BIOLOGICAL INVESTIGATIONS IN THE REGULATED, UNREGULATED AND POLLUTED STREAMS OF THE DEE WATERSHED.

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor of Philosophy by:

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November 1974.

MISSING PRINT

ACKNOWLEDGEMENTS

I am grateful to Professor A.J. Cain, in whose Department this work was carried out, and especially to Dr. J.W. Jones, O.B.E. who suggested the problem and supervised the research.

I thank Mr. Williams, Mr. Lloyde, Mr. Barette, Mr. Alden, Mr. Davis and Mr. Franks for permission to take fish from their waters. I am also grateful to Captain G.H.A. Boyle, Mr. George Williams, Miss Dickson Barr and Miss J. Evans for their continued help in the field and at other times.

My special thanks go to the following for help of various kinds: Dr. J.O. Young for confirming the identifications of Turbellaria; Dr. E.G. Easton for Oligochaeta; Dr. A. Thomas and Dr. S. Prudoe for helminth parasites; Dr. Lewis Davis for Simulidae; Mr. Allan Brindle for Trichoptera, Coleoptera, Tipulidae and Dixidae; Dr. P.M. Kerney for Lamellibranchiata; Miss N.F. McMillan for Gastropoda, Mr. T. Gledhill for Hydracarina. My thanks also to Mr. R. Wagstaffe for suggesting useful laboratory techniques; Dr. J.C. Chubb for criticising the chapter relating to parasites; Dr. J.V. Woolland for providing trout stomachs from the feeder streams ; Dr. Jack Green and Mr. Yousuf for statistical advice, Dr. M. Abdullah for chemical analysis of water of the feeder streams and the Dee; Mr. D.J.Roberts for providing the data relating to rain fall and Mr. I.Bowland for chemical analysis of water of the River Alyn.

I am very grateful to Dr. R G.Pearson,Dr.A.E.J.Went, Dr. J.W.Banks and DR.P.G.Smith who have corrected the drafts and given helpful criticism.

My sincere thanks to Dr. D.R. Rothwell whose inspirational guidance has been a constant source of encouragement and support at all stages of the work.

Finally I must record my gratitude to the Water Resources Board for the award of a Research Studentship for two years.

SUMMARY

The studies presented in this thesis are divided into three sections, which are a part of a long-term investigation sponsored by the W.R.B.

Section I: The ecology of bottom fauna with reference to food and feeding habits of trout and salmon parr in five unregulated Llyn Tegid feeder streams.

Section II: The ecology of bottom invertebrates of regulated river Dee (upper Dee) and its comparison with unregulated Llyn Tegid feeder streams.

Section III: The ecology of the bottom fauna and biology of trout in polluted river Alyn.

The research undertaken in the five unregulated Llyn Tegid feeder streams was principally concerned with the ecology of benthic communities with particular reference to their seasonal variations and distribution according to different types of substrata. It was found that there is a gradual increase in number of Hirudinea, Lammellibranchiata, Amphipoda, Plecoptera, Ephemeroptera, Megaloptera, Trichoptera and Coleoptera from muddy and sandy bottom to the gravel and finally to the stony substrata with scattered vegetation. On the other hand the Oligochaeta, Gastropoda, Isopoda, Hydracarina, Hemiptera and Diptera were recorded more in the muddy and sandy bottom and less in gravel and stony bottom with scattered vegetation. Food and feeding habits which include composition of the diet, seasonal variation in food intake, seasonal changes in the food, food in relation to age, food availability, interspecific competition and utilization of the fauna were assessed in trout and salmon parr separately in each of the unregulated Llyn Tegid feeder streams. Very few trout and salmon parr were found to be infected by the tape worm (<u>Cyathocephalus truncatus</u>) in the anterior of intestine.

The bottom fauna of the regulated river Dee was examined and a comparison made between the benthic fauna of upper Dee and unregulated Bala feeder streams. It was noticed that Turbellaria, Hirudinea, Oligochaeta, Lamellibranchiata, Amphipoda, Isopoda, Hydracarina, Megaloptera and Coleoptera were apparently favoured by the regulation of the river Dee; whereas Gastropoda, Plecoptera, Hemiptera and Diptera were found relatively more in unregulated Bala feeder streams. There seems to be no effect of regulated or unregulated conditions of the river on Ephemeroptera.

Observations were made on the ecology of bottom invertebrates with particular reference to their distribution according to organic and industrial pollution in the river Alyn. I found the numbers of Oligochaeta, Hydracarina, Plecoptera, Ephemeroptera and Diptera (Dixidae, Ceratipogonidae, Tipulidae, Chironomidae and Simulidae) to be drastically reduced and the organisms belonged to Gastropoda, Lamellibranchiata, Amphipoda, Isopoda and Coleoptera showing dramatic increases immediately below the sources of pollution.

Amongst the other forms like Turbellaria, Hirudinea, Megaloptera, Hemiptera, and Trichoptera were relatively unaffected.

The age, growth, food and feeding habits, sexual maturation and movement of trout were studied. The changes in the fauna are reflected in the diet of the trout. There was a greater tendency to move upstream rather than down. Growth conditions for trout in the upper Alyn may be poorer than Llyn Tegid feeder streams and the upper Dee. The trout had consumed more food during summer and less in winter. The seasonal condition cycle increases to a maximum in July and declines thereafter. Gammarus seem to have become more popular items of the trout diet.

The endoparantes, Cystidicola ferionis from air bladder, Echinorhynchus truttae from intestine, Cyathocephalus truncatus from the region of blind caecae and Cucullanus truttae from stomach were recorded. 22.6% of the total trout were infected by Echinorhynchus truttae, 7.4% by C. farionis, 7.4% by C. trucatus, 5.3% by P. neglectus, 0.5% by Cucullanus truttae and 0.3% by M. truttae. The incidence and intensity of infestation gradually rises from 0+ to 4+ age groups in both sexes.

One species of helminth parasite C. truncatus was recorded from the trout and salmon parr of Afon Dyfrdwy and Afon Glyn, the unregulated Llyn Tegid feeder streams. Their frequency, number per host, percentage of trout infection, monthly and seasonal variation in the degree of infection and possible co-relation between percentage infection and age of the host and between parasite number and sex and state of maturity were also assessed.

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PART 1

CHAPTER I

INTRODUCTION

Since 1939 several investigators have worked on the biology of the fishes of Llyn Tegid (Lake Bala); notable among these are Williams (1939), Jones (1951, 1953, 1956), Dunn (1952), Ball (1957, 1961), Graham (1960), Hynes (1961), Chubb (1961), Pugh-Thomas (1959), Haram (1968), Siddiqui (1969) and Hunt (1970). Morris (1967) described the biology of Minnow, Loach and Bullhead in the Afon Llafar, a tributary to the lake; there is no well-documented information concerning the dynamics of bottom fauna and food habits of salmonids in any of the unregulated tributaries namely Afonydd: Llafar, Lliw, Dyfrdwy, Twrch, and Glyn of Llyn Tegid.

The effect of regulation on all aspects of the biology of water is the main purpose of the Dee Project and my work is a part of the work of a team of scientists. The River Dee, one of the finest salmon rivers in England and Wales was first regulated in 1956.

Before 1956, when the River Dee was not regulated, work was published by Carpenter (1940) about the feeding of salmon parr in the Cheshire Dee, and Badcock (1949) on the stream life of the Welsh Dee. There is no published work since regulation and my work is an attempt to find out some of the biology of regulated parts of the Dee catchment.

A knowledge of the major factors affecting the bottom fauna and fish is essential if we are to protect and enhance, if possible, the fishing resources of the river. The investigation described in part II of the present work arose out of the practical need for finding the possible effects of regulation on bottom invertebrates and food habits of salmonids and other fish.

The pollution of rivers and streams both by industrial effluents and by domestic and farm sewage is the greatest factor inimical to fish and other aquatic life. The first scientific examination of a river polluted by metallic salts and the effects of the pollution on invertebrates and fish was carried out by Carpenter (1924) in Aberystwyth district. Jones (1937, 1938) described the effects of zinc salts and other toxic substances on different aquatic invertebrates and fishes. Hynes (1965) showed the effects on biological communities of conditions in polluted streams.

I have looked at the possible effects of pollution on the biology of the brown trout (Salmo trutta), and on the distribution of bottom invertebrates, in the River Alyn, a polluted lowland main tributary of the Dee.

The purpose of this biological investigation of three different environments is to add to our understanding of the factors affecting the gross changes in the ecology of bottom invertebrates and food habits of salmonids in unregulated, regulated and polluted streams of the Dee Watershed which provide some notably good salmon, brown trout and coarse fishing.

CHAPTER II

SAMPLING METHODS

Several methods have been developed for taking quantitative samples of the bottom fauna of streams; for example the Petersen grap, the Eckman grab, Allan grab and Suber square-foot sampler. The effectiveness of the sampler varies especially with the nature of the bottom, the velocity of the water current and the depth of the water. Sampling is difficult especially in those streams where rocks can prevent the closing of the jaws of most grabs especially those used by Macan (1949), Surber (1937), Allan (1952), Kellen (1954), Mann (1965), and Larimore (1970).

In the present study Petersen and Allan grabs have been used to sample the benthic fauna quantitatively. None of these devices gave realistic estimates of benthic fauna in the substrate encountered. The need arose for a simple and light device to minimize the erros, so I designed a sampler which was found to be successful. This device is best suited to areas where the bottom is primarily stony and the water depth ranges up to 1 meter.

A. The Sampler

The sampler consists of six aluminium frames, four of which have a phosphor-bronze mesh of 30 meshes per inch

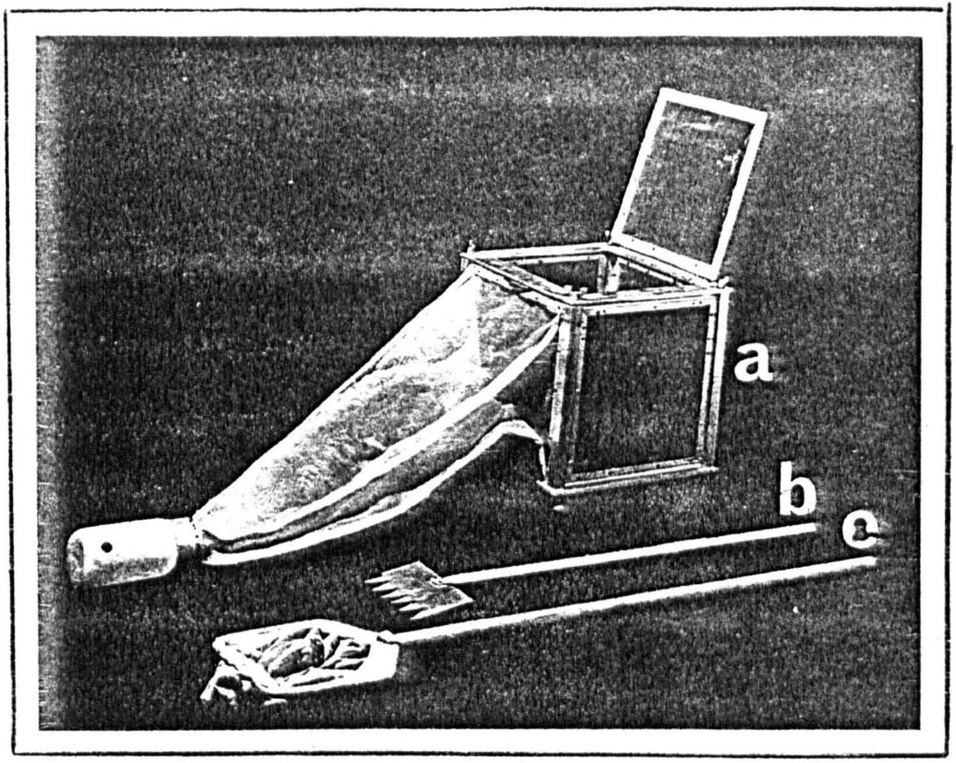

PLATE 2.1 (a) SQUARE FOOT BOX SAMPLER.
(b) STIRRER
(c) FBA POND NET.

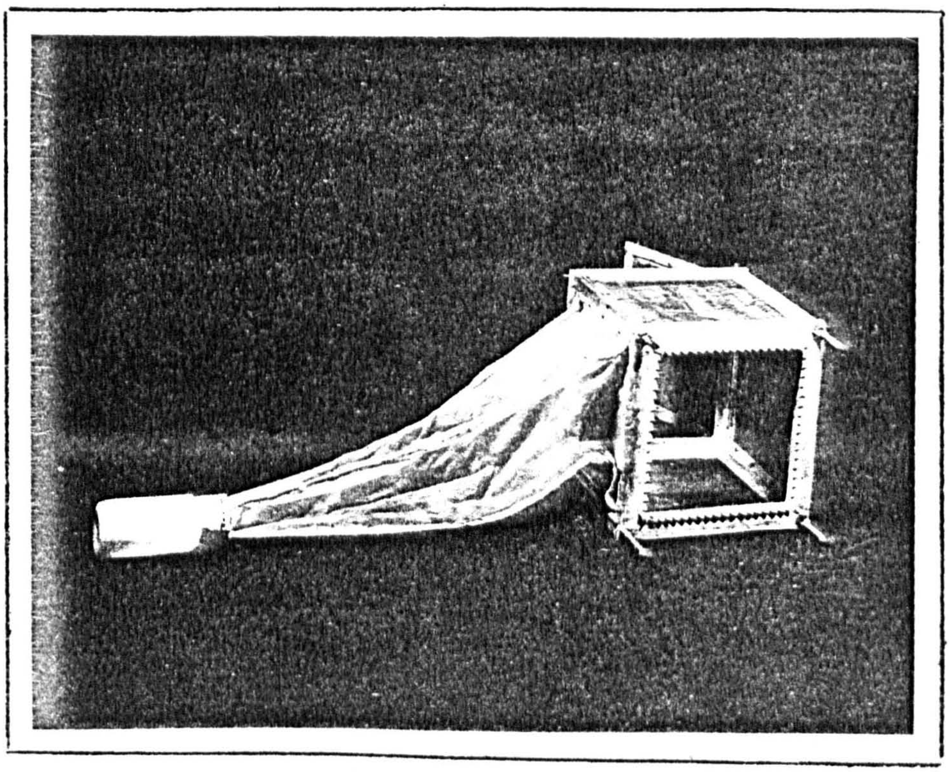

PLATE 2.2 SHOWING THE BOTTOM OF THE SAMPLER BOUNDED BY THE STRIPS OF CLAWS.

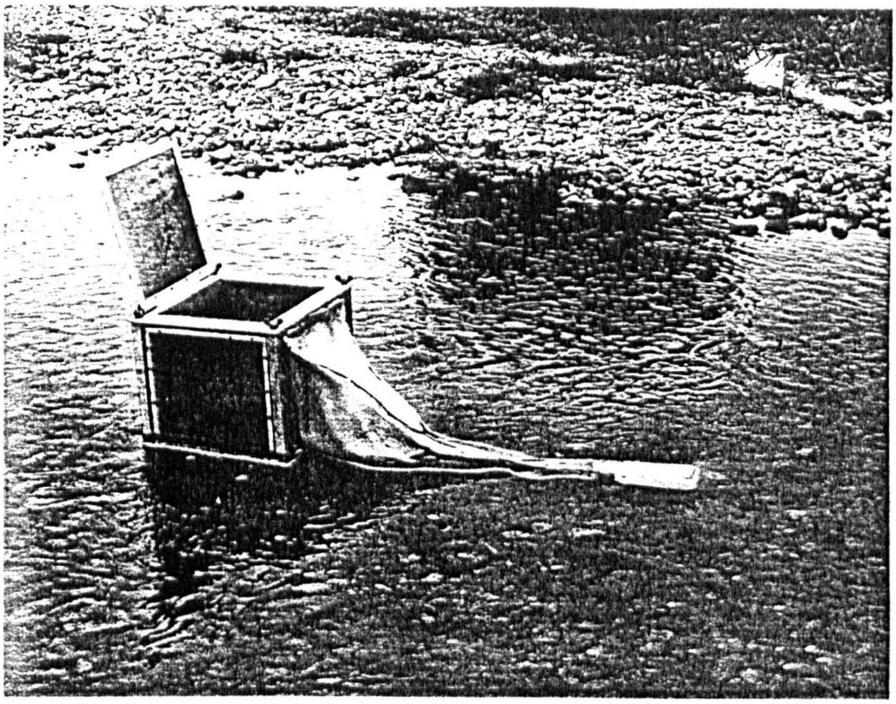

PLATE 2.3 FIXING THE SAMPLER ON THE STONY BED OF THE STREAM.

PLATE 2.4 STIRRING THE BOTTOM OF THE RIVER.

PLATE 2.5 'WASHING LIFTING' PROCESS USED IN GETTING ALL THE MATERIAL FROM THE NET INTO THE BOTTLE.

screwed on securely. Three of these frames are hinged and a tapering net of 30 meshes to an inch bolting silk, is attached to the fourth frame. At the narrow end of the net is a 70 mm screw to which is screwed a plastic bottle. The fifth side hinges over the top to act as a lid. Around the bottom of the box are a series of teeth 70 mm wide and about 85 mm deep. These are pushed into the river bed and anchor the sampler. No drifting organisms can enter the sampler. (Plate 2.1 and 2.2).

(a) Technique

A plastic jar was screwed to the net. The apparatus was lowered gently on to the river bottom without disturbing the silt and pushed into the river bed so that the net opens against the flow of the stream. The lid was opened and each large stone washed so that the fauna drifted into the net and then the stream bottom was gently stirred by hand so that the remaining fauna were dislodged and carried by the water current into the net. The finger raking was repeated twice more. (See Plate 2.3, 2.4 and 2.5).

B. Sorting and Preserving

Various methods have been tried to remove the benthic fauna completely from the debris by different workers, notably among them are Danials (1933), Moon (1935), Ledell (1936), Beak (1938) and Birkett (1957). Dunn (1961) modified Beak's (op cit) method by applying saturated

Magnesium sulphate solution repeatedly.

During this investigation I used Dunn's (op cit) technique for sorting the bottom fauna. The debris was emptied into a white enamel tray. Conspicuous forms were picked out and the mixture was stirred up and saturated solution was run in. The small forms floated at the surface together with a good deal of plant debris. The floating organisms could quickly and accurately be sorted out into main groups. The debris was repeatedly stirred and retreated with the solution until no more animals were obtained. Close inspection of the residue shows that this technique when carefully used leads to the collection of almost all the animals.

All organisms thus sorted out were presevd in 5% formalin with a small quantity of Borax to neutralize the formic acid which decolorizes the organisms (Wagstaffe, personal communication).

CHAPTER III

AFON LLAFAR

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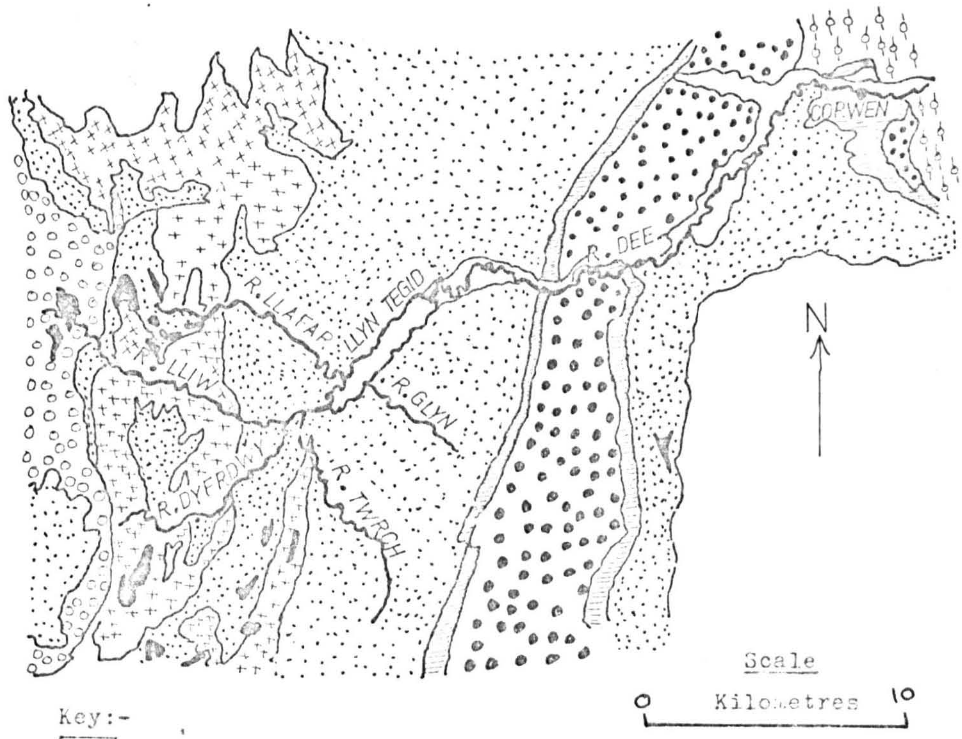

Key:-

- Felsite. Lime bostonite. Andesite.
- Hornblend and Glaucophae (Pre-Cambrian.)
- Bala(Ashgill and Caradoc)
- Ludlow bed, (Silurian.)
- Basalt; Dolerite and Diabase (Igneous rocks)
- Wenlock limestone (Silurian)
- Llandovery and Tarannon beds.
- Alluvium. River terraces and Peat (Recent)

Fig. 3.1 GEOLOGICAL SURVEY OF THE LLYN TEGID FEEDER STREAMS AND THE DEE UPTO CORWEN.

CHAPTER III

1. INTRODUCTION

A number of investigators have been working on the invertebrate life of the stream in different parts of the Dee Watershed, for example Edmonds (1939), Carpenter (1940), Badcock (1949), Dunn (1952), Hynes (1961) and Hunt (1970). None of these had studied unregulated Llyn Tegid feeder streams, so part of my work was undertaken in the lower and middle reaches of these streams, a zone which extends roughly two miles from the lake.

2. THE ENVIRONMENT

(a) General topography

Afon Llafar rises from the eastern slopes of Arenig Fawr 933m high and is fed by few tributary streams. It is one of the main tributaries of the lake. It enters the lake at its south eastern border after flowing through sandstones, mudstones with calcareous ashes and thin limestones which constitute collectively what used to be called 'Bala limestones' (Fig. 3.1). In parts the river drops steeply and fast; near the lake it flows more slowly. On either side of the river are farmlands devoted to the rearing of sheep and cattle.

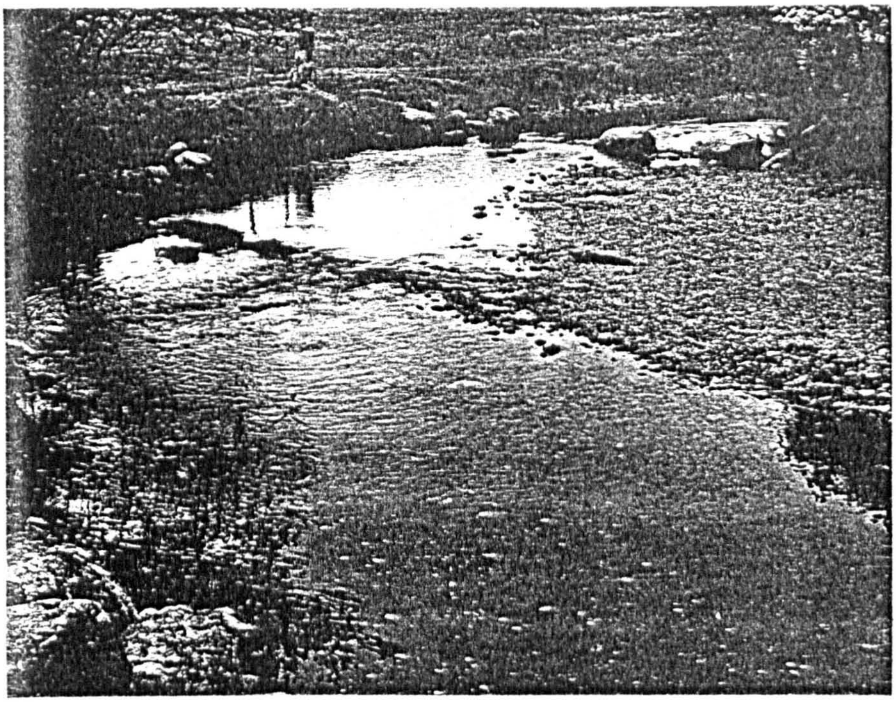

PLATE 3.1 SAMPLING STATION L1

PLATE 3.2 SAMPLING STATION L2

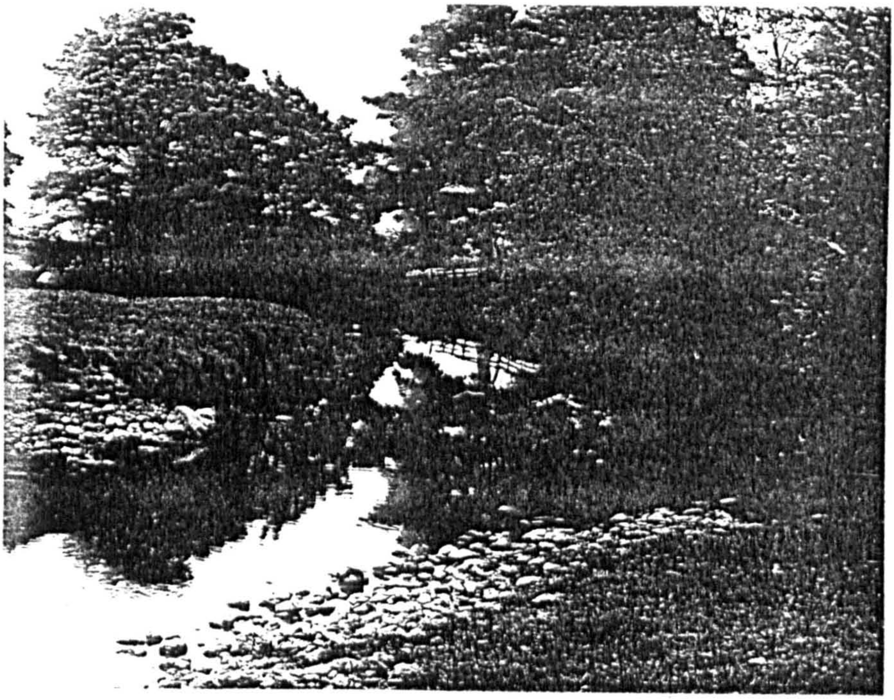

PLATE 3.3 SAMPLING STATION L3

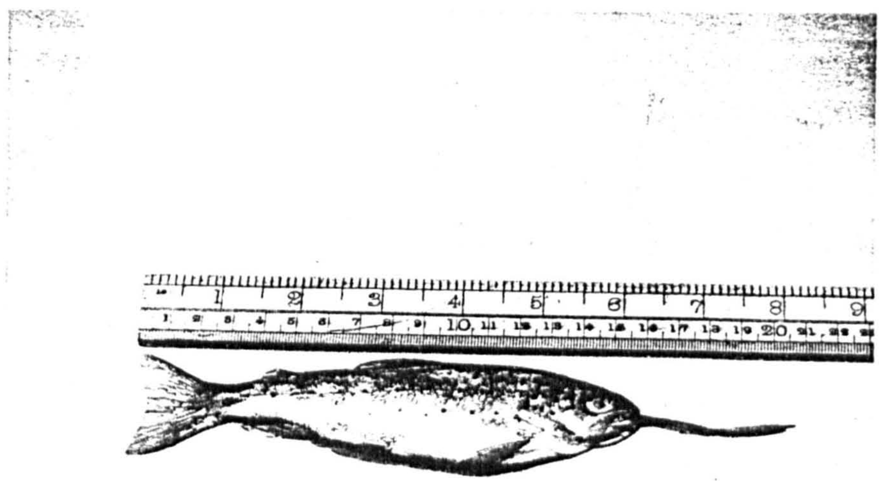

PLATE 3.4 TROUT EATING AQUATIC GRASS

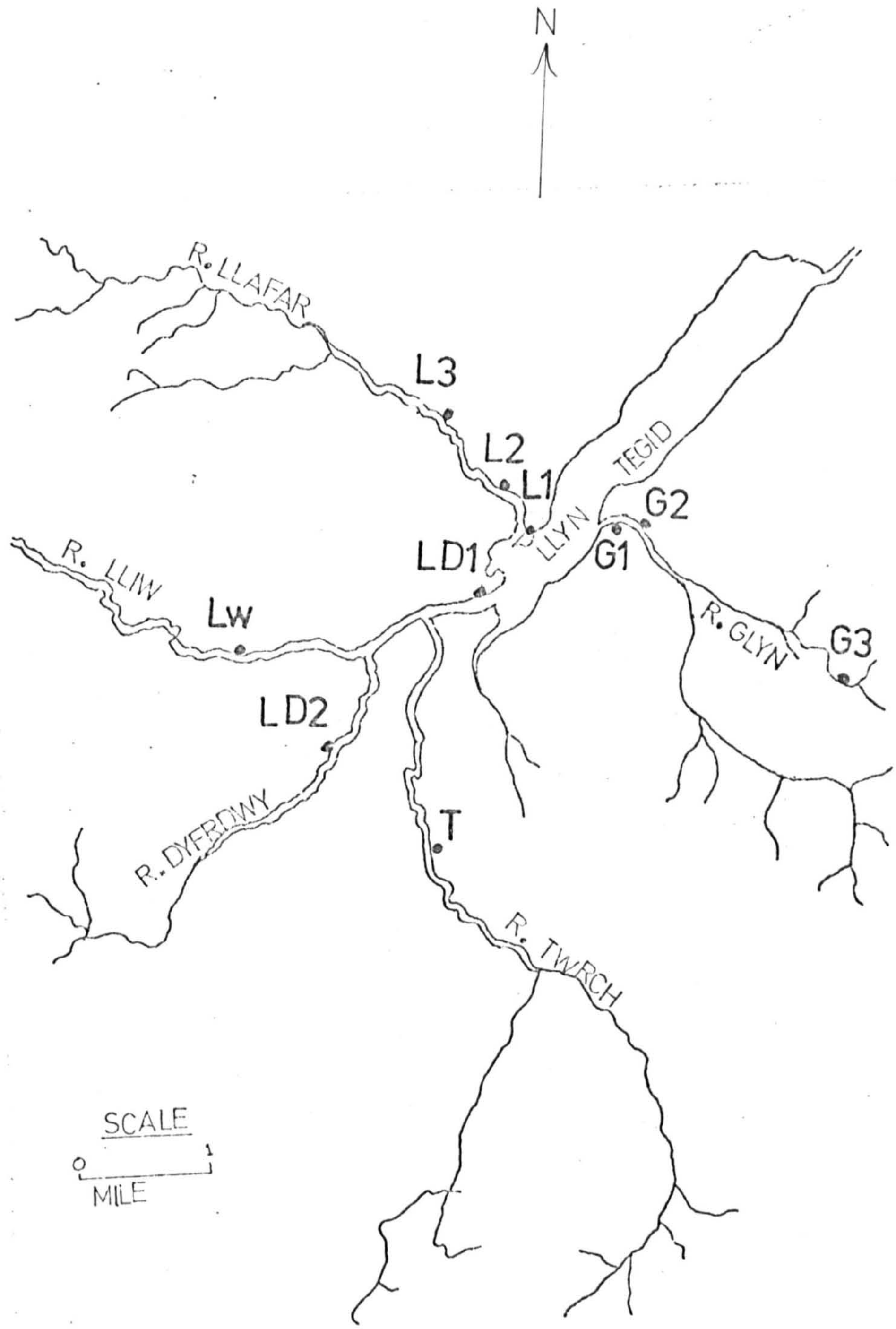

Fig.3.2 LLYN TEGID FEEDER STREAMS SHOWING SAMPLING STATIONS.

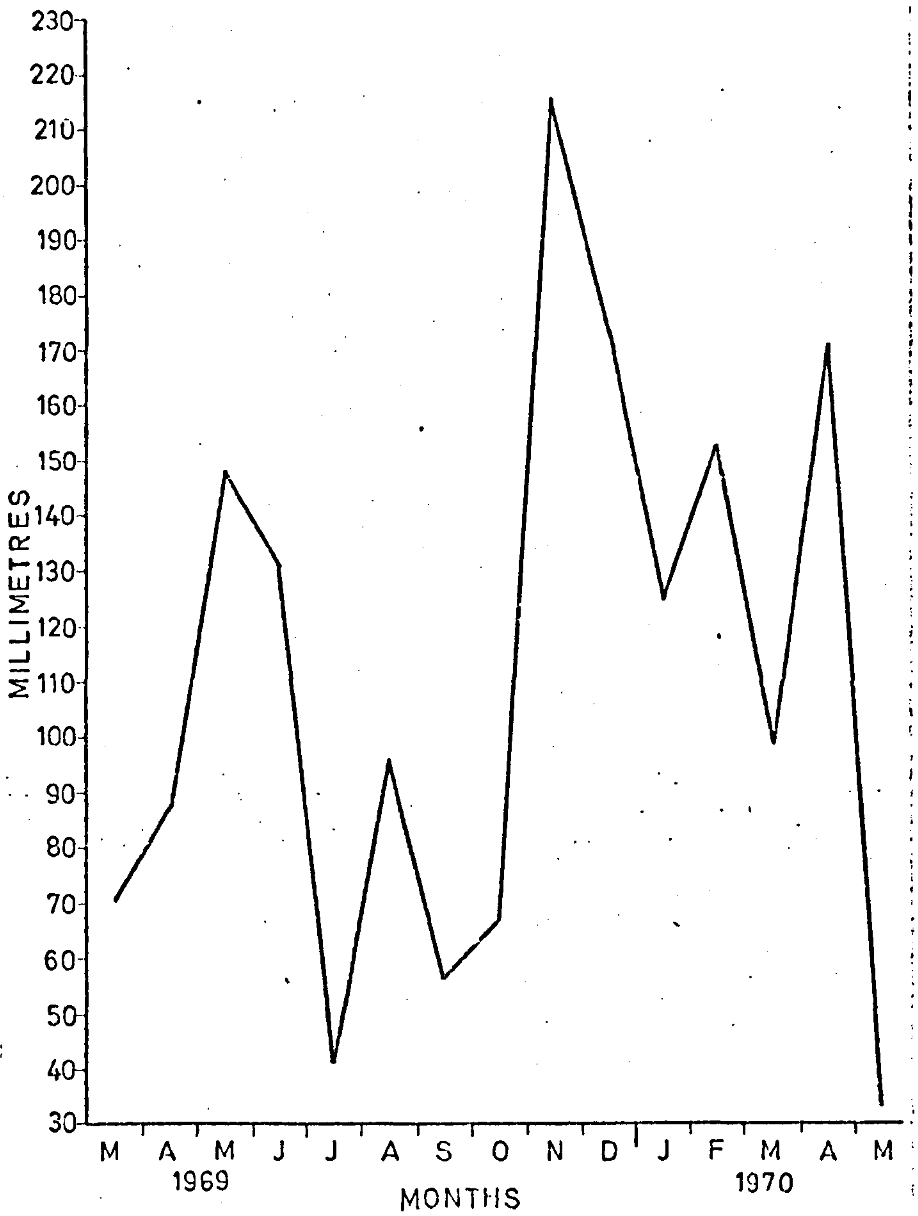

Fig. 3.3
Total rainfall around Lake Bala each month for the total period of observation at L1,L2,L3,Lw,LD1,LD2,T,G1,G2,G3, D1,D2,D3 and D4 stations.

Data was obtained from the Dee and Clwyd River Authority.

TABLE 3.1 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT L1 SAMPLING STATION IN AFON LLAFAR.

Months	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Water Temp. °C	4.8	7.2	7.5	14.4	14.6	15.5	8.4	7.5	5.4	4.2	4.4	4.5	7.2	7.8
pH	7.5	7.2	6.8	6.9	7.0	7.2	7.4	7.2	7.8	7.8	7.6	7.5	7.5	7.2
Specific conductance (micromhos / cm^3 at 25 °C)	183	216	210	198	119	288	309	285	460	415	440	310	212	201
Dissolved 02, % Sat.	98	101	112	118	105	98	102	95	93	98	97	110	107	101
Velocity of water current (m / sec)	0.26	0.19	0.23	0.13	0.11	0.14	0.23	0.29	0.75	0.71	0.66	0.60	0.53	0.41
Turbidity (as Fuller's Earth)	21.	20	24.	19	18.	28.	30.	27.	53.	97.	92.	80	71.	41

TABLE 3.2 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT L2 SAMPLING STATION IN AFON LLAFAR. (1969–70)

Months	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Water Temp. °C	4.8	7.2	7.5	14.4	14.6	15.5	8.4	7.5	5.4	4.2	4.4	4.5	7.2	7.8
pH	7.4	7.2	6.9	6.9	7.0	7.2	7.2	7.2	7.4	7.8	7.6	7.1	7.4	7.1
Specific conductance (micromhos / cm^3 at 25.°C)	62	101	88	73	75	83	112	120	285	301	298	321	120	82
Dissolved O2, % Sat.	111	103	98	95	94	103	97	98	105	102	105	101	97	98
Velocity of water current (m / sec.)	0.21	0.16	0.13	0.17	0.13	0.26	0.35	0.57	0.64	0.81	0.76	0.46	0.23	0.19
Turbidity (as Fuller's Earth.)	21.	20.	23.	18	18.	26.	30	25.	61.	87.	82.	90.	43.	20.

TABLE 3.3 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT L3 SAMPLING STATION IN AFON LLAFAR.
(1969–70)

Months	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Water Temp. °C	4.5	5.0	6.5	11.5	13.0	14.2	8.8	7.8	5.0	3.8	4.0	3.8	6.7	7.8
Specific conductance (micromhos / cm^3 at 25 °C)	65	68	72	77	81	87	101	121	240	308	278	301	132	87
Dissolved O2, % Sat.	95	101	94	98	97	103	96	93	101	111	104	106	84	99
Velocity of water current (m / sec.)	0.29	0.24	0.21	0.20	0.13	0.12	0.14	0.21	0.27	0.89	0.85	0.68	0.35	0.23
pH	7.1	7.0	6.8	6.9	7.0	7.2	7.4	6.8	7.2	7.4	7.4	7.3	7.2	7.1
Turbidity (as Fuller's Earth)	20	19.	22.	17.	17.	18.	28.	22.	53.	84.	78.	80.	40.	18.

(b) Description of the sampling sites

Site L_1 (Plate 3.1, Fig. 3.2) is located 16 metres before the stream joins the lake, at an altitude of 75 metres above mean sea level. Here the stream is 10 metres wide and 0.7 to 1m in depth when the river is not in flood. The stream bed is sand and gravel, and the water is normally clear. Aquatic plants, namely *Callitriche aquatica* and *Ranunculus fluitans* were found near the banks.

Site L_2 (plate 3.2, Fig. 3.2) is 0.804km upstream from the lake at an altitude of 177m O.D. Here the stream is 8m wide and 0.5m to 1.0m deep. The substratum is stony and there is no emergent vegetation near the banks.

Site L_3 (Fig. 3.2 and Plate 3.3) is 2.413km upstream from the lake at an altitude of 200m O.D. Here the stream is 12m wide and 0.3 to 0.5m deep. The bottom is stony and covered with moss *Fontinalis antipyretica*.

(c) Physical and Chemical conditions

The mountains of Merionethshire receive well over 2070mm of rain annually. The lake and its surroundings received a total of 1659mm of rain with an average of 110.6mm per month during the period of study (Fig.3.3). Mean monthly estimates of physical factors at L_1, L_2 and L_3 are shown in Tables 3.1, 3.2, 3.3. The water temperature showed a steady rise during the summer and a fall in winter.

TABLE 3.4 CHEMICAL ANALYSIS OF WATER.
Samples were taken at the depth of one meter in June 1969.

	UNREGULATED STREAMS.					REGULATED STREAM.
Name of the streams.	Afon Llafar	Afon Lliw	Afon Dyfrdwy	Afon Twrch	Afon Glyn	River Dee
Temp. C°	12.3	12.2	12.3	12.1	12.3	12.6
pH	7.1	7.0	7.1	7.2	7.3	7.3
Time	09.55	10.15	10.30	10.43	11.13	11.48
Cations.						
Calcium (Ca)	3.80	3.6	5.6	6.7	15.12	4.20
Magnesium (Mg)	5.59	0.48	1.58	1.33	3.02	1.21
Sodium (Na)	4.37	4.36	4.14	2.76	2.14	3.12
Potassium (K)	3.90	4.29	4.29	4.29	3.01	4.06
Iron, total as Fe	0.14	0.13	0.14	0.12	0.12	0.21
Anions						
Alkalinity (HCO3)	6.71	6.71	6.71	6.81	7.31	6.71
Carbonate (CO3)	5.6	5.78	6.23	6.84	8.21	5.21
Chloride (Cl)	6.72	4.95	4.95	4.60	5.31	4.95
Sulphate (SO4)	6.72	6.72	7.20	7.68	7.68	6.72
Nitrate (NO3)	1.24	1.86	1.86	1.68	1.67	2.84
TOTAL IONS	45.31	39.39	43.12	43.15	53.96	39.89

Results, except where stated otherwisw, as mg. per litre.

Table 3.5 The density of the bottom fauna at three sampling sites, based on 14 monthly samples (+ = <0.1%)

Sampling sites →	L1		L2		L3		Total
Bottom fauna ↓	%	Av.No /m²	%	Av.No /m²	%	Av.No /m²	%
Turbellaria	(-)	(-)	(0.3)	(5.3)	(-)	(-)	0.1
Polycelis nigra	-	-	0.3	5.3	-	-	
Hirudinea	(0.3)	(10.7)	(0.6)	(10.7)	(0.6)	(13.8)	0.5
Erpobdella octoculata	0.3	8.5	0.5	9.6	0.6	12.8	
Glossiphonia complanata	+	2.1	+	0.7	-	-	
Helobdella stagnalis	-	-	-	-	+	1.0	
Oligochaeta	(14.0)	(435.8)	(8.7)	(156.2)	(1.6)	(37.4)	8.2
Eiseniella tetrahedra	+	1.0	0.6	11.7	0.2	5.3	
Haplotaxis gordioides	-	-	+	0.7	-	-	
Limnodrilus hoffmeisteri	0.2	5.3	+	0.7	-	-	
Lumbriculus variegatus	1.4	44.9	0.6	10.7	0.2	5.3	
Peloscolex ferox	0.2	7.4	-	-	-	-	
Stylodrilus heringianus	12.2	376.6	7.3	130.5	1.1	18.1	
Gastropoda	(0.2)	(6.4)	(0.2)	(2.1)	(0.3)	(6.4)	0.2
Ancylastrum fluviatile	+	1.0	0.2	2.1	0.2	5.3	
Potamopyrgus jenkinsi	+	4.2	-	-	-	-	
Limnaea pereger	0.1	0.7	-	-	+	0.7	
Lamellibranchiata	(+)	(1.0)	(0.7)	(12.8)	(2.5)	(58.8)	1.1
Pisidium lilljeborgii	-	-	0.3	5.3	-	-	
Pisidium milium	+	1.0	0.4	7.4	0.2	4.2	
Pisidium subtruncatum	-	-	-	-	2.3	53.5	
Amphipoda	(-)	(-)	(0.4)	(7.4)	(0.1)	(2.1)	0.2
Gammarus pulex	-	-	0.4	7.4	0.1	2.1	
Isopoda	(2.1)	(62.2)	(1.2)	(21.4)	(-)	(-)	1.1
Asellus meridianus	2.1	62.2	1.2	21.4	-	-	
Hydracarina	(3.2)	(98.4)	(-)	(-)	(0.3)	(7.4)	1.1
Hygrobates nigromaculatus	3.0	94.1	-	-	0.2	4.2	
Lebertia porosa	0.1	4.2	-	-	0.1	2.1	
Plecoptera	(0.3)	(9.6)	(20.8)	(372.3)	(8.2)	(182.9)	9.8
Amphinemura standfussi	-	-	0.1	1.0	1.7	39.5	
Amphinemura sulcicollis	0.1	3.2	4.0	71.6	2.7	62.0	
Brachyptera risi	-	-	0.1	1.0	-	-	
Chloroperla torrentium	-	-	1.0	18.1	0.6	12.8	
Chloroperla tripunctata	+	0.7	0.1	1.0	1.4	33.1	

Table 3.5 (contd)

Sampling sites →	L1		L2		L3		Total
Bottom fauna ↓	%	Av.No/m²	%	Av.No/m²	%	Av.No/m²	%
Isoperla grammatica	-	-	0.4	7.4	1.0	21.4	
Leuctra fusca	-	-	0.1	1.0	+	0.7	
Leuctra hippopus	0.1	2.1	14.2	252.5	0.2	5.3	
Leuctra inermis	-	-	0.1	1.0	+	0.7	
Leuctra moselyi	-	-	0.1	2.1	-	-	
Leuctra nigra	+	1.0	0.1	2.1	+	1.0	
Nemoura erratica	+	0.7	-	-	-	-	
Nemurella picteti	-	-	-	-	+	0.7	
Protonemura meyeri	-	-	0.5	8.5	0.5	11.7	
Ephemeroptera	(0.1)	(3.2)	(11.2)	(202.2)	(8.1)	(189.3)	6.5
Baëtis pumilus	-	-	1.5	26.7	2.0	42.8	
Baëtis rhodani	-	-	2.3	40.6	1.6	37.4	
Baëtis scambus	-	-	0.3	5.3	1.0	21.4	
Caenis horaria	+	1.0	-	-	-	-	
Caenis moesta	+	0.7	-	-	+	1.0	
Centroptilum luteolum	+	0.7	3.3	59.9	0.1	3.2	
Ecdyonurus venosus	-	-	0.1	2.1	-	-	
Ephemerella ignita	-	-	1.8	32.1	2.7	64.2	
Heptagenia lateralis	-	-	0.1	2.1	0.1	3.2	
Heptagenia sulphurea	-	-	0.2	3.2	+	1.0	
Leptophlebia marginata	-	-	0.5	8.5	0.3	7.4	
Leptophlebia vespertina	-	-	0.4	7.4	-	-	
Paraleptophlebia submarginata	+	0.7	+	0.7	-	-	
Paraleptophlebia tumida	-	-	+	0.7	-	-	
Rhithrogena semicolorata	-	-	0.5	7.4	0.1	2.1	
Hemiptera	(32.0)	(988.6)	(8.1)	(144.5)	(0.1)	(2.1)	13.4
Corixa panzeri	-	-	-	-	0.1	2.1	
Micronecta poweri	31.4	969.2	8.0	142.3	-	-	
Sigara distincta	+	0.7	-	-	-	-	
Sigara dorsalis	+	2.1	-	-	-	-	
Sigara falleni	0.2	8.5	-	-	-	-	
Sigara venusta	+	0.7	-	-	-	-	
Sigara nymphs	0.2	5.3	0.1	2.1	-	-	
Valia spp.	+	2.1	-	-	-	-	
Megaloptera	(+)	(9.6)	(0.2)	(3.2)	(0.5)	(12.8)	0.2
Sialis lutaria	+	9.6	0.2	3.2	0.5	12.8	

Table 3.5(contd)

Sampling sites → Bottom fauna ↓	L_1 %	L_1 Av.No /m²	L_2 %	L_2 Av.No /m²	L_3 %	L_3 Av.No /m²	Total %
Trichoptera	(3.5)	(115.5)	(10.3)	(186.1)	(3.1)	(72.7)	5.8
Agapetus fuscipus	-	-	0.3	5.3	+	1.0	
Anabolia nervosa	0.1	3.2	-	-	0.2	4.2	
Glossoma boltoni	-	-	-	-	0.2	4.2	
Glyphotaelius pellucidus	2.5	79.1	5.6	95.9	1.0	21.4	
Halesus digitalus	-	-	1.2	21.4	-	-	
Hydropsyche fulvipes	-	-	-	-	+	0.7	
Hydropsyche instabilis	-	-	1.6	28.8	1.0	21.4	
Hydroptila tineoides	+	.0.7	+	0.7	0.2	4.2	
Limnephilus rhombicus	-	-	-	-	0.1	2.1	
Mystacides nigra	0.4	11.7	0.4	7.4	-	-	
Plectrocnemia conspersa	0.4	16.0	0.5	9.6	-	-	
Polycentropus flavomaculatus	+	0.7	-	-	+	1.0	
Potamophylax latipennis	-	-	0.3	5.3	0.1	3.2	
Rhyacophila dorsalis	-	-	0.2	2.1	-	-	
Sericostoma personatum	+	0.7	0.1	1.0	0.1	2.1	
Silo pallipes	-	-	-	-	0.1	3.2	
Tinodes waeneri	+	1.0	-	-	-	-	
Coleoptera	(1.6)	(55.6)	(6.7)	(121.9)	(10.7)	(251.4)	6.5
Deronectes depressus	1.0	29.9	+	0.7	-	-	
Gyrinus aeratus	+	0.7	-	-	-	-	
Haliplus lineatocollis	0.3	10.7	-	-	-	-	
Helmis maugei	+	1.0	1.2	21.4	3.5	81.3	
Helodes marginata	-	-	-	-	0.1	2.1	
Helophorus flavipes	-	-	+	0.7	-	-	
Hydroporus pubescens	0.1	3.2	-	-	0.1	2.1	
Hydraena riparia	-	-	-	-	+	0.7	
Laccobius biguttatus	-	-	0.2	2.1	-	-	
Latelmis volkmari	0.2	7.4	5.1	85.6	6.7	156.2	
Platambus maculatus	-	-	-	-	0.2	5.3	
Oreodytes rivalis	-	-	0.1	2.1	0.1	2.1	
Tipulidae	(0.1)	(2.1)	(0.3)	(5.3)	(0.4)	(9.6)	0.3
Tipula lateralis	0.1	2.1	0.2	3.2	+	1.0	
Tipula montium	-	-	0.1	2.1	0.3	7.4	

Table 3.5 (contd)

Sampling sites →	L_1		L_2		L_3		Total
Bottom fauna ↓	%	Av.No. /m^2	%	Av.No. /m^2	%	Av.No. /m^2	%
<u>Ceratopogonidae</u>	(1.3)	(40.6)	(1.4)	(26.7)	(0.4)	(9.6)	1.0
Bezzia spp	1.3	40.6	1.4	26.7	0.4	9.6	
<u>Chironomidae</u>	(39.0)	(1166.8)	(23.6)	(424.7)	(32.4)	(1309.6)	40.2
Brillia modesta	-	-	0.2	4.2	+	0.7	
Criptochironomus spp.	-	-	2.4	43.8	1.7	39.5	
Dicrotendipes pulsus	-	-	-	-	0.5	10.7	
Endochironomus spp.	-	-	-	-	2.6	60.9	
Microtendipes chlories	-	-	0.2	4.2	-	-	
Metriocnemus atratulus	16.8	522.1	-	-	-	-	
Pentaneura monilis	1.0	25.6	3.3	59.9	6.8	157.2	
Procladius choreus	0.4	14.9	0.7	12.8	1.0	19.2	
Prodiamesa olivacea	0.4	16.0	11.6	205.4	6.0	136.9	
Polypedilum nubeculosus	17.5	540.3	4.0	71.6	6.6	154.0	
Sergentia coracinus	0.1	4.2	-	-	-	-	
Stictochironomus spp.	+	1.0	-	-	-	-	
Tanytarsus signatus	0.1	5.3	1.0	19.2	26.7	616.3	
Trichocladius rufiventris	1.2	37.4	-	-	4.7	109.1	
<u>Simulidae</u>	(+)	(1.0)	(1.2)	(21.4)	(1.8)	(42.8)	1.0
Simulium aureum	-	-	-	-	+	0.7	
Simulium brevicaule	-	-	0.2	3.2	0.2	5.3	
Simulium monticola	+	1.0	0.8	16.0	1.5	34.2	
Simulium morrsitans	-	-	+	0.7	-	-	
Simulium naturale	-	-	+	0.7	-	-	
Simulium ornatum	-	-	+	0.7	+	0.7	
Prosimulium arvernense	-	-	-	-	+	1.0	
<u>Other dipteran larvae</u>	(+)	(2.1)	(1.8)	(34.2)	(1.6)	(37.4)	1.1
Dicranota robusta	+	2.1	1.0	19.2	1.0	21.4	
Hermerodromia unilineata	-	-	0.4	6.4	0.4	9.6	
Limnophora spp.	-	-	-	-	0.1	2.1	
Limnophila verralli	-	-	+	0.7	-	-	
Pericoma pseudoexquisita	-	-	0.4	6.4	-	-	
Taphrophila vitripennis	-	-	-	-	0.1	3.2	
<u>Dipteran pupae</u>	1.4	44.9	1.7	29.9	1.7	39.5	1.6
Total no. of animals in sample	4024		2327		3019		
Av. no. animals/month	287.4		166.2		215.6		
Av. no. animals/m^2	3075.1		1778.3		2306.9		

pH values, taken by means of a portable pH meter, varied from 6.8 at low water to 7.8 at high. Dissolved oxygen taken by a D.O. Meter at the depth of 0.4 - 0.7m ranged from 94.0% to 118% saturation. A flow meter was used to record the velocity of the water (m/sec) at each site. A conductivity meter was used to obtain the specific conductance (micromhos/cm^3 at 25°C) of water each month at each sampling station. Turbidity was measured by comparing the sample with standard solutions of various graded values of silica (Fuller's Earth) in distilled water.

A water sample taken from station L_2 in June 1969 was stored in a polythene bottle and analysed within a short time after being taken. The results are summarized in Table 3.4.

As the rocks in the valley are hard and non-calcareous it is not surprising that the water is exceedingly poor in dissolved salts.

3. COMPOSITION OF THE FAUNA

Table 3.5 shows the constituents of the fauna in each of the three sampling sites examined. It is apparent from this, that at the taxonomic level at which it was identified, the small invertebrate fauna was similar at every station, and characteristic of small fast flowing stony hill stream of North Wales. A fall in the total number of animals

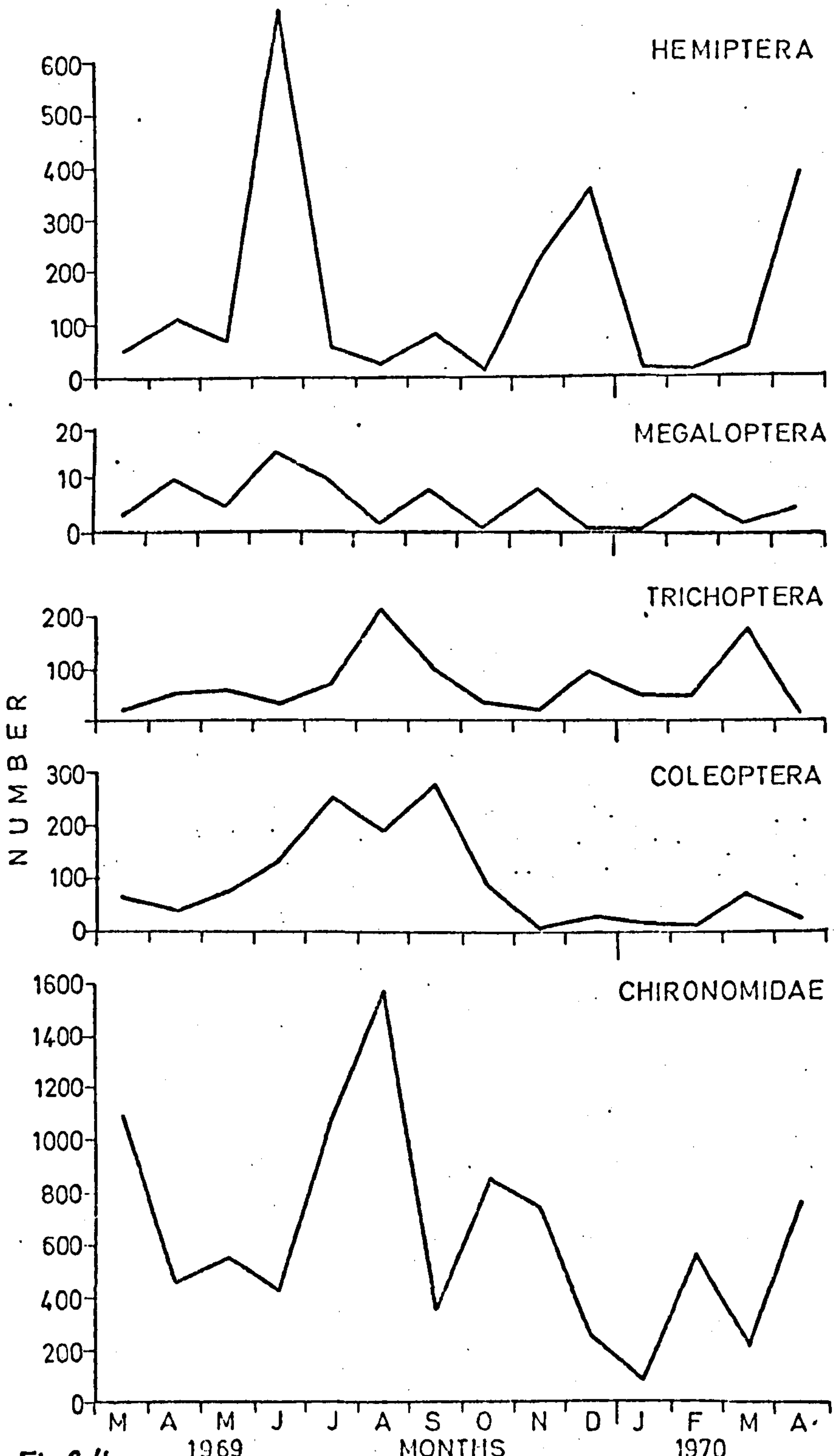

Fig. 3.4
Seasonal variations in the numbers of different groups of bottom fauna

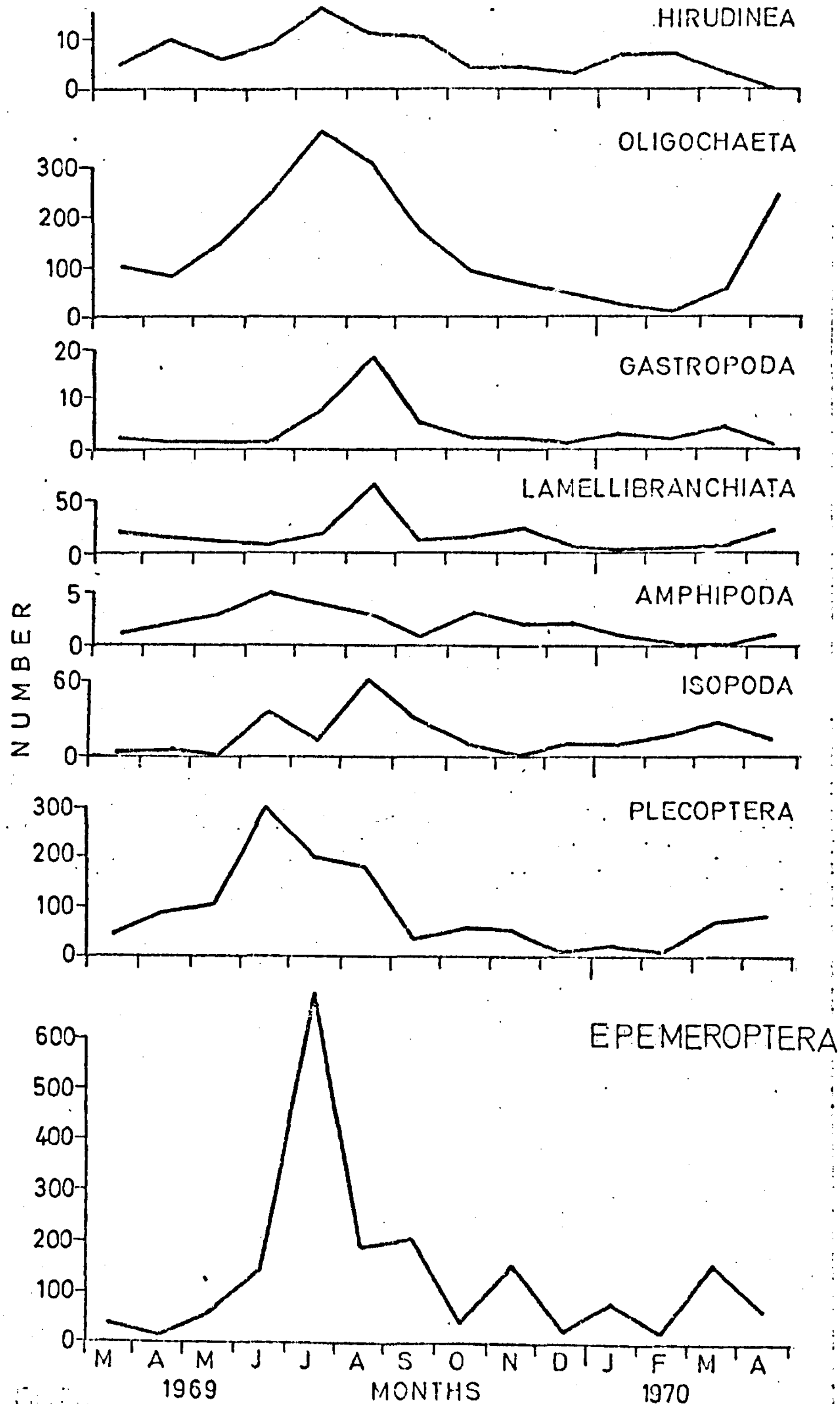

Fig. 3.5 Seasonal variations in the numbers of different groups of bottom fauna

during winter months and rise during spring and summer was found at each of the three stations (Fig. 3.4, 3.5). Humphries and Frost (1937), Frost (1942) showed a steady downward trend during late winter and early spring. Badcock (1949) and Hynes (1961) said that the minimum numbers during winter and autumn were due to the emergence of most of the mayflies and stoneflies and their young were too small to be retained by the net.

The stream harbours a rich and varied fauna. The total number of species recorded at L_1 where the bottom is sandy, was 137, 163 at L_2 where the substrate is of stones and finally 159 at L_3 where the substrate is stony and covered with moss. There was a significant difference in the density of oligochaetes at L_1, L_2 and L_3 ($P<0.05$). The common animals were chironomid larvae, nymphs of stoneflies and mayflies, caddis larvae, oligochaetes, Coleoptera and Hemiptera. The following groups of the benthic animals were collected during the study (Table 3.5).

A. Platyhelminthes

(1) Turbellaria

This group constituted 0.1% of the total fauna and was represented by one species *Polycelis nigra*.

B. Annelida

(1) Hirudinea

This group formed 0.5% of the total benthic fauna and was represented by three species, *Erpobdella octoculata* was found in all the sampling sites and Helobdella stagnalis at L_2 and L_3.

(2) Oligochaeta

Species of this group formed 8.2% of the total fauna, and were very common at all the sampling sites. Haplotaxis gordioides and Peloscolex ferox were rare.

C. Mollusca

(1) Gastropoda

Only four species were recorded of which Ancylastrum fluviatile was common and Limnaea pereger and Potamopyrgus jenkinsi were rare.

(2) Lamellibranchiata

This group formed 1.1% of the total animals. Pisidium subtruncatum and Pisidium milium were common in the upper reaches and Pisidium lilljeborgii was rare.

D. Arthropoda

(1) Crustacea

(a) Amphipoda

Gammarus pulex was rare and formed 0.2% of the total benthos.

(b) Isopoda

Asellus meridianus constituted 1.1% of the total fauna. They were common at L_1 and L_2 and rare at L_3 sites. They did not seem to occur on or under the stones covered with moss. Their absence according to Hynes (1961) may be related to the scarcity of their food.

(2) Arachnida

(a) Hydracarina

These formed 1.1% of the total fauna. Hygrobates nigromaculatus and Lebertia porosa were rare at L_1 and L_2 stations.

(3) Insects

(a) Plecoptera

The species listed in the Table 3.5 were widely distributed in the stream and formed 9.8% of the total benthic fauna. Amphinemura sulcicollis, Chloroperla torrentium and Leuctra hippopus were common at L_2 and Amphinemura standfussi, Amphinemura sulcicollis, Chloroperla tripunctata and Isoperla grammatica were common at L_3.

(b) Ephemeroptera

The ecological factors affecting the nymphal environment have the greates effect on the distribution of mayflies. The early instars in the stream were found in vegetation or detritus. As the nymphs grew they moved from the vegetation to the stones to avoid entanglement. The species listed in the Table 3.5 formed 6.5% of the total benthic fauna.

Baetis spp. Centroptilum luteolum and Ephemerella ignita were common at L_2 and Baetis spp. Ephemerella ignita were common at L_3.

(c) Hemiptera

These formed 13.4% of the total bottom fauna in which Micronecta poweri was common at L_1 and L_2 and the rest of the species mentioned in Table 3.5 were rare.

(d) Megaloptera

This group was represented by Sialis lutaria and formed 0.2% of the total bottom fauna.

(e) Trichoptera

This group constituted 5.8% of the total organisms. Glyphotaelius pellucidus was common at L_1, L_2 and L_3 and and Hydropsyche instabilis was common at L_2 and L_3. I found predatory species like Polycentropus flavomaculatus in the stony beds as did Slack (1936).

(f) Coleoptera

Laccobius biguttatus is a lake dwelling species but it was found at L_2, probably as a result of the water level fluctuation of the lake; 6.5% of the benthic fauna was composed of coleopterans. Helmis maugei and Latelmis volkmari were common at all the stations (Table 3.5).

(g) Diptera

Chironomid larvae formed 40.2% of the total fauna and were identified as far as possible (Table 3.5).

Other dipteranlarvae that belonged to family Tipulidae, Dixidae, Psychodidae, Limnobiidae, Ptychopteridae, Stratiomyidae, Dolichopodidae and Empididae were identified to species; this has not been done by previous workers and my identifications were confirmed by Mr. Allan Brindle of the Manchester Museum.

Similarly the simuliid larvae were not identified to species by others working in the Dee watershed. I have done this in the present study and the identifications were confirmed by Dr. Lewis Davies of Durham University (see Table 3.5).

4. THE FEEDING OF SALMONIDS

(a) Introduction

Food of the trout and salmon parr have been studied by a number of previous investigators notably Frost (1939, 1945, 1950); Neil (1938); Allen (1938, 1941); Frost and Went (1940); Ball (1961); Graham and Jones (1962); Thomas (1962) and Wooland (1972). The food consists chiefly of aquatic insect larvae, Crustacea, Mollusca and Annelida. Until recently no study has been made of the food and feeding behaviour of salmonids in Llyn Tegid feeder streams, although general biology other than feeding has been investigated by Wooland (1972). The results presented in the present work are intended to give additional information

Table 3.6 Number of brown trout examined for food in all Llyn Tegid feeder streams.

SWF = Stomach with Food; ES = Empty Stomach

	Streams →	L		LW		LD		T		G	
	Total No. Fish→	81		113		120		63		101	
Total	Months ↓	No. SWF	No. ES	No. SWF	No. ES	No. SWF	No. ES	No. SWF	No. ES	No. SWF	No. ES
27	November 1968	-	-	13	-	14	-	-	-	-	-
25	December	-	-	23	2	-	-	-	-	-	-
16	January 1969			3	3					10	-
21	February	3	1	-	-	3	1	9	4	-	-
43	March	-	-	18	1	13	-	-	-	10	1
23	April	10	1	-	-	-	-	-	-	12	-
38	May	5	-	11	1	15	-	5	-	1	-
16	June	4	-	-	-	-	-	-	-	12	-
49	July	9	-	6	-	12	-	17	-	5	-
12	August	2	-	-	-	-	-	-	-	9	1
74	September	17	-	21	1	16	3	5	-	10	1
19	October	9	-	-	-	5	-	-	-	5	-
49	November	8	-	8	1	13	2	11	-	5	1
4	December	-	-	-	-	-	-	-	-	4	-
27	January 1970	2	-	-	-	12	1	2	-	10	-
6	February	3	-	-	-	-	-	-	-	3	-
31	March	9	-	1	-	10	-	8	2	-	1
	Total	79	2	104	9	113	7	57	6	96	5

Total No. of trout in all Llyn Tegid feeder streams = 465
Total with empty stomachs = 29
Total examined for food = 436

L = Llafar, Lw = Lliw, LD = Dyfrdwy, T = Twrch, G = Glyn.

Table 3.7 Number of salmon parr examined for food in all Llyn Tegid feeder streams.

SWF = Stomach with food : ES = Empty stomach

	Streams →	L		Lw		LD		T		G	
	Total No. Fish→	136		93		122		77		123	
Total No.	Months ↓	No. SWF	No. ES	No. SWF	No. ES	No. SWF	No. ES	No. SWF	No. ES	No. SWF	No. ES
12	November 1968	-	-	1	-	11	-	-	-	-	-
24	December	-	-	21	3	-	-	-	-	-	-
13	January 1969	-	-	-	-	-	-	-	-	8	5
38	February	19	2	-	-	4	4	9	-	-	-
31	March	-	-	10	-	10	-	-	-	11	-
14	April	8	-	-	-	-	-	-	-	6	-
50	May	3	-	10	-	26	-	7	-	3	1
22	June	10	-	-	-	-	-	-	-	12	-
65	July	10	-	12	-	16	-	16	-	10	1
19	August	9	-	-	-	-	-	-	-	10	-
64	September	9	-	9	3	27	-	10	-	6	-
16	October	11	-	-	-	1	-	-	-	4	-
59	November	14	1	9	2	5	4	12	3	9	-
25	December	11	2	-	-	-	-	-	-	10	2
51	January 1970	13	1	7	-	8	1	11	1	8	1
15	February	9	-	-	-	-	-	-	-	6	-
39	March	10	-	3	3	5	-	7	1	6	4
	Total	130	6	82	11	113	9	72	5	109	14

Total No. of salmon parr in all Llyn Tegid feeder streams = 537

Total with empty stomachs = 45

Total examined for food = 492

on the feeding habits of salmonids.

The feeding of salmonids from Afon Llafar was studied at monthly intervals for a period of 14 months beginning in February 1969 and ending in March 1970. A total of 81 trout and 136 salmon parr stomachs were collected for food analysis; of these 2 trout and 6 salmon parr stomachs were found to be empty (Table 3.6,3.7).

(b) Material and Methods

The pharynx leads by a short gullet into a 'U'-shaped stomach consisting of a wide cardiac and a narrow pyloric division. A sphincter separates the pyloric division from the pyloric caecae. The contents of the stomach up to the sphincter were examined.

The wall of each stomach was slit open and the amount of food, or "the degree of fullness" was recorded in the following terms : "distended", "full", "$\frac{3}{4}$ full", "$\frac{1}{2}$ full", "$\frac{1}{4}$ full", "T (traces)", and "E (empty)", then the points were allotted in the following manner.

Visual estimation of fullness			Points
Distended	:	The stomach extended with food	5
Full	:	Food filling the stomach	4
$\frac{3}{4}$ full	:	Food filling three quarters of the stomach	3
$\frac{1}{2}$ full	:	Food filling about half of the total volume of the stomach	2

Table 3.8 The fullness index and the percentage of stomach of trout and salmon parr containing food as shown by two-monthly samples.

Period	Trout		Salmon parr	
	Percentage of stomach containing food	Fullness index	Percentage of stomach containing food	Fullness index
Feb/Mar	66.6	0.4	89.4	1.0
Apl/May	93.3	3.5	100	3.2
June/July	100	3.8	100	3.5
Aug/Sept	100	3.4	100	3.0
Oct/Nov	100	2.5	96.0	1.6
Dec/Jan	100	1.5	87.5	1.0
Feb/Mar	100	2.8	100	2.4

Visual estimation of fullness			Points
¼ full	:	Food occupying about one quarter of the total volume	1
T	:	Traces of food items in the stomach	0.5
E	:	Stomach collapsed, no food present	0

The visual estimation of fullness was made in accordance with the widely used classification established by Ball (1961).

'Points' were allocated to each sample and the mean number of points per stomach per sample was calculated. The resulting figure was termed the "Fullness Index" (Table 3.8). The degree of fullness of the stomach was estimated by a points system similar to that used by Graham and Jones (1962), Morris (1966), Sinha (1965), Siddiqui (1969), Hunt (1970) and Woolland (1972).

Each stomach was first studied as a unit. The contents were removed and sorted under a low power binocular microscope into various taxonomic categories (Tables 3.9, 3.12). In addition to the fullness method, three standard methods of food analysis, namely occurrence, volume and number, as reviewed by Hynes (1950) were used.

The food items were recorded in the following manner.

The total number of stomachs in which each food item occurred was listed as a percentage of the number of

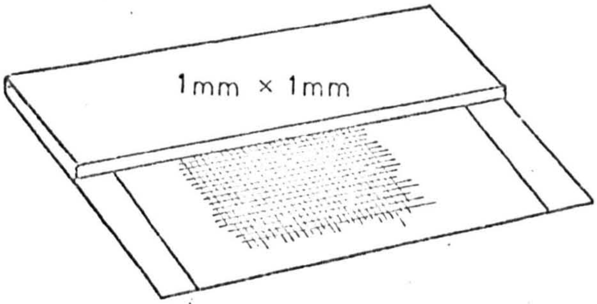

Fig.3.6 The volume scale used to estimate the volume of food items in each stomach

occurrences of all items to show the percentage composition of the diet (occurrence method).

The total numbers of individuals of each food item were counted individually and expressed as percentages of the total number of organisms found in all stomachs examined (number method).

The volume in cubic millimetres was then found using a method devised by Chubb (1961). Each particular group of organisms was separately piled into a grid marked off in square millimetres and pushed against a step which was one millimetre in height. The food was then levelled by means of a glass slide and the volume in cubic millimetres was then recorded (Fig. 3.6). For bigger food items like tipulid larvae, caddis cases or larvae and fish volume was determined by water displacement.

The percentage representation by occurrence, number and volume of all the food items was calculated. The occurrence method shows the percentage of occurrence of each food category in all the stomachs examined. The number and volume methods express the percentage composition of each food by number/volume in the total number/volume of food eaten.

For convenience, various stomach contents were divided into four categories: terrestrial and aerial food, midwater food, benthic food and miscellaneous food. Terrestrial and

Table 3.9 The total annual composition of the diet of 81 trout assessed by Occurrence, Volume and Number methods. (+ = <0.1%).

	Average percentage represented in total sample by:		
Food organisms	Occurrence	Volume	Number
Benthic food			
Lumbriculus spp.	0.6	0.6	1.4
Ancylastrum fluviatile	1.4	0.8	1.1
Limnaea pereger	1.0	0.2	0.7
Amphinemura sulcicollis	1.3	0.5	1.5
Leuctra spp.	0.3	+	0.1
Chloroperla spp.	0.7	0.1	0.4
Baetis rhodani	10.3	6.2	11.4
Ephemerella spp.	6.4	6.1	8.2
Leptophlebia marginata	4.1	2.1	4.6
Caenis spp.	1.7	0.3	1.0
Other Ephemeroptera nymphs	2.3	1.9	2.1
Glyphotaelius spp.	10.1	11.1	7.3
Plectrocnemia conspersa	4.2	8.5	7.4
Hydropsyche spp.	2.0	4.1	3.2
Other Trichopteran larvae	2.1	2.0	1.1
Chironomid larvae	6.0	2.1	7.5
Simuliid larvae	1.9	0.7	1.9
Simuliid pupae	1.7	0.7	1.6
Other dipteran larvae	1.7	0.3	0.9
Helmis maugei	1.4	0.4	1.3
Midwater food			
Hygrobates spp.	0.1	+	+
Micronecta spp.	0.5	+	0.1
Helmis maugei adults	1.1	0.5	0.5
Latelmis volkmari adults	0.7	0.4	0.4
Fish	2.0	15.8	1.8
Aerial and Terrestrial food			
Aerial and Terrestrial insects	23.0	31.8	25.5
Miscellaneous food			
Plant materials	4.1	2.2	2.5
Stones	6.1	3.0	2.1
Total	99.8	99.4	99.6

aerial food included any food item originating outside the river. Midwater food, a less well-defined category, included the adult forms of water bugs, beetles and mites and fish. The benthic component included those organisms that spend the majority of their time on the bottom of the stream. This included the permanent bottom dwellers (snails, clams and oligochaetes) and the transient population of juvenile aquatic insects. Finally the miscellaneous food included the stones of the caddis cases and plant materials.

(c) Results

(a) Brown trout

(i) Composition of the diet

Table 3.9 shows the composition of the diet of trout from February 1969-March 1970. The most important dietary items from the benthic food were Ephemeroptera nymphs, Trichoptera and chironomid larvae. The oligochaetes, gastropods, Plecoptera nymphs, Hemiptera, Coleoptera adults and larvae and dipteran larvae are not major food items. Terrestrial and aerial insects, which included Aphididae, Chloropidae, Nabidae, Miridae, Empidae and their larvae, were important food items subject to availability. Midwater food items like Hydracarina, Hemiptera, Coleoptera and fish are less important and occurred in 0.1%, 0.5%, 1.8% and 2.0% of the total stomachs respectively. The miscellaneous food, which includes stones of the caddis cases and plant

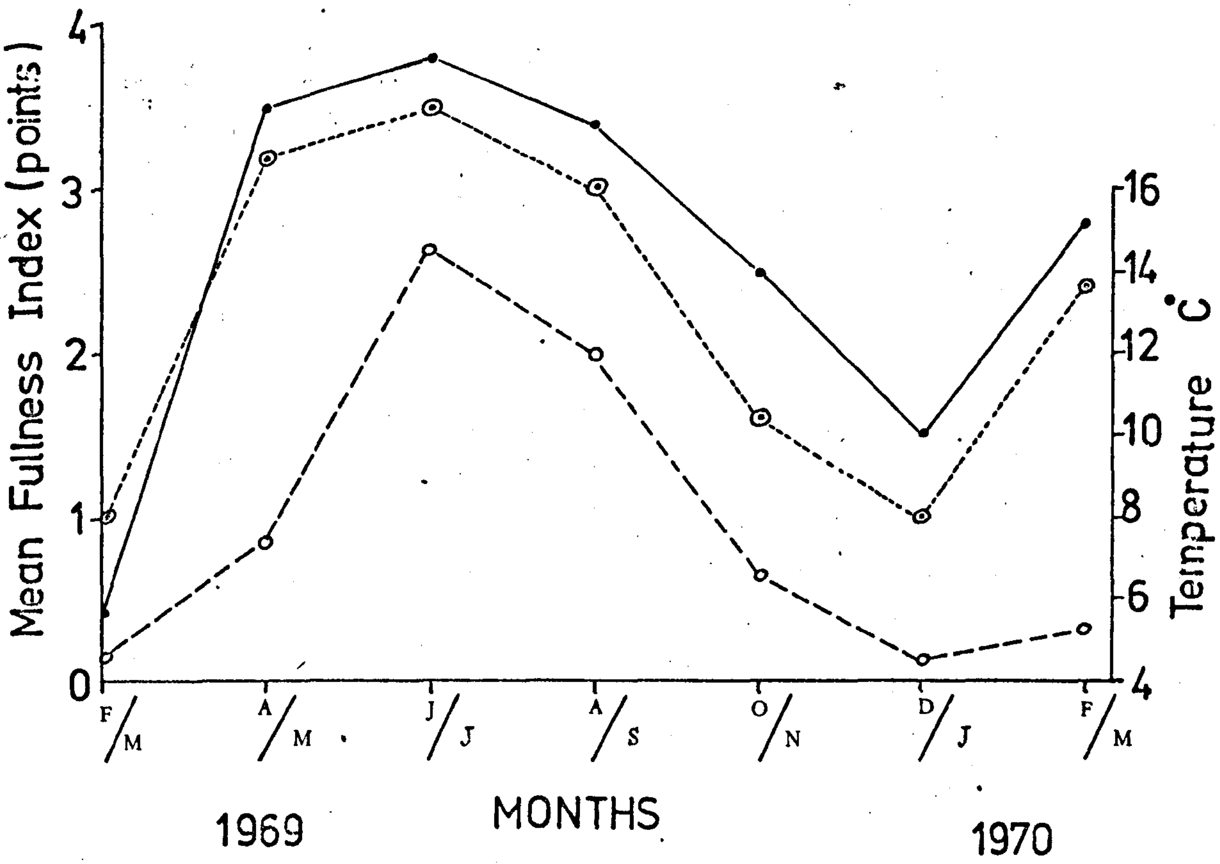

Fig 3.7 SEASONAL VARIATION IN FOOD INTAKE OF THE TROUT AND SALMON PARR.

TROUT = •———• SALMON PARR = ⊙·········⊙ WATER TEMPERATURE = ○– – – –○

Table 3.10 The Food of Trout in Afon Llafar

Food organisms	Feb/Mar				Apl/May				June/July				Aug/Sept				Oct/Nov				Dec/Jan				Feb/Mar			
	Organism present in the total sample A		No. Fish containing each item B		A		B		A		B		A		B		A		B		A		B		A		B	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Oligochaeta													5	0.5	1	2.7												
Gastropoda													3	0.3	1	2.7	2	1.8	1	2.5								
Plecoptera Nymphs					5	1.6	3	8.3																	19	17.2	4	10.8
Ephemeroptera Nymphs					23	7.6	9	25	104	42.6	9	21.4	18	1.9	9	24.3	37	33.3	12	30	11	55	2	25	30	27.2	8	21.6
Hemiptera									2	0.8	1	2.3					24	21.6	8	20								
Trichoptera Larvae					22	7.2	9	25	50	20.4	12	28.5	5	0.5	4	10.8					5	25	2	25	15	13.6	6	16.2
Coleoptera. Adults and larvae					6	1.9	2	5.4	10	4	4	9.5	9	0.9	2	5.4	5	4.5	2	10					11	10	3	8.1
Diptera. Larvae and Pupae	1	33.3	1	33.3	2	0.6	1	2.7	11	4.5	3	7.1	12	1.3	5	13.5	5	4.5	3	7.5					13	11.8	2	5.4
Aerial and Terrestrial insects	1	33.3	1	33.3	240	79.4	8	22.1	59	24.1	8	19.0	857	93.7	10	27	27	24.3	8	20					14	12.7	6	16.2
Fish																	6	5.4	1	2.5	2	10	2	25	1	0.9	1	2.7
Stone	1	33.3	1	33.3	4	1.2	4	11.1	6	2.4	3	7.1	3	0.3	3	8.1	2	1.8	2	10	2	10	2	25	5	4.5	5	13.5
Plant material									2	0.8	2	4.6	2	0.2	2	5.4	3	2.7	3	7.5					2	1.8	2	5.4

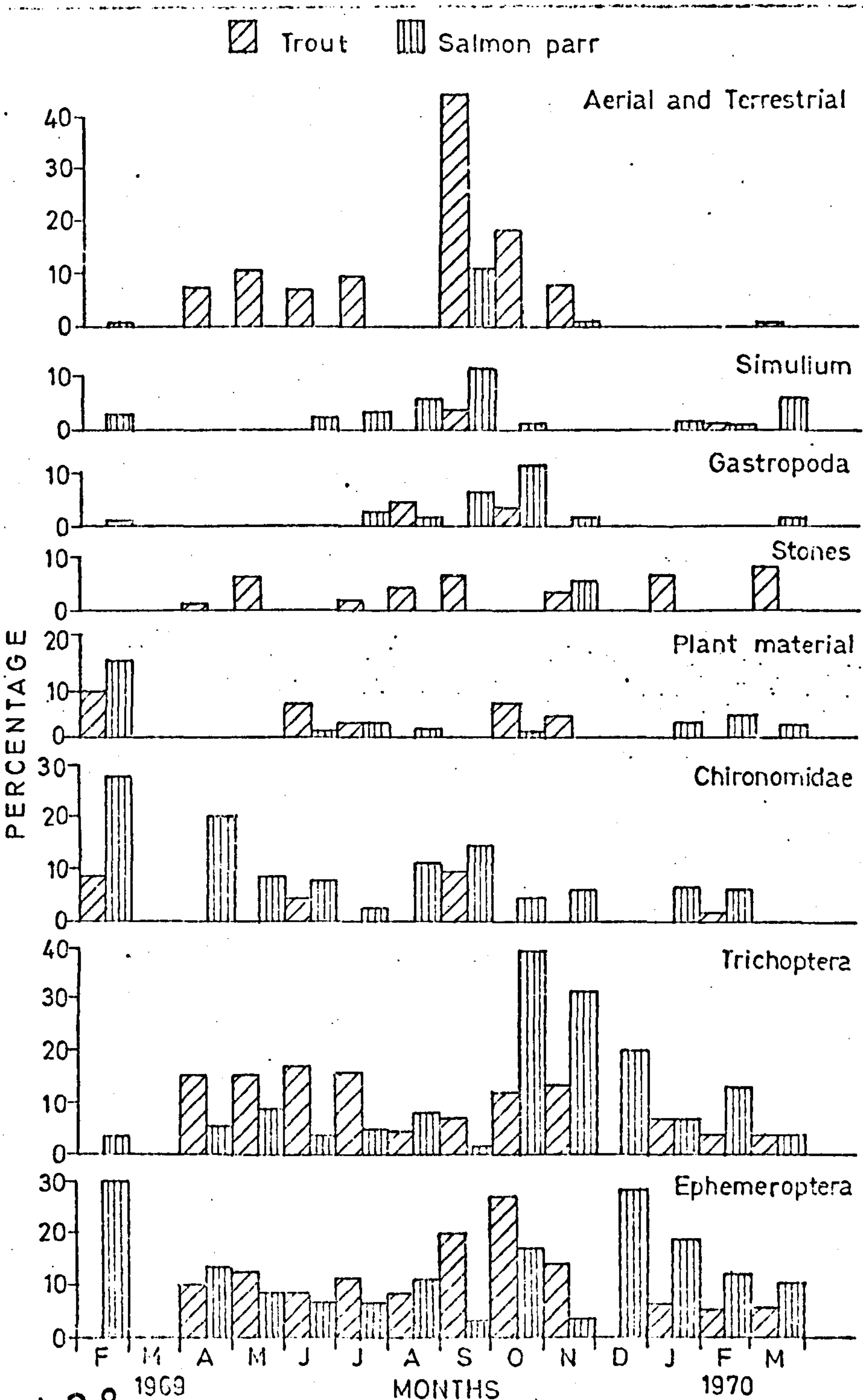

Fig.3.8
Percentage of stomachs of trout and salmon parr containing each type of food organism in different months

materials, was found in 10.2% of the total stomachs examined. In plant material is included moss, algae, leaves and, rarely, fruit and seed. The stones present probably included the remains of the cases of stony-cased caddis larvae together with stones ingested accidentally with the food.

(ii) Seasonal variation in food intake

Fig. 3.7 shows the seasonal variation in the food intake of trout in Afon Llafar. The curves are based on the mean fullness index of the stomachs. It seems that maximum food intake was from April/May to August/September and it gradually decreased to a minimum in the winter months. Each of the various seasons, winter, spring, summer and autumn, designated in the following discussion of seasonal variation in salmonid food and feeding encompasses three months. Winter includes December, January and February; spring includes March, April and May; summer includes June, July and August and finally the autumn includes September, October and November.

(iii) Seasonal changes in the food of trout

Table 3.10 and Fig. 3.8 show the seasonal food of trout in Afon Llafar. Ephemeroptera, Trichoptera, Diptera, Coleoptera and aerial and terrestrial food were eaten throughout the year but their frequency of occurrence varied. During Autust to November gastropods were common in the diet. Plecoptera nymphs occurred in the food during

Table 3.11 The average percentage composition of the food assessed by Occurrence, Volume and Number methods of brown trout of each age group for the total period of observation (+ = < 0.1%)

Species of Fish	Salmo trutta											
Total No. Fish	81											
Age	0+			1+			2+			3+		
No. Fish in each age group	6			31			26			18		
Method of Assessment	O	V	N	O	V	N	O	V	N	O	V	N
Food items												
Lumbriculus spp										2.7	2.5	5.9
Ancylastrum spp	7.1	3.1	4.0							2.7	1.1	3.5
Hygrobates spp				0.5	0.1	+						
Plecoptera nymphs				1.7	0.7	2.8	2.2	0.3	1.8	5.5	1.4	5.5
Ephemeroptera nymph	35.6	30.5	42.0	26.8	21.1	26.6	17.6	5.5	17.8	19.4	7.7	23.8
Micronecta spp				2.0	0.3	0.4						
Trichoptera larvae	7.1	22.5	6.0	15.1	20.8	11.2	19.6	40.9	29.9	31.4	18.8	29.2
Coleoptera adults				6.7	2.0	3.0	0.7	1.8	0.7			
Coleoptera larvae				3.1	1.1	2.6				2.7	0.5	2.7
Chironomid larvae	14.2	4.8	20.0	2.9	1.4	3.1	5.5	2.2	5.5	1.5	0.2	1.7
Chironomid pupae												
Simuliid larvae	7.1	2.4	6.6	0.8	0.5	1.1						
Simuliid pupae	7.1	2.8	6.6									
Other dipteran larvae				6.8	1.2	3.8						
Aerial and terrestrial forms	21.3	35.4	14.2	24.1	34.5	42.1	36.4	41.3	33.5	10.4	8.3	12.4
Stones				3.6	2.8	0.9	9.4	3.8	4.0	11.4	4.7	5.5
Plants				4.1	2.6	1.0	8.3	3.8	7.2	4.1	2.5	2.0
Fish				0.8	10.9	0.1				7.5	52.3	7.2

late winter and spring. Hemiptera were found during summer and autumn. Fish formed a small percentage of the food during October/November to February/March. Though aerial and terrestrial food occurred thoughout the year, most of this was eaten in April/May to October/November. Plant material was eaten very frequently during June/July to October/November. The stones were found in the stomachs round the year in varied numbers. Oligochaetes did not seem to be preferred.

