The estimate numbers of leeches in the river Wear and some of its tributes, with notes on the factors affecting them

Kemball, A. G.

AN ESTIMATE OF THE NUMBERS OF LEECHES IN THE RIVER WEAR AND SOME OF ITS TRIBUTARIES, WITH NOTES ON THE FACTORS AFFECTING THEM.

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CONTENTS

INTRODUCTION

Leeches are among the most important fresh-water predators, but the factors affecting their numbers and distribution are not well known. Three of the most important pieces of original research into the ecology of leeches are by Bennike (1943), Mann (1955), and Tucker (1958).

Bennike noted the presence or absence of leech species in ponds, lakes, and marshes, and measured the total alkalinity of the water. He did not measure total alkalinities from rivers, although he did note the presence or absence of leech species. Mann related the total alkalinity to the number of leeches caught per hour in 47 ponds and 11 streams or rivers. Both authors made some comparisons between the leech faunas of different substrates. Unfortunately, Bennike compared stone and reed populations which did not come from the same lakes or rivers. Tucker (1958) related the numbers of leeches and other invertebrates caught per hour in 16 ponds to the calcium and magnesium concentrations, and the total alkalinity.

Only two estimates of the densities of leech populations per unit area could be found. One was given by Mann (1965), the other, based on three small areas of an unspecified substrate, by Bennike (1943).

Since the leech populations of flowing waters have been less thoroughly studied than those of ponds, it was decided to concentrate on the local rivers in the present work. Mean densities of leeches per square yard were estimated to give figures which could be compared with those for other animals.

The effect of substrate on leeches appears not to have been studied much. It was therefore decided in the present work to record the type of substrate from which leeches were collected. By recording the nature of the substrate, misleading comparisons between different streams were avoided. As far as possible the population densities of leeches found were related to the nature of the substrate and the chemical factors found.

METHODS

1. Choice of Site

The sites chosen were mainly in the river Wear or its tributaries at or above Durham City. Wherever possible a number of randomly chosen areas within an apparently uniform substrate were searched for leeches. Any site chosen was approximately uniform in current and substrate. In Whitewell Beck no attempt was made at random selection because of the small size of the stream and the absence of any large areas of uniform substrate. The size of the areas examined varied with the nature of the substrate, but was kept approximately constant for any one type of substrate. This variation occurred because areas covered with small stones take longer to examine than those covered with large ones.

Larger samples were used to reduce the degree of variation between the samples.

Sites were investigated at regular intervals when transport was readily available. It was not possible to make regular visits to the sites above Bishop Auckland.

In the river Wear, all substrates present at depths of less than 3ft were examined. In the other streams stones resting on mud or sand, shingle, banks, and areas covered by Sparganium erecta were examined.

ii. Collecting and Counting

In stony sites all the stones within a measured area were turned over, and all the leeches present were collected or counted. The substrate beneath the stones was sieved when erpobdellids were present.

Plants of Sparganium erecta within a measured area were pulled up by the roots, and leeches were collected from between the leaves. The mud between the plants was sieved to a depth of about 6in.

When the substrate consisted of mud it was sieved to a depth of about 6in. A sieve with meshes 2mm apart was used in all cases.

Three areas in the river Browney were sampled at monthly intervals to test whether repeated sampling of the same areas gave more accurate estimations of population changes than random sampling. To reduce the amount of disturbance, the mud beneath the stones was not sieved.

iii. Identification

Individual leeches were identified with the help of K.H. Mann's key to British fresh-water leeches. During the first two months of the work all specimens were taken to the laboratories for identification under the microscope. At the end of this period it was found that identifications could be made accurately without a microscope, and most identifications were made in the field.

iv. Estimation of Numbers

The numbers of leeches per square yard was calculated for each area investigated. If five or more areas of the same substrate at a given site were investigated within a period of ten days, the mean density and the 95% confidence limits for the mean and for individual areas were calculated.

Arithmetical probability paper was used to test whether the distribution of densities approximated to a normal distribution. In the majority of cases the distribution was transformed to a normal. The transformation used is noted in each case.

When one or more of the areas at a site had no leeches of a particular species it was impossible to transform that distribution to a normal one. In such cases the confidence limits were calculated by the negative binomial formula (see Anscombe 1950, Bliss 1953, Fisher 1953). There was unfortunately not time enough to apply this formula in all cases where it was needed.

v. Water Testing

Calcium and magnesium concentrations, total resistivity, and pH were measured.

Resistivity was measured by a Mullard conductivity cell at $0^{\circ}C$.

pH was measured by a direct reading pH meter.

Dissolved substances derived from peat are described throughout this work as peat effluents. It was not possible to make any measurements of the amounts of peat effluents present.

Calcium and Magnesium concentrations were measured by an E.E.L. atomic absorbtion spectrophotometer.

10,000 p.p.m. of Lanthanum (Lanthanum chloride solution) were used to prevent interference by phosphorous with calcium determination.

vi. Measurement of Current

The only available method for measuring current was the Pitot tube. This has two serious disadvantages; it cannot be used to measure current speed in crevices between stones; and it can only measure currents more than approximately 50cm per second. Most of the currents measured at the surface of the substrate were too slow to be measured by this method.

Water speeds were therefore measured by eye, and described as:

fast, rapids with disturbed water surface.

moderate, where objects float at above normal walking speed.

slow, where objects float at less than normal walking speed, or

negligible.

The substrate generally corresponds with the current as follows:

fast, moderate current, substrate of stones on sand.

slow current, substrate includes smaller stones on sandy mud.

negligible current, substrate of mud.

vii. Weighings

A number of leeches from each site were taken at monthly intervals and identified in the laboratory. They were then blotted dry with filter paper and weighed on a Mettler balance, accurate to .0001gm.

viii. Ages, births, and deaths of the leeches

Mortality among the older leeches, and births were deduced from changes in the weight profile of the population, as shown in the figures giving individual weights. In general no distinction was made between animals of different ages when estimating populations. The young of Trocheta subviridis were excluded from density calculations because of their extreme tendency to aggregate. They were distinguished by their small size and weight and their red colour due to blood pigment.

ix. Gut contents

The gut contents of 20 specimens of Trocheta bykowskii were examined.

Ten were obtained by diesecting animals which had been killed with alcohol; the other ten by gently squeezing the near end of the live animal between two pieces of filter paper. All were taken from adults.

RESULTS

LEECH POPULATIONS

Densities are expressed as numbers per square yard. The population density of each area examined is given separately. Where five or more areas within a single site have been examined in one week the mean density, 95% confidence limits of the mean density, and 95% confidence limits for the population densities of single areas are given. It was not possible in some cases to calculate confidence limits for the mean. The type of calculation used to determine the confidence limits of the mean is described as normal when the distribution could be transformed into a normal one, or as negative binomial when the negative binomial equation was used. The type of transformation used to convert the distribution found into a normal one is given in the tables.

In the figures giving individual weights each dot represents the position of an individual animal on the weight scale. Weights are expressed in grams. Different weight scales are used for different species. Glossiphonids with attached eggs or young are shown by an oblique dahs, thus / .

The following species were found in the rivers under investigation:

Glossiphonidae:

Helobdella stagnalis

Glossiphonia complanata

Theromyzon tesselatum

Erpobdellidae:

Erpobdella octoculata

Trocheta bykowskii

Trocheta subviridis

Hirudidae:

Haemopis sanguisuga

The following species were found near Durham but not in the rivers investigated:

Glossiphonidae:

