Shelligan Burn.

Samples were taken, using a modified Surber technique which involved the removal of 0.09 m^2 of substrate to a depth of about 15 cm, from the riffles and pools of the Shelligan Burn in April and in September 1964. A net with 60 meshes/in. (24 meshes/cm) was used in April but, because of the large number of small larvae known to occur in September, a net with 120 meshes/in. (48 meshes/cm) was used in that month. Using a diver's face mask an observer checked that animals were not swimming away from or being washed back out of the net. Animals 3 mm long could be clearly seen as the samples were being taken.

The results of this comparison between the bottom fauna of riffles and pools is given in Table VIII. The riffles were shown to contain a higher numerical density of bottom fauna than the pools both in the spring and in the autumn. There was, however, no significant difference in the biomass densities of the bottom fauna in the two habitats.

As expected some animals were more concentrated in one habitat than they were in the other. *Leuctra* spp. and *Baetis* spp. were several times more common in the riffles than in the pools in both April and September. In September *Rhithrogena semicolorata* was found in greater concentration in the riffles than in the pools. At that time all (except one at 5 mm) of the *R. semicolorata* were less than 4 mm long. In April the *R. semicolorata* ranged from 2 mm to 8 mm with 43% 5 mm or longer. *Ecdyonurus* spp. were found in greater concentration in the pools than in the riffles in April, but were more common in the riffles in September. This unusual change in distribution may be due to movements of individuals prior to emergence or, possibly, to different distributions of either the two species involved *(E. venosus* and *E. torrentis)* or different generations of the same species. Unfortunately the larvae of the two species are not easily separated. Some animals which were more densely distributed in the pools than in the riffles were the heavier, burrowing species such as *Dicranota* spp., other Tipulidae and *Eiseniella* spp. *Chloroperla torrentium* occurred in equal densities in the riffles and the pools. This species has previously been shown (EGGLISHAW, 1964) to be, at times, randomly distributed among the type of sites at which samples were taken in riffles, and it is the only stream organism known with this distribution.

The important predatory invertebrates *Perla bipunctata, Dinocras cephalotes, Rhycophila* spp. and *Hydropsyche* spp. which occurred in

TABLE VIII

The bottom fauna of pools and riffles of the Shelligan Burn. The figures are the mean values of five samples.

Date sampled	Riffles 2—4—64	Pools 9—4—64	P values	Riffles 6—10—64	Pools 7—10—64	P values
Depth in cm	15	18		25	26	
Current speed in cm/sec 10 cm above substrate	60	9		35	6	
Crenobia alpina	10	1	*	12	1	*
Eiseniella spp.	1	11	**	1	7	n.s.
Naididae	+	0	n.s.	318	76	***
Gammarus pulex	+	1	n.s.	0	1	***
Amphinemura sulcicollis	20	11	*	96	29	**
Leuctra spp.	129	13	***	65	15	**
Dinocras cephalotes	5	+	***	15	0	***
Chloroperla torrentium	26	26		67	51	
Isoperla grammatica	28	10	**	5	2	n.s.
Baetis spp.	78	3	***	86	6	***
Rhithrogena semicolorata	27	17	n.s.	52	3	***
Ecdyonurus spp.	6	32	***	30	12	**
Limnephilidae	10	16	n.s.	37	64	n.s.
Hydropsyche spp.	3	+	**	5	0	***
Rhyacophila spp.	9	1	***	25	1	***
Hydroptilidae	0	1		2	12	**
Oreodytes rivalis a.	0	56	***	0	1	n.s.
Helmis maugei l.	11	18		57	59	
Esolus parallelopipedus l.	13	33	**	22	38	*
Dicranota spp.	3	18	***	2	4	n.s.
Tipulidae less *Dicranota*	+	2	***	14	33	*
Chironomidae l.	171	55	n.s.	489	383	n.s.
Ancylastrum fluviatile	1	6	n.s.	1	17	**
Total number	587	393	**	1495	866	***
Total wet weight (g)	1.045	1.040	n.s.	1.002	0.646	n.s.