I tried to determine whether plants were ingested purposely and not accidentally. As some stomachs contained only plant material, I deduced that the feeding on plants was intentional. It is interesting to note that all the leaves eaten were approximately the same length, and they thus appear to have been cropped. (Plate 3.4).

(iv) Food in relation to age

Table 3.11 shows the percentage composition of the food of trout of each age group. There is no significant change in the diet in relation to age for food items like Plecoptera, Trichoptera, Coleoptera, aerial and terrestrial insects, plant materials, and chironomid larvae. I found a significant difference in the occurrence of ephemeropteran food items in the different age groups of trout (x^2_3 = 9.05, $P < 0.05$).

Table 3.12 The total annual composition of the diet of 136 salmon parr assessed by Occurrence Volume and Number methods. (+ = < 0.1%)

	Average percentage represented in total sample		
Food organisms	Occurrence	Volume	Number
Benthic food			
Lumbriculus spp	0.9	1.2	0.5
Ancylastrum fluviatile	2.1	0.5	0.7
Limnaea pereger	0.2	1.0	0.2
Amphinemura spp.	1.1	0.3	0.9
Leuctra spp.	1.1	0.1	0.7
Nemoura spp.	0.8	0.6	1.0
Protonemura meyeri	1.2	0.7	0.9
Baetis rhodani	12.4	4.2	9.7
Caenis spp.	3.7	1.1	2.8
Ecdyonurus spp.	0.9	0.6	0.5
Ephemerella spp.	2.6	1.3	3.2
Other Ephemeroptera nymphs	6.9	9.4	10.4
Anabolia spp.	4.1	3.3	3.7
Plectrocnemia conspersa	9.8	9.2	5.6
Rhyacophila dorsalis	1.2	3.6	1.0
Hydroptila spp.	3.0	2.3	1.6
Other trichopteran larvae	13.3	20.5	16.7
Helmis maugei larvae	0.6	0.3	0.2
Latelmis vokmari	0.3	+	0.1
Chironomid larvae	13.4	10.6	18.3
Chironomid pupae	+	+	+
Simuliid larvae	4.8	3.0	8.1
Tipulid larvae	1.5	3.8	1.0
Other dipteran larvae	0.6	0.5	0.6
Other dipteran pupae	0.3	0.6	0.1
Midwater food			
Helmis maugei adults	2.2	2.2	1.0
Micronecta spp.	2.2	2.0	1.6
Aerial and Terrestrial food			
Aerial and Terrestrial arthropods	2.1	8.1	1.9
Miscellaneous food			
Plant materials	6.0	7.8	6.7
Stones	0.7	0.4	0.2
Total	100.0	99.2	99.5

(b) Salmon parr

(i) Composition of the diet

Trichoptera larvae were the predominant item in the diet of salmon parr (Table 3.12). Among them larvae of *Anabolia spp*, *Plectrocnemia conspersa*, *Rhyacophila dorsalis*, *Hydroptila spp*. and other trichopteran larvae were well-represented. The ephemeropteran nymphs occurred in 26.5% of the total stomachs, were the next important dietary item and represented by *Baetis spp*, *Caenis spp*, *Ecdyonurus spp*, *Ephemerella spp*, and other ephemeropteran nymphs. The dipteran larvae which included chironomids, simuliids, tipulids and others occurred in 13.4%, 4.8%, 1.5% and 0.6% of the total stomachs respectively. Aerial and terrestrial organisms were consumed by 2.1% of the total fish. *Amphinemura spp*, *Leuctra spp*, and *Protonemura meyeri* were the important Plecoptera in the diet. Oligochaetes, gastropods and Coleoptera were of insignificant importance as compared with other food organisms. 6.7% of the total stomachs contained the miscellaneous food i.e. plant materials and stones; of these 6.0% had plant material and 0.7% had stones.

(ii) Seasonal variation in food intake

Fig. 3.7 shows the seasonal variation in the food intake of salmon parr. It is apparent that most food was taken from April/May to August/September and it decreased to a minimum in winter.

Table 3.13 The food of salmon parr in Afon Llafar. (+ = <.1%)

Food organisms	Feb/Mar				Apl/May				June/July				Aug/Sept				Oct/Nov				Dec/Jan				Feb/Mar			
	Organism present in the total sample A		No. Fish containing each item B		A		B		A		B		A		B		A		B		A		B		A		B	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Oligochaeta					3	0.2	1	4.0	1	0.1	1	1.6													5	2.2	2	3.5
Gastropoda	2	0.4	1	2.3					6	0.9	3	5.0	35	6.6	7	12.2	11	4.0	5	9.0					1	0.4	1	1.7
Plecoptera nymphs	1	0.2	1	2.3	4	0.3	2	8.0	2	0.3	1	1.6					1	0.3	1	1.8	25	32.8	9	23.6	7	3.1	3	5.3
Ephemeroptera nymphs	66	13.1	14	33.3	23	2.0	7	28.0	201	31.8	18	30.0	209	39.6	12	21.0	58	21.2	14	25.4	26	34.2	13	34.2	66	33.5	18	32.1
Trichoptera larvae	23	4.5	4	9.5	17	1.5	5	20.0	39	6.1	11	18.3	11	2.0	6	10.5	173	63.3	18	32.7	16	21.0	9	23.6	41	18.3	12	21.4
Chironomid larvae	45	9.0	11	26.1	1076	95.7	9	36.0	291	46.1	13	21.6	99	18.7	15	26.3	14	5.1	7	12.7	2	2.6	2	5.2	47	21.0	8	14.2
Simuliid larvae	354	70.6	4	9.5					78	12.3	7	11.6	116	22.0	7	12.2	4	1.3	1	1.8	1	1.3	1	2.6	23	10.3	6	10.7
Dipteran larvae and pupae									2	0.3	1	1.6													9	4.0	2	3.5
Coleoptera adults and larvae	1	0.2	1	2.3					2	0.3	1	1.6	6	1.1	4	7.0	1	0.3	1	1.8	3	3.9	2	5.2				
Aerial and Terrestrial insects	1	0.2	1	2.3									49	9.2	4	7.0	2	0.6	1	1.8								
Stones	3	0.6	1	2.3	1	+	1	4.0	7	1.1	2	3.3					6	2.1	4	7.2					2	0.8	2	3.5
Plants	5	1.0	4	9.5					2	0.3	2	3.3	2	0.3	2	3.5	3	0.9	3	5.4	3	3.9	2	5.2	2	0.8	2	3.5

Table 3.14 The average percentage composition of the food assessed by occurrence, volume and number methods of salmon parr of each age group.

Species of fish	*Salmo salar*											
Total No. Fish	136											
Age	0+			1+			2+			3+		
No. fish in each age group	9			74			43			10		
Method of Assessment	O	V	N	O	V	N	O	V	N	O	V	N
Food items:												
Lumbriculus spp.				0.2	0.7	0.1	1.2	2.5	0.8	2.3	1.7	1.4
Ancylastrum spp.				4.5	3.0	2.2	5.0	3.0	1.5			
Hygrobates spp.												
Plecoptera nymphs							5.7	4.6	6.1	2.3	2.5	1.7
Ephemeroptera nymphs	16.6	12.4	13.3	27.5	20.7	26.8	31.6	25.9	41.3	30.5	7.5	25.3
Micronecta spp.				8.8	8.1	6.4						
Trichoptera larvae	83.3	87.6	86.6	15.5	25.5	14.6	13.1	18.5	7.1	13.8	24.2	9.7
Coleoptera adults				3.4	4.5	2.0				5.5	4.5	2.2
Coleoptera larvae							0.3	0.1	+	5.5	1.2	1.0
Chironomid larvae				25.0	17.3	36.3	18.5	4.9	20.7	10.2	20.3	62.9
Chironomid pupae				0.2	0.4	0.1						
Simuliid larvae				3.7	4.5	6.6	9.1	5.4	17.5	6.7	2.3	8.4
Tipulid larvae							6.2	15.2	4.1			
Other dipteran larvae				0.2	0.6	0.1				2.3	1.7	2.6
Other dipteran pupae				1.5	2.6	0.3						
Aerial & terrestrial forms				1.3	8.9	1.9	5.1	18.2	7.2	2.3	5.5	0.8
Stones				3.1	1.8	1.1						
Plants				2.9	1.4	0.6	3.5	1.8	0.9	17.8	28.3	25.3

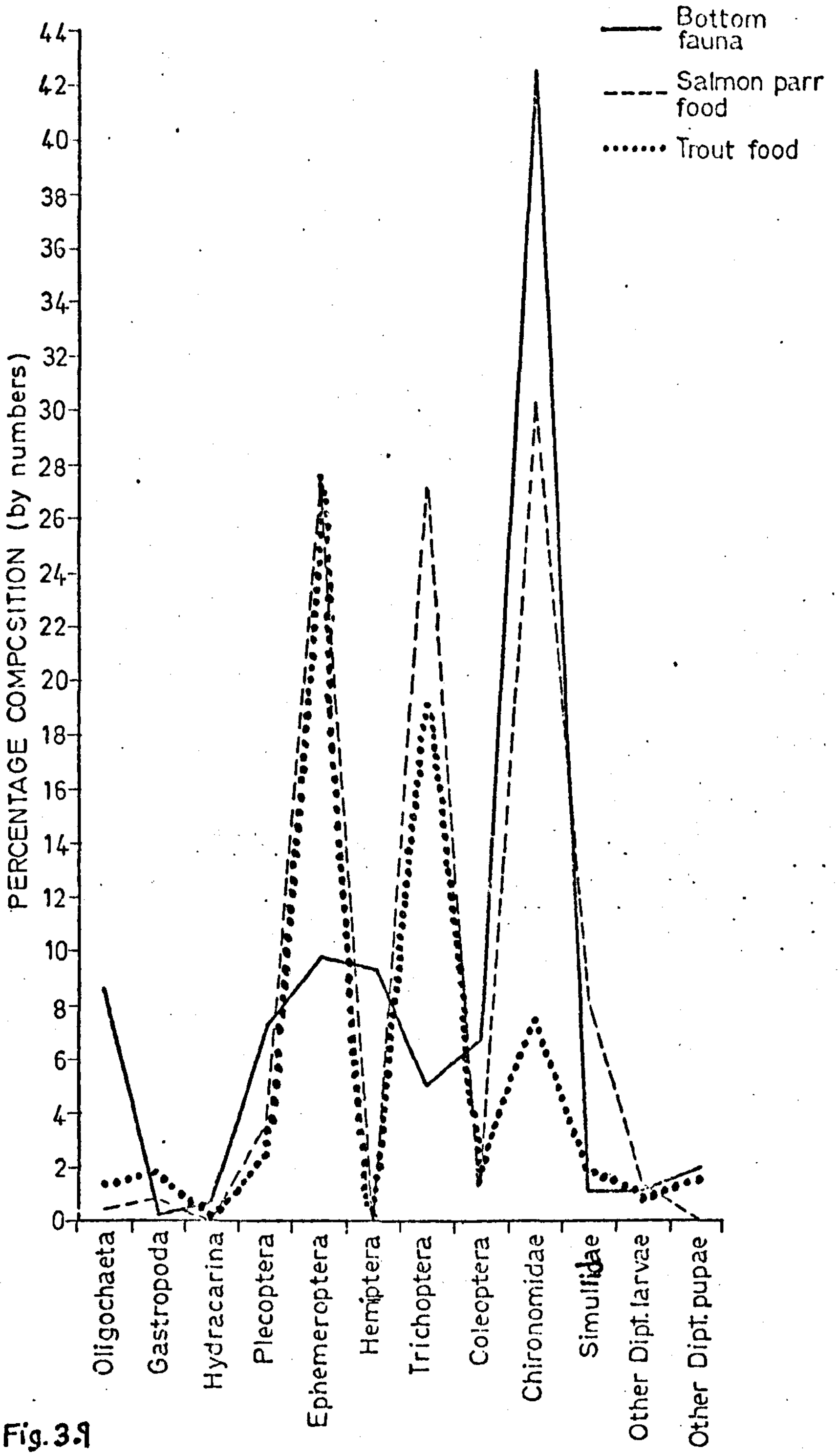

Fig. 3.9
The percentage composition (by numbers) of the bottom fauna and benthic food items of trout and salmon parr

(iii) Seasonal changes in the food of salmon parr

Table 3.13 and Fig. 3.8 show the seasonal food of salmon parr in Afon Llafar. Trichoptera and Diptera (Chironomidae and Simuliidae) larvae, Ephemeroptera and Plecoptera nymphs were found in the stomachs throughout the year. Trichoptera larvae were more frequent in the diet in October/November to February/March than in April/May to August/September as most of them emerge during summer. Chironomid and simuliid larvae were very common food items in April/May to August/September, because of their attaining a maximum size and consequently becoming more prominent at this time. Oligochaetes, gastropods, Coleoptera were insignificant food items in any season. Aerial and terrestrial insects were found from early spring to late autumn.

(iv) Food in relation to age

Table 3.14 shows the food of salmon parr assessed by three different methods in each age group. x^2 test showed a highly significant difference in the occurrence of chironomid larvae $(x^2_3 = 12.41, P < 0.05, < 0.02 < 0.01)$ in the food of different age groups of salmon parr.

(c) Utilisation of fauna

Fig.3.9 shows the percentage composition by number of the fauna and food items of trout and salmon parr. Oligochaetes were common (8.6%) in the river, but

Lumbriculus spp. comprised only 0.5% and 1.4% of the total food of salmon parr and trout respectively. This could be due to swift digestion by the fish. Gastropods and Hydracarina were rare in the fauna and food. 7.1% of Plecoptera were recorded in the bottom fauna survey; but only 2.5% of the trout and 3.5% of the salmon parr food belonged to this group. Ephemeroptera were found in 9.7% of the total benthic fauna. The members of this group formed a significant part of the benthic food of salmonids i.e. 27.3% for trout and 26.6% for salmon parr. The aquatic Hemiptera formed a small proportion (0.1%) of the salmonid food, although this group made up a substantial (9.2%) part of the total fauna. 27.0% of the diet of salmon parr and 19.0% of the diet of trout were trichopteran larvae, whereas only 5.0% of the bottom invertebrates belonged to this group. Coleoptera larvae and adults were recorded in 1.2% of salmon parr and 2.2% of the trout food, though the number (6.7%) in the bottom fauna was high. Chironomid larvae were abundant in the river and formed 42.5% of the total benthic fauna. 30.0% and 7.5% of the chironomid larvae were recorded in the total diet of salmon parr and trout respectively. There is a significant difference between trout and salmon parr as far as the consumption of chironomid larvae is concerned ($F=14.4$; $df=1/11$; $P<0.05$). *Simulium* larvae constituted 8.0% of the salmon parr and 1.9% of the trout diet, though only 1.0% was found in the bottom.

Overall, 70% of the trout diet comprised bottom invertebrates whereas the salmon parr diet comprised 91.8%. The rest, i.e. 30.0% and 8.2% of the diet is made up of aerial and terrestrial insects, plant materials and stones.

5. SUMMARY

(1) With the exception of oligochaetes there are no significant differences in the bottom fauna at L_1, L_2 and L_3 (P 0.05).

(2) There is a steady downward trend in the number of animals from summer to winter. During summer, populations fluctuate owing to insect emergence (chironomid, mayflies and caddis flies) and hatching of eggs and development of larvae of succeeding insect generation. In winter many forms are more or less dormant and inactive and not easily available to fish.

(3) Ephemeroptera nymphs, Trichoptera and Diptera larvae are the main benthic food of salmonids in the stream.

(4) Aerial and terrestrial insects occur in 19.1% and 1.4% of the total trout and salmon parr stomachs respectively.

(5) Plant material appear to have been eaten deliberately and not accidentally. Algae, moss and leaves of other aquatic plants were found in 6.0% of salmon parr and 4.1% of the trout stomachs.

(6) There is no seasonal relationship between the consumption of invertebrate food of aquatic origin and aerial and terrestrial forms.

(7) 70% of the food of trout and 91.8% of the food of salmon parr is derived from the benthic fauna.

CHAPTER IV.

AFON LLIW

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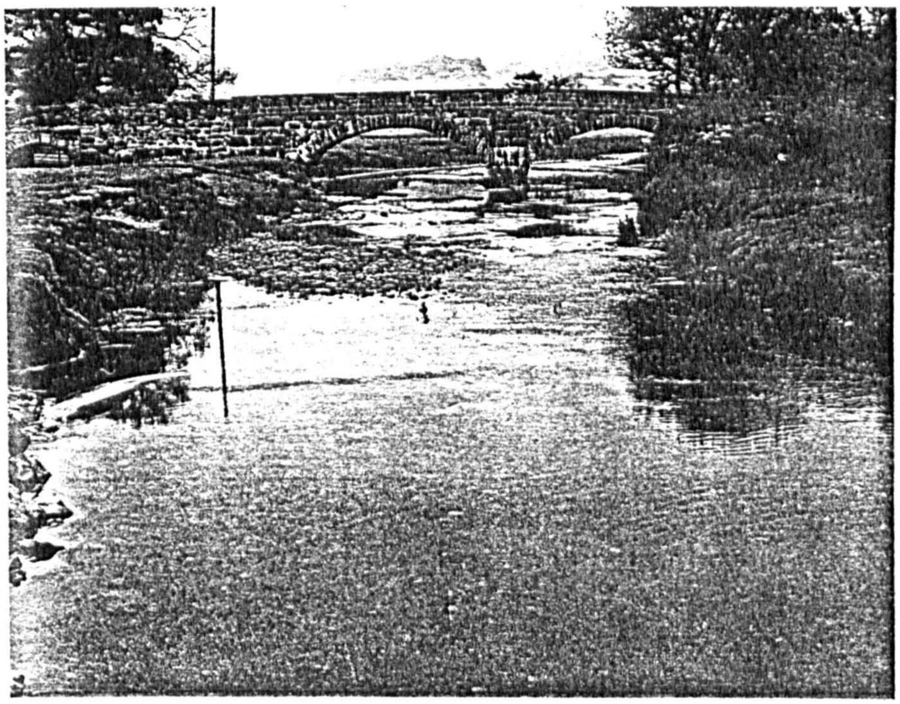

PLATE 4.1 SAMPLING STATION Lw

CHAPTER IV

1. THE ENVIRONMENT

(a) General topography

Afon Lliw is situated on the south western part of the Llyn Tegid, Merionethshire, North Wales. It flows from the southern slopes of Moel Llyfnant, 745m high. The source of the stream is 484m above mean sea level. It is the main tributary stream of Afon Dyfrdwy (Little Dee), and joins the latter about 300m from the lake after flowing through the so-called "Bala Beds" (Ashgill and Caradoc). The stream descends through the mountains into the hilly farm lands. Before joining the Little Dee it is joined by many tributary streams. Upon its approach to the junction the river gradually widens into a broad waterway. The united waters of the Afon Lliw and Afon Dyfrdwy find their way towards the southern end of the lake.

(b) Description of the sampling site

One sampling station (LW) was selected on this stream (Plate 4.1). The station is located 3.2km away from the lake at an altitude of 200m O.D. Here the stream is about 6m wide and 0.3m deep. The substratum is composed of loose rocks of varying sizes as well as solid rock. There is scattered vegetation (patches of *Fontinalis antipyretica* and *Callitriche aquatica*) on the bottom and a few beech trees on the banks (Figs. 3.2 and Plate 4.1).

TABLE 4.1 MEAN MONTHLY ESTIMATES OF PHYSICAL CONDITIONS IN AFON LLIW.

(1969–70)

Months	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Water Temp. °C	5.5	5.0	8.5	13.3	15.5	16.1	9.7	9.0	5.0	4.3	4.0	4.0	4.5	5.8
pH	7.0	7.1	6.8	6.8	6.7	7.1	7.2	7.2	7.0	7.4	7.4	7.1	7.2	7.5
Specific conductance (micromhos/ cm^3 at 25 °C)	183	216	210	198	119	288	309	285	460	415	440	310	212	201
Dissolved O2 , % sat.	98	101	112	118	105	98	102	96	95	98	96	110	107	101
Turbidity(as Fuller's Earth)	21	23	24	19	18	28	30	27	54	77	89	80	68	32
Velocity of water current (m/sec.)	0.26	0.19	0.23	0.13	0.11	0.14	0.23	0.29	0.75	0.71	0.66	0.60	0.53	0.41

Table 4.2 The density (Av. No./m^2) of the fauna at one sampling site, based on 14 monthly samples. (+ = < 0.1%).

	Sampler		
Name of Species	No. spp.	%	Av.No/m^2
Hirudinea (TOTAL)	(11)	(0.3)	(7.4)
Helcbdella stagnalis	7	0.2	5.3
Erpobdella octoculata	4	0.1	2.1
Oligochaeta	(437)	(15.3)	(333.8)
Homochaeta naidina	5	0.1	3.2
Eiseniella tetraedra	5	0.1	3.2
Lumbriculus variegatus	61	2.1	46.0
Stylodrilus heringianus	356	12.5	271.7
Peloscolex ferox	6	0.2	4.2
Aulodrilus pluriseta	4	0.1	2.1
Gastropoda	(5)	(0.1)	(3.2)
Ancylastrum fluviatile	5	0.1	3.2
Lamellibranchiata	(6)	(0.2)	(4.2)
Pisidium cinerium	1	+	0.7
Pisidium suletruncatum	5	0.1	3.2
Amphipoda	(3)	(+)	(2.1)
Gammarus pulex	3	+	2.1
Hydracarina	(2)	(+)	(1.0)
Sperchon denticulatus	1	+	0.7
Hygrobates fluviatilis	1	+	0.7
Plecoptera	(80)	(2.8)	(60.9)
Nemoura avicularis	1	+	0.7
Leuctra hippopus	5	0.1	3.2
Protonemura meyeri	15	0.5	10.7
Chloroperla tripunctata	2	+	1.0
Amphinemura sulcicollis	20	0.7	14.9
Isoperla grammatica	8	0.2	5.3
Amphinemura standfussi	11	0.3	7.4
Leuctra nigra	2	+	1.0
Chloroperla torrentium	11	0.3	7.4
Leuctra fusca	5	0.1	3.2
Ephemeroptera	(700)	(24.6)	(535.0)
Baëtis pumilus	12	0.4	8.5
Leptophlebia vespertina	20	0.7	14.9
Baetis rhodani	7	0.1	5.3
Ecdyonurus venosus	10	0.2	7.4
Centroptilum luteolum	629	22.1	480.4
Paraleptophlebia sulemarginata	2	+	1.0
Rhithrogena semicolorata	3	0.1	2.1
Caenis moesta	1	+	0.7
Ephemerella ignita	3	0.1	2.1
Leptophlebia marginata	10	0.3	7.4
Ecdyonurus dispar	2	+	1.0
Heptagenia lateralis	1	+	0.7
Hemiptera	(266)	(9.8)	(202.5)
Micronecta poweri	264	9.8	201.1
Corixa panzeri	1	+	0.7
Sigara nymph	1	+	0.7

Table 4.2 (contd.)

Name of Species	Sampler No. spp.	%	Av.No m^2
Megaloptera	(6)	(0.2)	(4.2)
Sialis lutaria	3	0.1	2.1
Sialis fuliginosa	3	0.1	2.1
Trichoptera	(166)	(5.8)	(126.2)
Sericostoma personatum	5	0.1	3.2
Plectrocnemia conspersa	93	3.2	70.6
Potamophylax latipennis	1	+	0.7
Potamophylax cingulatus	1	+	0.7
Anabolia nervosa	21	0.7	16.0
Glyphotaelius pellucidus	34	1.1	25.6
Hydropsyche instabilis	6	0.2	4.2
Hydroptila tineoides	2	+	1.0
Polycentropus flavomaculatus	1	+	0.7
Diplectrona felix	2	+	1.0
Coleoptera	(51)	(1.7)	(38.5)
Haliplus lineatocollis	2	+	1.0
Platambus maculatus	12	0.4	8.5
Helmis maugei	16	0.5	11.7
Helophorus flavipes	1	+	0.7
Latelmis volkmari	14	0.5	10.7
Helodes marginata	6	0.2	4.2
Diptera			
(1) Ceratopogonidae	(12)	(0.4)	(8.5)
Bezzia spp.	12	0.4	8.5
(2) Simuliidae	(4)	(0.1)	(2.1)
Simulium monticola	3	0.1	2.1
Simulium brevicaule	1	+	0.7
(3) Tipulidae	(6)	(0.1)	(4.2)
Tipula montium	5	0.1	3.2
Tipula cauckei	1	+	0.7
(4) Chironomidae	(1007)	(35.4)	(769.3)
Polypedilum nubeculosus	592	20.8	451.5
Tanytarsus signatus	169	5.9	128.4
Prodiamesa olivacea	110	3.8	83.4
Pentaneura monilis	98	3.4	74.9
Procladius choreus	38	1.3	28.8
Trichocladius rufiventris			
(6) Other dipteran larvae	(19)	(0.6)	(13.9)
Dicranota robusta	13	0.4	9.6
Limnophora spp.	1	+	0.7
Lianealus virens	3	0.1	2.1
Taphrophila vitripennis	2	+	1.0
Dipteran pupae	57	2.0	42.8
Total number of animals	2842		
Av. no. animals/month	202.9		
Av. no. animals/m^2	2171.0		

(c) Physical and Chemical conditions

Table 4.1 indicates the mean monthly estimates of physical factors at LW. Water temperature, recorded at monthly intervals, varied between 4 and 16.1°C. The pH was generally constant (6.7-7.5), reflecting the chemical stability of the stream. The velocity of water current ranged from 0.11-0.75 m/sec. The lowest values of conductivity and turbidity of water were recorded during summer, and highest values in winter. An increase in oxygen saturation during summer and a decrease in winter was observed.

Water samples for chemical analysis were taken as before and the results are given in Table 3.4. There was little difference between Llafar and Lliw water.

2. COMPOSITION OF THE FAUNA

Table 4.2 lists the animal fauna found in the stream during routine sampling, and also the total number of specimens of each category taken by the sampler. As far as possible the material was identified to species. The almost complete absence of *Gammarus pulex* and *Limnaea peregar* (0.1% and 0.1% by number of the total fauna) was similar to the findings of Jones (1948a) who noted their absence from several soft water streams in south Wales, although they were present in large numbers in a nearby hard water stream.

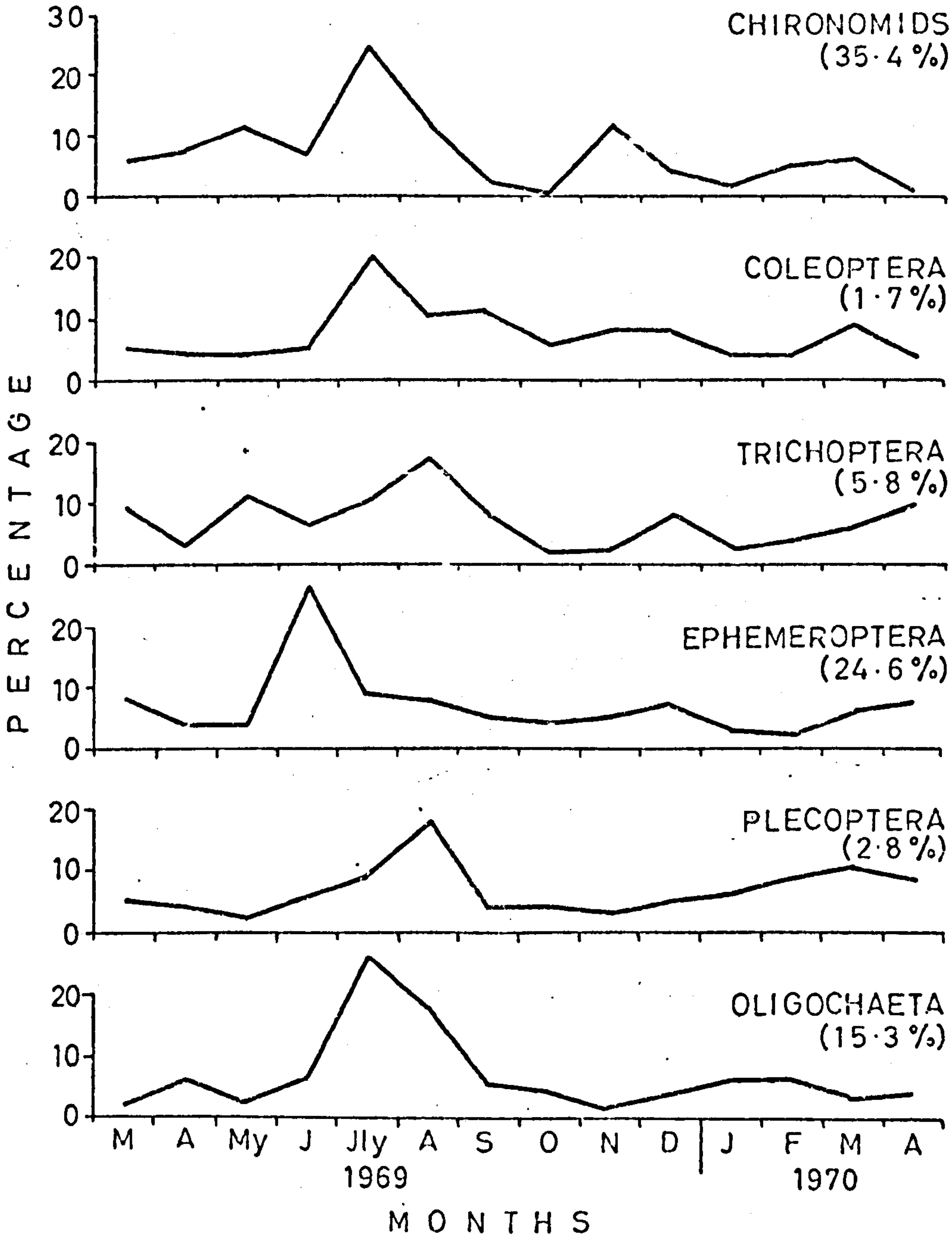

Fig 4·1 Seasonal variations in the numbers of different groups of bottom fauna

I found a steady increase in the total number of individuals from winter to summer as did Frost (1942), Badcock (1949) and Hynes (1961).

Seasons	Spring	Summer	Autumn	Winter
Total No. animals	1229	3118	989	915

Altogether 85 species were recorded from this stretch. The species belonged mainly to groups Oligochaeta, Plecoptera, Ephemeroptera, Trichoptera, Coleoptera and Chironomidae. Fig. 4.1 illustrates the seasonal fluctuations in numerical abundance of six groups, as a percentage of the yearly catch for each group. These six groups together account for over 85% of the total catch. The fall in numbers in winter for these six groups parallels the fall in overall numbers.

(A) Annelida

(1) Hirudinea

0.2% of the benthic fauna was composed of Helobdella stagnalis and Erpobdella octoculata

(2) Oligochaeta

This group formed 14.2% of the total fauna in which Lumbriculus variegatus and Stylodrilus heringianus were very common. I collected more oligochaetes during summer (Fig. 4.1).

(B) Mollusca

(1) Gastropoda

Limnaea pereger was very rare compared to Ancylastrum fluviatile.

(2) Lamellibranchiata

0.2% of the fauna was composed of Pisidium hibernicum and Pisidium subtruncatum.

(c) Arthropoda

(1) Crustacea

(a) Amphipoda

This group was represented by Gammarus pulex which formed 0.1% of the total fauna.

(2) Arachnida

(a) Hydracarina

The members of this group were almost absent being 0.1% of the total aquatic invertebrates.

(3) Insects

(a) Plecoptera

11 species of stoneflies were represented in this group which formed 2.6% of the total macrobenthos. Protonemura meyeri, Amphinemura sulcicollis, Isoperla grammatica and Chloroperla torrentium were common and the rest occasional. I found that the number increased during summer (Fig.4.1).

(b) Ephemeroptera

14 species occurred in this group and constituted

18.4% of the total animals. *Centroptilum luteolum* was common. An increase in number of mayfly nymphs during summer was nticed which may be due to their spring emergence (Fig.4.1); though according to Macan (1957) the timings of their life histories vary, and are affected by high summer temperatures and oxygen deficiency.

(c) *Hemiptera*

11.6% of the fauna was represented by three species of this group which were not the usual inhabitants of the stream. They were usually found when the current was slow and there was more vegetation near the bank during summer and autumn. Maybe they have been washed away from back waters by the flood and colonized again in sheltered places; but according to Popham (1943) they are stimulated to migrate by high temperature, over-crowding and unsuitable background.

(d) *Megaloptera*

0.2% of the fauna was composed of *Sialis lutaria* and *Sialis fuliginosa*.

(e) *Trichoptera*

14 species were identified and listed in Table 4.2 which constituted 5.9% of the total benthos. *Plectrocnemia conspersa* was very common. I noticed more trichopteran larvae during summer (Fig. 4.1).

(f) *Coleoptera*

Five species listed in Table 4.2 were rare and make

Table 4.3 The total annual composition of the diet of 113 trout and 93 salmon parr assessed by Occurrence, Volume and Number method. (+ = < 0.1%)

Food organisms	Trout			Salmon parr		
Benthic food	O (%)	V (%)	N (%)	O (%)	V (%)	N (%)
Lumbriculus spp	1.0	0.2	0.8	-	-	-
Ancylastrum fluviatile	0.6	+	+	0.2	0.1	+
Leuctra spp	0.1	+	0.1	.6	0.1	0.4
Amphinemura spp	0.6	0.1	0.4	1.8	0.4	0.9
Protonemura spp	0.4	0.1	0.6	1.6	0.2	0.6
Caenis spp	2.3	1.0	4.8	4.2	2.1	9.1
Baëtis spp	4.8	2.2	3.1	9.4	3.6	5.2
Other Ephemeroptera nymphs	7.3	5.0	7.4	19.3	22.4	14.8
Plectrocnemia conspersa	7.8	12.9	10.9	14.3	7.9	11.5
Other Trichoptera larvae	12.0	7.0	8.2	19.3	30.1	17.1
Helmis maugei larvae	2.8	0.3	1.7	0.2	0.1	0.3
Latelmis volkmari larvae	2.0	0.8	1.6	0.2	+	+
Chironomid larvae	2.7	1.0	3.1	4.7	5.5	8.9
Chironomid pupae	-	-	-	0.6	0.1	0.4
Simuliid larvae	0.7	0.3	2.0	5.6	2.9	8.3
Tipulid larvae	0.2	0.1	+	-	-	-
Other dipteran larvae	4.8	3.4	9.0	6.6	1.6	4.3
Midwater food						
Helmis adults	0.8	0.3	1.1	-	-	-
Other coleoptera adults	1.1	0.4	1.0	-	-	-
Fish	24.9	33.7	22.2	-	-	-
Aerial and terrestrial food						
Aerial and terrestrial insects	12.4	19.4	13.6	9.7	16.0	13.7
Miscellaneous food						
Plant material	8.3	10.0	6.4	8.5	3.6	2.9
Fish eggs	0.4	3.3	1.2	2.5	2.6	1.6
Stones	1.0	0.5	0.5	-	-	-
Total	99.0	99.5	99.7	99.4	99.3	100.0

1.4% of the total organisms. _Latelmis volkmari_ was present in every season.

(g) _Diptera_

(i) _Chironomidae_

A large component (39.6%) of the benthic fauna was formed by this family in which seven species were identifiable. I observed that their numbers were much greater in summbr than in any other season (Fig.4.1).

Other dipteran larvae

Dicranota robusta, Limnophora spp, Taphrophila vitripennis and _Lianealus virens_ constituted 0.8% of the total bottom invertebrates.

3. FEEDING HABITS OF SALMONIDS

A total of 113 trout and 93 salmon parr were taken approximately at 2 monthly intervals, November 1968 - March 1970, for food studies. Of these 104 trout and 82 salmon parr contained food in varying amounts and the rest of the stomachs were empty (Tables 3.6, 3.7).

Detailed examination of stomachs was carried out by applying the four different standard methods mentioned in Chapter 3.4b.

(i) _Brown trout_

(a) _Composition of the diet_

Table 4.3 shows the composition of the diet of trout in Afon Lliw, from November 1968 to March 1970.

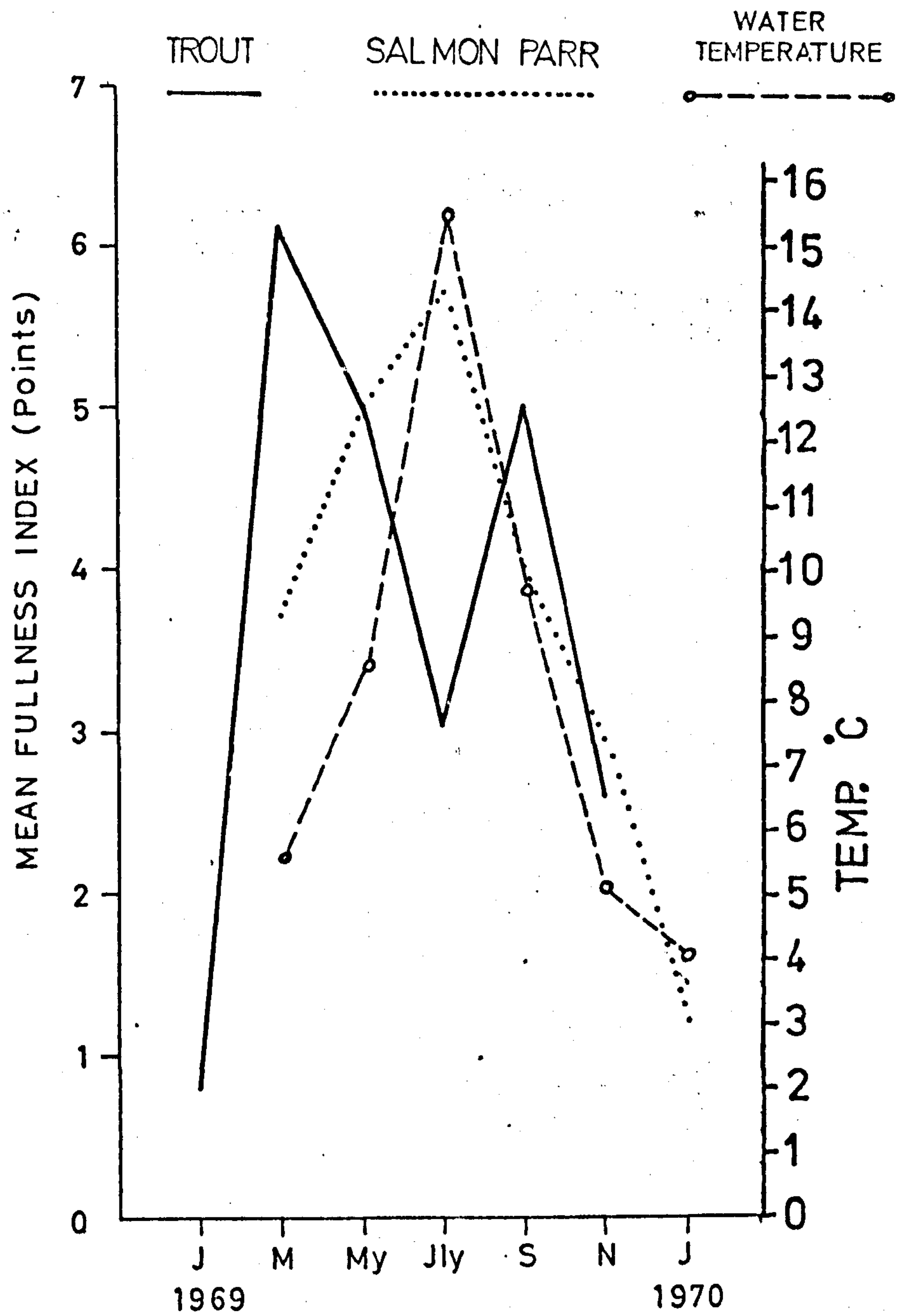

Fig 4·2 Seasonal variation in food intake of trout and salmon parr based on alternate months (Jan 1969 - Jan 1970)

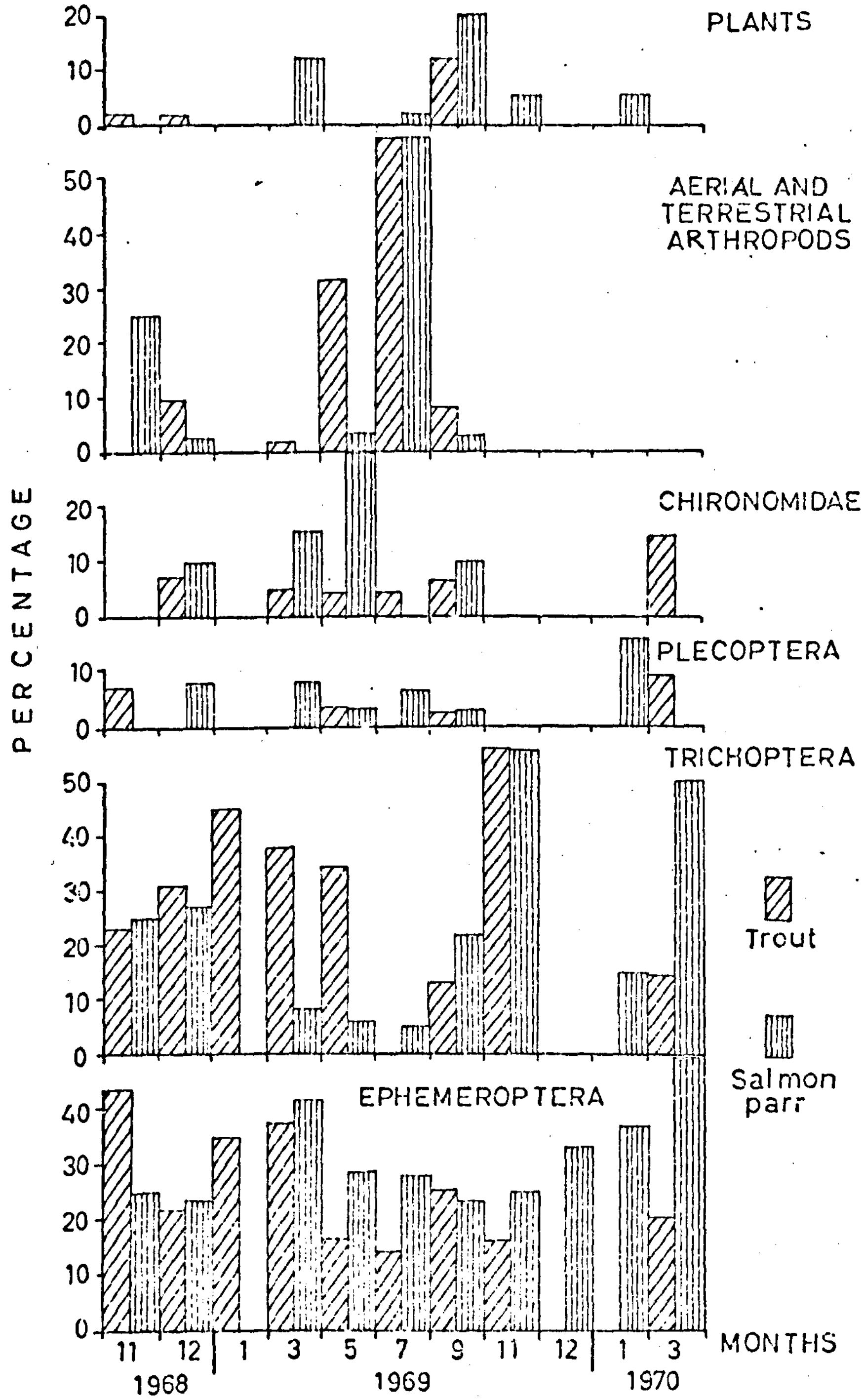

Fig 4·3 Percentage of stomachs of trout and salmon parr containing each type of food item in different months

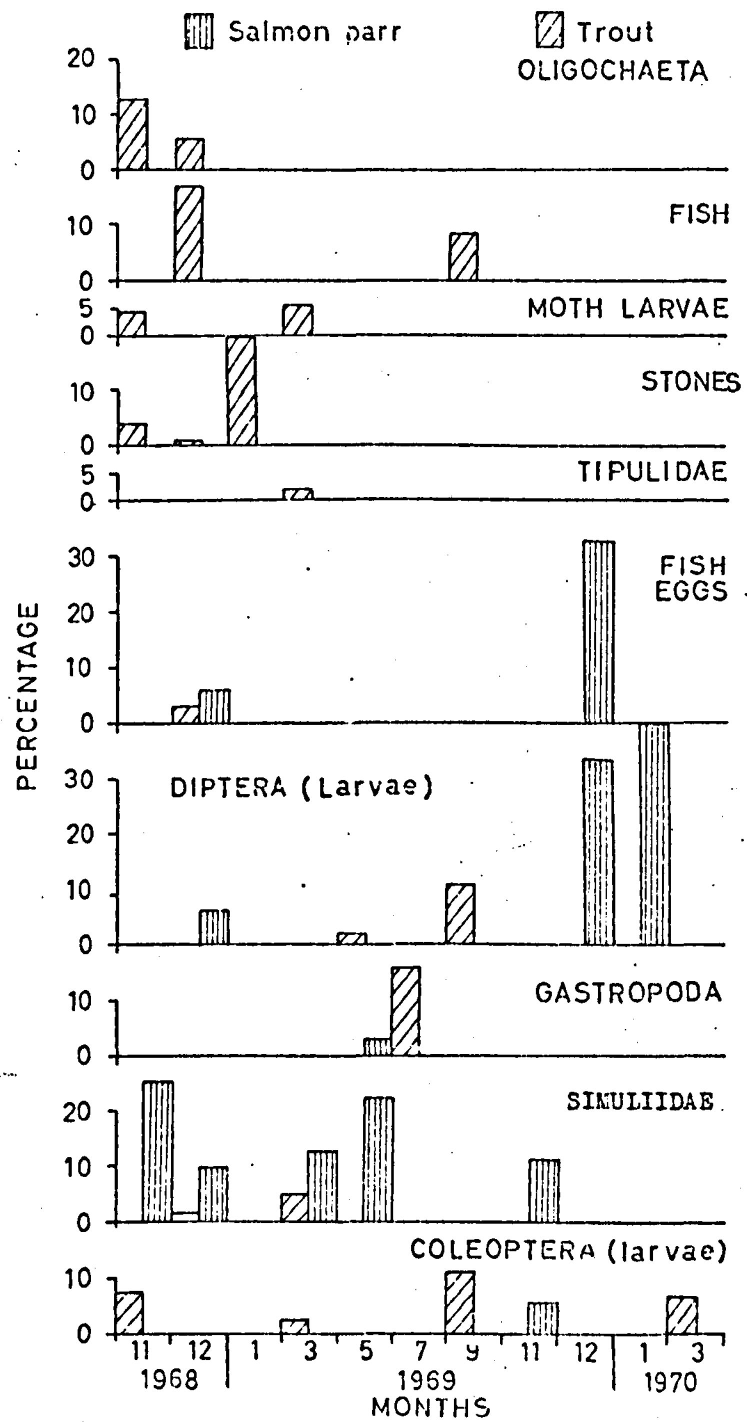

Fig 4.4 Percentage of stomachs of trout and salmon Parr containing each type of organism in different months in Afon Lliw

Trichoptera larvae, Ephemeroptera nymphs and dipteran larvae, which formed 19.9%, 8.2% and 4.8% of the total volume respectively, were important benthic food items. 33.7% (by volume) of the food was composed of the fish and 19.4% of aerial and terrestrial insects. The miscellaneous food which includes plant materials, occurred in 10.0% of the total volume of food. Oligochaetes, gastropods, Plecoptera nymphs and Coleoptera adults and larvae were not major food items.

(b) Seasonal variation in food intake

Fig. 4.2 shows the seasonal variation of food intake of trout in Afon Lliw. The curve clearly indicates that the feeding activities are at their peak from March to September and they gradually decrease to a minimum in winter months.

(c) Seasonal changes in the food of trout

Figs. 4.3, 4.4 show the seasonal variation of the more common food items in the stomachs of trout. Oligochaetes, mainly *Lumbriculus* sp. were found during November and December. Gastropods were represented by *Ancylastrum* spp. in the month of August. More Plecoptera nymphs were eaten during autumn and spring than in summer. Ephemeroptera nymphs and Trichoptera larvae were consumed throughout the period. Coleoptera adults and larvae, particularly of *Helmis* spp. and *Latelmis* spp. were eaten

Table 4.4 The percentage composition of the food assessed by occurrence, volume and number methods of trout of each age group.

Name of Species	Salmo trutta														
Total No. of Stomachs	113														
Age	0+			1+			2+			3+			5+		
No. sp. in each age group	2			61			24			25			1		
No. empty stomachs	-			4			0 4			1			-		
Methods of assessment	O	V	N	O	V	N	O	V	N	O	V	N	O	V	N
Lumbriculus spp.				2.8	1.3	2.7				2.2	0.1	1.5			
Ancylastrum spp.				3.3	0.1	0.2									
Plecoptera				2.1	0.4	1.8	2.0	0.3	1.6	1.5	0.7	1.4			
Ephemeroptera				35.4	23.3	37.2	20.2	10.3	13.1	16.7	7.7	11.2			
Trichoptera				24.1	38.5	21.3	45.5	50.8	44.9	29.6	10.4	28.7			
Coleoptera adults							9.7	3.7	10.1	4.4	+	0.9			
Coleoptera larvae	20.0	6.2	12.5	4.1	0.6	4.2									
Chironomid larvae				6.1	3.0	5.6	4.7	1.7	5.4	2.8	0.7	4.9			
Simuliid larvae				0.7	0.1	0.7				2.8	1.7	9.5			
Tipulid larvae							1.4	0.8	0.4						
Other dipteran larvae	20.0	15.5	37.5	1.3	0.6	1.6	1.5	0.4	0.9	1.5	0.7	5.2			
Aerial and terrestrial insects	20.0	30.0	12.5	17.9	27.7	21.8	13.1	31.7	22.6	11.1	8.0	11.1			
Fish										18.0	68.5	13.6	100	100	100
Fish eggs										2.2	1.7	6.3			
Stones				0.8	1.6	0.4				4.4	1.1	2.4			
Plants	40.0	48.3	37.5	1.7	2.3	1.4									

more during summer than in spring and autumn. The trout had fed more on chironomid larvae during summer than in winter. Other dipteran larvae were present in the food during summer only. Aerial and terrestrial insects were present in greater abundance during spring, summer and early autumn than in winter. Fish were found in the stomachs during December to March. Miscellaneous food, which includes fish eggs, stones, and plant materials, were found mostly during winter.

(d) Food in relation to age

Table 4.4 shows the food of trout assessed by three different methods in each age group. 48.3% and 2.3% of the total volume of food were composed of plant materials in 0+ and 1+ age groups of trout; whereas those were absent in the food of older fish. Similarly, fish made up 68.5% and 100.0% of the food (by volume) in the 3+ and 5+ age groups, but none in the fish that belonged to 0+ to 2+. I found a significant difference in the occurrence of ephemeropteran ($x^2_3 = 12.1$, $P < 0.05 < 0.02 < 0.01$) and aerial and terrestrial ($x^2_3 = 7.83$, $P < 0.05$) food items in the different age groups of trout.

(ii) Salmon parr

(a) Composition of the diet

Table 4.3 shows the total composition of the diet assessed by three different methods. Food items of many kinds were found in the stomachs of salmon parr and there were considerable difficulties in the exact identification of fragments of food. 77.8%, 16.0% and 6.3% of the total volume of food items were composed of benthic, aerial and terrestrial, and miscellaneous food. 38.0% by volume of the diet was Plectrocnemia conspersa, and other unidentifiable trichopteran larvae; 28.8% by volume was Ephemeroptera nymphs amongst which Baetis spp. and Centroptilum spp. were identifiable. 5.5% by volume of the diet was chironomid larvae. Leuctra spp, Amphinemura spp, and Protonemura spp, of the group Plecoptera; Ancylastrum spp. of Gastropoda; Latelmis volkmari of Coleoptera and finally the other dipteran larvae were occasionally present.

(b) Seasonal variation in food intake

Fig. 4.2 shows that the maximum food intake occurred in the month of July and it gradually decreased to a minimum in January.

(c) Seasonal changes in the food

Figs. 4.3 and 4.4 show the seasonal changes in the food of salmon parr. Plecoptera nymphs were eaten more during spring, summer and early autumn than in winter. Ephemeroptera nymphs and Trichoptera larvae, being major food items, were consumed throughout the period. More chironomid and simuliid larvae were found in the stomachs during summer than in any other season. Other dipteran larvae occurred in the food only in winter. Not surprisingly,

Table 4.5 The percentage composition of the food assessed by occurrence, volume and number methods of salmon parr of each age group.

Name of Species	Salmo salar											
Total No. of Stomachs	93											
Age	0+			1+			2+			3+		
No. Stomachs in each age group	13			40			36			4		
No. empty stomachs	5			-			6			-		
Methods of assessment	O	V	N	O	V	N	O	V	N	O	V	N
Lumbriculus spp.												
Ancylastrum spp.				0.8	0.5	0.1						
Plecoptera nymphs				9.4	2.3	5.1	6.6	0.7	2.8			
Ephemeroptera nymphs	33.3	20.0	27.0	29.7	23.9	21.9	29.1	28.5	24.2	39.5	41.2	39.5
Trichoptera larvae	41.6	67.5	63.3	20.7	32.0	20.1	24.8	31.5	20.0	6.2	20.6	10.7
Coleoptera larvae				2.3	0.8	0.7						
Chironomid larvae				10.9	11.6	21.6	8.2	10.6	14.0			
Chironomid pupae				2.7	0.7	1.9						
Simuliid larvae				4.7	4.0	8.5	11.8	7.1	21.5	6.2	0.8	3.5
Other dipteran larvae				1.7	0.6	1.5	4.0	1.1	2.5	20.8	4.8	13.3
Aerial and terrestrial forms				5.3	19.1	13.1	15.0	20.0	14.6	18.7	25.0	27.2
Fish eggs				1.7	2.1	1.5				8.3	8.6	5.0
Plants	24.9	12.5	9.1	7.6	2.0	2.6						

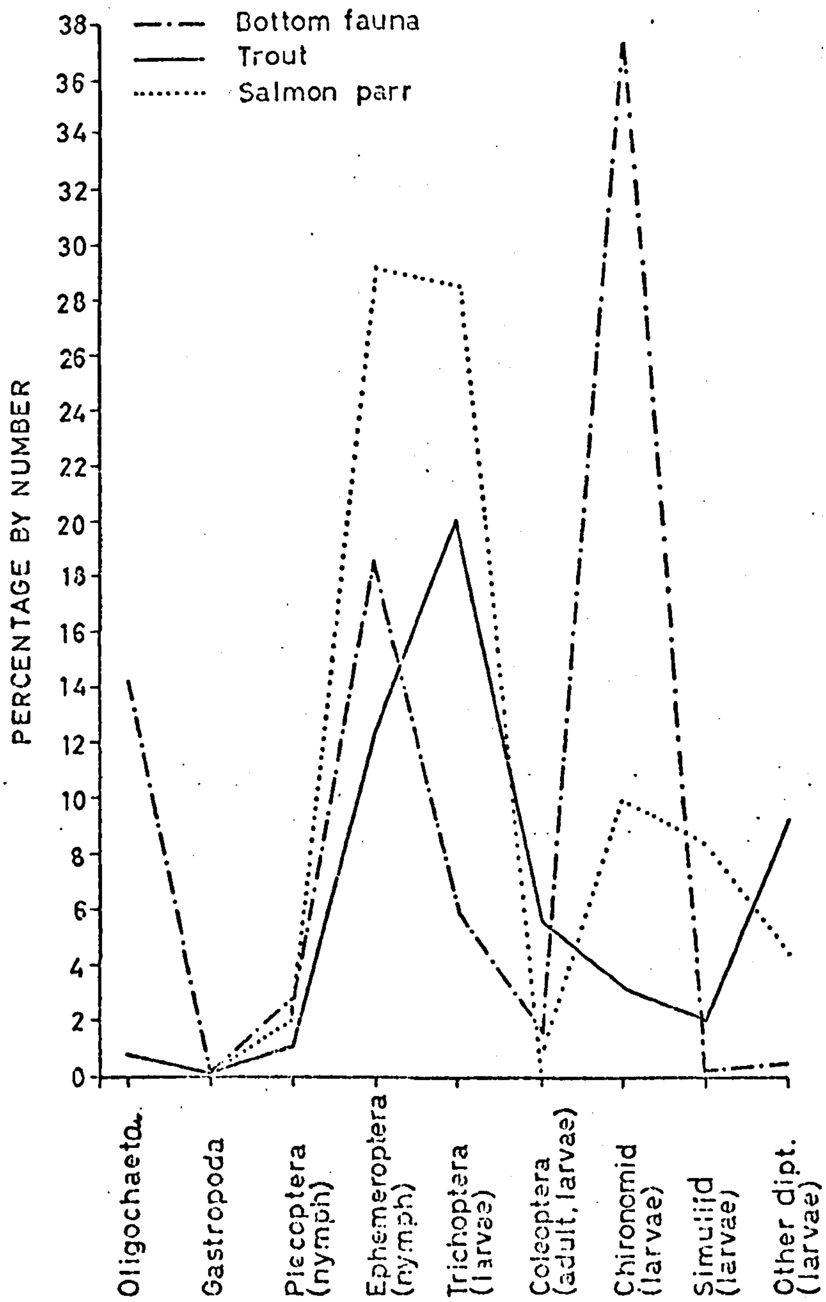

Fig 4·5 The percentage composition (by number) of the bottom fauna and benthic food items of trout and salmon parr salmon parr had fed more on aerial and terrestrial insects during summer than in winter. Aquatic plants occurred in stomachs during late autumn and winter.

(d) Food in relation to age.

x^2 test showed a significant difference in the occurrence of ephemeropteran (x^2_3 = 10.07, P $<$ 0.05 $<$ 0.02) and aerial and terrestrial (x^2_3 = 9.28, P $<$ 0.05) food items in the different age groups. As far as other food items were concerned, there were no significant changes in the diet in different age groups (Table 4.5).

(iii) Utilisation of the fauna

Fig. 4.5 shows the percentage composition by numbers of the fauna and food items of trout and salmon parr. Oligochaetes formed 14.2% of the fauna but they did not seem to be eaten by salmon parr; only 2.1% were recorded from the trout. Gastropods were found in a very small quantity in the fauna and food. 2.1% of the benthic fauna was composed of stonefly nymphs, though they too were not often taken by the trout. I found a significantly high positive correlation (r= 0.72, P $<$ 0.01) between benthic Plecopteran numbers and the numbers of plecopteran food found in the stomachs of salmon parr from month to month. Mayfly nymphs constituted 18.4% of the total bottom fauna; 29.1% of the food of salmon parr and 18.5% of the trout food belonged to this group. The correlation between the numbers of Ephemeroptera, Trichoptera and chironomid larvae present in the food of salmonids, and the numbers in the benthic fauna was insignificant. This could be caused by patchy distribution of the above groups in the fauna; or the fish might have been feeding at a place rich in mayfly nymphs, trichopterans and chironomid larvae. Trichoptera larvae as a food item were found more in the stomachs of trout (18.9%) and salmon parr (28.5%) than the fauna itself (5.5%). 0.7% and 6.9% of Coleoptera were eaten by salmon parr and trout, whereas in the fauna only 1.4% were recorded. There was a significant correlation ($r = 0.7$; $P < 0.01$) between coleopterans present in the food of trout and in the benthic fauna. Chironomid larvae were the largest group of the benthic fauna (35.0%), although in the trout stomachs they were only 3.1% of the total, and 8.9% in salmon parr. Simuliid larvae together with other dipteran larvae comprised a small percentage of the bottom invertebrates, although they had a high percentage representation in the food of salmonids (Fig. 4.5).

5. SUMMARY

(1) Oligochaeta, Ephemeroptera, Hemiptera, Trichoptera and Chironomidae form more than 90% of the bottom fauna.

(2) The number of Chironomidae, Coleoptera, Trichoptera Ephemeroptera, Plecoptera and Oligochaeta increases during summer and gradually decreases in winter.

(3) The members of the Trichoptera, Ephemeroptera, Diptera

and Plecoptera are the main aquatic food of trout and salmon parr.

(4) 53.3% and 81.6% of the bottom fauna (by number) were consumed as a food by trout and salmon parr and the remining 46.7% and 18.6% were fish, aerial and terrestrial and miscellaneous food items.

CHAPTER V

AFON DYFRDWY

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PLATE 5.1 SAMPLING STATION LD1

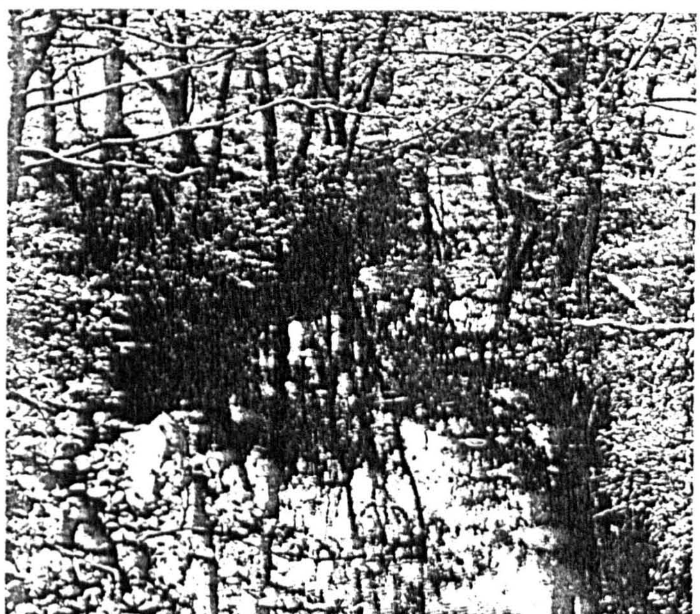

PLATE 5.2 SAMPLING STATION LD2

CHAPTER V

1. THE ENVIRONMENT

(a) General topography

Afon Dyfrdwy rises as a small stream in the Dduallt at an elevation of 660m OD; and flows through the Pre-Cambrian beds, contemporaneous igneous rocks and Ashgill and Caradoc beds of Bala Series. The Dyfrdwy as the Dee is called in Welsh, before entering the lake receives on the right the Twrch from Foel Rhudd, and on the left the Lliw from Moel Llyfnant. The three streams meet at the little village of Llanuwchllyn, and the united waters enter Llyn Tegid, the largest natural lake in Wales.

(b) Description of the sampling sites

Two sampling stations, namely LD_1 and LD_2 were selected and monthly samples taken over fourteen consecutive months at both sites. The first station, which is referred as LD_1 (Plate 5.1) in the text, was located near the lake about 40m upstream from the shore, at an altitude of 175m O.D. River width here ranged from 10m at low to 20m at high water. Depths in summer water ranged from 0.15m to 1m. The substratum was sand and gravel. There was no aquatic vegetation near the banks.

Site two which is referred as LD_2 in the text (Fig.3.2) was located on Afon Dyfrdwy near its junction with Afron Twrch at

TABLE 5.1 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT LD1 SAMPLING STATION IN AFON DYFRDWY.

Months	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Water Temp. °C	5.1	5.5	8.5	12.5	16.0	15.0	8.4	7.5	5.4	3.6	3.5	4.2	4.9	8.1
Specific conductance (micromhos / cm^3 at 25 °C)	194	226	232	119	132	124	201	276	460	420	453	336	201	112
Dissolved O2, % Sat.	95	96	[illegible]	97	98	108	94	102	111	116	108	98	102	99
Velocity of water current (m / sec.)	0.25	0.18	0.20	0.14	0.11	0.14	0.21	0.34	0.41	0.58	0.64	0.68	0.32	0.28
pH	7.4	7.1	6.8	6.9	6.8	7.1	7.4	7.0	7.1	7.8	7.2	7.4	7.1	7.1
Turbidity (as Fuller's Earth.)	18.1	22.1	25.8	19.1	20.1	27.6	36.2	30.7	63.5	84.4	97.5	78.3	67.3	26.6

TABLE 5.2 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT LD2 IN AFON DYFRDWY.

Months	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Water Temp. ^{o}C	5.0	5.8	8.6	12.6	16.2	15.0	8.2	7.4	5.6	3.4	3.6	4.1	4.6	7.8
Specific conductance (micromhos / cm^3 at 25 ^{o}C)	68	62	70	79	80	72	75	131	251	326	268	309	146	89
Dissolved O2, % Sat.	96	103	95	99	98	104	96	93	102	112	108	104	101	98
Velocity of water current (m / sec.)	0.21	0.23	0.18	0.12	0.09	0.13	0.18	0.15	0.29	0.58	0.64	0.70	0.60	0.21
pH	7.2	7.1	6.9	6.8	6.7	7.1	7.2	7.0	7.1	7.2	7.4	7.6	7.1	7.0
Turbidity (as Fuller 's Earth.)	21.1	19.2	18.4	19.3	18.2	17.5	26.4	21.8	56.4	88.8	79.5	86.5	41.1	23.7

an elevation of about 183m O.D and 1.6km upstream from site LD_1. The width varied from about 5m at low water to 10m at high water. The river had deep channels in some places. The substratum was of stones. There were trees all along the banks (Plate 5.2).

(c) Physical and Chemical conditions

Mean monthly temperatures of the water were recorded and estimates were made of dissolved oxygen, pH, current velocity, conductivity and turbidity of water each month at LD_1 (Table 5.1) and LD_2 (Table 5.2).

There was no significant differences between the mean monthly estimates of pH, water temperature, velocity of water current, and percentage saturation of oxygen (Tables 5.1, 5.2) recorded each month at the two stations.

The water was soft and clear except during the flood season. Turbidity, which is largely due to silt and detritus, occurred during high water.

Water samples for chemical analysis were taken as described in Chapter 3.2c and the results are given in Table 3.4.

No significant differences between the chemical constituents of this stream and Afon Lliw, were found other than a slight elevation in the amount of Ca and Mg ions which could be due to its geological environment (Fig. 3.1).

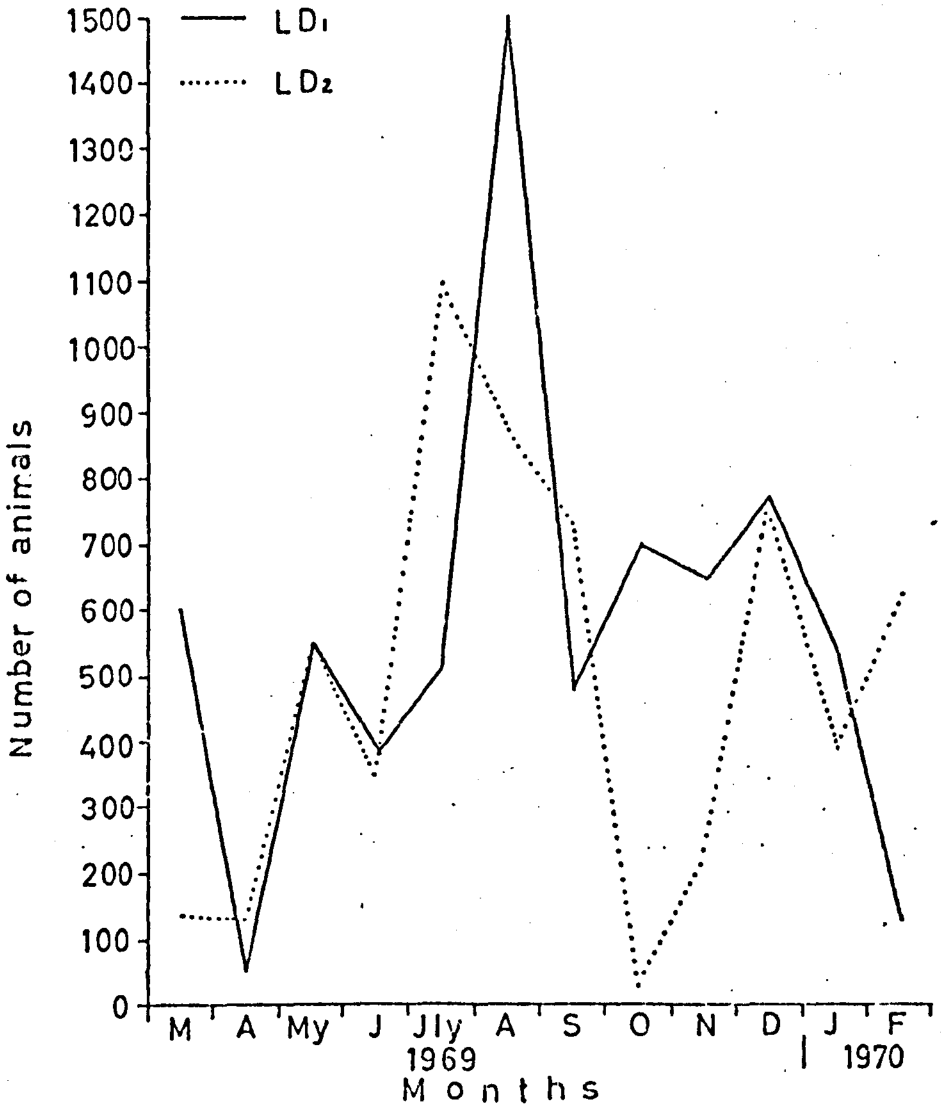

Fig. 5·1 Monthly fluctuations of the total fauna at the station LD_1 and LD_2 from March 1969 to February 1970

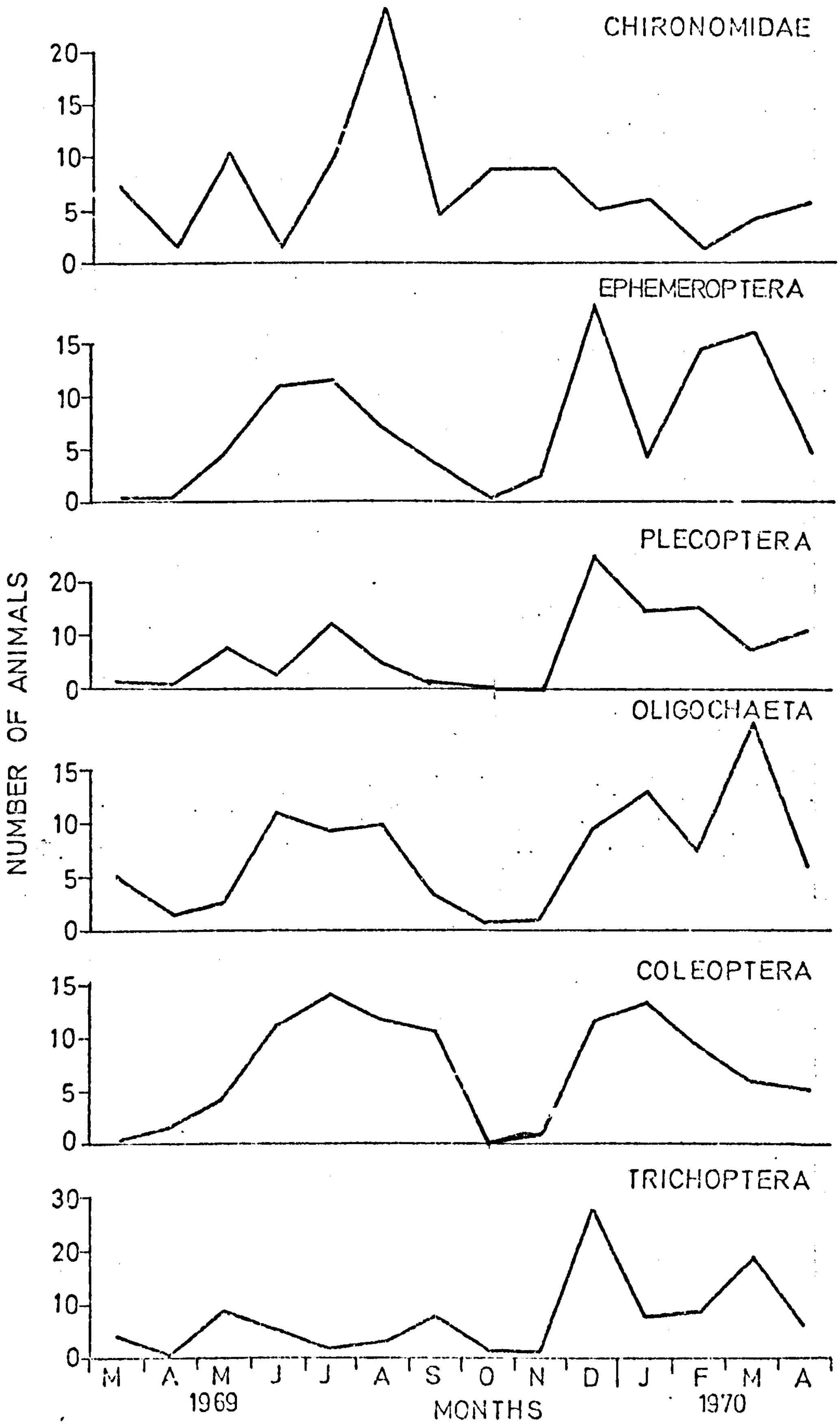

Fig.5.2 Seasonal variations in the numbers of different groups of bottom fauna in Afon Dyfrdwy

Table 5.3 The percentage composition (by number) of the fauna at two sampling sites, based on 14 monthly samples (+ = < 0.1%)

Sampling stations	LD_1	LD_2	% total
Bottom fauna	Av. No. $/m^2$	Av. No. $/m^2$	
Turbellaria	(0.7)	-	+
Polycelis nigra	0.7	-	+
Hirudinea	(2.1)	(14.9)	(0.3)
Helobdella stagnalis	-	0.7	+
Erpobdella octoculata	2.1	13.9	0.3
Oligochaeta	(272.8)	(147.6)	(7.5)
Stylodrilus heringianus	238.6	121.9	6.1
Lumbriculus variegatus	43.8	18.1	1.0
Limnodrilus hoffmeisteri	3.2	-	+
Peloscolex ferox	2.1	-	+
Aulodrilus pluriseta	1.0	-	+
Eiseniella tetraedra	0.7	5.3	0.1
Homochaeta naidina	2.1	1.0	0.1
Gastropoda	(6.4)	(23.5)	(0.5)
Limnaea pereger	6.4	1.0	0.1
Ancylastrum fluviatile	-	21.4	0.4
Lamellibranchiata	(3.2)	(4.2)	(0.1)
Pisidium milium	2.1	0.7	+
Pisidium hibernicum	0.7	-	+
Pisidium casertanum	0.7	-	+
Pisidium subtruncatum	-	3.2	+
Amphipoda	(3.2)	(1.0)	(0.1)
Gammarus pulex	3.2	1.0	0.1
Isopoda	(107.0)	-	(1.8)
Asellus meridianus	107	-	1.8
Hydracarina	(1.0)	(2.1)	(+)
Lebertia porosa	-	2.1	+
Hygrobates nigromaculatus	1.0	-	+
Plecoptera	(17.1)	(315.6)	(6.8)
Amphinemura sulcicollis	7.4	96.3	2.2
Amphinemura standfussi	2.1	103.7	2.1
Chloroperla torrentium	-	16.0	0.3
Nemoura cinerea	-	0.7	+
Protonemura meyeri	0.7	23.5	0.5
Isoperla grammatica	1.0	28.8	0.6
Chloroperla tripunctata	0.7	7.4	0.2
Leuctra hippopus	1.0	12.8	0.3
Leuctra fusca	-	16.0	0.3
Leuctra inermis	-	3.2	+
Taeniopteryx nebulosa	-	0.7	+
Nemoura avicularis	1.0	0.7	+
Leuctra nigra	0.7		+

Table 5.3(contd.)

Sampling stations	LD_1	LD_2	% total
Bottom fauna	Av. No. /m^2	Av. No. /m^2	
Ephemeroptera	(149.8)	(184.0)	(6.1)
Siphlonurus lacustris	3.2		+
Centroptilum luteolum	93.0	53.5	2.5
Ephemerella notata	2.1	-	+
Ephemerella ignita	2.1	7.4	0.1
Baëtis pumilus	2.1	18.1	0.3
Leptophlebia marginata	2.1	1.0	+
Baëtis rhodani	19.2	46	1.3
Caenis moesta	2.1	2.1	0.1
Paraleptophlebia tumida	0.7	2.1	0.1
Heptagenia sulphurea	0.7	5.3	0.1
Baëtis scambus	-	16.0	0.3
Ecdyonurus venosus	0.7	10.7	0.3
Leptophlebia vespertina	12.8	0.7	0.3
Paraleptophlebia sulemarginata	1.0	2.1	0.1
Heptagenia lateralis	-	8.5	0.1
Caenis horraria	1.0	1.0	0.1
Rhithrogena semicolorata	-	2.1	0.1
Hemiptera	(422.6)	(401.2)	(14.7)
Micronecta poweri	390.5	388.4	14.2
Sigara spp. (Nymphs)	3.2	-	0.1
Sigara distincta	1.0	-	+
Sigara falleni	12.8	-	0.2
Corixa panzeri	3.2	12.8	0.3
Sigara dorsalis	8.5	-	+
Megaloptera	(1.0)	(7.4)	0.6
Sialis fuliginosa	-	1.0	0.6
Trichoptera	(39.5)	(263.7)	(4.1)
Glyphotaelius pellucidus	2.1	65.2	1.4
Plectrocnemia conspersa	3.2	36.3	1.1
Mystacides nigra	0.7	1.0	0.1
Rhyacophila dorsalis	-	2.1	+
Agapetus fusipus	-	1.0	+
Hydropsyche instabilis	1.0	18.1	0.3
Sericostoma personatum	-	5.3	0.1
Polycentropus flavomaculatus	0.7	2.1	0.1
Silo pallipes	-	2.1	+
Hydropsyche fulvipes	-	2.1	+
Diplectrona felix	-	0.7	+
Hydroptila tineoides	-	22.4	0.5
Agraylea multipunctata	-	0.7	+
Potamophylax latipennis	2.1	-	+
Anabolia nervosa	26.7	-	0.4
Coleoptera	(28.8)	(90.9)	(2.3)
Haliplus lineatocollis	7.4	-	0.1
Deronectes depressus	5.3	-	0.1
Latelmis volkmari	3.2	48.1	1.2
Helmis maugei	0.7	32.1	0.7

Table 5.3 (contd.)

Sampling stations	LD_1	LD_2	% total
Bottom fauna	Av. No. /m^2	Av. No. /m^2	
Platambus maculatus	0.7	5.3	0.1
Oreodytes rivalis	2.1	0.7	+
Hydroporus pubescens	2.1	2.1	+
Helophorus flavipes	1.0	1.0	+
Hyphydrus ovatus	2.1	0.7	+
Diptera			
Ceratopogonidae	(5.3)	(6.4)	(0.1)
Bezzia spp.	5.3	6.4	0.1
Tipulidae	(6.4)	(7.4)	(0.3)
Tipula montium	-	2.1	+
Tipula couckei	0.7	-	+
Tipula lateralis	3.2	3.2	0.1
Tipula palludosa	0.7	2.1	0.1
Tipula maxima	1.0	-	+
Simuliidae	-	(9.6)	(0.2)
Simulium naturale	-	3.2	0.1
Simulium monticola	-	4.2	0.1
Simulium brevicaule	-	1.0	
Chironomidae	(2153.9)	(863.4)	(50.1)
Pentaneura monilis	17.1	58.8	1.6
Prodiamesa olivacea	10.7	7.4	0.3
Cryptochironomus camptolakis	-	3.2	0.1
Procladius choreus	3.2	9.6	0.7
Tanytarsus signatus	0.7	48.1	1.0
Polypedilum nebeculosus	2120.7	732.9	47.4
Endochironomus spp.	0.7	-	+
Other dipteran larvae	(2.1)	(22.4)	(0.4)
Dicranota robusta	2.1	9.6	0.2
Atherix marginata	-	1.0	+
Taphrophila vitripennis	-	5.3	0.1
Hermerodromia unilineata	-	5.3	(3.3)
Dipteran pupae	42.8	127.3	3.3
Total no. animals	4313	3144	
Av. no. animals/month	308.0	224.5	
Av. no. animals/m^2	3295.6	2402.1	

2. COMPOSITION OF THE FAUNA

Table 5.3 shows the animals recorded in Afon Dyfrdwy. These have been identified as far as possible. The total fauna fluctuated greatly with a period of maximum density in summer and a smaller peak in winter (Fig. 5.1). These findings are similar to those of Frost (1942) and Humphries and Frost (1937). Seasonal variations in the individual groups are recroded in Fig. 5.2).

A total of 103 species were recorded from this stretch, belonging to the Oligochaeta, Plecoptera, Ephemeroptera, Hemiptera, Trichoptera, Coleoptera and Diptera. The total number of organisms taken at LD_1 were 4,313 and at LD_2 3,144. The decrease in number at LD_2 may be attributed to the shading effect of dense stands of trees on the banks. The significant observations on individual species are noted below.

(A) Platyhelminthes

(1) Turbellaria

Polycelis nigra was scarce in the stream (Table 5.3).

(B) Annelida

(1) Hirudinea

0.3% of the total fauna was formed by this group. Helobdella stagnalis was scarce at both the sites and this may be due to the lack of abundant marginal vegetation (Mann, 1955). I found Erpobdella octoculata common at LD_2 and scarce at LD_1.

Table 5.4 Statistical significance of the benthic fauna at LD_1 and LD_2 at 5% level.

t = 't' test P = Probability

Benthic fauna	t	P
Oligochaeta	1.4	> 0.05
Plecoptera	3.0	< 0.05
Ephemeroptera	0.6	> 0.05
Hemiptera	0.1	> 0.05
Trichoptera	1.6	> 0.05
Coleoptera	1.8	> 0.05
Ceratopogonidae	0.4	> 0.05
Chironomidae	7.0	< 0.05
Other Dipt. larvae	3.4	< 0.05
Dipteran pupae	1.0	> 0.05

(2) Oligochaeta

The members of this group composed 7.5% of the total benthic fauna. Stylodrilus heringianus, Lumbriculus variegatus were common. Limnodrilus hoffmeisteri was common at LD_1 which may be due to fine sandy bottom, and scarce at LD_2 where the substrate was of coarse sand. There was no significant difference in the number of oligochaetes at LD_1 and LD_2 (Table 5.4).

(C) Mollusca

(1) Gastropoda

Only two species were found of which Limnaea pereger was common at LD_1 and scarce at LD_2. 0.6% of the fauna belonged to this group. They were found to be more numerous during summer than in any other season.

(2) Lamellibranchiata

0.1% of the fauna was represented by four species of this group listed in Table 5.3. All were scarce and obtained when the current was low.

(D) Arthropoda

(1) Crustacea

(a) Amphipoda

Gammarus pulex was scarce and constituted 0.1% of the total macrobenthic animals.

(b) Isopoda

Asellus meridianus was scarce and formed 1.8% of the total catch.

(2) Arachnida

(a) Hydracarina

The members of this group were very scarce in the stream.

(3) Insects

(a) Plecoptera

16 species of this group comprised 6.8% of the total bottom fauna. Of these *Amphinemura sulcicollis*, *Amphinemura standfussi*, *Chloroperla torrentium* and *Protonemura meyeri* were common. I found *Amphinemura spp.* and *Isoperla grammatica* in summer and *Chloroperla torrentium* in winter as did Hynes (1961). The above species were frequent in all seasons except autumn (Fig. 5.2). There was a significant difference ($t = 3.0$; $P < 0.05$) in the number of plecopterans collected in the benthic fauna from month to month at LD_1 and LD_2 (Table 5.4).

(b) Ephemeroptera

6.1% of the bottom fauna was represented by 17 species of this group of which *Centroptilum luteolum*, a characteristic species of the stony stream (Macan 1957), was very common at both the stations particularly in winter, spring and summer (Fig. 5.2). *Baetis pumilus*, *Baetis rhodeni*, *Heptagenia sulphurea* and *Ecdyonurus venosus* were also in the stream. There was no significant difference in ephemeropterans at LD_1 and LD_2 (Table 5.4).

(c) Hemiptera

The species of this group had a widespread occurrence

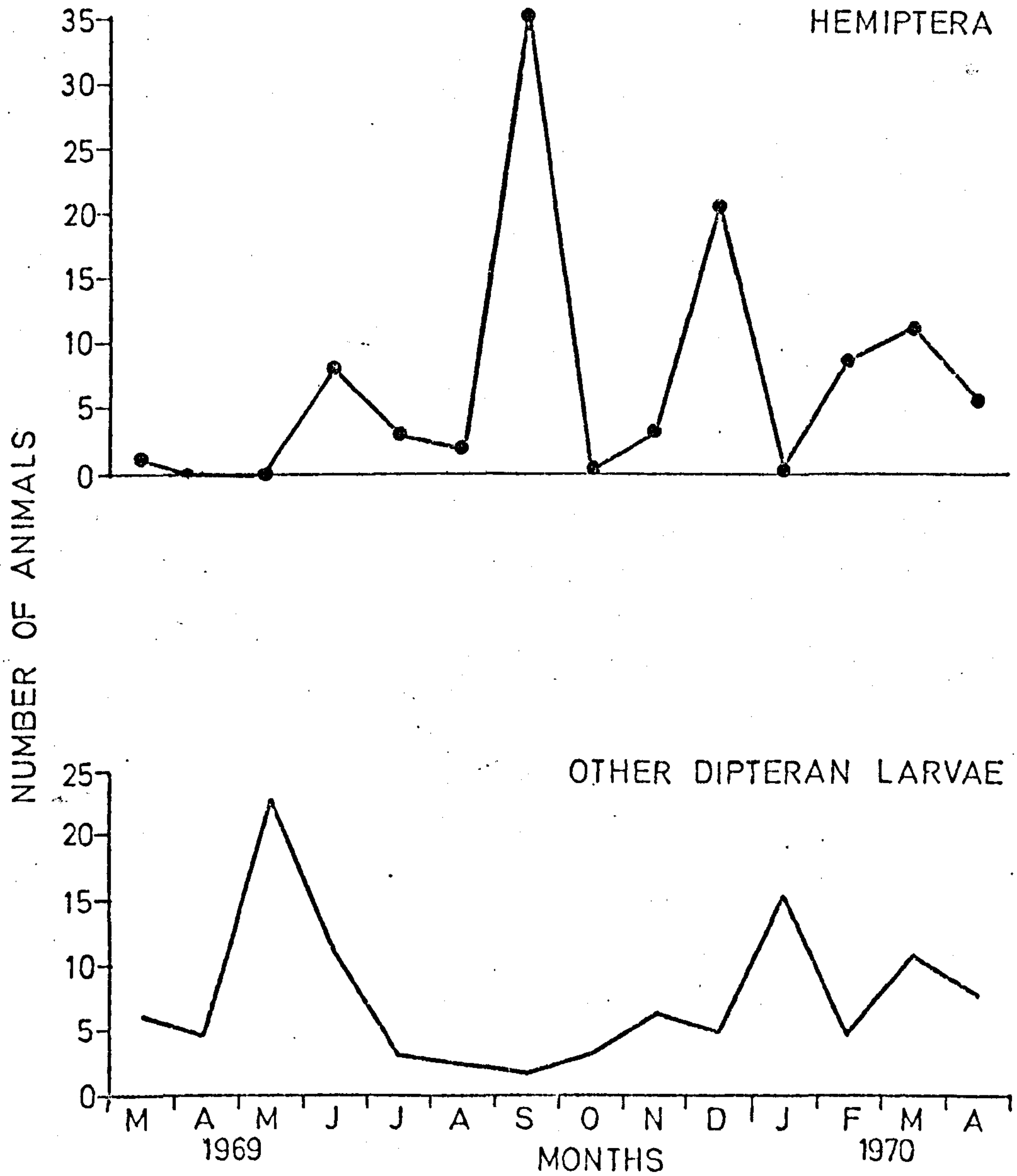

Fig.5.3 Seasonal variations in the numbers of different groups of the bottom fauna in Little Dee (Afon Dyfrdwy)

and made up 14.7% of the total bottom invertebrates. Micronecta poweri was common in all seasons (Fig. 5.3). According to Macan (1962) this species is widespread in the slow stretches of stony streams. No significant difference was observed in the number of hemipterans at LD_1 and LD_2 (Table 5.4).