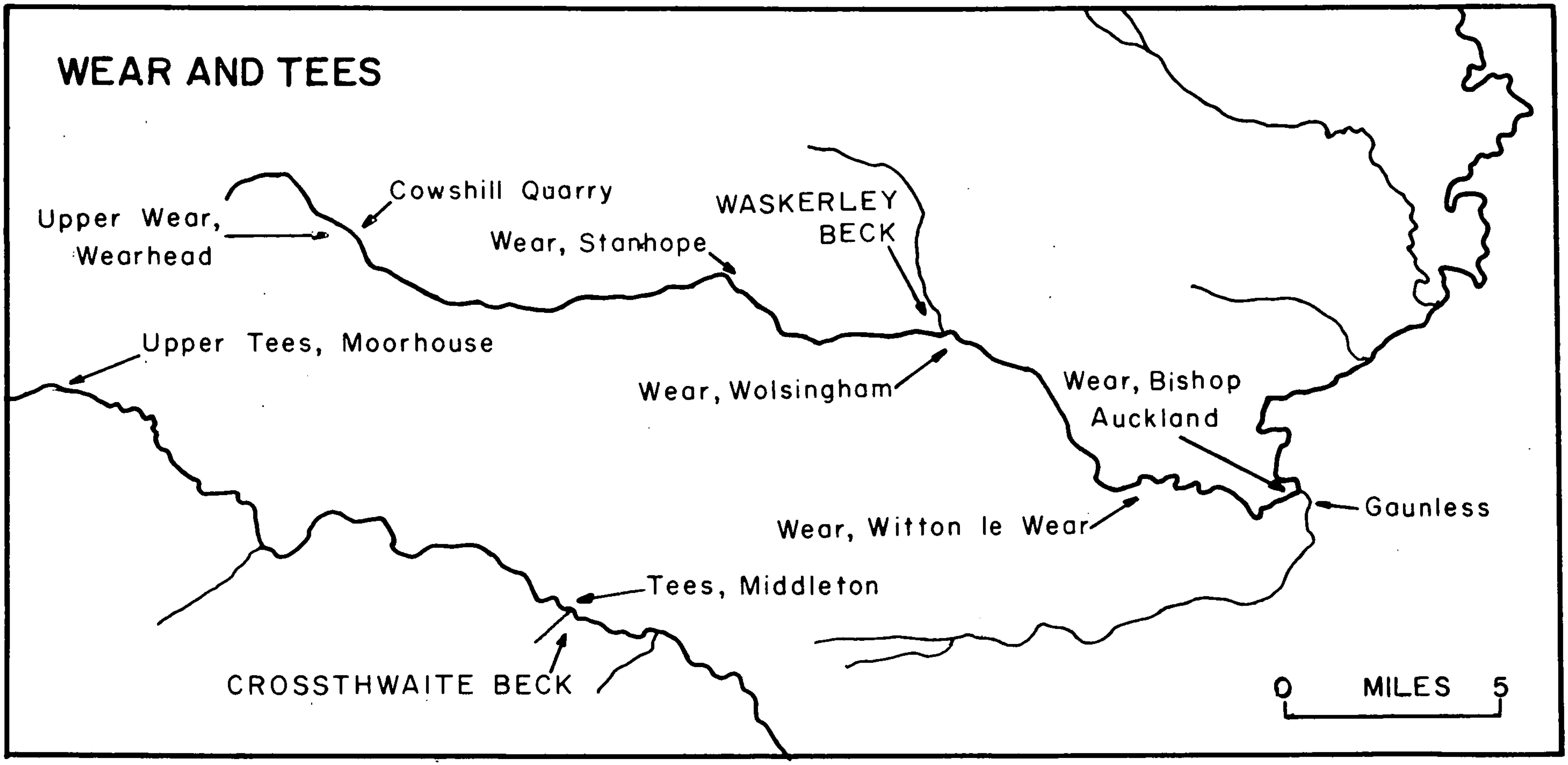
Batracobdella paludosa

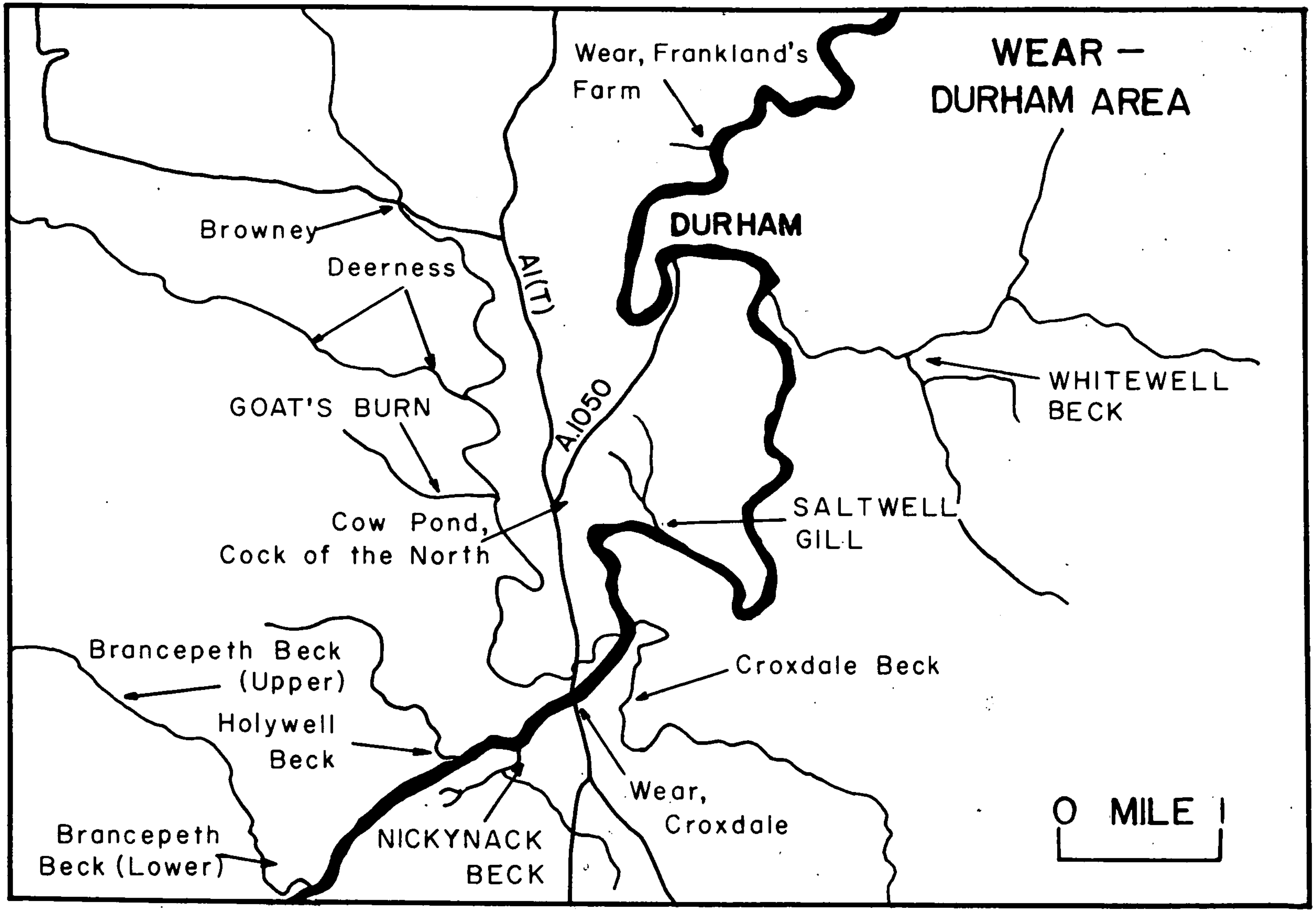
Piscicolidae:

Piscicola geometra

Erpobdellidae:

Dina lineata


WEAR AND TEES
Upper Wear, Wearhead
Cowshill Quarry
Wear, Stanhope
WASKERLEY BECK
Upper Tees, Moorhouse
Wear, Wolsingham
Wear, Bishop Auckland
Gaunless
Wear, Witton le Wear
Tees, Middleton
CROSSTHWAITE BECK
0 MILES 5


WEAR –
DURHAM AREA
Wear, Frankland's
Farm
DURHAM
Browney
Deerness
A1(T)
A.1050
GOAT'S BURN
Cow Pond,
Cock of the North
SALTWELL
GILL
WHITEWELL
BECK
Brancepeth Beck
(Upper)
Holywell
Beck
Croxdale Beck
Wear,
Croxdale
Brancepeth
Beck (Lower)
NICKYNACK
BECK
0 MILE 1

RIVER WEAR

The river Wear was investigated at Wearhead, Stanhope, Wolsingham, Witton-le-Wear, Bishop Auckland, above and below the confluence with the river Gaunless, Croxdale, and below Durham.

Wear from Wearhead to Wolsingham

The areas investigated were all about 5 sq.ft. with a substrate of stones on muddy sand, and a slow current. Four areas were investigated at Wearhead and at Stanhope on July 7th. Four areas were examined at Wolsingham, two above and two below the confluence with Waskerley Beck on August 3rd.

No leeches were found in any of the areas examined.

Witton-le-Wear

Two types of substrate were investigated on August 22nd.

i. Stones on muddy sand, at or above the water level.

Two areas, each about 6 sq.ft. were searched.

No leeches were found.

ii. Stones on sand, current slow.

Nine areas, each about 6 sq.ft. were investigated.

The population densities found are given in Table 1.

Table 1

Area no.	Species	Number per sq. yd.
(1)	-	0
(2)	H. stagnalis	8.6
(3)	"	3.0
(4)	"	364.5
(5)	"	5.4
(6)	"	36.0
(7)	"	11.5
(8)	"	25.2
(9)	"	7.2
	G. complanata	7.2

For H. stagnalis the following results were calculated, using the negative binomial method.

Mean density = 51 per sq.yd.

95% confidence limits of mean density = up to 115 per sq.yd.

The mean weight of 95 specimens of H. stagnalis was .0049 gm. Individual weights are given in figure 1.