+ = present but less than 0.5 n.s. $P > 0.1$ * $P = 0.1-0.05$
** $P = 0.05-0.01$ *** $P < 0.01$

the riffles were almost absent from the pools. The reasons for the absence, from the pools, of these predators other than *Hydropsyche* spp., which feed by catching animals from flowing water in a net they construct, are not obvious. In the spring the main predatory species in the pools appears to be the small (3 mm long) *Oreodytes rivalis*, but these are absent in the autumn. Investigations of the factors affecting the distribution of the larger invertebrate predators at all stages of their life-cycles are at present being made by MACKAY.

Summary

1. The paper deals with seasonal changes in the composition and amount, by number and weight, of benthic organisms in riffles of three streams of different character (Shelligan Burn, River Almond, Allt dos Mhuicarain). Of the three streams the Shelligan Burn has the richest, and Allt dos Mhuicarain the poorest, chemical composition and surrounding vegetation. The River Almond has similar surroundings to Allt dos Mhuicarain but contains a much greater concentration of dissolved ions.
2. The technique used to sample the bottom fauna is critically examined and compared with that using the Surber sampler.
3. The mean standing stocks of bottom fauna, as dry weight per m^2, were 2.88 g for the Shelligan Burn, 0.93 g for the River Almond and 0.70 g for Allt dos Mhuicarain. The greatest weight of bottom fauna in the Shelligan Burn occurred in May, and in the River Almond in April and May, when a high proportion of the organisms were of a large size prior to emergence. After their emergence the numbers of animals fell by $^1/_4$ but the weight of animals present fell by $^1/_2$. The largest numbers of animals in the Shelligan Burn occurred in July and February.
4. The animals collected from the three streams were separated into 67 taxonomic categories, 37 of which were species. Fifty-three categories were represented in the Shelligan Burn, 45 in the River Almond and 49 in Allt dos Mhuicarain. Thirty-four categories, of which 17 were species, were common to all three streams.

   The fauna of the River Almond was similar in composition but quantitatively less than that of the Shelligan Burn. Allt dos Mhuicarain usually had less dense populations of the species present in the Shelligan Burn and River Almond. Some differences between the faunas of the streams can be attributed to differences in the chemical composition of the streams and special features of Allt dos Mhuicarain.
5. Details of the seasonal changes in the numbers of *Leuctra inermis*, *Amphinemura sulcicollis*, *Isoperla grammatica*, *Ephemerella ignita* and *Rhithrogena semicolorata* caught in the three streams, and the seasonal changes in their biomass and size-frequency distribution in the Shelligan Burn are given. The sampling programme extended over three winters of differing severity, but no differences were found in the sizes attained in mid-February each year, by species of bottom fauna usually considered to grow during the winter months.
6. Riffle stretches make up the greatest part of the three streams examined, but there are pools of slower flowing water and, in the

Shelligan Burn, they constitute about 10% of the surface area. Riffles and pools of the Shelligan Burn were sampled in April and September. The riffles contained a higher numerical density of bottom fauna than the pools in the spring and in the autumn. There was no significant difference in the biomass densities of the bottom fauna in the two habitats. *Leuctra* spp. and *Baetis* spp. were several times more common in the riffles than in the pools. *Ecdyonurus* spp. were found in greater concentration in the pools than in the riffles in April, but were more concentrated in the riffles in September. The heavier, burrowing species such as *Dicranota* spp., other Tipulidae and *Eiseniella* spp. were more densely distributed in the pools than in the riffles. *Chloroperla torrentium* occurred in equal densities in the riffles and pools.