(d) Megaloptera

Sialis fuliginosa and Sialis lutaria made up 0.6% of the total organisms and were scarce.

(e) Trichoptera

The species listed in Table 5.3 amounted to 4.1% of the total bottom invertebrates. Glyphotaelius pellucidus, Plectrocnemia conspersa, Hydropsyche instabilis and Potamophylax latipennis were present in considerable numbers at station LD_2. There was no significant difference in the numbers of Trichoptera larvae at LD_1 and LD_2 (Table 5.4).

(f) Coleoptera

The adults and larvae of this group made up 2.3% of the total benthic fauna. Latelmis volkmari, Helmis maugei and Platambus maculatus were common. There was no significant difference in the numbers of coleopterans at LD_1 and LD_2 (Table 5.4).

(g) Diptera

The members of the families (given below) of this group constituted 54.0% of the benthic fauna and were common in all seasons.

(1) Ceratopogonidae

This family was represented by *Bezzia spp.* which was common at both the stations and made up 0.2% of the total fauna. No significant difference was observed in the number of ceratopogonid larvae at LD_1 and LD_2 (Table 5.4).

(2) Tipulidae

Six species of this group were found in 0.3% of the bottom organisms of which *Tipula montium* was common in LD_2

(3) Simuliidae

Only 0.2% of the bottom invertebrates were represented by this group.

(4) Chironomidae

The species identified were listed in Table 5.3, which made 50.1% of the total bottom fauna. There was a significant difference ($t = 7.0$; $P < 0.05$) in the numbers of chironomid larvae collected in the benthic fauna from month to month at LD_1 and LD_2.

Other dipteran larvae

0.4% of the animals were represented by this group which included the families Empididae and Rhagionidae. A significant difference ($t = 3.4$; $P < 0.05$) was observed in the numbers of other dipteran larvae collected in various months at LD_1 and LD_2.

Dipteran pupae

They were common in the stream and constituted 3.3% of the total organisms.

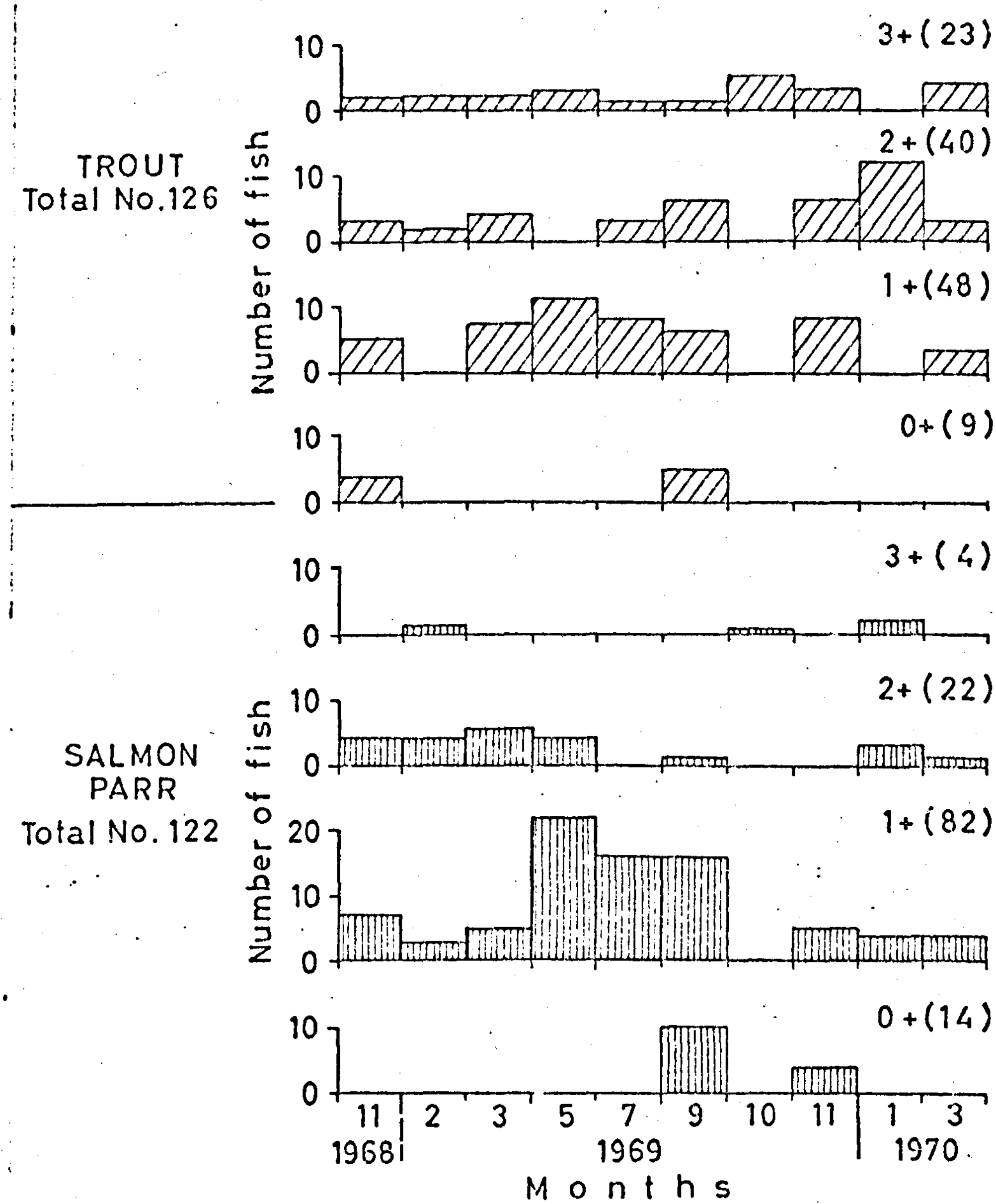

Fig. 5·4 The distribution of trout and salmon parr in each age group from November 1968 to March 1970 (The number of fish in each age group is shown in brackets

Table 5.5 The total annual composition of the diet of trout and salmon parr assessed by Occurrence, Volume, and Number method. (+ = < 0.1%)

Food organisms	Trout			Salmon parr		
Benthic food	O (%)	V (%)	N (%)	O (%)	V (%)	N (%)
Lumbriculus spp.	4.5	4.5	4.1	0.8	0.6	0.7
Limnaea pereger	0.8	0.8	0.5	4.1	1.6	0.9
Gammarus pulex	0.6	1.1	0.3	-	-	-
Amphinemura standfussi	1.2	0.4	1.1	1.5	1.0	1.6
Protonemura spp.	1.8	0.7	1.3	2.0	1.8	1.5
Chloroperla torrentium	1.5	0.3	1.2	2.6	2.4	2.1
Leuctra spp.	1.0	0.2	1.1	0.7	0.1	0.5
Other Plecoptera	2.1	0.6	1.2	1.5	1.0	1.1
Baetis spp.	7.0	5.1	10.2	10.8	7.5	6.4
Caenis spp.	3.4	2.1	2.2	5.2	2.1	3.1
Ecdyonurus venosus	4.4	3.2	3.3	3.5	2.3	4.2
Other Ephemeroptera	10.1	7.3	11.4	9.5	6.1	6.3
Hydropsyche instabilis	4.1	3.2	2.2	3.5	5.2	4.1
Plectrocnemia conspersa	7.1	8.0	7.2	7.1	10.4	6.1
Potamophylax spp.	2.1	2.2	1.2	3.6	5.3	5.0
Other Trichoptera	8.2	7.2	6.2	14.3	20.2	13.5
Latelmis volkmari	0.5	0.2	0.3	1.0	1.1	0.4
Helmis maugei	0.8	0.4	0.9	0.6	0.5	0.3
Chironomid larvae	3.1	3.2	7.7	13.4	22.0	36.1
Simulium monticola	-	-	-	1.4	0.9	0.8
Tipula montium	-	-	-	0.4	0.4	0.1
Other dipteran larvae	0.2	+	+	0.5	0.6	0.2
Dipteran pupae	2.4	1.7	2.7	5.2	1.7	2.3
Midwater food						
Latelmis volkmari adults	2.3	2.1	1.2	.2	0.1	0.1
Helmis maugei adults	2.4	2.2	1.4	.1	0.1	+
Fish	3.2	11.3	1.6	-	-	-
Aerial & terrestrial food						
Insects	18.7	29.2	25.3	2.4	3.1	0.9
Miscellaneous food						
Plant materials	6.8	2.8	3.8	3.4	0.9	1.3
Total %		100.0	99.6		99.0	99.6

3. THE FEEDING OF SALMONIDS

(i) Brown trout

A total of 120 trout ranging in age from 0+ to 3+ from Afron Dyfrdwy were received approximately at two monthly intervals from November 1968 to March 1970. Seven of the stomachs of these fish were empty (Tables 3.6, 3.7) and the rest were examined quantitatively and qualitatively by applying four different methods (Chapter 3.4b). The trout of each age group were very unequally distributed throughout the period (Fig. 5.4).

(a) Composition of the diet

Table 5.5 contains details of the total annual composition of the diet of trout from November 1968 to March 1970. 56.7% (by volume) of the total diet belonged to benthic food, Oligochaeta, Gastropoda, Plecoptera, Ephemeroptera, Trichoptera, Coleoptera and Diptera constituted 4.5%, 1.9%, 2.2%, 17.7%, 20.6%, 4.9% and 4.9% (by volume) respectively. Oligochaeta was represented by Lumbriculus spp., Ephemeroptera by Centroptilum luteolum, Baetis spp. and Ecdyonurus venosus; Trichoptera by Hydropsyche instabilis, Plectrocnemia conspersa; Coleoptera by Helmis spp. and Latelmis spp. and Diptera by the members of the family Chironomidae, Tipulidae, and Simuliidae. 11.3% of the total volume was composed of fish, a midwater food item. 29.2% of the food (by volume) was made up of terrestrial insects, and 2.8% of plant materials, a miscellaneous food item.

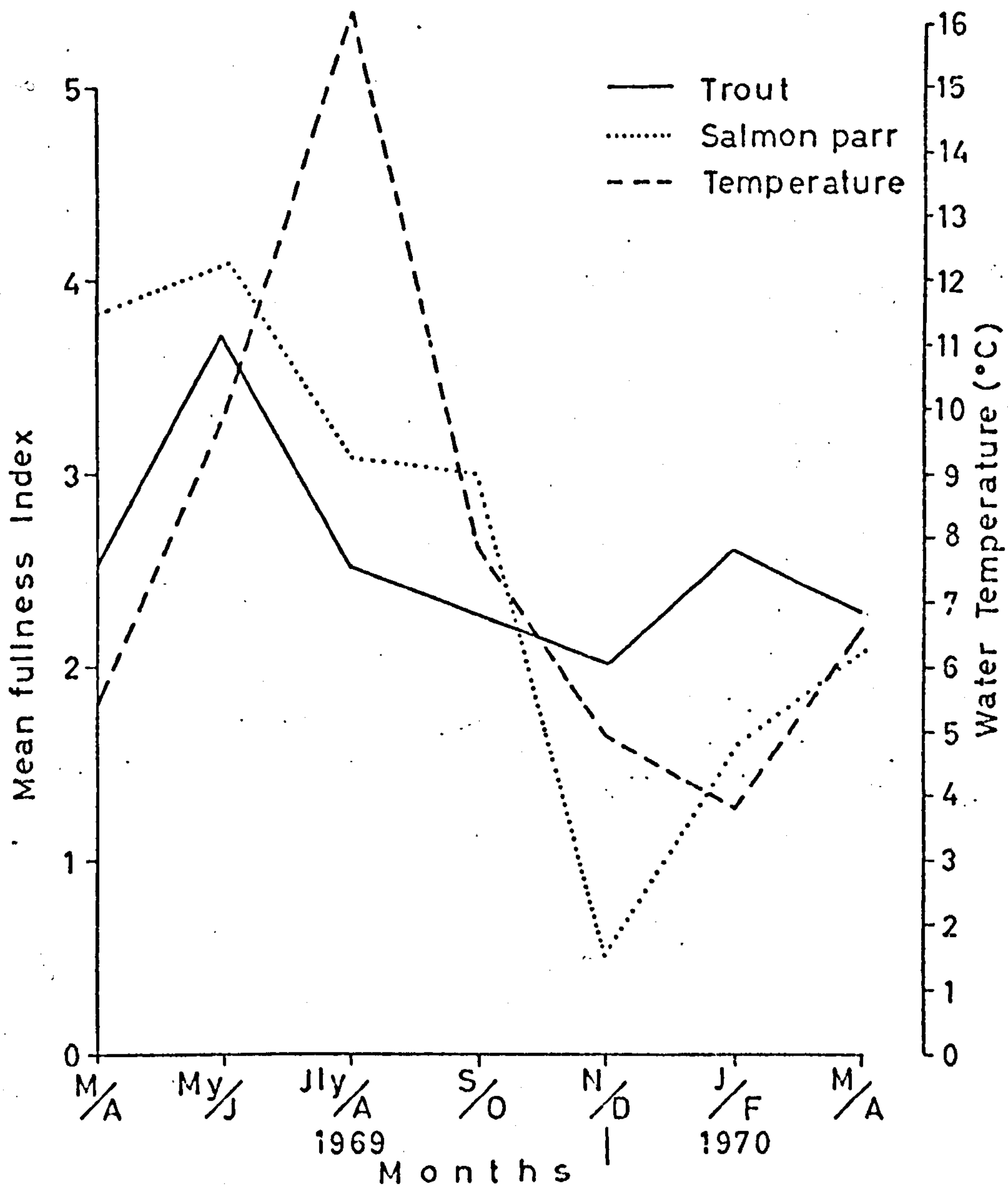

Fig. 5·5 Seasonal variation in food intake of the trout and salmon parr

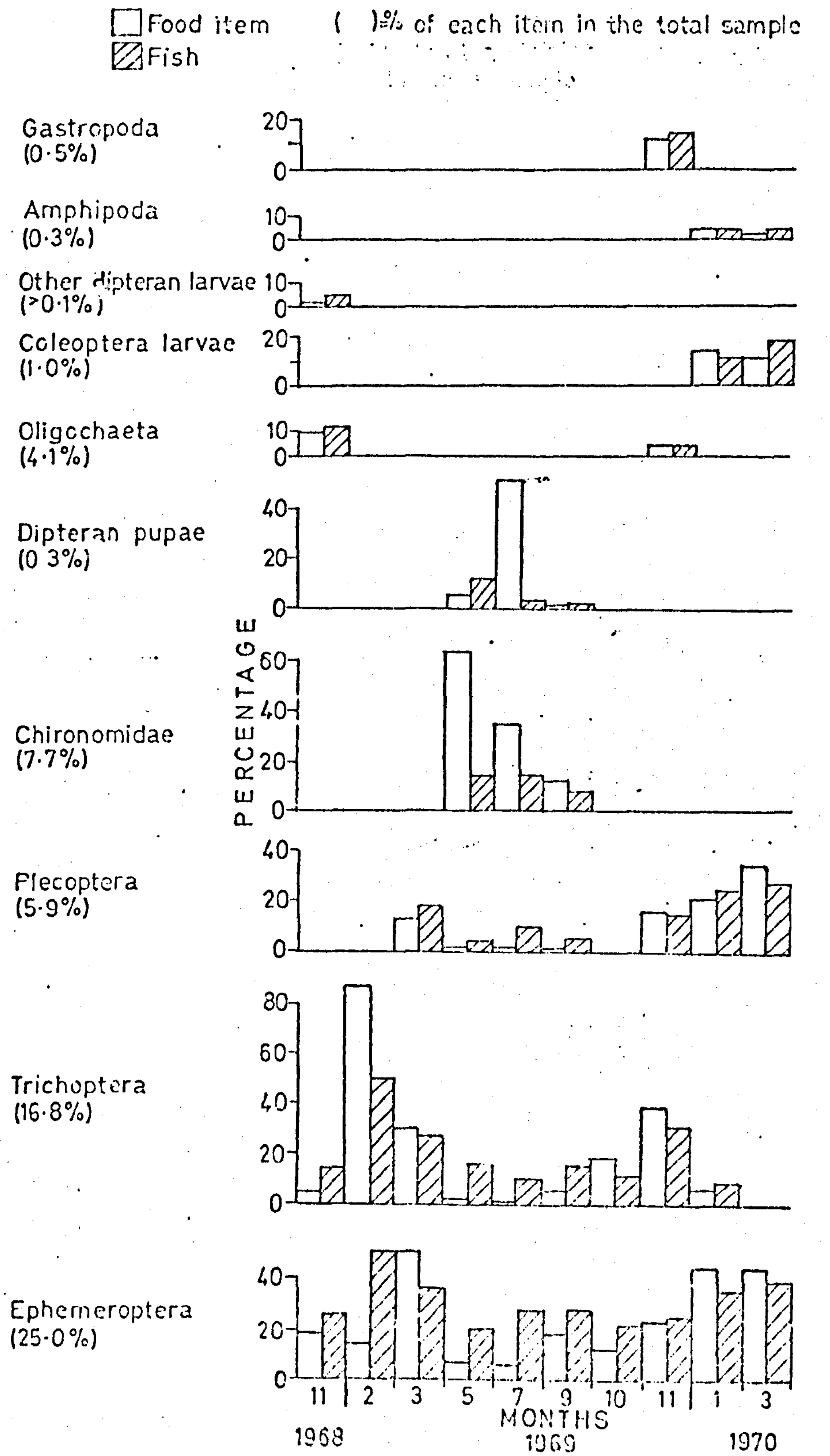

Fig.5.6 : SEASONAL VARIATIONS OF THE FOOD ITEMS OF TROUT AND STOMACHS CONTAINING EACH FOOD ITEM IN DIFFERENT MONTHS.

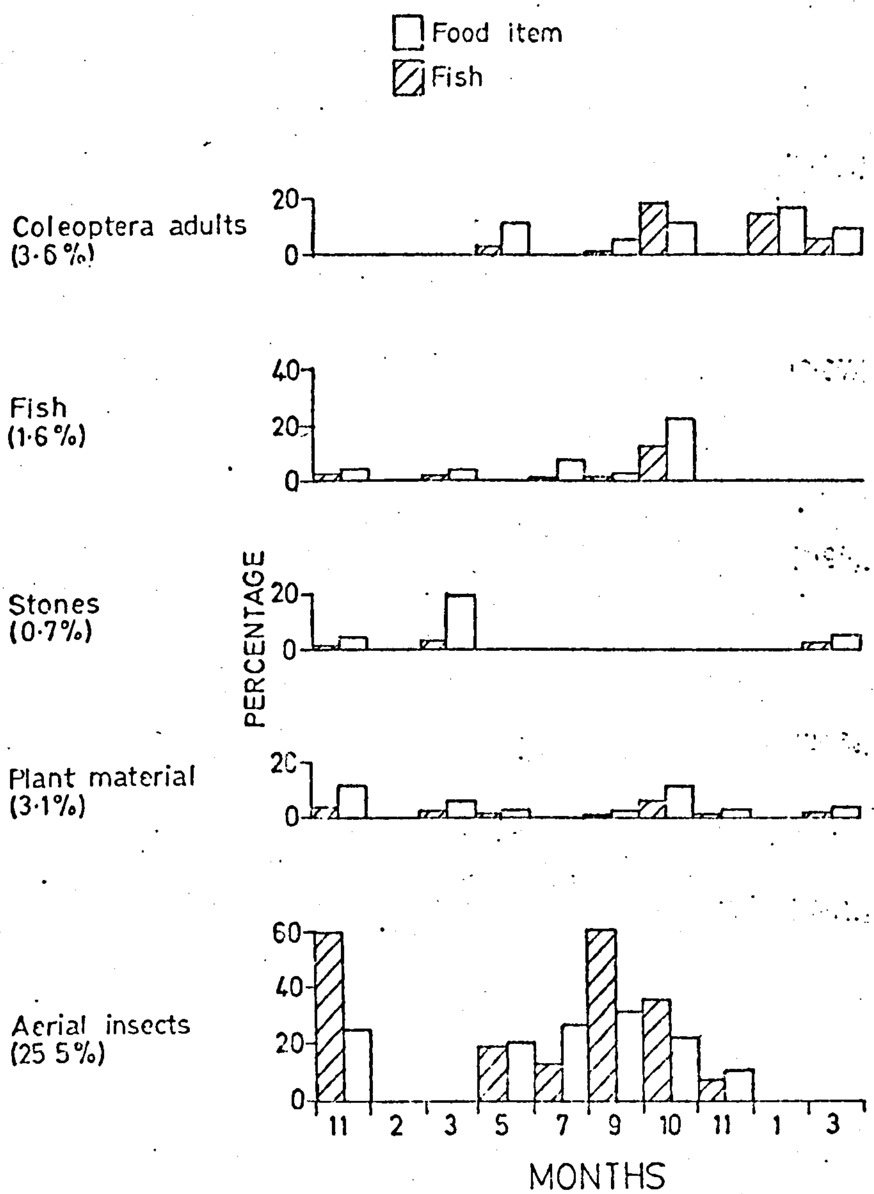

Fig.5.7 SEASONAL VARIATIONS OF THE FOOD ITEMS OF TROUT AND STOMACHS CONTAINING EACH FOOD ITEM IN DIFFERENT MONTHS.

Table 5.6 The percentage composition of the food assessed by occurrence, volume, and number methods of trout of each age group. (+ = < 0.1%)

Name of species	Salmo trutta											
Total No. Stomachs	120											
Age	0+			1+			2+			3+		
No. sp. in each age group	9			48			40			23		
No. Empty stomachs	-			-			6			1		
Methods of assessment	O	V	N	O	V	N	O	V	N	O	V	N
Benthic food												
Oligochaeta	12.5	12.5	12.5	-	-	-	1.8	2.7	1.8	3.7	3.1	2.4
Gastropoda	-	-	-	1.5	1.2	1.2	1.8	2.1	0.9	-	-	-
Amphipoda	-	-	-	0.5	1.7	0.2	2.0	2.8	1.0	-	-	-
Plecoptera nymphs	-	-	-	14.4	5.8	12.0	11.0	4.0	8.3	3.1	2.1	3.6
Ephemeroptera nymphs	27.0	19.5	24.5	28.2	11.1	22.9	23.9	21.9	31.8	20.9	15.3	20.9
Trichoptera larvae	25.0	22.5	16.2	10.9	10.8	5.9	25.2	30.0	20.6	33.0	20.2	24.5
Coleoptera larvae	-	-	-	-	-	-	2.9	1.0	2.8	2.3	1.5	1.3
Chironomidae	-	-	-	6.4	5.4	18.0	3.8	3.9	8.8	2.2	3.5	4.3
Other dipteran larvae				0.9	0.2	0.1						
Dipteran pupae				2.6	2.1	1.1	2.7	1.9	3.7	4.4	3.1	6.5
Midwater food												
Coleoptera adults	8.3	2.1	1.8	1.0	0.5	0.1	5.4	12.1	7.7	4.2	2.7	4.9
Fish	-	-	-	5.1	20.7	2.2	-	-	-	7.8	25.7	4.5
Aerial & terrestrial food												
Insects	20.8	40.0	40.5	24.8	38.4	31.4	21.5	25.2	19.9	11.3	17.5	11.0
Miscellaneous food												
Plant material	6.2	2.3	4.1	3.1	1.8	1.0	4.4	2.2	3.1	13.6	4.9	7.9

O = Occurrence V = Volume N = Number

(b) Seasonal variation in food intake

Fig. 5.5 shows the seasonal variation in feeding activity of trout in Afon Dyfrdwy. The curve shows that the maximal quantities of food were taken in the months of May and June and that food intake was minimal in November and December. This curve shows a similar pattern to the fluctuations in total fauna (Fig. 5.1).

(c) Seasonal changes in the food

Figs. 5.6 and 5.7 show the seasonal changes in the food of trout in Afon Dyfrdwy. Ephemeroptera and Plecoptera nymphs, and Trichopera larvae were found in the stomachs throughout the period.

The Ephemeroptera, Plecoptera and Trichoptera were eaten more frequently during winter and spring than in summer and autumn. Large numbers of chironomid larvae and other diperan pupae were consumed during summer and autumn. Oligochaetes, Coleptera, other dipteran larvae, Amphipoda and Gastropoda were insignificant food items. Aerial insects which include Aphididae, Cercopidae, Empidae, Bibionidae and Chrysomelidae, formed a substantial amount of food during summer and autumn. Plant material, fish and Coleoptera adults were present in small quantities in any season.

(d) Food in relation to age

Table 5.6 shows the percentage composition of the food assessed by occurrence, volume and number methods in each age group of trout. I found a highly significant difference in the occurrence of aerial and terrestrial food items (x^2_3 = 16.01, P $<$ 0.05 $<$ 0.02 $<$ 0.01) in the different age groups of trout. There was no significant difference in the other food items consumed by the different age groups (Table 5.6).

(ii) Salmon parr

A total of 122 salmon parr ranging in age from 0+ to 3+ were captured from this stream at approximately two monthly intervals; of these 113 contained food and the rest had empty stomachs (Table 3.7).

(a) Composition of the diet

Table 5.5 shows the total annual composition of the diet of salmon parr in Afon Dyfrdwy. Trichoptera larvae (41.1% of the total volume) were the predominant dietary item. Among them larvae of *Hydropsyche instabilis*, *Plectrocnemia conspersa*, *Potamophylax* spp. and other trichopteran larvae were well represented. 24.0% of the total volume was formed by chironomid larvae. Plecoptera reflected by *Amphinemura standfussi*, *Protonemura* spp. *Chloroperla torrentium*, *Leuctra* spp. and other plectoperan nymphs were common, forming 6.3% (by volume) of the diet. *Centroptilum luteolum*, *Baetis* spp., *Ecdyonurus venosus* and other ephemeropteran nymphs comprised 18.0% of the total volume. Aerial insects amounted to 3.1% (by volume). Oligochaeta represented by *Lumbriculus* spp., Gastropoda by

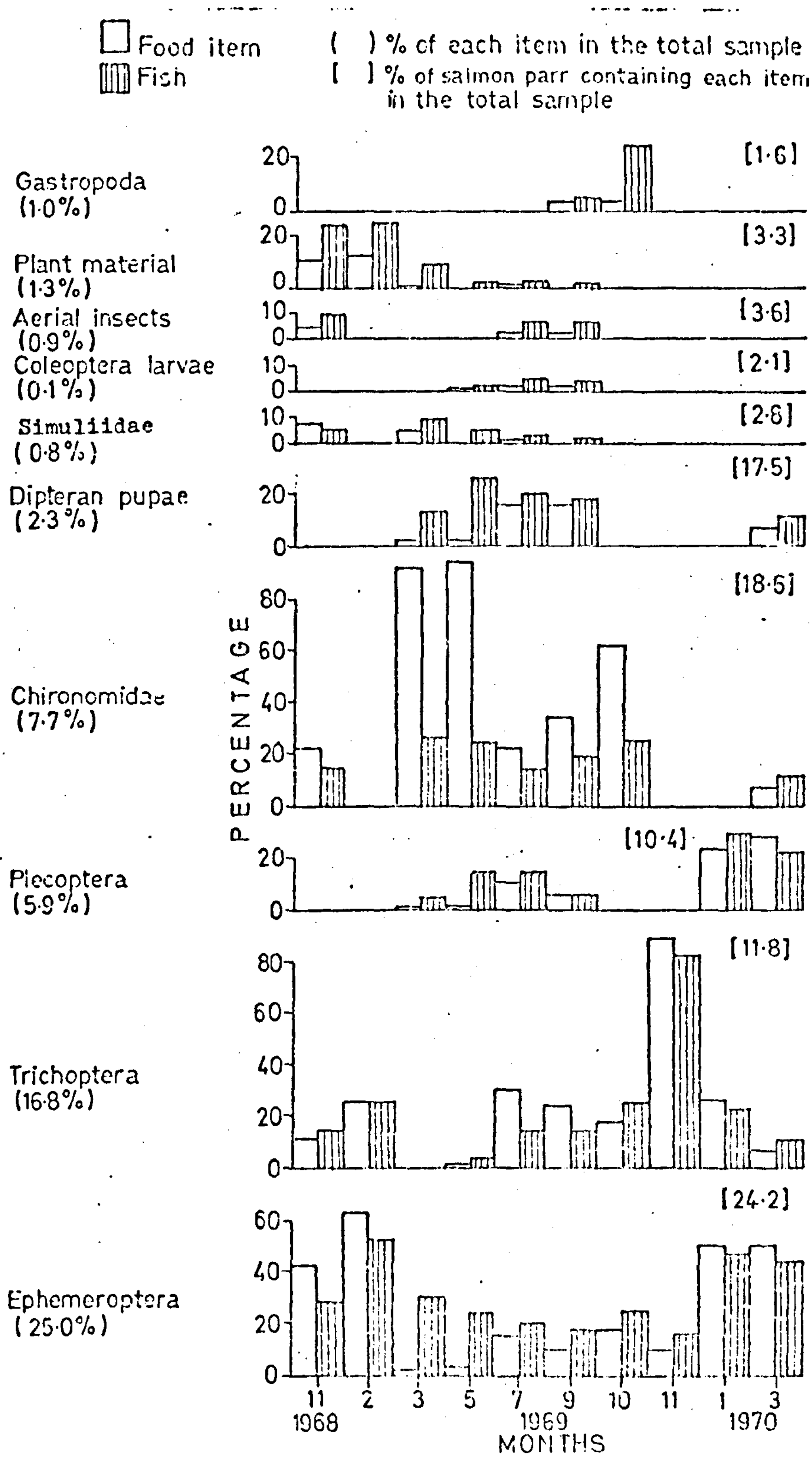

Fig.5.8 Seasonal variations of the benthic food items of salmon parr and percentage of stomachs containing each food item in different month.

Table 5.7 The percentage composition of the food assessed by occurrence, volume and number methods of salmon parr of each age group. (+ =< 0.1%)

Name of species	Salmo salar											
Total No. stomachs	122											
Age	0+			1+			2+			3+		
No. sp. in each age group	14			32			22			4		
No. Empty stomachs	3			3			2			1		
Methods of assessment	O	V	N	O	V	N	O	V	N	O	V	N
Benthic food												
Oligochaeta	1.6	1.1	0.5	-	-	-	1.7	1.5	2.4	-	-	-
Gastropoda	2.5	2.3	0.6	1.7	1.6	1.6	-	-	-	12.5	2.8	1.4
Plecoptera nymphs	1.6	1.0	0.5	8.2	5.3	7.4	23.4	19.0	19.5	-	-	-
Ephemeroptera nymphs	14.3	6.4	5.6	27.4	21.5	18.5	36.8	22.6	26.5	37.5	22.2	31.5
Trichoptera larvae	44.3	60.0	39.6	21.6	29.5	26.2	10.9	22.6	17.8	37.5	52.0	31.5
Coleoptera larvae	5.1	5.1	2.3	1.4	1.5	0.5	-	-	-	-	-	-
Chironomidae larvae	18.5	17.4	44.1	12.4	26.7	31.3	10.2	29.2	30.3	12.5	23.0	30.8
Simuliid larvae	1.6	2.1	1.5	1.7	1.1	1.2	2.6	0.5	0.8	-	-	-
Tipulidae larvae	-	-	-	1.0	1.6	+	0.9	0.3	+	-	-	-
Other dipteran larvae	1.6	1.8	0.5	0.6	0.7	0.3	-	-	-	-	-	-
Dipteran pupae	1.6	3.2	1.0	12.4	3.2	6.4	5.5	0.4	0.9	-	-	-

O = Occurrence V = Volume N = Number

Table 5.7 (contd.)

Name of species	Salmo salar											
Total No. stomachs	122											
Age	0+			1+			2+			3+		
No. sp . in each age group	14			82			22			4		
No. Empty stomachs	3			3			2			1		
Methods of assessment	O	V	N	O	V	N	O	V	N	O	V	N
Midwater food												
Coleoptera adults	-	-	-	1.3	1.1	0.5	-	-	-	-	-	-
Aerial and terrestrial food												
Insects	5	9.5	2.5	3.9	3.0	1.2	-	-	-	-	-	-
Miscellaneous food												
Plant material	-	-	-	6.9	2.3	4.0	6.9	1.5	1.2	-	-	-

Limnaea pereger and Coleoptera by Helmis spp. and Latelmis spp. were less important dietary items. Simuliid and tipulid larvae occurred in a small percentage (0.9% and 0.4%) of the total volume.

(b) Seasonal variation in food intake

Fig. 5.5 shows the period of maximum feeding activity was May and June. The food intake decreased gradually to its minimum in November and December. The pattern is again similar to the fluctuations in total fauna (Fig. 5.1).

(c) Seasonal changes in the food

Fig. 5.8 shows the amounts and kinds of food eaten by salmon parr in this stream during the period of observation. Ephemeropera nymphs, Trichoptera and chironomid larvae formed the major food items. Ephemeroptera and Trichoptera were found in larger numbers during winter than in any other season. More of the chironomid larvae were consumed in summer and autumn than in winter and spring. In all months of the year Plecoptera nymphs, plant materials and simuliid larvae were present in the stomachs although they never formed a large part of the food. Small numbers of dipteran pupae, Coleoptera larvae, aerial insects and Gastropoda were eaten during summer and autumn.

(d) Food in relation to age

Table 5.7 shows the percentage composition of the food assessed by occurrence, volume and number methods of salmon parr of each age group. Coleoptera adults and plant material were not eaten by the 0+ fish. x^2 test showed a significant

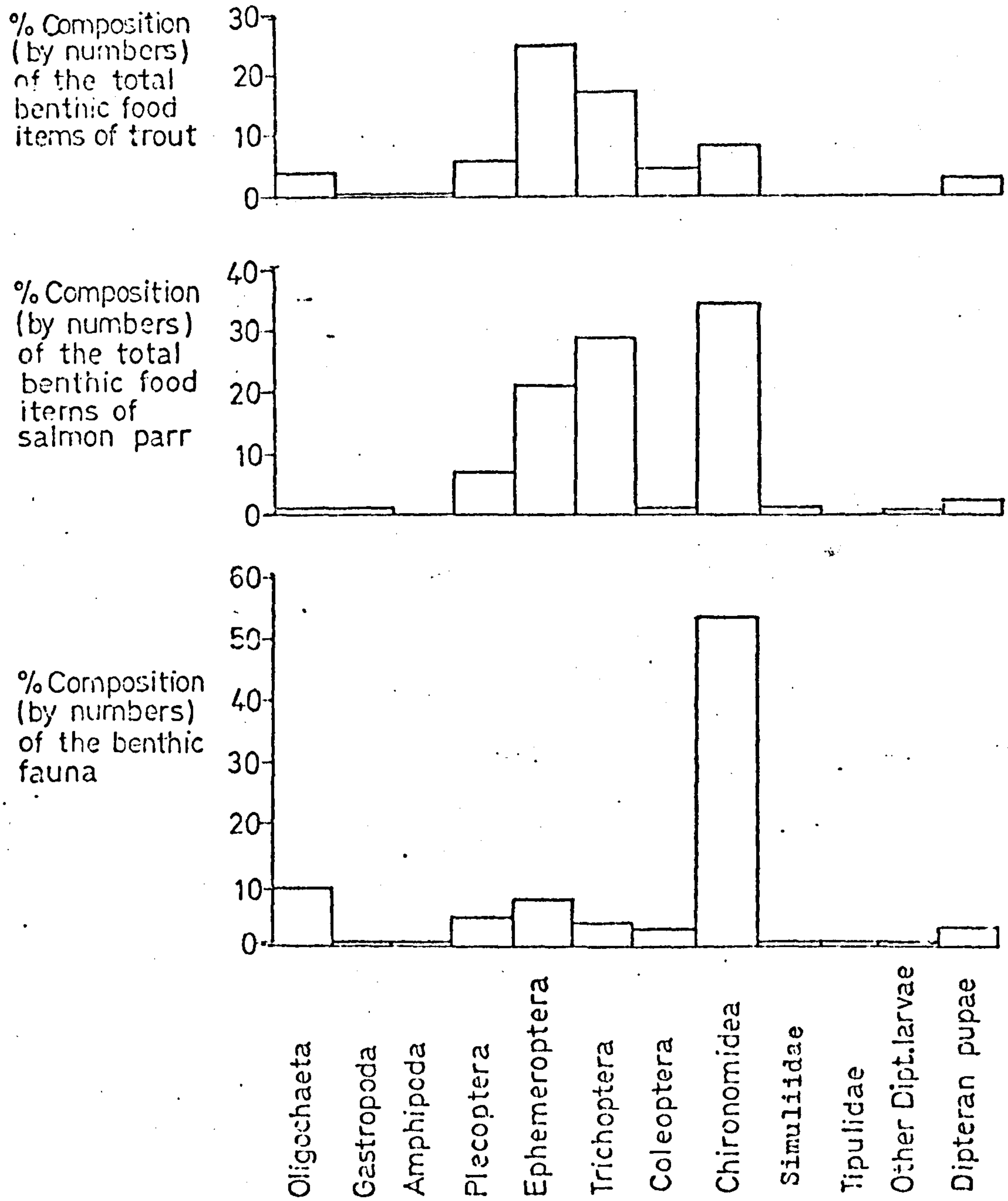

Fig. 5.9 Percentage composition by number of the benthic fauna and food of trout and salmon parr

difference in the occurrence of plecoptera ($x^2_3 = 9.22$, $P < 0.05$) and trichoptera ($x^2_3 = 8.4$, $P < 0.05$) food items in different age groups of salmon parr. As far as other food items are concerned there were no changes worth noting.

(iii) Utilisation of the fauna

Fig. 5.9 shows the relative abundance of the bottom fauna groups (No/sm²t.) together with the percentage composition of the diet of the trout and salmon parr by number. 9.3% of the bottom fauna were found to be Oligochaeta while 4.7% of the trout food and 0.7% of the food of salmon parr belonged to this group. Gastropods and amphipods were scarce and rarely eaten. Plecoptera constituted 4.7% of the total benthic fauna. This as a food item was present in 6.8% and 5.9% of the total food of salmon parr and trout respectively. Ephemeroptera comprised only 7.1% of the macrobenthos though represented 25.0% and 20.5% of the total food of trout and salmon parr. Large percentages (that is 16.8% and 28.7%) of Trichopera were consumed by trout and salmon parr, but only 3.7% were found in the bottom fauna. A significant difference was observed between the numbers of trichopteran larvae present in the bottom fauna and in the trout food ($t = 3.2$; $P < 0.05$), but no significant difference was found for salmon parr. Coleoptera made up 4.6% of trout and 0.8% (by number) of salmon parr food; whereas in the fauna there were only 2.3%. The chironomid larvae were the

Table 5.8: Statistical significance of changes of benthic food of the fish with benthic fauna at 5% level.

t = 't' test

p = probability

Fish →	Trout		Salmon parr	
Food items ↓	't'	p	't'	p
Plecoptera	1.3	>0.05	0.6	>0.05
Ephemeroptera	1.6	>0.05	1.3	>0.05
Trichoptera	3.2	<0.05	1.2	>0.05
Coleoptera	0.6	>0.05	0.4	>0.05
Chironomidae	0.4	>0.05	4.0	<0.05
Simuliidae	-	-	1.1	>0.05
Other dipteran larvae	-	-	-	-
Dipteran pupae	1.0	>0.05	0.6	>0.05

highest in the bottom invertebrates (53.1%) by number, but as a food item they were present in 34.1% and 7.7% of the total food of salmon parr and trout. There was a significant difference in the numbers of chironomid larvae found in the benthic fauna and in the food of salmon parr ($t = 4.0$; $P < 0.05$), but no significant difference was found in trout (Table 5.8). Other dipteran larvae like Tipulidae and Simuliidae occurred in small amounts in the food and fauna.

4. SUMMARY

(1) The invertebrates of a soft water trout stream were investigated.

(2) The general physiography of the stream is described.

(3) The bottom fauna at the stations LD_1 and LD_2 are similar.

(4) Seasonal changes in the food of salmonids are related to seasonal changes in the fauna.

(5) Summer is the period of maximum feeding activity and feeding decreases to a minimum in winter.

(6) 95.8% (by volume) of the food of salmon is benthic in origin compared with 56.7% in the trout.

(7) 30.2% and 3.1% of the total volume of food is composed of aerial insects in trout and in salmon parr respectively.

CHAPTER VI

AFON TWRCH

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PLATE 6.1 SAMPLING STATION T

CHAPTER VI

1. THE ENVIRONMENT

(a) General topography

Afon Twrch comes from the southern declivities of Foel Rhudd 700m O.D. It flows through the Bala or Caradoc beds (Ordovician) which consist of sandstones, flags, shales, and limestones with interbedded volcanic rocks. Upon its approach towards Afon Dyfrdwy it gradually widens and joins the latter near the village of Llanuwchllyn. The united waters find their way towards Llyn Tegid. The countryside is hilly with pasture land and woods.

(b) Description of sampling site

One sampling station referred to as "T" in the text was selected near the Llanuwchllyn disused railway station. Regular collecting started in May 1969 and ended in June 1970. The width of the river at the sampling place was about 3m and the greatest depth at low water was about 20cm. The site T was situated at about 2640m upstream from the junction (Fig.3.2) at an elevation of 216m O.D. The river bed was of large stones and gravel. Submerged and semi-submerged boulders were also present (Plate 6.1). Almost all the stones, large or small had a heavy growth of moss, mostly *Fontinalis squamosa* and rarely *Fontinalis antipyretica*. On one side of the stream

TABLE 6.1 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT "T" SAMPLING STATION IN AFON TWRCH.

Months	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Water Temp. C°	8.0	10.4	14.0	15.4	8.6	7.4	4.5	3.5	4.8	4.3	5.7	5.2	8.6	12.3
Specific conductance (micromhos /cm³ at 25 C°)	74	77	85	80	101	120	231	301	268	201	140	80	70	64
Dissolved O2, % Sat.	96	98	97	101	102	96	111	118	115	106	84	91	92	97
Velocity of water current (m/sec)	0.33	0.25	0.27	0.23	0.29	0.35	0.60	0.74	0.80	0.60	0.52	0.47	0.40	0.29
pH	6.5	7.0	6.8	7.1	7.1	7.2	7.4	7.4	7.6	7.5	7.1	7.0	6.8	7.1
Turbidity (as Fuller's Earth)	18.2	17.1	19.6	18.6	21.2	26.1	43.1	63.6	71.6	61.2	20.1	18.8	20.1	19.4

there were trees and on the other was a pasture land (Plate 6.1).

(c) Physical and Chemical conditions

Table 6.1 shows the extreme temperatures of water recorded were 3.5°C in December and 15.4°C in August. The velocity of water current was measured throughout the sampling period. Table 6.1 shows the minimum velocity recorded in August and the maximum in January. Oxygen determinations were made every month; during winter the water was relatively more saturated with oxygen than in summer. The pH of water at site 'T' varied between 6.5 - 7.5. Other climatic conditions like rainfall and atmospheric temperature were the same as described in Chapter 3.1.

Water samples for analysis of major ions were taken from the stream in the month of June 1969. The broad chemical characteristics of the water are given in Table 3.4.

The water was soft and clean except during high flood, The chemical condition indicates no pollution. There were relatively higher concentrations of Ca and CO_3 ions. This may be due to the stream's geological environment.

2. COMPOSITION OF THE FAUNA

The importance of aquatic vegetation as a place of abode for aquatic animals has long been recognised.

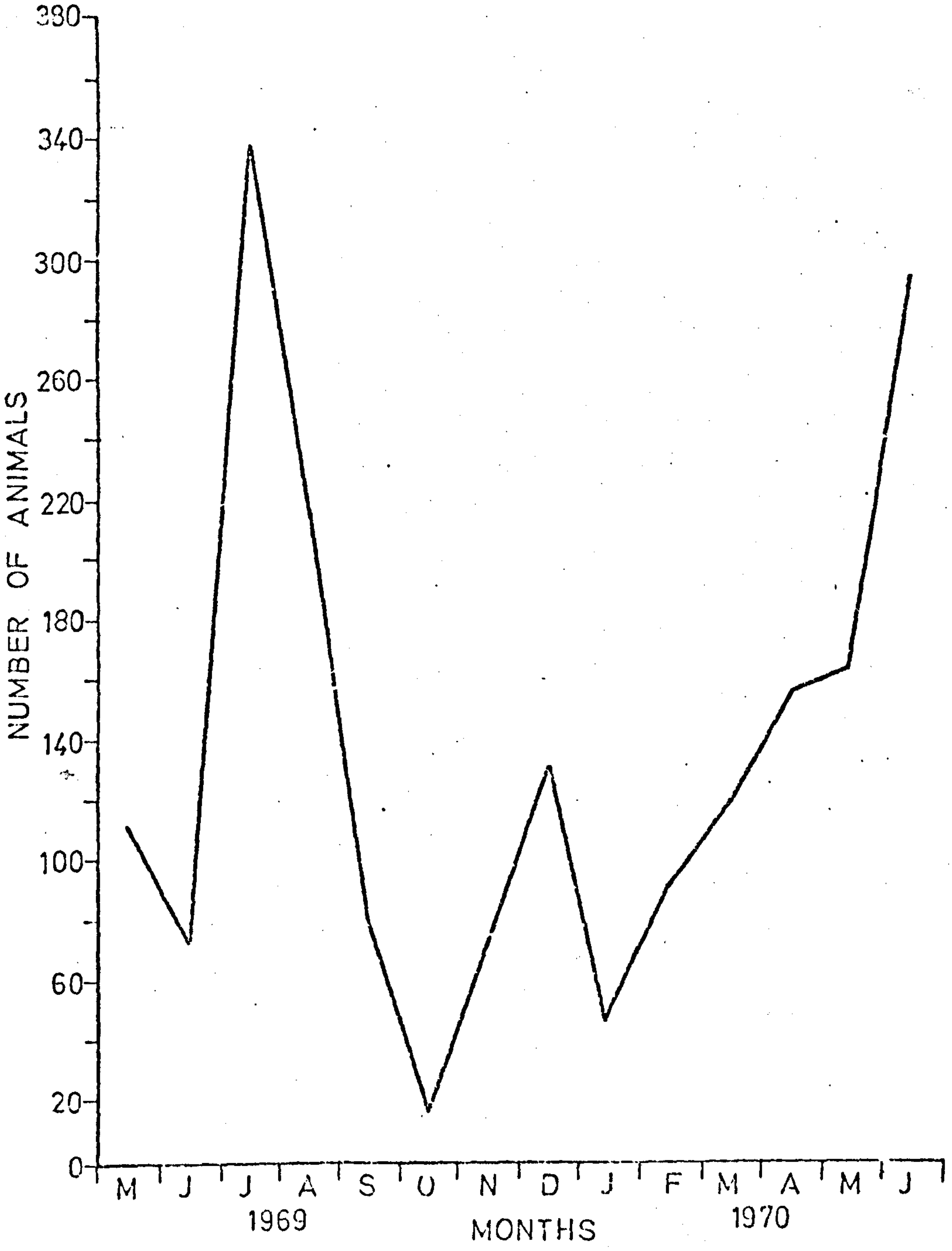

Fig 6.1 Seasonal variation of the monthly benthic fauna in Afon Twrch

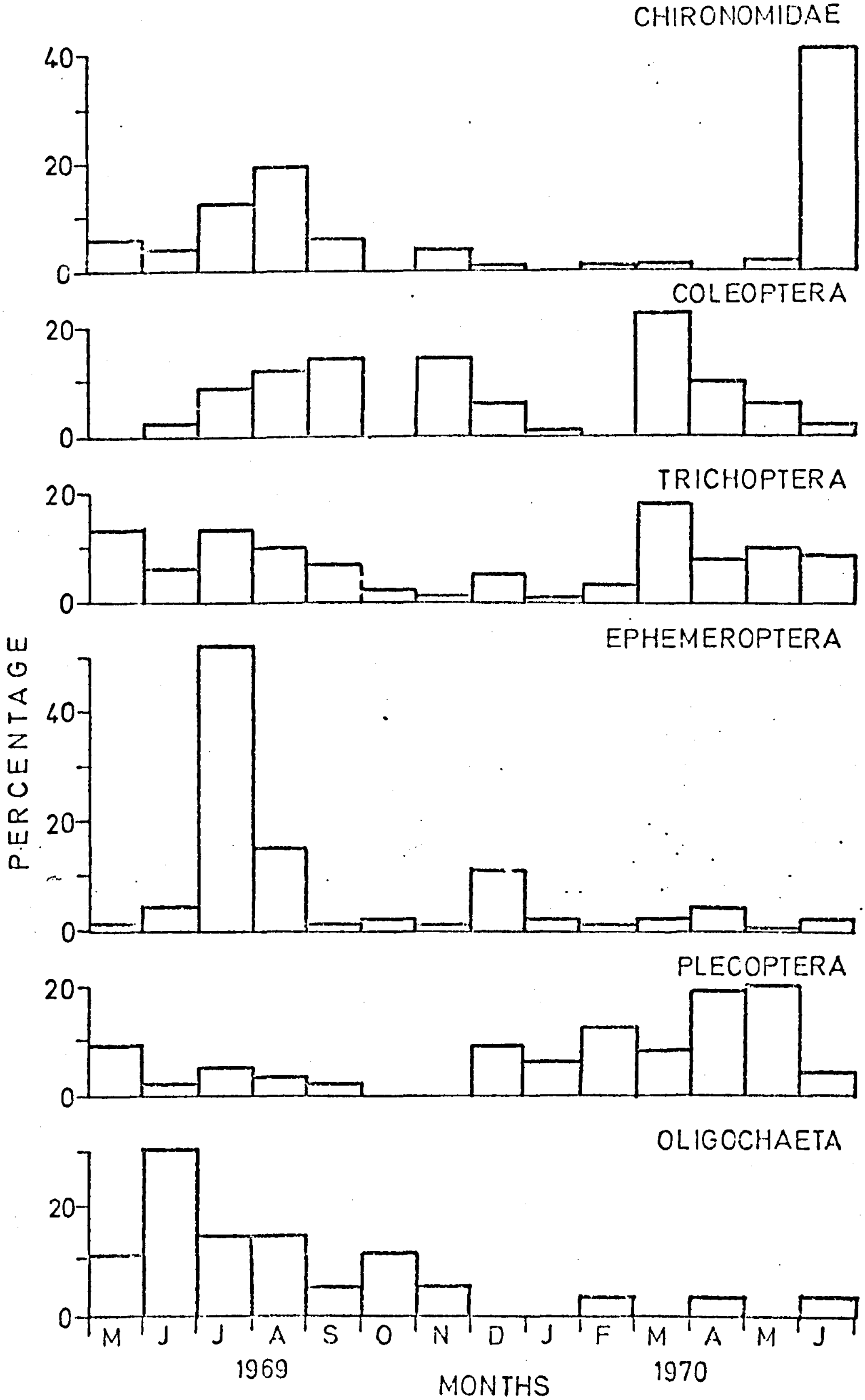

Fig 6.2 Seasonal variation in the numbers of different groups of bottom fauna in Afon Twrch

Table 6.2 The percentage composition (by number) of the fauna at one sampling site of Afon Twrch based on 14 monthly samples. (+ =< 0.1%)

Benthic fauna	Total no. spp.	%	Av. No. /m²
Hirudinea	(1)	(+)	(0.7)
Helobdella stagnalis	1	+	0.7
Oligochaeta	(36)	(1.9)	(26.7)
Lumbriculus variegatus	8	0.4	5.3
Homochaeta naidina	2	0.1	1.0
Stylodrilus heringianus	19	1.0	13.9
Eiseniella tetraedra	7	0.3	5.3
Gastropoda	(8)	(0.4)	(5.3)
Ancylastrum fluviatile	8	0.4	5.3
Lamellibranchiata	(24)	(1.2)	(18.1)
Pisidium subtruncatum	24	1.2	18.1
Amphipoda	(14)	(0.7)	(10.7)
Gammarus pulex	14	0.7	10.7
Hydracarina	(3)	(0.1)	(2.1)
Hygrobates nigromaculatus	1	+	0.7
Sperchon denticulatus	1	+	0.7
Sperchon setiger	1	+	0.7
Plecoptera	(594)	(31.6)	(253.6)
Protonemura meyeri	67	3.5	50.2
Leuctra hippopus	40	2.1	29.9
Chloroperla torrentium	32	1.7	23.5
Chloroperla tripunctata	2	0.1	1.2
Amphinemura sulcicollis	142	7.5	108.0
Isoperla grammatica	188	10.0	143.3
Perla bipunctata	2	0.1	1.2
Leuctra moselyi	4	0.2	2.1
Leuctra fusca	11	0.5	7.4
Protonemura praecox	15	0.8	10.7
Leuctra inermis	20	1.0	14.9
Leuctra geniculata	2	0.1	1.2
Amphinemura standfussi	65	3.4	49.2
Leuctra nigra	3	0.1	2.1
Nemoura avicularis	1	+	0.7
Ephemeroptera	(354)	(18.8)	(269.6)
Baëtis pumilus	41	2.1	29.9
Heptagenia lateralis	4	0.2	2.1
Siphlonurus lacustris	2	0.1	1.0
Baëtis atrebatinus	2	0.1	1.0
Baëtis rhodani	28	1.4	21.4
Ephemerella ignita	242	12.9	184.0
Baëtis scambus	4	0.2	2.1
Ecdyonurus venosus	9	0.4	6.4
Centroptilum luteolum	12	0.6	8.5
Heptagenia sulphura	2	0.1	1.0
Rhithrogena semicolorata	2	0.1	1.0
Ecdyonurus dispar	1	+	0.7
Leptophelebia marginata	5	0.2	3.2
Hemiptera	(1)	(+)	(0.7)
Corixa panzeri	1	+	0.7

Table 6.2 (contd.)

Benthic fauna	Total no. spp.	%	Av. No. /m^2
Megaloptera	(3)	(0.1)	(2.1)
Sialis fuliginosa	3	0.1	2.1
Trichoptera	(199)	(10.6)	(151.9)
Plectrocnemia conspersa	63	3.3	48.1
Rhyacophila dorsalis	27	1.4	20.3
Hydropsyche instabilis	64	3.4	48.1
Halesus digitalus	2	0.1	1.0
Glyphotaelius pellucidus	15	0.8	10.7
Agraylea multipunctata	2	0.1	1.0
Potamophylax latipennis	12	0.6	8.5
Limnephilus rhombicus	12	0.6	8.5
Sericostoma personatum	1	+	0.7
Lepidostoma hirtum	1	+	0.7
Coleoptera	(80)	(4.2)	(60.9)
Helmis maugei	45	2.4	34.2
Helophorus flavipes	3	0.1	2.1
Oreodytes rivalis	4	0.2	2.1
Laccobius biguttatus	2	0.1	1.0
Hydraena riparia	4	0.2	2.1
Helodes marginata	1	+	0.7
Latelmis volkmari	16	0.8	11.7
Hydroporus pubescens	3	0.1	2.1
Gyrinus spp.	1	+	0.7
Hyphydrus ovatus	1	+	0.7
Diptera			
Dixidae	(7)	(0.3)	(5.3)
Dixa puberula	7	0.3	5.3
Simuliidae	(5)	(0.2)	(3.2)
Simulium monticola	4	0.2	2.1
Simulium brevicaule	1	+	0.7
Tipulidae	(2)	(0.1)	0.7
Tipula lateralis	1	+	0.7
Tipula montium	1	+	0.7
Chironomidae	(451)	(24.0)	(344.5)
Cryptochironomus spp.	176	9.3	133.7
Pentaneura monilis	62	3.3	47.0
Tanytarsus signatus	193	10.2	146.5
Brillia modesta	6	0.3	4.2
Procladius choreus	14	0.7	10.7
Other dipteran larvae	(34)	(1.8)	(25.6)
Dicranota robusta	24	1.2	18.1
Hermerodromia unilineata	3	0.1	2.1
Pericoma pseudo-exquisita	4	0.2	2.1
Limnophora spp.	3	0.1	2.1
Dipteran pupae	58	3.0	43.8
Total no. animals	1874		
Av. no. animals/month	133.8		
Av. no. animals/m^2	1431.6		

Furthermore it is quite generally accepted that the submerged leafy types of vegetation are more densely populated than any other type.

Among the studies made on the fauna of submerged "mosses" are those of Carpenter (1927), Percival and Whitehead (1929, 1930), Moon (1939), Frost (1942), Hynes (1961) and Egglishaw (1968, 1969).

As far as I am aware, except on Afon Hirnant (Hynes op.cit), no information on the fauna of submerged "mosses" is available in the Dee watershed.

During the course of the present investigation a total of 1874 aquatic macro invertebrates belonging to 75 different species were collected. Seasonal variation of the benthic fauna (Figs. 6.1, 6.2) shows that there was a gradual increase in the total number of animals from autumn to summer, rather similar to that observed by Hynes (1961) and Frost (1942); both the workers believe that the total fauna fluctuates greatly, with a period of maximum density in summer and early winter.

The aquatic fauna of Afon Twrch consisted chiefly of Plecoptera and Ephemeroptera nymphs and Trichoptera and chironomid larvae, which together formed 84.4% of the total bottom fauna (Table 6.2). Other groups were represented by occasional immigrants or by scanty populations.

The species listed in Table 6.2 are those which were collected from this habitat during 14 monthly samples, and although no claim is made that the list is a complete record of everything that was present, it is extensive enough to indicate common and rare species.

(A) Annelida

(1) Hirudinea

One Helobdella stagnalis was recorded during this period.

(2) Oligochaeta

1.9% of the total bottom fauna belonged to this group. Lumbriculus variegatus and Stylodrilus heringianus were common and Homochaeta naidina and Eiseniella tetrahedra were rare.

(B) Mollusca

(1) Gastropoda

Ancylastrum fluviatile were scarce and formed 0.4% of the total fauna.

(2) Lamellibranchiata

Pisidium subtruncatum a rare species constituted 1.2% of the total benthos.

(C) Arthropoda

(1) Arachnida

(a) Hydracarina

Three species listed in Table 6.2 were scarce and formed 0.1% of the total organisms.

(2) Insecta

(a) Plecoptera

This group formed 31.6% of the total bottom invertebrates, of these Protonemura meyeri, Leuctra hipponus, Chloroperla torrentium, Amphinemura sulcicollis and Isoperla grammatica were common [illegible] and the rest were scarce (Table 6.2).

(b) Ephemeroptera

This group formed 18.8% of the total faunal samples. Baetis pumilus and Baetis rhodani were common. I found the above species more common in summer and less in winter (Fig. 6.2).

(c) Hemiptera

One Corixa panzeri was recorded during this investigation. They were not the usual inhabitants of the stream. Probably this individual had been washed away by the flood from the backwaters or adjacent pools.

(d) Megaloptera

Sialis fuliginosa were scarce and constituted 0.1% of the total macro invertebrates.

(e) Trichoptera

Ten species were identified from this group which formed 10.6% of the bottom fauna. Plectrocnemia conspersa, Rhyacophila dorsalis, Hydropsyche instabilis, Glyphotaelius pellucidus, and Potamophylax latipennis were common. They were caught more during spring and summer than in winter and autumn (Fig. 6.2).

(f) Coleoptera

4.2% of the total fauna consisted of this group. *Helmis maugei* was common. Adults of this species were found more during summer than in any other season.

(g) Diptera

(1) Dixidae

This family was represented by *Dixa puberula* which was scarce in the fauna.

(2) Simuliidae

Simulium monticola and *Simulium brevicaule* constituted 0.2% of the total catch and were scarce.

(3) Tipulidae

These were rare, forming only 0.1% of the benthos by *Tipula lateralis* and *Tipula monticola*.

(4) Chironomidae

These were common, forming 24.0% of the fauna. The most common forms were *Cryptochironomus spp.*, *Pentaneura monilis*, *Tanytarsus signatus* and *Procladius choreus*, whereas *Brillia modesta* was scarce.

Other dipteran larvae

1.8% of the bottom fauna was comprised of *Dicranota robusta*, *Hemerodromia unilineata*, *Pericoma pseudo-exquisita* and *Limnophora spp.* which were scarce.

Dipteran pupae

All the pupae of aquatic Diptera were grouped together and formed 3.0% of the total benthic fauna.

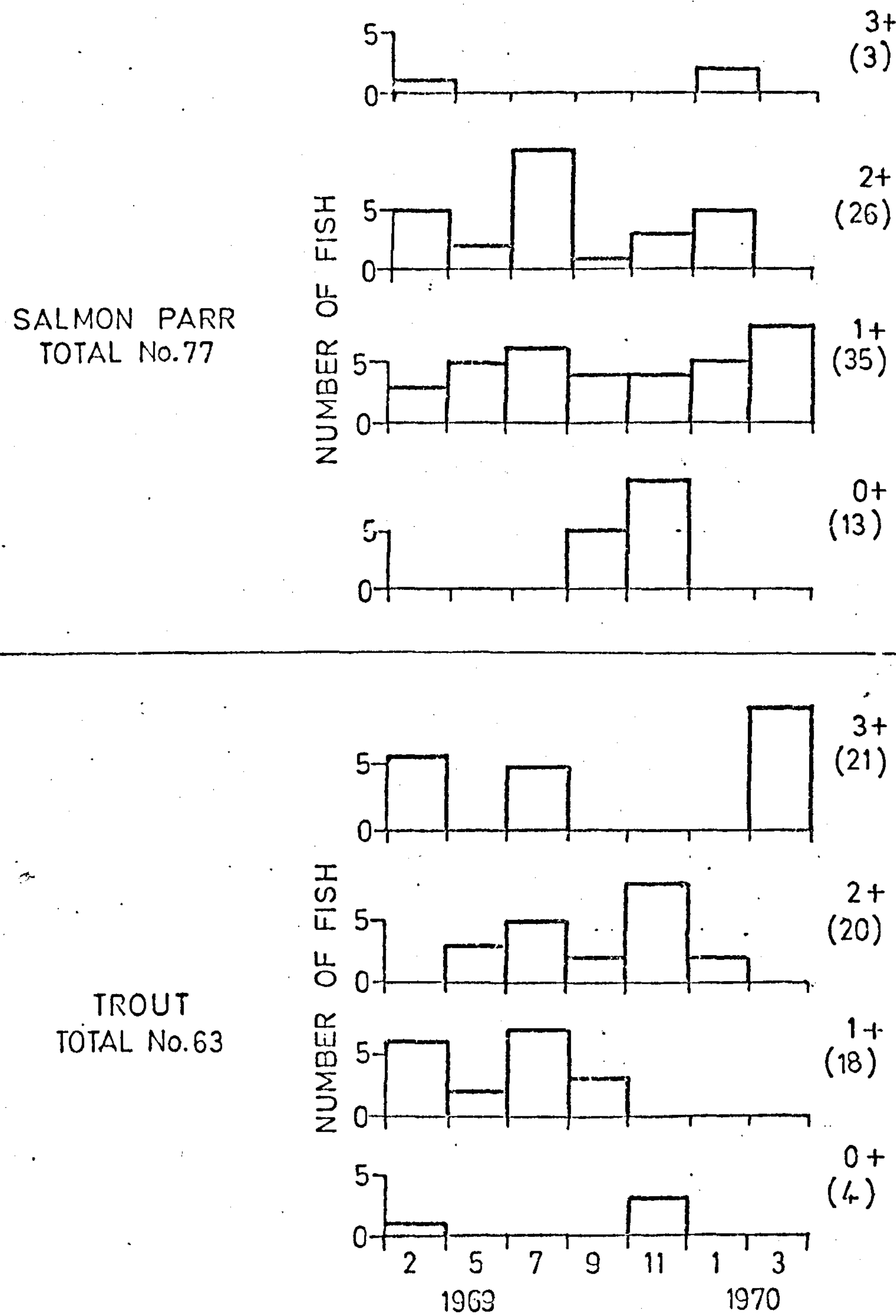

Fig 6.3 The number of salmon parr and trout in each age group from February 1969 to March 1970

Number of fish in each age group is shown in brackets

Table 6.3 The average percentage composition of the total annual diet of trout and salmon parr assessed by occurrence, volume and number methods. (+ =< 0.1%)

	Trout			Salmon parr		
Food Organisms	O	V	N	O	V	N
<u>Benthic food</u>						
Ancylastrum fluviatile	2.8	2.4	3.1	1.9	0.7	0.3
Limnaea spp.	1.3	0.8	1.0	-	-	-
Protonemura meyeri	1.4	2.3	1.9	2.2	1.9	1.3
Leuctra spp.	1.2	1.6	1.0	2.1	1.1	2.6
Chloroperla torrentium	1.1	1.7	1.4	1.3	1.0	1.1
Amphinemura sulcicollis	1.3	1.5	1.2	1.1	1.0	1.0
Isoperla grammatica	1.2	2.2	2.2	2.3	1.4	1.1
Other Plecoptera	3.2	2.0	4.2	3.2	2.5	2.2
Baetis spp.	5.6	3.1	7.4	6.6	7.3	4.3
Ecdyonurus venosus	5.5	4.3	2.4	8.4	5.3	7.5
Ephemerella spp.	6.8	4.5	4.2	6.3	4.4	11.3
Other Ephemeroptera	7.4	6.2	9.4	10.3	8.3	6.2
Plectrocnemia conspersa	2.8	1.2	1.1	5.2	6.7	3.4
Rhycophila dorsalis	1.5	0.8	1.2	4.4	5.4	3.2
Hydropsyche instabilis	3.3	2.3	2.1	3.2	4.3	5.2
Other Trichoptera	5.2	7.5	4.2	8.4	10.3	7.2
Helmis maugei (larvae)	1.4	0.6	0.6	0.7	0.5	1.1
Latelmis volkmari (larvae)	1.2	0.3	0.5	0.5	0.3	0.6
Chironomid larvae	7.5	3.1	13.1	16.6	25.5	30.0
Simulium monticola				3.2	2.6	7.0
Simulium brevicaule				4.2	3.1	3.2
Other Dipt. larvae	3.9	0.6	2.4	0.4	+	+
Dipt. pupae	0.3	0.3	0.5	0.6	+	0.1
<u>Midwater food</u>						
Helmis spp. adults	4.6	1.0	1.4	0.3	0.5	0.1
Latelmis spp. adults	2.0	0.4	1.0			
Fish	6.2	17.2	6.2			
<u>Aerial & terrestrial food</u>						
Insects	14.6	27.2	23.0	0.9	0.8	0.1
<u>Miscellaneous food</u>						
Plant material	5.7	4.9	2.7	4.5	4.4	2.1

3. THE FEEDING OF SALMONIDS

(i) Brown trout

Trout were collected bimonthly and a total of 63 trout of 0+ to 3+ age groups were taken during February 1969 to March 1970 (Table 3.6). Six had empty stomachs and the rest had a wide range of items in them. Total number of trout in each age group each month during sampling period is shown in Fig. 6.3.

(a) Composition of the diet by volume

The important benthic food items were Plecoptera, Ephemeroptera, Trichoptera and Chironomidae which together constituted 44.3% of the total volume. Other dietary items of infrequent occurrence were Gastropoda, Coleoptera, Simuliidae, other dipteran larvae and pupae (Table 6.3).

Plecoptera represented by *Protonemura meyeri*, *Leuctra spp.* *Chloroperla torrentium*, *Amphinemura sulcicollis*, *Isoperla grammatica* and other plecopteran nymphs formed 11.3% of the total volume. 18.1% of the diet consisted of ephemeropteran nymphs, represented by *Baetis spp.*, *Ecdyonurus venosus*, *Ephemerella* spp. and other unidentifiable ephemeropteran nymphs. Trichoptera larvae belonged to the species *Plectrocnemia conspersa*, *Rhyacophila dorsalis*, *Hydropsyche instabilis* and other species of the same group, had a high percentage representation in the stomachs and amounted to 11.8% of the total volume. Chironomid larvae were also

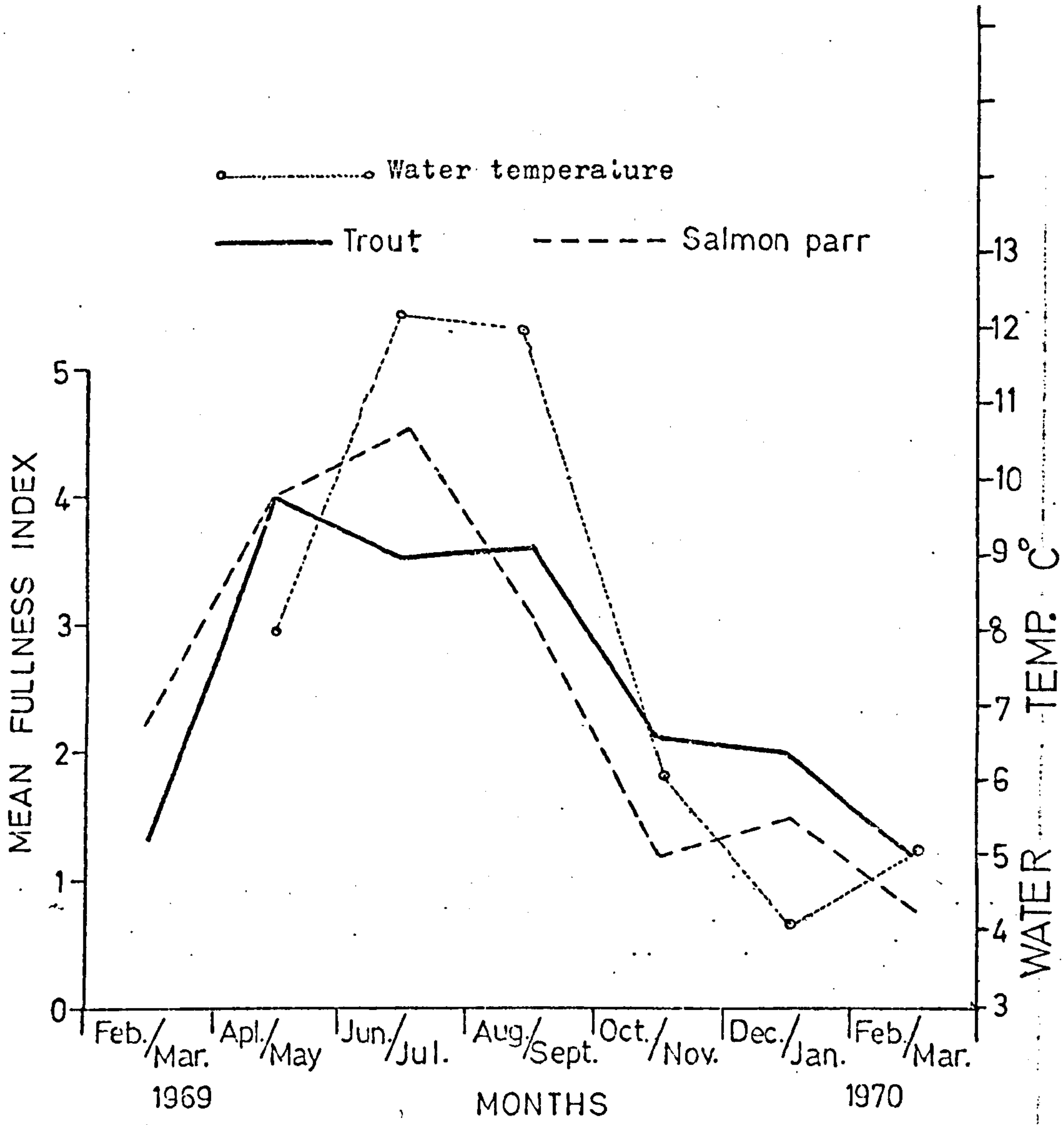

Fig. 6.4 Seasonal variation in food intake of trout and salmon parr

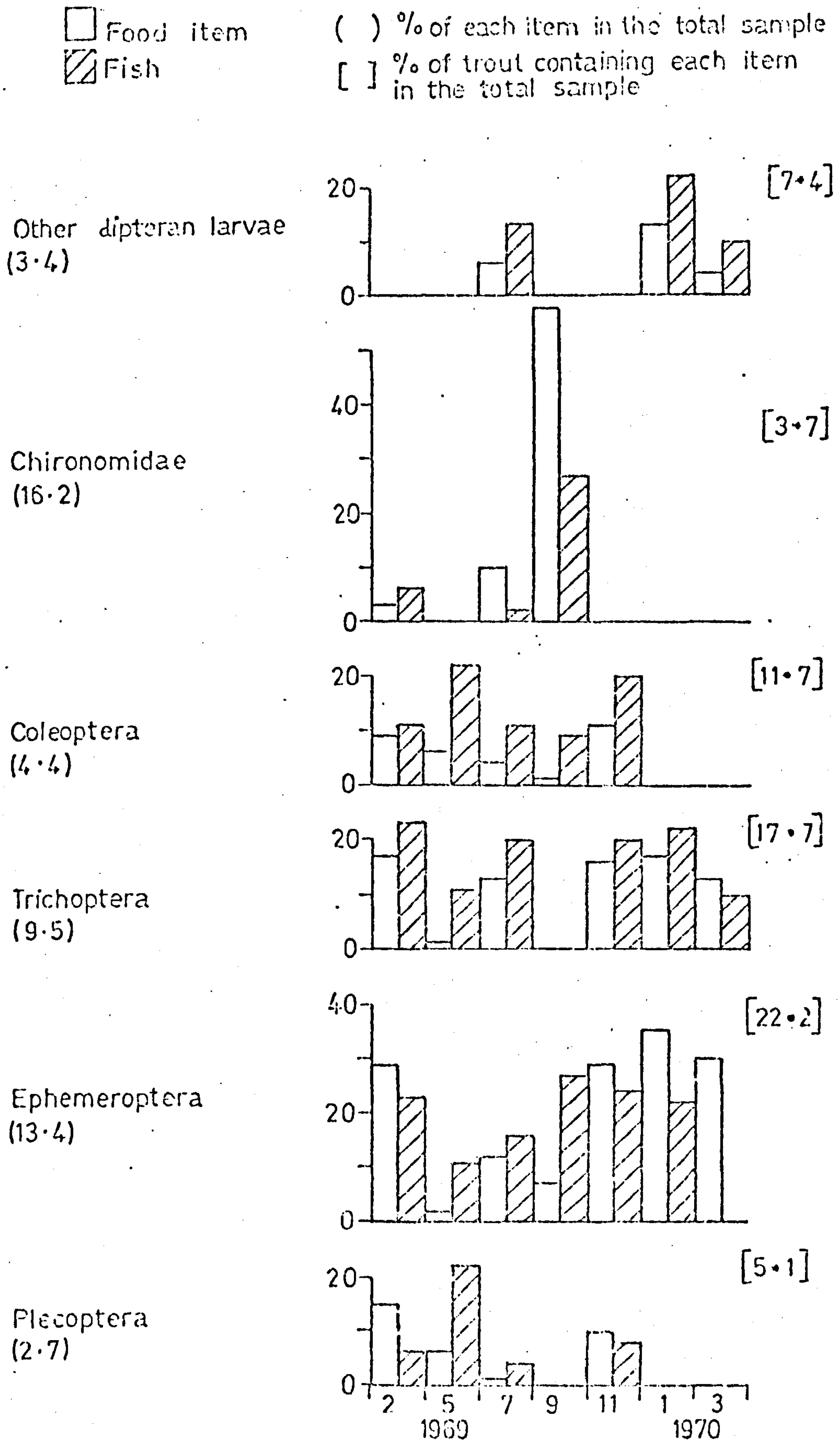

Fig.6.5 SEASONAL VARIATIONS OF THE FOOD ITEMS OF TROUT AND PERCENTAGE OF STOMACHS CONTAINING EACH FOOD ITEM IN DIFFERENT MONTHS.

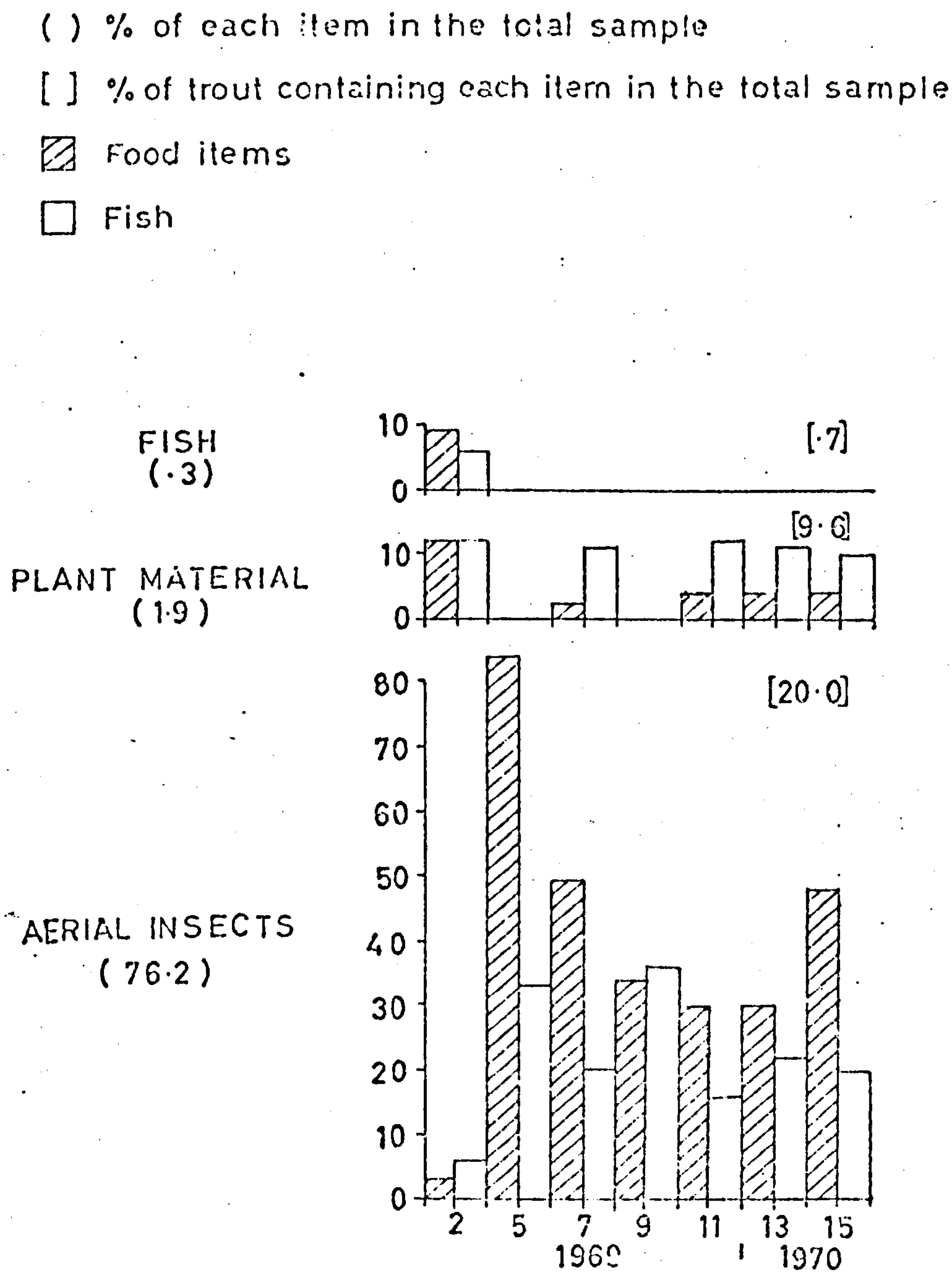

Fig. 6·6 SEASONAL VARIATIONS OF THE FOOD ITEMS OF TROUT AND PERCENTAGE OF STOMACHS CONTAINING EACH FOOD ITEM IN DIFFERENT MONTHS.

present in the food and totalled 3.1%. Among the less important food items 3.2% Gastropoda (Ancylastrum fluviatilis), 0.9% Coleoptera larvae (Helmis maugei and Latelmis volkmari), 0.6% other dipteran larvae (Dicranota spp., Hermerodromia spp.) and 0.3% dipteran pupae were accounted in the total volume.

18.6% (by volume) of the midwater food items were composed of bullheads (17.2%) and Coleoptera adults (1.4%).

Finally 27.2% of the total volume were aerial and terrestrial insects and 4.9% plant materials.

(b) Seasonal variation in food intake

Fig. 6.4 indicates that the period of maximum feeding activity was from April/May to August/September and it gradually declined in December/January and February/March.

(c) Seasonal changes in the food

Figs. 6.5, 6.6 show the seasonal variations of the different food items. Ephemeroptera nymphs, Trichoptera larvae and Coleoptera adults and larvae were significant benthic food items present throughout the season. The ephemeropteran nymphs were present more in the winter than in summer. Coleoptera and Plecoptera nymphs were eaten more during spring and summer than in autumn and winter. Most chironomid larvae were eaten in summer whereas more Dicranota spp. and Hermerodromia spp. were eaten in winter

Table 6.4 The average percentage composition of the food assessed by occurrence, volume and number methods of trout of each age group.

Name of Species	Salmo trutta											
Total No. Stomachs	63											
Age	0+			1+			2+			3+		
No. sp . in each age	4			18			20			21		
No. empty stomachs	-			3			-			3		
Methods of assessment	O	V	N	O	V	N	O	V	N	O	V	N
Benthic food												
Gastropoda	16.6	13.1	16.6									
Plecoptera nymphs	14.2	20.2	15.9	23.7	25.3	31.8						
Ephemeroptera nymphs	38.0	42.8	43.9	23.9	9.1	12.4	16.2	10.8	14.0	23.3	10.0	23.3
Trichoptera larvae	7.1	18.5	4.5	11.5	18.9	8.4	14.5	5.7	8.3	18.2	4.2	13.4
Coleoptera larvae				10.6	3.6	4.7						
Chironomid larvae	16.6	3.5	16.6	8.5	5.2	28.1	5.0	3.8	7.7			
Other dipteran larvae				2.9	0.4	0.8	7.9	2.1	3.8	5.0	.2	5.0
Dipteran pupae				1.4	1.3	2.0						
Midwater food												
Coleoptera adults	7.1	1.8	2.2				12.2	3.6	4.5	7.3	.5	3.2
Fish										25	69	25
Aerial & terrestrial food												
Insects				12.7	24.8	8.8	34.7	71.4	58.6	11.2	15.7	24.7
Miscellaneous food												
Plant material				7.0	11.0	2.5	9.0	5.3	2.4	9.8	3.3	6.0

O = Occurrence, V = Volume, N = Number.

and spring. Aerial and terrestrial insects occurred most frequently in the food in summer and autumn. Plant materials predominated during winter and spring. Fish were eaten occasionally during winter.

(d) Food in relation to age

Table 6.4 shows the average percentage composition of the food assessed by occurrence, volume and number methods of each age group. I found a highly significant difference in the occurrence of aerial and terrestrial food items ($x^2_3 = 18.30$, $P < 0.05 < 0.02 < 0.01$) inthe different age groups of trout.

(ii) Salmon parr

Seventy seven salmon parr ranging from 0+ to 3+ age groups were taken (Table 3.7). Five stomachs were empty and the rest were examined for food by the methods mentioned in Chapter 3.4b. The total numbers of salmon parr in each age group each month throughout the sampling period are given in Fig. 6.3.

(a) Composition of the diet

There was a variety of different food in the diet of salmon parr (Table 6.3). Plecoptera and Ephemeroptera nymphs, Trichoptera, chironomid and simuliid larvae were more pronounced among the benthic food items. 8.9% by volume of the food consisted of Plecoptera nymphs which included *Protonemura meyeri*, *Leuctra spp.*, *Chloroperla spp.*

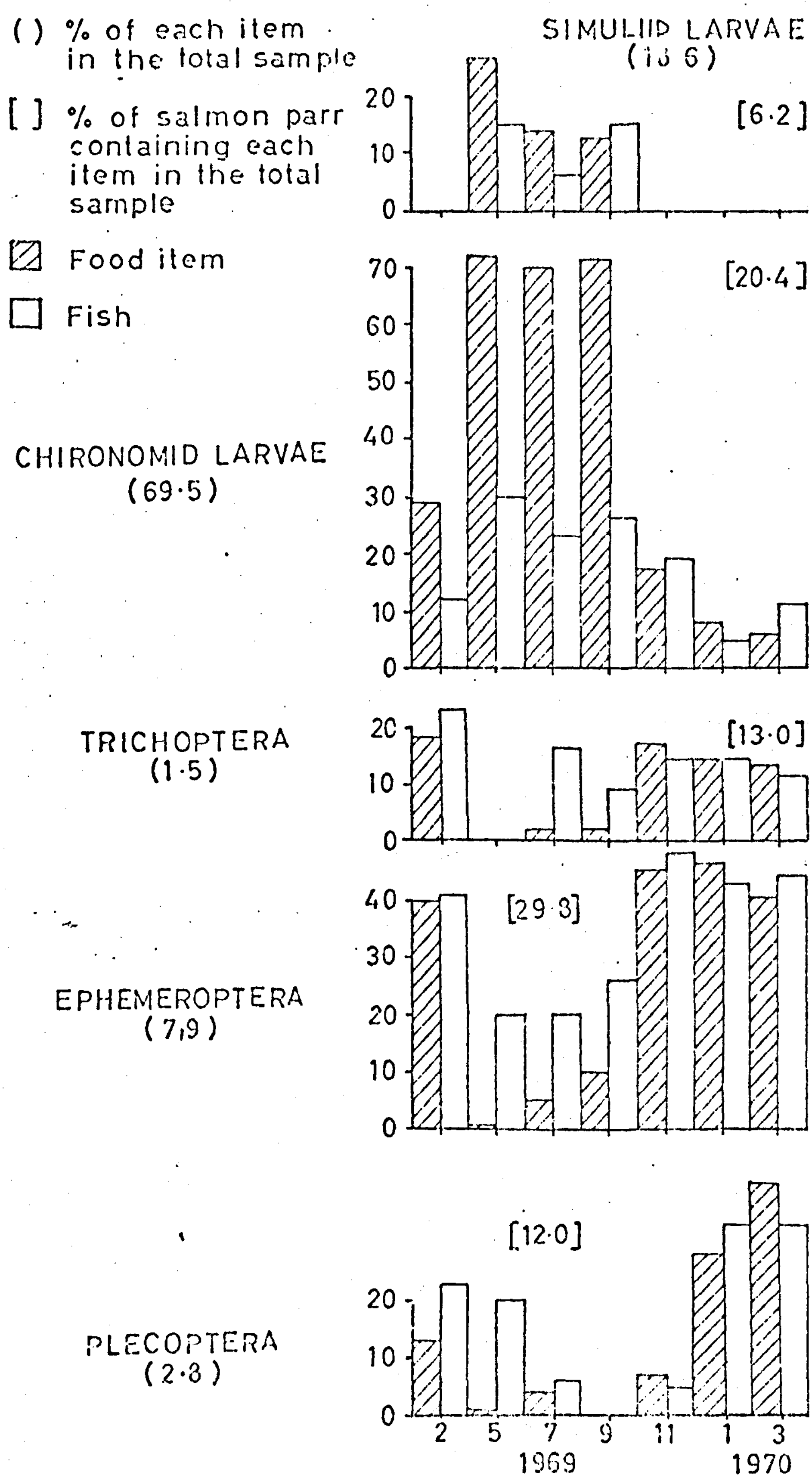

Fig. 6·7 SEASONAL VARIATIONS OF THE FOOD ITEMS OF SALMON PARR AND PERCENTAGE OF STOMACHS CONTAINING EACH FOOD ITEM IN DIFFERENT MONTHS.