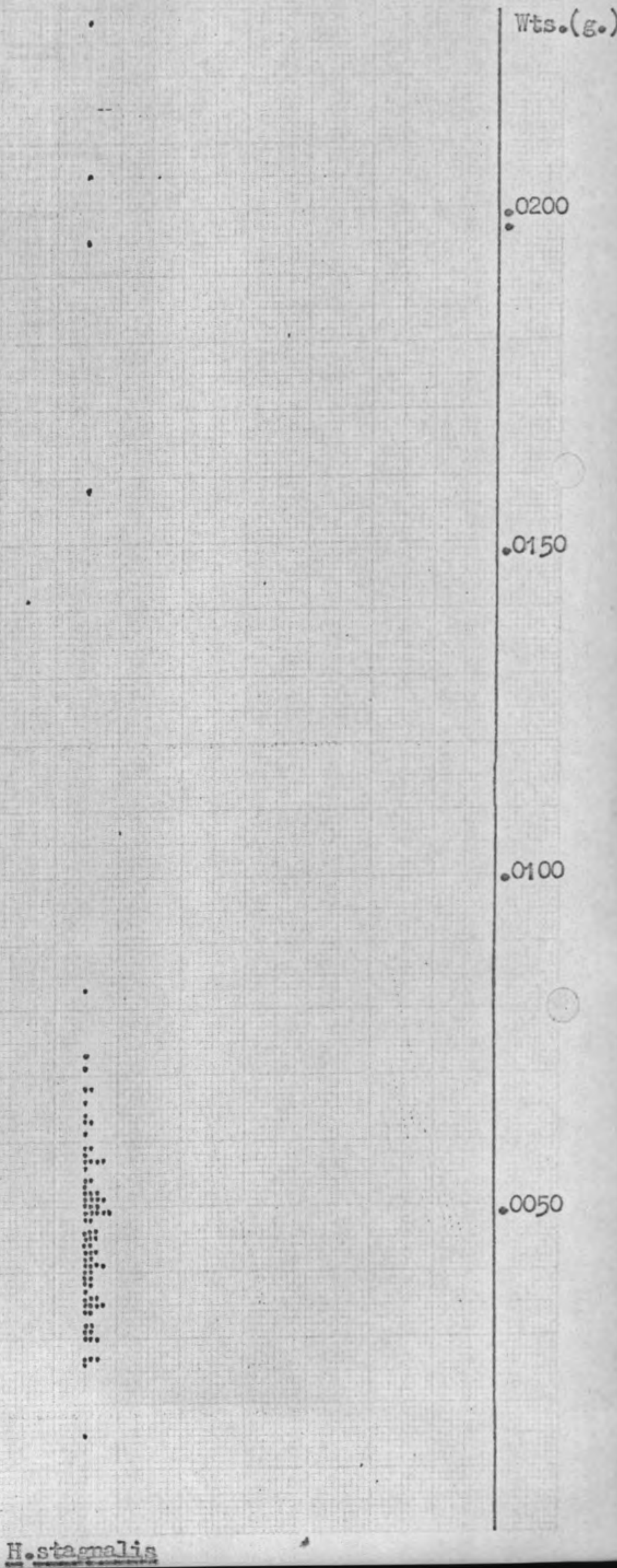
Wear from Bishop Auckland to Durham

Substrate types investigated:

i. Stones on sand in regions of rapid current.

Six areas, each about 1 sq.yd. were investigated on March 10 - 15. Three were at Durham, three at Croxdale. No leeches were found.

Figure 1. Weights of individual leeches from Witton le Wear.



ii. Stones on sand in regions of moderate current.

This type of substrate was investigated at Bishop Auckland above the confluence with the river Gaunless, and at Croxdale. Each area was between 2 and 2.5 sq.yds. The numbers of each species found per square yard in each area are shown in table 2. Individual weights are shown in figures 2 & 3. Mean weights are shown in table 4.

Estimations of the mean density per square yard of each species, and its range of probable variation, are given in table 3.

The populations of H.stagnalis and G.complanata appear similar, since the means for each site lie well within the 95% confidence limits for the other site. The main difference between the two sites is that T. subviridis is absent at Croxdale, while E.octoculata is scarce above the Gaunless.

It should be noted that the areas examined at Croxdale on 30th April and 1st June were closer to the bank and therefore probably more sheltered than those examined on 4th July and 6th August.

 ..15..

Table 2. Numbers per sq.yd. of leeches in the areas of substrate type ii. investigated in the river Wear

Above Gaunless, Bishop Auckland

Date	15 July		21 August				
Area No.	16	17	18	19	20	21	22
Species:							
H. stagnalis	0	0	2.0	0	3.4	2.8	0
J. complanata	1.9	.5	1.3	9.0	11.1	1.4	1.0
E. octoculata	0	0	0	0	0	2.1	0
T. subviridis (total)	1.4	1.4	.7	58.5	3.4	1.4	2.1
T. subviridis (adults)	.9	1.4	.7	13.5	3.4	1.4	2.1
T. subviridis (juveniles)	.5	0	0	45.0	0	0	0
H. sanguisuga	2.5	0	0	0	0	0	0

Croxdale

Date	30 Apr.		1 June		4 July					6 August					
Area No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Species:															
H. stagnalis	0	1.3	0	6.6	.5	2.8	.8	0	6.2	.8	4.3	0	1.4	1.1	5.1
G. complanata	8.8	5.7	17.4	0	2.5	2.8	.4	12.2	1.6	2.6	10.1	2.6	13.0	3.9	6.4
E. octoculata	51.2	35.8	49.3	13.1	4.0	5.6	4.1	8.1	3.1	9.2	15.8	5.2	23.0	3.9	9.0
H. sanguisuga	0	.6	1.5	3.3	0	0	0	0	1.6	0	0	0	1.4	0	0

Table 3. Mean population densities and confidence limits for substrate type ii, River Wear

Above Gaunless, Bishop Auckland

	21 August			15 July - 21 August
	H. stagnalis	G. complanata	T. subviridis (adults)	T. subviridis (adults)
Mean density (untransformed)	1.7	4.8	4.2	3.2
(transformed)	Not calculated		2.0	1.7
Type of calculation used for confidence limits	None	None	Normal	Normal
95% confidence limits of mean:				
upper	Not calculated		11.6	4.8
lower	,,		.5	.6
95% confidence limits for single areas:				
upper	,,		162.5	33.7
lower	,,		.1	.2
Transformation used	None	None	$\sqrt{\log}$	$\sqrt{\log}$

Croxdale

	4 July			6 August		
	H. stagnalis	G. complanata	E. octoculata	H. stagnalis	G. complanata	E. octoculata
Mean density (untransformed)	2.1	3.9	4.9	2.1	6.4	11.0
(transformed)	Not calculated	2.5	4.6	Not calculated	5.9	9.8
Type of calculation used for confidence limits	Neg. binomial	Normal	Normal	Neg. binomial	Normal	Normal
95% confidence limits of mean:						
upper	4.9	10.8	7.6	4.3	11.1	19.3
lower	0	.4	2.8	0	2.3	4.1
95% confidence limits for single areas:						
upper	Not calculated	48.9	13.6	Not calculated	21.5	38.3
lower	,,	0	1.4	,,	.1	.5
Transformation used	None	$\sqrt[8]{\ }$	$\sqrt[8]{\ }$	None	$\sqrt{\ }$	$\sqrt[3]{\ }$

Table 4. Mean weights of leeches from substrate type ii. River Wear

Above Gaunless, Bishop Auckland

Date	15 July		21 August	
	No. weighed	Mean wt.(gm)	No. weighed	Mean wt. (gm)
Species:				
H. stagnalis	-	-	3	.0054
G. complanata	8	.0252	2	.0638
E. octoculata	1	.0645		
T. subviridis (total)	11	.5484	27	.1467
T. subviridis (adult)	9	.6630	7	.5252
T. subviridis (juvenile)		.0332	20	.0155
H. sanguisuga	9	1.8102		

Croxdale

	30 April		1 June		4 July		6 Aug.	
	No. weighed	Mean wt. (gm)	No. weighed	Mean wt. (gm)	No. weighed	Mean wt. (gm)	No.weighed	Mean tw.(gm)
Species:								
H. stagnalis	3	.0079	4	.0090	13	.0019	7	.0038
G. complanata	16	.0176	12	.0100	28	.0160	21	.0343
E. octoculata	85	.0758	42	.0667	49	.1200	25	.1076
H. sanguisuga	1	1.4778	4	1.4165	4	2.3662	--	--

Figure 2. Weights of individual leeches from the Wear above Gaunless, substrate type ii.