Zusammenfassung

1. Der Artikel behandelt die jahreszeitlichen Veränderungen der benthischen Organismen, deren Zusammensetzung, Anzahl und Gewicht an schnell fliessenden seichten Stellen in 3 Flüssen (Shelligan Burn, River Almond, Allt dos Mhuicarain) mit unterschiedlichen Eigenschaften. Von diesen 3 Flüssen hat der Shelligan Burn die höchste und der Allt dos Mhuicarain die niedrigste chemische Zusammensetzung und Vegetation. Der Almond hat ähnliche Eigenschaften wie der Allt dos Mhuicarain, jedoch die gelöste Eisenkonzentration ist höher.
2. Die Methode, welche angewendet wurde um Proben von der Fauna des Fluss-Grundes zu erhalten, wurde kritisch mit dem 'Surber Sampler' verglichen.
3. Der durchschnittliche Bestand der Boden-fauna, ausgedrückt in Trockengewicht pro m^2, war für den Shelligan Burn 2.88 g, für den Almond 0.93 g und für den Allt dos Mhuicarain 0.70 g. Das höchste Gewicht der Bodenfauna des Shelligan Burns wurde im Mai gefunden und das des Almonds in April und Mai, wenn ein grosser Teil der Organismen vor dem Ausschlüpfen an Grösse zunahm. Nach dem Ausschlüpfen fiel die Anzahl der Tiere um ein Viertel, jedoch das Gewicht der anwesenden Tiere fiel um die Hälfte. Im Shelligan Burn wurde die grösste Anzahl der Tiere im Juli und Februar gefunden.
4. Die Tierproben der 3 Flüsse wurden in 67 Gruppen eingeteilt, 37 davon waren Arten. 53 Gruppen wurden im Shelligan Burn gefunden, 45 im Almond und 49 im Allt dos Mhuicarain. 34 Gruppen, 17 davon Arten, wurden in jedem der 3 Flüsse gefunden.

   Die Fauna des Almonds war in der Zusammensetzung ähnlich

wie die des Shelligan Burns, jedoch quantitativ niedriger. Allt dos Mhuicarain hatte normalerweise eine weniger dichte Population der Arten welche im Shelligan Burn und im Almond vorkamen. Der Grund für einige Unterschiede zwischen den Tierwelten der 3 Flüsse kann in der chemischen Zusammensetzung der Flüsse und in den speziellen Eigenschaften des Allt dos Mhuicarain liegen.

5. Einzelheiten über die Anzahl der jahreszeitlichen Veränderungen von *Leuctra inermis*, *Amphinemura sulcicollis*, *Isoperla grammatica*, *Ephemerella ignita* und *Rhithrogena semicolorata*, welche in den 3 Flüssen gefangen wurden. Die jahreszeitlichen Veränderungen in deren Biomasse und deren Grössen-Häufigkeitsverteilung im Shelligan Burn sind angegeben. Das Programm für die Proben dehnte sich über 3 verschieden strenge Winter aus. Die Tiere, welche jedes Jahr in Mitte Februar gesammelt wurden, differierten nicht in der Grösse, obwohl angenommen wird, dass Arten der Bodenfauna meistens während der Wintermonate wachsen.
6 Die Flüsse, die untersucht wurden, waren überwiegend seicht mit schneller Strömung, aber es gab einige Stellen mit langsam fliessendem Wasser, wo eine Art von Teich entstand. Im Shelligan Burn nehmen diese Teiche ungefähr 10% der Oberfläche ein. Proben von seichten Stellen und Teichen des Shelligan Burns wurden im April und September unternommen. Die seichten Stellen enthielten im Frühling und Herbst eine grössere Anzahl an Bodenfauna als die Teiche. Es wurde kein bedeutender Unterschied in der Dichte der Biomasse der Bodenfauna an den beiden Stellen beobachtet. *Leuctra* spp. und *Baetis* spp. wurden viel öfter in den seichten Stellen beobachtet und *Ecdyonurus* spp. bevorzugten im April in grosser Anzahl die Teiche, jedoch im September die seichten Stellen. Die schweren sich eingrabenden Arten wie *Dicranota* spp., Tipulidae und *Eiseniella* spp. bevorzugten in grosser Anzahl die Teiche. *Chloroperla torrentium* war in gleicher Dichte in Teichen und seichten Stellen zu finden.

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