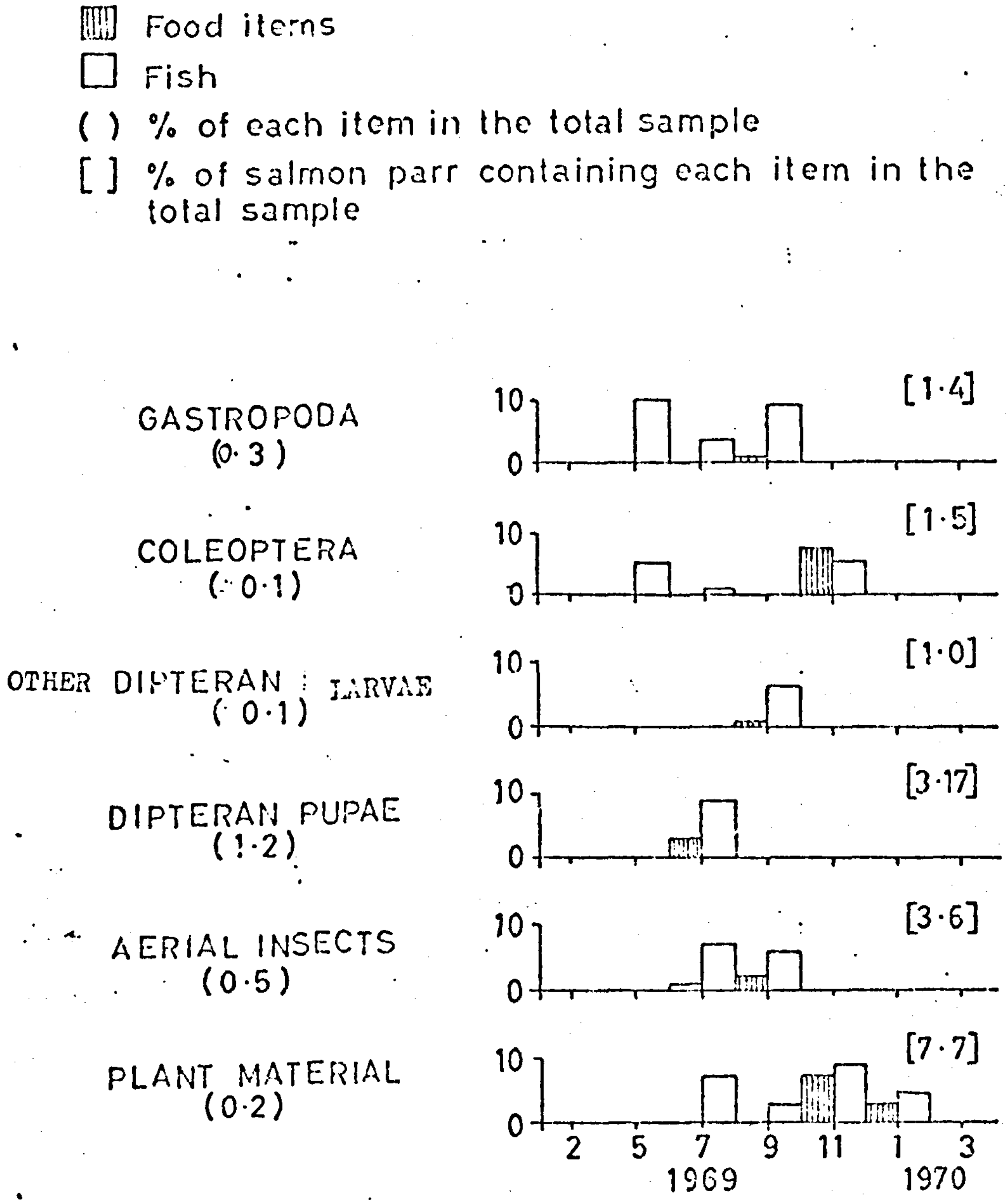

Fig. 6·8: SEASONAL VARIATIONS OF THE FOOD ITEMS OF SALMON PARR AND PERCENTAGE OF STOMACHS CONTAINING EACH FOOD ITEM IN DIFFERENT MONTHS.

Amphinemura sulcicollis, *Isoperla grammatica* and other plecopteran nymphs. 25.3% by volume of the food was made up of *Baetis spp.*, *Ecdyonurus spp.*, *Ephemerella spp.* and other unidentifiable nymphs of the group Ephemeroptera. Trichopera larvae ranked first in the list of dietary items and formed 26.7% of the total volume. Prominent amongst those were *Plectrocnemia conspersa*, *Rhyacophila dorsalis*, *Hydropsyche instabilis* and other unidentifiable species of the same group. Chironomid larvae ranked second in the list of food eaten by forming 25.5% of the total volume. Simuliid larvae represented by *Simulium monticola* and *Simulium brevicaule* formed 5.7% by volume.

Of the midwater food Coleoptera adults, chiefly *Helmis maugei*, formed 0.5% of the total volume. Aerial and terrestrial insects and plant materials formed 0.8% and 4.4% of the total volume respectively.

(b) Seasonal variation in the food intake

As seen from Fig. 6.4 much more food was taken during April/May to August/September than at other times. Minimum feeding activity occurred during winter months.

(c) Seasonal changes in the food

Figs. 6.7, 6.8 illustrate the seasonal variations of the different food items of salmon parr. Plecoptera and Ephemeroptera nymphs and Trichoptera and chironomid larvae were most significant throughout. Large numbers of

Table 6.5 The average percentage composition of the food assessed by occurrence, volume and number methods of salmon parr of each age group.

+ = < 0.1%

Name of Species	Salmo salar											
Total No. Stomachs	77											
Age	0+			1+			2+			3+		
No. sp. in each age	13			35			26			3		
No. Empty Stomachs	2			3			-			-		
Methods of assessment	O	V	N	O	V	N	O	V	N	O	V	N
Benthic food												
Gastropoda	3.3	2.5	1.0	3.9	.6	0.3	.7	+	+			
Plecoptera nymphs				23.5	22.2	21.6	8.7	6.6	6.7	16.6	6.8	9.0
Ephemeroptera nymphs	38.3	35.8	29.9	39.4	24.8	31.8	32.2	20.7	33.0	16.6	20.2	22.7
Trichoptera larvae	5.0	8.7	3.5	5.2	5.0	2.8	16.6	29.5	15.2	58.3	63.8	54.5
Coleoptera larvae	5.0	3.5	7.1									
Chironomid larvae	31.6	38.3	43.8	15.5	70	39.5	12.1	16.6	23.1	8.3	7.2	13.6
Simuliid larvae	16.6	11.5	14.4	0.8	+	0.1	12.5	11.3	14.6			
Other dipteran larvae				1.6	+	.1						
Dipt. pupae							2.4	.3	.5			
Midwater food												
Coleoptera adults				1.4	0.5	+						
Aerial & terrestrial food												
Insects				2.8	1.8	0.7	1.0	1.6	+			
Miscellaneous food												
Plant material				4.6	4.7	2.5	13.4	13.1	6.1			

O = Occurrence, V = Volume, N = Number.

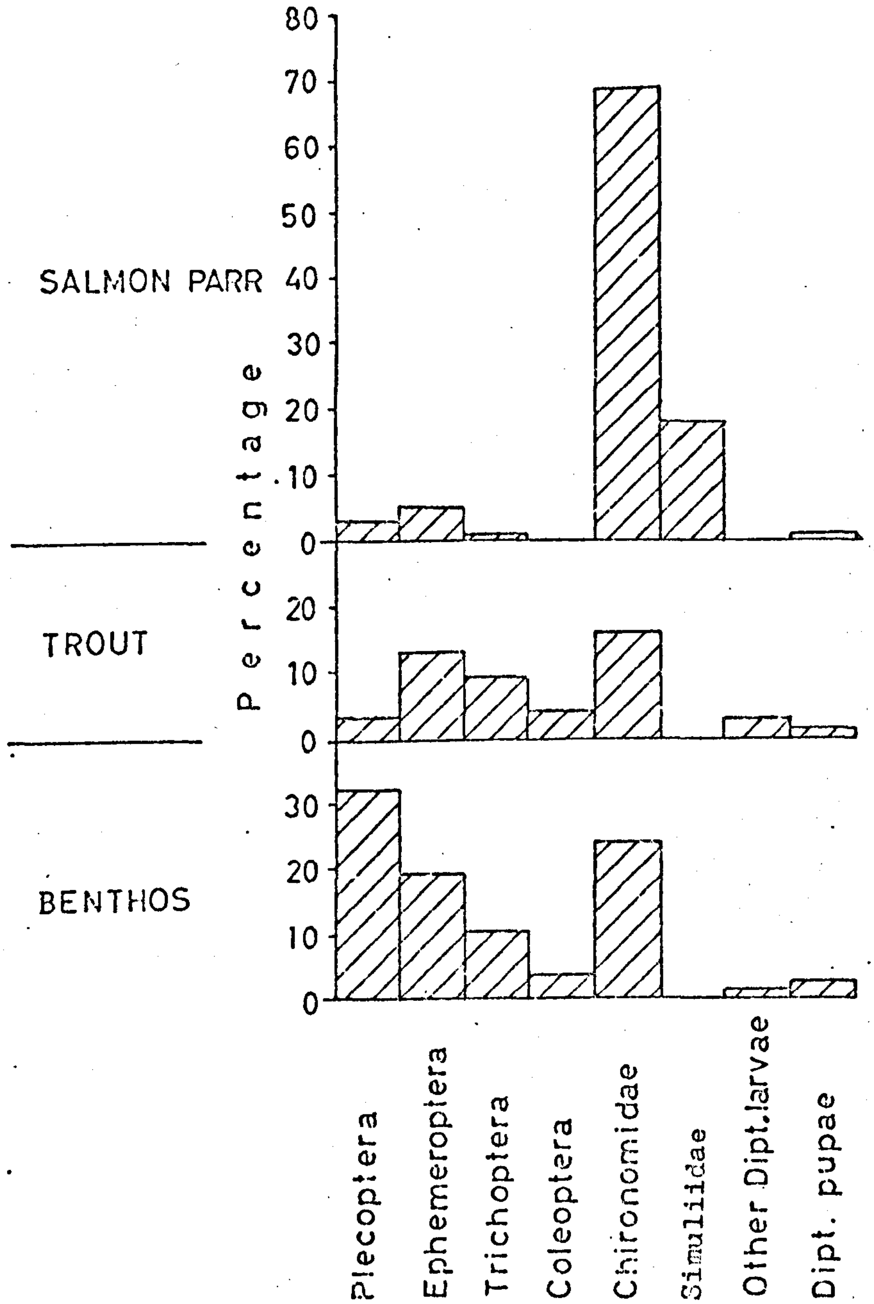

Fig. 6.9 Percentage composition by number of the benthic fauna utilised by trout and salmon parr (Values >0·5% is not shown)

Plecoptera and Ephemeroptera nymphs occurred in winter and spring. A similar seasonal pattern was observed in Trichoptera larvae. Chironomid larvae were found in abundance during summer and autumn. Simuliid larvae were recorded only during summer and autumn. The food items of insignificant occurrence were Gastropoda, Coleoptera, other dipteran larvae, dipteran pupae and aerial insects; these were confined mainly to the summer and autumn. Most of the plant material was utilised during autumn and winter.

(d) Food in relation to age

Table 6.5 shows the average percentage composition of the food assessed by occurrence, volume and number methods of salmon parr in each age group. There was no appreciable change in the diet observed from 0+ to 3+ age groups except that the older salmon parr (3+ age group) confined their diet to Ephemeroptera, Plecoptera, Trichoptera and Chironimidae. x^2 test showed a significant difference in the occurrence of plecopteran (x^2_3 = 9.77, P $<$0.05) and trichopteran (x^2_3 = 17.56, P $<$0.05 $<$ 0.02 $<$ 0.01) food items in different age groups of salmon parr.

(iii) Utilisation of the fauna

Fig. 6.9 shows the percentage composition of benthic fauna by number utilised by trout and salmon parr and Table 6.6 shows the statistical significance of benthic food with the benthic fauna in trout and salmon parr.

Table 6.6 Statistical significance of changes of benthic food of the fish with benthic fauna at 5% level.

t = Robust 't' test

P = Probability

Fish	Trout		Salmon parr	
Food items	t	P	t	P
Gastropoda	-	-	1.8	>0.05
Plecoptera	3.7	<0.05	1.3	>0.05
Ephemeroptera	0.8	>0.05	0.3	>0.05
Trichoptera	0.2	>0.05	1.0	>0.05
Coleoptera	0.9	>0.05	2.3	>0.05
Chironomidae	0.6	>0.05	1.7	>0.05
Simuliidae	-	-	6.6	<0.05
Other Dipt. larvae	1.0	>0.05	-	-

Plecoptera nymphs were present in 31.6% of the total bottom fauna but only 2.7% were used by trout and 2.8% by salmon parr. The number of plecopterans were significantly different in the fauna and in the food of trout ($t = 3.7$; P 0.05), whereas no such significance was observed in salmon parr (Table 6.6). Trichoptera larvae formed 10.6% of the total benthos whereas 9.5% were taken by trout and 1.5% by salmon parr. Coleoptera were not popular, for they occured in only 4.4% of trout and 0.1% of salmon parr food. Chironomid larvae ranked second, by forming 24.0% of the total macrofaunal community, while 16.2% of the trout and 69.5% of salmon parr food fell into this category. Very few simuliid larvae (0.2%) were present in the fauna, but 18.6% (by number) were eaten by salmon parr and none by trout. I found a significant difference ($t = 6.6$; $P < 0.05$) in the number of simuliid larvae in the bottom and in the food of salmon parr. 1.8% of the other dipteran larvae were present in the stream whereas trout used 3.4% and salmon parr 0.1%. Dipteran pupae formed 3.0% of the total bottom invertebrates while 1.3% and 1.2% were utilised by trout and salmon parr respectively.

4. SUMMARY

(1) A detailed investigation of the fauna and the food and feeding habits of salmonids in the submerged mosses of Afon Twrch was carried out.

CHAPTER VII

AFON GLYN

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CHAPTER VII

1. THE ENVIRONMENT

(a) General topography

Afon Glyn rises in Foel-y-Geifr at 500m o.D. Of all the tributaries of Llyn Tegid (Fig. 3.2) this stream has the steepest descent from its source to low flood plain. All along its upper course it runs along cracks in rocks. In some places the flow helped in cutting the land and dropping downwards to the deep valley. The steps formed by the cracks take the form of a series of falls at the upper reaches. On either side of the stream there were more trees in the lower reaches than the upper. The stream flows through the upper Bala beds of shales, flags and limestones of Caradoc series of Ordovician (Fig. 3.1).

(b) Description of the sampling sites

Three sampling sites G_1, G_2 and G_3 were selected on this stream (Fig. 3.2) and regular monthly collections were taken from March 1969 to June 1970.

Site G_1 was located about 16m upstream from Llyn Tegid at an altitude of 176m OD. Here the stream was about 12m wide and its depth averaged 0.4m to 0.1m. Some aquatic vegetation was present in the form of clumps of *Fontinalis antipyretica* near the banks. The shores were

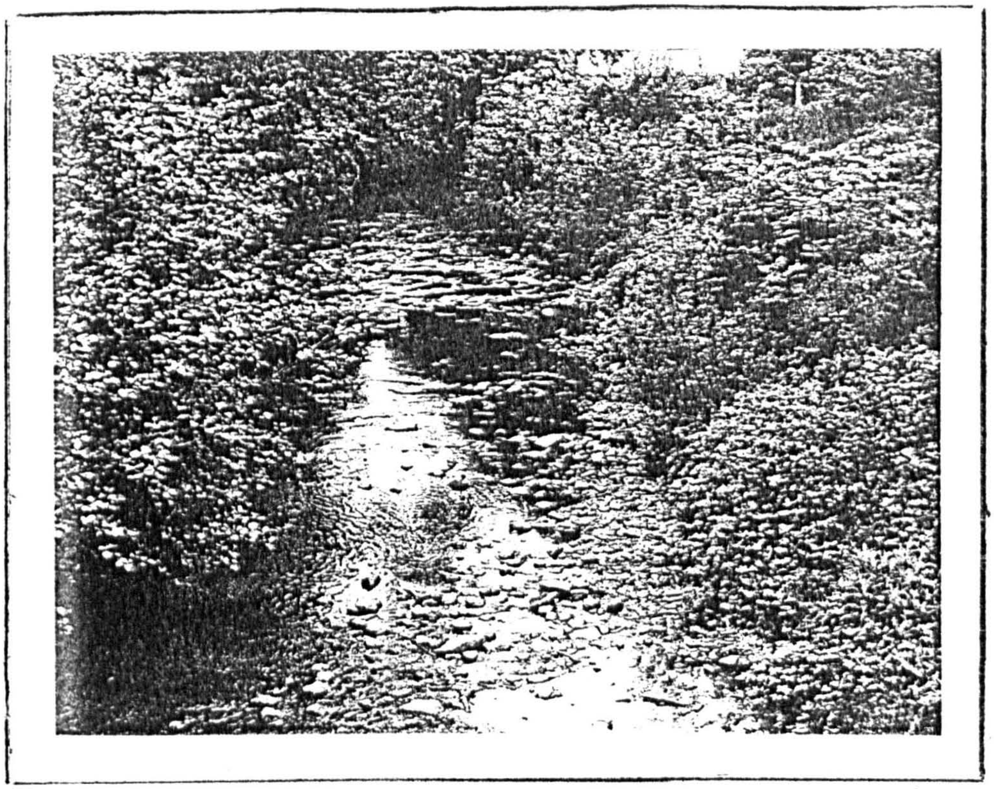

PLATE 7.1 SAMPLING STATION G1

PLATE 7.2 SAMPLING STATION G2

PLATE 7.3 SAMPLING STATION G3

TABLE 7.1 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT G1 SAMPLING STATION IN AFON GLYN.

Months	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Water Temp. °C	3.0	4.5	5.0	10.0	14.5	13.4	8.0	7.0	5.5	4.0	3.5	3.2	5.1	5.1
Specific conductance (micromhos / cm^3 at 25 °C)	166	216	226	109	121	104	157	166	320	387	403	397	203	112
Dissolved O2, % Sat.	96	95	103	112	98	104	94	101	111	117	107	108	101	98
Velocity of water current (m/sec)	0.22	0.23	0.16	0.14	0.11	0.12	0.17	0.24	0.29	0.41	0.70	0.64	0.60	0.29
pH	7.1	7.4	6.7	6.9	6.8	7.2	7.2	7.0	7.2	7.6	7.8	7.4	7.1	7.1
Turbidity (as Fuller's earth)	21.2	24.1	23.3	19.4	18.1	28.2	31.2	28.2	53.2	75.2	87.3	88.2	77.1	35.1

TABLE 7.2 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT G2 SAMPLING STATION IN AFON GLYN.

Months	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Water Temp. °C	3.2	4.5	5.0	10.2	14.6	13.5	8.1	7.2	5.5	4.0	3.5	3.2	5.1	5.1
Specific conductance (micromhos / cm^3 at 25 °C)	161	215	216	101	115	101	141	151	301	385	398	402	201	102
Dissolved O2, % sat.	96	96	108	111	98	103	98	96	101	118	113	101	98	97
Velocity of water current (m / sec)	0.19	0.20	0.18	0.14	0.11	0.13	0.17	0.25	0.29	0.52	0.73	0.68	0.57	0.26
pH	7.2	7.4	6.8	6.9	7.1	6.8	7.1	7.1	7.4	7.3	7.6	7.4	7.1	7.2
Turbidity (as Fuller's Earth.)	20.1	19.6	21.4	18.1	19.2	16.3	26.4	28.8	63.8	71.8	81.4	84.1	72.4	31.2

TABLE 7.3 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT G3 SAMPLING STATION IN AFON GLYN.

Months	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Water Temp. °C	3.1	4.2	5.4	10.8	15.1	14.2	8.8	8.1	5.1	3.8	3.6	3.2	4.1	5.6
Specific conductance (micromhos / cm^3 at 25 °C)	124	180	173	83	93	98	123	135	268	301	308	366	123	118
Dissolved O2, % Sat.	98	96	95	102	111	98	108	101	115	118	121	113	101	96
Velocity of water current (m /sec)	0.29	0.25	0.24	0.20	0.18	0.21	0.26	0.28	0.46	0.78	0.75	0.78	0.64	0.27
pH	7.1	7.2	6.8	6.9	6.6	6.8	7.1	7.1	7.4	7.6	7.8	7.4	7.1	7.1
Turbidity (as Fuller's Earth)	17.1	18.2	18.2	20.3	21.4	15.3	24.8	23.1	46.3	63.2	79.2	84.8	60.2	28.9

sheltered and the bottom was composed of silty sand with scattered gravel and stones (Plate 7.1).

Site G_2 was near the road bridge at about 100m upstream from the lake at an altitude of about 183m OD. Here the stream was 8m wide and 0.3 to 0.6m deep except during flood. The shores and substratum were similar to G_1 and there was some vegetation near the banks (Plate 7.2).

Site G_3 was located at about 4400m upstream from Llyn Tegid at an altitude of 467m OD. Here the stream was 2.3m wide and its depth averaged 0.6m. This site had some deep pools and falls. The shores were exposed and composed of rocks with overyling gravel and some silt with little vegetation apart from algae on the stones and clumps of <u>Fontinalis squamosa.</u> The substratum consisted of solid rocks and huge boulders (Plate 7.3).

(c) <u>Physical and chemical composition</u>

Tables 7.1, 7.2, 7.3 show the mean monthly estimates of physical factors at G_1, G_2 and G_3 sites. The range of water temperatures was 3.0°C and 15.1°C during this period. The dissolved oxygen (percentage saturation) was relatively more concentrated during winter than in summer. pH values varied between 6.6 and 7.8. The velocity of the water current (m/sec) was higher during winter months than summer. Conductivity and turbidity were higher during winter than in summer at each sampling site.

Table 7.4 The percentage composition (by number) of the fauna at G1, G2 and G3 sites of Afon Glyn based on 14 monthly samples. (+ = < 0.1%)

Sampling Stations →	G1		G2		G3		Total %
Bottom fauna ↓	Av. No. /m²	%	Av. No. /m²	%	Av. No. /m²	%	
Turbellaria	(1.0)	(+)	(-)	(-)	(0.7)	(+)	(+)
Polycelis nigra	1.0	+	-	-	-	-	+
Phagocata vitta	-	-	-	-	0.7	+	+
Hirudinea	(0.7)	(+)	(4.2)	(0.2)	(1.0)	(+)	(0.1)
Erpobdella octoculata	0.7	+	3.2	0.2	-	-	+
Helobdella stagnalis	-	-	0.7	+	1.0	+	+
Oligochaeta	(157.2)	(11.3)	(48.1)	(3.2)	(49.2)	(3.1)	(5.1)
Stylodrilus heringianus	107	7.8	25.6	1.7	40.6	2.6	3.5
Homochaeta naidina	4.2	0.3	-		-	-	.1
Lumbriculus variegatus	41.7	3.0	7.4	0.5	4.2	0.3	1.0
Aulodrilus pluriseta	3.2	0.2	2.1	0.2	-	-	0.2
Eiseniella tetraedra	0.7	+	8.5	0.6	3.2	0.2	0.2
Haplotaxis gordioides	-	-	1.0	0.1	-	-	+
Limnodrilus hoffmeisteri	-	-	-	-	0.7	+	+
Gastropoda	(1.0)	(+)	(24.6)	(1.7)	(14.9)	(0.8)	(1.1)
Ancylastrum fluviatile	1.0	+	24.6	1.7	11.7	0.7	1.1
Limnaea pereger	-	-	-	-	2.1	0.1	+
Potamopyrgus jenkinsi	-	-	-	-	0.7	+	+
Lamellibranchiata	(0.7)	(+)	(71.6)	(4.7)	(2.1)	(+)	(1.1)
Pisidium nitidum	0.7	+	0.7	+	-	-	0.1
Pisidium milium	-	-	8.5	0.6	1.0	+	0.1
Pisidium hibernicum	-	-	0.7	+	-	-	+
Pisidium subtruncatum	-	-	60.9	4.1	0.7	+	0.8
Amphipoda	(5.3)	(0.3)	(10.7)	(0.6)	(13.9)	(0.9)	(0.6)
Gammarus pulex	5.3	0.3	10.7	0.6	13.9	0.9	0.6

Table 7.4 (contd.)

Sampling Stations →	G1		G2		G3		Total %
Bottom fauna ↓	Av. No. /m²	%	Av. No. /m²	%	Av. No. /m²	%	
Isopoda	(1.0)	(+)	(2.1)	(0.1)	(-)	(-)	(0.1)
Asellus meridianus	1.0	+	2.1	0.1	-	-	0.1
Hydracarina	(-)	(-)	(-)	(-)	(2.1)	(+)	(+)
Hygrobates fluviatilis	-	-	-	-	1.0	+	+
Sperchon setiger	-	-	-	-	0.7	+	+
Plecoptera	(162.6)	(11.5)	(303.8)	(19.9)	(411.9)	(25.9)	(16.5)
Chloroperla tripunctata	36.3	2.6	16	1.1	12.8	0.8	1.3
Amphinemura sulcicollis	16	1.1	20.3	1.3	77.0	4.9	2.0
Chloroperla torrentium	95.2	7.0	34.2	2.3	67.4	4.4	3.8
Isoperla grammatica	6.4	0.5	10.7	0.6	73.8	4.7	1.7
Leuctra hippopus	2.1	0.2	72.7	4.9	16.0	1.0	1.8
Leuctra nigra	2.1	0.1	5.3	0.3	25.6	1.6	0.6
Leuctra moselyi	0.7	+	34.2	2.3	4.2	0.3	0.8
Leuctra inermis	1.0	+	33.1	2.2	26.7	1.7	1.4
Amphinemura standfussi	0.7	+	-	-	25.6	1.7	.6
Nemoura cinerea	-	-	0.7	+	-	-	+
Protonemura meyeri	-	-	5.3	0.4	52.4	3.3	1.0
Isoperla obscura	-	-	2.1	0.1	-	-	+
Perlodes microcephala	-	-	1.0	0.1	-	-	+
Perla bipunctata	-	-	0.7	+	12.8	0.8	.2
Leuctra fusca	-	-	62.0	4.3	2.1	0.1	1.1
Protonemura praecox	-	-	-	-	10.7	0.6	.1
Brachyptera risi	-	-	-	-	0.7	+	+
Ephemeroptera	(124.1)	(8.5)	(258.9)	(17.1)	(419.4)	(26.1)	(17.8)
Centroptilum luteolum	48.1	3.5	73.8	5.0	16.0	1.0	4.8
Ephemerella ignita	0.7	+	87.7	5.9	99.5	6.3	3.2
Ecdyonurus venosus	33.1	2.5	9.6	0.6	48.1	3.0	1.7
Paraleptophlebia submarginata	5.3	0.4	4.2	0.3	2.1	0.2	.3

Table 7.4 (contd.)

Sampling Stations	G1		G2		G3		Total %
Bottom fauna	Av. No. /m^2	%	Av. No. /m^2	%	Av. No. /m^2	%	
Baëtis rhodani	5.3	0.3	16.0	1.1	139.1	8.8	2.7
Heptagenia lateralis	18.1	1.3	11.7	0.8	34.2	2.1	2.0
Heptagenia sulphurea	4.2	0.3	26.7	1.8	42.8	2.7	1.6
Ecdyonurus dispar	2.1	0.1	-		9.6	2.6	.2
Caenis moesta	2.1	0.1	-		-	-	.1
Paraleptophlebia cinta	0.7	+	-		-	-	+
Leptophlebia marginata	1.0	+	-		0.7	+	+
Baëtis pumilus	-	-	19.2	1.2	1.0	+	.4
Ecdyonurus torrentis	-	-	0.7	+	-	-	+
Paraleptophlebia tumida	-	-	0.7	+	-	-	+
Baëtis atrebetinus	-	-	2.1	0.2	-	-	+
Ephemera danica	-	-	0.7	+	0.7	+	+
Rhithrogena semicolorata	-	-	-	-	3.2	0.2	.4
Baëtis scambus	-	-	-	-	18.1	1.2	.3
<u>Hemiptera</u>	(105.1)	(7.7)	(118.4)	(7.8)	(-)	(-)	(7.3)
Micronecta poweri	103.7	7.6	117.7	7.8	-	-	7.2
Valia spp.	0.7	+	-	-	-	-	+
Corixa panzeri	0.7	+	-	-	-	-	+
Sigara distincta	-	-	0.7	+	-	-	+
<u>Megaloptera</u>	(1.0)	(+)	(5.3)	(0.4)	(8.5)	(.5)	(0.2)
Sialis fuliginosa	0.7	+	0.7	+	0.7	+	+
Sialis lutaria	0.7	+	4.2	0.3	7.4	0.5	.2
<u>Trichoptera</u>	(65.2)	(4.4)	(208.6)	(13.4)	(204.3)	(12.6)	(9.8)
Rhyacophila dorsalis	0.7	+	-	-	16.0	1.0	.2
Odontocerum albicorne	0.7	+	-	-	-	-	+
Plectronemia conspersa	13.9	1.0	51.3	3.4	32.1	2.0	2.4
Hydropsyche instabilis	0.7	+	22.4	1.5	121.9	7.7	2.3
Anabolia nervosa	0.7	+	84.5	5.6	-	-	1.1
Sericostoma personatum	2.1	0.2	5.3	0.3	-	-	.2
Potamophylax latipenis	0.7	+	28.8	1.9	12.8	0.8	1.9

Table 7.4 (contd.)

Sampling Stations →	G1		G2		G3		Total %
Bottom fauna ↓	Av. No. /m²	%	Av. No. /m²	%	Av. No. /m²	%	
Glyphotaelius pellucidus	33.1	2.4	7.4	0.5	5.3	0.3	1.1
Mystacides nigra	3.2	0.2	-	-	-	-	0.1
Halesus digitatus	6.4	0.5	-	-	12.8	0.8	0.4
Agapetus fuscipus	-	-	0.7	+	1.0	+	+
Silo pallipes	-	-	0.7	+	-	-	+
Hydropsychae fulvipes	-	-	3.2	0.2	-	-	+
Diplectrona felix	-	-	-	-	0.7	+	+
<u>Coleoptera</u>	(16.0)	(1.0)	(35.3)	(2.3)	(28.8)	(1.6)	(1.5)
Platambus maculatus	2.1	0.2	2.1	0.2	-	-	0.1
Latelmis volkmari	10.7	0.7	16	1.0	3.2	0.2	0.6
Deronectus depressus	0.7	+	-	-	0.7	+	+
Helmis maugei	1.0	+	10.7	0.7	17.1	1.1	0.6
Haliplus lineatocollis	-	-	1.0	0.1	-	-	+
Helophorus flavipes	-	-	1.0	0.1	5.3	0.3	0.1
Oreodytes rivalis	-	-	1.0	0.1	0.7	+	+
Hyphydrus ovatus	-	-	0.7	+	-	-	+
<u>Diptera</u>							
(1) <u>Ceratopogonidae</u>	(7.4)	(0.5)	(7.4)	(0.5)	(2.1)	(0.2)	(0.3)
Bezzia spp.	7.4	0.5	7.4	0.5	2.1	0.2	0.3
(2) <u>Dixidae</u>	(-)	(-)	(0.7)	(+)	(55.3)	(3.5)	(0.7)
Dixa puberula	-	-	0.7	+	55.3	3.5	0.7
(3) <u>Tipulidae</u>	(7.4)	(0.5)	(4.2)	(0.3)	(0.7)	(+)	(0.2)
Tipula couckei	0.7	+	-	-	-	-	+
Tipula lateralis	0.7	+	1.0	0.1	0.7	+	0.1
Tipula maxima	5.3	0.4	3.2	0.2	-	-	0.1
Tipula rufira	0.7	+	-	-	-	-	+
Simuliidae	(-)	(-)	(1.0)	(0.1)	(1.0)	(+)	(+)
Simulium monticola	-	-	-	-	0.7	+	+
Simulium brevicaule	-	-	1.0	0.1	0.7	+	+

Table 7.4 (contd.)

Sampling Stations	G1		G2		G3		Total %
Bottom fauna	Av. No. /m²	%	Av. No. /m²	%	Av. No. /m²	%	
(5) <u>Chironomidae</u>	(647.3)	(47.3)	(269.6)	(17.8)	(64.4)	(16.8)	(29.4)
Pentaneura monilis	24.6	1.8	71.6	4.8	26.7	1.7	2.9
Microtendipes chloris	7.4	0.6	-		-	-	0.1
Strictochironomus spp.	5.3	0.3	-		-	-	+
Polypedilum nubeculosus	563.8	41.3	33.1	2.2	-	-	16.2
Procladius choreus	16	1.1	11.7	0.8	-	-	.8
Tanytarsus signatus	3.2	0.2	25.6	1.7	37.4	2.3	1.4
Cryptochironomus spp.	2.1	0.1	-		-	-	+
Prodiamesa olivacea	16	1.1	74.9	5.0	-	-	4.5
Brillia modesta	6.4	0.5	-		-	-	+
Trichocladius rufiventris			50.2	3.3	201.1	12.7	3.5
<u>Other dipteran larvae</u>	(21.4)	(1.5)	(87.7)	(5.7)	(73.5)	(5.5)	(3.0)
Hermerodromia unilineata	-	-	2.1	0.1	3.2	0.2	0.1
Dicranota robusta	18.1	1.4	81.3	5.4	63.1	4.0	2.8
Taphrophila vitripennis	2.1	0.1	1.0	0.1	6.4	0.4	0.1
Pedicia rivosa	-	-	0.7	+	0.7	+	+
Pericoma pseudoexquisita	-	-	1.0	0.1	-	-	+
Dipteran pupae	29.9	2.2	21.4	1.4	13.9	0.9	1.7
Total no. animals	1785		1951		2068		
Av. no. animals per month	127.5		139.3		147.7		
Av. no. animals / m²	1364.2		1490.5		1560.3		

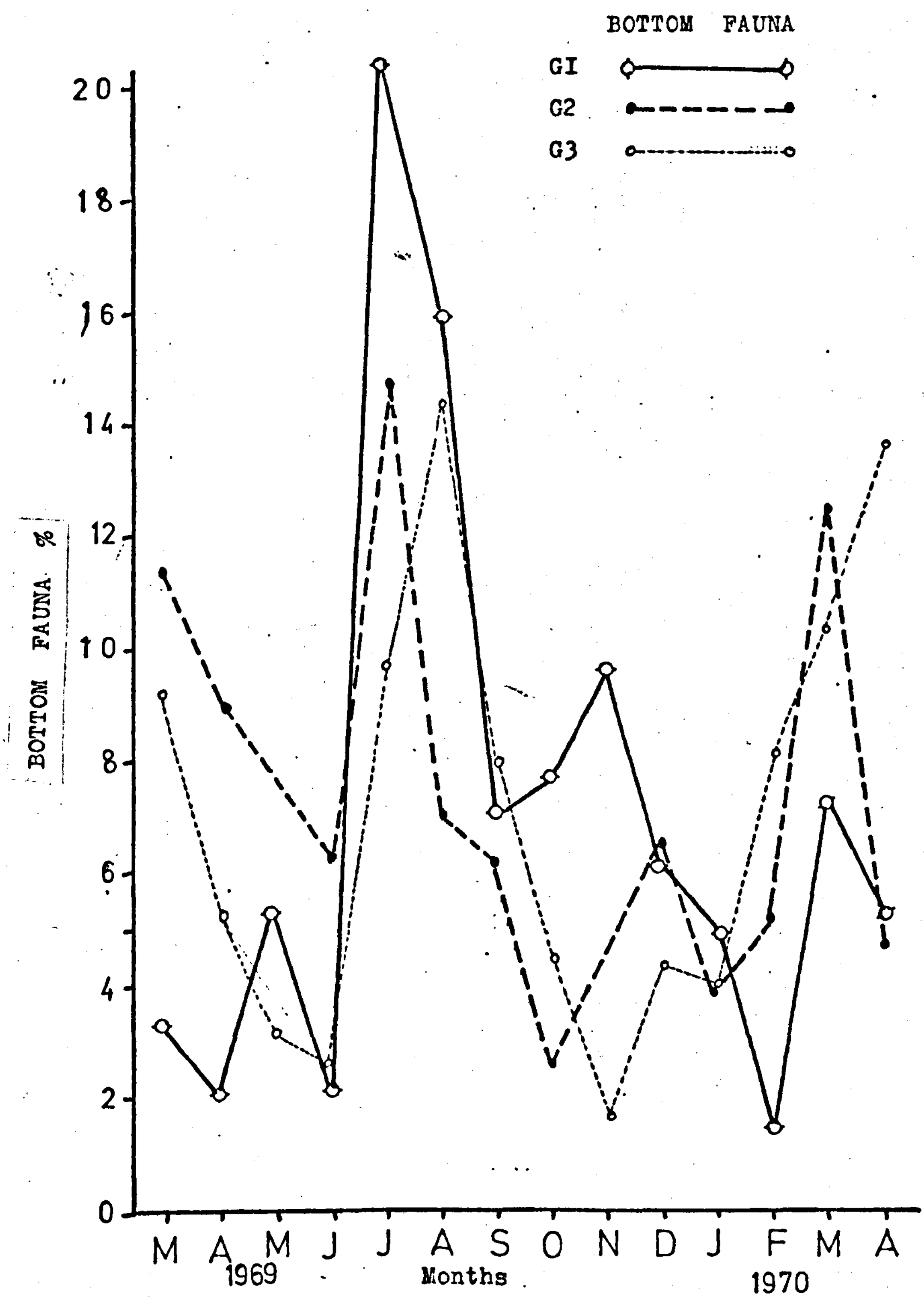

Fig 7.1 Percentage composition of the bottom fauna at each month at each station.

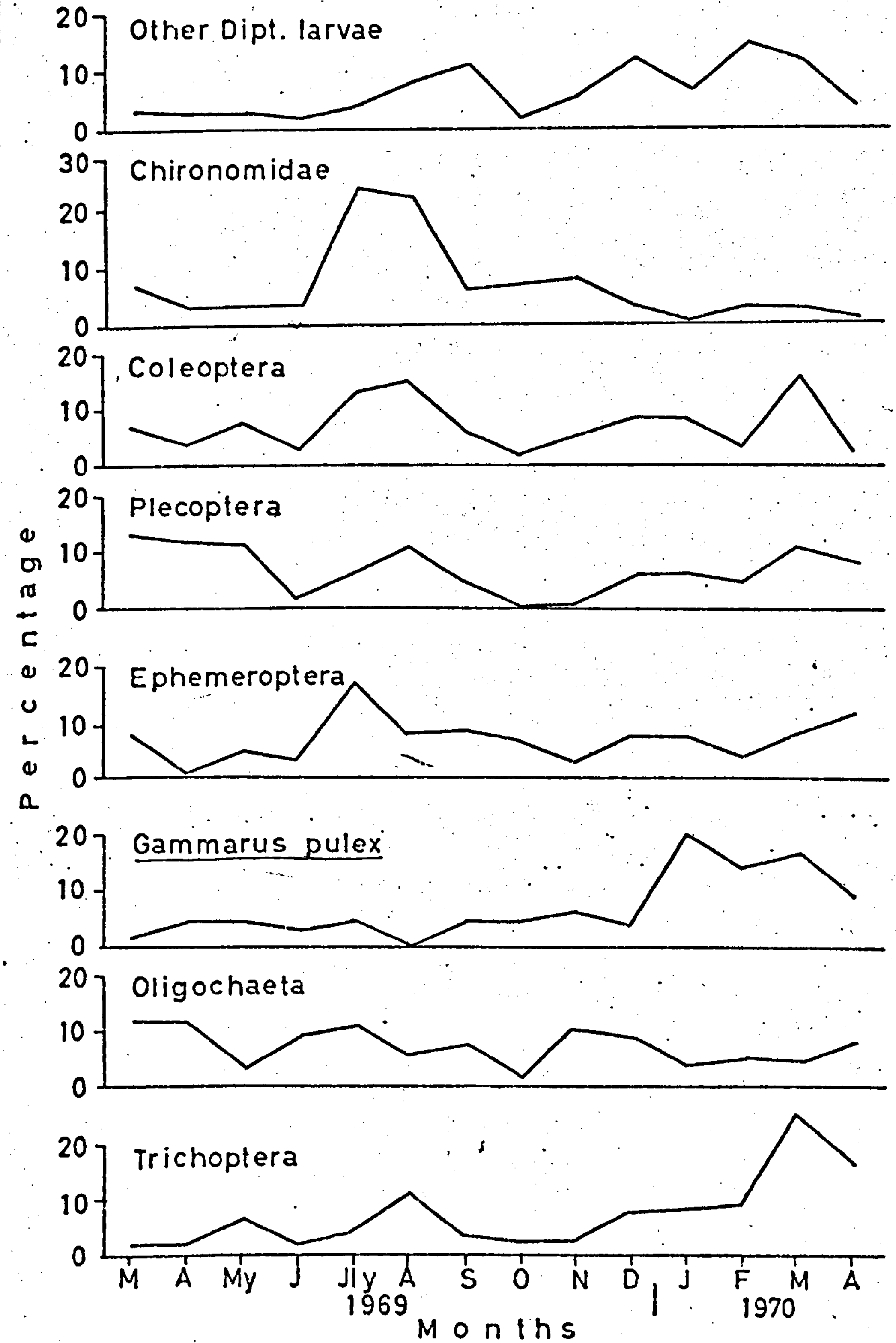

Fig. 7·2 Seasonal variations in the number of different groups of bottom fauna in Afon Glyn

Table 7.5 Percentage composition of the different groups in the total fauna sampled at G_1, G_2 & G_3. (+ = < 0.1%)

Sampling sites →	G_1 (%)	G_2 (%)	G_3 (%)
Elevation OD →	176 m	183 m	500 m
Turbellaria	0.1	-	+
Hirudinea	-	+	+
Oligochaeta	5.5	3.1	3.1
Gastropoda	0.2	2.4	0.8
Lamellibranchiata	-	0.7	+
Amphipoda	0.5	0.7	0.9
Isopoda	0.2	-	-
Hydracarina	0.4	-	+
Plecoptera	10.7	14.9	25.9
Ephemeroptera	11.1	24.3	26.1
Hemiptera	6.8	14.3	-
Megaloptera	-	0.3	0.5
Trichoptera	6.5	10.0	11.3
Coleoptera	1.6	1.2	1.6
Diptera			
Ceratopogomidae	+	0.3	0.2
Tipulidae	0.8	0.2	+
Simuliidae	-	+	+
Chironomidae	50.2	21.0	16.7
Dixidae	-	-	3.5
Other dipteran larvae	0.7	2.2	4.6
Dipteran pupae	1.5	2.4	0.9

Table 7.6 Statistical significance in the number of benthic fauna between G_1/G_3 and G_2/G_3 sampling sites at 5% level.

Sampling sites →	G_1/G_3		G_2/G_3	
Benthic fauna ↓	t	p	t	p
Oligochaeta	1.3	> 0.05	0.6	> 0.05
Gastropoda	-	-	1.6	> 0.05
Plecoptera	2.7	< 0.05	0.7	> 0.05
Ephemeroptera	1.7	> 0.05	0.8	> 0.05
Trichoptera	1.5	> 0.05	0.1	> 0.05
Coleoptera	0.8	> 0.05	0.5	> 0.05
Chironomidae	3.9	< 0.05	1.0	> 0.05
Other dipteran larvae	0.4	> 0.05	0.6	> 0.05

Water samples for chemical analysis were taken in the month of June 1969. The analytical results are summarised in Table 3.4.

I found more calcium ions in this stream, as did Dunn (1961) and Woolland (1972). This is probably due to its flow oever the Hirnant limestone of the Bala beds.

2. COMPOSITION OF THE FAUNA

The species of this stream as established by systematic collecting at three stations over a period of 14 months are listed in Table 7.4. A total of 7772 organisms, belonging to 117 different species were identified.

The seasonal variation of the bottom fauna is shown in Figs. 7.1 and 7.2. A gradual increase in the total number of organisms from winter to summer was observed.

The samples taken yield a fairly accurate picture of the bottom fauna of the area studied. The regular invertebrate population would appear to comprise Oligochaeta, Ephemeroptera, Trichopera, Diptera, Coleoptera, Plecoptera and Crustacea, which account for 97.7% of the total Hirudinea, Hydracarina, Mollusca and Turbellaria were also represented. As is to be expected the fauna changed with altitude (Tables 7.5 and 7.6). In the following account short descriptions are given to supplement the list in Table 7.4.

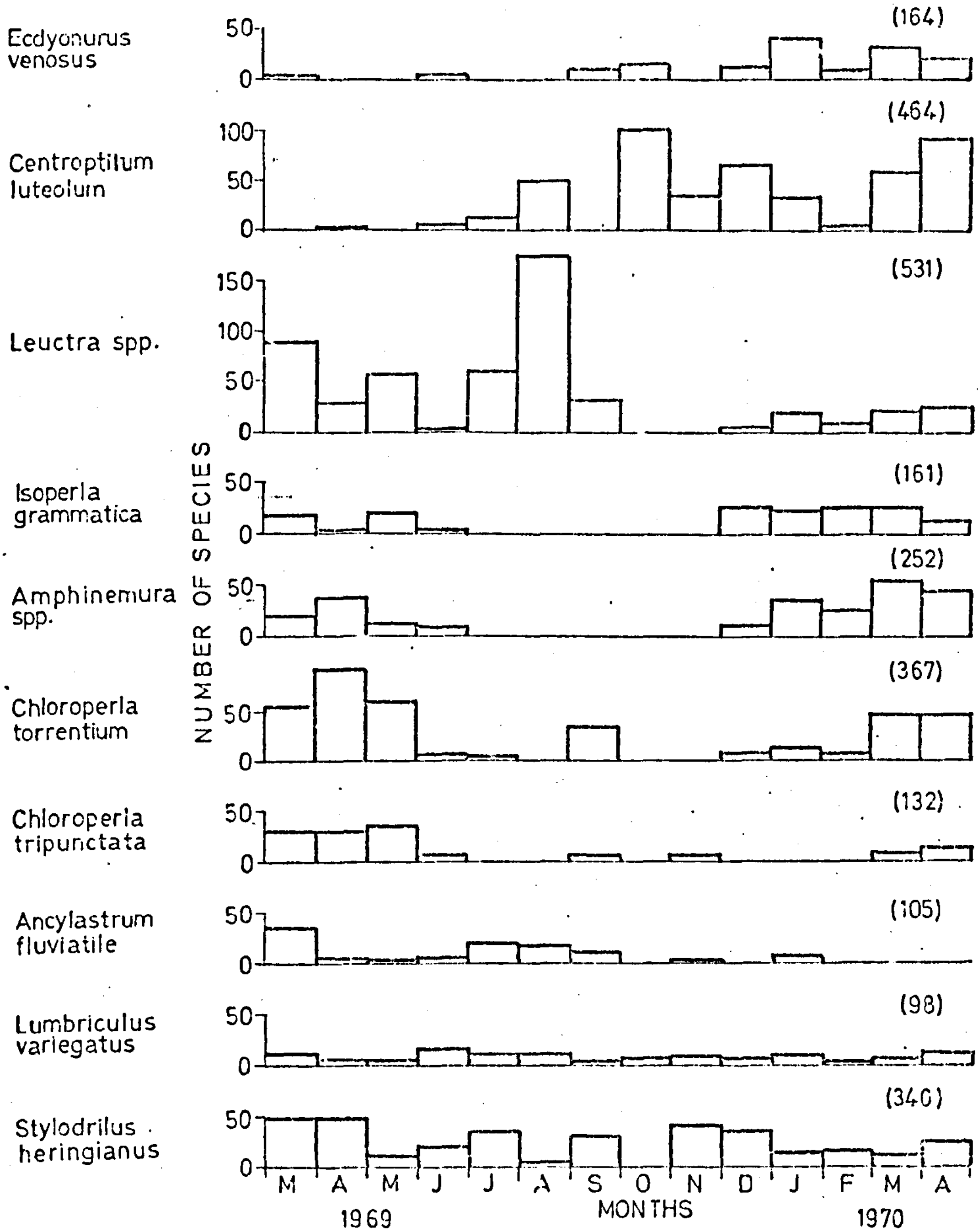

Fig. 7.3 Seasonal variations of the common species of bottom fauna. The total number is shown in brackets

A. Annelida

(1) Oligochaeta

4.0% of the total bottom fauna was formed by this group. Stylodrilus heringianus and Lumbriculus variegatus were common and the rest (Table 7.4) were scarce. These were distributed at all the stations and there was no strong pattern in the seasonal variation (Fig. 7.3).

(B) Mollusca

(1) Gastropoda

1.1% of the total benthic fauna belonged to this group. Ancylastrum fluviatilis was common and Limnaea pereger and Hydrobia jenkensi were scarce. Ancylastrum fluviatilis occurred on exposed rocks and bare stones and was found more during spring and summer (Fig. 7.3) (see also Berg et.al. 1958).

(2) Lamellibranchiata

0.2% of the total macrometazoans were formed by this group. Four species listed (Table 7.4) were scarce, and no change was noted in the total number at any sampling sites.

(C) Arthropoda

(1) Crustacea

(a) Amphipoda

Gammarus pulex formed 0.6% of the total fauna. These were recorded more during winter (Fig. 7.2) and collected less at G_1 and G_2 than at G_3 sampling site.

(b) Isopoda

Asellus meridianus was scarce and constituted 0.1% of the total catch. This was not recorded from G_3.

(2) Arachnida

(a) Hydracarina

Hygrobates nigromaculatus, Hygrobates fluviatilis and Sperchon setiger were collected from G_3 and formed 1.0% of the total.

(3) Insecta

(a) Plecoptera

This group formed 16.4% of the total organisms and was represented by seventeen species, of which Chloroperla tripunctata, Amphinemura sulcicollis, Chloroperla torrentium Isoperla grammatica and Leuctra hippopus were common, and recorded in large numbers in every season (Fig. 7.2). I found the above species numerous during winter and spring and Leuctra spp. in spring and summer (Fig. 7.3). These were collected in large numbers at higher elevation (Table 7.5) which according to Macan (1962) is probably a function of temperature. A significant difference was observed between the numbers of plecopterans present in the bottom fauna at G_1 and G_3 ($t = 2.7$; $P < 0.05$) (Table 7.6).

(b) Ephemeroptera

17.7% of the total fauna belonged to this group. Centroptilum luteolum, Ecdyonurus venosus, Baetis rhodani

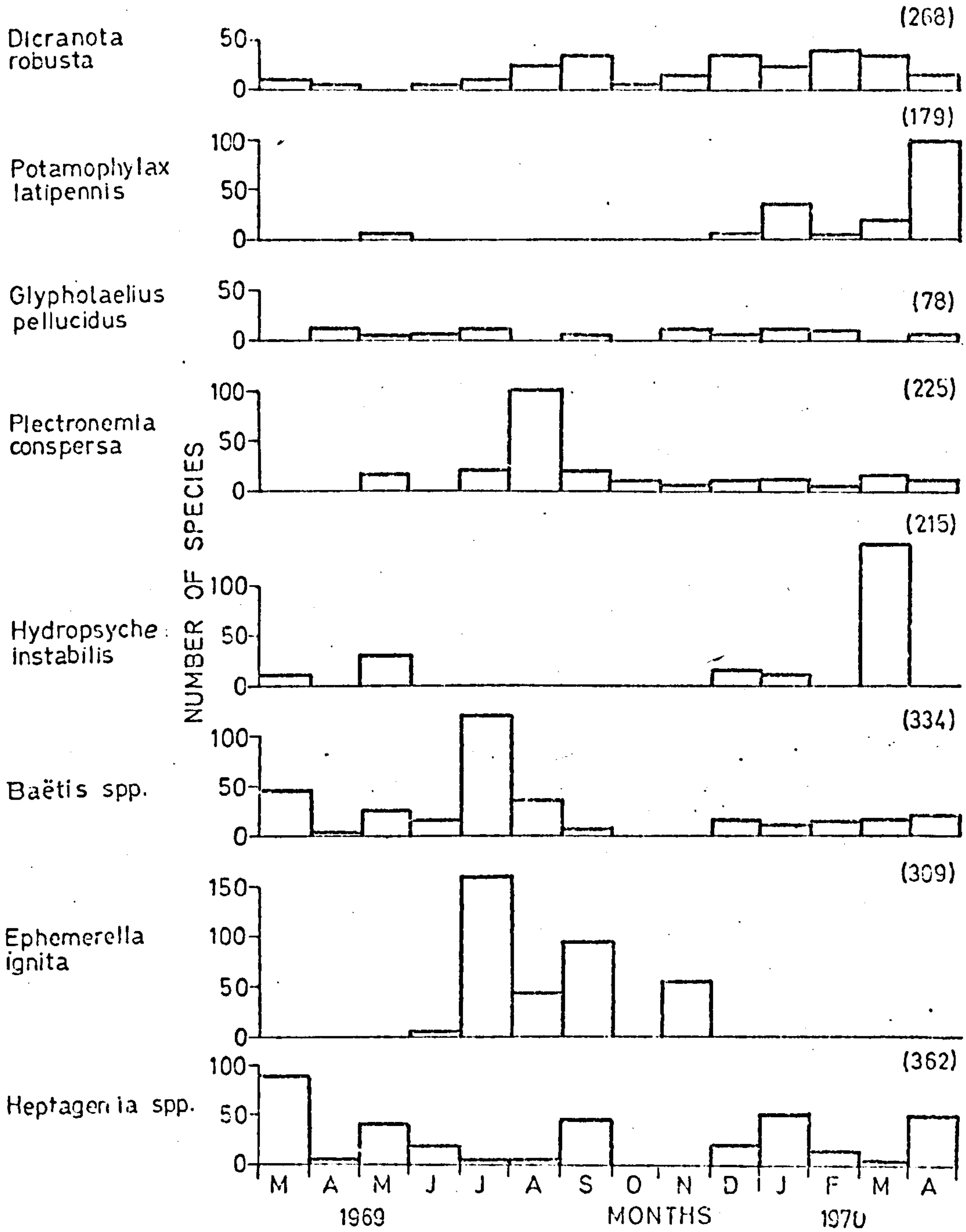

Fig. 7.4 Seasonal variations of the common species of bottom fauna. The total number is shown in brackets

and *Heptagenia lateralis* were present in large numbers at every station and the rest (Table 7.4) scarce. *Centroptilum luteolum* and *Heptagenia spp.* were recorded in every season, but *Ecdyonurus venosus* was present more during winter and spring, and *Baetis spp.* in spring and summer (Fig. 7.4). I found *Ephemerella ignita* during summer (Fig. 7.4) as did those of Macan (1957).

(c) *Hemiptera*

7.2% of the bottom fauna was composed of this group. *Micronecta poweri* was common and *Corixa panzeri*, *Sigara distincta* and *Velia spp.* were scarce at G_1 and G_2. Not a single species was recorded from G_3; this may be due to higher elevation and relatively fast currents. The above hemipterans were present at G_1 and G_2 probably due to the proximity of the lake and low velocity. They occurred mostly where the rooted aquatics were confined to the margins of the stream.

(d) *Megaloptera*

This group was represented by *Sialis fuliginosa* and *Sialis lutaria*. Both were scarce, formed C.2% of the total and collected more from G_3.

(e) *Trichoptera*

This group constituted 9.4% of the total benthic fauna. *Plectrocnemia conspersa* and *Glyphotaelius pellucidus* were common and the rest (Table 7.4) scarce. Quantitatively, this group was recorded more during spring and summer (Fig. 7.2). I found *Glyphotaelius pellucidus* abundant in the vicinity of the lake. Very few caddis larvae were collected from G_3.

(f) Coleoptera

1.4% of the total catch was formed by aquatic beetles. *Latelmis volkmari* and *Helmis maugei* were common. The adults were found among weeds and the larvae on stones. Unlike Maitland (1972) I found the above species more common in the lower reaches than the upper. Maitland said that they were uncommon in the lower reaches of a Scottish river, and said that the population is controlled by the fish predation or removal by spates.

(g) Diptera

This group formed 35.8% of the total organisms and was represented by the families Ceratopogonidae, Dixidae, Tipulidae, Simuliidae, Chironomidae, other aquatic dipteran larvae and pupae. These were collected more during summer and autumn (Fig. 7.2).

(1) Ceratopogonidae

0.3% of the fauna was composed of *Bezzia spp.*

(2) Dixidae

0.7% of the benthic fauna were constituted by *Dixa puberula*; almost all were collected from G_3 (Table 7.4).

(3) Tipulidae

Five species listed in Table 7.2 formed 0.2% of the total. These were collected more from G_1 and G_2 than G_3.

(4) Simuliidae

Simulium monticola and *Simulium brevicaule* were scarce.

Table 7.7 The average percentage composition of the total annual diet of trout and salmon parr assessed by occurrence, volume and number methods. (+ = < 0.1%)

Food organisms ↓	Trout			Salmon parr		
Methods of assessment →	O	V	N	O	V	N
Benthic food						
Lumbriculus variegatus	0.6	0.3	0.1	.2	.1	.1
Ancylastrum fluviatile	0.8	1.1	0.3	3.6	2.6	3.2
Asellus meridianus	0.3	0.4	0.2	-	-	-
Plecoptera nymphs	(11.8)	(6.5)	(8.3)	(8.8)	(5.8)	(7.0)
Chloroperla tripunctata	1.8	0.9	1.1	0.5	0.8	0.8
Chloroperla torrentium	1.5	0.8	0.9	2.5	1.1	1.2
Amphinemura sulcicollis	1.2	0.6	0.7	1.7	1.2	1.4
Leuctra spp.	2.3	1.1	2.1	1.3	0.4	0.6
Isoperla grammatica	1.6	0.7	1.3	0.6	0.7	0.9
Other plecopteran nymphs	3.3	2.4	2.3	2.2	1.6	2.1
Ephemeroptera nymphs	(35.4)	(29.9)	(36.5)	(37.3)	(37.5)	(41.1)
Baëtis rhudani	4.7	3.7	4.1	4.5	3.4	6.8
Ecdyonurus venosus	5.5	4.5	5.2	9.5	11.6	8.6
Heptagenia lateralis	8.7	6.7	8.5	3.7	5.6	5.4
Ephemerella ignita	5.8	5.1	6.6	6.5	5.4	6.1
Other ephemeropteran nymphs	10.7	9.8	12.1	13.1	11.5	14.2
Trichoptera larvae	(6.9)	(9.1)	(5.8)	(13.4)	(19.8)	(17.2)
Plectronemia conspersa	0.3	0.8	0.5	1.5	2.1	1.1
Hydropsyche instabilis	0.6	1.1	0.5	2.1	3.9	2.9
Potamophylax latipennis	1.2	1.8	1.0	2.4	2.8	2.0
Sericostoma personatum	0.5	0.3	0.6	2.8	3.2	3.8
Rhyacophila dorsalis	1.8	1.0	0.8	1.2	2.5	1.2
Other trichopteran larvae	3.6	4.1	2.4	3.4	5.3	6.2
Coleoptera larvae	-	-	-	(1.2)	(0.3)	(0.4)
Latelmis volkmari	-	-	-	1.1	.3	.3
Helmis maugei	-	-	-	.1	+	.1

Table 7.7 (contd.)

Food organisms ↓	Trout			Salmon parr		
Methods of assessment ⟶	O	V	N	O	V	N
Diptera	(6.1)	(4.2)	(7.4)	(24.6)	(19.5)	(24.4)
Chironomidae	5.0	3.3	6.3	21.2	17.4	22.0
Simuliidae	0.7	0.4	0.8	2.4	1.6	1.9
Other dipteran larvae	-	-	-	1.0	0.5	0.6
Dipteran pupae	0.4	0.5	0.3	-	-	-
<u>Midwater food</u>						
Coleoptera adults	(4.3)	(5.0)	(4.3)	(0.4)	(0.6)	(0.1)
Latelmis volkmari	3.1	4.2	2.3	0.3	0.4	+
Platambus maculatus	1.2	0.8	2.0	0.1	0.2	+
Phoxinus phoxinus	(1.1)	(1.1)	(0.5)	(0.2)	(2.1)	(0.1)
<u>Aerial & terrestrial food</u>						
Insects (Hemiptera, Diptera, Hymenoptera)	20.0	31.8	26.6	6.4	8.4	3.5
<u>Miscellaneous food</u>						
Plant material	8.7	6.5	4.3	2.8	1.7	1.9
Fish eggs	2.8	3.7	2.8	0.2	1.0	0.1

Av. No. Org. per stomach in trout = 10.4

Av. No. Org. per stomach in Salmon parr = 10.8

No effect of elevation was noticed in the distribution of this group.

(5) Chironomidae

This group formed 29.4% of the total fauna. *Pentaneura monilis*, *Polypedilum nubeculosus* and *Prodiamesa olivacea* were common, (Table 7.4). These were abundant during summer and found more at low altitude than at high (Table 7.5). A significant difference ($t = 3.9$; $P < 0.05$) was observed between the numbers of chironomid larvae present in the bottom fauna at G_1 and G_3 (Table 7.6).

(6) Other Dipteran larvae

3.0% of the total organisms belonged to this category in which *Dicranota robusta* was common.

(7) Dipteran pupae

1.7% of the limnetic invertebrates were constituted by the dipteran pupae.

3. THE FEEDING OF SALMONIDS

(1) Brown trout

A total of 101 trout belonging to 0+ to 4+ age groups were collected at monthly intervals during January 1969 to March 1970; of these five stomachs were empty and the rest had food in varying quantities (Table 3.6).

(a) Composition of the diet (by volume)

Table 7.7 shows a wide spectrum of different organisms eaten. The most important dietary items which belonged to the benthic food, were Plecoptera and Ephemeroptera nymphs, and Trichoptera and chironomid larvae which together formed 48.8% of the total volume. Oligochatea, Gastropoda, Coleoptera and other dipteran larvae were among the less important benthic food which constituted 2.7% by volume of the total.

Plecoptera represented by Chloroperla tripunctata, Amphinemura sulcicollis, Chloroperla torrentium, Leuctra spp. and other unidentifiable plecopteran nymphs formed 6.5% of the total. Baetis rhodani, Ecdyonurus venosus and Heptagenia lateralis represented the Ephemeroptera which formed 29.9% of the total volume. Trichoptera larvae mostly belonged to Plectrocnemia conspersa, Hydropsyche instabilis, Potamophylax latipennis and Sericostoma personatum and amounted to 9.1%. Chironomid larvae formed 3.3% of the total volume.

Among the less important food items, Lumbriculus variegatus occurred in 0.3%, Simulium brevicaule in 0.4% Ancylastrum fluviatile 1.1%, Asellus meridianus in 0.4% and finally dipteran pupae in 0.5% of the total volume.

Midwater food was composed of adult Coleoptera which formed 5.0% of the total volume and belonged to species Latelmis volkmari, Helmis maugei and Platambus maculatus. A fish, Phoxinus phoxinus amounted to 1.1% of the total volume.

Aerial and terrestrial food, which included Amphididae,

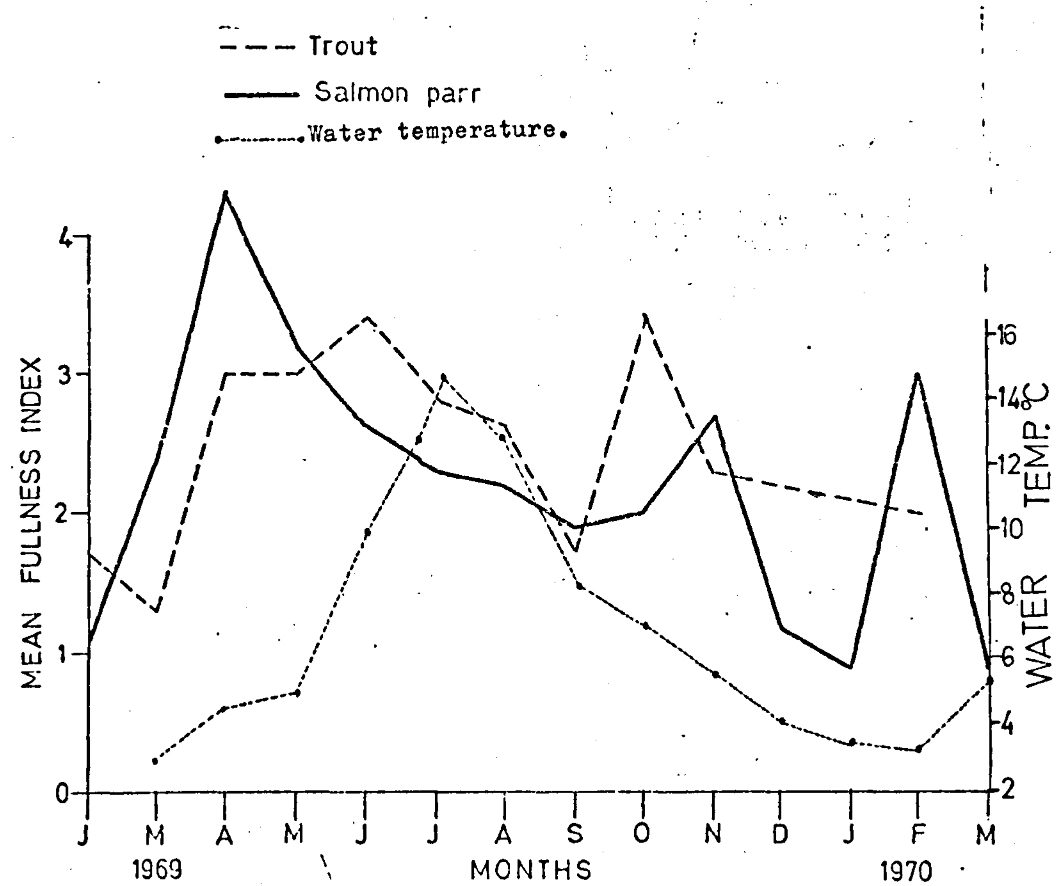

Fig.7.5 Seasonal variations in food intake of trout and salmon parr

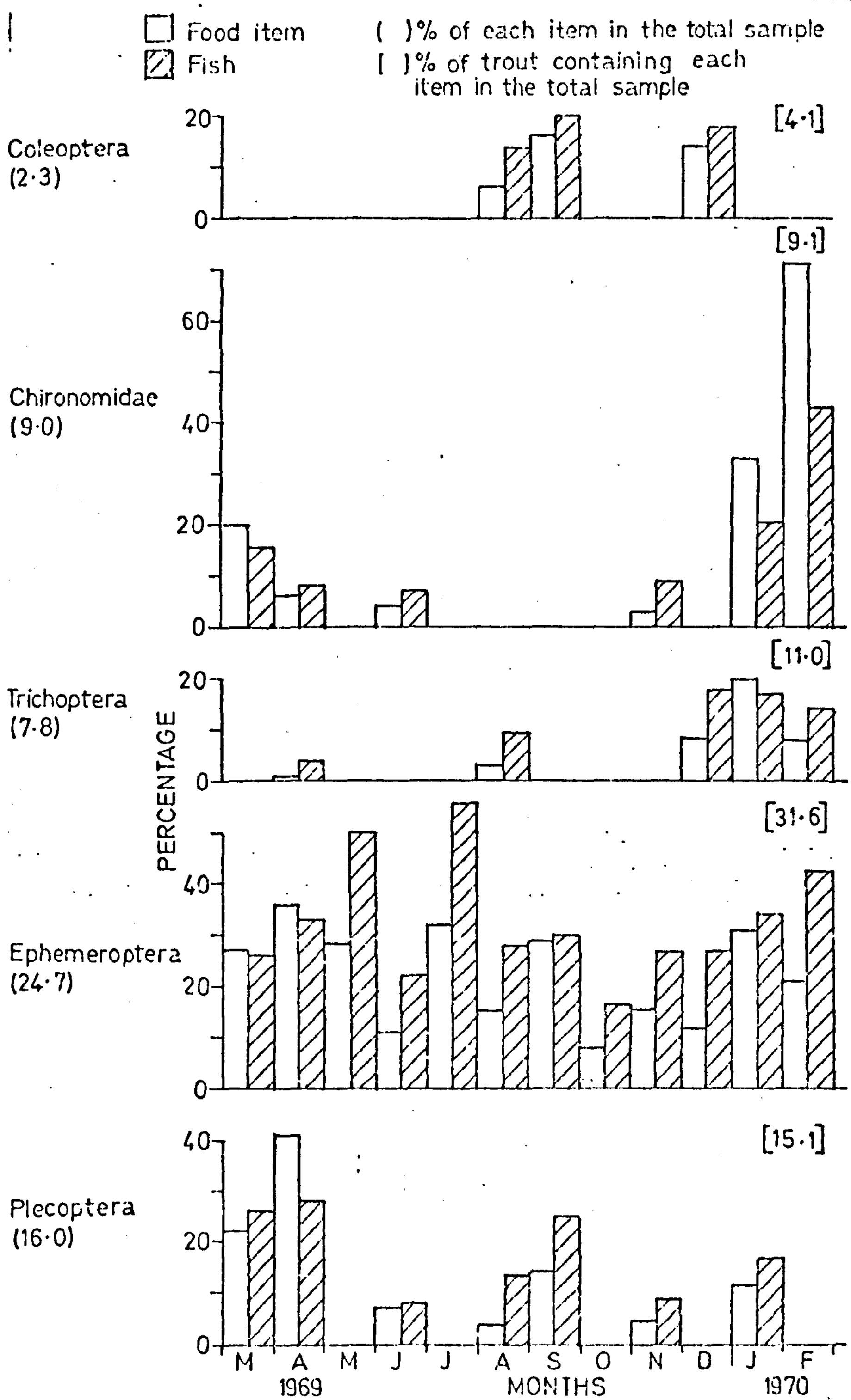

Fig. 7.6 Seasonal variations of the food items of trout and percentage of stomachs containing each food item in different months.

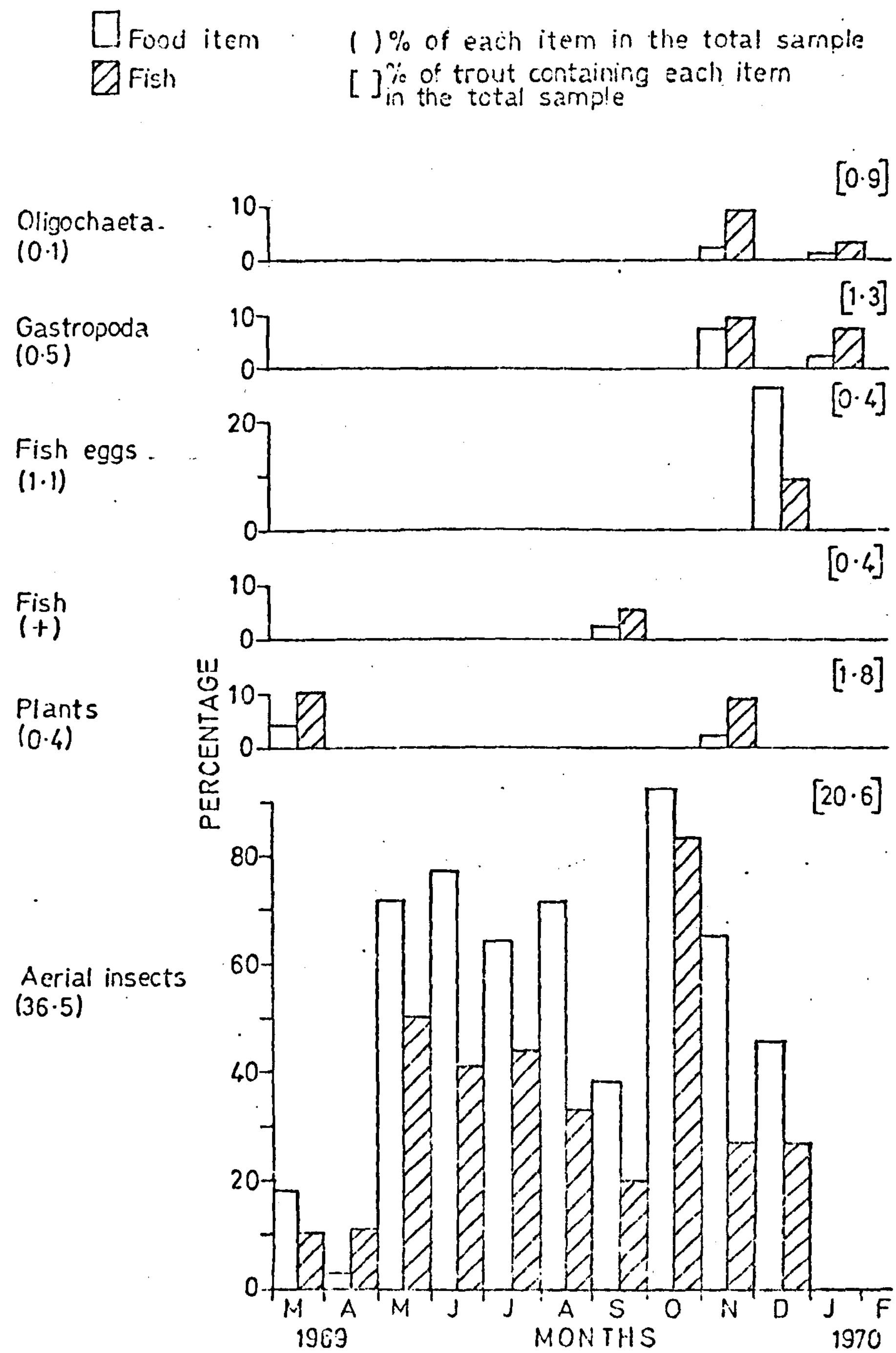

Fig.7.7 Seasonal variations of the food items of trout and percentage of stomachs containing each food item in different months.

Nabidae, Formicidae, Empidae, and Bibionidae, formed 31.8% of the total volume.

Finally, 6.5% of the food was plant material and 3.7% was fish eggs.

(b) Seasonal variation in food intake

Fig. 7.5 shows that the maximum feeding activity occurred during summer and it gradually decreased in winter.

(c) Seasonal changes in the food

Figs. 7.6, 7.7 show the seasonal changes in the food. Ephemeroptera and Plecoptera nymphs and Trichoptera larvae occurred in the stomachs throughout. Most of the Plecoptera nymphs for example *Leuctra spp.*, *Isoperla spp.* and *Amphinemura spp.* were eaten during spring and autumn. Ephemeroptera nymphs, mostly *Baetis spp.*, *Ephemerella spp.* and *Heptagenia spp.* were present in substantial quantities throughout. Larger numbers of Trichopera larvae particularly *Plectrocnemia spp.* and *Glyphotaelius spp.* were eaten during winter than in any other season. Chironomid larvae occurred in a smaller percentage of stomachs during summer and autumn. Trout ate aerial and terrestrial insects belonging to Emphidae, Bibionidae and Formicidae most frequently during summer and autumn. The food items of infrequent occurrence were Coleoptera adults and larvae, Oligochaeta, Gastropoda, fish eggs and plant material. These items were found

Table 7.8 The average percentage composition of the food assessed by occurrence, volume and number methods of trout of each age group.

Name of Species	Salmo trutta														
Total No. Stomachs	101														
Age	0+			1+			2+			3+			4+		
No. sp.. in each age group	8			46			29			16			2		
No. Empty stomachs	-			2			-			3			-		
Methods of assessment	O	V	N	O	V	N	O	V	N	O	V	N	O	V	N
Benthic food															
Oligochaeta				.8	.1	.2				2.3	1.5	.3			
Gastropoda							1.7	2.3	.6	2.3	3.1	1.2			
Isopoda				1.8	2.1	1.2									
Plecoptera nymphs	13.6	4.5	6.5	12.4	6.8	9.9	19.0	14.0	11.2	14.2	7.2	14.2			
Ephemeroptera nymphs	28.1	25.0	31.4	32.9	17.6	21.4	29.4	25.5	29.5	20.4	8.9	17.0	66.6	71.7	83.4
Trichoptera larvae				3.7	1.5	2.1	14.5	20.3	12.4	16.5	23.8	14.7			
Coleoptera larvae															
Chironomid larvae				10.4	8.1	14.9	8.5	6.4	10.2	6.4	2.1	6.7			
Simuliid larvae										3.5	2.3	4.0			
Other dipteran larvae															
Dipteran pupae							2.0	2.7	1.7						
Midwater food															
Coleoptera adults	18.1	20.5	19.5	1.2	1.6	.5	2.2	3.2	1.9						
Fish							5.5	5.5	2.7						
Aerial & terrestrial food	40.0	50.0	42.5	36.4	62.2	49.2	14.4	18.6	19.2	9.5	28.5	22.1			
Insects															
Miscellaneous food															
Plant material							.5	1.1	+	10.0	3.5	4.9	33.3	28.3	16.6
Fish eggs										14.2	18.8	14.2			

during late autumn and winter. The minnow (*Phoxinus phoxinus*) was eaten during autumn.

(d) Food in relation to age

x^2 test showed a significant difference in the occurrence of plecopteran (x^2_3 = 10.93, P < 0.05 < 0.02), coleopteran (x^2_3 = 18.93, P < 0.05 < 0.02 < 0.01), and aerial and terrestrial (x^2_3 = 10.64, P < 0.05 < 0.02) food items in different age groups of trout. As far as the other food items were concerned there were no significant changes in the diet of fish belonging to 0+ to 4+ age groups (Table 7.8).

(ii) Salmon parr

A total of 123 salmon parr were collected from January to March 1970. Of these, 14 stomachs were empty (Table 3.7).

(a) Composition of the diet (by volume)

Table 7.7 shows the composition of the total diet of salmon parr. The most significant items of benthic food were Gastropoda, Plecoptera and Ephemeroptera nymphs; Trichoptera, chironomid and simuliid larvae. Oligochaeta, Coleoptera and other aquatic dipteran larvae were insignificant in the diet.

Ancylastrum fluviatile formed 2.6% of the diet. Plecoptera were represented by *Chloroperla tripunctata*, *Amphinemura sulcicollis*, *Chloroperla torrentium*, *Leuctra* spp.

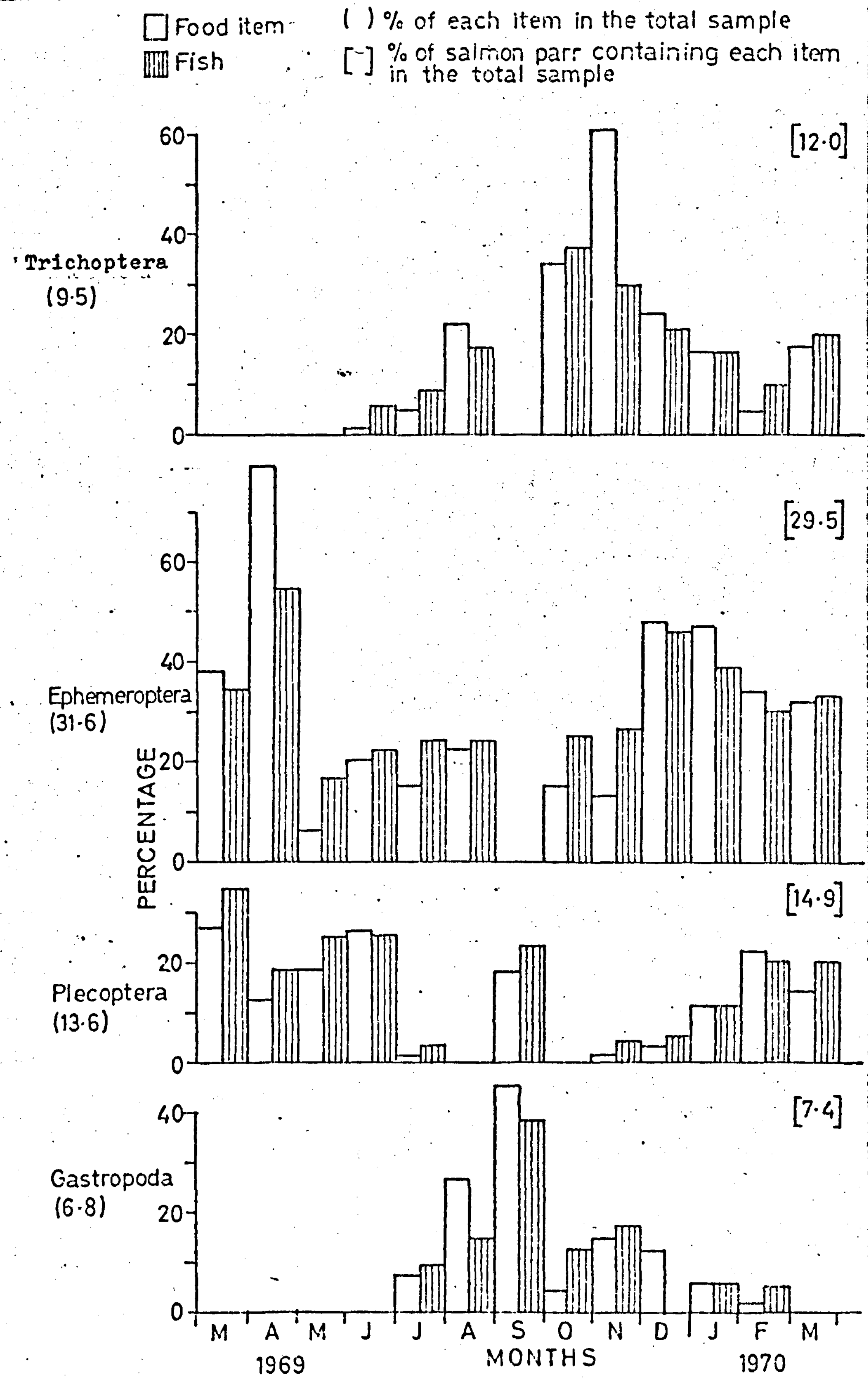

Fig. 7.8 Seasonal variations of the food items of salmon parr and percentage of stomachs containing each food item in different months.

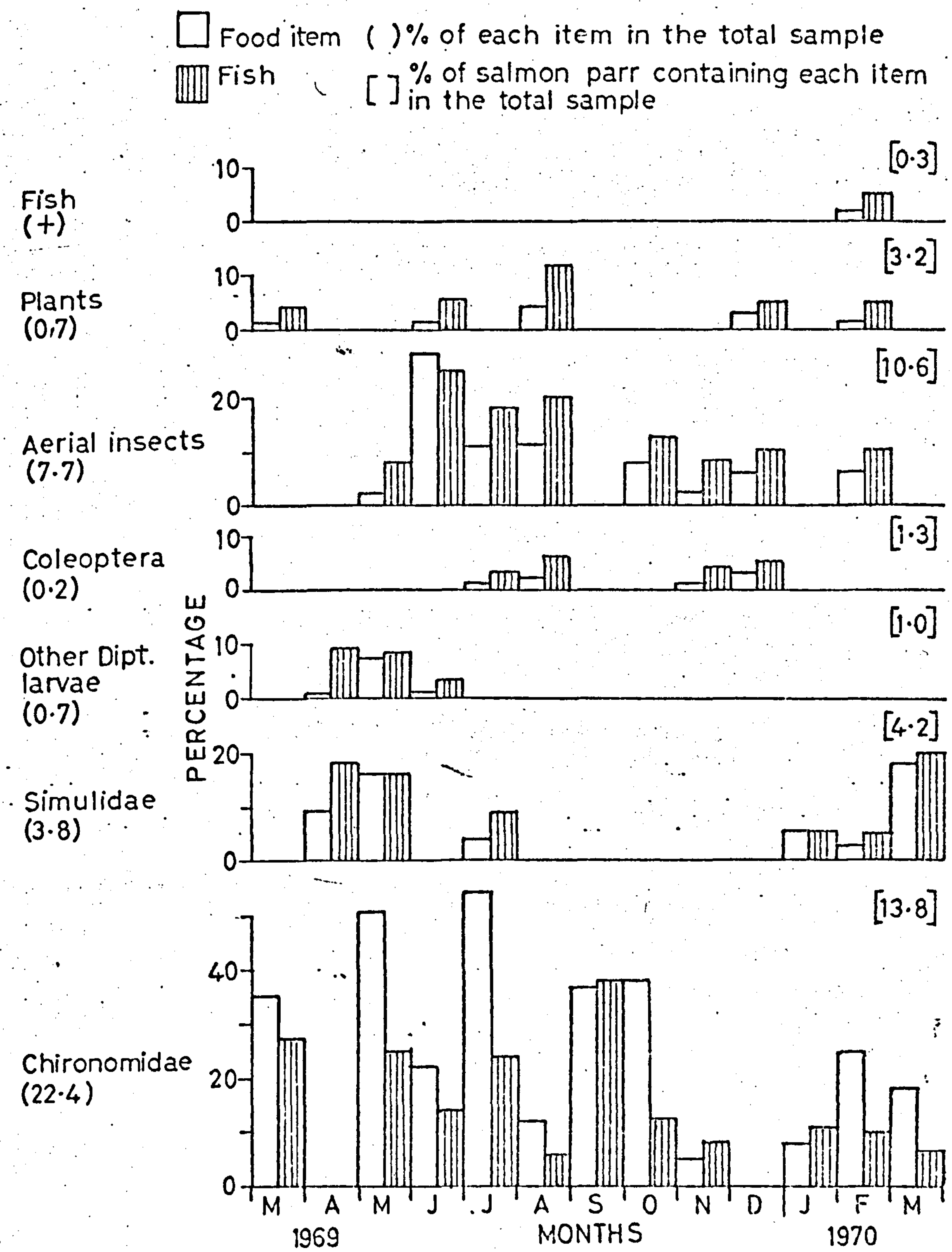

Fig. 7.9 Seasonal variations of the food items of salmon parr. and percentage of stomachs containing each food item in different months.

and other unidentifiable Plecoptera nymphs in 5.8% of the diet; Ephemeroptera represented by *Paraleptophlebia submarginata*, *Baetis rhodani*, *Ecdyonurus venosus*, *Heptagenia lateralis* and other unidentifiable Ephemeroptera nymphs, formed 19.8%; and Trichoptera, represented by *Plectrocnemia conspersa*, *Hydropsyche instabilis*, *Potamophylax latipennis*, *Sericostoma personatum* and other unidentifiable Trichoptera larvae constituted 19.8% of the total diet. Chironomid larvae were found in 17.4%.

Among the insignificant benthic food were *Latelmis volkmari* and *Helmis maugei* which together formed 0.3% of the total. Finally simuliid larvae were present in 1.6% of the total diet.

The midwater food was composed of adult *Platambus maculatus* (0.6%) and the bullhead (Cottus gobbio) (2.1%).

Aerial and terrestrial insects belong to Empidae, Bibionidae and Formicidae, and formed 8.4% of the total diet.

Miscellaneous food formed 2.7% of the diet in which 1.7% was plant material and 1.0% fish eggs.

(b) Seasonal variation in food intake

The maximum feeding activity was observed during April to June and it gradually decreased in winter (Fig.7.5).

(c) Seasonal changes in the food

Figs. 7.8, 7.9 show the presence of Plecoptera,

Table 7.9 The average percentage composition of the food assessed by occurrence, volume, and number methods of salmon parr of each age group.

Name of Species	Salmo salar											
Total No. Stomachs	123											
Age	0+			1+			2+			3+		
Total No. Sp. in each age	13			71			36			3		
No. Empty stomachs	1			4			7			2		
Methods of assessment	O	V	N	O	V	N	O	V	N	O	V	N
<u>Benthic food</u>												
Oligochaeta							0.9	.7	0.4			
Gastropoda	4.1	1.5	1.2	9.4	8.0	11.0	0.9	1.1	0.8			
Plecoptera nymphs	3.3	2.3	1.9	13.2	8.3	11.5	18.9	12.9	14.6			
Ephemeroptera nymphs	31.1	15.0	24.0	37.6	31.3	34.7	30.6	27.3	34.3	50.0	76.7	71.4
Trichoptera larvae	32.0	50.0	48.0	8.6	10.6	10.4	13.0	18.8	10.6			
Coleoptera larvae	4.7	1.2	1.7	0.4	+	.1						
Chironomid larvae	8.9	10.6	14.5	16.0	20.4	21.5	10.2	15.4	23.4	50.0	23.3	28.6
Simuliid larvae				4.3	4.1	4.2	5.5	2.5	3.6			
Other dipteran larvae				0.3	+	.1	4.0	2.0	2.1			
<u>Midwater food</u>												
Coleoptera adults				1.6	2.6	0.7						
Fish							0.9	8.6	0.2			
<u>Aerial & terrestrial food</u>												
Insects	15.5	19.3	8.1	6.7	12.5	4.8	3.4	1.9	1.4			
<u>Miscellaneous food</u>												
Plant material				1.4	1.7	0.4	9.9	5.4	7.3			
Fish eggs							0.9	4.1	0.5			

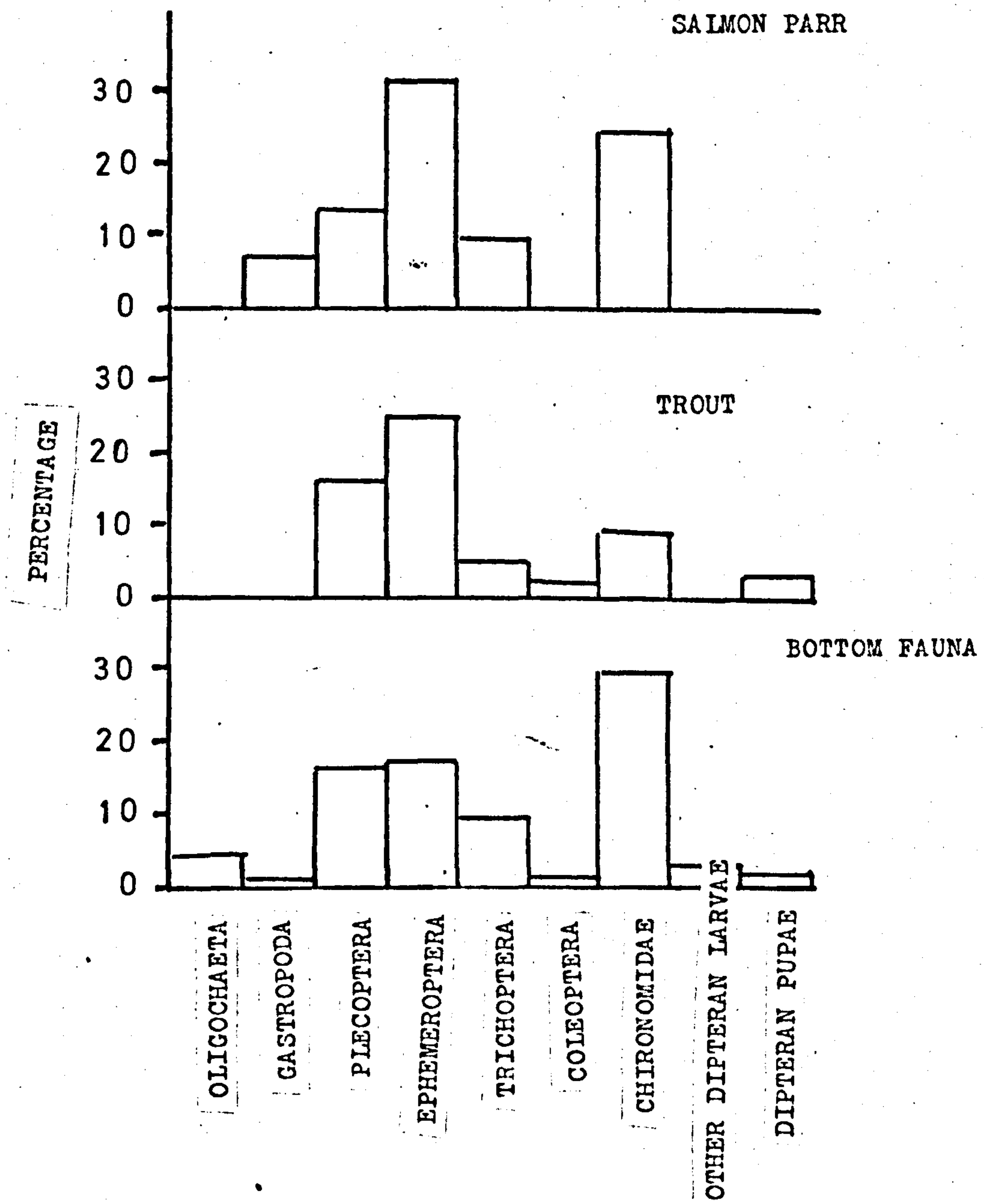

Fig 7.10 Percentage composition by number of the benthic fauna and food of trout s and salmon parr.