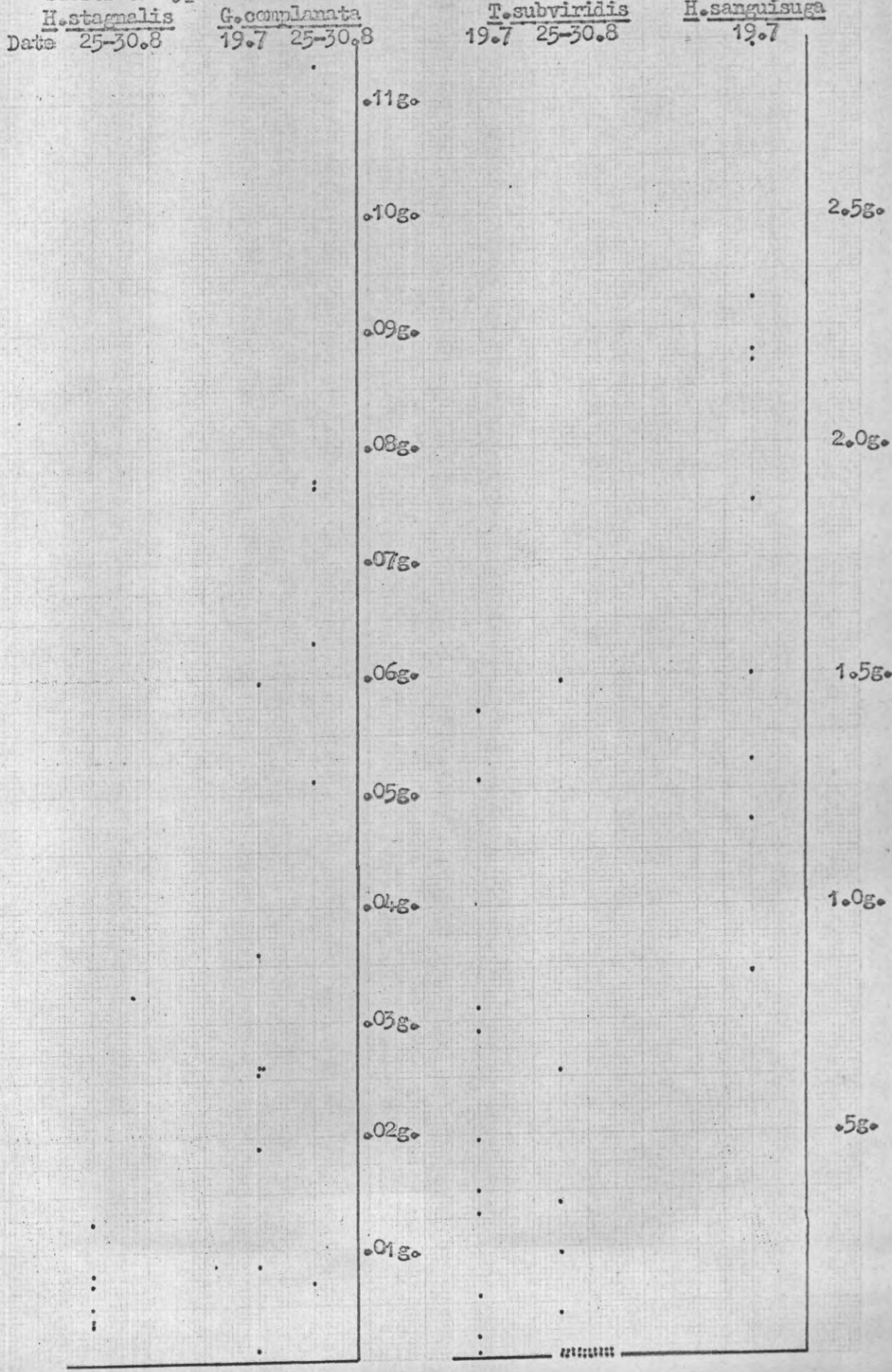
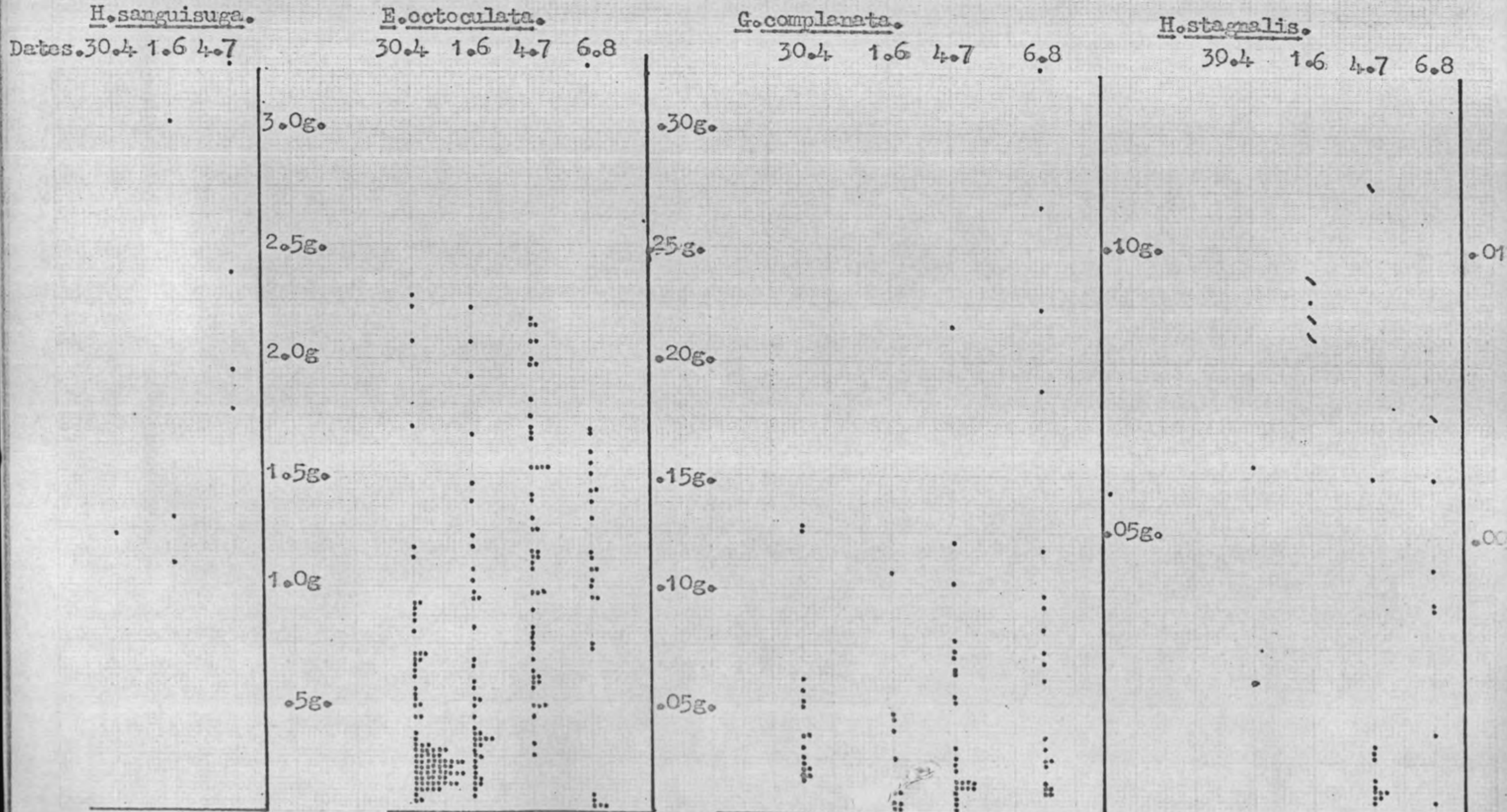


Figure 3. Weights of individual leeches from substrate type ii, Wear, Croxdale.



iii. Stones on muddy sand in regions of slow current.

This type of substrate was investigated at Bishop Auckland above and below the confluence with the river Gaunless, and at Frankland's Farm, below Durham City. Each area investigated measured approximately one square yard. The numbers of each species in each area investigated are given in table 5. Mean weights for the specimens taken from each site are shown in table 6. Individual weights are shown in figures 4 & 5. Mean population densities and range of probable variation are shown in table 7.

iv. Plants of Sparganium erecta on soft mud at Croxdale.

The current was slow to negligible. This site was 20ft from the nearest stony area.

The numbers of each species per square yard in each area investigated are given in table 8 together with the mean weights of each species on each date. Individual weights are shown in figure 6.

Each area examined measured about 2 sq.yds.

v. Mud, including some organic detritus (rotten leaves, twigs etc.), current slow to negligible.

The numbers of each species per square yard in each area investigated on 6th September are shown in table 9. Each area investigated measured about 1 sq.yd.

Table 5. Numbers of leeches per square yard in substrate type iii.

Bishop Auckland, above Gaunless

Date	19 July			26 July		
Area No.	1	2	3	4	5	6
Species :						
H.stagnalis	33.7	174.9	235.4	31.5	228.0	48.0
G.complanata	22.5	28.3	0	2.3	12.0	2.0
E.octoculata	6.4	30.9	24.2	4.5	32.0	43.0
H.sanguisuga	8.0	0	0	0	0	0

Bishop Auckland, below Gaunless

Date	30 August					
Area No.	7	8	9	10	11	12
Species :						
H.stagnalis	141.1	249.6	63.0	149.8	60.0	80.0
G.complanata	51.8	81.6	18.0	11.7	43.5	11.4
E.octoculata	106.6	100.8	48.0	32.3	93.0	29.6

Frankland Farm.

Date	May 24	24 June			25 July						27 August							
Area No	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Species :																		
H.stagnalis	1.4	85.4	119.0	36.0	189.0	193.8	68.6	81.0	66.0	91.0	162.0	225.0	679.2	406.5	189.2	136.5	111.6	41.7
G.complanata	9.1	26.8	12.0	20.0	94.5	90.0	25.7	9.0	12.0	3.3	20.8	35.4	134.4	80.3	31.0	5.8	10.6	4.9
E.octoculata	18.2	15.4	21.0	12.0	36.0	103.8	32.1	58.5	24.0	3.3	41.5	96.4	117.6	96.2	54.9	20.2	90.0	9.8
T.bykowskii	0	0	0	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0	0
H.sanguisuga	1.0	1.0	0	0	0	0	0	0	0	0	0	0	2.4	0	0	0	0	0

Table 6. Mean weights of leeches from substrate type iii.

Frankland's Farm, Durham

Date	24 May		24 June		26 July	
	No. weighed	Mean Wt. (gm)	No. weighed	Mean Wt. (gm).	No. weighed	Mean Wt. (gm)
Species:						
H. stagnalis	3	.0164	83	.0029	84	.0024
G. complanata			26	.0209	42	.0020
E. octoculata	38	.0596	17	.1170	17	.0658
H. sanguisuga	2	1.6555	1	.1103		

Table 7. Mean population densities for substrate type iii. River Wear

Bishop Auckland, above Gaunless

19 - 26 July

	H. stagnalis	*G. complanata*	*E. octoculata*
Mean density (untransformed)	125.4	11.2	23.5
(transformed)	Not calculated	Not calculated	Not calculated
Type of calculation used for confidence limits	None	None	Normal
95% confidence limits for mean:			
upper	Not calculated	Not calculated	37.1
lower	,,	,,	9.9
95% confidence limits for single areas:			
upper	,,	,,	56.7
lower	,,	,,	0
Transformation used	None	None	None

Frankland's Farm, below Durham

25 July

	H. stagnalis	*G. complanata*	*E. octoculata*
Mean density (untransformed)	100.0	28.0	44.3
(transformed)	Not calculated	16.5	36.5
Type of calculation used for confidence limits	Neg. binomial	Normal	Normal
95% confidence limits for mean:			
upper	146.0	80.0	107.7
lower	54.4	2.3	2.9
95% confidence limits for single areas:			
upper	Not calculated	397.2	247.8
lower	,,	.1	0
Transformation used	None	$\sqrt[3]{\ }$	$\sqrt{\ }$

Table 7. (continued) Mean population densities for substrate type iii. River Wear

Bishop Auckland, below Gaunless

30th August

	H. stagnalis	*G. complanata*	*E. octoculata*
Mean density (untransformed)	123.9	36.3	68.4
(transformed)	Not calculated	29.0	Not calculated
Type of calculation used for confidence limits	Neg. binomial	Normal	None
95% confidence limits for mean:			
upper	187.6	70.6	Not calculated
lower	60.4	10.2	,,
95% confidence limits for single areas:			
upper	Not calculated	210.9	,,
lower	,,	1.5	,,
Transformation used	None	$\sqrt{\ }$	None

Frankland's Farm, below Durham

27th August, areas 23 - 27

	H. stagnalis	*G. complanata*	*E. octoculata*
Mean density (untransformed)	332.4	52.4	81.2
(transformed)	Not calculated	40.5	78.5
Type of calculation used for confidence limits	Neg. binomial	Normal	Normal
95% confidence limits for the mean:			
upper	538.1	109.7	130.8
lower	126.7	16.8	39.4
95% confidence limits for single areas:			
upper	Not calculated	443.7	213.5
lower	,,	6.7	9.9
Transformation used	None	$\sqrt{\log}$	$\sqrt{\ }$

Table 8. Numbers per square yard, and mean weights of leeches in substrate, type iv.

Leeches on <u>Sparganium erecta</u>, Croxdale

Date	2nd May		30th May		2nd July		3rd August	
	No. per sq.yd.	No. per plant	No. per sq.yd.	No. per plant	No. per sq.yd.	No. per plant	No. per sq.yd.	No. per plant
Species:								
H. stagnalis	5.4	.05	3.9	.05	4.5	.05	25.2	.42
G. complanata	10.8	.11	9.0	.12	34.5	.37	22.8	.38
E. octoculata	90.0	.91	55.3	.72	76.5	.83	46.8	.78
H. sanguisuga	7.2	.07	12.9	.17	6.0	.07	3.0	.05
	No. weighed	Mean wt.(gm)	No. weighed	Mean wt.(gm)	No. weighed	Mean wt.(gm)	No. weighed	Mean wt.(gm)
Species:								
H. stagnalis	3	.0091	3	.0088	3	.0053	42	.0025
G. complanata	6	.0275	7	.0218	23	.0046	38	.0040
E. octoculata	49	.0672	43	.0447	51	.1479	78	.0438
H. sanguisuga	4	.6229	10	1.5265	4	1.1039	5	1.9176

Figure 4. Weights of individual specimens of H. stagnalis from the Wear, Franklands Farm (below Durham), substrates iii & vi.

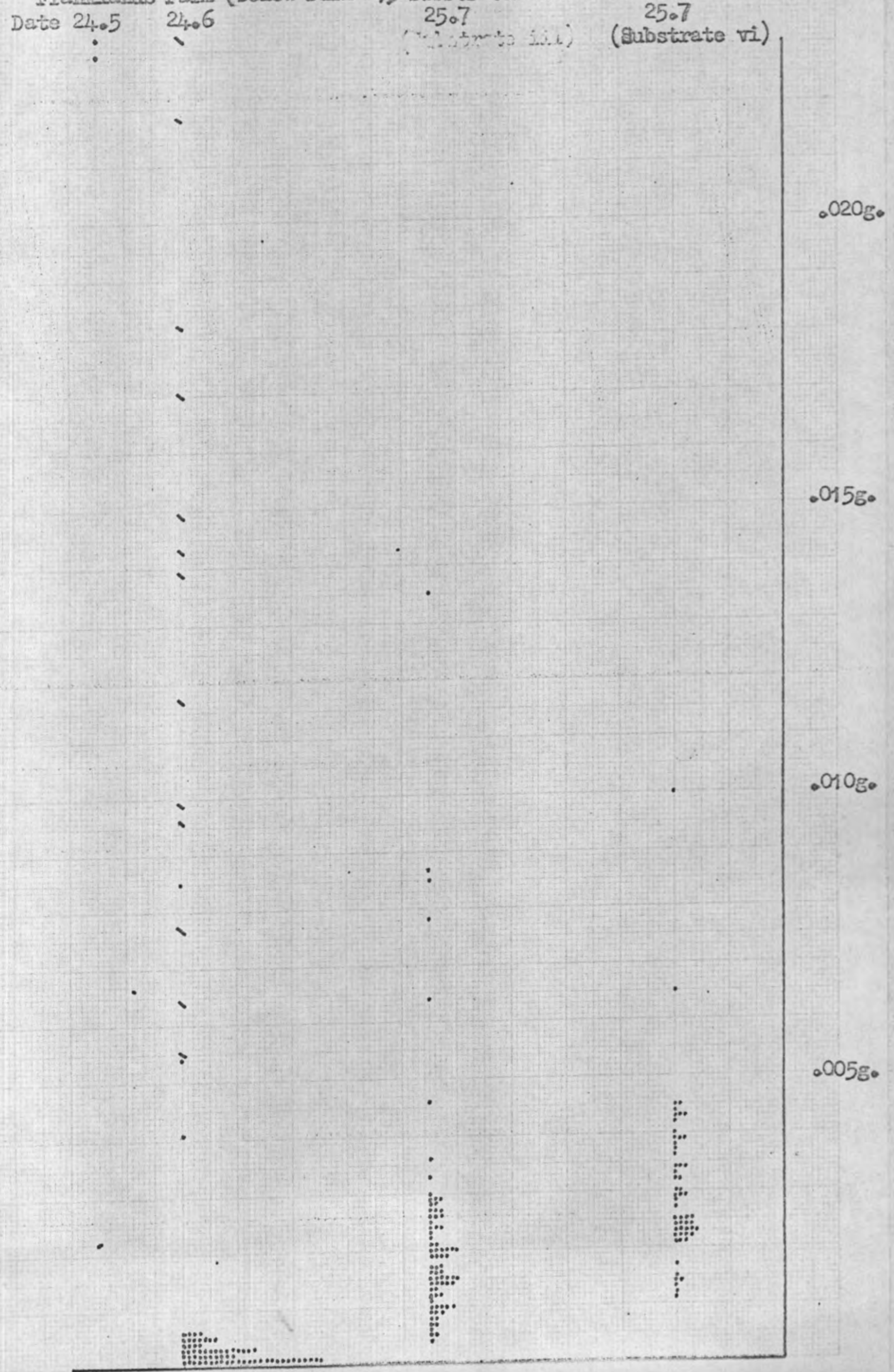


Figure 5. Weights of individual leeches (excluding H. stagnalis) from the Wear, Franklands Farm (below Durham).

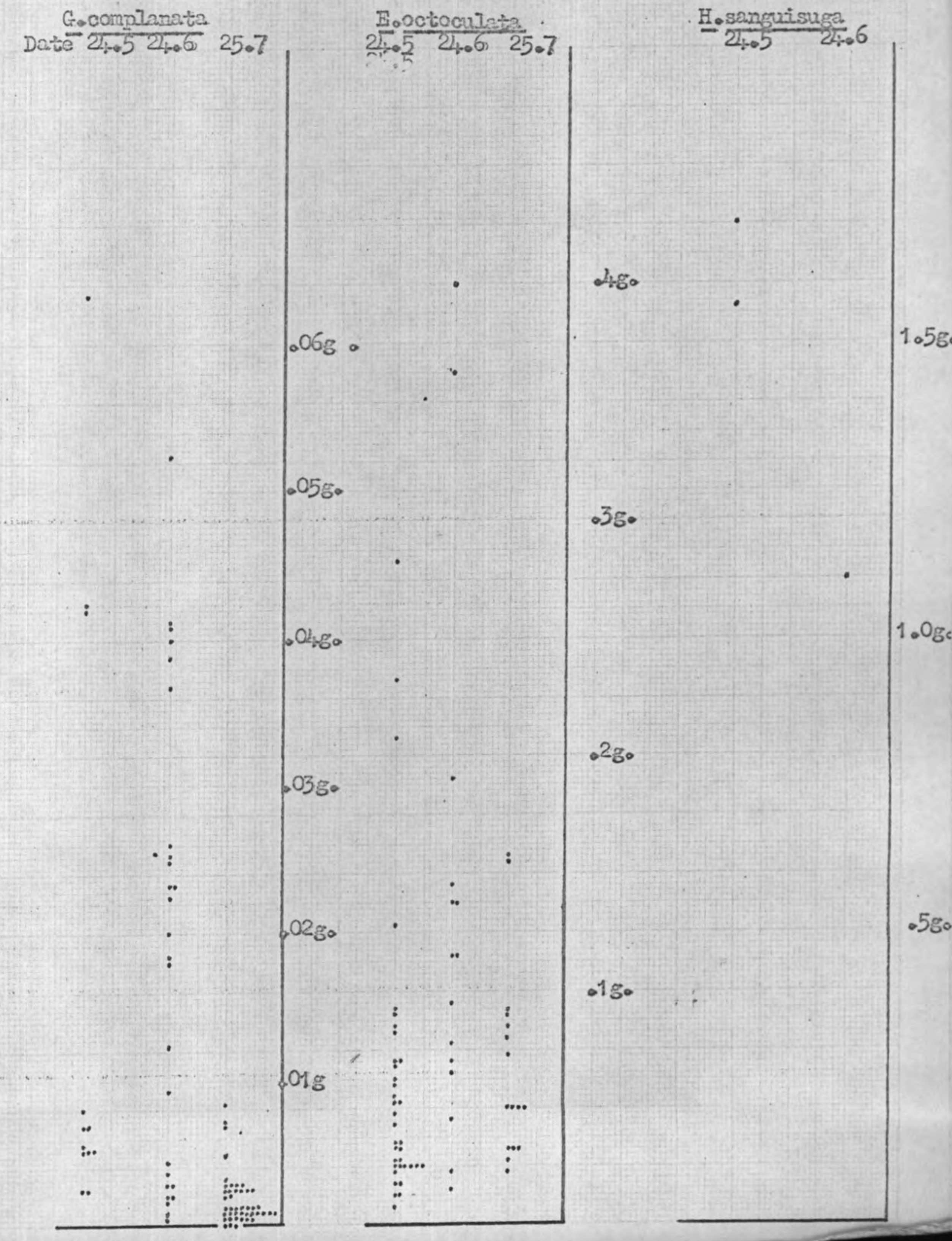


Figure 6a. Individual weights of H. stagnalis & G. complanata from reeds in the Wear at Croxdale.