Ephemeroptera, Trichoptera and Chironomidae throughout the period. Most of the Plecoptera were eaten during winter and spring. Ephemeroptera nymphs were most frequent in the diet during winter and spring. Trichoptera larvae were the dominant food item during autumn and winter. Considerable numbers of chironomid larvae were eaten during summer and autumn. Gastropods, aerial and terrestrial insects, were confined mainly to summer and autumn.

Among the food items of infrequent occurrence were simuliid larvae and Coleoptera adults and larvae which occurred in winter and spring. Other dipteran larvae were consumed in spring and fish, Cottus gobio, in winter. Low values were reported for plant material except during autumn.

(d) Food in relation to age

The fish of all age groups had a similar diet (Table 7.9).

I found a significant difference in the occurrence of Gastropoda ($x^2_3 = 10.47$, $P < 0.05 < 0.02$), and Trichoptera ($x^2_3 = 9.81$ $P < 0.05$) in the food of trout of different age groups.

(iii) Utilisation of the fauna

Fig. 7.10 shows the percentage composition by number of the bottom fauna and benthic food items utilised by trout and salmon parr. Very few oligochaetes were eaten by trout and salmon parr, despite their abundance in the fauna. The absence of oligochaetes from the diet was probably related to their burrowing habits. Ancylastrum fluviatile was the only mollusc eaten by trout and salmon parr. It was consumed more by salmon parr than trout. Asellus meridinus was the only crustacean eaten by trout. Maitland (1965) also found crustacea to be more available to trout than to salmon parr, and Frost and Went (1940) found very few crustacea in River Liffey salmon parr and trout, despite their abundance in the fauna. Plecoptera nymphs, mostly Chloroperla, Isoperla and Amphinemura were common and frequently consumed more by trout than by salmon parr. I found Trichopera larvae eaten more often by salmon parr than by trout, as did Frost and Went (1940). Coleoptera larvae and adults belonging to the species Latelmis volkmari and Helmis maugei were eaten more by trout than by salmon parr. A significant difference ($t = 8.3$, $P < 0.05$) was observed between the numbers of Coleoptera present in the bottom fauna and in the trout food. Salmon parr utilised more chironomid and simuliid larvae than trout; this suggests that salmon parr feeds more on bottom fauna than trout.

4. SUMMARY

(1) The bottom fauna of this stream at low and high altitude was 1427.3 and 1560.3 animals/m^2 respectively.

(2) The percentage of Amphipoda, Plecoptera, Ephemeroptera,

Megalopera and Dixidae increased gradually from low altitude to high.

(3) Isopoda, Ceratopogonidae, Tipulidae, Simuliidae, Chironomidae and their pupae occurred more at low altitude than at high.

(4) There was no change in the number of Turbellaria, Hirudinea, Oligochaeta, Gastropoda, Trichoptera and Coleoptera with elevation.

(5) 60.9% and 90.7% by volume of the total food of trout and salmon parr respectively was benthic fauna.

(6) Aphidae, Empididae, Bibionidae and Formicidae were consumed more (31.8%) by trout than by salmon parr (8.4% by volume).

CHAPTER VIII

DISCUSSION (PART I)

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(1) BOTTOM FAUNA 192

(2) FOOD AND FEEDING RELATIONSHIP BETWEEN TROUT AND SALMON PARR. 203

CHAPTER VIII

DISCUSSION

Having considered the observations stream by stream (Chapters 3 to 7 inclusive), they will now be discussed under two headings : (1) Bottom fauna, (2) Food and feeding relationship between trout and salmon parr.

(1) Bottom Fauna

Huet (1959) characterised the biotopes mainly by means of the slopes and width of the streams. Illies (1952) and Dittmar (1955) characterised the different stream-zones by means of the annual temperature amplitude. Schmitz (1955) preferred to characterise them by the difference between water temperature and air temperature. Macan (1961) objected to classifying stream-zones by means of temperature mainly because there are no direct relationships between temperature, stream and bottom conditions. Berg (1943, 1948) made a classification of the stream on two ecological factors which he thought were of major importance for the fauna, namely the velocity of current and the type of substratum. The importance of the substratum has been stressed by Percival and Whitehead (1929, 1930), Whitehead (1935), Butcher, Longwell and Pentelow (1937), Moon (1939), Jones 1949a, 1949b), Macan (1957), Hynes (1961), Thorup (1966) and Egglishaw (1969) who said that the type of substratum

(2) The number of benthic animals increases during summer and decreases during winter.

(3) 68.0% and 97.8% benthic fauna were utilised as food by trout and salmon parr respectively.

(4) 27.2% aerial and terrestrial insects were eaten by trout and 0.1% by salmon parr.

Table 8.1 Density (Av. no./m^2) of the bottom fauna in all Llyn Tegid feeder streams.

Nature of bottom:-

A = Mud, sand and pebble. B = Gravel. C = Stones with scattered vegetations. D = Stones covered with moss.

Streams	Llafar			Lliw	Dyfrdwy		Turch	Glyn		
Nature of bottom	A	B	C	C	A	C	D	A	B	C
Height (m O.D.)	175	177	200	200	175	183	216	176	183	500
Sampling sites	L1	L2	L3	Lw	LD1	LD2	T	G1	C2	G3
Turbellaria	0	5.3	0	0	0.7	0	0	1.0	0	0.7
Hirudinea	10.7	10.7	13.8	7.4	2.1	14.9	0.7	0.7	4.2	1.0
Oligochaeta	435.8	156.2	37.4	333.8	272.8	147.6	26.7	157.2	48.1	49.2
Gastropoda	6.4	2.1	6.4	3.2	6.4	23.5	5.3	1.0	24.6	14.9
Lamellibranchiata	1.0	12.8	58.8	4.2	3.2	4.2	18.1	0.7	71.6	2.1
Amphipoda	0	7.4	2.1	2.1	3.2	1.0	10.7	5.3	10.7	13.9
Isopoda	62.2	21.4	0	0	107.0	0	0	1.0	2.1	0
Hydracarina	98.4	0	7.4	1.0	1.0	2.1	2.1	0	0	2.1
Plecoptera	9.6	372.3	182.9	60.9	17.1	315.6	253.6	162.6	303.8	411.9
Ephemeroptera	3.2	202.2	189.3	535.0	149.8	184.0	269.6	124.1	258.9	419.4
Hemiptera	988.6	144.5	2.1	202.5	422.6	401.2	0.7	105.1	118.4	0
Megaloptera	9.6	3.2	12.8	4.2	1.0	7.4	2.1	1.0	5.3	8.5
Trichoptera	115.5	186.1	72.7	126.2	39.5	263.7	151.9	65.2	208.6	204.3
Coleoptera	55.6	121.9	251.4	38.5	28.8	90.9	60.9	16.0	35.3	28.8
Diptera:										
Ceratopogonidae	40.6	26.7	9.6	8.5	5.3	6.4	0	7.4	7.4	2.1
Dixidae	0	0	0	0	0	0	5.3	0	0.7	55.3
Tipulidae	2.1	5.3	9.6	4.2	6.4	7.4	1.0	7.4	4.2	0.7
Simuliidae	1.0	21.4	42.8	2.1	0	9.6	3.2	0	1.0	1.0
Chironomidae	1166.8	424.7	1309.6	769.3	2153.9	863.4	344.5	647.3	269.6	64.4
Other dipteran larvae	2.1	34.2	37.4	13.9	2.1	22.4	25.6	21.4	87.7	73.5
Total no. animals	4024	2327	3019	2842	4313	3144	1874	1785	1951	2068
Av.no.animals/month	287.4	166.2	215.6	202.9	308.0	244.5	133.8	127.5	139.3	147.7
Av.no.animals/m^2	3075.1	1778.3	2306.9	2171.0	3295.6	2402.1	1431.6	1364.2	1490.5	1580.3

is one of the important factors in the distribution of aquatic fauna.

In the present study, four different types of bottoms, namely (A) Mud, sand and pebbles, (B) Gravel, (C) Stones with scattered vegetation and (D) Stones covered with moss, and their characteristic species are discussed. The densities of species found in all the Llyn Tegid feeder streams are tabulated in Tables 3.5, 4.2, 5.3, 6.2 and 7.4. A comparison of the benthic fauna in terms of groups of five unregulated Llyn Tegid feeder streams shows the similarity of the animal inhabitants though their numbers differ on different types of substratum (Table 8.1). The feeder streams have a dense population (mean number of organisms $2382.8/m^2$) composed of many species. Ephemeroptera, Hemiptera, Trichoptera, Plecoptera, Chironomidae and Oligochaeta together formed 81.4%, 89.2%, 87.4%, 85.4% and 88.5% of the benthic standing crop in Afon Llafar, Lliw, Dyfrdwy, Twrch and Glyn respectively.

Phagocata vitta was scarce and collected relatively more at G_1 than G_3 (Table 8.1). Extensive sampling may reveal their presence at L_1 and LD_1 as they have an 'A' type bottom, though Reynoldson (1967) showed a high density of *P. vitta* in peaty ground. *Erpobdella octoculata* and *Helobdella stagnalis* were commonly collected. These appear to prefer stony substrata with scattered vegetation

Table 8.2 The distribution of benthic fauna (expressed in average percentages) according to the type of substratum in Llyn Tegid feeder streams. + = <0.1%

	A	B	C	D
Types of substratum	Mud and small pebbles	Gravel	Stones with scattered vegetation	Stones covered with moss
Sampling stations	L1, LD1, G1	L2, G2	L3, Lw, G3	T
Turbellaria	+	-	+	-
Hirudinea	+	+	0.1	+
Oligochaeta	6.5	5.1	6.2	1.9
Gastropoda	0.2	1.2	1.0	0.4
Lamellibranchiata	+	0.8	0.4	1.2
Amphipoda	0.2	0.4	1.0	0.7
Isopoda	2.1	-	-	-
Hydracarina	0.4	+	+	0.1
Plecoptera	3.8	8.0	16.3	31.6
Ephemeroptera	6.3	19.4	20.3	18.8
Hemiptera	9.5	7.2	4.7	+
Megaloptera	0.1	0.3	.5	0.1
Trichoptera	3.6	7.1	9.3	10.6
Coleoptera	1.3	3.3	4.1	4.2
Ceratopogomidae	0.3	0.4	0.3	-
Dixidae	-	-	1.7	0.3
Tipulidae	0.4	0.4	0.1	0.1
Simuliidae	-	1.1	0.2	0.2
Chironomidae	57.8	37.8	25.9	24.0
Other dipteran larvae	0.4	1.5	2.8	1.8
Dipteran pupae	1.6	2.2	4.1	3.0

(Tables 8.1, 8.2, 9.3). Similar observations were made by Mann (1955). Stylodrilus heringianus and Lumbriculus variegatus were most significant among the oligochaete fauna in all the streams except Afon Twrch (Tables 8.1, 9.3). The obvious reason is the lack of a muddy bottom in the stretch sampled. The molluscan fauna in the feeder streams is varied. Limnaea pereger, Ancylastrum fluviatile in the Gastropoda and Pisidium subtruncatum in Lamellibranchiata are among the prominent species collected. These were found relatively more commonly in Afon Twrch and Glyn and less frequently in Afon Llafar, Lliw, and the Dyfrdwy. This may be due to higher concentrations of calcium ions in the Twrch and Glyn waters (Table 3.4). The amphipod fauna though scarce in the feeder streams is represented by Gammarus pulex which seems to favour thick vegetation and a higher calcium concentration. These were recorded less frequently in Llafar, Lliw and Dyfrdwy and more commonly in the Twrch and Glyn (Table 8.1). Asellus meridianus were collected from L_1, LD_1 and G_1 stations, the bottoms of which are of sand, mud and pebbles. The commonest of the Hydracarina was Hygrobates nigromaculatus and Sperchon setiger. These were well represented at the stations near the lake and their presence may be due to the slow current and more abundant marginal vegetation. Amphinemura sulicollis, Amphinemura standfussi, Leuctra hippopus, Protonemura meyeri, Chloroperla torrentium and Isoperla grammatica are the chief representatives of the Plecoptera. These occur in considerable numbers in Afon Twrch which has a thick carpet of moss on the bottom, at G_3 where altitude may be one of the factors; and are relatively less in number in other feeder streams, for which shelter afforded by the stones and availability of food like moss, algae, detritus and vegetable matter (Hynes 1941, Jones 1950, Badcock 1949) may not be adequate. There is an increase in plecopteran nymphs from L_1, having a muddy bottom, to L_2 and L_3 where the bottom is gravel and stones with scattered vegetation as in the Afon Dyfrdwy and Glyn (Table 8.1). Nymphs of the mayflies Ephemerella ignita, Baetis spp, Centroptilum luteolum, Heptagenia spp, Ecdyonurus venosus, and Leptophlebia marginata are predominant in the feeder streams (Tables 8.1, 9.3). These appear to favour B, C and D types of bottom (Tables 8.1, 8.2, 9.3). Ephemerella ignita occurs most frequently in stoney bottoms covered with moss. Paraleptophlebia spp, and Heptagenia spp. were common in the upper reaches of Afon Llafar, Dyfrdwy and Glyn (Table 3.5, 5.3 and 7.4) as was also found by Macan (1957). Baetis spp. and Centroptilum spp. were common in slower waters. It is not usual to find Centroptilum in rapid areas where Baetis is frequently abundant. Baetis spp. appears in all stations. Rhithrogena semicolorata and Ecdyonurus venosus frequently occur together. There is a gradual increase in the number of mayfly nymphs from the muddy bottoms of L_1, LD_1 and G_1 to L_2, LD_2 and G_2 where the bottom is of gravel and finally to L_3 and G_3 where the bottom is stony with scattered vegetations, (Tables 8.1, 8.2, 9.3). Small round flattened Micronecta poweri are an important constituent of the benthic community in all feeder streams except Afon Twrch. Probably their carnivorous habits and the subsequent difficulty in finding the food in the thick carpet of moss may have an important effect in regulating their numbers in this stream. Micronecta poweri is common in the lower waters particularly L_1 LD_1 and G_1 where there is a slow current and more marginal vegetation, both submerged and floating. Sialis spp. are scarce in the feeder streams (Tables 8.1, 8.2, 9.3). Larvae of the caddis flies Plectrocnemia conspersa, Hydropsyche instabilis, Potamophylax latipennis, Glyphotaelius pellucidus, Helesus digitatus and Sericostoma personatum are plentiful in all the feeder streams (Table 8.1.). Silo spp. and Agapetus spp. are small and infrequently found. The caddis larvae increase in number from A type bottoms to B and C types in Afon Llafar, Dyfrdwy and Glyn (Tables 8.1, 8.2, 9.3). Helmis maugei and Latelmis volkmari are abundant and widely distributed in the feeder streams (Table 8.1) though the larvae of these forms are more frequent than adults. There is an increase in the number of aquatic beetles from A type bottoms to B and C types in Afon Llafar, Dyfrdwy and Glyn (Tables 8.1, 8.2). Bezzia spp. are scarce in the feeder streams except Llafar and seem to prefer gravel and stony substrata (Tables 8.1, 8.2, 9.3). Dixa puberula was the only species recorded from

Table 8.3 The average percentage composition of the total annual diet of salmon parr assessed by volume method in all Llyn Tegid feeder streams.

+ = <0.1% ; - = No record

Streams	L	Lw	LD	T	G
Total No. Fish	136	93	122	77	109
Total No. Empty stomachs	6	11	9	5	14
Lumbriculus spp.	1.2	-	0.6	-	0.1
Ancylastrum fluviatile	0.5	0.1	-	0.7	2.6
Limnaea pereger	1.0	-	1.6	-	-
Amphinemura spp.	0.3	0.4	1.0	1.0	1.2
Leuctra spp.	0.1	0.1	0.1	1.1	0.4
Nemoura spp.	0.6	-	-	-	-
Protonemura meyeri	0.7	0.2	1.8	1.9	-
Chloroperla spp.	-	-	2.4	1.0	1.9
Isoperla grammatica	-	-	-	1.4	0.7
Other Plecoptera	-	-	1.0	2.5	1.6
Baëtis rhodani	4.2	3.6	7.5	7.3	3.4
Caënis spp.	1.1	2.1	2.1	-	-
Ecdyonurus spp.	0.6	-	2.3	5.3	11.6
Ephemerella spp.	1.3	-	-	4.4	5.4
Heptagenia lateralis	-	-	-	-	5.6
Other Ephemeroptera	9.4	22.4	6.1	8.3	11.5
Anabolia spp.	3.3	-	-	-	-
Plectrocnemia conspersa	9.2	7.9	10.4	6.7	2.1
Rhyacophila dorsalis	3.6	-	-	5.4	2.5
Hydroptila spp.	2.3	-	-	-	-
Hydropsyche spp.	-	-	5.2	4.3	3.9
Potamophylax spp.	-	-	5.3	-	2.8
Sericostoma personatum	-	-	-	-	3.2
Other Trichoptera	20.5	30.1	20.2	10.3	5.3
Helmis maugei larvae	0.3	0.1	0.5	0.5	+
Latelmis volkmari larvae	+	+	1.1	0.3	0.3
Chironomid larvae	10.6	5.5	22.0	25.5	17.4
Chironomid pupae	+	0.1	-	-	-
Simuliid larvae	3.0	2.9	0.9	5.7	1.6
Tipulid larvae	3.8	-	0.4	-	-
Other dipteran larvae	0.5	1.6	0.6	+	0.5
Dipteran pupae	0.6	-	1.7	+	-
<u>Midwater food</u>					
Helmis maugei adults	2.2	-	0.1	0.5	-
Micronecta spp.	2.0	-	-	-	-
Latelmis volkmari adults	-	-	0.1	-	0.4
Platambus maculatus adults	-	-	-	-	0.2
Cottus gobio	-	-	-	-	2.1
<u>Aerial and terrestrial food</u>	8.1	16.0	3.1	0.8	8.4
<u>Miscellaneous food</u>					
Plant materials	7.8	3.6	0.9	4.4	1.7
Stones (caddis cases)	0.4	-	-	-	-
Fish eggs	-	2.6	-	-	1.0

Table 8.4 The average percentage composition of the total diet of salmon parr assessed by number method in all Llyn Tegid feeder streams.

+ = <0.1%; - = No record;

Streams	L	Lw	LD	T	G
Total No. Fish	136	93	122	77	109
Total No. Empty Stomachs	6	11	9	5	14
Lumbriculus spp.	0.5	-	0.7	-	0.1
Ancylastrum fluviatile	0.7	+	-	0.3	3.2
Limnaea pereger	0.2	-	0.9	-	-
Amphinemura spp.	0.9	0.9	1.6	1.0	1.4
Leuctra spp.	0.7	0.4	0.5	2.6	0.6
Protonemura meyeri	0.9	0.6	1.5	1.3	-
Chloroperla spp.	-	-	2.1	1.1	2.0
Isoperla grammatica	-	-	-	1.1	0.9
Other Plecoptera	-	-	1.1	2.2	2.1
Baëtis rhodani	9.7	5.2	6.4	4.3	6.8
Caenis spp.	2.8	9.1	3.1	-	-
Ecdyonurus spp.	0.5	-	4.2	7.5	8.6
Ephemerella spp.	3.2	-	-	11.3	6.1
Heptagenia lateralis	-	-	-	-	5.4
Other Ephemeroptera	10.4	14.8	6.3	6.2	14.2
Anabolia spp.	3.7	-	-	-	-
Plectrocnemia conspersa	5.6	11.5	6.1	3.4	1.1
Rhyacophila dorsalis	1.0	-	-	3.2	1.2
Hydroptila spp.	1.6	-	-	-	-
Hydropsyche spp.	-	-	4.1	5.2	2.9
Potamophylax spp.	-	-	5.0	-	2.0
Sericostoma personatum	-	-	-	-	3.8
Other Trichoptera	16.7	17.1	13.5	7.2	6.2
Helmis maugei larvae	0.2	0.3	0.3	1.1	0.1
Latelmis volkmari larvae	0.1	+	0.4	0.6	0.3
Chironomid larvae	18.3	8.9	36.1	30.0	22.0
Chironomid pupae	+	0.4	-	-	-
Simuliid larvae	8.1	8.3	0.8	7.2	1.9
Tipulid larvae	1.0	-	0.1	-	-
Other dipteran larvae	0.6	4.3	0.2	+	0.6
Dipteran pupae	0.1	-	2.3	0.1	-
Midwater food					
Helmis maugei adults	1.0	-	+	0.1	-
Micronecta spp.	1.6	-	-	-	-
Latelmis volkmari adults	-	-	0.1	-	+
Platambus maculatus adults	-	-	-	-	+
Cottus gobio	-	-	-	-	0.1
Aerial and Terrestrial insects	1.9	13.7	0.9	0.1	3.5
Miscellaneous food					
Plant material	6.7	2.9	1.3	2.1	1.9
Stones (caddis cases)	0.2	-	-	-	-
Fish eggs	-	1.6	-	-	0.1
Total %	99.0	100.0	99.6	99.2	99.1

Table 8.5 The average percentage composition of the total annual diet of trout assessed by volume method in all Llyn Tegid feeder streams. + = <0.1%

Streams	L	Lw	LD	T	G
Total No. Fish	81	113	113	57	101
Total No. Empty Stomachs	2	9	7	6	5
Benthic food					
Lumbriculus spp.	0.6	0.2	4.5		0.3
Ancylastrum fluviatile	0.8	+		2.4	1.1
Limnaea pereger	0.2		0.8	0.8	
Gammarus pulex			1.1		
Asellus meridianus				0.4	
Amphinemura spp.	0.5	0.1	0.4	1.5	0.6
Leuctra spp.	+	+	0.2	1.6	1.1
Protonemura meyeri		0.1	0.7	2.3	
Isoperla grammatica				2.2	0.7
Chloroperla spp.	0.1	-	0.3	1.7	1.7
Other Plecoptera	-	-	0.6	2.0	2.4
Baëtis rhodani	6.2	2.2	5.1	3.1	3.7
Caënis spp.	0.3	1.0	2.1	-	-
Ecdyonurus spp.	-	-	3.2	4.3	4.5
Ephemerella spp.	6.1	-	-	4.5	5.1
Heptagenia lateralis					6.7
Leptophlebia marginata	2.1				
Other Ephemeroptera nymphs	1.9	5.0	7.3	6.2	9.8
Plectrocnemia conspersa	8.5	12.9	8.0	1.2	0.8
Rhyacophila dorsalis				0.8	1.0
Hydroptila spp.	-	-	-	-	-
Sericostoma personatum			-	-	0.3
Potamophylax spp.	-	-	2.2	-	1.8
Hydropsyche spp.	4.1	-	3.2	2.3	1.1
Glyphotaelius spp.	11.1				
Other Trichoptera	2.0	7.0	7.2	7.5	4.1
Helmis maugei	0.4	0.5	0.4	0.6	-
Latelmis volkmari	0.8	-	0.2	0.3	-
Chironomid larvae	2.1	1.0	3.2	3.1	3.3
Simuliid larvae	0.7	0.3	-	-	0.4
Simuliid pupae	0.7	-	-	-	-
Tipulid larvae	-	0.1	-	-	-
Other dipteran larvae	0.3	3.4	+	0.6	-
Dipteran pupae	-	-	1.7	0.3	0.5
Midwater food					
Hygrobates spp.	+	-	-	-	-
Helmis maugei adults	0.5	0.3	2.2	1.0	-
Micronecta spp.	+	-	-	-	-
Latelmis volkmari adult	0.4	-	2.1	0.4	4.2
Cottus gobio	15.8	34.7	11.3	17.2	1.1
Other Coleopteran adults		0.4			
Platambus maculatus					0.8
Aerial and Terrestrial insects	31.8	19.4	29.2	27.2	31.8
Miscellaneous food					
Plant material	2.2	10.0	2.8	4.9	6.5
Stones (caddis cases)	3.0	0.5	-	-	-
Fish eggs	-	0.3	-	-	3.7

Table 8.6 The average percentage composition of the total annual diet of trout assessed by number method in Llyn Tegid feeder streams. + = <0.1%

Streams	L	Lw	LD	T	G
Total No. Fish	81	113	113	57	101
Total No. Empty stomachs	2	9	7	6	5
<u>Benthic food</u>					
Lumbriculus spp.	1.4	0.8	4.1	-	0.1
Ancylastrum fluviatile	1.1	+	-	3.1	0.3
Limnaea pereger	0.7	-	0.5	1.0	0.2
Gammarus pulex	-	-	0.3	-	-
Asellus meridianus				0.2	
Amphinemura spp	1.5	0.4	1.1	1.2	0.7
Leuctra spp.	0.1	0.1	1.1	1.0	2.1
Protonemura meyeri	-	0.6	1.3	1.9	-
Isoperla grammatica	-	-	-	2.2	1.3
Chloroperla spp.	0.4	-	1.2	1.4	2.1
Other Plecoptera	-	-	1.2	4.2	2.3
Baëtis rhodani	11.4	3.1	10.2	7.4	4.1
Caënis spp.	1.0	4.8	2.2	-	
Ecdyonurus spp.	-	-	3.3	2.4	5.2
Ephemerella spp.	8.2	-	-	4.2	6.6
Heptagenia lateralis	-	-	-	-	8.6
Leptophlebia marginata	4.6	-	-	-	-
Other Ephemeroptera	2.1	4.4	11.4	9.4	12.1
Plectrocnemia conspersa	7.4	10.9	7.2	1.1	0.5
Rhyacophila dorsalis	-	-	-	1.2	0.8
Hydroptila spp.	-	-	-	-	-
Sericostoma personatum	-	-	-	-	0.6
Potamophylax spp.	-	-	1.2	-	1.0
Hydropsyche spp.	3.2	-	2.2	2.1	0.5
Glyphotaelius spp.	7.3				
Other Trichoptera	1.1	8.2	6.2	4.2	2.4
Helmis maugei	1.3	1.7	0.9	0.6	-
Latelmis volkmari	-	1.6	0.3	0.5	-
Chironomid larvae	7.5	3.1	7.7	13.1	6.3
Simuliid larvae	1.9	2.0	-	-	0.8
Simuliid pupae	1.6	-	-	-	-
Tipulid larvae		+			
Other dipteran larvae	0.9	9.0	+	2.4	-
Dipteran pupae	-	-	2.7	0.5	0.3
<u>Midwater food</u>					
Hygrobates spp.	+				
Helmis maugei adults	0.5	1.1	1.4	1.4	-
Micronecta spp.	0.1				
Latelmis volkmari adult	0.4	-	1.2	1.0	2.3
Cottus gobio	1.8	22.7	1.6	6.2	0.5
Other Coleoptera adult	-	1.0	-	-	
Platambus maculatus			-	-	2.0
<u>Aerial and Terrestrial insects</u>	25.5	13.6	25.3	23.0	26.0
<u>Miscellaneous food</u>					
Plant material	2.5	7.7	3.8	2.7	4.3
Stones (caddis cases)	2.1	0.5	-	-	-
Fish eggs	-	1.2	-	-	2.8
Total %	99.6	98.5	99.6	99.6	96.8

Afon Lliw, Twrch and Glyn though scarce except in Glyn (G_3). The scarcity may be related to the high altitude and fewer predators. Chironomid larvae, represented by seventeen species (Tables 8.1, 9.3) are abundant in the feeder streams and found in a variety of habitats. I found them entangled in roots, and moss, hanging on by their stumpy hooked appendages, sheltering in crevices, and they frequently inhabit discarded caddis cases. These are found frequently in A type bottoms and less in B and C type bottoms, (Tables 8.1, 8.2, 9.3). Simuliidae which were represented by seven species in the feeder streams were not recorded from the A type of bottom. These prefer shallow swift flowing water and stable habitats. Other dipteran larvae which includes Tipula spp. Atherix marginata, Dicronata robusta, Hermerodromia unilineata, Pericoma pseudo-exquisita, Limnophora spp. and Limonia spp. appeared insignificantly in all types of bottoms discussed above (Table 8.1).

(2) Food and Feeding Relationship between Trout and Salmon Parr

My results (Chapter 3.4, 4.3, 5.3, 6.3, 7.3) show a number of similar features in the food and feeding habits of trout and salmon parr in the Llyn Tegid feeder streams (Tables 8.3, 8.4, 8.5 and 8.6). The most obvious of these is the greater amount of benthic food eaten by salmon parr compared to trout, which eat more midwater and aerial and terrestrial food. Both consume similar amounts of

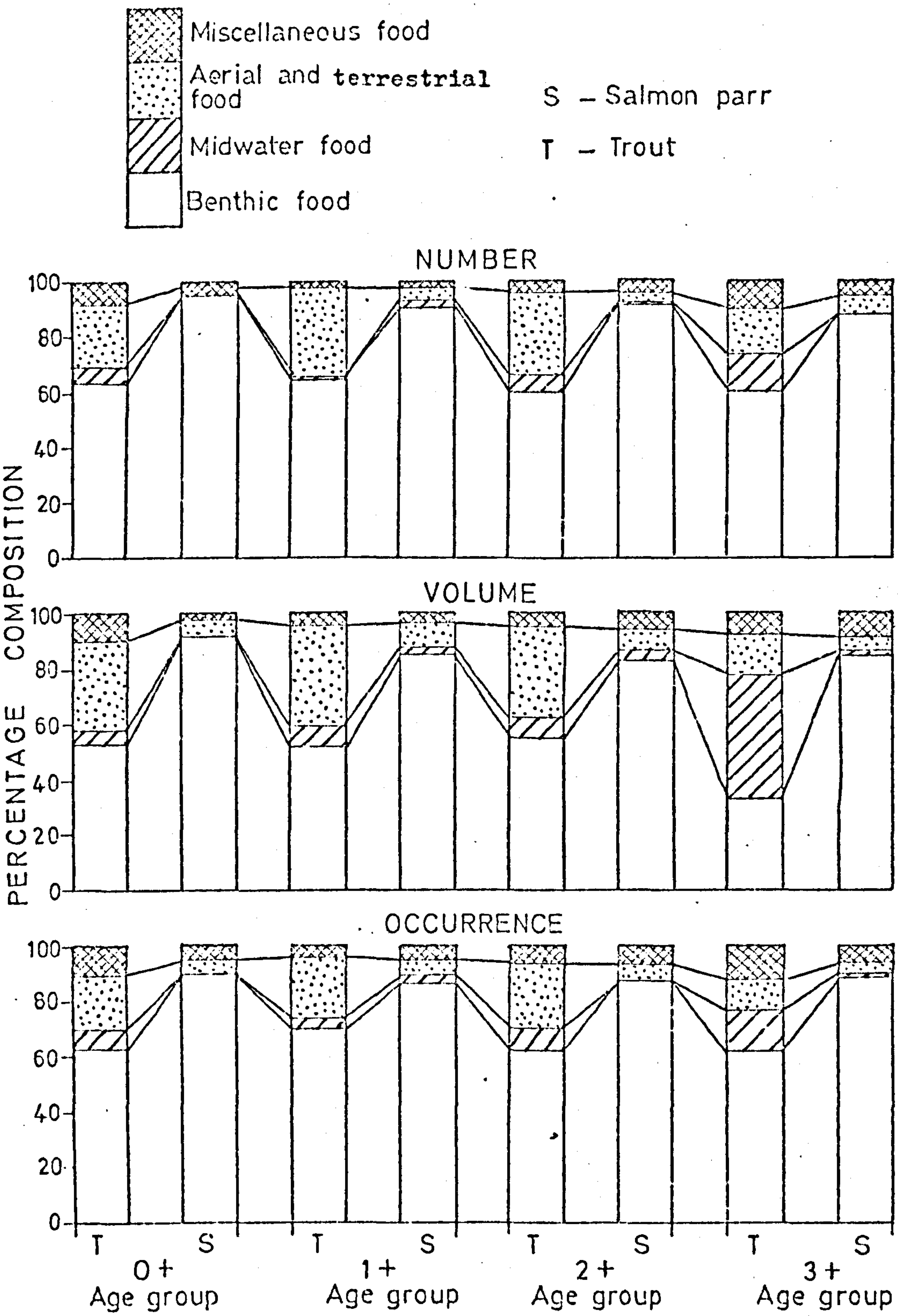

Fig. 8.1 Percentage composition of the total food of trout and salmon parr according to age groups assessed by occurrence, volume and number methods in all Llyn Tegid feeder streams

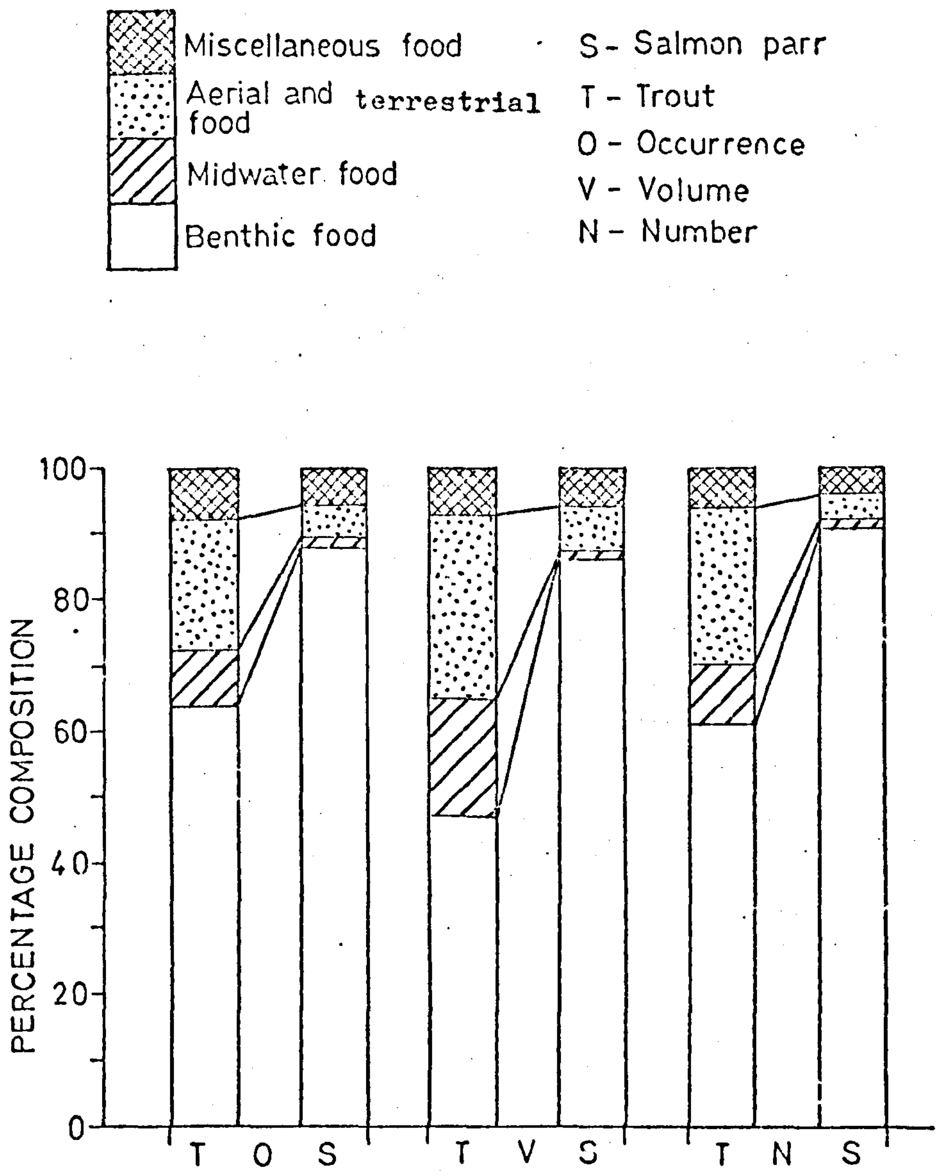

Fig. 8.2 Percentage composition of the total food of trout and salmon parr assessed by occurrence volume and number methods in all Llyn Tegid feeder streams

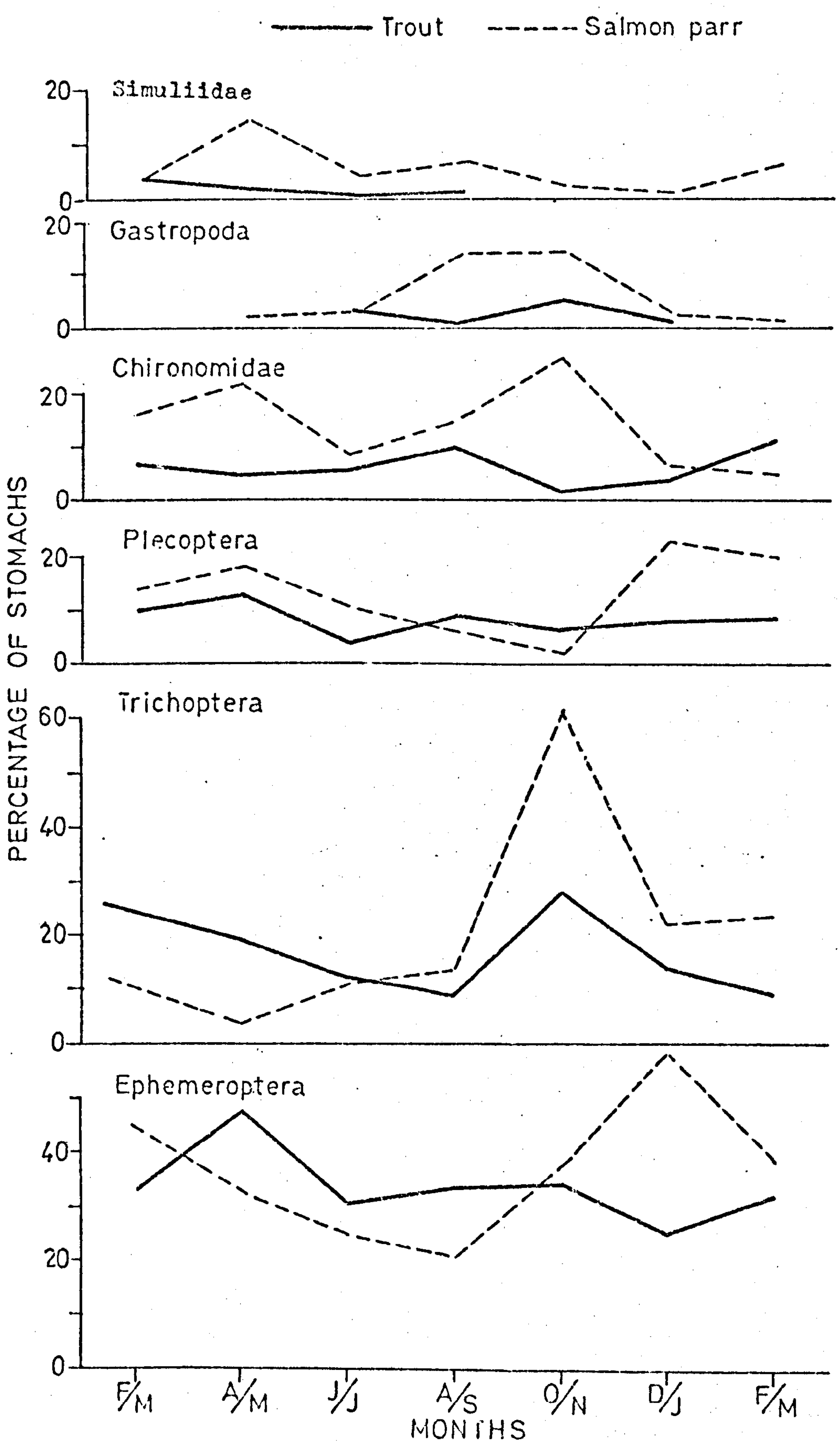

Fig. 8.3 Average percentage of stomachs of trout and salmon parr containing each food organism in all Llyn Tegid feeder streams in different months

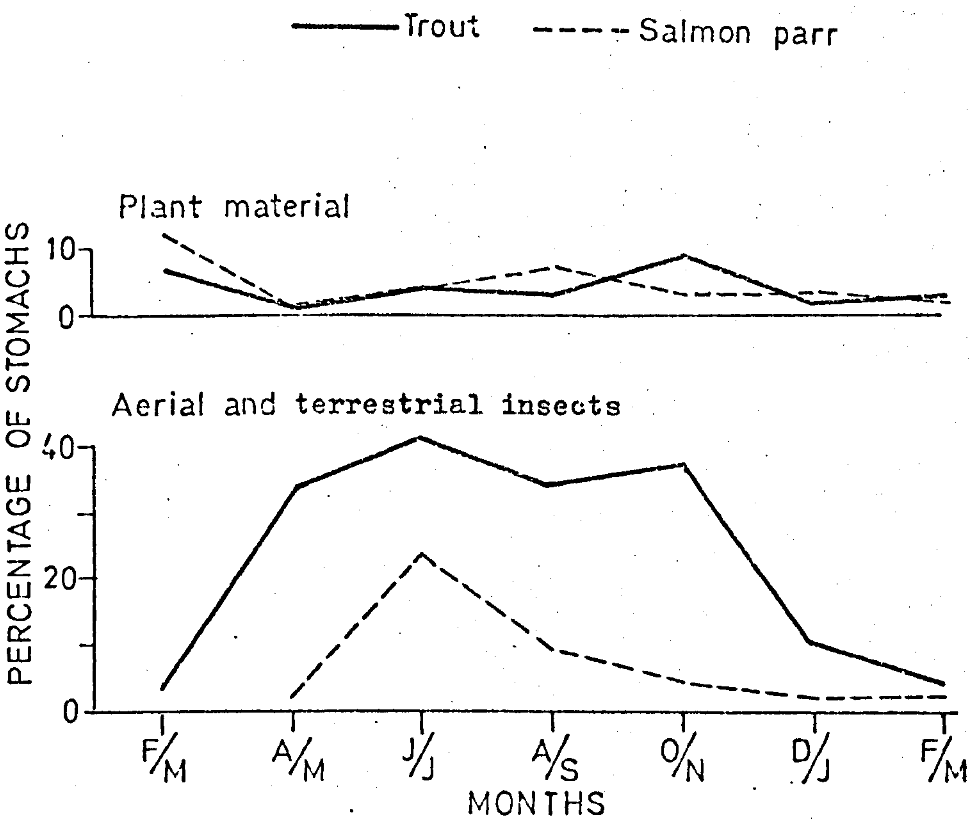

Fig. 8.4 Average percentage of stomachs of trout and salmon parr containing each type of food organism in all Llyn Tegid feeder streams in different months

Table 8.7 Comparison of the total annual diet (expressed in percentages) of trout and salmon parr assessed by volume and number methods in all Llyn Tegid feeder streams. + = < 0.1% - = No record

Methods of Assessment	Volume		Number	
Name of fish	Trout	Salmon Parr	Trout	Salmon Parr
Total No. fish	465	537	465	537
Total No. empty stomachs	29	45	29	45
Benthic food	(46.6)	(86.0)	(60.7)	(90.8)
Oligochaeta	(1.1)	(0.4)	(1.3)	(0.2)
Lumbriculus spp.	1.1	0.4	1.3	0.2
Gastropoda	(1.1)	(1.3)	(1.4)	(1.0)
Ancylastrum fluviatile	0.8	0.8	0.9	0.8
Limnaea pereger	0.3	0.5	0.5	0.2
Amphipoda	(0.2)	(-)	(+)	(-)
Gammarus pulex	0.2	-	+	-
Isopoda	(0.1)	-	(+)	-
Asellus meridianus	0.1	-	+	-
Plecoptera	(4.3)	(4.6)	(5.8)	(5.4)
Amphinemura spp.	0.6	0.8	1.0	1.1
Leuctra	0.6	0.4	0.9	0.9
Protonemura meyeri	0.6	0.9	0.7	0.8
Isoperla grammatica	0.6	0.4	0.7	0.4
Chloroperla spp.	0.9	1.0	1.0	1.1
Other Plecoptera	1.0	1.1	1.5	1.1
Ephemeroptera	(18.0)	(25.0)	(25.3)	(29.2)
Baëtis rhodani	4.1	5.2	7.2	6.5
Caenis spp.	0.7	1.0	1.4	3.0
Ecdyonurus spp.	2.4	4.0	2.2	4.2
Ephemerella spp.	3.1	2.2	3.8	4.1
Heptagenia lateralis	1.3	1.1	1.7	1.1
Leptophlebia marginata	0.4	-	0.9	-
Other Ephemeroptera	6.0	11.5	3.1	10.3
Trichoptera	(17.2)	(32.9)	(13.7)	(24.2)
Anabolia spp.	-	0.6	-	0.7
Plectrocnemia conspersa	6.3	7.2	5.4	5.5
Rhyacophila dorsalis	0.3	2.3	0.4	1.1
Hydroptila spp.	-	0.4	-	0.3
Sericostoma personatum	+	0.6	0.1	0.7
Potamophylax spp.	0.8	1.8	0.4	1.4
Hydropsyche spp.	2.1	2.7	1.6	2.4
Glyphotaelius spp.	2.2	-	1.4	-
Other Trichoptera	5.5	17.3	4.4	12.1
Coleoptera larvae	(0.6)	(0.6)	(1.4)	(0.7)
Helmis maugei	0.4	0.3	0.9	0.4
Latelmis volkmari	0.2	0.3	0.5	0.3
Diptera	(4.2)	(21.2)	(11.8)	(30.1)
Chironomid larvae	2.5	16.6	7.5	23.0
Chironomid pupae	-	+	-	0.1
Simuliid larvae	0.3	2.8	0.9	5.2
Simuliid pupae	0.1	-	0.3	-
Tipulid larvae	+	0.8	+	0.2
Other dipteran larvae	0.8	0.6	2.4	1.1
Dipteran pupae	0.5	0.4	0.7	0.5

Table 8.7 (contd)

Methods of Assessment	Volume		Number	
Name of fish	Trout	Salmon Parr	Trout	Salmon Parr
Total No. fish	465	537	465	537
Total No. empty stomachs	29	45	29	45
Midwater food	(18.4)	(1.4)	(9.3)	(0.5)
Hydracarina				
Hygrobates spp.	+	-	+	
Coleoptera adults	(2.4)	(0.6)	(2.5)	(0.2)
Helmis maugei	0.8	0.5	0.9	0.2
Latelmis volkmari	1.4	0.1	1.0	+
Platambus maculatus	0.1	+	0.4	+
Other Coleoptera	0.1	-	0.2	-
Hemiptera	(+)	(0.4)	(+)	(0.3)
Micronecta spp.	+	0.4	+	0.3
Fish				
Cottus gobio	(16.0)	(0.4)	(6.8)	(+)
Aerial & terrestrial insects	(27.9)	(7.3)	(22.7)	(4.0)
Miscellaneous food	(6.8)	(4.5)	(5.5)	(3.3)
Plant materials	5.3	3.7	4.2	3.0
Stones (caddis cases)	0.7	0.1	0.5	+
Fish eggs	0.8	0.7	0.8	0.3

miscellaneous food (Figs. 8.1, 8.2). Similar features have been demonstrated by many workers including Southern (1935), Frost (1939, 1950), Frost & Went (1940), Maitland (1965), Thomas (1962), Sinha & Jones (1967), Woolland (1972). The percentage of trout and salmon parr of all age groups (here 0+ to 3+) feeding on the principal food types in each month and year in which sufficiently representative samples were procured are given in Figs. 8.1, 8.2. These tend to confirm the variations already noted in Figs. 8.3, 8.4. It is now evident that salmon parr have a greater preference for benthic forms than do trout.

In Figs. 8.3, 8.4 the data have been grouped on a monthly or seasonal basis in order to demonstrate any possible seasonal variation in the nature of food. Ephemeroptera represented by Baetis rhodani, Caenis spp., Ecdyonurus spp., Ephemerella spp., Heptagenia lateralis and Leptophlebia marginata and other insignificant mayfly nymphs (Table 8.7) appear to be taken less frequently by salmon parr than by trout during late spring and summer but the opposite is true in winter (Fig. 8.3). Caenis spp. in spite of their mud dwelling habit (Maitland 1965) were consumed by trout (0.7% by volume) and salmon parr (1.0% by volume). Trichoptera larvae which include Plectrocnemia conspersa, Rhyacophila dorsalis, Sericostoma personatum, Potamophylax spp. Hydropsyche spp. and othercaddis larvae were commonly eaten by both the species of fish. Anabolia nervosa, Hydroptila spp.

were taken by salmon parr and Glyphotaelius spp. by trout. Frost (1939, 1950), Frost and Went (1940), Horton (1961), Thomas (1962) and Mann and Orr (1969) also recorded trichopteran larvae as a major food of salmon parr and trout throughout the year, but more so during winter than summer. I found that the caddis larvae were eaten more by trout during the months from February to July but from August to January the percentage of these larvae were much higher in the food of salmon parr (Fig.8.3). Plecopteran nymphs were of great dietary importance during spring, summer and winter particularly to salmon parr rather than to the trout in the feeder streams. Similar observations were made by Frost (1939), Maitland (1965), Egglishaw (1967), Elliott (1967) and Woolland (1972). Plecopteran nymphs (4.3% by volume) in trout and (4.6% by volume) in salmon parr were recorded and represented by Amphinemura spp., Leuctra spp., Protonemura meyeri, Isoperla grammatica and Chloroperla spp. in both the species of fish in the feeder streams. Fig. 8.3 shows that these were taken more from February to July and in December and January by salmon parr. In autumn the percentage of these was greater in trout than in salmon parr stomachs. Asellus meridianus (0.2% by volume) and Gammarus pulex (0.1% by volume) were recorded only in the diet of trout, though Woolland (1972) observed them from November to May in the stomachs of trout in the upper Dee and found them particularly abundant in November.
Chironomid larvae were the most important dietary constituent

to salmon parr of the feeder streams in all seasons (Fig. 8.3). This may be because of their abundance, availability and small size. Simuliid larvae were consumed by salmon parr in all seasons (Fig. 8.3) though these were not common in the diet of trout. Woolland (1972) found simuliid larvae common in July and August in the diet of salmon parr whereas Carpenter (1940) found them most commonly eaten in July. I found these larvae more in spring (Fig. 8.3). Tipula larvae (0.8% by volume) were recorded only in the diet of salmon parr of the feeder streams (Table 8.7) though the trout of the upper Dee had been feeding on these larvae extensively during autumn and winter (Woolland 1972). Gastropoda, particularly Ancylastrum fluviatile, were eaten by trout in very insignificant numbers (0.8% by volume), whereas the trout of the upper Dee ate more of them in July and salmon parr in August (Woolland 1972). Terrestrial and aerial insects were a more significant food item for trout than salmon parr. This food was dominant in trout of all age groups in all seasons (Figs. 8.1, 8.4). Carpenter (1940), Thomas (1962), Egglishaw (1967) and Woolland (1972) found these organisms were eaten during spring, summer and autumn. The Coleoptera, mostly the larval forms of Helmis maugei and Latelmis volkmari, were eaten by salmon parr and adults were consumed by trout. This again reflects the bottom feeding behaviour of the former and midwater feeding of the latter (Figs. 8.1, 8.2).

Table 8.8 Comparison of the total annual diet (expressed in percentages) of trout and salmon parr of 0+ age group assessed by occurrence, volume and number methods in all Llyn Tegid feeder streams.

Total No. Trout = 29 Total No. Salmon parr = 62

No. Empty Stomachs = Nil No, Empty Stomachs = 11

Methods of assessment	Occurrence		Volume		Number	
Name of fish	Trout	Salmon parr	Trout	Salmon parr	Trout	Salmon parr
Benthic food	(63.1)	(90.1)	(53.5)	(93.4)	(64.3)	(95.5)
Oligochaeta	2.5	0.3	2.3	0.2	2.4	0.1
Gastropoda	4.7	2.0	3.2	1.2	3.9	0.5
Plecoptera	5.5	1.0	4.9	0.6	4.5	0.5
Ephemeroptera	25.7	26.7	23.5	17.9	28.3	20.0
Trichoptera	7.8	41.2	12.7	54.7	5.3	48.2
Coleoptera	4.0	2.9	1.2	2.0	2.5	2.2
Chironomid	6.1	11.8	1.6	13.2	7.3	20.5
Simuliid	1.4	3.6	0.5	2.7	1.3	3.2
Other Dipt. larvae	5.4	0.3	3.6	0.3	8.8	0.1
Dipt. pupae	-	0.3	-	0.6	-	0.2
Midwater food	(6.7)	(-)	(4.9)	(-)	(4.7)	(-)
Coleoptera adult	6.7	-	4.9	-	4.7	-
Aerial & terrestrial insects	(20.4)	(4.1)	(31.0)	(5.7)	(21.9)	(2.1)
Miscellaneous food	(9.2)	(4.9)	(10.1)	(2.5)	(8.1)	(1.8)
Plant material	9.2	4.9	10.1	2.5	8.1	1.8

Table 8.9 Comparison of the total annual diet (expressed in percentages) of trout and salmon parr of 1+ age group assessed by occurrence, volume and number methods in all Llyn Tegid feeder streams. + = < 0.1% - = No record

Total No. of trout = 204
No. Empty stomachs = 9

Total No. Salmon Parr = 302
No. Empty stomachs = 12

Methods of Assessment	Occurrence		Volume		Number	
Name of Fish	Trout	Salmon Parr	Trout	Salmon Parr	Trout	Salmon Parr
Benthic food	(69.6)	(87.1)	(50.6)	(85.4)	(65.2)	(91.3)
Oligochaeta	0.7	+	0.3	0.1	0.6	+
Gastropoda	0.9	4.0	0.2	2.7	0.3	3.0
Amphipoda	0.1	-	0.3	-	+	-
Isopoda	0.3	-	0.4	-	0.2	-
Hydracarina	0.1	-	+	-	+	-
Plecoptera nymphs	10.9	10.8	8.0	7.6	11.6	9.1
Ephemeroptera nymphs	29.4	32.3	16.4	24.4	24.1	26.7
Micronecta spp.	0.4	1.7	+	1.6	0.1	1.3
Trichoptera larvae	13.0	14.3	18.1	20.5	9.8	14.8
Coleoptera larvae	3.5	0.7	1.0	0.4	2.3	0.2
Chironomid larvae	6.8	15.9	4.6	23.2	14.1	30.0
Simuliid larvae	0.3	3.0	0.1	2.8	0.3	4.1
Tipulid larvae	-	0.2	-	0.3	-	+
Other Dipteran larvae	2.4	0.9	0.5	0.4	1.2	0.4
Dipteran pupae	0.8	3.3	0.7	1.4	0.6	1.7
Midwater food	(3.0)	(1.5)	(7.1)	(1.7)	(1.1)	(0.6)
Coleoptera adults	1.8	1.5	0.8	1.7	0.7	0.6
Cottus gobio	1.2	-	6.3	-	0.4	-
Aerial and terrestrial insects	(23.1)	(4.0)	(37.5)	(9.0)	(30.6)	(4.3)
Miscellaneous food	(3.5)	(5.5)	(4.3)	(3.2)	(1.4)	(2.5)
Plant material	2.6	4.7	3.5	2.4	1.2	2.0
Stones (caddis cases)	0.9	0.8	0.8	0.8	0.2	0.5

Table 8.10 Comparison of the total annual diet (expressed in percentages) of trout and salmon parr of 2+ age groups assessed by occurrence, volume and number methods in all Llyn Tegid feeder streams.

Total No. Trout = 139 +=< 0.1% Total No. Salmon parr = 163

No. Empty Stomachs = 11 No. Empty Stomachs = 17

Methods of Assessment	Occurrence		Volume		Number	
Name of Fish	Trout	Salmon Parr	Trout	Salmon Parr	Trout	Salmon Parr
Benthic food	(62.6)	(86.9)	(55.3)	(83.2)	(59.7)	(92.8)
Oligochaeta	0.3	0.7	0.5	0.9	0.3	0.7
Gastropoda	0.7	1.3	0.9	0.8	0.3	0.4
Amphipoda	0.4	-	0.6	-	0.2	-
Plecoptera	6.8	12.6	3.7	8.7	4.6	9.9
Ephemeroptera	21.4	32.0	14.8	24.2	21.2	31.8
Trichoptera	23.8	15.6	29.5	24.2	23.2	14.1
Coleoptera	0.6	+	0.2	+	0.5	+
Chironomidae	5.5	11.8	3.6	15.3	7.5	22.3
Simuliidae	-	8.3	-	5.3	-	11.6
Tipulidae	0.3	1.4	0.1	3.1	0.1	0.8
Other Dipt. larvae	1.9	1.6	0.5	0.6	0.9	0.9
Dipteran pupae	0.9	1.6	0.9	0.1	0.9	0.3
Midwater food	(7.1)	(0.1)	(6.1)	(1.7)	(5.5)	(+)
Coleoptera adults	6.0	-	4.9	-	5.0	-
Cottus gobio	1.1	0.1	1.2	1.7	0.5	+
Aerial & terrestrial food	(24.0)	(4.9)	(37.6)	(8.3)	(30.7)	(4.6)
Miscellaneous food	(6.2)	(6.9)	(3.2)	(5.1)	(3.3)	(3.2)
Plant material	4.4	6.7	2.5	4.3	2.5	3.1
Stones (caddis cases)	1.8	-	0.7	-	0.8	-
Fish eggs	-	0.2	-	0.8	-	0.1

Table 8.11 Comparison of the total annual diet (expressed in percentages) of trout and salmon parr of 3+ age group assessed by occurrence, volume and number methods in all Llyn Tegid feeder streams.

Total No. trout = 103

Total No. Empty Stomachs = 9

Total No. Salmon Parr = 24

Total No. Empty Stomachs = 4

Method of assessment	Occurrence		Volume		Number	
Name of fish	Trout	Salmon Parr	Trout	Salmon Parr	Trout	Salmon Parr
Benthic food	(60.9)	(89.2)	(33.2)	(84.9)	(60.4)	(88.1)
Oligochaeta	2.2	0.4	1.4	0.3	2.0	0.3
Gastropoda	1.0	2.5	0.8	0.6	0.9	0.3
Plecoptera nymphs	4.9	3.8	2.3	1.8	4.9	2.1
Ephemeroptera nymphs	20.1	34.8	9.9	33.3	19.2	38.1
Trichoptera larvae	25.7	23.2	15.5	32.1	22.6	21.3
Coleoptera larvae	1.0	1.1	0.4	0.2	0.8	0.2
Chironomid larvae	2.6	16.2	1.3	14.7	3.5	20.2
Simuliid larvae	1.2	2.6	0.8	0.6	2.7	2.4
Other Dipt. larvae	1.3	4.6	0.2	1.3	2.5	3.2
Dipt. pupae	0.9	-	0.6	-	1.3	-
Midwater food	(14.8)	(1.1)	(43.7)	(0.9)	(12.9)	(0.4)
Coleoptera adults	3.2	1.1	0.6	0.9	1.8	0.4
Cottus gobio	11.6	-	43.1	-	11.1	-
Aerial & terrestrial food	(10.7)	(4.2)	(15.6)	(6.1)	(16.3)	(5.6)
Aerial & terrestrial insects	10.7	4.2	15.6	6.1	16.3	5.6
Miscellaneous food	(13.9)	(5.1)	(8.0)	(7.3)	(9.8)	(6.1)
Plant materials	7.5	3.5	2.8	5.6	4.1	5.1
Stones (caddis cases)	3.1	-	1.1	-	1.6	-
Fish eggs	3.3	1.6	4.1	1.7	4.1	1.0

Allan (1941a) and Maitland (1965) have recorded a decreasing consumption of dipteran larvae in trout and salmon parr with increasing age and greater consumption of trichopteran larvae and aerial insects by older fish. Similar observations were made by Thomas (1962), McCormack (1962) and Woolland (1972). It has been shown Tables 8.8, 8.9, 8.10 and 8.11) that the food of salmon parr and trout in the feeder streams consists predominantly of ephemeropteran nymphs, Trichoptera larvae, chironomid larvae and aerial and terrestrial insects. The proportions vary according to the age groups of the individual species and the ecology of the respective stream bottom. 1+ age group of trout, 2+ age group of salmon parr and trout and 3+ age group of trout predate on *Cottus gobio*.

Jones and King (1949) found salmon parr feeding at a water temperature of 2°C. McCormack (1962) reported extensive feeding in trout even when the water temperature was below 6°C. Elliot (1967) found no correlation between water temperature and the amount of food in trout stomachs. Thomas (1962) found that salmon parr and trout fed actively at all seasons regardless of temperature. Carpenter (1940) and Thomas (1962) found that an August decrease in food consumption was due to low availability of food organisms at this time. Ball (1961) considered spring rise in food intake was due to day length, temperature, appetite and availability of food supply. Egglishaw (1967) considered the low winter feeding activity was due to physical loss in the capability of the alimentary canal system of salmonids to digest food. The seasonal variations in food intake of salmon parr and trout in the feeder streams are shown in Figs. 3.7, 4.2, 5.5, 6.4, 7.5 in terms of fullnes index in relation to water temperatures. These figures show that the feeding activity is at a minimum during winter and increases during spring and rises to a maximum in summer. Feeding intensity drops rapidly after August/September in Afon Twrch; in November in Afon Glyn; August/September in Afon Llafar; September in Afon LLiw and September/October in Afon Dyfrdwy. There appears to be a definite correlation between food intake and water temperatures (Figs. 3.7, 4.2, 5.5, 6.4 and 7.5). Salmon parr and trout fed more during summer and less intensively in winter. The period of maximum food intake coincided with the maximum availability of benthic fauna.

Any investigation of the food of fishes particularly of the same genus inevitably leads to a consideration, however brief, of the competition they encounter in their quest for their favoured food types. Interspecific competition, its importance and existence in nature have been debated vigorously (Nicholson 1933, Andrewartha and Birch, 1954, Birch 1957 and Milne 1961). Conclusions reached on the basis of laboratory experiments are difficult to apply to field conditions (Hairston 1951), and difficult to demonstrate adequately under natural conditions because of the complexity of most ecosystems (Larkin 1956). Weatherby (1963) defined competition as the demand typically at the same time, of more than one organism for the same resource of the environment in excess of immediate supply. Maitland (1965) assumed that when two species ate the same food then that consumed by one species could be used to an advantage by the other. Andrewartha (1961) has pointed out that no two species are ever likely to have identical requirements. This may appear true of the two species Salmo trutta and Salmo salar in feeder streams as far as food is concerned. Several other workers (Frost 1950, Thomas 1962, Maitland 1965 and Woolland (1972) have found similar relationships between these two species. It is certain that salmon and trout have similar food requirements, and it is probable that under certain conditions at least there is competition for food among them though the significance of this competition cannot yet be fully assessed due to complex ecosystem and features of behaviour. Some individuals may be more available to one species than to another.

The main difference between the diets of salmon parr and trout in the present study is the greater amount of surface food consumed by the latter species. This is in agreement with Frost and Went (1940), Frost (1950), Thomas (1962), Mills (1963), Maitland (1965) and Mann and Orr (1969).

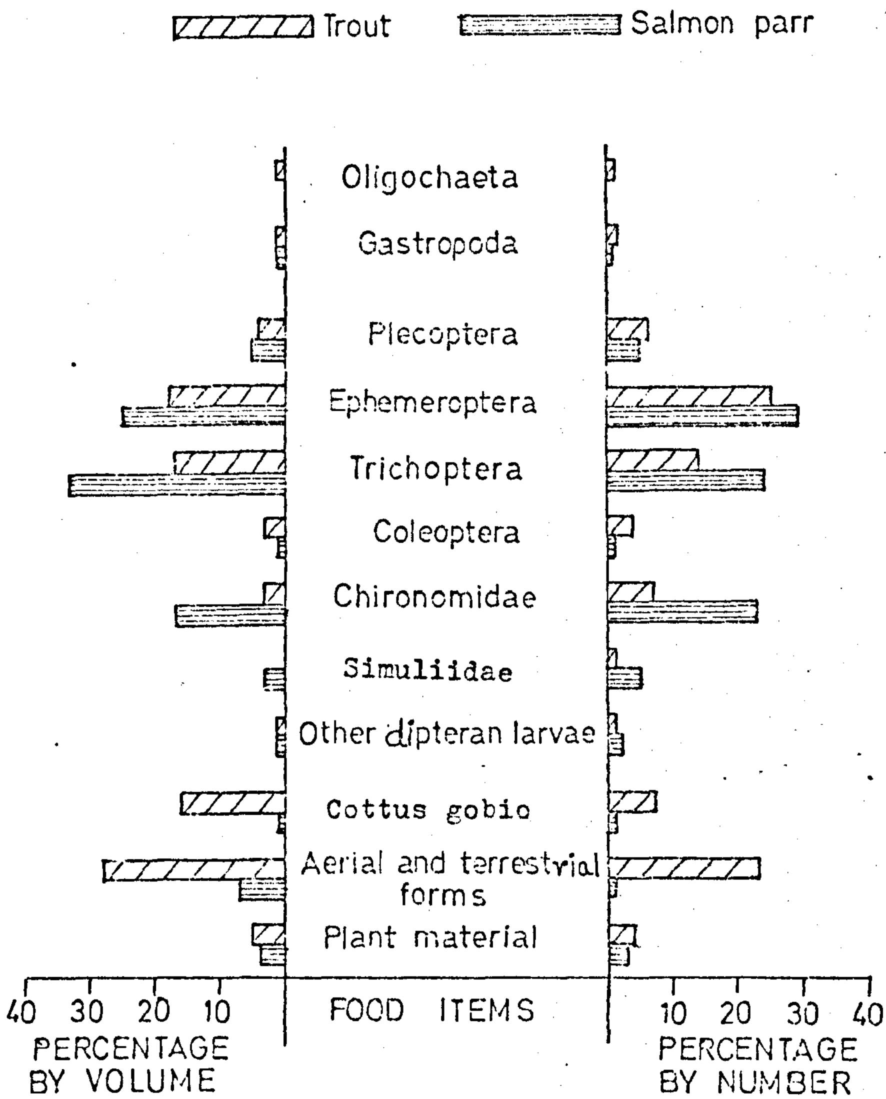

Fig. 8.5 Average percentage composition of the total annual diet expressed in groups of trout and salmon parr in all Llyn Tegid feeder streams

There are few comparative studies of the behaviour of young salmon and trout. Stuart (1953) found salmon to be initially gregarious and spend most of the time resting on the substrate whereas trout are not gregarious as fry and tend to keep up a constant position in midwater. Stuart further states that trout are more spasmodic in their feeding habits than salmon, tending to gorge themselves and then fast for a period instead of eating regularly as do salmon. Kalleberg (1958) considers that trout are definitely the more aggressive and dominant of the two species.

Despite the differences in the diet and behaviour as mentioned above, both have a common interest in certain species of benthic food items (Table 8.7). The total food assessed by volume and number methods of both the species (Table 8.7, Fig. 8.5), seasonal variations of significant food items (Figs. 8.3, 8.4), and the total food in each species according to their age groups (Tables 8.8, 8.9, 8.10, 8.11) suggests that the food and feeding areas of both the species overlap as far as the aquatic invertebrates are concerned. Both feed on the same kinds of organisms (Table 8.7) and these organisms follow similar seasonal patterns of occurrence in the stomachs of the two species of fish (Fig. 8.5). This suggests similarities in feeding habits of the two species and hence there may be a competition between the two for the same items on the same ground.

The percentage saturation of oxygen and pH did not account for any significant variation in the feeding intensity. Conductivity and turbidity both exhibited a negative correlation with food intake of trout and salmon parr. The influence of turbidity on feeding intensity could be related to visibility.

The observed influence of physical factors on the feeding periodicities indicates a need for more information. A more intensive study is desirable to find out the effect of the physical factors and also solar radiation, hydrostatic pressure and light penetration on the seasonal variation of the bottom fauna and the feeding periodicities of the trout and salmon parr.

PART 11

CHAPTER IX

THE RIVER DEE

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CHAPTER IX

1. INTRODUCTION

The recent history of regulation of the river Dee began in the nineteen thirties, when the River Dee Catchment Board prepared a scheme to provide detention storage in Llyn Tegid for reducing the extent of flooding in the Dee valley. Detailed descriptions of the River Dee regulating schemes were given by Wright (1955), Boddington et al. (1962) and Blezard et al. (1970). The effects of regulation on the Dee fisheries were discussed by Iremonger (1971) who mentioned loss of spawning grounds and obstruction to salmon migration as the main factors involved after regulation. Similar observations were made by Lees (personal communication) and Woolland (1972).

So far as I am aware, no work has been done on the benthic fauna of a regulated stream in this country. Very few papers have appeared from the U.S.A. and Canada in which the bottom fauna of regulated streams has been investigated. In 1969, I had an opportunity to study the influence of regulation on the macroinvertebrates of the upper Dee. The results of this study are given herein.

2. THE ENVIRONMENT

(a) Topography

The river emerges from the north-east end of Llyn Tegid and flows as a wide swift stream in an east and

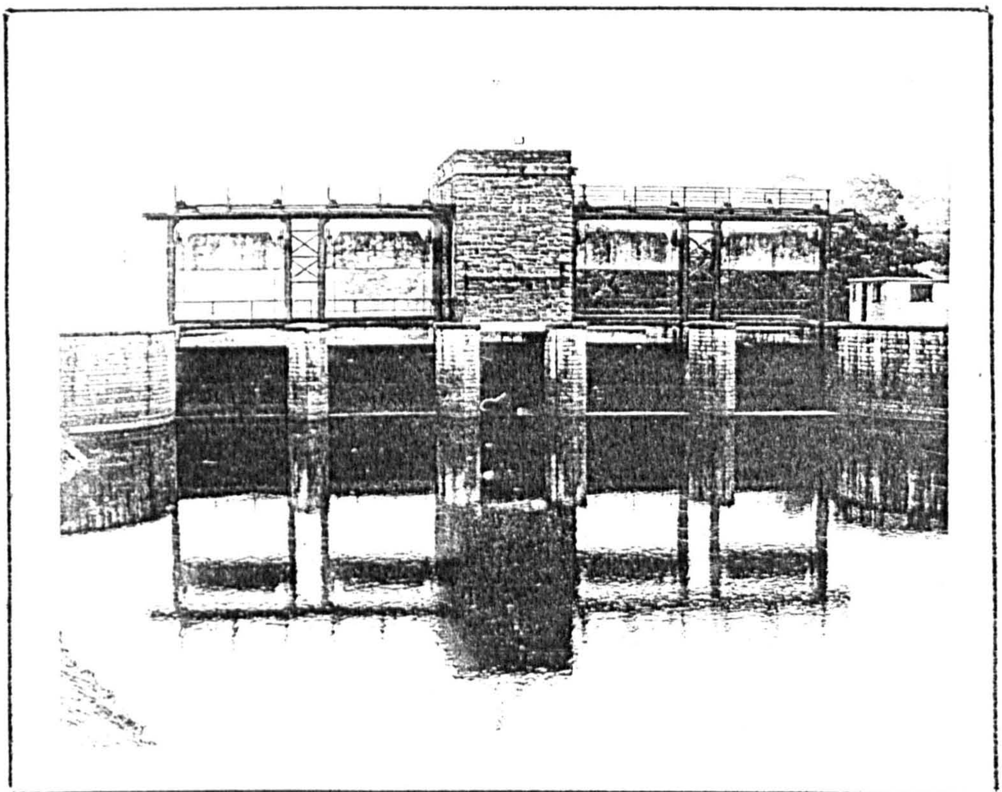

PLATE 9.1 BALA SLUICES.

Table 9.1 Monthly measured flow (cumecs) in the River Dee at Bala.

Month	Total monthly flow	Mean daily flow	Max. d.F.	Min. d.F.	Highest flow	Lowest flow
Oct. 1969	185.7	5.9	9.1	4.2	9.2	4.0
Nov.	561.0	18.7	45.3	5.0	46.0	4.9
Dec.	506.5	16.3	39.7	7.0	41.5	5.9
Jan.	425.4	13.7	28.1	6.0	29.6	5.5
Feb.	653.5	23.3	62.3	8.2	65.5	7.7
March	379.4	12.3	20.4	6.3	24.0	5.9
April	787.5	26.2	62.8	8.3	67.4	8.1
May	141.5	4.5	18.9	2.5	20.3	2.4
June	171.5	5.7	14.8	3.8	18.1	1.8
July	234.8	7.5	23.5	4.7	25.6	4.6
August	213.1	6.8	24.6	2.6	30.2	0.5
Sept.	355.0	11.8	54.2	4.5	55.3	4.5
Oct. 1970	397.0	12.8	48.1	5.0	51.0	4.9

From the office of the Dee and Clwyd River Authority.

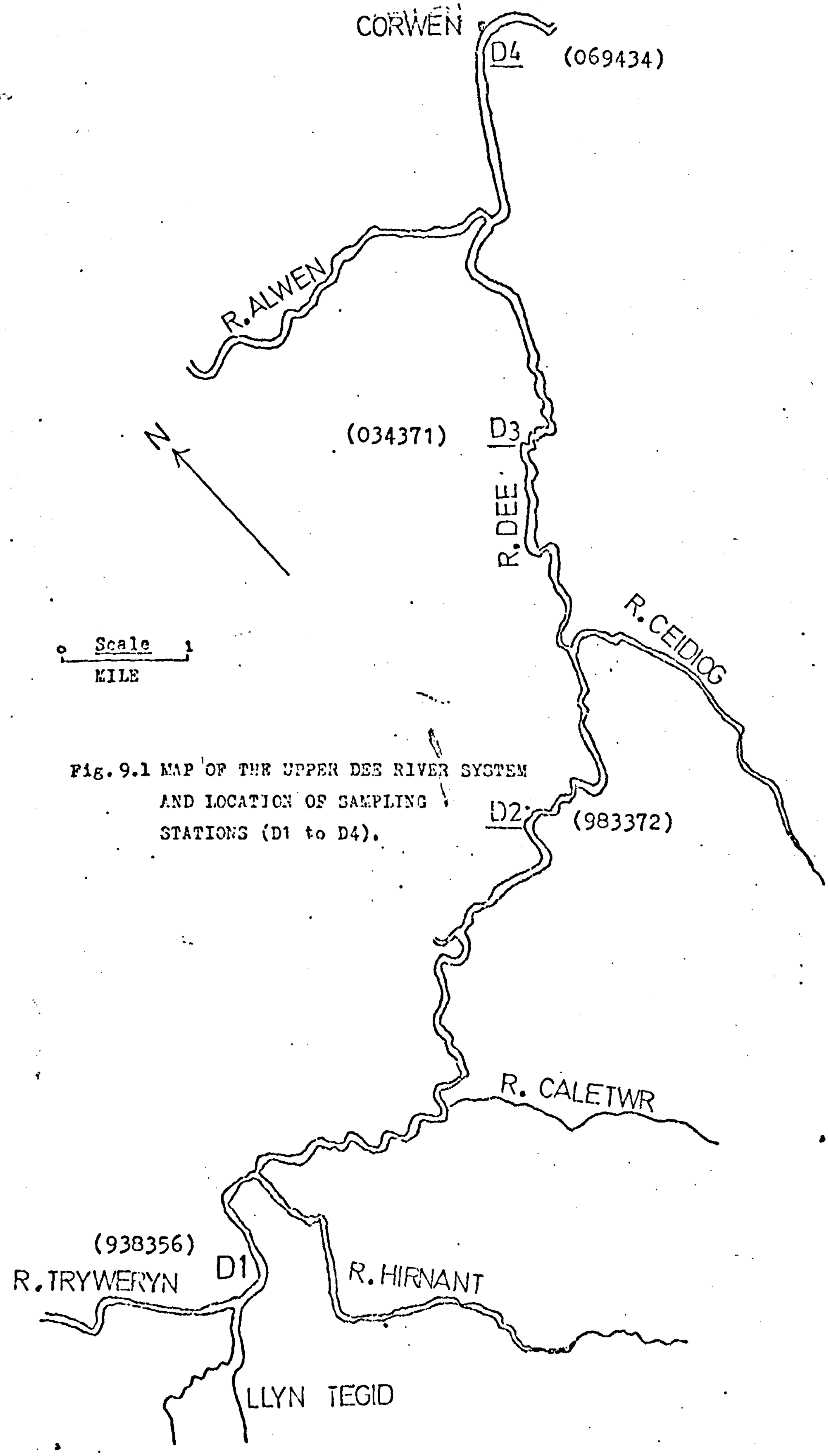

Fig. 9.1 MAP OF THE UPPER DEE RIVER SYSTEM AND LOCATION OF SAMPLING STATIONS (D1 to D4).

north-east direction. The geological formation of the watershed shows that it is composed of shales, limestones, mudstones, igneous rocks, such as felsite, porphyrite and andesites, volcanic ashes and carboniferous areas with shales and sandstones. On erosion these formations would contribute mainly lime, silicates, potash and some iron to water.

Afon Dyfrdwy, a small stream running into the lake is regarded as the source of the Dee (Fig. 3.2). At the eastern end of the lake stands the town of Bala, and here the Dee leaves the lake and receives the Tryweryn, which passes through Llyn Celyn and is regulated. The waters of Tryweryn and Dee unite in the flat meadows below the lake. For about 19.3km (Bala to Corwen) the river passes through an alluvial tract formed of detritus brought from the hills by several tributaries, notably among these are Tryweryn, Llanfor, Hirnant, Ceidiog and Alwen. Sluices were constructed at the outlet of Llyn Tegid in 1956 by the River Board to provide in winter short-term flood detention and in summer water storage for release to the river to maintain the flow. Water flow measurements for the River Dee taken by the Dee and Clwyd River Authority at a gauging station below the Bala sluices (Plate 9.1) are given in Table 9.1.

(b) Description of the sampling sites

Four stations were selected in the upper Dee from Bala to Corwen. As seen in Fig. 9.1 the first sampling site D_1

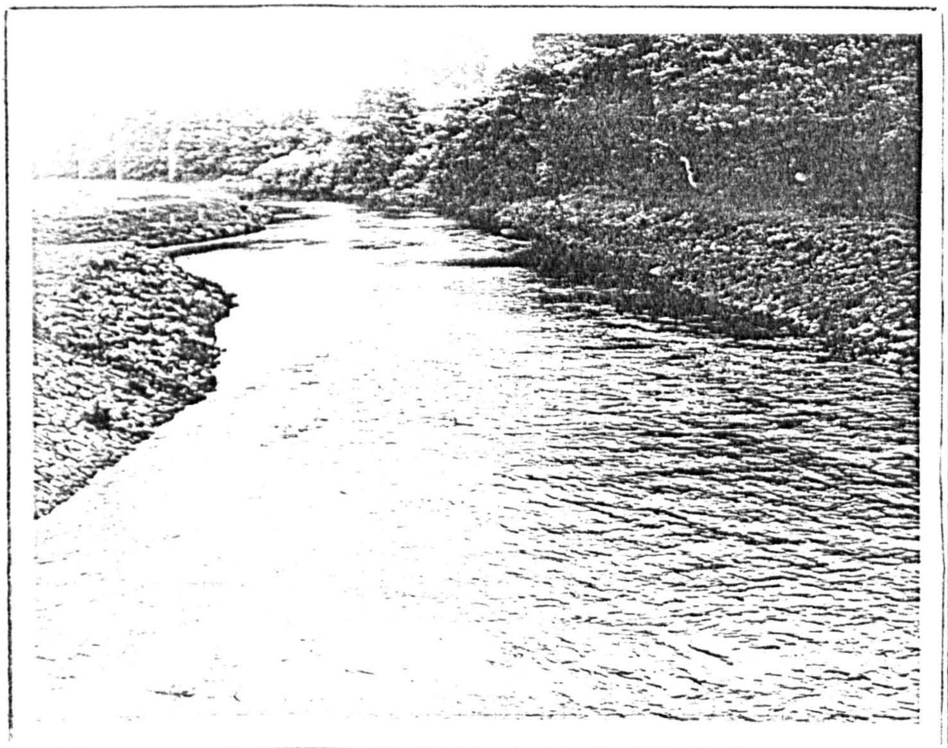

PLATE 9.2 SAMPLING STATION D1.

PLATE 9.3 SAMPLING STATION D2.

PLATE 9.4 SAMPLING STATION D3.

PLATE 9.5 SAMPLING STATION D4.

was near the Bala sluices (Nat. Grid Ref. 938356), the D_2 near Llanddorfel (Nat. Grid Ref. 983372), the D_3 at Llandrillo (Nat. Grid Ref. 034371), and the D_4 near Corwen bridge (Nat. Grid Ref. 069434).

D_1 was located at about 17m downstream from the sluices near the back waters. The stream here was 20m wide and 1-2m deep near the bank. There was some vegetation near the bank but the whole area of backwater was covered with aquatic vegetation, (Elodea canadensis, Ceratophyllum submersum, Callitriche stagnalis and Ranunculus aquatilis). There were sheep farms on either side. The water flows swiftly (except during summer) over a bed of gravel, silt and coarse sand. Some large rounded stones and tufts of filamentous algae were also present (Plate 9.2).

D_2 was situated 4.8km downstream from the lake. Here the stream was about 25m wide and 0.5-1.5m deep. The bottom was of gravel and there were some patches of vegetation on the bed. There were trees on either side (Plate 9.3).

D_3 was located 16.0km downstream from the lake. Here the substratum of stones and scattered patches of Ranunculus fluitans and Ceratophyllum demersum were present. At this station the river was 27m wide and 1-2m deep near the bank. There were trees on either side (Plate 9.4).

D_4 was situated near the bridge where the river was

Table 9.2 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT D1 SAMPLING STATION IN THE RIVER DEE.

MONTHS	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Water Temp. C^{o}	6.5	6.8	10.1	12.2	14.6	12.5	9.1	4.8	3.6	3.7	4.2	5.2	5.8	5.1
Specific conductance(micromhos /cm^{3} at 25 ^{o}C)	170	232	228	129	121	143	95	346	446	406	376	201	119	146
Dissolved O_2,% Sat.	96	98	95	95	97	97	101	98	119	115	117	98	101	95
Velocity of water current(m/sec)	0.26	0.28	0.24	0.24	0.22	0.29	0.36	0.50	0.72	0.81	0.71	0.59	0.53	0.35
pH	7.2	7.1	6.9	6.8	7.0	7.2	7.1	7.4	7.8	7.6	7.8	7.2	7.1	7.2
Turbidity (as Fuller's Earth)	26.2	24.1	28.2	19.8	18.2	28.2	26.1	63.2	85.1	79.3	91.1	78.2	43.2	28.2

TABLE 9.3 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT D2 IN THE RIVER DEE.

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Water Temp. °C	4.5	5.0	9.6	13.8	13.0	8.4	6.5	4.5	3.5	3.8	4.1	4.5	5.8	5.9
Specific conductance (micromhos /cm³ at 25 °C)	140	216	236	119	128	167	186	342	432	404	382	201	116	196
Dissolved O2, % Sat.	96	95	103	105	97	96	95	109	111	119	115	102	98	97
Velocity of water current (m/sec)	0.23	0.20	0.13	0.09	0.11	0.27	0.34	0.47	0.60	0.71	0.74	0.57	0.46	0.36
pH	7.1	7.0	6.8	6.6	6.9	7.1	7.2	7.2	7.6	7.8	7.8	7.1	7.1	7.2
Turbidity (as Fuller's Earth.)	20.1	21.2	19.6	18.2	17.8	23.3	21.6	65.2	86.2	79.6	81.1	78.2	53.2	24.6

TABLE 9.4 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT D3 IN THE RIVER DEE.

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Water Temp. C°	4.5	5.2	9.4	13.8	13.2	8.8	6.5	4.6	3.6	3.8	4.1	4.6	5.8	6.1
Specific conductance (micromhos /cm³ at 25 °C)	128	116	136	119	132	193	186	332	441	413	281	242	106	115
Dissolved O2, % Sat.	95	96	98	95	96	97	101	112	111	119	120	101	97	98
Velocity of water current (m/sec.)	0.19	0.16	0.10	0.09	0.10	0.21	0.28	0.50	0.56	0.64	0.67	0.51	0.60	0.29
pH	7.2	6.8	6.6	6.8	6.9	7.1	7.2	7.1	7.6	7.8	7.9	7.3	7.4	7.1
Turbidity (as Fuller's Earth)	19.6	20.2	21.4	18.6	17.2	19.1	21.8	55.2	75.2	88.9	73.6	85.2	42.8	21.8

TABLE 9.5 MEAN MONTHLY ESTIMATES OF PHYSICAL FACTORS AT D4 IN THE RIVER DEE.

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Water Temp. °C	4.4	5.1	9.4	13.7	13.0	8.6	6.4	4.6	3.6	3.8	3.8	4.2	4.7	5.9
Specific conductance (micromhos /cm^3 at 25 °C)	120	126	135	129	135	161	176	362	465	443	321	202	116	123
Dissolved O2, % Sat.	95	97	97	98	97	96	95	102	108	120	115	103	97	96
Velocity of water current (m/sec)	0.20	0.16	0.10	0.09	0.11	0.17	0.28	0.38	0.81	0.68	0.60	0.47	0.34	0.25
pH	7.1	6.6	6.8	6.9	6.7	7.1	7.3	7.2	7.6	7.9	7.8	7.6	7.3	7.1
Turbidity (as Fuller's Earth)	18.4	19.6	18.2	20.2	17.8	19.8	20.8	65.8	85.8	96.1	83.2	76.1	52.2	29.1

about 50m wide and 0.5-1m deep during low water. The bottom was of gravel and scattered patches of Ranunculus fluitans, Sagittaria sagittifolia and Sparganium simplex were common. There were few trees on either side of the river (Plate 9.5).

(c) Physical and Chemical Conditions

The mean monthly estimates of physical factors at each sampling site are shown in Tables 9.2, 9.3, 9.4 and 9.5.

The highest temperature measured in August was 14.4°C and the lowest in December of 3.6°C. The concentration of O_2 was relatively higher during winter than in summer. Maximum velocity of water current was observed during winter and minimum in summer at D_1, D_2, D_3 and D_4. The pH range was between 6.6-7.9 throughout the sampling period. Lower values for conductivity and turbidity were obtained in summer and higher in winter at all the sampling sites.

Water samples were taken from the river for chemical analysis in the month of June 1969 and the results are given in Table 3.4.

3. COMPOSITION OF THE FAUNA

Collections were made from the four stations over a period of fourteen months, from March 1969 to April 1970. Each month the material was taken from the various accessible parts of the bed by using the sampler (for details of sampling methods, see Chapter II). At D_2, D_3

Table 9.6 The density (Av. No./m^2) of the species identified in four sampling sites of the upper reaches of the River Dee. Total is shown in bracket. - = No. record + = < 0.1 %

Sampling sites →	D_1		D_2		D_3		D_4		Total	
Density →	Total No.	Av.No/m^2	Total No.	Av. No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	%
Turbellaria	(15)	(10.7)	(18)	(12.8)	(1)	(0.7)	(2)	(1.0)	(36)	(0.4)
Polycelis nigra	15	10.7	18	12.8	1	0.7	2	1.0	36	0.4
Hirudinea	(32)	(23.3)	(16)	(11.6)	(8)	(5.3)	(16)	(10.6)	(72)	(0.7)
Helobdella stagnalis	7	5.3	6	4.2	5	3.2	5	3.2	23	0.2
Erpobdella octoculata	17	12.8	10	7.4	3	2.1	8	5.3	38	0.4
Glossiphonia complanata	6	4.2	-	-	-	-	3	2.1	9	+
Piscicola geometra	2	1.0	-	-	-	-	-	-	2	+
Oligochaeta	(344)	(258.7)	(482)	(366.8)	(549)	(416.0)	(113)	(82.1)	(1488)	(15.5)
Lumbriculus variegatus	223	170.1	66	50.2	113	85.6	36	26.7	438	4.6
Stylodrilus heringianus	29	21.4	345	263.2	391	298.5	22	16.0	787	8.3
Limnodrilus offmeisteri	17	12.8	42	32.1	13	9.6	33	24.6	105	1.1
Eiseniella tetrahedra	5	3.2	3	2.1	19	13.9	9	6.4	36	0.4
Homochaeta naidina	25	18.1	-	-	-	-	2	1.0	27	0.3
Aulodrilus pluriseta	40	29.9	3	2.1	-	-	-	-	43	0.4
Stylaria lacustris	5	3.2	-	-	11	7.4	-	-	16	0.1
Rhyacodrilus corcineus	-	-	23	17.1	-	-	9	6.4	32	0.3
Psammonyctes barbatus	-	-	-	-	2	1.0	2	1.0	4	+
Gastropoda	(15)	(11.4)	(1)	(0.7)	(3)	(2.1)	(2)	(1.0)	(21)	(0.2)
Limnaea pereger	14	10.7	-	-	-	-	2	1.0	16	0.1
Ancylastrum fluviatile	1	0.7	-	-	3	2.1	-	-	4	+
Potamopyrgus jenkinsi	-	-	1	0.7	-	-	-	-	1	+
Lamellibranchiata	(115)	(86.6)	(32)	(23.4)	(18)	(12.4)	(100)	(75.9)	(265)	(2.7)
Pisidium milium	55	41.7	5	3.2	1	0.7	3	2.1	64	0.6
Pisidium hibernicum	60	44.9	20	14.9	12	8.5	-	-	92	1.0
Pisidium subtruncatum	-	-	7	5.3	5	3.2	97	73.8	109	1.1
Amphipoda	(8)	(5.3)	(27)	(20.3)	(8)	(5.3)	(21)	(16.0)	(64)	(0.6)
Gammarus pulex	8	5.3	27	20.3	8	5.3	21	16.0	64	0.6

Table 9.6 (contd.)

Sampling sites →	D_1		D_2		D_3		D_4		Total	
Density →	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	%
Isopoda	(269)	(205.4)	(111)	(84.5)	(105)	(80.2)	(80)	(60.9)	(565)	(5.9)
Asellus meridianus	269	205.4	111	84.5	105	80.2	80	60.9	565	5.9
Hydracarina	(4)	(2.1)	(16)	(11.2)	(1)	(0.7)	(1)	(0.7)	(22)	(0.2)
Hygrobates nigromaculatus	4	2.1	10	7.4	1	0.7	-	-	15	0.1
Lebertia porosa	-	-	3	2.1	-	-	-	-	3	+
Hygrobates fluviatilis	-	-	2	1.0	-	-	-	-	2	+
Sperchon setiger	-	-	1	0.7	-	-	-	-	1	+
Lebertia insignis	-	-	-	-	-	-	1	0.7	1	+
Plecoptera	(122)	(88.1)	(166)	(123.0)	(244)	(182.0)	(165)	(120.0)	(697)	(7.3)
Protonemura meyeri	7	5.3	2	1.0	6	4.2	5	3.2	20	0.2
Amphinemura sulcicollis	71	53.5	51	38.5	77	58.8	65	49.2	264	2.8
Isoperla grammatica	11	7.4	15	10.7	44	33.1	13	9.6	83	0.9
Leuctra hippopus	4	2.1	12	8.5	17	12.8	8	5.3	41	0.4
Chloroperla torrentium	19	13.9	34	25.6	50	37.4	38	28.8	141	1.4
Leuctra inermis	4	2.1	-	-	8	5.3	-	-	12	0.1
Chloroperla tripunctata	3	2.1	6	7.2	10	7.4	9	6.4	28	0.3
Isoperla obscura	2	1.0	-	-	-	-	2	1.0	4	+
Nemurella picteti	1	0.7	1	0.7	-	-	-	-	2	+
Leuctra fusca	-	-	2	1.0	13	9.6	5	3.2	20	0.2
Leuctra geniculata	-	-	1	0.7	1	0.7	-	-	2	+
Amphinemura standfussi	-	-	42	32.1	12	8.5	5	3.2	59	0.6
Nemoura cinerea	-	-	-	-	1	0.7	2	1.0	3	+
Leuctra nigra	-	-	-	-	3	2.1	10	7.4	13	0.1
Nemoura avicularis	-	-	-	-	1	0.7	-	-	1	+
Protonemura praecox	-	-	-	-	1	0.7	-	-	1	+
Perlodes microcephala	-	-	-	-	-	-	2	1.0	2	+
Brachyptera nisi	-	-	-	-	-	-	1	0.7	1	+

Table 9.6(contd....)

Sampling sites →	D1		D2		D3		D4		Total	
Density →	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	%
Ephemeroptera	(157)	(115.7)	(279)	(208.5)	(439)	(33.1)	(481)	(362.0)	(1356)	(14.2)
Leptophlebia vespertina	10	7.4	1	0.7	7	5.3	5	3.2	23	0.2
Baetis rhodani	40	29.9	60	44.9	118	89.8	51	38.5	269	2.9
Heptagenia sulphurea	20	14.9	5	3.2	-	-	-	-	25	0.2
Ecdyonurus venosus	3	2.1	1	0.7	10	7.4	14	10.7	28	0.3
Paraleptophlebia tumida	1	0.7		-	-	-	-	-	1	+
Centroptilum luteolum	17	12.8	109	82.3	37	27.8	99	74.9	262	2.8
Leptophlebia marginata	9	6.4	7	5.3	5	3.2	11	7.4	32	0.3
Caënis moesta	14	10.7	2	1.0	27	20.3	12	8.5	55	0.6
Ephemerella ignita	34	25.6	79	59.9	178	135.8	219	166.9	510	5.3
Paraleptophlebia submarginata	1	0.7	3	2.1	6	4.2	-	-	10	+
Baëtis scambus	4	2.1	-	-	13	9.6	51	38.5	68	0.7
Siphlonurus lacustris	2	1.0	3	2.1	3	2.1	-	-	8	+
Heptagenia lateralis	1	0.7	-	-	4	2.1	-	-	5	+
Baëtis pumilus	1	0.7	2	1.0	31	23.5	2	1.0	36	0.4
Caënis horaria		-	7	5.3	-	-	-	-	7	+
Ephemerella notata	-	-	-	-	-	-	13	9.6	13	0.1
Cloeon dipterum	-	-	-	-	-	-	3	2.1	3	+
Rithrogena semicolorata	-	-	-	-	-	-	1	0.7	1	+
Hemiptera	(418)	(317.5)	(29)	(20.5)	(2)	(1.0)	(168)	(126.4)	(617)	(6.4)
Notonecta maculata	13	9.6	-	-	-	-	-	-	13	0.1
Corixa panzeri	206	157.2	4	2.1	-	-	-	-	210	2.2
Notanecta glauca	1	0.7	-	-	-	-	-	-	1	+
Sigara falleni	35	26.7	-	-	-	-	-	-	35	0.4
Sigara dorsalis	47	35.3	1	0.7	-	-	2	1.0	50	0.5
Sigara distincta	114	86.6	20	14.9	-	-	3	2.1	137	1.5
Micronecta poweri	1	0.7	3	2.1	-	-	157	119.8	161	1.6
Velia nymph	1	0.7	-	-	-	-	4	2.1	5	+
Sigara nigrolinaeta	-	-	1	0.7	-	-	-	-	1	+
Sigara nymph	-	-	-	-	2	1.0	1	0.7	3	+

Table 9.6 (contd...)

Sampling sites →	D_1		D_2		D_3		D_4		Total	
Density →	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	%
Callicorixa praeusta	-	-	-	-	-	-	1	0.7	1	+
Megaloptera	(11)	(7.4)	(11)	(7.4)	(12)	(8.4)	(17)	(11.7)	(51)	(0.5)
Sialis fuliginosa	5	3.2	4	2.1	2	1.0	2	1.0	13	0.1
Sialis lutaria	6	4.2	7	5.3	10	7.4	15	10.7	38	0.4
Trichoptera	(326)	(245.9)	(562)	(424.3)	(513)	(389.4)	(335)	(248.8)	(1736)	(18.1)
Plectrocnemia conspersa	5	3.2	11	7.4	10	10.7	7	5.3	33	0.3
Sericostoma personatum	5	3.2	6	4.2	6	4.2	4	2.1	21	0.2
Potamophlax latipennis	9	6.4	5	3.2	38	28.8	44	33.1	96	1.0
Hydropsyche instabilis	31	23.5	33	24.6	155	117.7	41	29.9	260	2.7
Glyphotaelius pellucidus	272	207.5	191	145.5	55	41.7	23	17.1	541	5.7
Agapetus fuscipus	4	2.1	6	4.2	186	141.2	89	67.4	285	3.1
Anabolia nervosa	-	-	273	208.6	53	39.5	85	64.2	411	4.3
Halesus digitatus	-	-	13	9.6	4	2.1	2	1.0	19	0.2
Limnephilus lunatus	-	-	8	5.3	-	-	-	-	8	+
Mystacides nigra	-	-	16	11.7	4	2.1	18	12.8	38	0.4
Silo pallipes	-	-	-	-	1	0.7	-	-	1	+
Diplectrona felix	-	-	-	-	1	0.7	-	-	1	+
Rhycophila dorsalis	-	-	-	-	-	-	6	4.2	6	+
Stenophylax permistus	-	-	-	-	-	-	16	11.7	16	0.1
Coleoptera	(71)	(51.1)	(82)	(58.2)	(143)	(107.8)	(112)	(83.6)	(408)	(4.2)
Helophorus flavipes	9	6.4	3	2.1	3	2.1	-	-	15	
Helmis maugei	13	9.6	8	5.3	8	5.3	16	11.7	45	0.4
Haliplus lineatocollis	14	10.7	18	12.8	5	3.2	1	0.7	38	0.4
Hydroporus pubescens	2	1.0	-	-	3	2.1	-	-	5	+
Gyrinus aeratus	1	0.7	-	-	-	-	-	-	1	+
Laccobius biguttatus	1	0.7	1	0.7	-	-	-	-	2	+
Deronectus depressus	5	3.2	4	2.1	-	-	1	0.7	10	+
Oreodytes rivalis	2	1.0	-	-	1	0.7	4	2.1	7	+

Table 9.6 (contd.)

Sampling sites →	D_1		D_2		D_3		D_4		Total	
Population density →	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	%
Latelmis volkmari	23	17.1	46	34.2	121	93.0	90	68.4	280	3.0
Platambus maculatous	1	0.7	2	1.0	1	0.7	-	-	4	+
Hydraena riparia	-	-	-	-	1	0.7	-	-	1	+
Diptera										
Ceratopoginidae	(27)	(20.3)	(10)	(7.4)	(1)	(0.7)	(16)	(11.7)	(54)	(0.5)
Bezzia spp.	27	20.3	10	7.4	1	0.7	16	11.7	54	0.5
Tipulidae	(4)	(3.9)	(12)	(9.5)	(15)	(9.8)	(15)	(10.2)	(46)	(0.5)
Tipula lateralis	3	3.2	1	0.7	3	2.1	1	0.7	8	+
Tipula paludosa	-	-	1	0.7	1	0.7	-	-	2	+
Tipula vittala	-	-	4	4.2	-	-	-	-	4	+
Tipula couckei	-	-	1	0.7	2	1.0	-	-	3	+
Tipula montium	-	-	-	-	1	0.7	-	-	1	+
Tipula maxima	-	-	-	-	-	-	2	1.0	2	+
Dicranota robusta	1	0.7	5	3.2	8	5.3	12	8.5	26	0.2
Simuliidae	(-)	(-)	(4)	(2.4)	(6)	(3.9)	(10)	(6.0)	(20)	(0.2)
Simulium naturale	-	-	1	0.7	-	-	1	0.7	2	+
Simulium ornatum	-	-	1	0.7	-	-	4	2.1	5	+
Simulium angustitarse	-	-	2	1.0	-	-	-	-	2	+
Simulium brevicaule	-	-	-	-	1	0.7	-	-	1	+
Simulium monticola	-	-	-	-	5	3.2	5	3.2	10	+
Dixidae	(-)	(-)	(-)	(-)	(3)	(1.7)	(1)	(0.7)	(4)	(+)
Dixa puberula	-	-	-	-	1	0.7	1	0.7	2	+
Paradixa amphibia	-	-	-	-	2	1.0	-	-	2	+
Chironomidae	(309)	(233.3)	(489)	(371.0)	(512)	(388.1)	(571)	(430.9)	(1881)	(19.7)
Cryptochironomus spp.	70	53.5	-	-	140	107.0	4	2.1	214	2.2
Polypedilum nubeculosus	10	7.4	-	-	52	39.5	185	141.2	247	2.6
Tanytarsus signatus	109	82.3	60	44.9	114	86.6	93	70.6	376	3.9
Pentaneura monilis	6	4.2	43	32.1	36	26.7	8	5.3	93	1.0

Table 9.6 (contd...)

Sampling sites →	D_1		D_2		D_3		D_4		Total	
Density →	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	Av.No/m^2	Total No.	%
Trichocladius rufiventris	1	0.7	-	-	69	52.4	22	16.0	92	1.0
Procladius choreus	93	70.6	136	103.7	42	32.1	106	80.2	377	3.9
Chironomus anthracinus	1	0.7	-	-	-	-	-	-	1	+
Dicrotendipes pulsus	19	13.9	-	-	-	-	9	6.4	28	0.3
Brillia modesta	-	-	3	2.1	4	2.1	-	-	7	+
Metriocnemus spp.	-	-	213	162.6	-	-	-	-	213	2.2
Prodianesa olivacea	-	-	34	25.6	55	41.7	113	85.6	202	2.1
Microtendipes chloris	-	-	-	-	-	-	31	23.5	31	0.3
<u>Other dipteran larvae</u>	(7)	(4.2)	(12)	(8.1)	(5)	(2.8)	(3)	(1.7)	(27)	(0.2)
Taphrophila vitripennis	2	1.0	-	-	-	-	-	-	2	+
Limnophora spp.	5	3.2	8	5.3	-	-	1	0.7	14	0.1
Hermerodromia unilineata	-	-	3	2.1	4	2.1	-	-	7	+
Pericoma pseudoexquisita	-	-	-	-	1	0.7	-	-	1	+
Atherix marginata	-	-	1	0.7	-	-	2	1.0	3	+
<u>Dipteran pupae</u>	(41)	(29.9)	(34)	(25.6)	(26)	(19.2)	(8)	(5.3)	(109)	(1.1)
Total No. of animals	2295		2395		2614		2237			
Av. No. animals per month	164		171		186		159			
Av. No. animals/m^2	1754.8		1829.7		1988.2		1701.3			

and D_4 the bed was easy of access, but at D_1 collecting was limited owing to the nature of the bank and the depth of water.

The species (Table 9.6) gathered at various stations show a great similarity at D_2, D_3 and D_4 while the D_1 fauna differs slightly because of its close vicinity to backwater which was full of weeds. A total of 9531 organisms of 83 species was collected. The average number of animals per station/month was 170 $\pm$ 10.1 ($\pm$ S.D).

The animals found are listed in Table 9.6 which gives a fairly complete picture of invertebrate life in the upper Dee.

(A) Platyhelminthes

(1) Turbellaria

Polycelis nigra which was common at D_1 and scarce at the rest of the stations formed 0.3% of the total benthic fauna. The relative abundance of this species at D_1 may be due to availability of food in the nearby backwater.

(B) Annelida

(1) Hirudinea

0.7% of the limnetic invertebrates belonged to this group in which *Erpobdella octoculata* was common.

(2) Oligochaeta

15.5% of the bottom fauna was formed by *Lumbriculus variegatus*, *Stylodrilus heringianus* and *Limnodrilus*

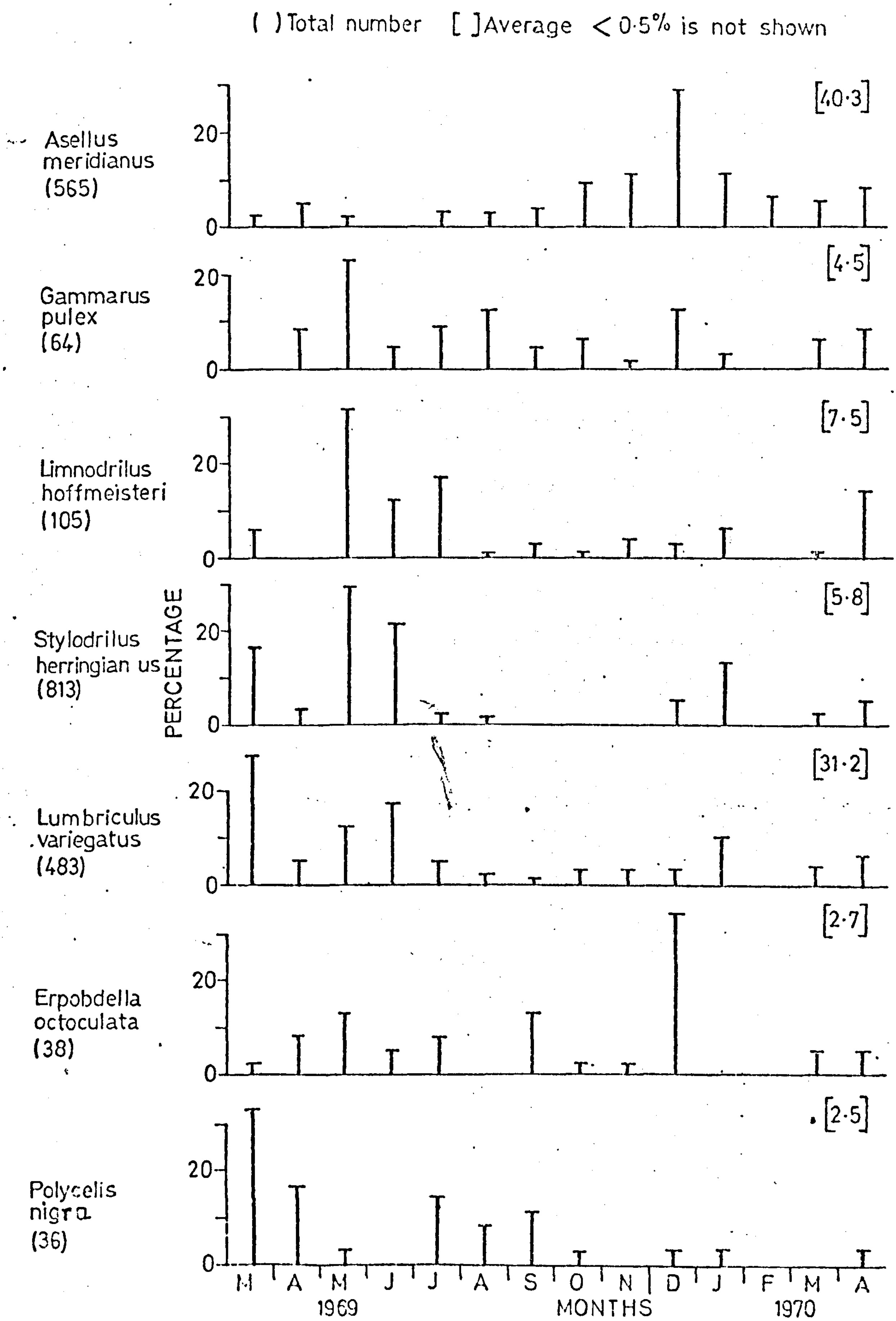

Fig 9.2 Seasonal variations of some of the common species of bottom fauna of the upper Dee (other groups in Figs 9.3, 9.4, and 9.5)

hoffmeisteri as common species and the rest (Table 9.6) were scarce. The above species showed minima in autumn and winter and maxima in spring and summer (Fig. 9.2).

(C) *Mollusca*

(1) *Gastropoda*

This group was represented by *Limnaea pereger*, *Ancylastrum fluviatile* and *Potamophyrgus jenkinsi* which formed 0.2% of the total macroinvertebrates and all the above species were scarce. *Ancylastrum fluviatile* can tolerate a low calcium content (Boycott 1936), but it was not common even on clean stones, and all the above species were absent from the stones having muddly and algal crusts on.

(2) *Lamellibranchiata*

2.7% of the bottom invertebrates were formed by this group of which *Pisidium hibernicum* and *Pisidium subtruncatum* were common in the stony and gravelly substratum of D_2 and D_4 respectively.

(D) *Arthropoda*

(1) *Crustacea*

(a) *Amphipoda*

Gammarus pulex, formed 0.6% of the total fauna. These were found in all seasons, but I found relatively more in summer as did Badcock (1949) and Hynes (1955), because of the appearance of young stages between April to June.

(b) *Isopoda*

Asellus meridianus though commonly present at all the

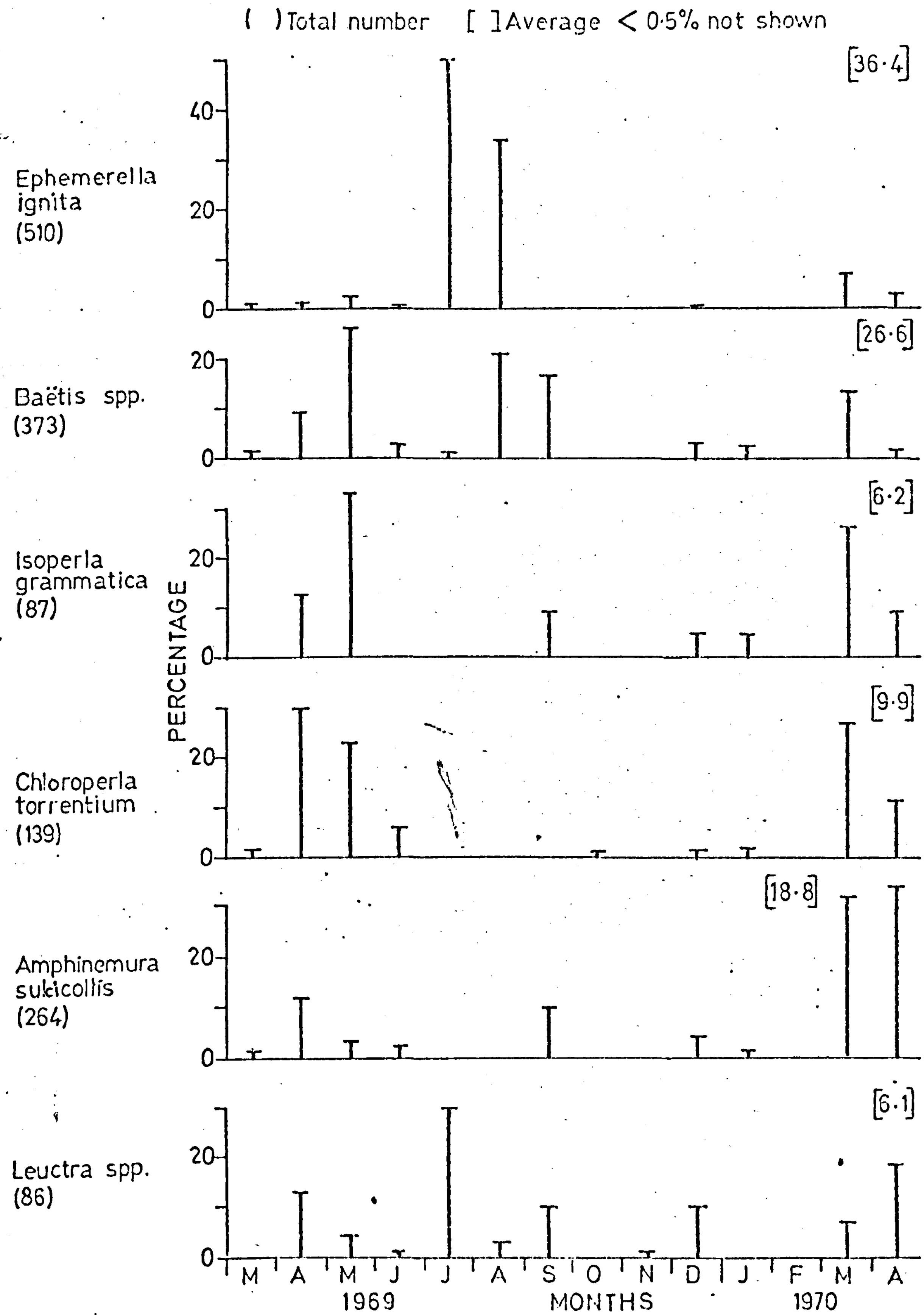

Fig. 9.3 Seasonal variations of the common species of Ephemeroptera and Plecoptera of the upper Dee.

sampling sites, formed 5.9% of the total benthic fauna. These were collected in abundance in every season but more so in late autumn and winter (Fig. 9.5).

(2) Arachnida

(a) Hydracarina

This group was scarce, forming 0.2%. They seemed to favour stony bottoms with vegetation.

(3) Insecta

(a) Plecoptera

7.3% of the bottom fauna belonged to this group in which *Amphinemura sulcicollis*, *Chloroperla torrentium* and *Chloroperla tripunctata* were common and the rest scarce (Table 9.6). *Leuctra spp.* were found in all seasons (Fig. 9.3) because of a steady succession of species and long hatching perids (Hynes 1961). I did not find *Amphinemura sulcicollis* in summer, but *Isoperla grammatica* and *Chloroperla torrentium* were numerous in late spring as found by Hynes (1961).

(b) Ephemeroptera

This group formed 14.2% of the total bottom organisms; of these *Centroptilum luteolum*, *Leptophlebia marginata*, *Baetis rhodani*, *Ephemerella ignita*, *Baetis scambus* and *Ecdyonurus venosus* were common. Fig. 9.3 shows the presence of *Baetis spp.* in every season and *Ephemerella ignita* was recorded in large numbers during summer as found by Macan (1957b) and Pleskot (1958).

(c) Hemiptera

6.4% of the bottom invertebrates were formed by this

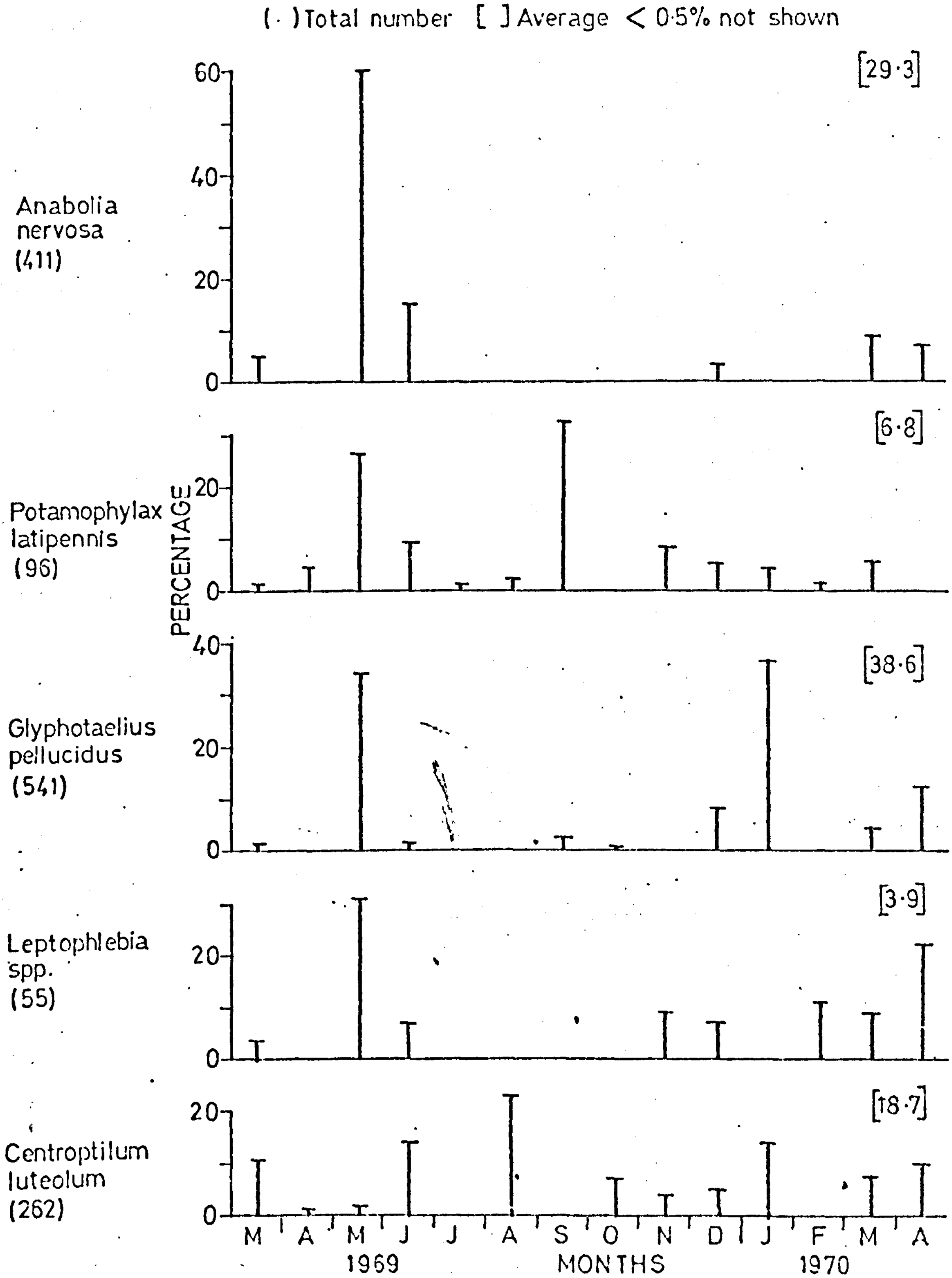

Fig 9.4 Seasonal variations of the common species of Trichoptera of the upper Dee.

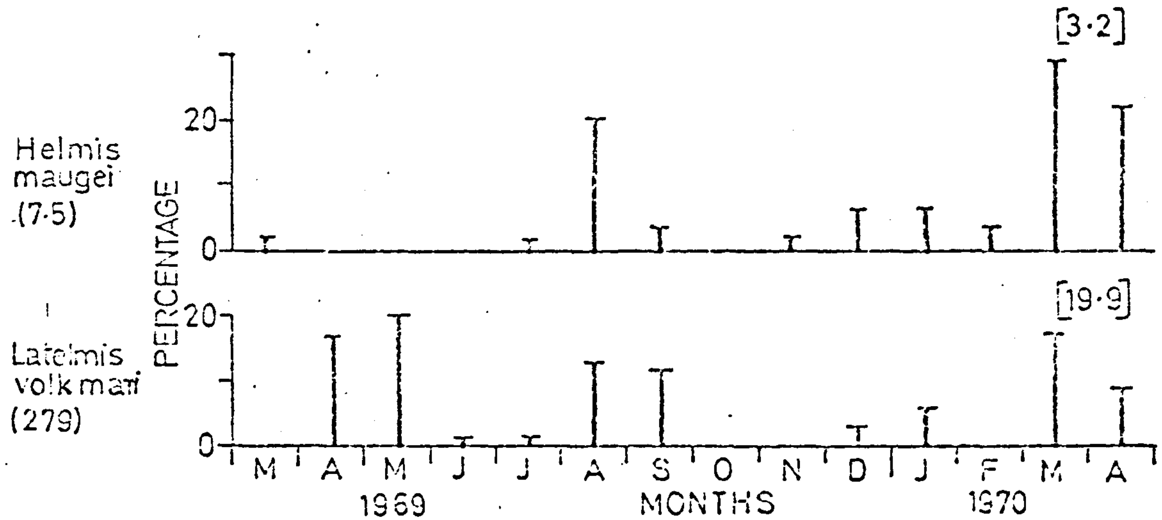

Fig 9.5 Seasonal variations of the common species of Coleoptera of the upper Dee.

group. Corixa panzeri, a very common species at D_1 mainly due to the vicinity of backwater vegetation, was scarce at other stations. This and other species (Table 9.6) were observed throughout the period.

(d) Megaloptera

0.5% of the benthic fauna were formed by Sialis fuliginosa and Sialis lutaria. Both were scarce and were collected from the stones with or without any vegetation

(e) Trichoptera

18.1% of the bottom fauna was formed by Glyphotaelius pellucides, Anabolia nervosa, Plectrocnemia conspersa, Potamophylax latipennis and Hydropsyche instabilis, which were common. Glyphotaelius pellucides was found relatively more in spring and winter; Anabolia nervosa in spring and autumn and Potamophylax latipennis in spring and autumn (Fig. 9.4).

(f) Coleoptera

4.2% of the benthic fauna belonged to this group in which Latelmis volkmari and Helmis maugei were common and recorded in large numbers in every season except autumn (Fig. 9.5).

(g) Diptera

(1) Ceratopogonidae

This family was represented by Bezzia spp. which formed 0.5% of the total fauna in all stations.

(2) Tipulidae

Seven species of this group formed 0.5% of the total macro-benthos, of these *Dicranota robusta* was common and the rest (Table 9.6) were scarce. These were found in all four stations.

(3) *Simulidae*

0.2% of the bottom fauna belonged to five species of this family and are listed in the Table 9.6. All of them were scarce and absent from the bottom of D_1.

(4) *Dixidae*

Dixa puberula and *Paradixa amphibia* were collected from the stony bottom of D_3 and D_4.

(5) *Chironomidae*

This group formed 19.8% of the benthic fauna and was represented by *Cryptochironomus spp.*, *Procladius choreus*, *Pentaneura monilis*, *Tanytarsus signatus*, *Metriocnemus spp.* *Prodiamesa olivacea*, *Trichocladius rufiventris* and *Polypedilum nubeculosus*. The above species were common and found to be less abundant in the muddy bottom with thick vegetation.

(6) *Other dipteran larvae*

The species belonged to the family Empididae, Rhagionidae, Limoniinae and Anthomyiidae, presented a small portion (0.2%) of the total bottom fauna and few were recorded from the muddy stretches.

(7) *Dipteran pupae*

These formed 1.1% of the total catch.

4. COMPARISON OF THE BOTTOM FAUNA OF REGULATED DEE WITH UNREGULATED LLYN TEGID FEEDER STREAMS.

In order to study the resulting status of the benthic fauna of regulated Dee (upper Dee), it is necessary to

Table 9.7 Distribution of the catch between samples taken from the Unregulated Llyn Tegid feeder streams and the Regulated Dee.

Groups and species	Catches		Total	Chi squared	P
	Feeder streams Unregulated	Dee Regulated			
Turbellaria (Total)	(7)	(36)	(43)	(19.4)	(<0.001)
Polycelis nigra	7	36	43	19.4	<0.001
Hirudinea	(51)	(72)	(123)	(3.4)	(>0.05)
Erpobdella octoculata	41	38	79	0.1	>0.05
Glossiphonia complanata	1	9	10	6.4	<0.05
Helobdella stagnalis	9	23	32	6.1	<0.05
Oligochaeta	(899)	(1488)	(2387)	(145.2)	(<0.001)
Stylodrilus heringianus	722	787	1508	2.6	>0.05
Lumbriculus variegatus	110	438	548	196.1	<0.001
Eiseniella tetrahedra	41	36	77	0.2	>0.05
Aulodrilus pluriseta	8	43	51	24	<0.001
Homochaeta naidina	7	27	34	11.6	<0.001
Gastropoda	(73)	(21)	(94)	(28.6)	(<0.001)
Limnaea pereger	2	16	18	10.8	<0.001
Ancylastrum fluviatile	71	4	75	59.8	<0.001
Lamellibranchiata	(125)	(265)	(390)	(50.2)	(<0.001)
Pisidium subtruncatum	91	109	200	1.6	>0.05
Pisidium milium	30	64	94	12.2	<0.001
Pisidium hibernicum	8	92	100	92.0	<0.001
Amphipoda	(30)	(64)	(94)	(12.2)	(<0.001)
Gammarus pulex	30	64	94	12.2	<0.001
Isopoda	(31)	(565)	(596)	(478.4)	(<0.001)
Asellus meridianus	31	565	596	478.4	<0.001
Hydracarina	(6)	(22)	(28)	(9.0)	(<0.01)
Lebertia porosa	4	3	7	0.14	>0.05
Hygrobates fluviatiles	1	2	3	0.2	>0.05

Table 9.7 (contd.)

Groups and species	Catches: Feeder streams Unregulated	Catches: Dee Regulated	Total	Chi squared	P
<u>Plecoptera</u>	(1380)	(697)	(2077)	(190.4)	(<0.001)
Amphinemura sulcicollis	269	264	533	0.004	>0.05
Nemoura cinerea	2	3	5	0.2	>0.05
Amphinemura standfussi	150	59	209	39.6	<0.001
Leuctra hippopus	450	41	491	340.6	<0.001
Nemoura avicularis	2	1	3	0.2	>0.05
Protonemura meyeri	67	20	87	25.0	<0.001
Chloroperla torrentium	101	141	242	6.6	<0.05
Isoperla grammatica	71	83	154	0.8	>0.05
Leuctra fusca	110	20	130	62.2	<0.001
Leuctra inermis	51	12	63	24.0	<0.001
Chloroperla tripunctata	37	28	65	1.2	>0.05
Isoperla obscura	3	4	7	0.14	>0.05
<u>Ephemeroptera</u>	(1545)	(1356)	(2901)	(12.2)	(<0.001)
Ephemerella ignita	171	510	681	168.6	<0.001
Baëtis rhodani	144	269	413	37.8	<0.001
Caënis horaria	2	7	9	2.6	>0.05
Caënis mosta	5	55	60	41.6	<0.001
Centroptilium luteolum	875	262	1137	330.4	<0.001
Leptophlebia vespertina	32	23	55	1.4	>0.05
Paraleptophlebia tumida	5	1	6	2.6	>0.05
Heptagenia lateralis	32	5	37	19.6	<0.001
Heptagenia sulphurea	49	25	74	7.6	<0.01
Baëtis pumilus	99	36	135	29.2	<0.001
Baëtis scambus	29	68	97	15.6	<0.001
Paraleptophlebia submarginata	13	10	23	0.2	>0.05
Ecdyonurus venosus	41	28	69	2.4	>0.05
Leptophlebia marginata	24	32	56	1.1	>0.05

Table 9.7 (contd.)

Groups and species	Catches		Total	Chi squared	P
	Feeder streams Unregulated	Dee Regulated			
Rhithrogena semicolorata	17	1	18	14.2	<0.001
Hemiptera	(1137)	(617)	(1754)	(154)	(<0.001)
Sigara nymph	4	3	7	0.14	>0.05
Micronecta poweri	114	161	1275	712.2	<0.001
Sigara distincta	1	137	138	134.0	<0.001
Corixa panzeri	18	210	228	161.6	<0.001
Megaloptera	(29)	(51)	(80)	(6.0)	(<0.05
Sialis lutaria	29	51	80	6.0	<0.05
Trichoptera	(898)	(1736)	(2634)	(266.6)	(<0.001)
Mystacides nigra	12	38	50	13.4	<0.001
Plectrocnemia conspersa	222	33	255	140	<0.001
Hydropsyche instabilis	100	260	360	71.0	<0.001
Potamophylax latipennis	48	96	144	16	<0.001
Silo pallipes	4	1	5	1.6	>0.05
Anabolia nervosa	132	411	543	143.2	<0.001
Glyphotaelius pellucidus	262	451	713	50.0	<0.001
Agapetus fuscipus	10	285	295	246.4	<0.001
Helesus digitalus	29	19	48	2.0	>0.05
Diplectrona felix	3	1	4	1.0	>0.05
Rhyacophila dorsalis	7	6	13	.03	>0.05
Coleoptera	(378)	(408)	(786)	(1.1)	(>0.05)
Platambus maculatus	23	4	27	13.2	<0.001
Decronectus depressus	1	10	11	7.2	<0.01
Haliplus lineatocollis	4	38	42	27.4	<0.001
Helmis maugei	102	45	147	22.0	<0.001
Latelmis volkmari	220	280	500	7.2	<0.01
Hydroporus pubescens	3	5	8	0.4	>0.05
Helophorus flavipes	6	15	21	3.8	<0.05

Table 9.7 (contd.)

Groups and species	Catches: Feeder streams Unregulated	Catches: Dee Regulated	Total	Chi squared	P
<u>Ceratopogonidae</u>	(67)	(54)	(121)	(1.3)	(>0.05)
Bezzia spp.	67	54	121	1.3	>0.05
<u>Tipulidae</u>	(30)	(46)	(76)	(3.3)	(>0.05)
Tipula maxima	5	2	7	1.2	>0.05
Tipula montium	11	1	12	8.2	<0.01
Tipula paludosa	3	2	5	0.2	>0.05
Tipula couckei	1	3	4	1.0	>0.05
Tipula lateralis	10	8	18	0.2	>0.05
<u>Simuliidae</u>	(48)	(20)	(68)	11.4	(<0.001)
Simulium monticola	30	10	40	10.0	<0.01
Simulium ornatum	1	5	6	2.6	>0.05
Simulium brevicaule	10	1	11	7.2	<0.01
Simulium naturale	6	2	8	1.0	>0.05
<u>Dixidae</u>	(1)	(4)	(5)	(1.7)	(>0.05)
Dixa puberula	1	4	5	1.7	>0.05
<u>Chironomidae</u>	(3048)	(1881)	(4929)	(276.2)	(<0.001)
Polypedilum nubeculosus	1690	247	1937	1074.8	<0.001
Pentaneura monilis	350	93	443	149	<0.001
Prodiamesa olivacea	490	202	692	119.8	<0.001
Tanytarsus signatus	293	376	669	10.2	<0.01
Procladius choreus	84	377	461	186.2	<0.001
Microtendipes spp.	6	31	37	16.8	<0.001
Trichocladius rufiventris	66	92	158	4.2	<0.05
Cryptochironomus spp.	58	214	272	89.4	<0.001
Brillia modesta	6	7	13	0.06	>0.05

Table 9.7 (contd.)

Groups and species	Catches		Total	Chi squared	P
	Feeder streams Unregulated	Dee Regulated			
Other dipteran larvae	(209)	(27)	(236)	(140.2)	(<0.001)
Dicranota robusta	159	26	185	95.6	<0.001
Hermerodromia unilineata	20	7	27	6.2	<0.05
Limnophora spp.	2	14	16	9.0	<0.01
Taphrophila vitripennis	11	2	13	6.2	<0.05
Atherix marginata	2	3	5	0.2	>0.05
Dipteran pupae	294	109	403	84.8	<0.001

Table 9.8 Average percentage composition of the total benthic fauna (expressed in groups) in unregulated Llyn Tegid feeder streams and regulated upper Dee. + = <0.1%

Condition	Unregulated	Regulated
Turbellaria	+	0.3
Hirudinea	0.1	0.7
Oligochaeta	7.9	15.6
Gastropoda	0.4	0.2
Lamellibranchiata	0.5	2.7
Amphipoda	0.3	0.6
Isopoda	0.5	5.9
Hydracarina	0.1	0.2
Plecoptera	11.9	7.3
Ephemeroptera	14.6	14.2
Hemiptera	7.5	6.4
Megaloptera	0.2	0.5
Trichoptera	6.9	18.2
Coleoptera	3.1	4.2
Ceratopogonidae	0.2	0.5
Dixidae	0.3	+
Tipulidae	0.2	0.2
Simuliidae	0.1	0.2
Chironomidae	39.0	19.7
Other Dipt. larvae	1.2	0.5
Dipt. pupae	3.3	1.1

compare results obtained during the same period and from similar substrata in both the regulated Dee and in the unregulated feeder streams of Llyn Tegid. Investigations were therefore made in the same period by applying the same method of collecting.

Table 9.8 shows a quantitative comparison of the benthic fauna of the unregulated feeder streams and regulated Dee. Plotting the mean number of each group as a percentage of the total, reveals an increase in Hirudinea, Oligochaeta, Lamellibranchiata, Isopoda, Amphipoda, Megaloptera, Trichopera and Coleoptera in the regulated Dee; whereas Hemiptera and Diptera particularly chironomid larvae, are favoured tremendously by the unregulated conditions of the feeder stream.

Tables 9.7, 9.8 show that Turbellaria, Hirudinea, Oligochaeta, Lamellibranchiata, Amphipoda, Isopoda, Trichoptera, Hemiptera and Coleoptera were poorly represented in the unregulated feeder streams. Aquatic diptera, which includes Chironomidae, Dixidae, Tipulidae, Simuliidae, Ceratopogonidae, Psychodidae, Limnobiidae, Ptychopteridae, Stratiomyidae, Dolichopodidae and Empididae ; Plecoptera and Gastropoda were quite distinct and abundant in number of individuals and species in unregulated feeder streams. The regulated or unregulated condition of the river appears to have no effect on Hydracarina, Ephemeroptera and Megaloptera (Table 9.8).

5. DISCUSSION

Butcher (1933) while working on the River Lark, Suffolk, found that a river bed of sand and gravel was washed away by a sudden flood along with the plants rooted in it. He further reported that the macrophytic vegetation, in itself not a source of food for the great majority of animals inhabiting a river, has a great influence on their quantity and distribution by action (1) as an area for the growth of epiphytic algae which are the chief source of food of smaller forms, (2) as a source of oxygen, (3) as a shelter and habitation, and (4) as an agent for cementing together stones and gravel where much of the fauna is found. Percival and Whitehead (1930) showed that the substratum controls the density of invertebrates. The more fixed the substratum and the greater amount of shelter available, the denser is the fauna. Ravera (1951) pointed out that the density fluctuations of benthic organisms were directly or indirectly conditioned by the current velocity. Thorup (1970) described the similar situation in the Danish spring Rold Kilda. Bishop and Hynes (1969) found a loss of organisms from the area after flood had scoured the bottom in the Speed River, Ontario. Ertlova (1968) while working on the River Danube in Czechoslovakia, found oligochaetes only where the current velocity reached 210cm/sec. Chutter (1969) showed that the increased amount of silt and sand in river beds adversely affected the fauna of Vaal River, South Africa. Radford and Rowe (1972) have shown, in a preliminary investigation of bottom fauna and invertebrate drift in an unregulated and a regulated stream in Alberta, that increased velocities of current during high water not only dislodge the animals but also settling becomes more difficult.

In the present study a comparison of the benthic fauna of the regulated river Dee (upper Dee) and Llyn Tegid feeder strema shows a distinct variation in the number of animals (Tables 9.7, 9.8).

The fauna of Oligochaeta in the regulated Dee can be considered abundant because the number of oligochaetes probably depends to a large extent on contributions from the soil washed down. This soil has been mixed up with decaying plant substances and has thereby formed a biotope which is favourable just for the oligochaetes. The relative increase in Hirudinea in the regulated Dee could be due to slow current and abundant marginal vegetation. Gammarus pulex was recorded more in the regulated Dee than in the feeder streams, perhaps due to the availability of more hiding places and the relatively slow water current in the former. The abundance of trichopteran larvae in the regulated Dee was remarkable, and may be due to their feeble ability of locomotion, the slow water currents and the greater availability of the case building material. There is an increase in Turbellaria, Lamellibranchiata and Isopoda in the regulated Dee as compared with the unregulated feeder streams. This may be attributed to 'permanent' substratum and sheltered zones, either because of the need of these groups for cover or because they are normally associated with vegetation.

There were relatively more Plecoptera recorded in unregulated feeder streams than in the regulated Dee (Tables 9.7, 9.8), due presumably to the availability of stony substrata with scattered vegetation, particularly macrophytes which the plecopteran nymphs feed on (Hynes, 1941). In the Dee, the lack of suitable food and proper substrata would probably have been a limiting factor. More hemipterans were recorded in unregulated feeder streams than in the regulated Dee. This may be due to slower currents, more marginal vegetation, and the vicinity of the lake in the lower reaches of the feeder streams. Greater numbers of Gastropoda in the feeder streams may be due to less silt deposition and relatively more calcium ions in the water. Among the Diptera, Chironomidae seemed to have endured the unregulated condition of the feeder streams very well (Tables 9.7, 9.8). Probably this is due to the presence of a thin mud and silt layer on the bottom.

There appears to be no difference in the relative abundance of Ephemeroptera in the regulated Dee and unregulated feeder streams (Table 9.8), though Harker (1953) in a Lancashire stream found that flooding affected *Ecdyonurus spp*. and *Heptagenia spp*. considerably, but *Baetis spp*. were not affected.

The presence of lower numbers of certain groups in the unregulated feeder streams may be due to the fact that the substratum, even when of stones and boulders, is moved due to high velocities of water currents in flooding, and much of the plant and animal life is insecurely anchored in gravel and among stones, and is torn away by the swirling waters. The greater the volume of water, the greater the damage done.

The regulation of the river Dee has favoured certain groups (Tables 9.7, 9.8). This may be due to considerable alteration in the banks and bottom of the river. The stony substratum seems to be covered by silt and algae, and consequently the sheltered banks have become soft and colonised by vegetation. It appears that the controlled flow has to a great extent minimised the physical disturbances of the bottom by flood and consequent bottom scouring. For the successful establishment and maintenance of animal or plant colonies in the river constant conditions must obtain for a considerable period, whereas large fluctuations may result in washing away of the entire fauna and flora. Jones (1951b) reported that severe summer floods in the River Towy, West Wales, reduced the invertebrate population from 1000 to 300/sq.m.

The results discussed here agree to some extent with those obtained by Rawson (1948) who observed that the standing crop of the benthic fauna was uniformly low before the development of the Pacaterra Dam on the Kananaskis River in Saskatchewan, Canada; Cronemiller (1955) showed that the production of food of trout had increased by constructing small dams to regulate the summer flow in a small trout stream in the U.S.A.; and Radford and Rowe (1972) made similar observations on the fauna and invertebrate drift in an unregulated and a regulated stream in Alberta, Canada.

6. SUMMARY

(1) A preliminary investigation of invertebrates was made of the upper regulated Dee.

(2) The species composition and the seasonal trends of the common species of the standing crops of the bottom fauna are discussed.

(3) A comparison of the benthic fauna of the regulated Dee and unregulated Llyn Tegid feeder streams was made.

(4) Low standing crops in the unregulated feeder streams could be due to flood and instability of substratum; whereas the relatively high number of benthic organisms in the regulated Dee on be attributed to a "fixed" substratum and less physical disturbance.

PART 111

CHAPTER X

1 River Alyn

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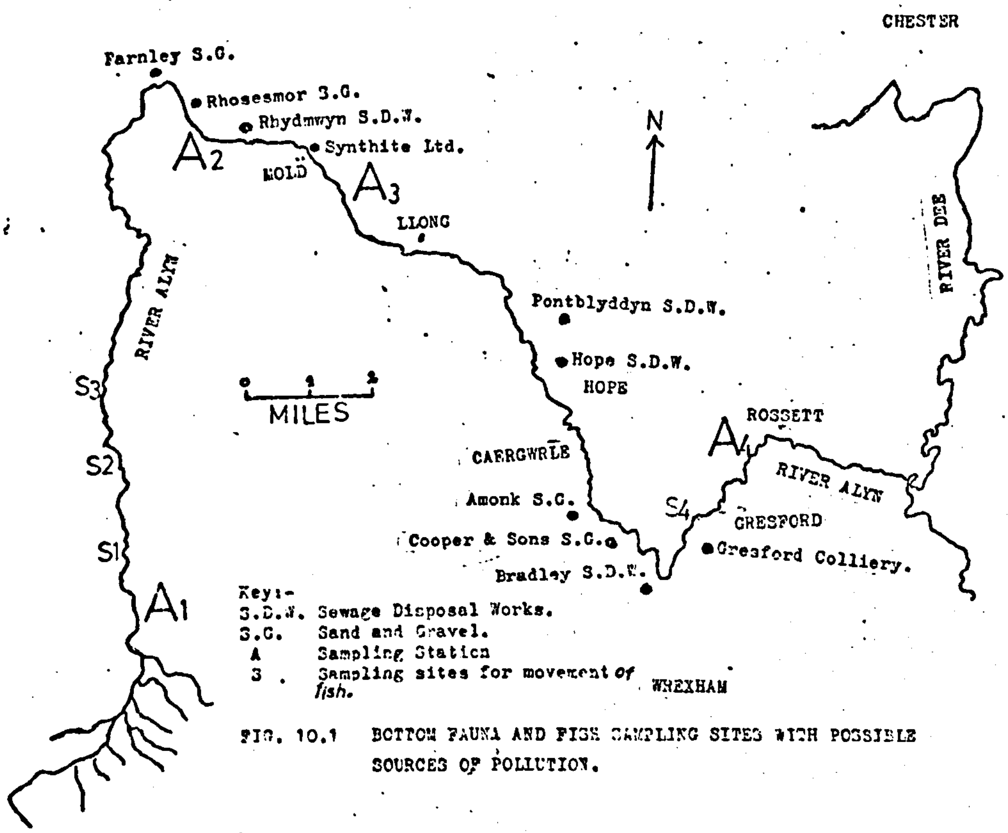


Key:-
S.D.W. Sewage Disposal Works.
S.G. Sand and Gravel.
A Sampling Station
S Sampling sites for movement of fish.

FIG. 10.1 BOTTOM FAUNA AND FISH SAMPLING SITES WITH POSSIBLE SOURCES OF POLLUTION.

CHAPTER X

INTRODUCTION

Although there is now a considerable body of information available on the biology of various polluted waters (Carpenter 1924, 1925, 1926; Jones 1940a, 1940b, 1941a, 1949b, 1958; Pentelow and Butcher 1938; Hynes 1960, 1961, 1962; Mann 1965; and Brinkhurst 1966, 1965) etc., there is no published information concerning the ecology of bottom invertebrates and biology of trout in a polluted stream of the Dee watershed. The following study describes the ecology of a macrofaunal community and the biology of trout in the River Alyn, a polluted tributary of the Dee.

MATERIAL AND METHODS

(a) Bottom fauna

The sampler described in Chapter II was used for collecting the bottom invertebrates from July 1969 to July 1970.

(b) Fish

Fish samples were taken monthly from the upper Alyn between A_1 and A_2 (Fig.10.1) from July 1969 to July 1970. All samples were collected by electrofishing between 10.00 and 15.00 hours. A Honda A.C. generator of 240V was employed. Stunned fishes were recovered by means of landing nets. The catches were preserved in the deepfreeze and examined the next day.

First the frozen fish were thawed in warm water and then each specimen was dried. Surplus water was removed from the body surface by filter paper and the weight was determined to the nearest 0.1g. Length, from the tip of the snout to the fork was measured to the nearest millimeter. Sex determination of larger fishes was made macroscopically and the gonads were weighed to the nearest 0.1g. Sex determinations of immature fishes were made by microscopic examination of squashed gonad tissue. The conditions of the gonads were noted according to Orton, Jones and King (1938) and Jones and Orton (1940).

The method adopted for food analysis is mentioned in Chapter III.

The scales of brown trout from particular British habitats have been described extensively in the literature (Southern 1935; Allen 1938; Went and Frost 1942; Frost 1950; Jones 1953 and Ball and Jones 1960) etc. The procedures adopted in scale preparation and reading was adopted from the works of Jones (1949) and Ball (1957, 1961). Scales were taken from an area above the lateral line and just below the dorsal fin. This was to offset, as much as possible, inaccuracies likely to arise from the variation in the number of rings on the scales from different regions of the body (Bhatia 1931). Each scale was cleaned by

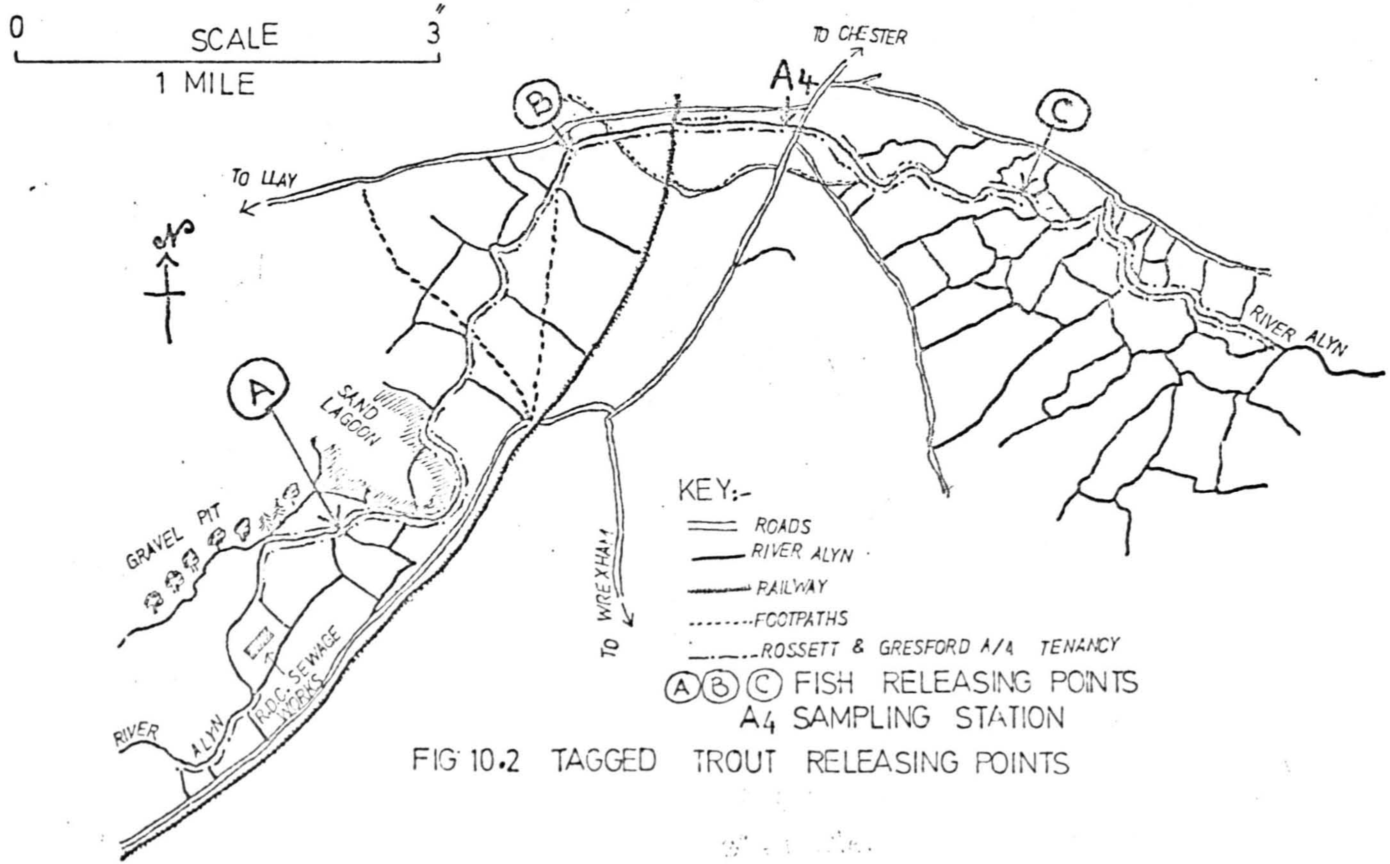


FIG 10.2 TAGGED TROUT RELEASING POINTS

rubbing between thumb and finger. About 10 scales were then picked up with a blunt scalpel and mounted in Euparal. Reading for age was done under the low power microscope. The scales I examined showed wide rings on their edge in early summer, with narrowing of these rings in late summer. In autumn and winter narrow rings were formed on the scales of most fish (Plates 10.5-10.9).

In order to investigate the movement of fish at A_4 (Fig. 10.2), 150 trout were tagged and released. Tagging was carried out at Chirk hatchery on the day before they were released. Fish were taken at random from each size group (here 16-18, 18-20, 20-22cms) and were tranquilised by placing them in a weak solution of MS222 Sandoz. A hypodermic needle was inserted into the base of the dorsal fin at its anterior end. One arm of the silver wire attached to the tag was threaded into the needle which was then withdrawn from the fish. The other arm of the silver wire was brought over the back of the fish and the two arms of silver wire were twisted together. The excess silver wire was cut off. The wire and the tag were pressed close to the sides of the fish. The trout were then placed in a plastic bucket half full of a solution of mercuric chloride to prevent any infection, before putting them in the delivery tank. 50 trout of the length group 16-18 cm were tagged and released at station A, 50 of 18-20 cm at B and 50 of 20-22 cm at C (Fig. 10.2). In the upper Alyn, between A_1 and A_2 (Fig.10.1) Pan-jet innoculation techniques

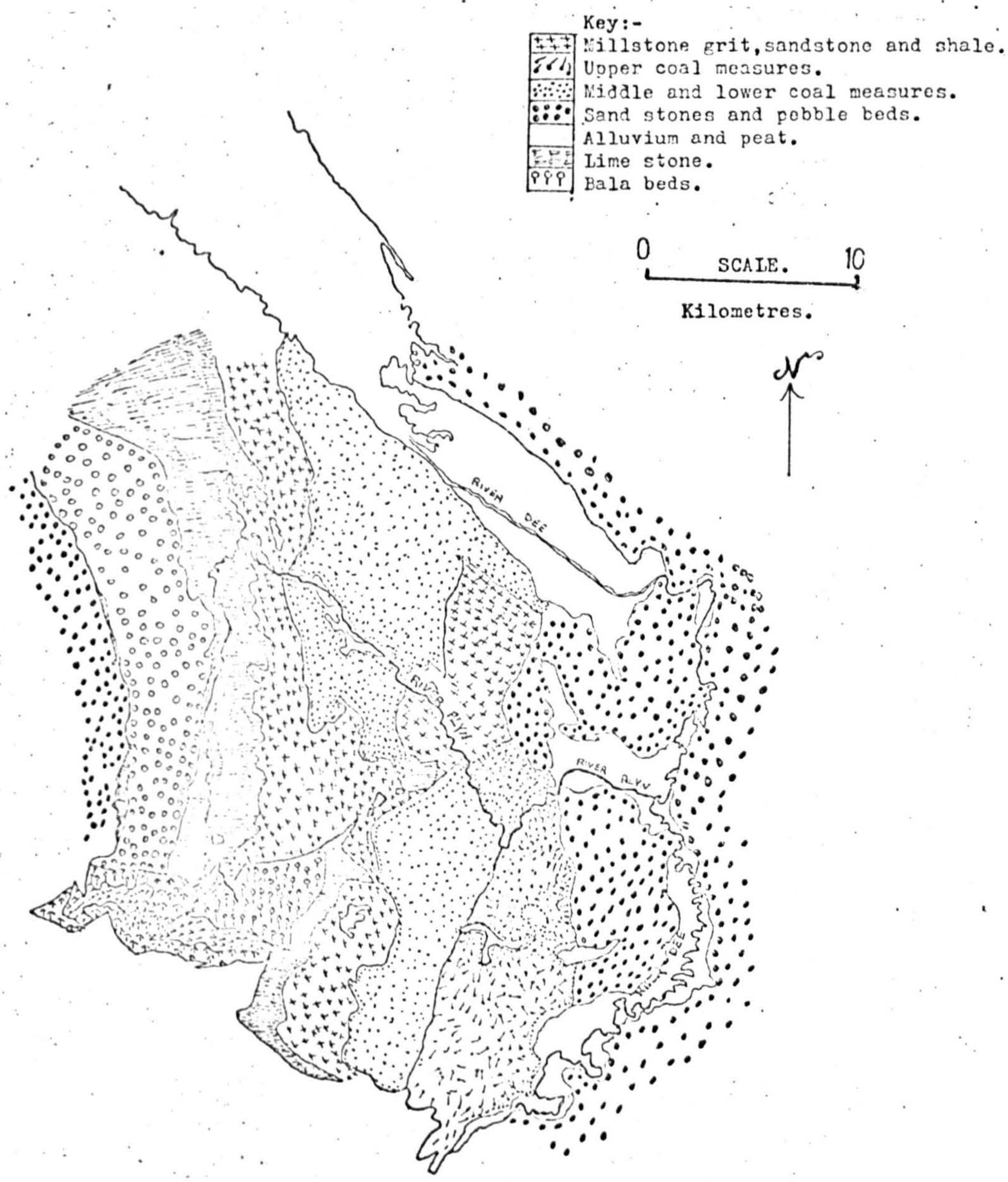


FIG. 10.3 THE GEOLOGY OF THE RIVER ALYN.
(LOWER DEE CATCHMENT AREA.)

(Hart and Pitcher 1969) using indian ink were carried out for the movement determinations.

Gonads were removed as soon as possible, weighed and preserved in modified Gilson's Fluid (Simpson, sited by Bagenal 1966), consisting of 100ml 60% alcohol, 15ml 80% nitric acid, 18ml glacial acetic acid, 880ml water and 20g mercuric chloride. The fluid preserved and hardened the eggs and helped to liberate them by breaking down the ovarian tissue. Before the eggs were counted the ovarian tissue was removed and clumps of adhering eggs were carefully separated.

3. THE ENVIRONMENT

(a) General topography

The River Alyn, a tributary of the Dee, rising around Cyrn-y-Brain 615.7 m O.D. in Denbighshire, follows approximately the outcrop of the basal carboniferous limestone for about 16km northward (Fig.10.3), but then suddenly turns to cut through the limestone belt in a deep gorge of sand and shales. After this it flows south-eastward through the coal measures and finally it enters into alluvium and peat to join the Dee at the Cheshire border. Two major contributing streams, Afon Terrig and Afon Cegrdog, enter the river near Long (Nat. Grid Ref. 261624) and Cefn-y-bedd (Nat. Grid Ref. 310562) respectively. The river follows a winding course of more than 45km. At Loggerheads (Nat. Grid Ref. 627195) some of the water

PLATE 10.1 SAMPLING STATION A1.

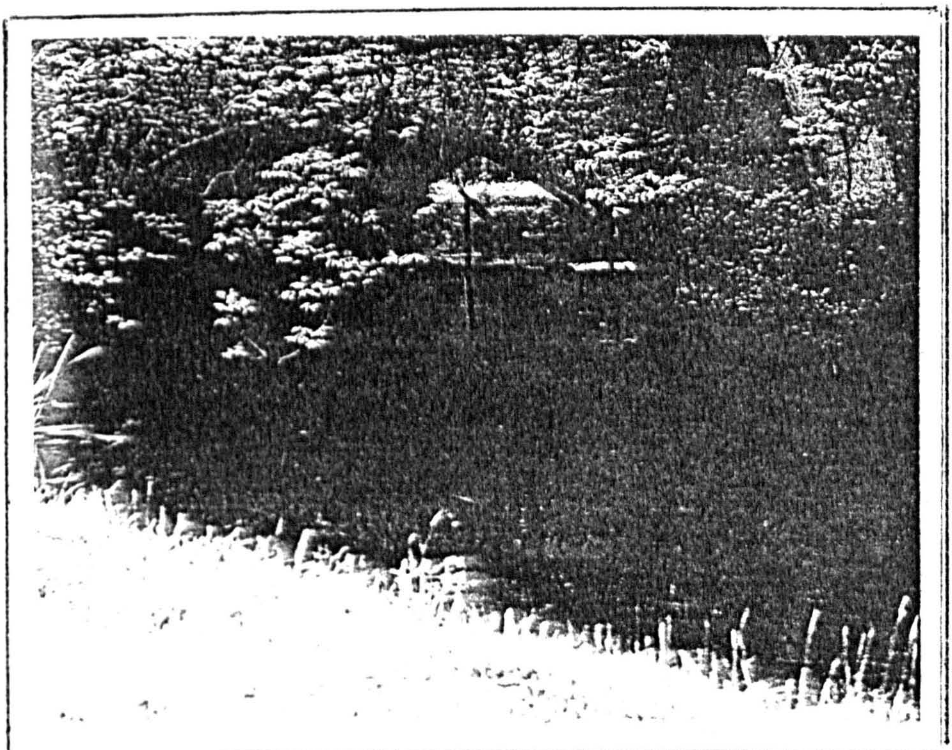


PLATE 10.2 SAMPLING STATION A2.

flows into the underground fissures and this also occurs at Mold (Nat. Grid Ref. 240639) which results in low summer level and sometimes drying out altogether.

(b) Description of the sampling sites

Four collection sites, namely A_1, A_2, A_3 and A_4, were established from the top to the bottom end of the stream (Fig. 10.1). These stations were selected not on the basis of different types of substrata but on the basis of pollution by domestic sewage and industrial wastes (Fig.10.1).

A_1 (Plate 10.1) was selected near the village of Llandegla (Nat. Grid Ref. 195525) at an altitude of 265.6m O.D. Here the stream is 0.3-2m wide and 0.5-1m in depth, with a hard bottom of gravel and mud at places. There were no trees and bushes of any kind on either side of the river. It receives a small amount of domestic untreated sewage, the source of which was shown to me by Mr. Williams, a local farmer.

A_2 (Plate 10.2) was situated at an altitude of 115.3m O.D. near Mold (Nat. Grid Ref. 240639) above the Synthite and Sewage disposal works (Fig.10.1). Here the stream is from 0.5-1m in depth and the width varies from 3-5m. There were Scots Pine trees on one side and pasture on the other. The bottom was covered with pebbles and sand. Sandy shoals were found over wide areas which may be due to two sand and gravel works nearby (Fig.10.1). There were a few scattered patches of *Fontinalis antipyretica* and *Ranunculus aquatilis*.

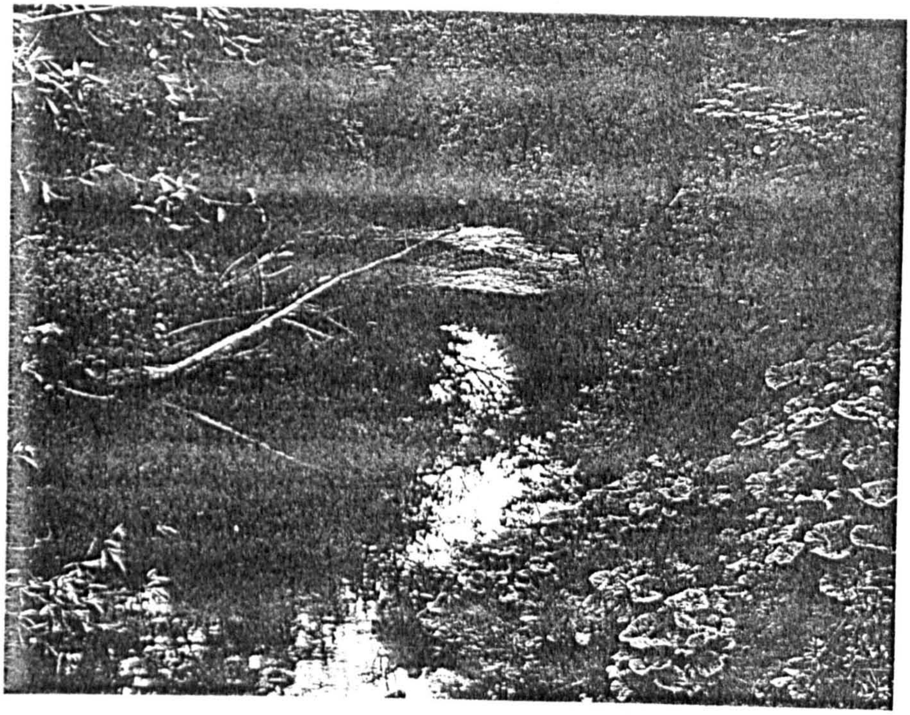


PLATE 10.3 SAMPLING STATION A3.

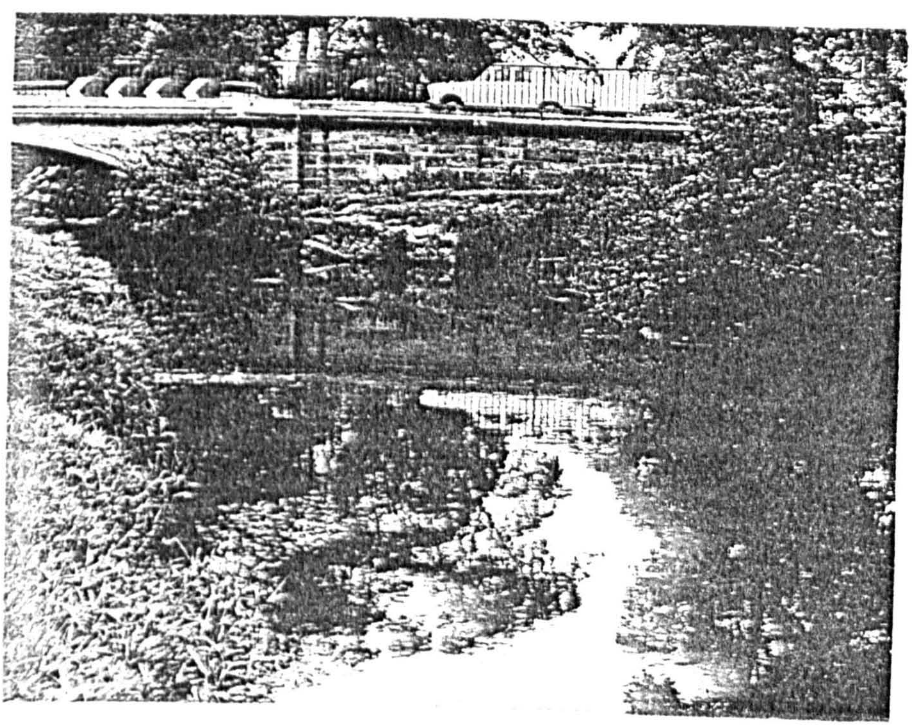


PLATE 10.4 SAMPLING STATION A4.

PLATE 10.5 SCALE OF BROWN TROUT FROM RIVER ALYN AT A1.
LENGTH 8.1 cm. AGE 0+. CAUGHT AUGUST 1969.

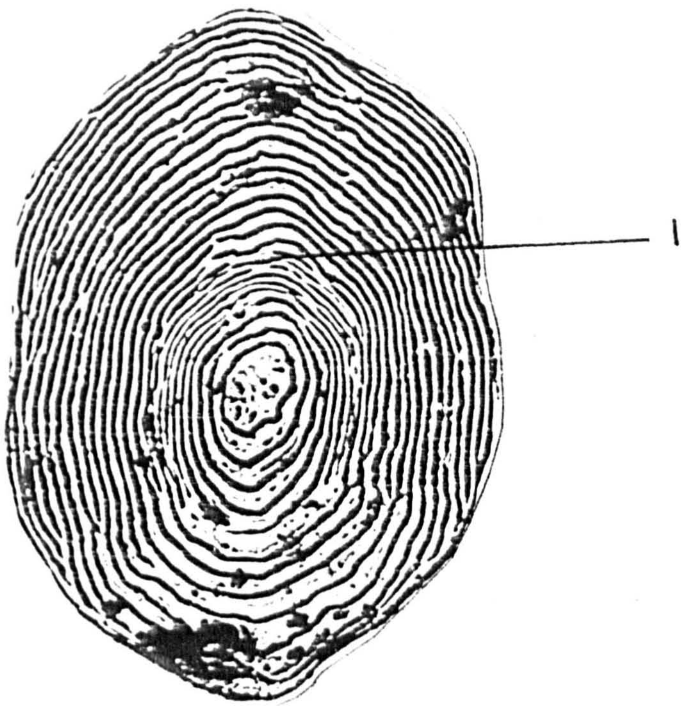


PLATE 10.6 SCALE OF BROWN TROUT FROM RIVER ALYN. CAUGHT IN NOVEMBER 1969 BETWEEN A1 AND A2. LENGTH 12.8 CM. AGE 1+.

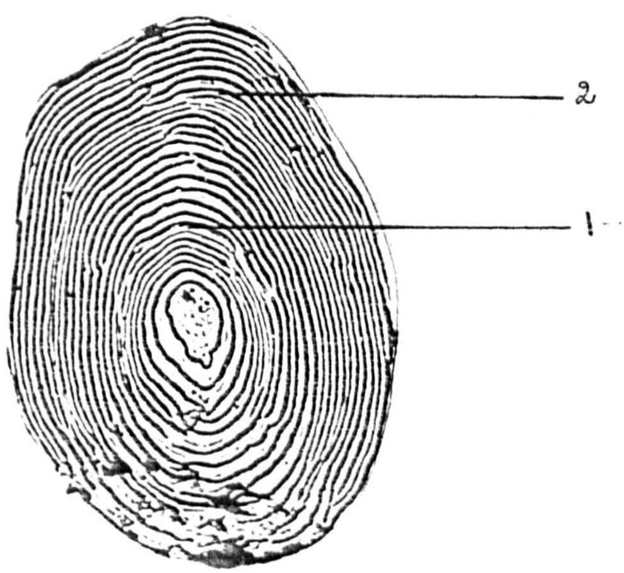


PLATE 10.7 SCALE OF BROWN TROUT FROM RIVER ALYN. CAUGHT IN NOVEMBER 1969 BETWEEN A1 AND A2. LENGTH 15.6 CM. AGE 2+.

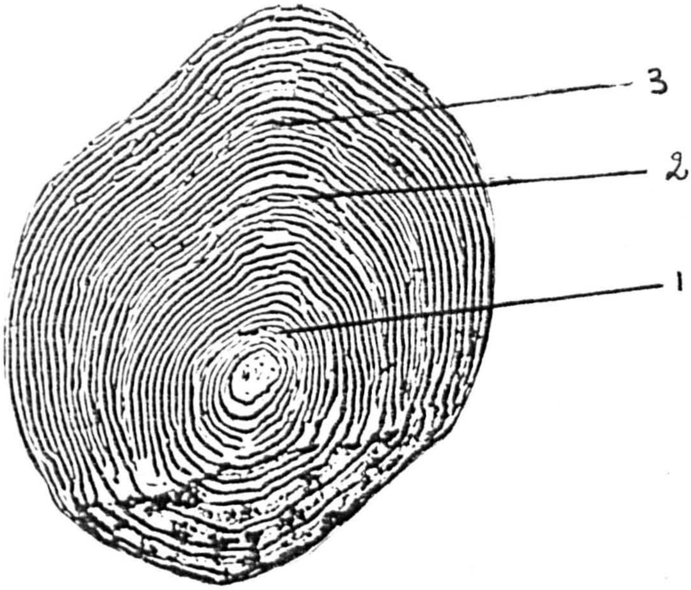


PLATE 10.8 SCALE OF BROWN TROUT FROM RIVER ALYN. CAUGHT IN OCTOBER 1969 BETWEEN A1 AND A2. LENGTH 18.6 CM. AGE 3+.

PLATE 10.9 SCALE OF BROWN TROUT FROM RIVER ALYN. CAUGHT IN OCTOBER 1969 BETWEEN A1 AND A2. LENGTH 22.6 CM. AGE 4+.

Table 10.1 Water samples were taken on 25.6.1970 and analysed by the pollution laboratories of the Dee and Clwyd River Authority

Sampling stations →	Rhyd-y-Golen bridge	U/S Synthite Ltd. Mold	Synthite Ltd. Mold	Opposite Synthite Ltd.	20 yds. U/S of Synthite ditch	Ditch taking Synthite Cooling water	20 yds. D/S of Synthite ditch	Lead mill bridge	Llang.	Pontblyddyn bridge	Caerowrle weir	Llay colliery water course.	Cefn-y-bedd	Bradley mill farm bridge	Rossett foot bridge	Ithell's bridge
Time	9.00	10.55	10.25	9.45	9.35	9.25	9.20	11.10	11.25	11.35	11.50	12.10	12.30	12.45	13.30	13.50
Appearance	T1 Y1	T2 Y1	T5 YG5	T1 YN1	T1 YN1	T2 N1	T1 Y1	T1 YN2	T2 YN1	T2 YG2	T2 YG2	T1 YG2	T2 YN2	T2 YN2	T2 YN2	T1 YN2
Odour	E1	E1	O.S	Em2	Em1	E2	E1	E1	EBs2	E2	Em2	O.S	O.S	E2	Em2	E1
pH	7.8	7.9	11.7	8.5	7.9	7.6	7.6	7.7	7.7	7.7	7.8	7.9	8.2	8.2	8.1	8.3
Temperature °C	13.0	14.5	45.0	15.0	15.0	18.0	15.5	15.5	13.5	14.5	15.0	14.5	16.0	15.0	15.5	16.5
Dissolved O2	9.9	10.6	-	10.4	10.5	7.1	9.2	7.7	7.1	8.7	9.0	9.7	10.1	10.6	10.7	13.3
Dissolved O2, % saturation	97	108	-	107	108	78	95	80	70	88	92	98	106	108	111	140
B.O.D. (4 hours at 27°C)	1.1	3.0	235.0	1.5	1.0	20.0	6.5	3.3	2.3	2.8	2.3	1.5	2.2	2.3	3.5	1.5
Permangenate value (4 hours at 27°C)	2.8	3.7	57.1	2.7	2.6	21.9	4.8	3.4	3.8	3.9	5.1	3.2	2.4	2.9	7.3	3.5
C.O.D. (Dichromate value)	-	-	374.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrogen, as N, ammoniacal, free + saline	0.13	0.06	12.5	0.03	0.44	13.5	6.0	0.14	0.21	0.59	0.33	0.70	0.24	0.43	0.28	0.09
Chloride, as Cl	26	30	216	33	34	38	35	35	45	41	54	184	54	43	59	60
Solids suspended	-	-	302	-	-	-	-	-	-	-	-	-	-	-	-	-

Results, except where stated otherwise, as mg. per litre.
Key:- U/S = Upstream, D/S = Downstream, O.S = Organic solvent

For qualitative descriptions of odours and appearances see code A.W.A. 12th edition.

Table 10.2 Seasonal variations of the chemical constituents of the River Alyn at Ithel's bridge, analysed by the pollution laboratories of the Dee and Clwyd River Authority. Results, except where stated otherwise, as mg. per litre.

For qualitative descriptions of odours and appearances see code A.W.A. 12th edition.

	20th July, 1969	18th August	16th September	15th October	13th November	12th December	10th January, 1970	8th February	9th March	10th April	1st May	4th June	3rd July, 1970
Time	9.55	9.5	9.10	9.10	9.5	8.10	11.45	11.55	13.15	11.50	11.45	11.50	11.30
Appearance	T2 NG2	T2 Y1	T3 NG2	T3 G2	T3 NY3	T3 G2	T4 NY3	T3 NY3	T3 NY3	T3 N3	T2 YG1	T2 YG2	T1 YN2
Odour	E2	E1	E2	E2	E/m2	E/m2	E/m3	m3	E/2	E/ch2	E1	mm/m3	Em2
Specific Conductance (micromhos/3 cm. at 25°C)						540				571	710		
pH	7.8	8.1	7.9	7.6	7.8	8.2	7.4	8.1	8.3	8.4	8.2	8.3	8.5
Temperature °C	16.3	15.7	12.7	12.0	6.0	4.0	4.0	4.0	3.7	5.7	14.0	15.4	13.5
Dissolved O2	9.6	9.4	9.2	9.4	11.4	13.0	12.6	12.7	13.0	12.4	12.1	11.0	13.6
Dissolved O2, % saturation	97	98	86	90	95	102	99	98	102	102	120	113	135
B.O.D. (5 days at 20°C)	2.0	1.2	2.3	2.3	2.4	1.6	4.7	1.8	3.1	3.3	1.6	3.1	1.5
Permanganate value (4 hours at 27°C)	3.2	3.2	3.2	3.6	98	2.9	138	3.3	2.6	6.5	2.3	5.4	1.4
C.O.D. (Dichromate value)	9.8					10.5	13.7						
Nitrogen, as N ammoniacal, free + saline	0.06	-	0.19	-	0.2	0.1	0.8	-	0.5	-	0.1	-	0.1
" " nitrate	0.02	-	0.04	-	0.03	0.04	0.04	-	0.03	-	0.1	-	0.03
" " total oxidised						7.2	-	-	-	-	4.2	-	-
Chloride, as Cl	53	60	56	61	45	35	70	36	85	30	45	53	52
Solids, dissolved						355					511		
" suspended	14					17					5		
Hardness, as CaCo3, total	320	325	300	330	140	220	160	160	135	175	340	310	270
" " " calcium	240	265	265	250	130	200	135	80	125	145	270	250	220
" " " magnesium	80	60	35	80	10	20	25	80	10	30	70	60	50
Alkalinity, as CaCo3						145				16.2	216		
Sulphates, as So4						38				24	-		
Phenols, as C6H5OH						-				-	-		
Detergents, Anionic						0.06				0.05			
Silicates, Reactive, as SiO2						2.8				5.2			
Phosphates, total as PO4						0.5				1.6	0.6		
Iron, total, as Fe						0.6				0.4	0.5		
" soluble, as Fe						0.1				0.16	0.1		
Manganese, total as Mn						0.1				-	0.06		
" soluble as Mn						0.06				-	-		
Formaldehyde	-	-	-	-	-	-	-	-	-	-	-	-	-

A_3 (Plate 10.3) was situated at an altitude of 109.3m O.D. near Mold below the Synthite and Sewage disposal works. The width of the river bed was between 2-4m and was covered with pebbles and gravel. The trees, mostly Scots Pine and silver birch, covered the stream and throughout the sampling period, except during flood, decaying plants and debris were noticed everywhere on the bottom. Here a putrid smell was noticed each time the site was visited.

A_4 (Plate 10.4) lies in the lower reaches of the stream near Rossett (Nat. Grid Ref. 366573). This station was situated at an altitude of 15m O.D. Here the stream was about 1-2m in depth and 5-7m in width. The bottom was muddy but at places covered with stones. The vegetation was poor on either side but there were thick patches of algae on the stones.

(c) Physical and Chemical conditions

Tables Io.1 and 10.2 show the physical and chemical conditions during July 1969 to July 1970. The water temperature ranged from 3.7 - 4°C in winter and from 14 - 16.3°C in summer. Maximum percentage saturation of oxygen was recorded during summer and minimum in autumn. pH ranged between 7.4 and 8.5. The dissolved chemicals indicated stream conditions only at the time of sampling and occasional spills of wastes were not detected. Chemical testing may not reveal evident pollution qualities when wastes are highly

Table 10.3 The density (Av. no./m^2) of the bottom fauna at four sampling sites, based on 14 monthly samples.

+ = <0.1% - = No record

	Above Synthite works		Below Synthite works		
Bottom fauna	A1	A2	A3	A4	Total (%)
Turbellaria (Total)	(-)	(6.4)	(5.3)	(-)	(+)
Polycelis nigra	-	0.7	4.2	-	+
Polycelis felina	-	5.3	1.0	-	+
Hirudinea	(6.4)	(10.3)	(9.6)	(8.5)	(0.2)
Glossiphonia complanata	6.4	9.6	5.3	2.1	0.1
Erpobdella octoculata	-	0.7	3.2	6.4	+
Helobdella stagnalis	-	-	0.7	-	+
Oligochaeta	(37.4)	(82.3)	(19.2)	(26.7)	(1.4)
Stylodrilus heringianus	28.8	34.2	5.3	10.7	0.7
Lumbriculus variegatus	2.1	28.8	2.1	9.6	0.3
Rhyacodrilus coccineus	0.7	0.7	-	-	+
Aulodrilus pluriseta	0.7	16.0	-	0.7	0.1
Homochaeta naidina	2.1	0.7	-	-	+
Eiseniella tetrahedra	1.0	0.7	2.1	1.0	0.1
Limnodrilus hoffmeisteri	-	-	7.4	0.7	+
Peloscolex ferox	-	-	-	2.1	+
Gastropoda	(24.8)	(96.1)	(2347.5)	(81.0)	(10.8)
Limnaea pereger	8.5	21.4	75.9	11.7	0.6
Ancylastrum fluviatile	14.9	51.3	18.1	19.2	0.8
Limnaea glabra	0.7	3.2	1.0	-	+
Succinea pfeifferi	0.7	-	3.2	2.1	+
Limnaea truncatula	-	7.4	1235.8	23.5	5.0
Potamopyrgus jenkinsi	-	12.8	1009.0	23.5	4.2
Limnaea palustris	-	-	2.1	-	+
Ancylus lacustris	-	-	-	1.0	+
Lamellibranchiata	(3.9)	(37.4)	(156.1)	(27.7)	(1.2)
Pisidium cinerium	3.2	35.3	32.1	2.1	0.5
Pisidium lilljeborgii	0.7	2.1	-	25.6	+
Pisidium subtruncatum	-	-	119.8	-	0.5
Pisidium milium	-	-	4.2	-	+
Amphipoda	(324.2)	(1058.2)	(2974.6)	(1748.3)	(37.4)
Gammarus pulex	324.2	1058.2	2974.6	1748.3	37.4
Isopoda	-	-	(10.7)	(6.4)	(0.1)
Asellus meridianus	-	-	10.7	6.4	0.1
Hydracarina	(113.3)	(39.5)	(1.0)	(2.8)	(1.5)
Sperchan denticulatus	-	-	-	0.7	+
Hygrobates nigromaculatus	111.2	37.4	-	2.1	1.4
Lebertia porosa	2.1	2.1	1.0	-	+
Plecoptera	(193.6)	(148.7)	(23.1)	(9.4)	(3.5)
Leuctra hippopus	21.4	2.1	1.0	3.2	0.3
Leuctra geniculata	87.7	16.0	21.4	-	1.1
Amphinemura sulcicollis	27.8	39.5	-	1.0	0.7
Nemoura avicularis	10.7	60.9	-	1.0	0.7
Leuctra fusca	1.0	7.4	0.7	-	0.1
Isoperla grammatica	8.5	0.7	-	-	0.1
Chloroperla tripunctata	0.7	-	-	-	+
Chloroperla torrentium	5.3	-	-	-	+
Brachyptera risi	3.2	0.7	-	-	+
Nemoura cambrica	2.1	-	-	-	+
Nemoura cinerea	2.1	-	-	-	+

Table 10.3 (contd.)