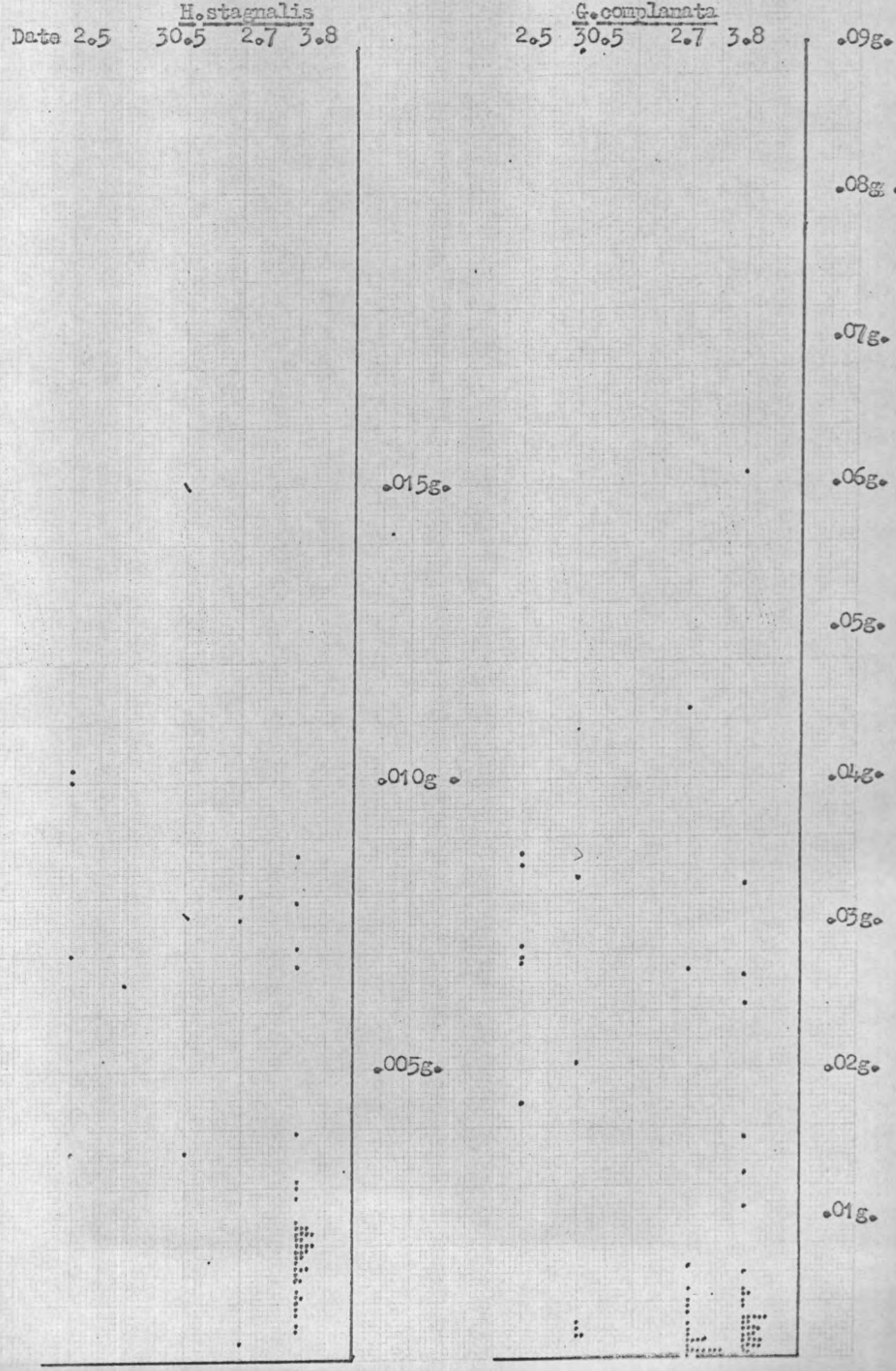


Figure 6b. Individual weights of E. octoculata & H. sanguisuga from reeds in the Wear at Croxdale.

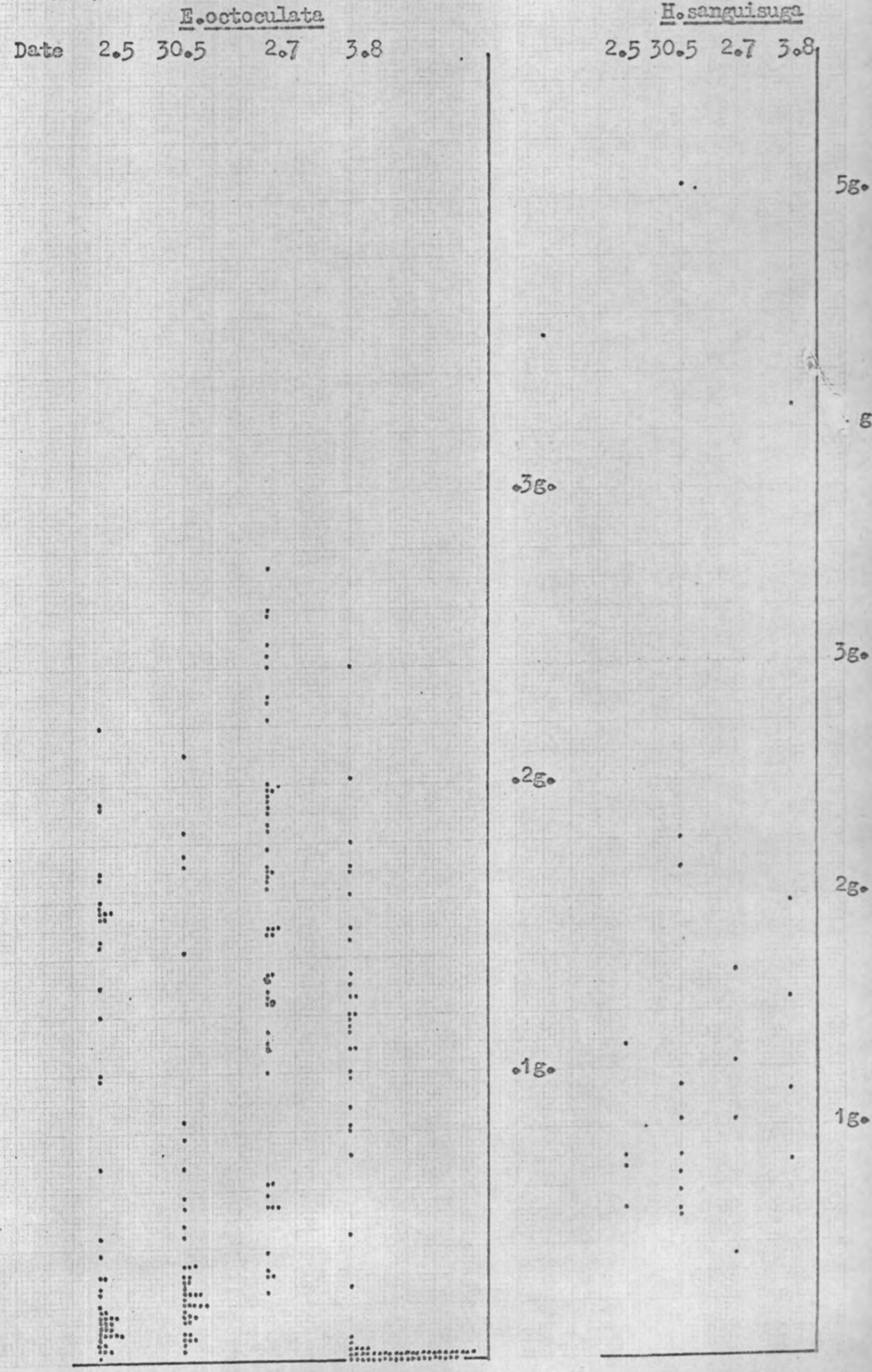


Figure 2. Weights of individual leeches from the Wear above Gaunless, substrate type ii.