Bottom fauna	A1	A2	A3	A4	Total (%)
Amphinemura standfussi	13.9	16.0	-	4.2	0.3
Leuctra inermis	1.0	-	-	-	+
Leuctra nigra	1.0	1.0	-	-	+
Nemurella picteti	-	0.7	-	-	+
Ephemeroptera	(370.0)	(489.2)	(299.9)	(866.9)	(15.9)
Baëtis rhodani	100.5	95.2	60.9	178.6	3.4
Heptagenia lateralis	64.2	-	-	2.1	0.6
Ecdyonurus venosus	14.9	5.3	20.3	6.4	0.3
Ecdyonurus dispar	0.7	13.9	71.6	23.5	0.8
Habrophlebia fusca	56.7	12.8	2.1	11.7	0.7
Centroptilum luteolum	36.3	96.3	0.7	42.8	1.6
Ephemerella ignita	37.4	187.2	44.9	551.0	6.3
Rhithrogena semicolorata	44.9	17.1	6.4	7.4	0.7
Paraleptophlebia submarginata	1.0	-	-	-	+
Baëtis pumilus	6.4	42.8	82.3	28.8	0.9
Baëtis scambus	5.3	8.5	10.7	10.7	0.2
Caenis mosta	0.7	-	-	-	+
Ephemera danica	1.0	1.0	-	0.7	0.2
Baëtis atribatinus	-	2.1	-	-	+
Ephemerella notata	-	0.7	-	-	+
Ecdyonurus torrentis	-	2.1	-	3.2	+
Heptagenia sulphurea	-	4.2	-	-	+
Megaloptera	(2.1)	(7.4)	(5.3)	(2.1)	(0.1)
Sialis lutaria	2.1	7.4	5.3	2.1	0.1
Hemiptera	(-)	(1.4)	(0.7)	-	(0.1)
Sigara distincta	-	0.7	-	-	+
Valia nymph	-	0.7	-	-	+
Corixa panzeri	-	-	0.7	-	+
Trichoptera	(58.9)	(95.9)	(100.3)	(17.6)	(2.0)
Hydropsyche instabilis	2.1	-	-	2.1	+
Potamophlax latipennis	32.1	39.5	79.1	7.4	1.0
Sericostoma personatum	6.4	-	-	2.1	0.1
Rhyacophila dorsalis	0.7	0.7	0.7	-	+
Agapetus fuscipus	1.0	2.1	0.7	-	0.4
Halesus digitatus	3.2	17.1	7.4	0.7	0.2
Mystacides nigra	0.7	1.0	-	2.1	+
Glyphotaelius pellucidus	9.6	26.7	10.7	3.2	0.4
Anabolia nervosa	2.1	0.7	-	-	+
Plectrocnemia conspersa	1.0	-	1.0	-	+
Diplectrona felix	-	0.7	-	-	+
Limnophylax centralis	-	7.4	-	-	0.1
Limnephilus rhombicus	-	-	0.7	-	+
Coleoptera	(237.6)	(79.7)	(385.9)	(142.7)	(5.7)
Oreodytes rivalis	85.6	0.7	8.5	69.5	1.5
Haliplus lineatocollis	6.4	-	18.1	2.1	0.1
Helophorus flavipes	8.5	-	-	4.2	0.1
Helmis maugei	29.9	25.6	317.7	21.4	2.0
Latelmis volkmari	35.3	44.9	40.6	23.5	1.3
Lacobius biguttatus	1.0	-	-	-	+
Platambus maculatus	5.3	2.1	1.0	0.7	0.1
Hydraena riparia	0.7	-	-	5.3	+
Hyphydrus ovatus	64.2	6.4	-	16.0	0.8
Helodes marginata	0.7	-	-	-	+
Dixidae	(0.7)	(-)	(-)	(-)	(+)
Dixa puberula	0.7	-	-	-	-
Ceratopogonidae	(34.2)	(16.0)	(2.1)	(3.2)	(0.5)
Bezzia spp.	34.2	16.0	2.1	3.2	0.5

Table 10.3 (contd.)

Bottom fauna	A1	A2	A3	A4	Total (%)
Tipulidae	(5.3)	(0.7)	(-)	(0.7)	(+)
Tipula lateralis	3.2	0.7	-	0.7	+
Tipula paludosa	2.1	-	-	-	-
Simuliidae	(37.1)	(3.8)	(0.7)	(8.8)	(1.1)
Simulium brevicaule	10.7	1.0	-	0.7	0.1
Simulium monticola	25.6	2.1	0.7	5.3	1.0
Simulium ornatum	0.1	-	-	0.7	+
Simulium angustitarse	0.7	-	-	2.1	+
Simulium armoricanum	-	0.7	-	-	+
Chironomidae	(926.3)	(312.4)	(87.4)	(350.7)	(15.0)
Polypedilum nubeculosus	6.4	35.3	14.9	78.1	1.0
Pentaneura monilis	38.5	53.5	6.4	28.8	1.1
Trichocladius rufiventris	64.2	23.5	17.1	78.1	1.5
Tanytarsus signatus	214.4	162.6	5.3	28.8	3.9
Prodiamesa olivacea	392.6	7.4	32.1	88.8	4.6
Procladius choreus	171.2	23.5	5.3	48.1	2.2
Orthocladius spp.	34.2	0.7	2.1	-	0.4
Strictochironomus spp.	2.1	-	2.1	-	+
Brillia modesta	1.0	4.2	2.1	-	+
Chironomus anthracinus	1.0	1.0	-	-	+
Cryptochironomus spp.	0.7	0.7	-	-	+
Other dipteran larvae	(95.0)	(72.6)	(32.0)	(37.3)	(1.9)
Dicranota robusta	71.6	36.3	21.4	7.4	1.1
Hermerodromia unilineata	22.4	36.3	9.6	29.9	0.8
Pericoma pseudo exquisita	1.0	-	1.0	-	+
Dipteran pupae	(63.1)	(64.2)	(5.3)	(43.8)	(1.3)
Total no. animals	3361	3461	8489	4455	
Av. no. animals/month	240.0	247.2	606.3	318.2	
Av. no. animals/m^2	2568.0	2745.0	6487.4	3404.7	

Table 10.4 Distribution of the catches sampled above (A2) and below (A3) the Synthite works.

Groups	Catches: Above Synthite works (A2)	Catches: Below Synthite works (A3)	Total	Chi squared $x^2(1)$	P
Turbellaria	9	8	17	.04	>0.05
Hirudinea	14	13	27	.02	>0.05
Oligochaeta	108	26	134	25.0	<0.001
Gastropoda	131	3072	3203	2700.0	<0.001
Lamellibranchiata	50	206	256	95	<0.001
Amphipoda	1385	3893	5278	1191.6	<0.001
Isopoda	-	-	-	-	
Hydracarina	52	2	54	46.2	<0.001
Plecoptera	195	32	227	117	<0.001
Ephemeroptera	647	397	1044	59.8	<0.001
Megaloptera	10	7	17	0.5	>0.05
Hemiptera	2	1	3	0.3	>0.05
Trichoptera	129	133	262	.06	>0.05
Coleoptera	107	509	616	262.2	<0.001
Diptera:					
Ceratopogonidae	21	4	25	11.4	<0.001
Simuliidae	6	1	7	21.8	<0.001
Tipulidae	-	-	-	-	
Chironomidae	413	120	533	161.0	<0.001
Dipteran larvae	96	44	140	19.2	<0.001
Dipteran pupae	85	7	92	66.0	<0.001

treated even though the receiving stream may be adversely affected by such effluents because the effects may be additive. The detailed chemical analysis (Tables 10.1, 10.2) showing seasonal variations in the chemical constituents of the river water was provided by the pollution laboratories of the Dee and Clwyd River Authority.

4. COMPOSITION OF THE BOTTOM FAUNA

Collections from A_1, A_2, A_3 and A_4 stations yielded a total of 84, 80, 62 and 65 species respectively (Table 10.3). The number of species found at A_1 and A_2 were typical of an unpolluted stream fauna (see Chapters III,IV,V,VI and VII) but at A_3 and A_4 the number decreased. Table 10.4 summarizes the relative abundance of different species collected during this period and is expressed in Av.No/m^2. The bottom fauna at stations A_3 and A_4 was reduced and had a smaller number of species as compared to A_1 and A_2. A decrease in the density of aquatic beetles, stoneflies, caddisflies, Dixidae, Ceratopogonidae, Tipulidae, Simuliidae, and Chironomidae was noticed from A_2 to A_3 (Table 10.4). These may be called 'pollution intolerant' organisms. Stations A_3 and A_4 located below the site of the spill (Fig.10.1) had a typical 'pollution tolerant' community. Pollution tolerant gastropods, isopods and amphipods made up the major part of the community, probably indicating the additive effect of sedimentation and toxicity from the spill. The common species collected are mentioned below (Table 10.3).

(A) Platyhelminthes

(1) Turbellaria

Polycelis nigra and Polycelis felina were scarce at A_2 and A_3.

(B) Annelida

(1) Hirudinea

0.2% of the total fauna belonged to this group in which Glossiphonia complanata and Erpobdella octoculata were collected from all the sites.

(2) Oligochaeta

1.4% of the benthic fauna was formed by this group, of these Stylodrilus heringianus were common at A_1, A_2 and A_4, and Lumbriculus variegatus at A_2 and A_4. The number of oligochaetes below the spill at A_3 was greatly reduced (Table 10.3) and may be due to the lack of a muddy bottom. Specimens of Limnodrilus hoffmeisteri were frequent at A_3 and according to Hynes (1960) are found in large numbers in grossly polluted water.

(C) Mollusca

(1) Gastropoda

10.8% of the macroinvertebrates were represented by this group in which Limnaea pereger and Ancylastrum fluviatile were common in all stations. Limnaea truncatula were common at A_3 and A_4, and Potamopyrgus jenkinsi at A_3 (Table 10.3). The high number of Potamopyrgus jenkinsi may be due not only to an ability to survive the effluent from Synthite works

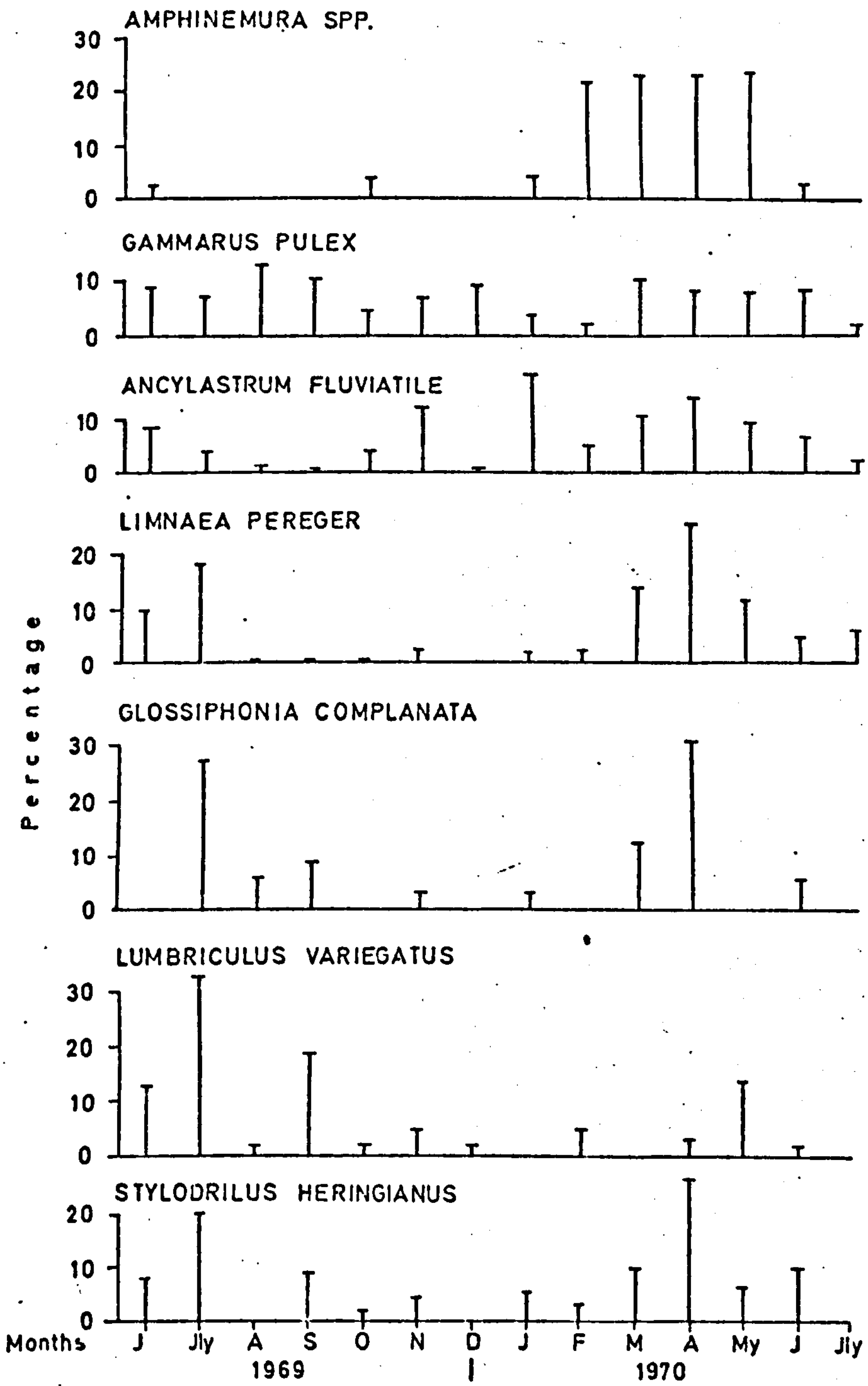


Fig. 10·4 Seasonal percentage composition of the common species of bottom fauna of the R. Alyn at A_3 but also to the absence of predators. Limnaea pereger were recorded more during spring and summer whereas few Ancylastrum fluviatile were collected during summer (Fig.10.4).

(2) Lamellibranchiata

This group made up 1.4% of the total fauna. Pisidium cinerium was common at A_2, Pisidium lillieborgii at A_4 and Pisidium subtruncatum at A_3.

(D) Arthropoda

(1) Crustacea

(a) Amphipoda

Gammarus pulex common in all stations formed 37.5% of the total benthic fauna and were collected in large numbers during every season (Fig.10.4), particularly at A_3 and A_4. Similar observations were made by Jones (1948a) in the hard water stream, the Clydach, in west Wales.

(b) Isopoda

Asellus meridianus were common in A_3 and A_4. This may be due to the presence of dead leaves.

(2) Arachnida

(a) Hydracarina

1.5% of the benthic fauna belonged to this group in which Hydrobates nigromaculatus was common at A_1 and the rest were scarce (Table 10.3).

(3) Insecta

(a) Plecoptera

This group formed 3.4% of the total benthic fauna in

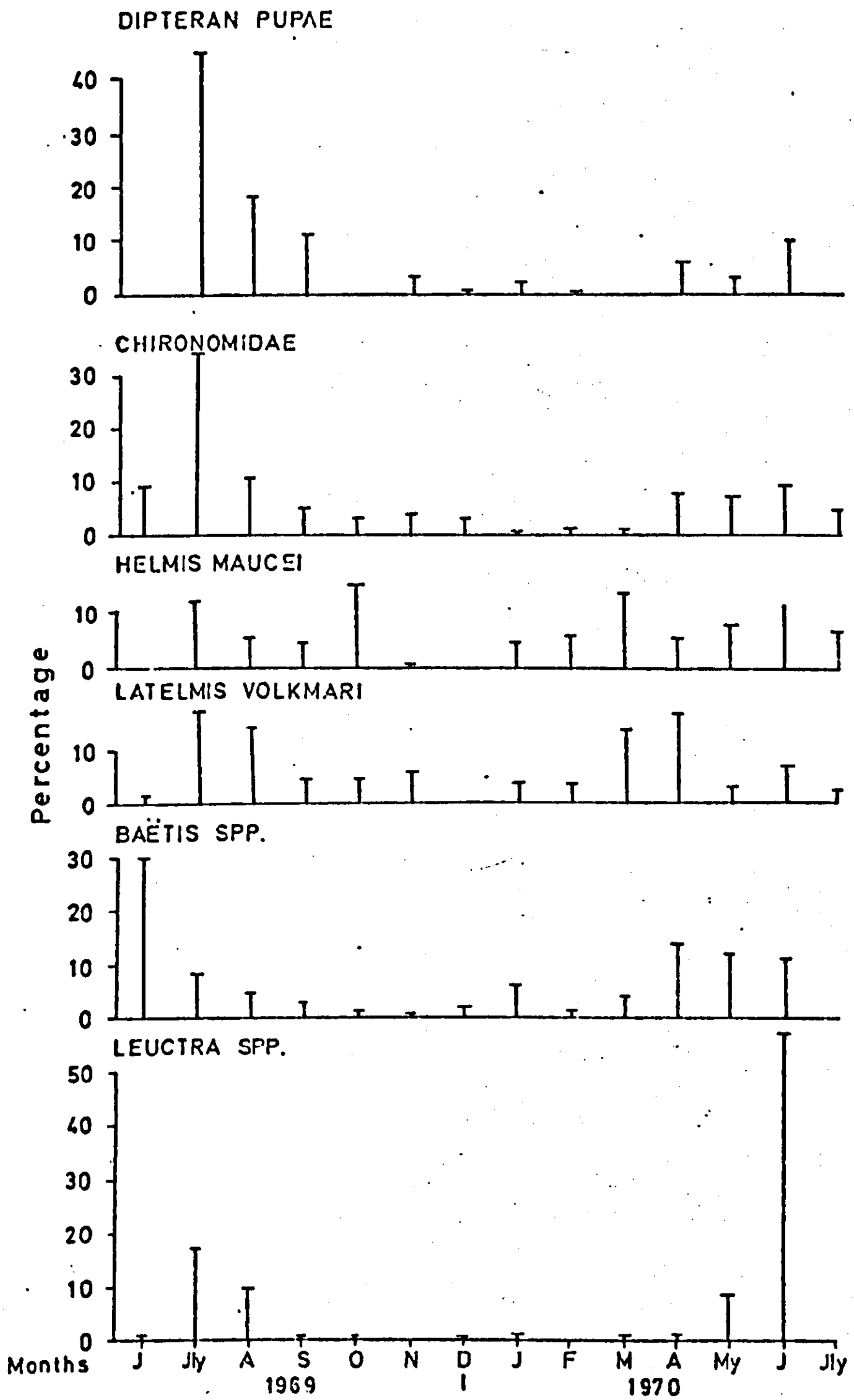


Fig.10·5 Seasonal percentage composition of the common species of bottom fauna which *Leuctra hippopus*, *Leuctra geniculata*, *Amphinemura sulcicollis*, *Nemoura avicularis*, *Isoperla grammatica* and *Amphinemura standfussi* were common at A_1 and *Nemoura avicularis* at A_2 (Table 10.3). *Leuctra* spp. were collected more during spring and summer and *Amphenemura spp.* during winter and spring (Figs. 10.4, 10.5). I found *Leuctra* more than *Amphinemura* at A_1 near the source of organic pollution, though *Amphinemura* seems to be the less affected by organic pollution than are most other Plecoptera (Hynes 1941).

(b) *Ephemeroptera*

These amounted to 15.8% of the total macrobenthic community. *Baetis rhodani* were at A_1, A_2 and A_4, *Heptagenia lateralis* at A_1, *Ecdyonurus venosus* in A_1, A_2 and A_3, *Habrophlebia fusca* in A_1, *Centroptilum luteolum* at A_1 and A_2, *Ephemerella ignita* at A_1 and A_4, *Rhithrogena semicolorata* at A_1 and *Baetis pumilus* at A_3 and A_4 (Table 10.3). *Baetis spp.* were recorded more during spring and summer (Fig.10.5). I recorded a decrease in *Rhithrogena* (Table 10.3) as did Butcher (1937) in the River Tees, a sewage-polluted river.

(c) *Megaloptera*

Sialis lutaria were scarce in all the stations.

(d) *Hemiptera*

Though scarce, they were recorded from A_2 and A_3 sites.

(e) *Trichoptera*

These formed 2.0% of the benthic fauna. *Potamophylax* *latipennis* were common in all the stations, *Sericostoma personatum* at A_1, *Helesus digitatus* at A_3 and *Glyphotaelius pellucidus* at A_2 (Table 10.3). I found *Sericostoma personatum* affected by pollution at A_3 and A_4. Similar observations were made by Hynes (1960) while working on the Dee polluted by effluents.

(f) *Coleoptera*

Coleoptera were represented by 5.7% of the total bottom fauna. *Helmis maugei* and *Latelmis volkmari* were common in all the stations and were collected in every season (Fig.10.5). *Oreodytes rivalis* occurred at A_1 and A_4, *Haliplus lineatocollis* at A_3, *Helophorus flavipes* at A_1 and *Platambus maculatus* were common at A_1.

(g) *Diptera*

(1) *Ceratopogonidae*

Bezzia spp. though common at A_1 and A_2, formed only 0.5% of the total benthic fauna.

(2) *Simuliidae*

Simulium brevicaule and *Simulium monticola* formed 0.5% of the total benthic fauna and were common at A_1.

(3) *Chironomidae*

This group formed 15.2% of the benthic community; of these *Polypedilum nubeculosus* and *Pentaneura monilis* were common in A_2, *Trichocladius rufiventris* in A_2 and A_3, *Tanytarsus signatus* in A_1 and A_2, *Prodiamesa olivacea* in A_1, A_3 and A_4 and *Procladius choreus* in A_1. Chironomid larvae were more often recorded during spring and summer (Fig.10.5).

Table 10.5 Average density (Av.No./m^2) of the bottom fauna of the River Alyn and above and below the spill (Synthite works).

Benthic fauna	Above the spill				Below the spill			
	A1		A2		A3		A4	
	No.spp.	Av.No./m^2	No.spp.	Av.No./m^2	No.spp.	Av.No./m^2	No.spp.	Av.No./m^2
Turbellaria	-	-	2	6.4	2	5.3	-	-
Hirudinea	1	6.4	2	10.3	3	9.6	2	8.5
Oligochaeta	6	37.4	6	82.3	4	19.2	6	26.7
Gastropoda	4	24.8	5	96.1	7	2347.5	6	81.0
Lamellibranchiata	2	3.9	2	37.4	3	156.1	2	27.7
Amphipoda	1	324.2	1	1058.2	1	2974.6	1	1748.3
Isopoda	-	-	-	-	1	10.7	1	6.4
Hydracarina	2	113.3	2	39.5	1	1.0	2	2.8
Plecoptera	14	193.6	10	148.7	3	23.1	4	9.4
Ephemeroptera	13	370.0	14	489.2	9	299.9	12	866.9
Megaloptera	1	2.1	1	7.4	1	5.3	1	2.1
Hemiptera	-	-	2	1.4	1	0.7	-	-
Trichoptera	10	58.9	9	95.9	7	100.3	6	17.6
Coleoptera	10	237.6	5	79.7	5	385.9	8	142.7
Dixidae	1	0.7	-	-	-	-	-	-
Ceratopogonidae	1	34.2	1	16.0	1	2.1	1	3.2
Tipulidae	2	5.3	1	0.7	-	-	1	0.7
Simuliidae	4	37.1	3	3.8	1	0.7	4	8.8
Chironomidae	11	926.3	10	312.4	9	87.4	6	350.7
Other dipteran larvae	3	95.0	2	72.6	3	32.0	2	37.3
Dipteran pupae		63.1		64.2		5.3		43.8
Total No. spp.	86		76		62		65	
Av. No. spp./month	7.1		6.3		5.1		5.4	
Av. No. spp./month/m^2	75.9		67.4		54.5		57.7	
Av. No. Orgms./month/m^2		2568.0		2645.0		6487.4		3404.7

I found chironomids were reduced at A_3 but reappeared in greater numbers at A_4 (T-ble 10.5). This may be due to the greater dilution of the effluents. Hynes (1961) while working on the River Lee polluted by sewage and copper salts, found Orthocladiinae, Tanypodinae and *Tanytarsus spp.* were quite unaffected.

Other dipteran larvae

These formed 2.1% of the total catch and were represented by *Dicranota robusta* common in all stations, and *Hermerodromia unilineata* common at A_2 and A_4.

5. BIOLOGY OF TROUT

Fish samples were taken from June 1969 to July 1970. Altogether 1078 trout were caught during this period between A_1 and A_2. I did not catch any trout between A_3 and A_4.

There seemed to be no physical barrier to prevent trout from migrating between upper and lower reaches. Frank (personal communication), secretary of the Wrexham and District Angling Association (AA), reported that all the fish died due to a sudden spill of formaldehyde in the river below Pontblyddn (Nat. Grid Ref. 615272) in 1967. A similar incident was reported to me by Mr. Davis, secretary of the Rossett and Gresford Angling Association. Lees (Pers.comm.) also told me that the spill of formaldehyde was so strong that all the bottom fauna disappeared.

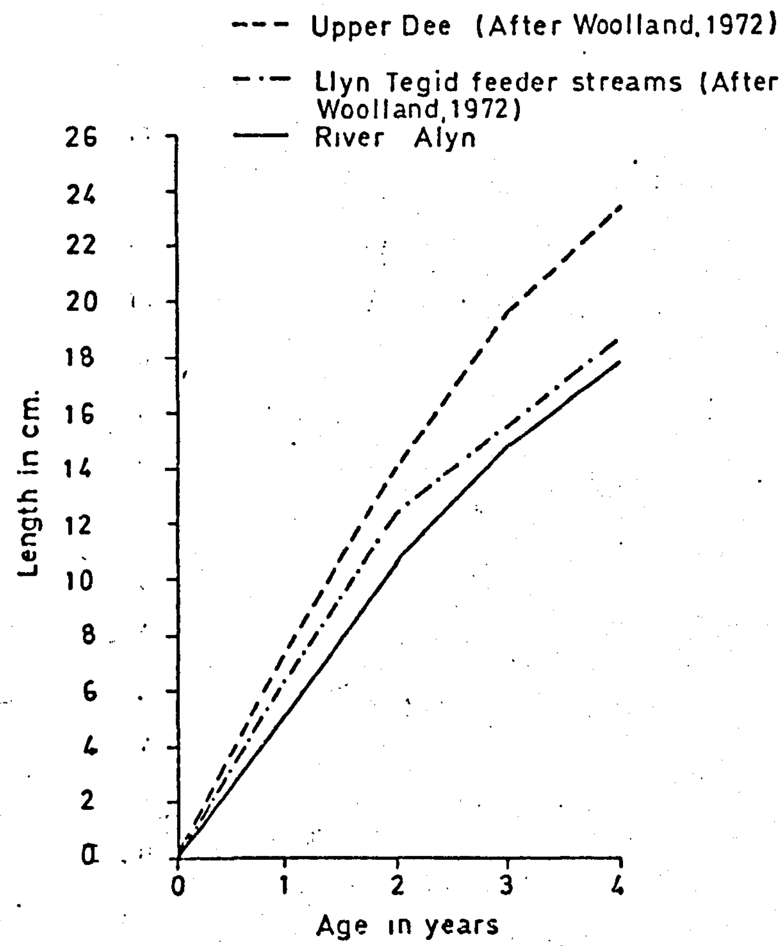


Fig. 10·6 Calculated growth of trout

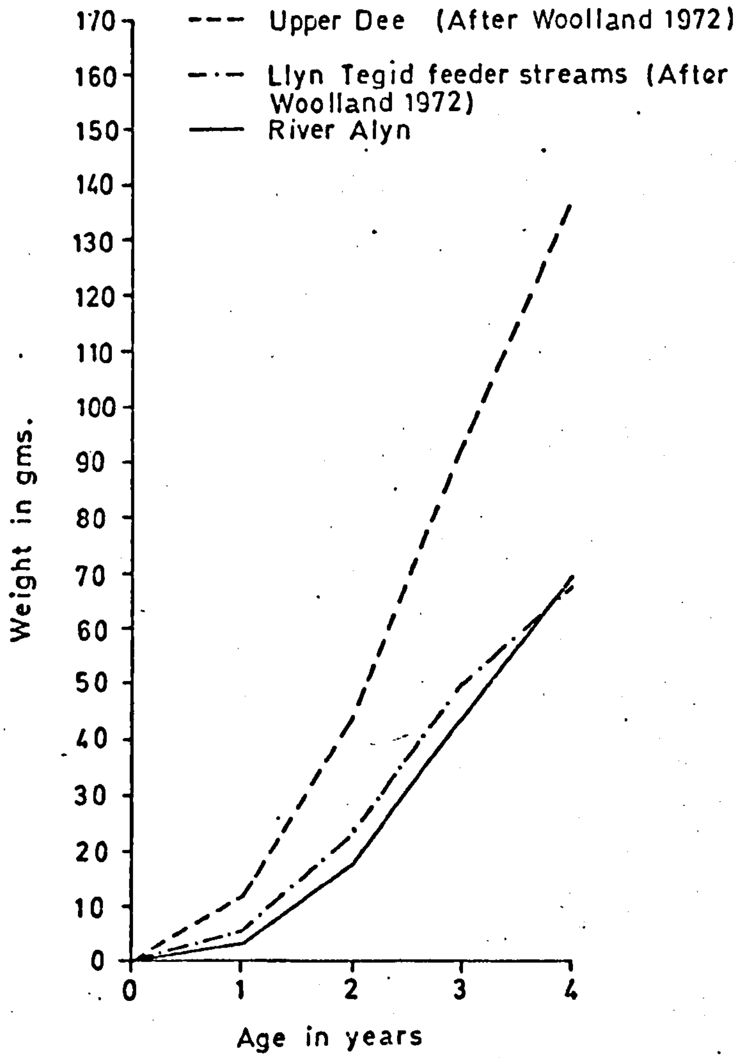


Fig.10·7 Annual growth in weight of trout

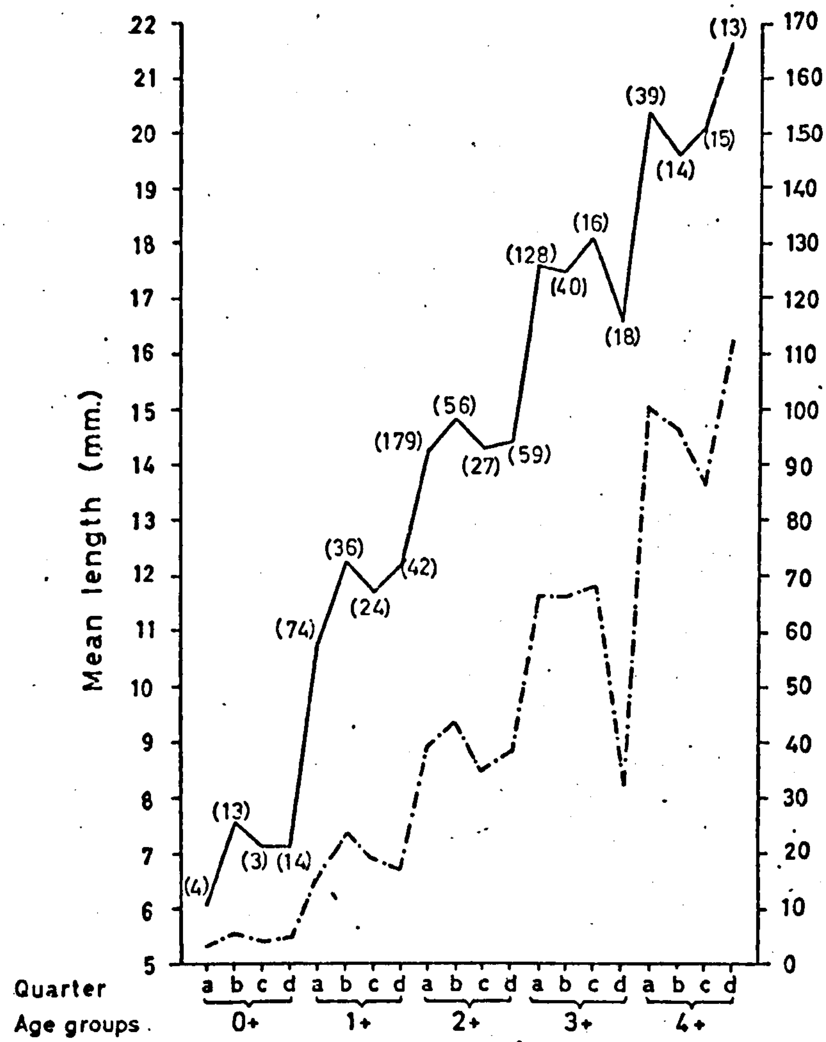


Fig.10·8 Length in each quarter and mean weight of 1,075 trout

a June-Aug. b Sep.-Nov. c Dec.-Feb d Mar.-May

—— Length —·— Weight ( ) Number of fish (trout)

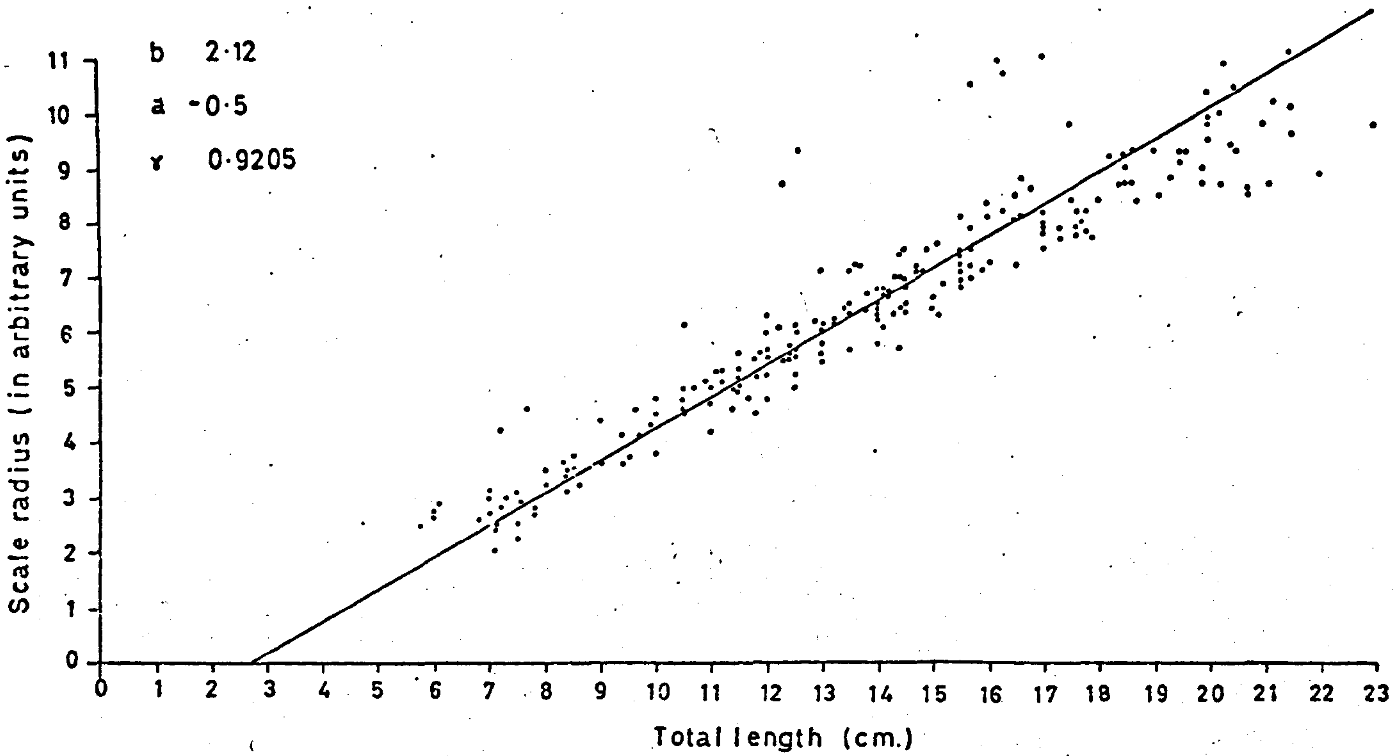


Fig.10·9. Body scale relationship of trout in the River Alyn.

(a) Age and growth

March 1st was chosen as a convenient birth date in view of Stuart's (1953) conclusions on the reproduction of loch brown trout. The open (or 'summer') rings were present on the edge of the scales during summer period April/May to September/October and the narrow 'winter' rings during the period September/October to April/May. This phenomenon has been described fully in Ball & Jones (1960).

Figs. 10.6 and 10.7 show the length and weight attained by each age group in the Alyn. In Fig. 10.8 the data have been arranged in quarterly groups so as to show seasonal as well as annual changes in growth rate. In age groups 0+ and 1+ a large increase in length and weight may be seen between June and November, but a small one between December and May. Visual examination of the slope of the curve suggests that in age group 2+ there was more increase in length and weight between June and November, and less between December and May. In age groups 3+ and 4+ the growth rates in length and weight decreased.

The relationship between body length and the anterior scale radii was calculated to determine whether growth of trout scales was proportional to growth of the body (Fig.10.9). A close correlation was found ($r = 0.9205$). These data demonstrated a linear relationship, indicating that they were subject to analysis by the linear regression formula

Log W = 1·8279 + 2·8708 Log L

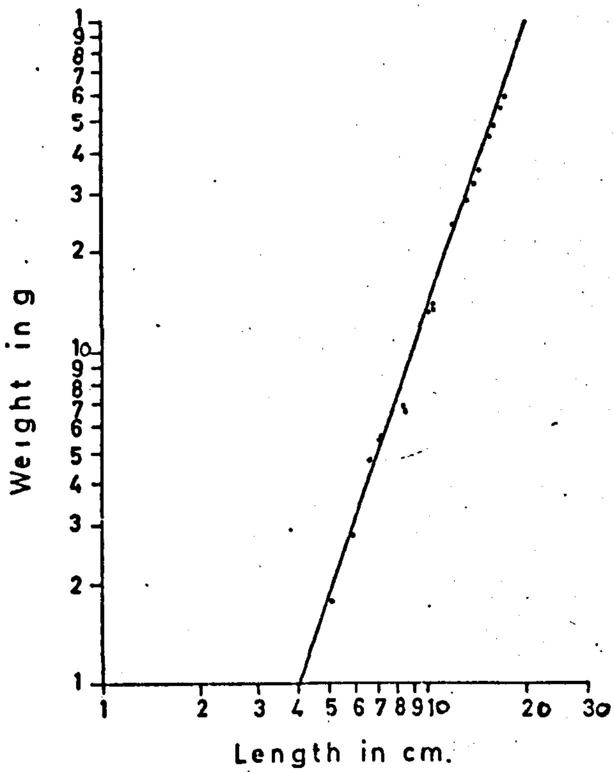


Fig.10·10 Length-weight relationship of trout

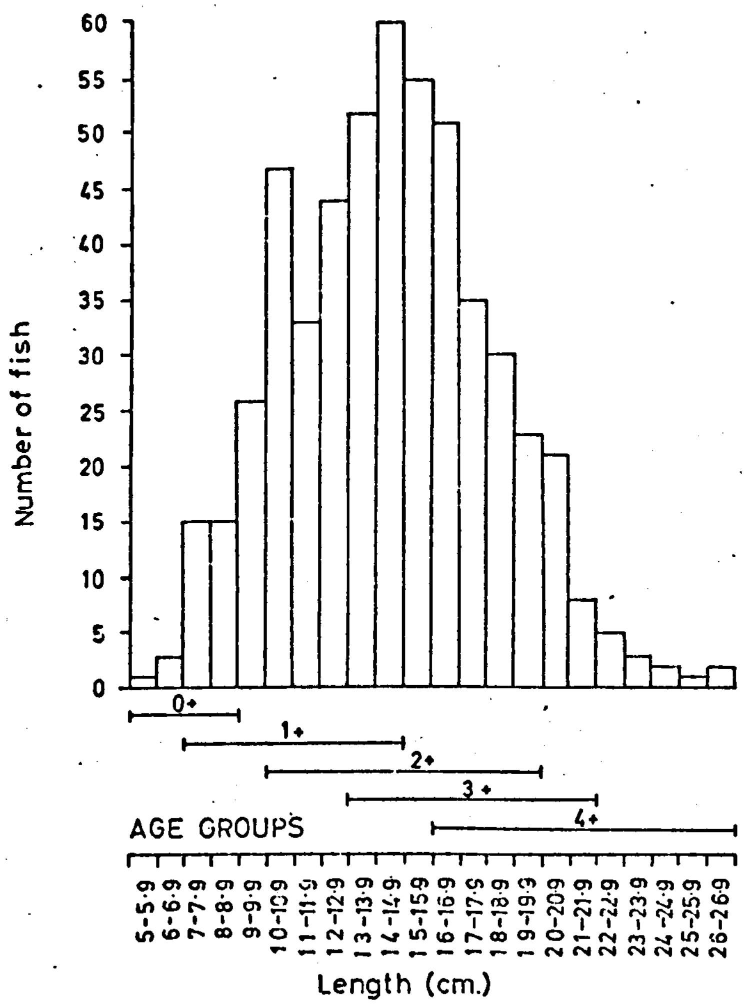


Fig. 10·11 Length frequency of 532 male trout showing overlap of age groups into different length groups

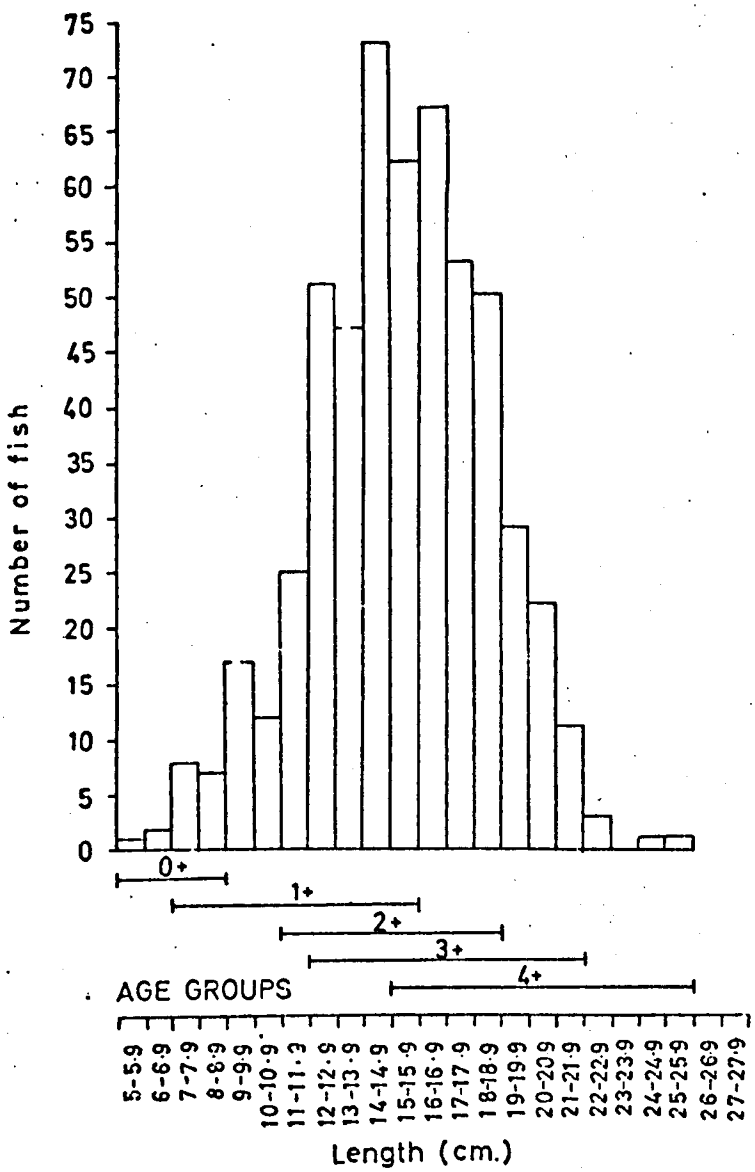


Fig. 10·12 Length-frequency of 542 female trout showing overlap of age groups into different length groups

Table 10.6 Length of trout in cm. as back-calculated from scales.

Year Class	No. Fish	Age at Capture	Sex	Mean calculated length at each year I	II	III	IIII
1968	362	1+	♂	5.6			
			♀	5.6			
			♂♀	5.6			
1967	350	2+	♂	5.0	10.7		
			♀	4.8	10.5		
			♂♀	4.9	10.6		
1966	149	3+	♂	4.9	10.8	14.5	
			♀	5.1	11.2	14.9	
			♂♀	5.0	11.0	14.7	
1965	42	4+	♂	5.2	10.5	15.1	17.8
			♀	4.9	10.8	14.8	18.1
			♂♀	5.1	10.6	14.9	17.9
Total fish 903							
Total mean calculated length			♂	5.2	10.6	14.8	17.8
			♀	5.1	10.8	14.8	18.1
			♂♀	5.1	10.7	14.8	17.9
Average increment			♂	5.2	4.4	4.2	3.0
			♀	5.1	5.7	4.0	3.3
			♂♀	5.1	5.6	4.1	3.1

$X = a + bY$. The calculated body scale regression is represented by : $L = -0.5 + 2.12S$ (See fig.10.9), where L is the length of the fish (cm) and S the scale radius (arbitrary units). These data reveal a straight-line relationship and demonstrate that scale length increases proportionally with body length. This relationship allows use of the Lee (1920) Method to calculate mean total lengths of fish at annulus formation (Table 10.6).

(b) Length-weight relationships

The length-weight relationship of the trout has been studied by plotting the logarithm of the mean annual length of each age group against the logarithm of the corresponding mean annual weight (Fig.10.10). The results lie in a straight line, indicating no fundamental change in the length-weight relationshp with age or locality.

The Le Cren method (1951) was employed to calculate the empirical mean length-weight relationship of the trout. The sample of 1078 fish was grouped into 10mm intervals of length ranging from 5cm to 25cm for which mean lengths and weights were determined (Figs. 10.11,10.12). The mean lengths and weights for each length group were plotted, and each sample exhibited a power-law relationship. This relationship is expressed by the formula :

$$W = aL^n$$ when

W = mean weight in grams of each length group at capture,

L = mean total length of a group, in millimetres,

a = empirical constant, n = empirical exponent.

Empirical constants, log a and n were determined as follows:

$$\log a = \frac{\log W. \quad (\log L)^2 - \log L. \quad (\log L.\log W)}{N. \quad (\log L)^2 - (\quad \log L)^2}$$

$$n = \frac{\log W - (N.\log a)}{\log L}$$

N = number of length groups.

Log a and N were substituted in the logarithmic form of the equation :

Log W = log a + n log L

Log W = 1.8279 + 2.8708 log L

When plotted, the smooth curve is used to express length-weight relationship (Fig.10.10).

(c) Condition

To quote Hile (1936) "weight in fishes may be considered a function of their length". Weight is proportional to the cube of the length in the ideal fish that does not change in shape with growth (Le Cren 1951). The Cube Law provides a method of indicating and comparing the condition or well-being of fish between length groups, age groups, sexes and populations. The formula used here for determination of the coefficient of condition is :

$$C = \frac{W \times 10^4}{L^n} \quad \text{where}$$

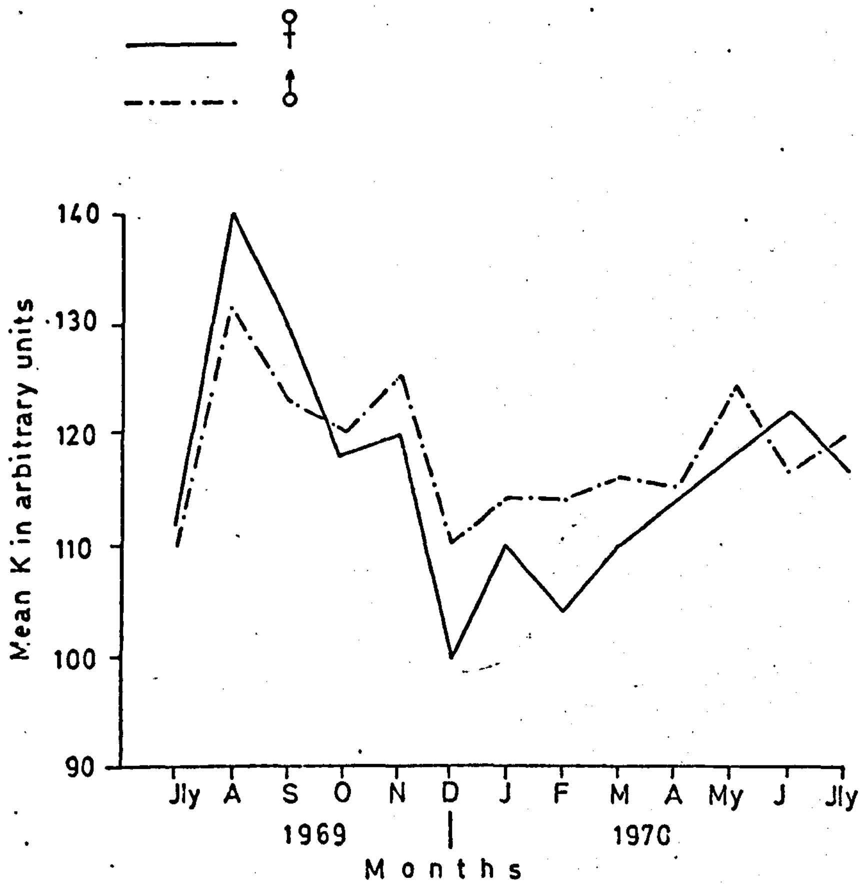


Fig. 10·13 Seasonal variations in mean condition factor K

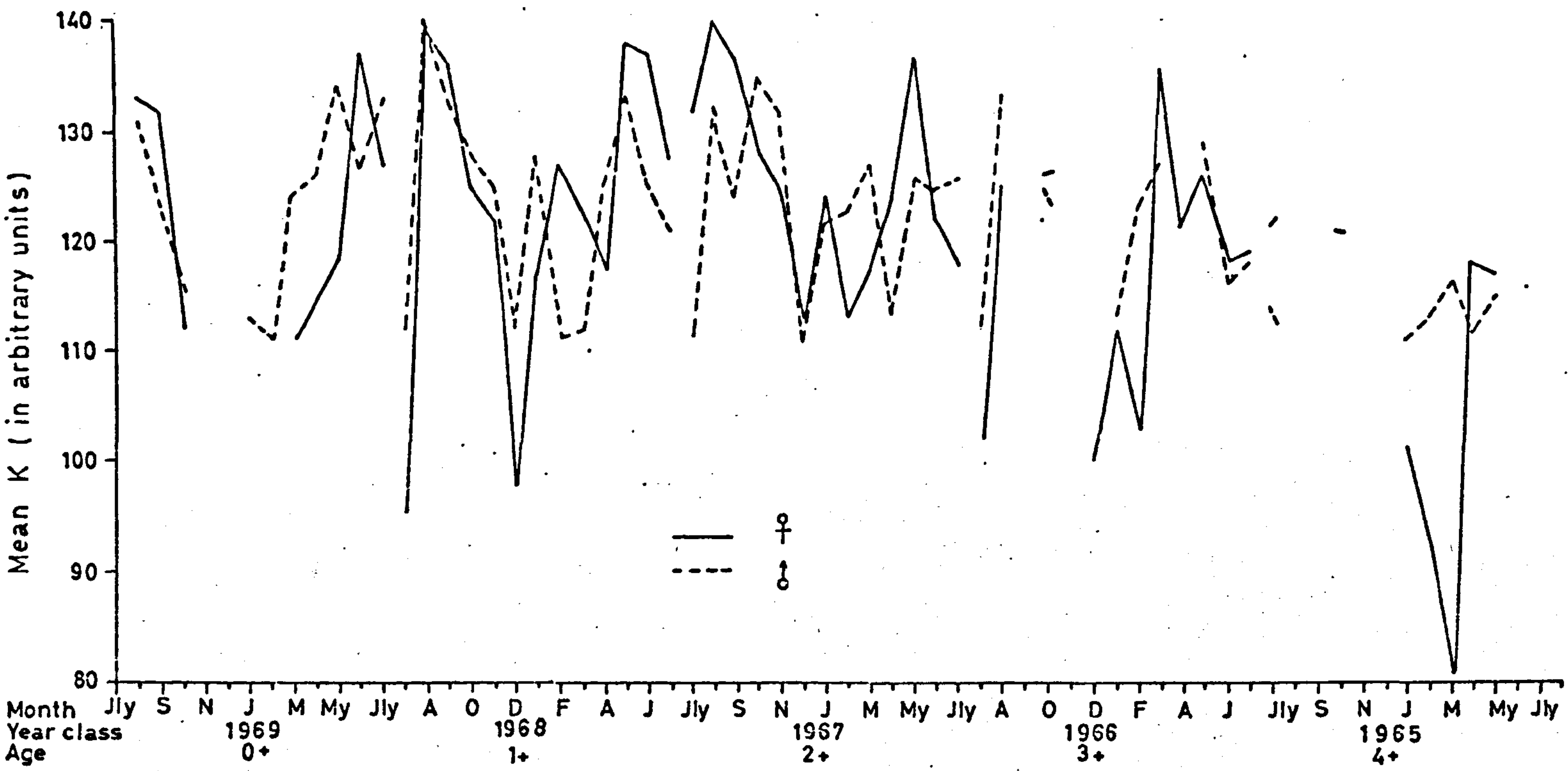


Fig. 10·14 Seasonal variations in mean condition factor K in each age group

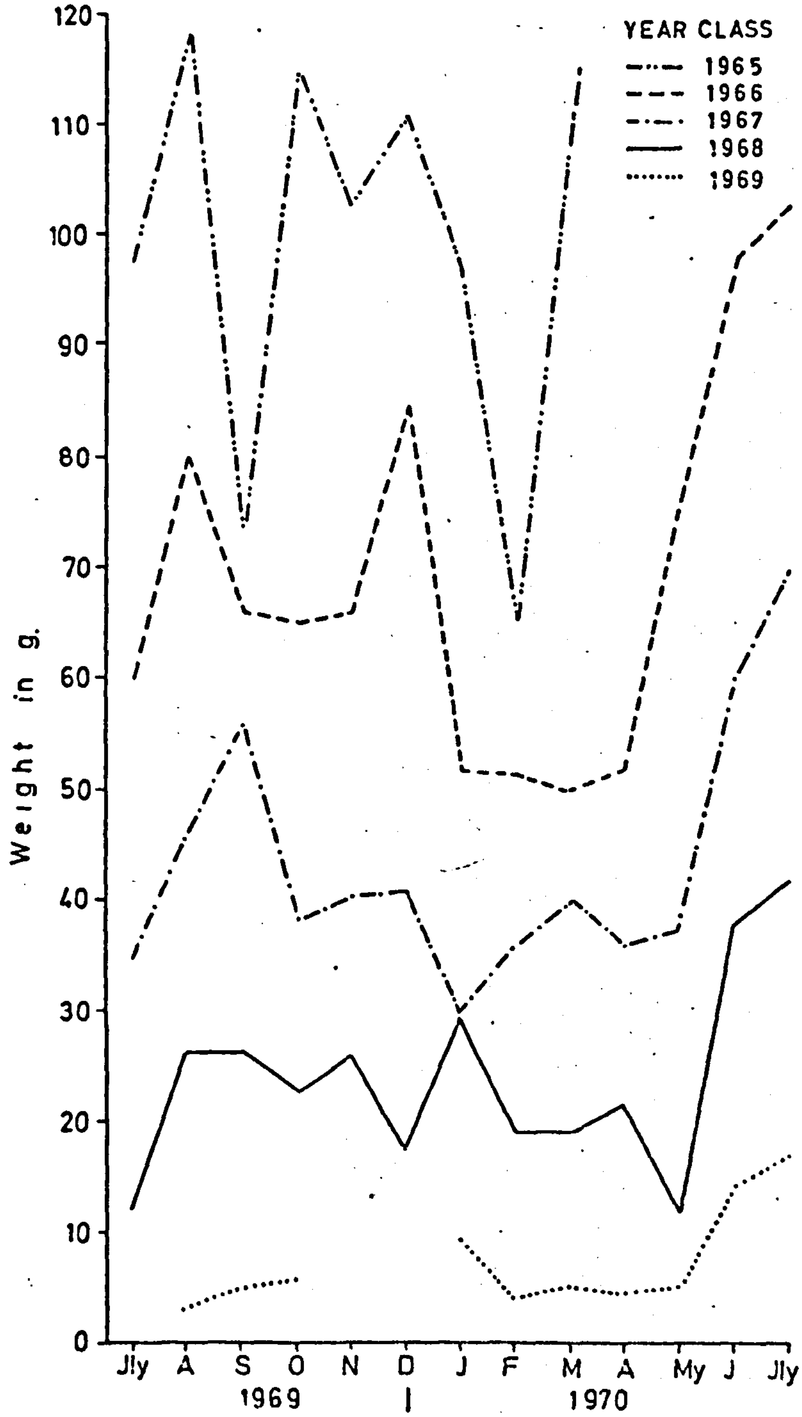


Fig. 10·15 Seasonal growth in weight of trout in the river Alyn.

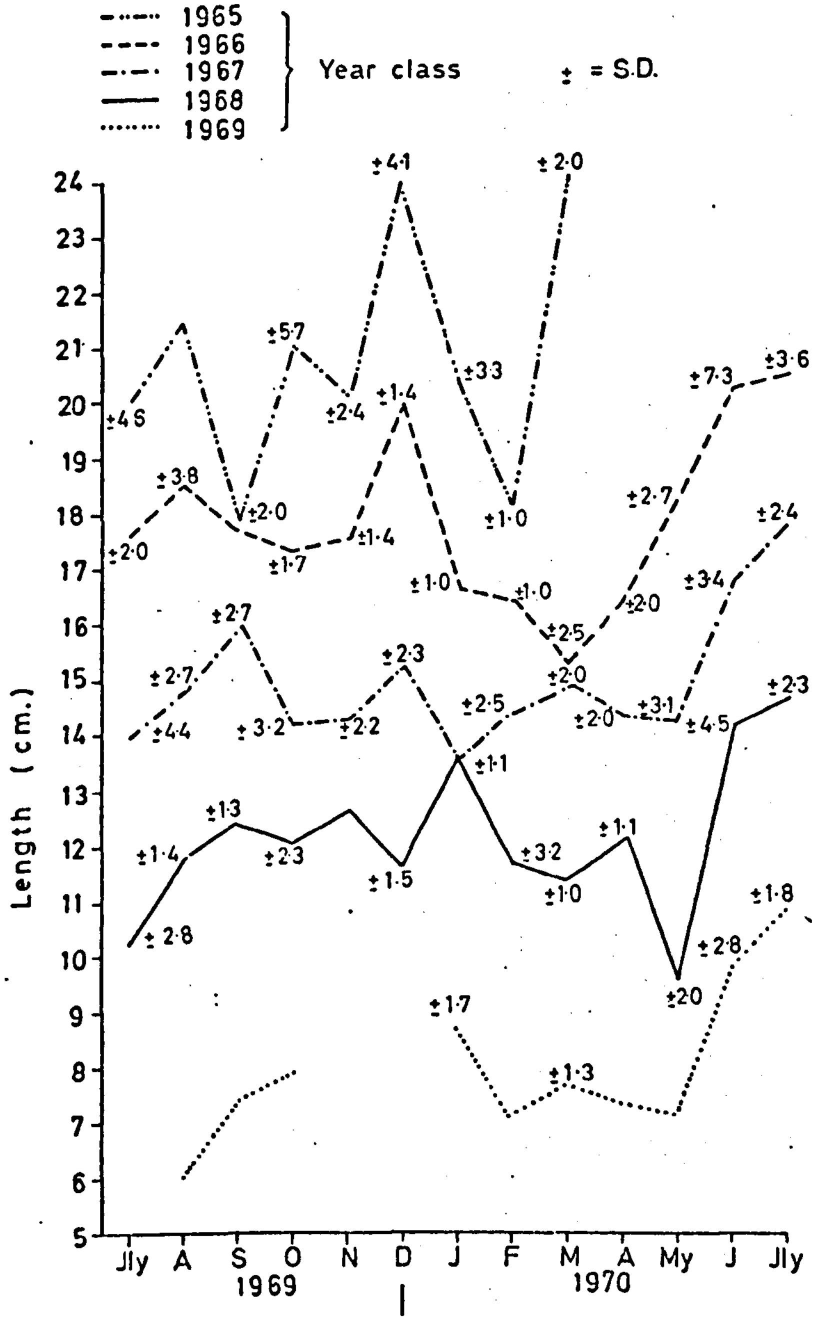


Fig. 10·16 Seasonal growth in length of trout in the river Alyn

C = denotes the condition of the fish; W = weight of fish (gms); L = total length of fish (mm); and n is the slope or regression line of a log length x log weight graph, i.e. length weight relationshp (Fig.10.10). The value of n determined from Fig.10.10, is close to 3 indicating that if the fish's specific gravity remains constant, the fish grows isometrically (Tesch 1968). The figures obtained justify the use of n = 3 in the usual equation

$$K = \frac{W \times 10^4}{L^3}$$

Values of K so obtained will fluctuate about 100 when using the metric system.

K was calculated for all the trout sampled excluding maturing and spent fish. Fig. 10.13 shows the seasonal variation in mean condition for 1969-70. Thus condition was at its highes in summer and low in winter.

The difference in values for the two curves (Figs.10.13, 10.14) is probably accounted for by the fact that n was taken as 3 in the equation used to calculate the mean K for each month in place of 2.87. Females tend to have slightly higher values of K than males of the same age.

(d) <u>Seasonal growth</u>

Seasonal growth curves for each of the year classes are given in Fig.10.15 and 10.16 respectively. The curves give the mean length of each year class in each monthly sample.

The growth curves show that the growth rate varied seasonally, with rapid growth from May/June until August/September. The period of faster growth was between May and August in the 1966, 1967 and 1968 year classes; whereas little growth occurred in 1965 year class.

Growth ceases from August to November in 1968 Y.C. (Year Class), from October-December in 1967 Y.C. and September-November in 1966 Y.C. fish. The growth curves show pronounced irregularities in the winter months, probably partly due to the small numerical size of the winter sample (Fig.10.15) and the preponderance of females. As females have a lower mean length than males, the total mean length of the sample will be reduced the larger the number of females in the sample.

Fig.10.16 shows the mean weight for each year class each month from July 1969 to July 1970. Increase in weight closely parallels the increase in length as shown in Figs. 10.15 and 10.16. It can be seen that the loss in wight in 1966 and 1967 year classes between October-November, presumably was a result of spawning. There was little loss in weight at this time in the 1968 group as only a small percentage of this year group were ripe (Table 10.8).

(e) Movement

Le Cren (1958) found that most trout remained in 30m section in the small stream he studied. Schuck (1945)

Table 10.7 Movements of marked trout at S1, S2, and S3 stations.

Station 1:-

Total marked = 29, Total unmarked = 22

Age of fish	1+		2+		3+		Total	
No. Fish released in July	15		20		21		56	
No. Fish recaptured in August	No.	%	No.	%	No.	%	No.	%
Upstream of the place of release	5	33.3	8	40.0	4	19.0	17	30.3
Downstream of the place of release	2	13.3	7	35.0	3	14.2	12	21.4
Total	7	46.6	15	75.0	7	33.2	29	51.7

Station 2 :-

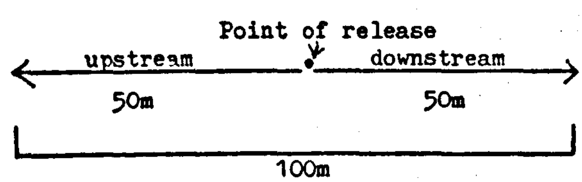
Total marked = 26 Total unmarked = 27

Age of fish	1+		2+		3+		Total	
No. Fish released in September	10		27		14		51	
No. Fish recaptured in October	No.	%	No.	%	No.	%	No.	%
Upstream of the place of release	4	40.0	8	29.6	6	42.8	18	35.2
Downstream of the place of release	2	20.0	4	14.8	2	14.2	8	15.6
Total	6	60.0	12	44.4	8	57.0	26	50.8

Station 3 :-

Total marked = 18 Total unmarked = 20

Age of fish	1+		2+		3+		Total	
No. Fish released in November	7		23		8		38	
No. Fish recaptured in December	No.	%	No.	%	No.	%	No.	%
Upstream of the place of release	3	42.8	7	30.4	2	25.0	12	31.5
Downstream of the place of release	1	14.2	4	17.3	1	12.5	6	15.7
Total	4	57.0	11	47.7	3	37.5	18	47.2



Total area fished at each station.

recaptured 42 of the 46 trout he tagged in Crystal Creek, U.S.A. in their original sections which were 65m long. Shetter (1937) working on brown trout in the Au Sable River system, U.S.A., found that 56-85% remained within one mile of the release point. Stefanich (1952) recorded little movement of trout in 91m sections of Prickly Pear Creek, Montana, but those that did move generally did so in a downstream direction.

In the present study a total of 56 young trout belonging to 1+, 2+ and 3+ age groups were collected from station 1 between A_1 and A_2 (Fig.10.1) in July 1970 over the substratum of stones and gravel with marginal vegetation and few trees (Acer pseuodplatanus) on either side. These were marked black (Indian ink) by panjet on the ventral surface near the anus and released. In August 1970 51.4% of the total marked fish were recaptured; of these 30% from upstream and 21.4% from downstream. At this station I did not find any significant difference ($p > 0.05$) in the number of trout moving upstream and downstream from the place of release (Table.10.7).

At station 2, which was 40m downstream from station 1, a total of 51 trout were collected, marked on the ventral surface between the anal and pectoral fins and released in September 1970. Here the bottom was of sand and pebbles with little marginal vegetation. In October I recovered 50.8% of the marked fish, 35.2% from upstream and 15.6%

from downstream from the point of release. No marked fish from station 1 were captured at station 2. There was no significant difference ($p > 0.05$) in the number of trout moving upstream and downstream from the place of release (Table 10.7).

At station 3 (Fig.10.1), which was 31m downstream from the station 2, a total of 38 trout were collected, marked on the ventral surface between the pectoral fins and released in November 1970. Here the bottom was of mud, sand and gravel with thick patches of *Ranunculus aquatilis*. There was no marginal vegetation and no trees. In December 1970 47.2% of the total marked fish were recaptured, 31.5% from upstream and 15.7% from downstream. I did not find any marked fish from stations 1 and 2 in this catch. No significant difference ($p > 0.05$) was observed in trout moving upstream and downstream from the place of release (Table 10.7).

In the above experiments 100m of the river were fished at each station having different types of substrata, to study the localised movement. The present study showed a tendency to form home areas. Within the limitations imposed by low numbers, it is suggested from the returns that trout may remain in or return to the same locality. There is no significant ($p > 0.05$) difference in the number of trout moving up and downstream, the trout can be considered fairly faithful to a restricted location.

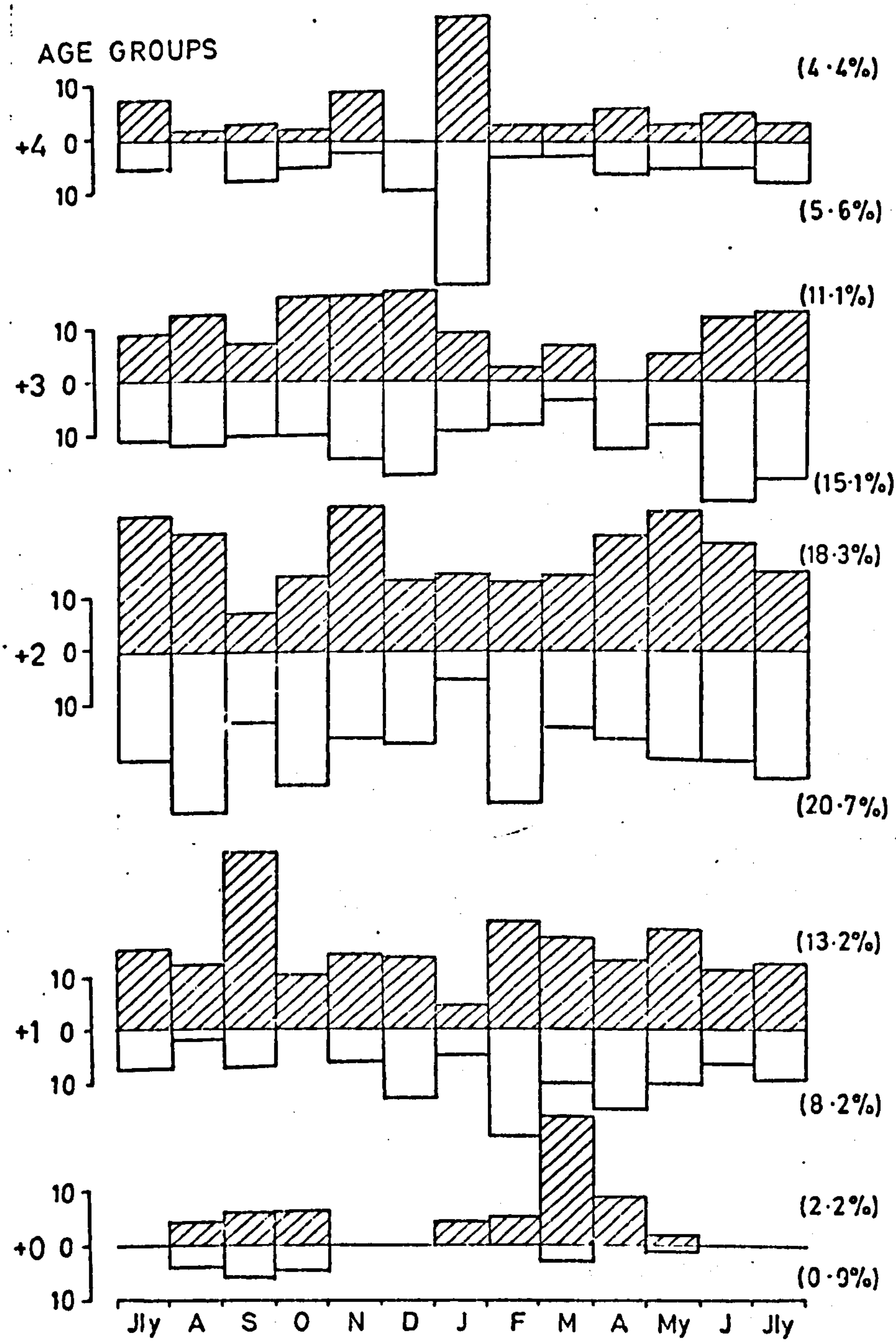


Fig. 10·17 Percentage of females and males in different age groups in the total catch

□ ♀ ▨ ♂

Table 10.8 Fecundity of 27 trout from the River Alyn.

Age and Month	Year Class	Mean weight of ovary (g)	Estimated mean eggs per fish (No)	No. fish	Length range (cm)	Mean Length (cm)	Weight range (g)	Mean weight (g)	Range of ova per female (No)	Egg per gram of ovary (No)
Age group 1+	1968									
Sept.		1.8	88	1	13	13-	28-	28	88	49
Age group 2+	1967									
Sept.		3.6	123	3	15.6-17.5	16.2	48-72	56.6	214-286	34
Oct.		8.6	233	4	15.5-17.8	16.7	42-72	60.2	150-370	27
Age group 3+	1966									
Sept.		6.3	297	3	17-17.5	17.3	55-68	61.6	260-320	47
Oct.		10.5	227	6	16.5-19.2	17.4	58-87	68.5	124-370	22
Nov.		10.5	245	6	16.5-18.7	17.9	54-87	71.3	186-354	23
Dec.		7.4	200	1	19.8-	19.8	82	82	200	27
Age group 4+	1965									
Sept.		6.0	166	2	15.4-17.2	16.3	41-62	51.5	145-188	27
Nov.		18.2	328	1	20.7-	20.7	111	111	328	18

(f) Sex ratio

The variation of the sex ratio with age was irregular (Fig.10.17). It is apparent, however, that females were predominant at the higher ages. The percentage of males varied more among the 0+ and 1+ age groups in the combined sample for all months, but males became less numerous at the higher ages (Fig.10.17).

(g) Fecundity

The number of eggs per individual varied considerably (Table 10.8). The averages for the age groups show low egg production among the 1+ age group and maximum production by 2+ and 3+ age groups, and slowly declining numbers among older age groups. In older fish I observed an increasing amount of connective tissue, hence they may produce fewer eggs per gram of ovary with increase in age. Yield of eggs per gram of ovary was highly variable even among the fish of the same age group (Table 10.8). This may be due to varying stages of development at the time the fish were captured.

(h) Mortality

The mortality coefficient were estimated from the formulae describing the general relationships between survival and mortality (Rousefell and Everhart 1953).

Table 10.9 The total annual composition of the diet of 1076 trout assessed by occurrence volume and number methods.

(+ = <0.1%)

Food organisms	Percentage represented in the total sample		
	O	V	N
Benthic food			
Oligochaeta	1.0	0.8	0.5
Limnaea pereger	1.9	1.2	2.2
Potamopyrgus jenkinsi	2.0	1.4	1.5
Pisidium spp.	+	+	+
Gammarus pulex	9.4	10.3	9.2
Sperchon spp.	+	+	+
Leuctra spp.	1.3	0.6	2.1
Amphinemura standfussi	2.5	1.1	0.6
Chloroperla spp.	1.1	0.9	0.4
Other Plecoptera	2.6	1.9	3.1
Baëtis rhodani	2.2	6.5	2.5
Ecdyonurus spp.	3.7	1.7	2.4
Paraleptophlebia spp.	4.4	1.2	4.2
Other Ephemeroptera	5.6	7.8	10.1
Sialis lutaria	+	+	+
Rhyacophila spp.	0.8	1.8	0.3
Hydropsyche spp.	1.9	0.3	2.3
Potamophylax spp.	1.1	2.5	1.1
Other Trichoptera	4.2	2.0	2.1
Latelmis volkmari larvae	4.9	1.6	4.7
Chironomid larvae	10.6	8.7	19.0
Simuliid larvae	1.4	0.3	0.8
Tipulid larvae	2.3	1.1	0.9
Other dipteran larvae	3.3	1.2	2.4
Dipteran pupae	3.2	3.3	5.5
Midwater food			
Helmis maugei adults	7.0	3.7	4.4
Hemiptera adults	0.5	0.2	0.3
Fish	1.4	21.9	0.8
Aerial and Terrestrial foods	12.0	11.7	10.7
Miscellaneous food			
Plants	7.0	2.6	4.8
Stone (caddis cases)	0.4	0.6	0.2
Eggs	+	+	+

$$r = (1 - S) \quad \text{or} \quad (1 - e^{-\Delta})$$

$$\Delta = \left[\log 10 \ (^1/_S) \ \ (^1/\log 10^e) \right] = \text{Log } e \ \ (^1/_{1-r})$$

$$\text{Log } S = \frac{\left(\sum_{y=x5}^{n-10} \text{Log } f\,(y) \right) - \left(\sum_{y=x+1}^{n} \text{Log } f\,(y) \right)}{n}$$

$f(y)$ = age frequency at any age (y)

yx = age at which all of population becomes "catchable"

r = annual mortality rate

S = rate of survival

Δ = instantaneous mortality rate

$^1/\log_e = 2.303$

The computations yielded an annual mortality coefficient (r) of 0.4812, rate of survival (S) of 0.5188 and an instantaneous mortality rate of 0.7015.

		Calculated		Weighted
Δ	=	0.7015	70.15%	0.6269
S	=	0.5188	51.88%	0.5563
r	=	0.4812	48.12%	0.4437

(i) <u>Composition of the diet</u>

The detailed percentage composition of the diet by occurrence, volume and number methods is shown in Table 10.9. 59.4% by volume and 79.3% by number of the total food consumed were invertebrate bottom fauna. Plecoptera and Ephemeroptera nymphs, Trichoptera and chironomid larvae

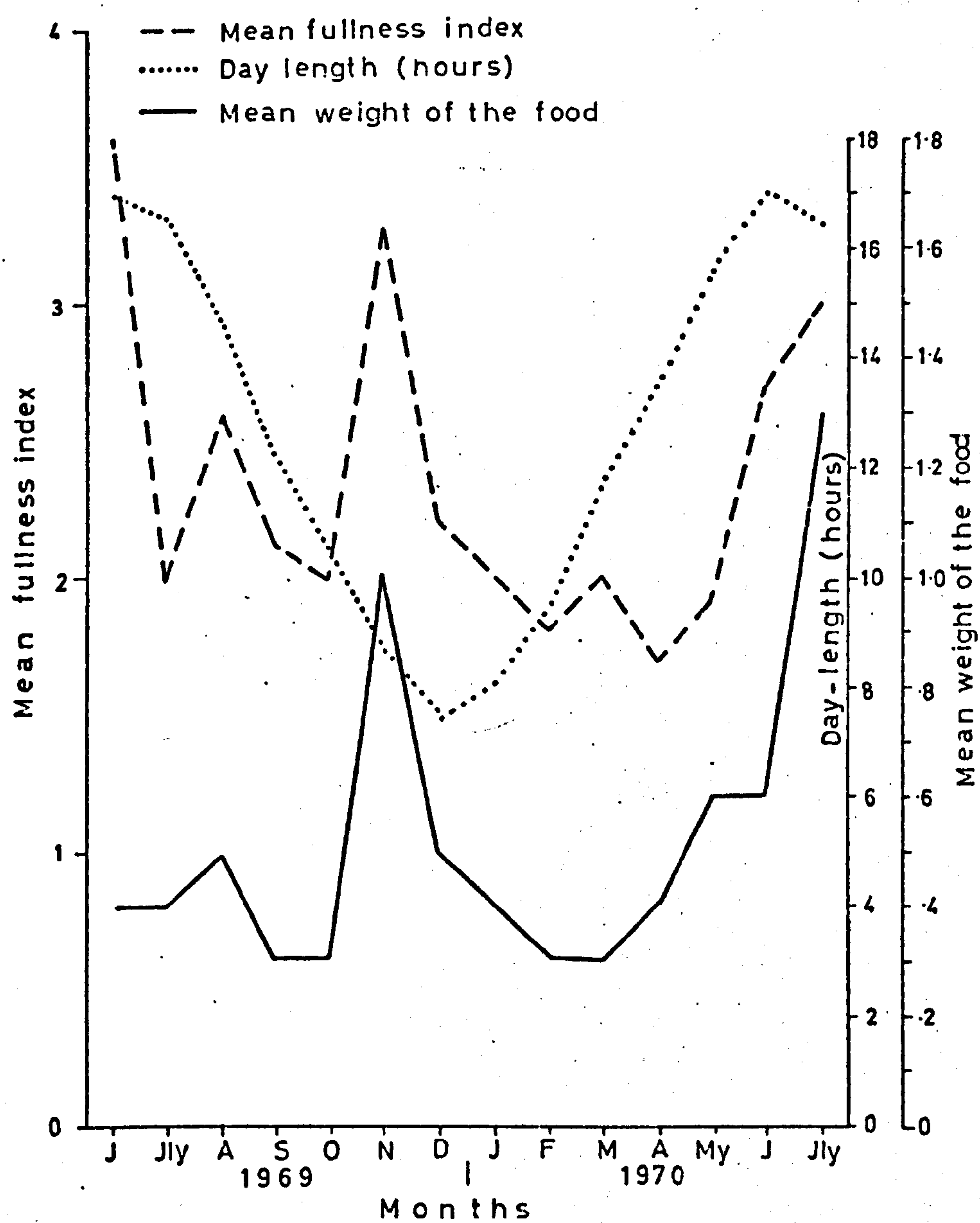


Fig. 10·18 Seasonal variation in the food intake of trout in the river Alyn and *Gammarus pulex* were the major food items. Plecoptera formed 4.5% by volume and 6.2% by number, and were composed of *Leuctra spp*, *Amphenemura standfussi*, *Chloroperla* spp. and other unidentifiable stone fly nymphs. Ephemeroptera represented by *Baetis rhodani*, *Ecyonurus spp*. *Paraleptophlebia spp*. and other mayfly nymphs formed 17.2% by volume and 18.2% by number of the total food. Trichoptera represented by *Rhyacophila spp*, *Hydropsyche spp*, *Potamophylax spp*. and other caddis larvae were noted in 7.3% by volume and 5.8% by number of the total food. Chironomid larvae were eaten by 10.6% and *Gammarus pulex* by 9.4% of the total fish. Food items of rare occurrence belonged to the Oligochaeta, Gastropoda, Simuliidae, Tipulidae and other dipteran larvae and pupae.

Aerial and terrestrial food formed 11.7% by volume and 10.7% by number of the total food.

The midwater food items, which included Coleoptera adults, Hemiptera and fish, formed 25.8% by volume and 5.5% by number of the total food.

Plant debris, filamentous algae and pebbles, grouped as miscellaneous foods occurred in 3.0% by volume and 5.0% by number of the total food.

(j) Seasonal variations in food intake

Fig. 10.18 shows a progressive change in the intensity of food consumption. The amount of food in trout stomachs

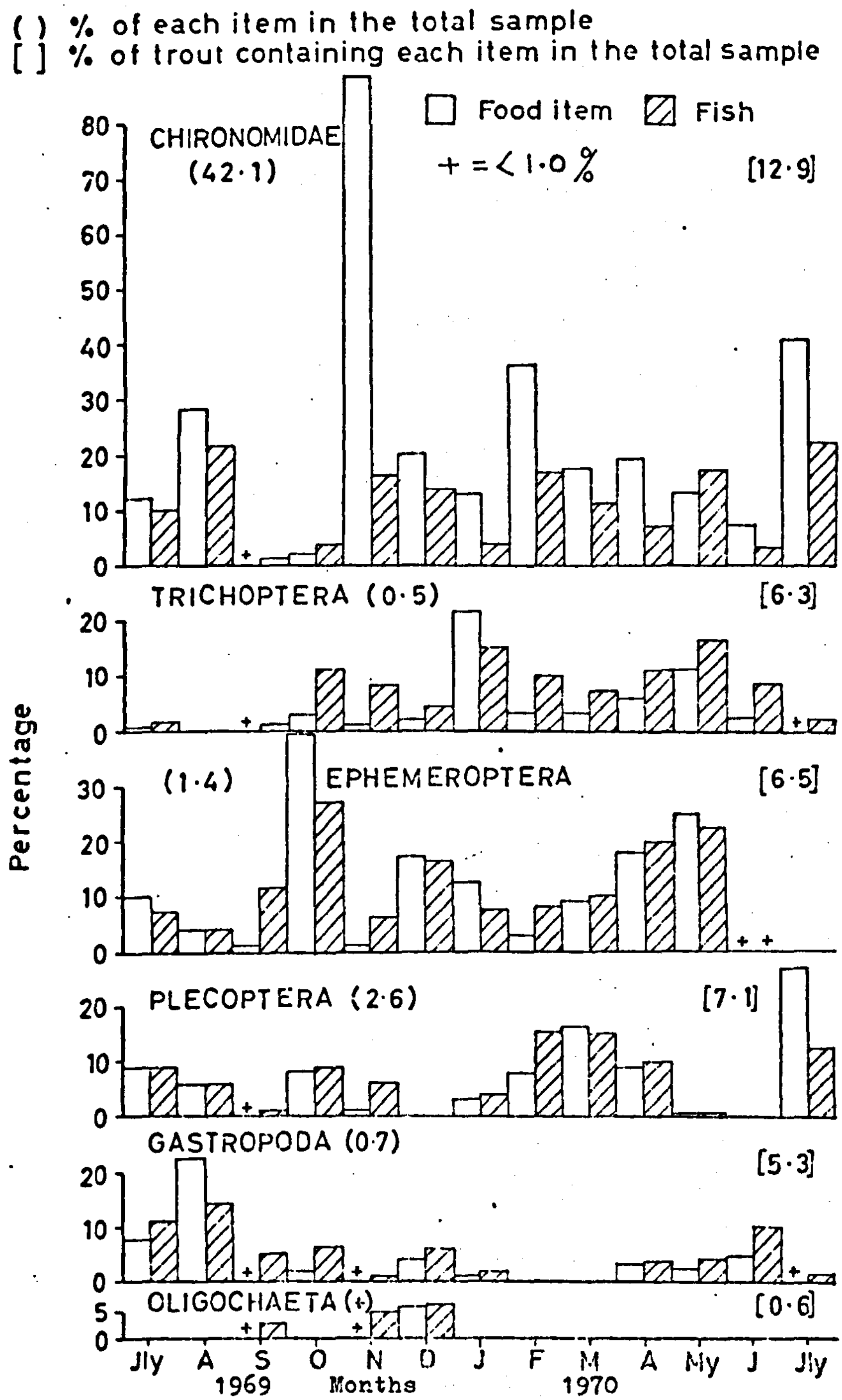


Fig 10.19 Seasonal variations of the benthic food items of trout and percentage of stomachs containing each food item in different months.

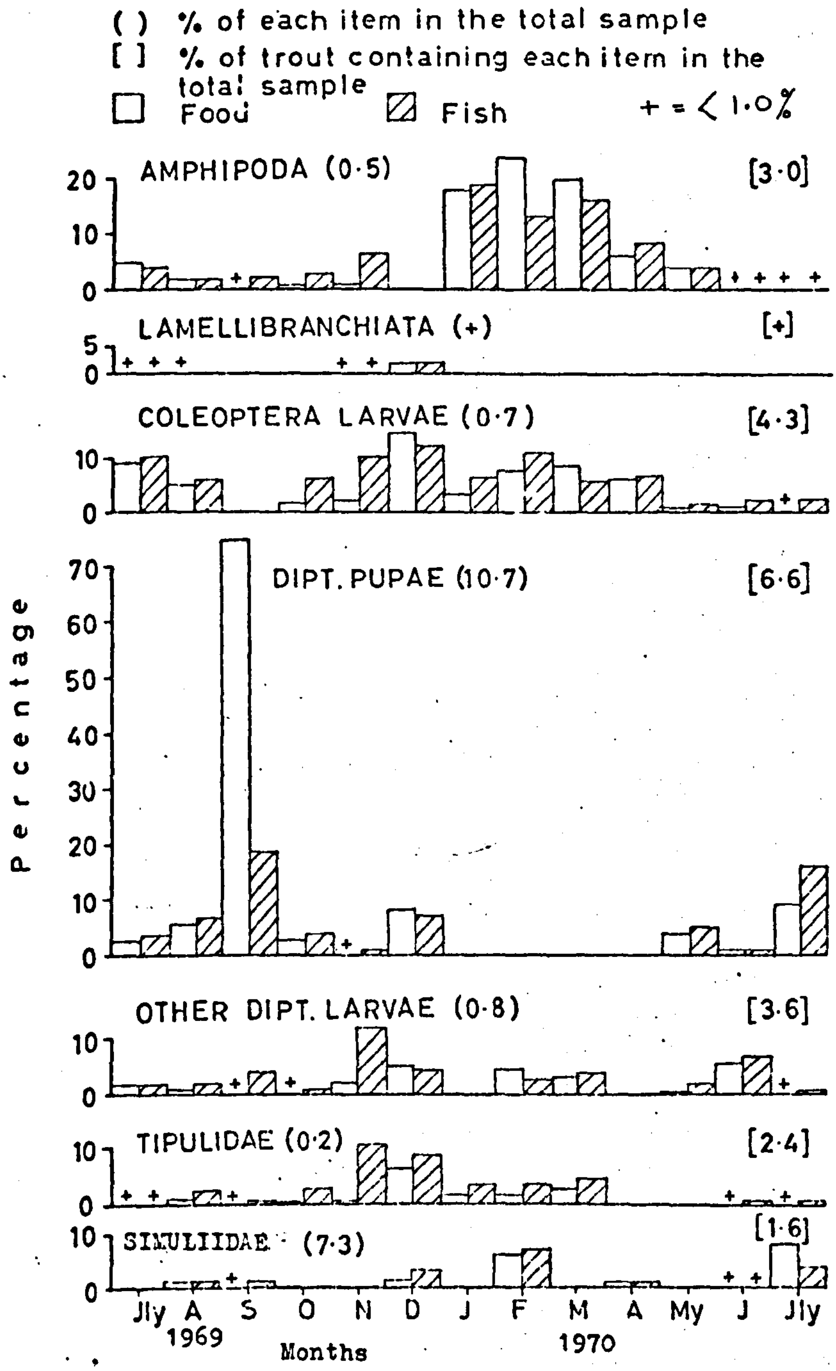


Fig 10. 20 Seasonal variations of the benthic food items of trout and percentage of stomachs containing each food item in different months.

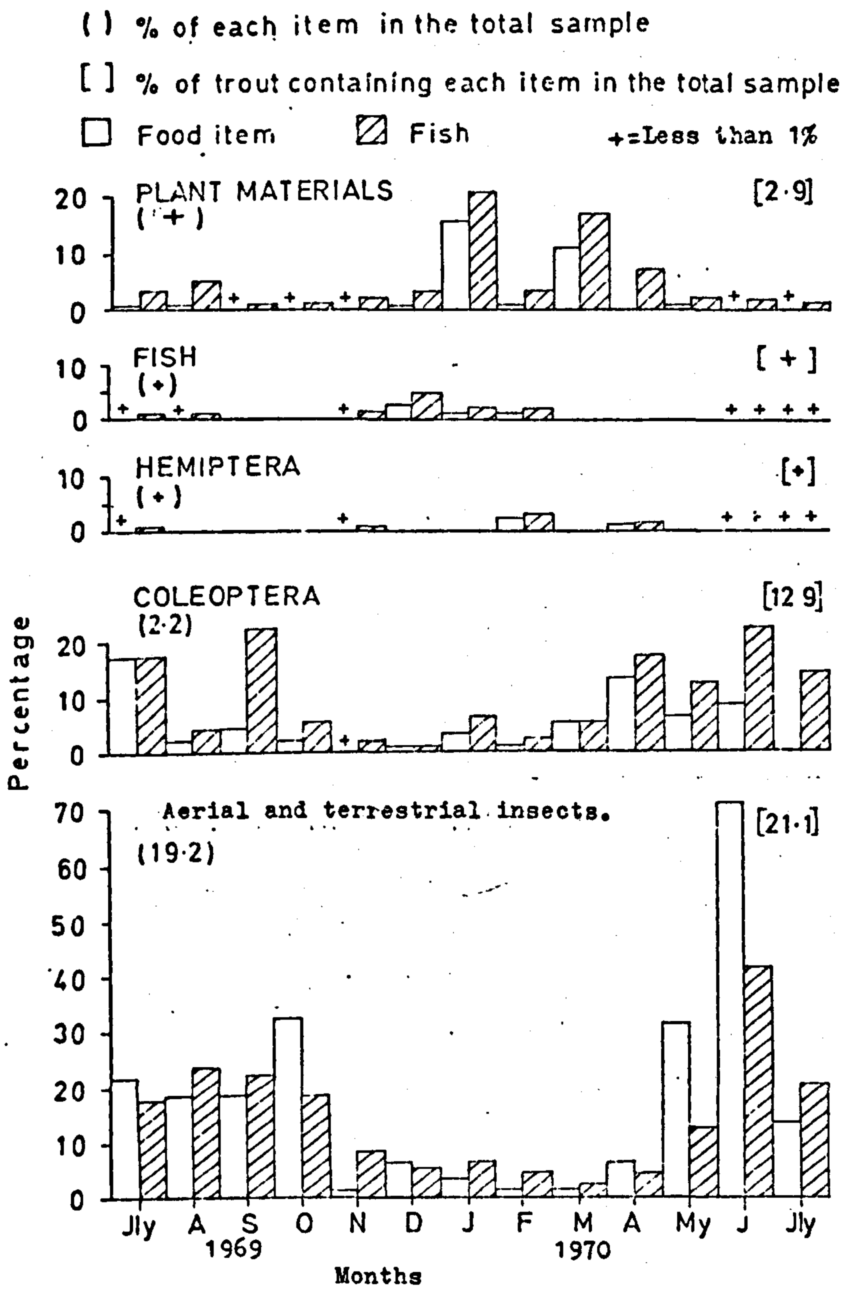


Fig 10.21 Seasonal variations of the benthic food items of trout and percentage of stomachs containing each food item in different months.

decreased from August to October and then suddenly increased in November; again gradually decreased from December to March and increased from April to July.

(k) Seasonal changes in the food

Seasonal changes in the quantity of food eaten by the fish are shown in Figs. 10.19, 10.20, 10.21, where data for each item are given separately. Chironomid larvae, Ephemeroptera and Plecoptera nymphs were eaten in all months (Fig.10.19). Trichoptera larvae were found in food during winter and spring. Gastropods were recorded more during spring and summer. Oligochaetes were found in November and December only. Gammarus pulex were consumed in large quantities during winter and spring (Fig.10.20). Coleoptera larvae were eaten in all months. Amongst dipteran pupae chironomid pupae were eaten in greater quantity during spring and summer. Other dipteran larvae, represented by Tipulidae and Simuliidae, were rare in the diet except in winter.

Aerial and terrestrial insects were most numerous in the food during summer and autumn (Fig.10.21). Among the less common items of food, Coleoptera adults of aquatic origin were mostly eaten during spring and summer, Hemiptera in small quantities during summer, fish rarely in winter and summer, and finally filamentous algae taken accidentally all the year.

Table 10.10 The average percentage composition of the food assessed by occurrence, volume, and number methods of trout of each age group. (+ = < 0.1%)

Total No. Fish															
Age	0+			1+			2+			3+			4+		
No. Fish in each Age group	32			232			423			284			104		
No. Empty Stomachs	5			16			30			12			8		
Mean length (Range) mm	6.9 (6.1-7.6)			11.7 (10.8-12.3)			14.4 (14.3-14.8)			17.4 (16.6-18.1)			20.4 (19.6-21.7)		
Mean Weight (Range) g	4.3 (3.2-5.3)			19.0 (15.6-24.3)			39.0 (35.3-43.8)			58.1 (31.6-68.3)			99.4 (19.6-21.7)		
Methods of Assessment	O	V	N	O	V	N	O	V	N	O	V	N	O	V	N
Oligochaeta	-	-	-	0.7	1.2	+	1.4	0.1	0.4	2.0	3.1	2.3	1.2	+	.2
Gastropoda	-	-	-	1.8	0.5	1.5	5.3	4.6	5.1	5.8	3.9	5.0	7.3	4.0	5.9
Lamellibranchiata	-	-	-	-	-	-	0.4	0.2	0.2	-	-	-	-	-	-
Amphipoda	13.2	17.2	8.9	11.8	5.2	10.3	5.5	8.2	6.6	8.5	11.2	10.5	6.7	10.0	9.7
Hydracarina	-	-	-	0.1	+	+	-	-	-	0.1	+	+	-	-	-
Plecoptera	11.3	11.5	10.4	6.8	3.9	4.3	6.4	2.3	5.4	6.4	2.2	4.6	6.8	3.0	6.7
Ephemeroptera	28.3	38.4	35.8	20.1	10.1	21.9	13.2	20.2	15.4	8.7	6.0	7.9	9.2	11.7	13.1
Megaloptera	-	-	-	0.8	+	0.2	0.2	+	+	0.1	+	+	.3	+	.3
Trichoptera	3.7	3.8	1.4	4.6	2.1	2.1	8.1	5.1	5.9	9.9	12.9	6.2	14.2	13.0	13.4
Coleoptera larvae	3.7	3.8	6.7	4.3	1.2	3.2	8.3	0.4	7.6	5.5	1.5	4.4	3.1	1.1	1.6
Chironomidae	13.2	11.5	16.4	13.8	9.1	25.6	10.6	10.4	21.5	10.0	7.2	19.9	5.7	5.5	11.8
Simuliidae	3.7	0.5	2.2	0.6	0.6	0.8	1.3	0.5	0.9	0.2	+	0.2	-	-	-
Tipulidae	-	-	-	2.4	0.5	0.9	3.0	1.1	1.3	2.7	2.5	0.5	3.4	1.5	2.1
Dipteran larvae	3.7	1.5	2.9	1.7	+	0.2	2.5	1.1	1.5	3.8	0.2	1.6	4.9	3.2	5.8
Dipteran pupae	1.8	1.8	1.4	4.1	3.6	7.5	4.9	8.4	9.3	4.4	2.1	7.5	1.1	1.0	1.5
Aerial and terrestrial	7.5	7.6	7.4	14.5	15.5	10.8	12.1	14.2	10.4	13.2	15.7	17.5	8.0	5.7	7.7
Coleoptera adults	3.7	1.5	2.9	3.6	2.4	1.9	10.3	8.5	6.3	6.6	2.6	3.4	11.2	3.7	7.7
Hemiptera	-	-	-	-	-	-	0.7	+	0.3	0.1	+	+	2.0	1.1	1.2
Fish	-	-	-	2.5	37.4	2.5	0.3	13.0	+	2.1	24.8	0.6	2.2	34.5	1.3
Eggs	-	-	-	0.2	0.6	1.5	0.2	+	0.2	-	-	-	-	-	-
Plant	5.6	1.0	2.9	4.9	3.5	3.8	4.4	1.1	1.5	8.4	3.0	6.2	12.1	3.6	9.8
Stones (caddis cases)	-	-	-	0.7	2.1	0.2	0.1	+	+	0.8	1.0	1.0	0.5	+	0.2

(1) Food according to age

Table 10.10 shows that similar types of food organisms were eaten by the trout belonging to all age groups (here 0+ to 4+ age groups).

6. DISCUSSION

In this section the results obtained during the investigations of this work will be discussed in two sub-sections : (1) Bottom fauna, (2) Biology of trout.

(1) Bottom fauna

Carpenter's early studies (1924) on the rivers Rheidol, Ystwyth and Clarch showed the disappearance of crustaceans, worms, leeches, molluscs and flatworms from the affected streams with lead salts.

Jones (1938) recorded stoneflies, mayflies and some chironomid larvae living in water containing nearly 60ppm of zinc. Worms, leeches, crustaceans and molluscs were very susceptible.

Pentelow and Butcher (1938), while working on the River Churnet polluted by organic matter, found Tubificidae, *Chironomus*, *Asellus*, leeches and molluscs disappeared below the copper works effluent. Butcher *et al*. (1937) found the invertebrate fauna of the River Tees above and below the outfall from Barnard Castle sewage works differed slightly.

Hynes (1960) showed the fauna of the unpolluted waters of Ditton Brook consisted largely of *Gammarus*, mayflies, caddisworms, flatworms, leeches and snails. He observed (1960) in the River Lee, polluted by sewage and copper salts, that the caddisworms, *Haliplus spp.*, *Orthocladiinae*, Tanypodinae were apparently unaffected but *Asellus*, *Gammarus*, *Baetis*, *Tanytarsus* and *Limnaea* were eliminated for long distances.

Learner *et al.* (1971) surveyed the macroinvertebrates and fish in the River Cynon in south-east Wales receiving industrial and domestic wastes. He found a very varied fauna upstream and one dominated by chironomids and oligochaetes downstream of the pollution.

The present studies of the stream have shown the number (Av.No/m^2) of Oligochaeta, Hydracarina, Plecoptera, Ephemeroptera and Diptera (Dixidae, Ceratopogonidae, Tipulidae, Chironomidae and Simuliidae) to be drastically reduced and the Gastropoda, Lamellibranchiata, Amphipoda, Isopoda and Coleoptera showing increases immediately below the sources of pollution (Tables 10.3, 10.5). Low dissolved oxygen concentrations, increased alkalinity, suspended solids, high temperature and chloride ions at Synthite Ltd., Mold (Table 10.1), may be the factors responsible for community changes below the sources of pollution.

The aquatic community seemed to show partial recovery at A_4 about 21.6km below the source of pollution. The number of organisms in each group, like Oligochaeta, Hydracarina, Plecoptera, Ephemeroptera and aquatic Diptera, were greater than those at A_3 (Table 10.5). These increases at A_4 may probably show what Brinley (1943) referred to as the 'fertilising effect' of domestic sewage or may well be the complexity of the possible interactions between factors of the environment (Jones 1958). I found improved environmental conditions at A_4 which may be due to greater dilution of the effluents and natural recovery. Turbellaria, Hirudinea, Megaloptera, Hemiptera and Trichoptera were relatively unaffected (Table 10.5). There was an indication of an increased population of Turbellaria, Hirudinea, Oligochaeta, Gastropoda, Lamellibranchiata, Amphipoda, Ephemeroptera, Megaloptera and Trichoptera at A_2 as compared to A_1. This may be due to mild pollution by the untreated domestic sewage.

(2) Fish

Little can be said about the biology of trout in a polluted water. The growth of brown trout depends on many environmental factors such as available food fauna, and population size (Frost 1945), population size, available food and temperature (Jones, 1956, Wingfield 1940, Brown 1946 and Pyefinch 1955) and egg size to a certain extent (Dahl 1918, 1919, and Rhudd 1946).

The accelerated growth period of trout started during

April and coincided with the first appearance of wide summer scale rings and the increase in feeding intensity. These findings closely agreed with those of Jones (1949), Ball and Jones (1960) and Woolland (1972) in the Dee watershed and those of other workers in different waters (Frost and Went 1940, Thomas 1964 and Egglishaw 1968). The growth rate was used to show whether there had been a change in the decline of the rate of growth with age or size. The reduction in the growth rate of trout of all ages as compared to that of unregulated Llyn Tegid feeder streams and the regulated River Dee (Figs. 10.6, 10.7) is paralleled with the work of Learner et al. (1972) who surveyed the River Cynon, a trout stream in south-east Wales polluted by industrial wastes and coal washing, and found the growth rate in the catchment was low. The relatively poor growth conditions of trout in the River Alyn as compared with the Llyn Tegid feeder streams and the Dee (Figs.10.6,10.7), could be due to its physical and chemical conditions (Tables 3.4,10.1,10.2); or may be affected by the parasites as is shown in chapter XI that 43.7% and 3.6% of the total trout were infected from the River Alyn and the feeder streams respectively.

I did not find trout below the spill of industrial wastes between A_3 and A_4; this may be caused by the effluents. Similar observations were made by Avery (1970) on the east Gallatin river in U.S.A. polluted by domestic sewage; Jones (1940) on the River Rheidol polluted by dissolved lead salts; and Learner et al. (1972) on the River Cynon polluted by coal washeries and industrial wastes.

The seasonal condition cycle of brown trout in this investigation (Figs.10.13, 10.14) was similar to those found by Ball & Jones (1960) and Woolland (1972), with a spring increase to the maximum in July, followed by a decline thereafter. This decline in subsequent years was also found by Allen (1951) and Thomas (1964).

While studying the movement and territorial behaviour of trout, I found that 30.3% of the total move upstream and 21.4% downstream at S_1 (Fig.10.1); 35.2% upstream and 15.6% downstream at S_2 and finally at S_3 31.5% upstream and 15.7% downstream of the place of release. The recaptures of fish marked in three experimental stretches showed an indication that there was a greater tendency to move upstream than down, though there was no significant difference ($P > 0.05$) in the number of trout moving upstream and downstream from the place of release (Table 10.7). Franks (unpublished 1968), while investigating the movement of stocked trout in the River Alyn at Pontblyddyn (Nat.Grid Ref. 615272) between A_3 and A_4, found that 25% of the total fish move downstream and 12.2% upstream.

The trout of both sexes were found to be mature at age 2+. I found one mature female of 1+ age group as did Ball (1957).

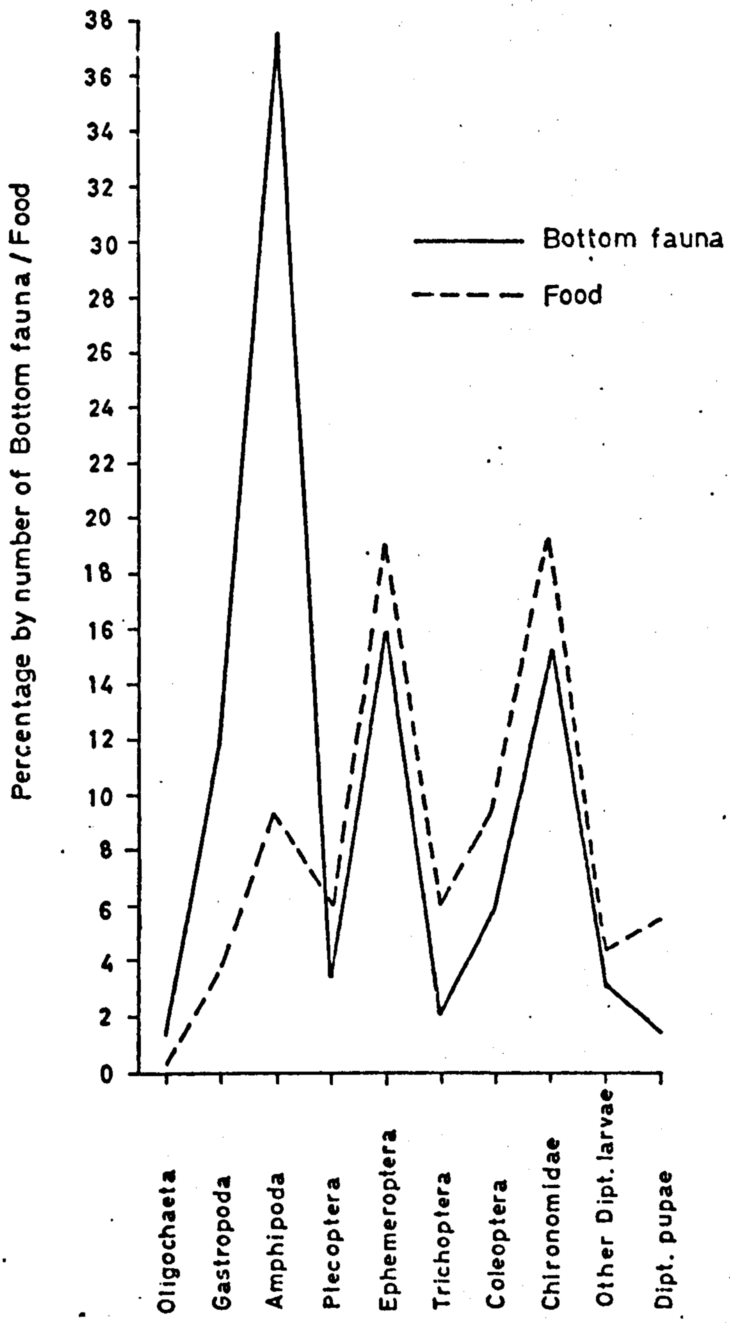


Fig.10.22 The percentage composition (by number) of the bottom fauna and benthic food of trout

In the mild organically polluted environment, I found 59.4% by volume and 79.3% by number of the total food consumed were bottom invertebrates. Plecoptera, Ephemereptera nymphs, Trichoptera and chironomid larvae and *Gammarus pulex* were the main portions of the identifiable food. Aerial and terrestrial food formed 11.7% by volume and 10.7% by number of the total food.

The changes in the bottom fauna were reflected in the diet of trout (Fig.10.22). *Gammarus spp.* seem to have become more common items of the trout diet (Fig.11.12). It was shown (Fig.10.18) that trout had consumed less food during winter.

In conclusion it is evident from the above discussion that there has been a change in the growth and growth rate of trout. These changes seem mainly to be related to the changes in the fauna and polluted environment of the stream. But the data available to date do not allow the making of categoric statements as to the causes of these changes. Nevertheless the changes may be of a temporary nature and may have been caused by the increased untreated spills of industrial wastes in previous years.

7. SUMMARY

(1) Pollution has affected the bottom fauna below the spill at A_3 near Mold. These changes in the fauna consist of differences in the number of animals rather than in the species present.

(2) The chironomids were reduced at A_3 but reappeared in greater number at A_4.

(3) The changes in the fauna are reflected in the diet of the trout.

(4) There was a greater tendency in trout to move upstream than downstream.

(5) Growth conditions of trout in the upper Alyn were relatively poorer than Llyn Tegid feeder streams and the upper Dee.

(6) The trout had consumed more food during summer than in winter.

(7) The seasonal conditional cycle increases to a maximum in July and declines thereafter.

CHAPTER XI

PARASITES OF TROUT

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CHAPTER XI

INTRODUCTION

The earlier investigations of the parasites of trout (Chaloner 1912, Brown 1927, Friend 1939, Duguid & Sheppard 1944 and Unsworth 1944) and of freshwater fish in general (Nicoll 1924, Baylis 1928, 1939) were concerned mostly with taxonomy, geographical distribution and host specificity.

Relatively little is known about the ecology of helminth parasites of brown trout of any stream. The only relevant works available when the present study was commenced were those of Thomas 1954, 1958, 1964 and Awachi 1965; as these were concerned with unpolluted streams, it was of obvious interest to investigate the ecology of helminth parasites of trout in a stream polluted by domestic sewage.

Studies of the parasites of the swimbladder, stomach and intestine of brown trout were undertaken on fish from the polluted River Alyn, a lowland (main) tributary of the Dee.

MATERIALS AND METHODS

The fish were carefully examined as soon as possible after capture for their helminth parasites. When time did not allow they were left overnight in a refrigerator, a treatment which did not appear to be harmful to the parasites.

Table 11.1 The total percentage incidence and intensity of infection in brown trout with *Cystidicola farionis* (C.F.), *Echinorhynchus truttae* (E.T.), *Cyathocephalus truncatus* (C.T.), *Protocephalus neglectus* (P.N.), *Cucullanus truttae* (Cuc. T.) and *Metabronema truttae* (M.T.).

Months	NUMBER AND PERCENTAGE OF FISH INFECTED													
	Parasites →	C.F		E.T		C.T.		P.N.		Cuc. T.		M.T.	
	Total No. Fish examined	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
June 1969	2	1	50	0	0	0	0	0	0	0	0	0	0
July	70	0	0	30	42.8	0	0	0	0	0	0	0	0
Aug.	50	3	6	7	14	0	0	0	0	0	0	0	0
Sept.	41	0	0	0	0	0	0	0	0	0	0	0	0
Oct.	85	1	1.1	10	11.7	0	0	0	0	0	0	0	0
Nov.	44	2	4.5	0	0	0	0	0	0	0	0	0	0
Dec.	23	3	13	0	0	0	0	0	0	0	0	2	8.6
Jan. 1970	22	4	18.1	7	31.8	9	40.9	-	-	1	4.5	2	9.0
Feb.	40	5	12.5	0	0	0	0	0	0	0	0	0	0
Mar.	29	7	24.1	19	65.5	12	41.3	0	0	1	3.4	0	-
April	32	7	21.8	0	0	2	6.2	0	0	0	0	0	0
May	86	16	18.6	36	41.8	23	26.7	0	0	1	1.1	0	0
June	296	18	6	104	35.1	24	8.1	46	15.5	2	.6	0	0
July	263	14	5.3	32	12.5	10	3.8	12	4.5	1	0.3	0	0
Total	1083	81	7.4	245	22.6	80	7.4	58	5.3	6	.5	4	.3

Total No. fish infected = 474
Total percentage infection = 43.7

Table 11.2 The average number of parasites per infected fish on monthly basis.

C.F. = Cystidicola farionis; E.T. = Echinorhynchus truttae; C.T. = Cythocephalus truncatus;

P.N. = Proteocephalus neglectus; Cuc.T. = Cucullanus truttae; M.T. = Metabronema truttae.

Parasites →	C.F.		E.T		C.T.		P.N.		Cuc.T.		M.T.	
Months ↓	Total No.	Av. No. per infected fish	Total No.	Av. No. per infected fish	Total No.	Av. No. per infected fish	Total No.	Av. No. per infected fish	Total No.	Av. No. per infected fish	Total No.	Av. No. per infected fish
June 1969	1	1	0	0	0	0	0	0	0	0	0	0
July	0	0	364	12.1	0	0	0	0	0	0	0	0
Aug.	10	3.3	67	9.5	0	0	0	0	0	0	0	0
Sept.	0	0	0	0	0	0	0	0	0	0	0	0
Oct.	2	2	60	6	0	0	0	0	0	0	0	0
Nov.	10	5	0	0	0	0	0	0	0	0	0	0
Dec.	24	8	0	0	0	0	0	0	0	0	4	2
Jan. 1970	29	7.2	57	8.1	47	5.2	0	0	1	1	6	3
Feb.	21	4.2	0	0	0	0	0	0	0	0	0	0
Mar.	79	11.2	88	4.6	55	4.5	0	0	0	0	0	0
April	22	3.1	0	0	18	9	0	0	0	0	0	0
May	201	12.5	550	15.2	250	10.8	0	0	1	2	0	0
June	277	15.3	941	9.1	159	6.6	403	9.3	0	0	0	0
July	419	29.9	172	5.2	57	5.7	64	5.3	0	0	0	0
Total	1095	13.5	2299	9.3	586	7.3	467	8.0	2	3	10	2.5

Each fish was examined for external parasites, wounds or an abnormality which might be revealed under macroscopic observation. The complete digestive tract and swimbladder were then removed for examination. In addition to these, liver, heart and gills were also inspected.

Living worms on removal from the host were placed in 5% solution of Chloral hydrate to facilitate narcotizing (Wagstaff, pers.comm.). When the worms ceased to move or respond to stimuli they were first fixed in Bouin's fluid and stored in 70% alcohol after for further examination. All the nematodes and Acanthocephala were first mounted in Polyvinyl lactophenol and then examined. The cestodes were first flattened and then stained in Meyer's paracarmine for 5 to 15 minutes. The worms were then returned to 70% alcohol for removal of excess paracarmine. Dehydration was completed via 90% and absolute alcohol. Finally the worms were cleared and mounted in Euparal.

The number of Cythocephalus truncatus, Proteocephalus neglectus, Cystidicola farionis, Cucullanus truttae, Metabronema truttae and Echinorhynchus truttae encountered in individual trout was recorded and the ages of the trout determined by scale examination. Consequently it became possible to draw up tables 11.1, 11.2 which show the percentage of trout infected and the average number of parasites per infected fish on a monthly basis. The latter was used to express the intensity of infestation.

Table 11.3 Cestodes, nematodes and acanthocephala found in 1083 trout.

Parasites	Region infected	Nos. Fish infected	% of infection	Av. No. host/month
Cythocephalus truncatus	Pyloric caeca	80	7.4	5.7
Proteocephalus neglectus	Pyloric caeca	58	5.3	4.1
Cystidicola farionis	Swim bladder	81	7.4	5.7
Cucullanus truttae	Stomach	6	0.5	0.4
Metabronema truttae	Stomach	4	0.3	0.2
Echinorhynchus truttae	Intestine	245	22.6	17.5
Total		474	43.7	5.6

Table 11.4 The relationship between the length and the incidence and intensity of infection with Proteocephalus neglectus in male and female trout.

Length (cm)	♂♂ Total No. Trout	♂♂ Total No. Infected	♂♂ % Infected trout	♂♂ Total No. parasites	♂♂ Av. No. parasites per infected fish	♀♀ Total No. Trout	♀♀ Total No. Infected	♀♀ % Infected trout	♀♀ Total No. parasites	♀♀ Av. No. parasites per infected fish
5 - 9.9	60	-	-	-	-	35	-	-	-	-
10 - 14.9	236	5	2.1	20	4	208	6	2.8	29	4.8
15 - 19.9	194	10	5.1	57	5.7	261	30	11.4	281	9.3
20 - 24.9	39	5	12.0	66	13.2	37	2	5.4	12	6.0
Total	529	20	3.7	143	7.1	541	38	7.0	322	8.4

♂♂

Sources of variation	Degree of freedom	Sum of squares	Mean squares	Variance ratio	P
Total	20	1708.6	-	-	-
Size groups in trout	2	1153.7	576.8	18.7	<0.001
Individuals in size groups	18	554.9	30.8		

♀♀

Sources of variation	Degree of freedom	Sum of squares	Mean squares	Variance ratio	P
Total	38	2167.5	-	-	-
Size groups of trout	2	115.6	57.8	1.01	>0.05
Individuals in size groups	36	2051.9	56.9		

Table 11.5 The relationship between the length and the incidence and intensity of infection with *Cythocephalus truncatus* in male and female trout.

Length (cm)	♂♂ Total No. Trout	♂♂ Total No. Infected	♂♂ % Infected trout	♂♂ Total No. parasites	♂♂ Av. No. parasites per infected fish	♀♀ Total No. Trout	♀♀ Total No. Infected	♀♀ % Infected trout	♀♀ Total No. parasites	♀♀ Av. No. parasites per infected fish
5 - 9.9	60	2	3.3	4	2.0	35	-	-	-	-
10 - 14.9	236	12	5.0	97	8.0	208	8	3.8	51	6.3
15 - 19.9	194	20	10.3	202	10.1	261	25	9.5	127	5.0
20 - 24.9	39	4	10.2	38	9.5	37	8	21.6	64	8.0
Total	529	38	7.1	342	9.0	541	41	7.5	242	5.9

♂♂

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio	P
Total	38	2429.0	-	-	-
Size groups of trout	3	133.2	44.4		
Individuals in size groups	35	2295.8	65.5	1.4	>0.05

♀♀

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio	P
Total	41	576.5	-	-	-
Size groups of trout	2	53.9	26.9		
Individuals in size groups	39	522.6	13.4	2.0	>0.05

Table 11.6 The relationship between the length and the incidence and intensity of infection with Echinorhynchus truttae in male and female trout.

Length (cm)	♂♂ Total No. Trout	♂♂ No. Trout Infected	♂♂ % Infected trout	♂♂ Total No. Parasites	♂♂ Av. No. Parasites per infected fish	♀♀ Total No. Trout	♀♀ No. Trout Infected	♀♀ % Infected trout	♀♀ Total No. Parasites	♀♀ Av. No. Parasites per infected fish
5 - 9.9	60	10	16.6	40	4.0	35	4	11.4	15	3.7
10 - 14.9	236	35	14.8	215	6.1	208	33	15.8	173	5.2
15 - 19.9	194	51	26.2	552	10.8	261	92	35.2	955	10.3
20 - 24.9	39	12	30.7	203	16.9	37	9	24.3	142	15.7
Total	529	108	20.4	1010	9.3	541	138	25.5	1285	9.3

♂♂

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio	P
Total	108	15922.7	-	-	-
Size groups in trout	3	1443.9	481.3	3.4	<0.05
Individuals in size groups of trout (error)	105	14478.8	137.8		

♀♀

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio	P
Total	138	21749.7	-	-	-
Size groups in trout	3	1151.5	383.8	2.5	<0.05
Individuals in size groups of trout (error)	135	20598.2	152.5		

Table 11.7 The relationship between the length of trout and the incidence and intensity of infection with <u>Cystidicola farionis</u>.

Length (cm)	♂♂					♀♀				
	Total No. Trout	Total No. Infected	% infected trout	Total No. Parasites	Av.No.para. per infected fish	Total No. Trout	Total No. Infected	% infected trout	Total No. Parasites	Av.No.para. /infected fish
5 - 9.9	60	2	3.3	9	4.5	35	3	8.5	15	5.0
10 - 14.9	236	11	4.6	75	6.8	208	14	6.7	75	5.3
15 - 19.9	194	20	10.3	210	10.5	261	21	8.0	469	22.3
20 - 24.9	39	6	15.3	148	27.0	37	4	10.8	94	23.5
Total	529	39	7.3	442	11.3	541	42	7.7	653	15.5

<u>♂♂</u>

Sources of variation	Degree of freedom	Sum of Squares	Mean Square	Variance ratio	P
Total	38	3750.1	-	-	-
Size groups of trout	3	1307.0	435.5	6.2	<0.01
Individuals in size groups	35	2443.1	69.8		

<u>♀♀</u>

Sources of variation	Degree of freedom	Sum of Squares	Mean Square	Variance ratio	P
Total	41	13060.5	-	-	-
Size groups of trout	3	3023.6	1007.8	3.8	<0.05
Individuals in size groups	38	10036.9	264.1		

This account of seasonal cycles of the helminth parasites mentioned above are based on the examination of 1083 trout of which 81 were invaded by Cystidicola farionis, 245 by Echinorhynchus truttae, 80 by Cythocephalus truncatus, 58 by Proteocephalus neglectus, 6 by Cucullanus truttae and finally 4 by Metabronema truttae (Table 11.3). The fish were collected by electric fishing apparatus from the River Alyn during the period June 1969 to July 1970.

RESULTS

The parasites taken from the fish may be listed as follows :

Group	Name of the species
1. Cestoda:	(a) Cythocephalus truncatus (Pallas 1781)
	(b) Proteocephalus neglectus La Rue 1911
2. Nematoda:	(a) Cystidicola farionis Waldheim 1798
	(b) Cucullanus truttae (Fabricicus 1794)
	(c) Metabronema truttae Baylis 1935
3. Acanthocephala:	(a) Echinorhynchus truttae Schrank 1788

Mrs. Anita Thomas of Zoology Department and Mr. Stephen Prudhoe of the British Museum (N.H.) have kindly confirmed my identifications.

Six species of helminth parasites were recorded throughout the period. All the fish examined were in the size range of 5-25cms (Tables 11.4, 11.5, 11.6, 11.7). 474 of the fish (43.7%) harboured parasites of at least one

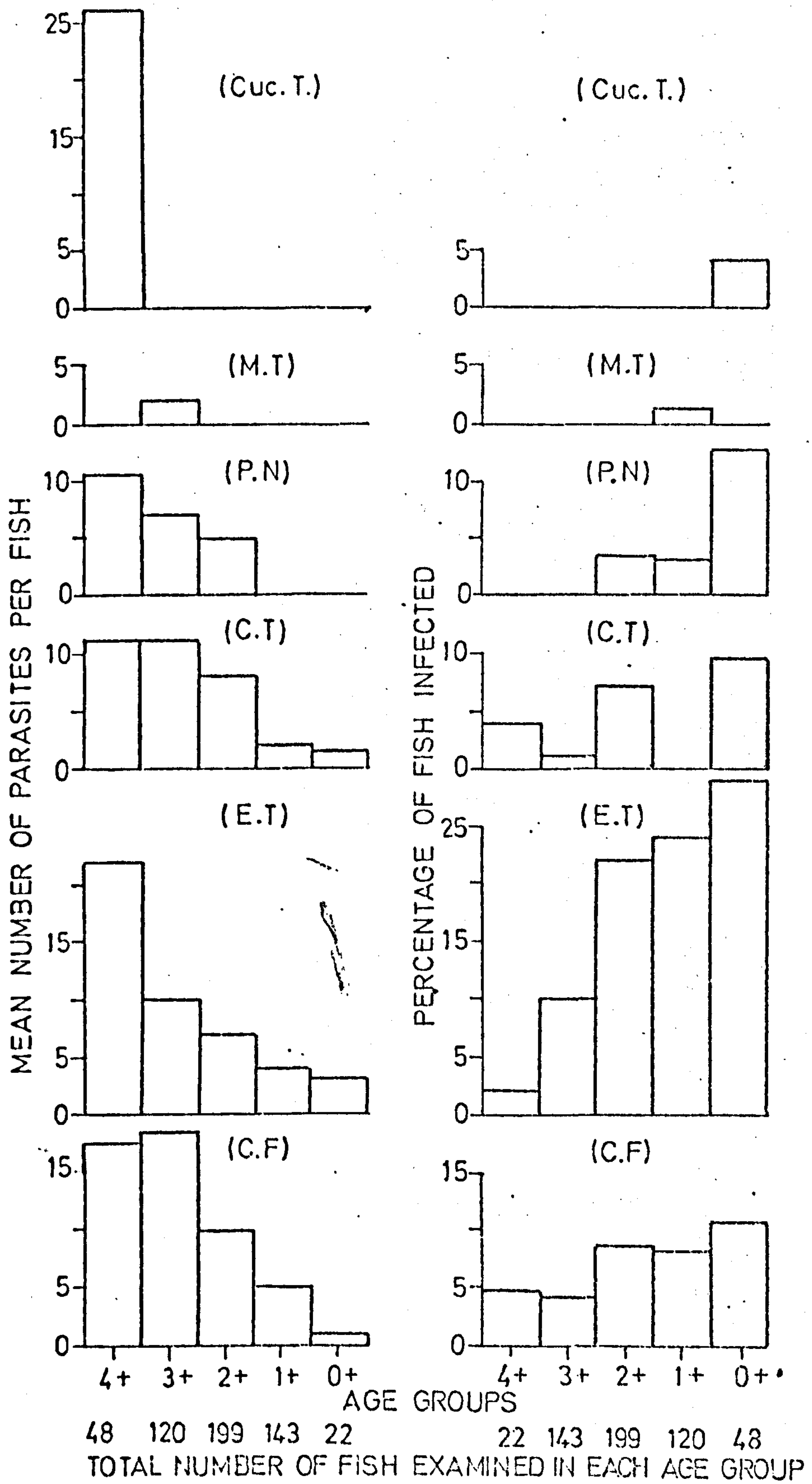

Fig 11. 1 The occurrence of Cystidicola farionis (C.F), Echinorhynchus truttae (E.T), Cyathocephalus truncatus (C.T), Protocephalus neglectus (P.N), Cucullanus truttae (Cuc.T), and Metabronema truttae (M.T), in male trout of various ages

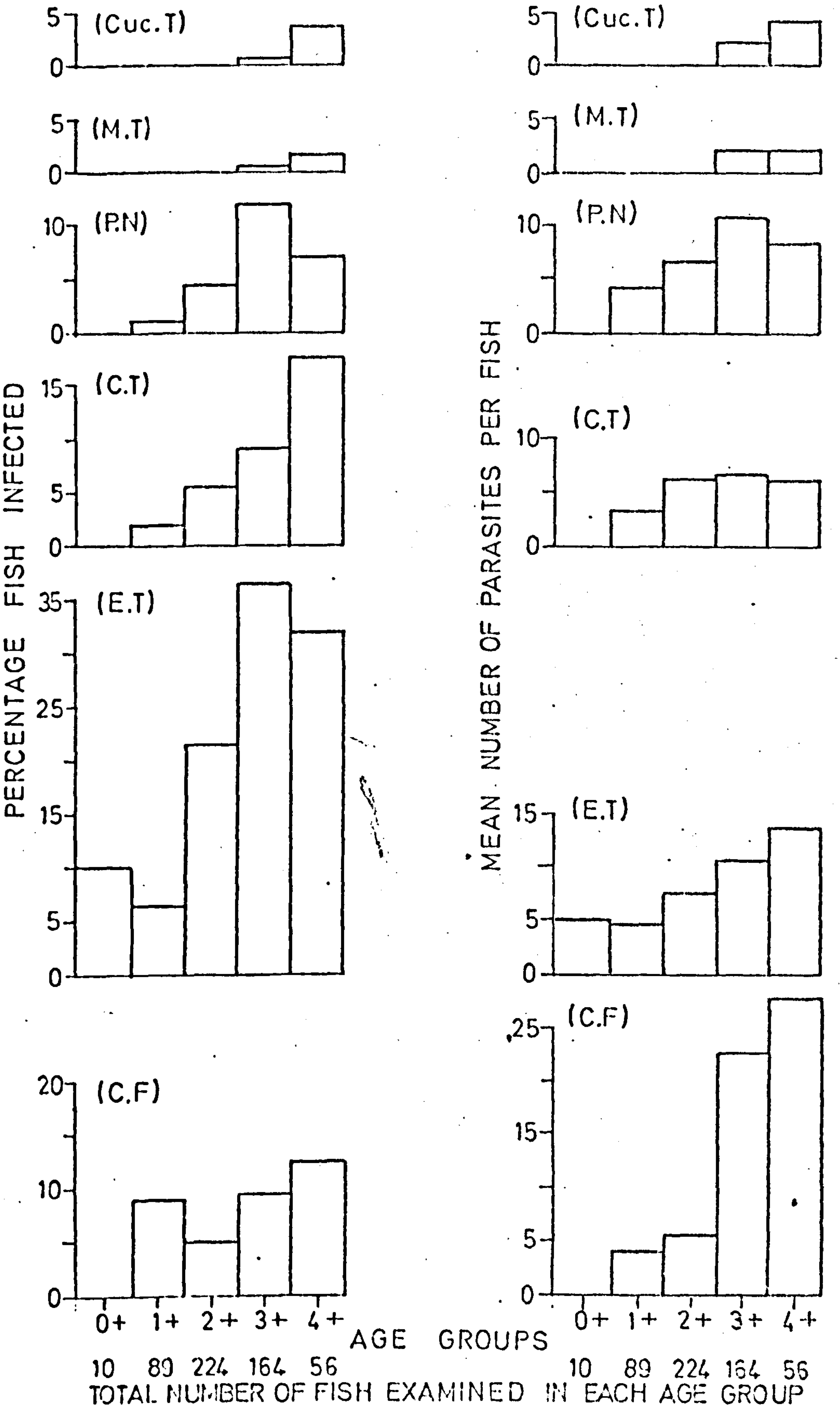

Fig 11.2 The occurrence of Cystidicola farionis (C.F.), Protocephalus neglectus (P.N.), Cucullanus truttae (Cuc.T), Echinorhynchus truttae (E.T.), Cyathocephalus truncatus (C.T) and Metabronema truttae (M.T.) in female trout of various ages

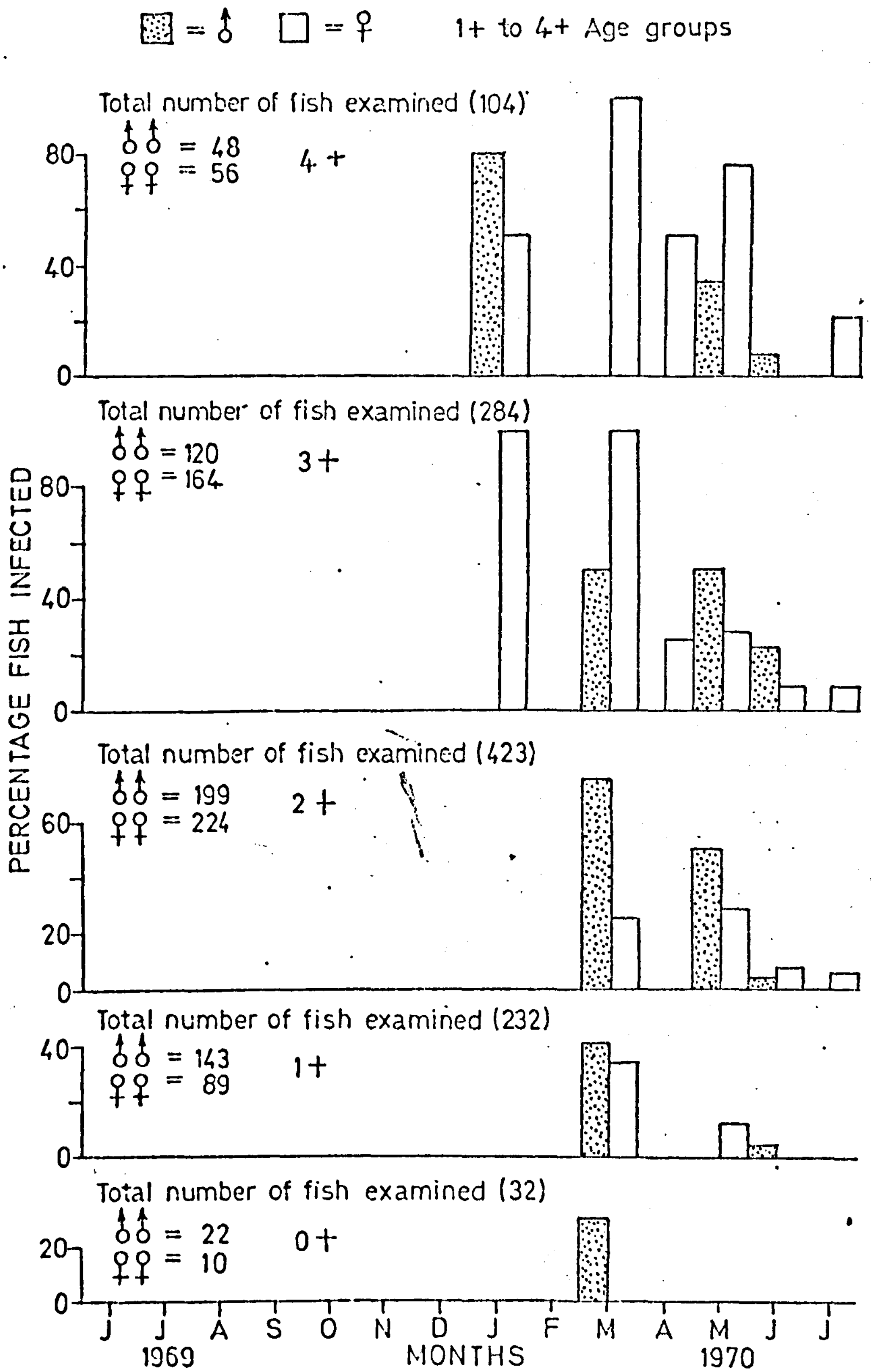

Fig. 11.3 The percentage incidence and seasonal intensity of infection in trout of various ages with <u>Cyathocephalus truncatus</u>

species. The greatest number of species in any one host was four (Tables 11.1, 11.2). All of the above mentioned species have been observed by earlier workers in the British Isles (Shipley 1908; Leipter 1908; Baylis 1928, 1939; Southwell and Krishner 1937; and Rawson 1952) from the standpoint of taxonomy and life history.

The species are dealt with in turn below. This includes an account of the occurrence, seasonal variations and the intensity of infection in various ages (Figs. 11.1, 11.2) and lengths (Tables 11.4, 11.5, 11.6, 11.7) of the male and female trout.

1. Cestoda

(a) Cythocephalus truncatus (Pallas, 1781)

7.4% of the total trout of upper Alyn were infected with this worm inhabiting the pyloric caeca (Table 11.1). The incidence of this parasite in its hosts is summarised in Fig.11.3. It may be seen from this figure that the pattern of the rate of infection in trout is indicative of seasonal periodicity. The rate was high from January to June (Fig.11.3). It may also be observed from Figs.11.1, 11.2 and Table 11.5 that the dynamics of the total number of parasites recovered as well as the mean per infected fish varied in accordance with the age and length groups. Large numbers of worms were taken mainly in January to March when the water temperature was between 4-6^{o}C. The rapid rise of temperature from April to July corresponded

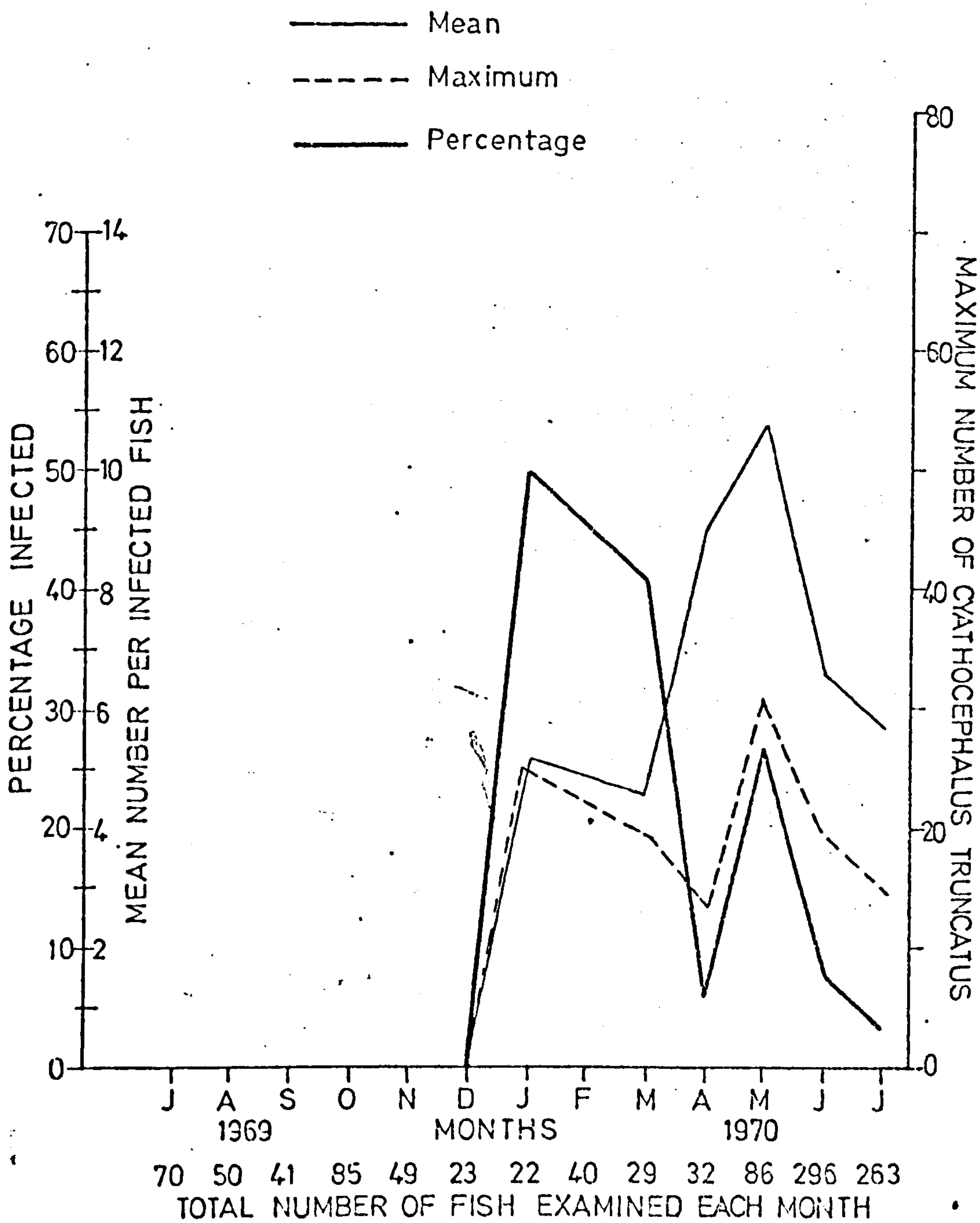

Fig. 11.4 Seasonal variations in the _Cyathocephalus truncatus_ infected in pyloric caecae of trout

(NO PARASITES WERE FOUND BETWEEN JULY AND DECEMBER.)

Table 11.8 The percentage incidence and intensity of infection in trout and salmon parr of the unregulated Llyn Tegid feeder streams.

Name of the stream	Afon Dyfrdwy				
Name of Parasite	Cyathocephalus truncatus				
Months	Name of fish	Age of fish	No. fish infected	Total No. fish	% of infection
3 - 69	S. trutta	3+	2	13	15.3
7 - 69	"	1+	1	12	8.3
9 - 69	"	2+	2	18	11.1
9 - 69	S. salar	1+	1	27	3.7

Total No. Fish examined=122 ; Number of fish infected=6 ; %=4.6ection

Name of the stream	Afon Glyn				
Name of Parasite	Cyathocephalus truncatus				
Months	Name of fish	Age of fish	No. fish infected	Total No. fish	% of infection
6 - 69	S. trutta	1+	7	12	58.3
7 - 69	"	1+	4	11	36.3

Total No.Fish examined=123 ; No.Fish infected=11 ; %=8.9

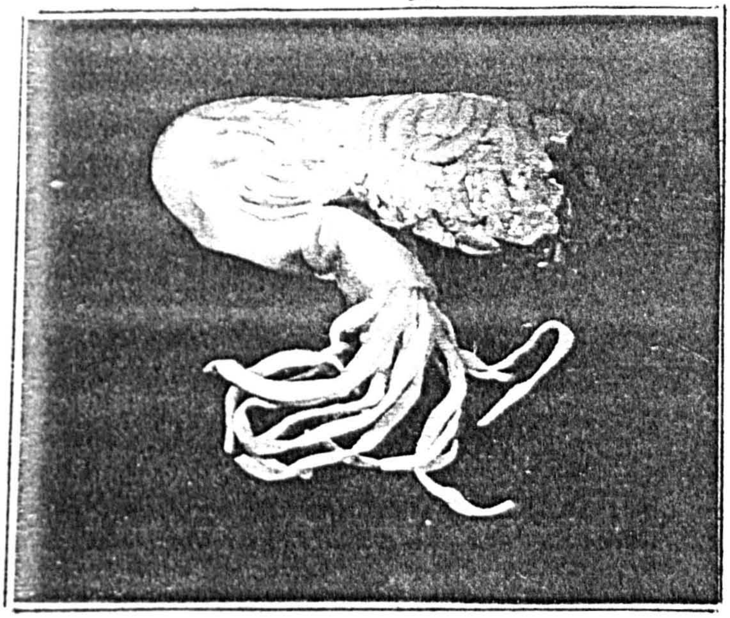

PLATE 11.1 PROTEOCEPHALUS NEGLECTUS IN THE INTESTINE OF TROUT.

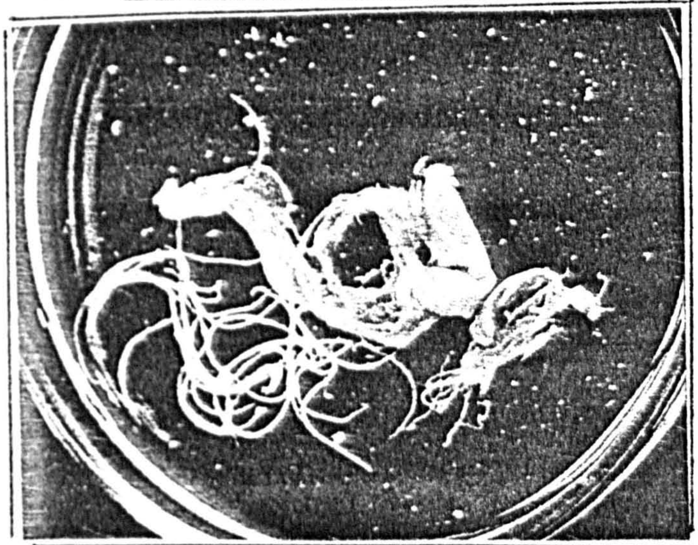

PLATE 11.2 CYCTIDICOLA FARIONIS IN THE SWIMBALDDER OF TROUT.

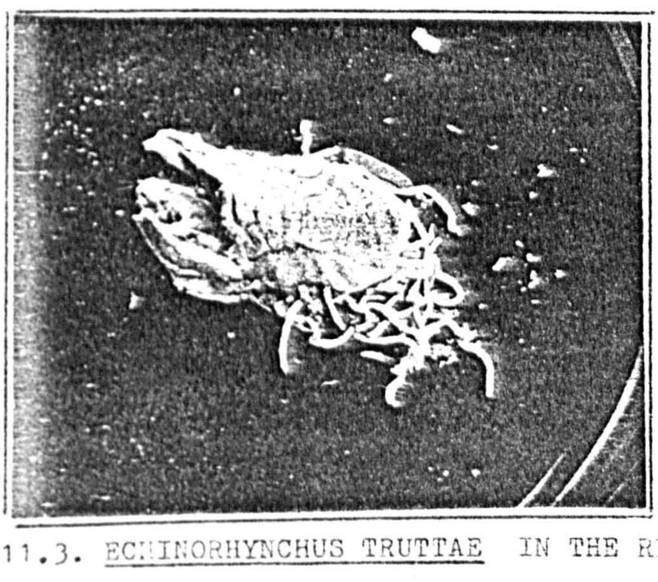

PLATE 11.3. ECHINORHYNCHUS TRUTTAE IN THE REGION OF PYLORIC CAECA.

with the decrease in the occurrence of worms in fish (Fig.11.4). Figures 11.1 and 11.2 show that 3+ and 4+ age groups of the females were more infected than the males of the same age. The reverse was true for the trout belonging to 0+ to 2+ age groups. It was also noticed in Figures 11.1, 11.2 that percentage of infection and mean number of parasites per infected fish increased gradually in both the sexes from 0+ to 4+ age groups of the fish.

In Afon Dyfrdwy 15.3% trout belonging to 3+ age group, 8.3% to 1+ and 11.1% to 2+ age group, were found to be infected by this parasite in the months of March, July and September respectively. In September 3.7% of the total salmon parr of 1+ age group were also infected by the same parasite (Table 11.8).

Cythocephalus truncatus were collected from the pyloric caeca of trout belonging to 1+ age group in Afon Glyn. The infection was observed in 58.3% and 36.3% of the total trout in the month of June and July respectively (Table 11.8).

(b) *Protocephalus neglectus* La Rue, 1911

This parasite was found in the anterior end of the intestine in a large sample of trout collected during June and July and formed 5.4% of the total infection (Table 11.1). The trout belonged to 3+ and 4+ age groups, and were infected by this parasite (Figs. 11.1, 11.2). In few older trout these were packed in the anterior end of the intestine (Plate 11.1).

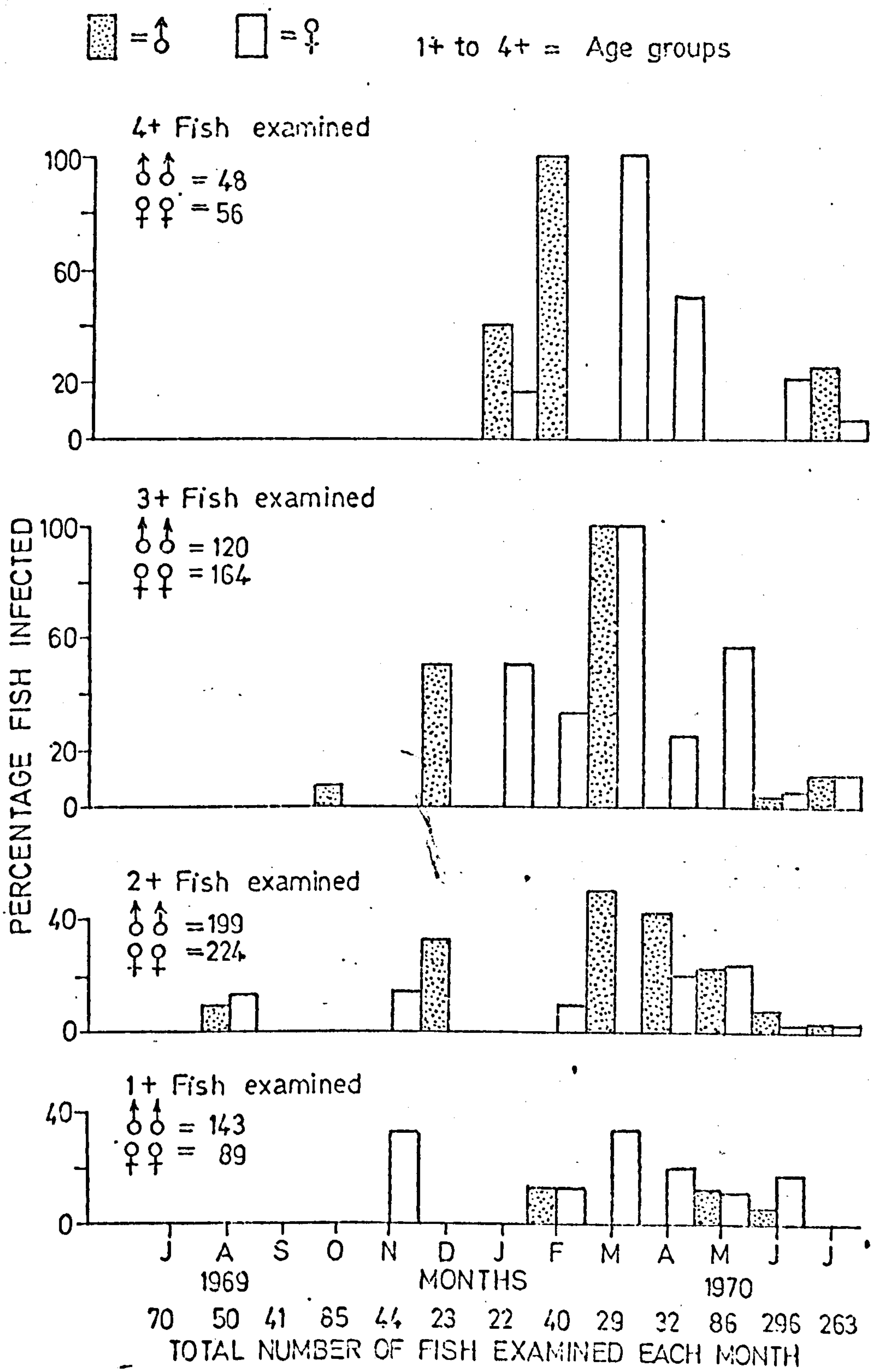

Fig. 11.5 The percentage incidence and seasonal intensity of infection in trout of various ages with *Cystidicola farionis*

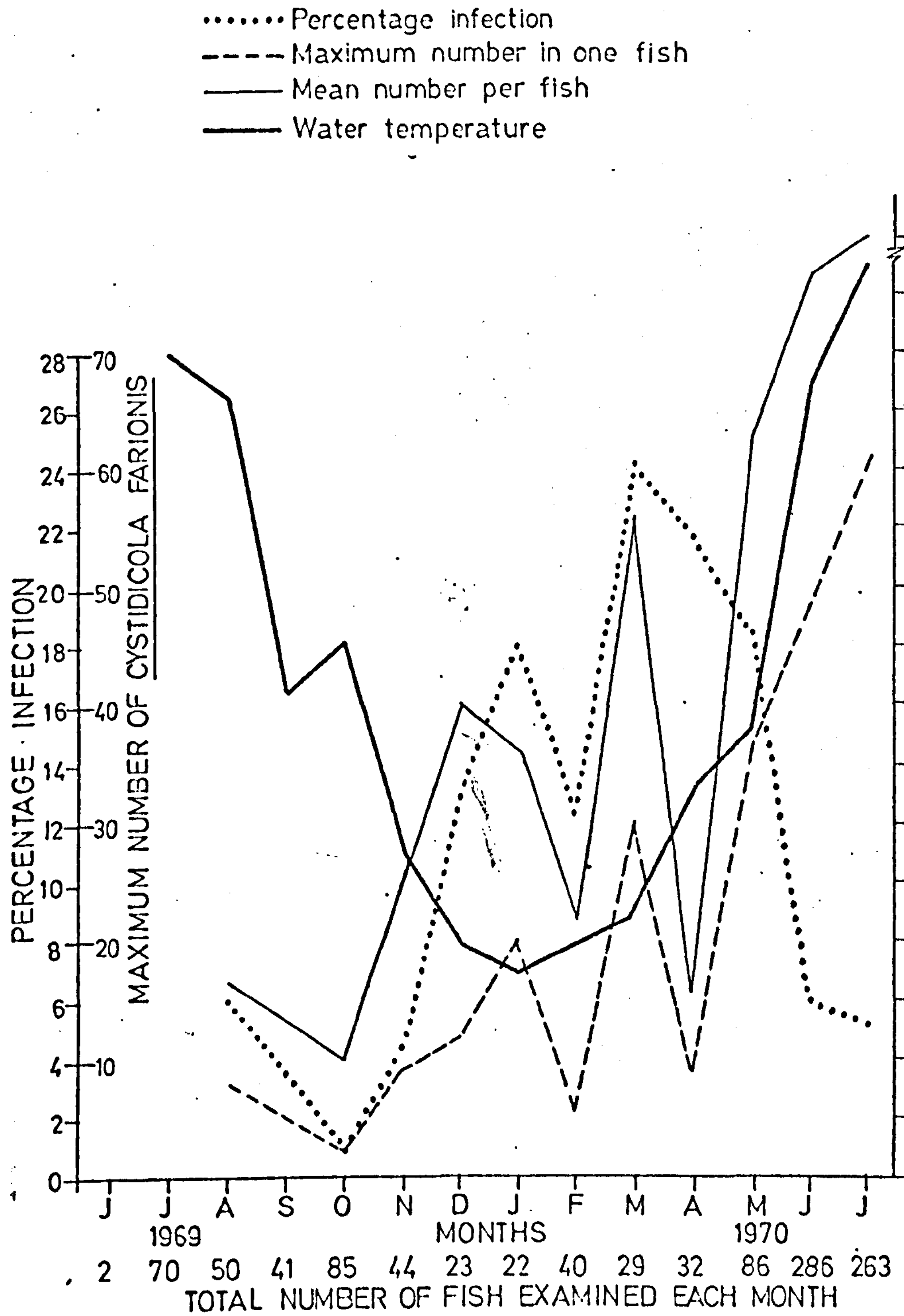

Fig. 11.6 Seasonal variations in the Cystidicola farionis infection in swim bladder of trout

There was a tendency for longer male trout to be more infected (Table 11.4). This was not pronounced in larger females belonging to 20-24.9cm length group, and may be due to less number of fish caught in that group.

2. Nematoda

(a) Cystidicola farionis Waldheim, 1798

Roundworm infestation of the swimbladder of trout was found to be at a comparatively low rate (Tables 11.1, 11.2). 7.4% of the total fish were infected with this parasite inhabiting the swimbladder (Plate 11.2). The seasonal fluctuations in the rate of infection by this worm are shown in Figs. 11.5, 11.6. These graphs show that the intensity of infection was higher during December-March and then it gradually decreases in summer months. The seasonal occurrence of the parasite was rather similar in male and female trout of various age groups (here 1+ to 4+) (Fig.11.5). Mean number of parasites per infected fish and percentage of the total fish infected increase from 1+ to 4+ age groups in both the sexes (Figs.11.1, 11.2). It was found that the rate of infection was generally higher when the water temperature was low, and the reverse was true when the temperature was high (Fig.11.6). The percentage of infected fish and mean number of parasites per infected fish gradually increased from lower length group to higher in male and female trout (Table 11.7).

(b) Cucullanus truttae (Fabricius, 1794)

This parasite was recorded attached in the stomachs

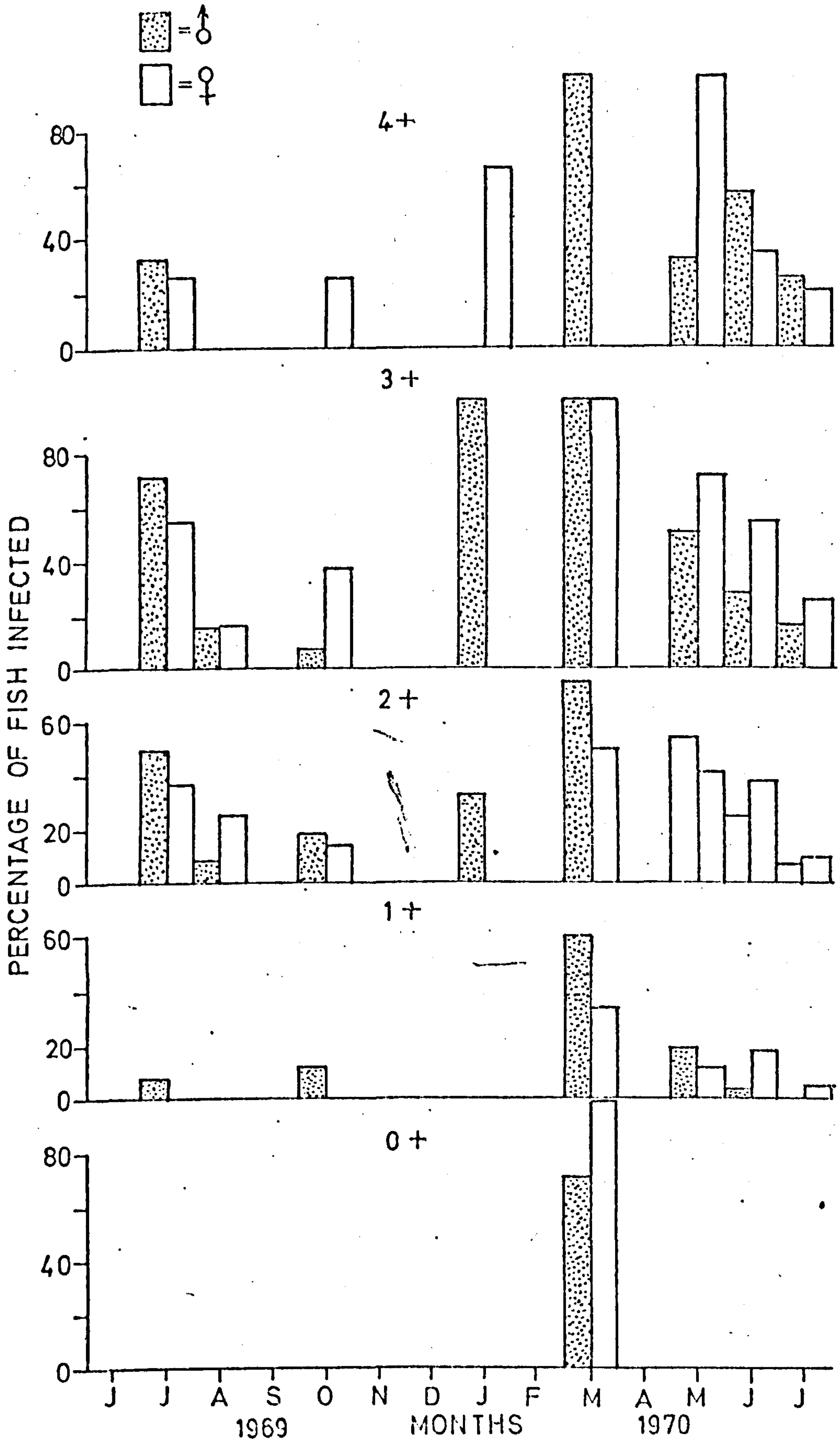

Fig 11.7 The percentage incidence and seasonal intensity of infection in trout of different age groups with Echinorhynchus truttae

of male and female trout belonging to 3+ and 4+ age groups (Figs. 11.1, 11.2). 0.5% of the total fish were infected by this parasite between January to July (Table 11.2).

(c) Metabronema truttae Baylis 1935

During the current study, records were also kept of the occurrence of this parasite. Tables 11.1, 11.2 show that 0.3% of the total fish were infected by this worm which was observed during December and January. These were very scarce in the stomachs of older trout (here 3+ and 4+ age groups) of both sexes (Figs. 11.1, 11.2).

3. Acanthocephala

(a) Echinorhynchus truttae Schrank, 1788

This parasite inhabits the intestine. It is a fairly common parasite of brown trout and occurs in many parts of the continent. These were comparatively abundant in the sample (Tables 11.1, 11.2). The immature adults were found attached to the inside of the intestinal wall, and frequently established all over the entire length of the intestinal tract including pyloric caeca (Plate 11.3). No worms were found in the stomachs. The mean number of parasites per infected fish and the percentage of infected fish were higher in 4+ age group in both sexes of trout (Figs. 11.1, 11.2). A gradual increase in infection from 0+ to 4+ age groups was also noticed. The seasonal incidence and intensity of infection in each age group has rather similar patterns in both sexes (Figs.11.7). More infected fish with this parasite were observed from

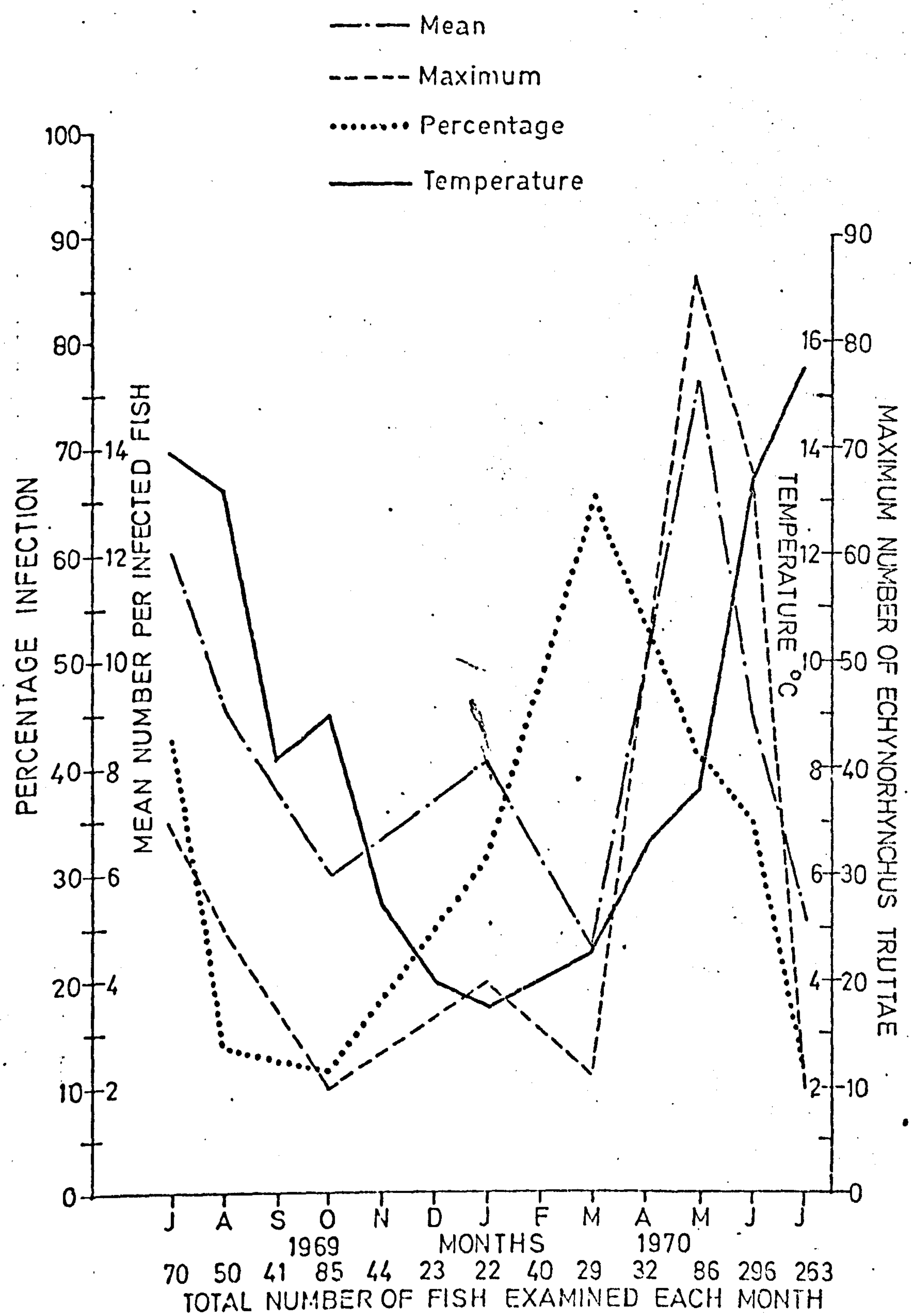

Fig 11.8 Seasonal variations in the *Echynorhynchus truttae* in the intestine of trout

October to March than in any other months (Fig.11.8). Chubb (1964) postulated that temperature may play a major part in determining the presence or absence of a well-defined seasonal periodicity of development of some of the Acanthocephala.

It was also observed that the average number of parasites per infected fish and the percentage of infected fish varied directly with the length groups in both sexes (Table 11.6). This may be readily explained on the premise that the larger fish require more food organisms to satisfy their needs than do the younger fish, and consequently are more liable to consume a greater number of infested intermediate hosts.

DISCUSSION

Baylis (1928) reported Cyathocephalus truncatus in the pyloric caeca of trout in November and December. Awachi (1963) observed that C. truncatus was the only one species of cestode occurring in the brown trout of Afon Terrig. He further reported Gammarus pulex as an intermediate host of this parasite.

In the current survey of the River Alyn 7.4% of the total fish were found to be infected with C. truncatus (Tables 11.1, 11.2). This parasite was recorded from January to July in which the mean number of parasites per infected fish attained a peak in May (Fig.11.3), and were slightly greater in males than in females (Table 11.5).

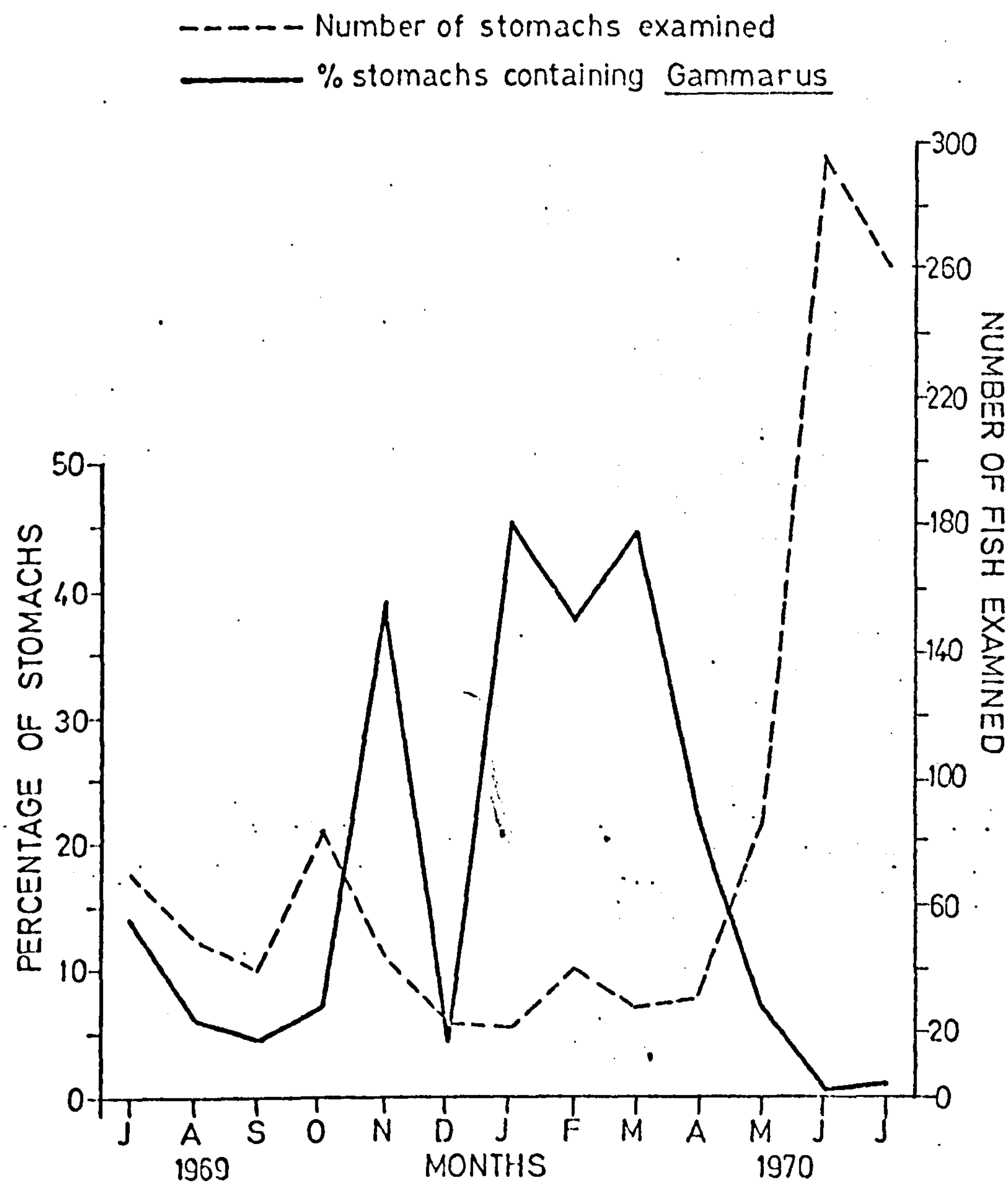

Fig 11.9 Percentage of stomachs of trout containing Gammarus pulex

Mean number of parasite per infected fish and the percentage of fish infected gradually increased from 1+ to 4+ age groups in both sexes (Figs.11.1, 11.2). This may be due to feeding activity of the trout and their choice of food (here Gammarus pulex) which may affect the degree to which they become infected. No clear picture of seasonal variation emerges from the data (Fig.11.4). Fig.11.3 does, to some extent, show an increased intensity of infection in winter and spring (January-May), in all age groups (1+ to 4+). This may be due to feeding on benthic invertebrates including Gammarus pulex (Fig.11.9) which is an intermediate host (Awachi 1963). This parasite inhabits principally the pyloric caeca and is only occasionally taken in the upper intestine. An examination of the worms taken shows that the specimens taken in January were rather young and recently established. These young ones were recognised by their relatively small size and lack of mature proglottids. Worms taken from March to May were predominantly adult and functionally mature. This reflects that C. truncatus establishes in the fish in late autumn, depending on the time of infection. Awachi (1963) pointed out that they mature in late winter and spring and disappear in late summer.

The ecology of the bottom fauna with reference to the food and feeding habits of salminids, in the Llyn Tegid feeder streams are reported in the present work (Chapters III-VII). During the course of this investigation any parasite encountered in the stomach and anterior region of the intestine were recorded from the trout and salmon parr of the unregulated Llyn Tegid feeder streams. The only parasite present, and that only occasionally, in the pyloric caeca of trout and salmon parr of Afon Dyfrdwy and Afon Glyn was C. truncatus. These incidences may be because Gammarus pulex was one of the benthic food items.

Proteocephalus neglectus was recorded by Aderounmu (1966) while examining the trout from Chirk hatchery. 5.3% of the total fish (sample of June and July) were infected by this parasite (Tables 11.1, 11.2). These were distributed in the trout belonging to 2+ to 4+ age groups in both sexes (Figs.11.1, 11.2). A very high significant difference was found in the mean numbers of parasites per infected male trout ($F = 18.7$, $df = 2/18$, $P < 0.001$) between the different length groups (Table 11.4).

While studying the nematode parasite fauna of brown trout Shipley (1908) appears to have been the first British worker to record Cystidicola farionis in the lumen of the swimbladder of trout sent to him from Royston in Herts. He further states that the parasites were more numerous in winter and they make their way to swimbladder through the oesophagus. Detailed anatomical study of the same parasite was made by Leiper (1908). C. farionis has recently been reported in the swimbladder of trout of Chirk hatchery (Aderounmu 1966), Hampshire and Hertfordshire (Baylis 1928), Llyn Tegid (Chubb 1963) and Afon Terrig (Awachi 1963).

In the present investigations it was found that the intensity of infection gradually increased with the increase in age (Figs.11.1, 11.2) and length (Table 11.7) groups. A significant difference was found in the intensity of infection per infected fish between different length groups (Table 11.7) in male trout ($F = 6.2$, $df = 3/35$, $P < 0.01$) and female ($F = 3.8$, $df = 3/38$, $P < 0.05$) trout. It was noticed that female fish were more heavily infected than the male (Table 11.7). The large increases in the incidence and intensity of Cystidicola farionis infection in the older fish may have occurred because the parasites accumulated as the older fish ate infected Gammarus pulex. The trout may have been feeding selectively on the intermediate hosts, which are Gammarus pulex. I examined the food contents of stomachs of trout and showed that distinct food preferences were established by individuals of different age groups (Table 10.10). Baylis (1931) reported the larvae of C. farionis in the body cavity of Gammarus spp. Bauer and Nikolskaya (1952) have also reported another amphipod Pontoporeia affinis as the intermediate host of this worm in Lake Ladoga in U.S.S.R. Table 10.10 showed that 8.9% (by number) of the total food were Gammarus pulex eaten by the fish belonging to 0+ age group, 10.3% by 1+, 6.6% by 2+, 10.5% by 3+ and finally 9.7% by 4+ age group. The infection thus increased progressively with the age and length of the fish as more parasites were acquired.

The rise in the degree of infestation during winter and spring, following the decline in summer months shown by all age groups, suggests that the trout had not acquired an immunity as a result of previous infestation, although the problem of immunity to C. farionis remains doubtful. I think that a more intensive and critical investigation in this problem would be profitable. A similar seasonal cycle (as mentioned above) was observed by Shipley (1908) while working on the stream trout at Herts. Awachi (1963) did not find any apparent seasonal fluctuations in the trout of Afon Terrig infected by C. farionis. The increase in the degree of infection during winter and spring and gradual decrease in summer may presumably be related with the water temperature (Fig.11.6) or may be due to the fact that the trout have been feeding relatively more on Gammarus pulex along with other benthic invertebrates (Fig.11.9). Awachi (1963) pointed out that the parasite establishes in late fall and winter in the intermediate host (Gammarus pulex).

Cucullanus truttae was recovered by Baylis (1928) during September and by Stranack (1966) in the trout of River Avon (Hampshire). Thomas (1964) noted that common occurrence of this parasite in the gut of trout from the River Teify, west Wales. Chubb (1964) showed the occurrence of C. truttae in the gut of trout in Llyn Padarn.

I found 0.5% of the total fish were infected by C. truttae. These occurred in the stomachs from January to July (Tables 11.1, 11.2) in 3+ and 4+ age groups in both sexes of the fish (Figs. 11.1, 11.2).

Baylis (1939) reported the occurrence of Metabronema truttae in the intestine of trout in April. Rawson (1952) recorded the same parasite from Lake Windermere in August and October. Awachi (1963) showed the occurrence of M. truttae in the intestine of trout throughout the year.

Metabronema truttae were found in the stomachs of trout only occasionally. 0.3% of the total fish were infected by this parasite. These were recorded during December and January in both the sexes (Figs. 11.1, 11.2) though Awachi (1963) showed the rate of infection with M. truttae was more or less even throughout the year in the intestine of trout of Afon Terrig.

I did not find nematode parasites from the trout and salmon parr in any of the Llyn Tegid feeder streams.

Echinorhynchus truttae has been reported to occur in a number of fish. Baylis (1939) found trout Salmo trutta, grayling Thymallus thymallus, eel Anguilla anguilla, roach roach Rutilus rutilus and dace Leuciscus leuciscus as recorded hosts of this parasite in Britain. The commonest final host from the point of view of incidence and intensity of infection is the trout. More recent contributions to the knowledge of life cycle of this parasite were made by Petrochenko (1956), Hynes and Nicholas (1957), Nicholas and Hynes (1958), Kovalenko (1960) and Awachi (1963, 1965). These and various other reports (Meyer 1933, Bauer 1953, Hoffman 1954 and Petrochenko 1956) show that the G. pulex is the usual intermediate host. A detailed study was made by Awachi (1963) who, while working on the trout of Afon Terrig, showed the developmental history of E. truttae in both its hosts. Aderounmu (1966) reported E. truttae in the intestine of Chirk hatchery trout during summer. Awachi (1963) found the same parasite throughout the year. Baylis (1939) noted them during November and December. Rawson (1952) pointed out their presence in August and Thomas (1964) showed the occurrence of E. truttae throughout the year in the intestine of trout of the River Teify.

In my study 22.6% of the total trout were found to be infected by E. truttae that established in all parts of the intestine (Table 11.1). Similar findings were made by Awachi (1963). The seasonal cycle of the intensity of infection does not rise with the rise in water temperature (Fig.11.8). Chubb (1964) and Awachie (1963) also found no cyclic fluctuation in the incidence of Acanthocephala E. clavula and E. truttae in Llyn Tegid and Afon Terrig respectively. It may be pointed out that there was a drop in the degree of parasitisation of trout in July (Fig.11.8), which may be due to the lack of Gammarus pulex in the food during summer (Fig.11.9). The mean number of parasites per infected fish was slightly higher in males (9.2) than in females (8.2) (Figs. 11.2, 11.3). A significant difference was observed in the mean numbers of parasites per infected male ($F = 3.4$, $df = 3/105$, $P < 0.05$) and female ($f = 2.5$, $df = 3/135$, $P < 0.05$) trout in different length groups (Table 11.6). Seasonal intensity of infection in various age groups (here 0+ to 4+) in both the sexes show a similar pattern (Fig.11.7). The percentage of fish infected and the mean number of parasites per fish progressively increases from 0+ to 4+ age and 5-9.9cm to 20-24.9cm length groups in both the sexes (Figs. 11.2, 11.3, Table 11.6), though Robertson (1953) found that only trout greater than 14.5cm in length were infected by E. truttae. I found young trout as small as 7.4cm to be infected by this parasite in the River Alyn.

In all fishes observed from the Llyn Tegid feeder streams, I did not record E. truttae, probably due to the scarcity (Table 8.4, Chapter VIII) of the intermediate host (G. pulex).

SUMMARY

(1) Six species of helminth parasites were found in the alimentary tract and swimbladder of the trout of the River Alyn.

(2) The incidence and intensity of infestation gradually rise from 0+ to 4+ age groups in both sexes.

(3) 22.6% of the total trout were infected by Echinorhynchus truttae, 7.4% by C. farionis, 7.4% by Cyathocephalus truncatus, 5.3% by P. neglectus, 0.5% by Cucullanus truttae and 0.3% by Metabronema truttae.

(4) The cyclic fluctuations in the intensity of infections were discussed.

(5) One species of helminth parasite C. truncatus was recorded from the trout and salmon parr of Afon Dyfrdwy and Afon Glyn, the unregulated Llyn Tegid feeder streams.

(6) It seems likely that the intensity of infestation of trout by most of these parasites is determined by consumption of Gammarus pulex as intermediate host.

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