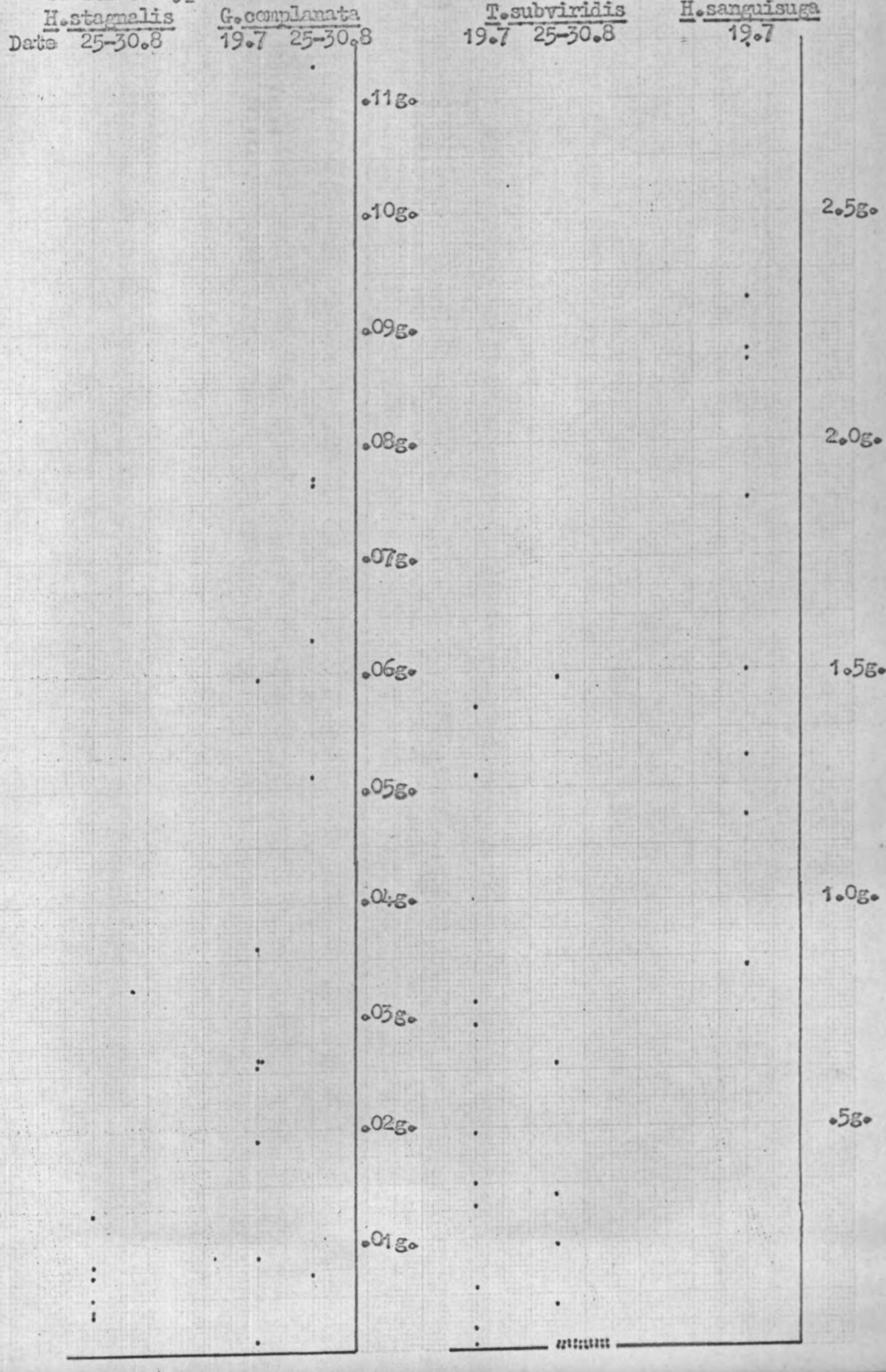


Figure 3. Weights of individual leeches from substrate type ii, Wear, Croxdale.

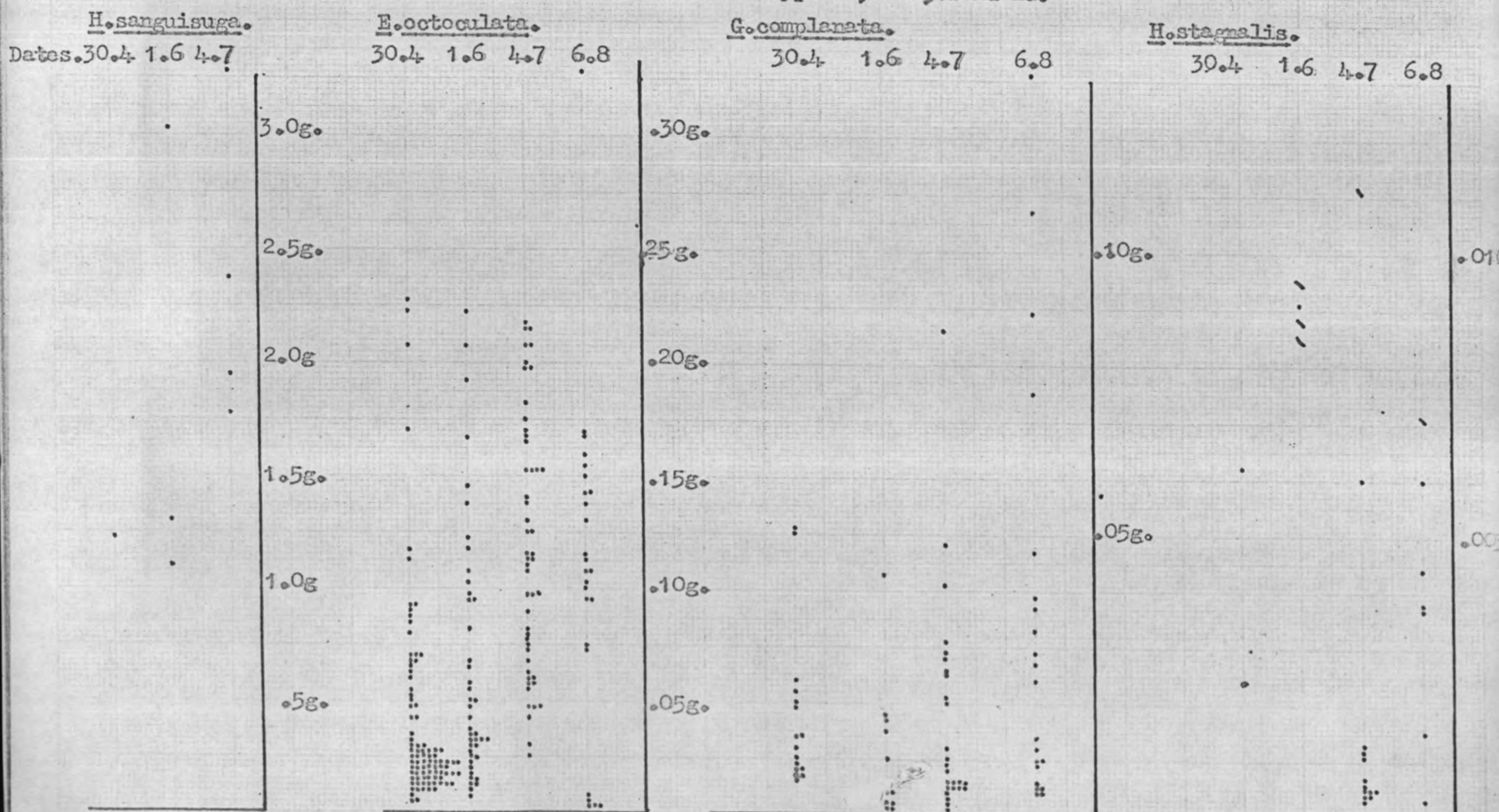


Figure 4. Weights of individual specimens of H. stagnalis from the Wear, Franklands Farm (below Durham), substrates iii & vi.

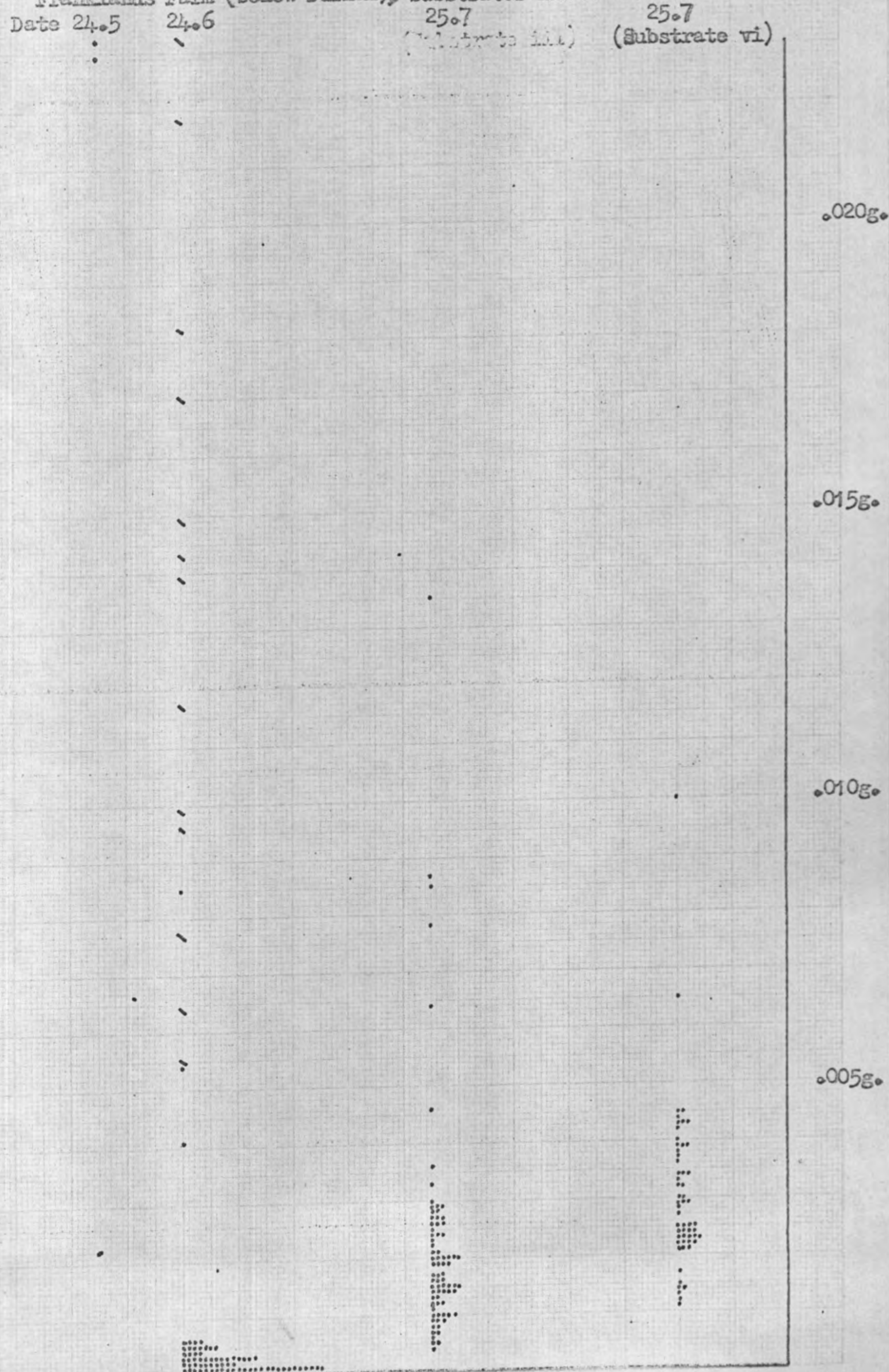


Figure 5. Weights of individual leeches (excluding H. stagnalis) from the Wear, Franklands Farm (below Durham).

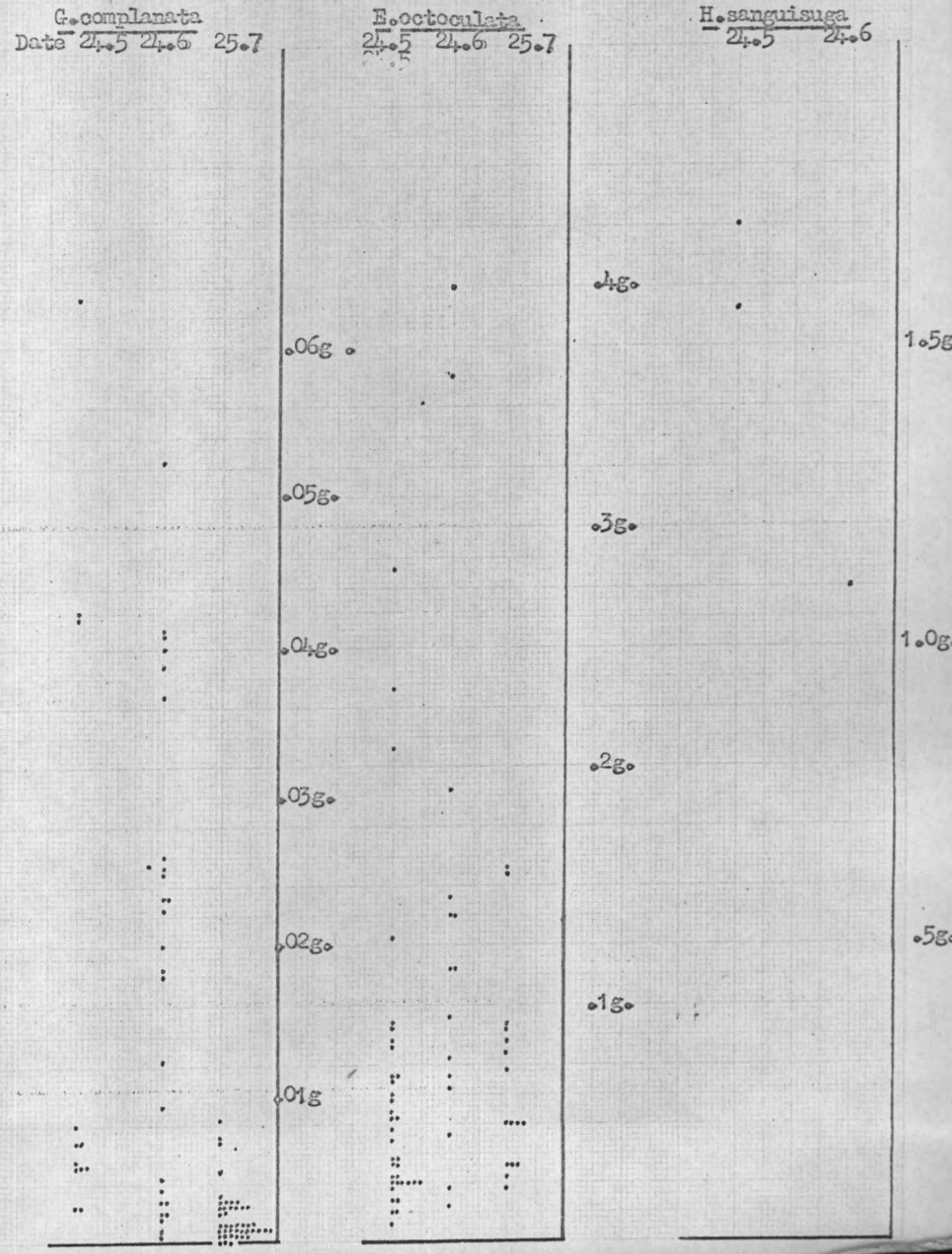


Figure 6a. Individual weights of H. stagnalis & G. complanata from reeds in the Wear at Croxdale.

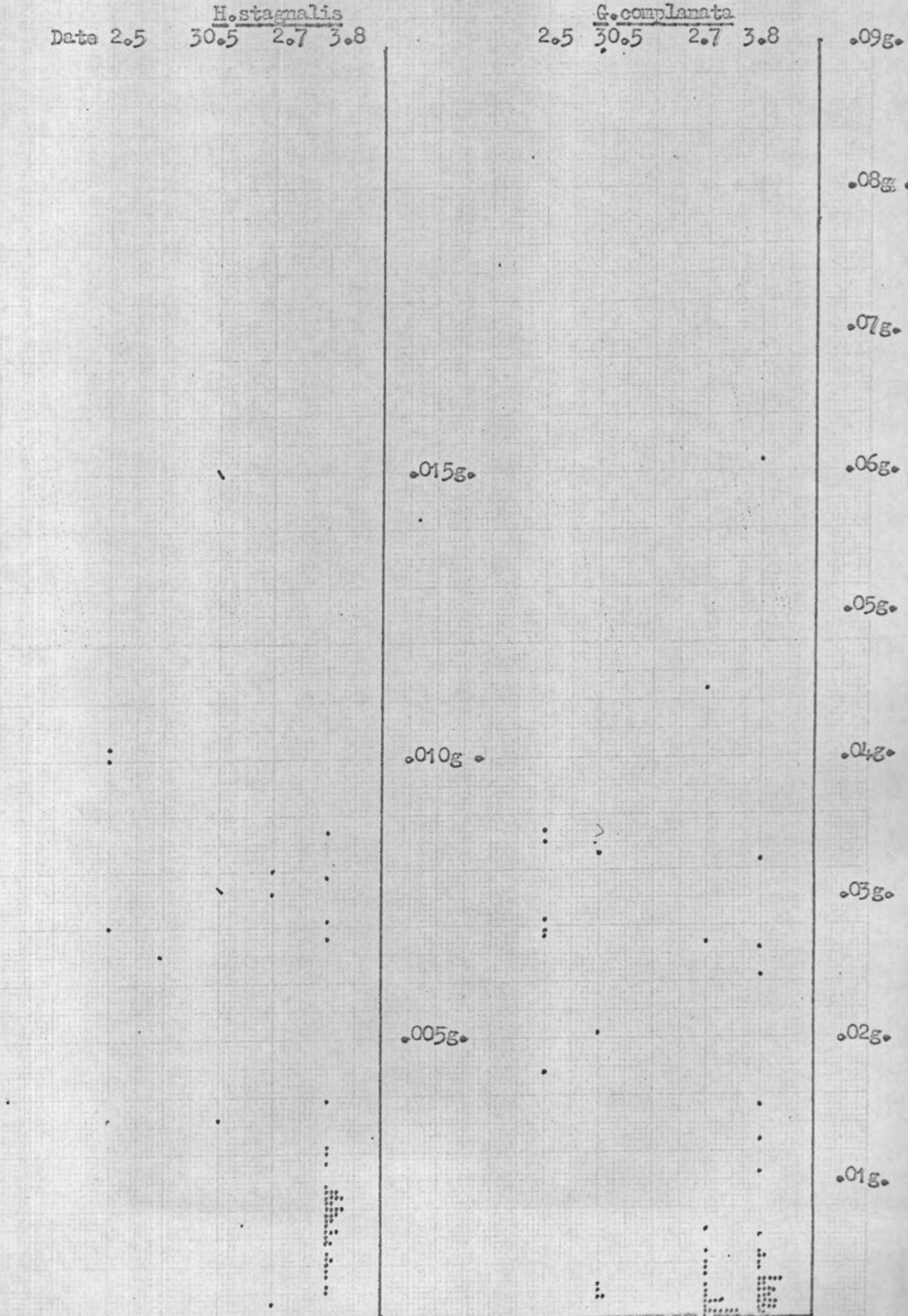


Figure 6b. Individual weights of E. octoculata & H. sanguisuga from reeds in the Wear at Croxdale.

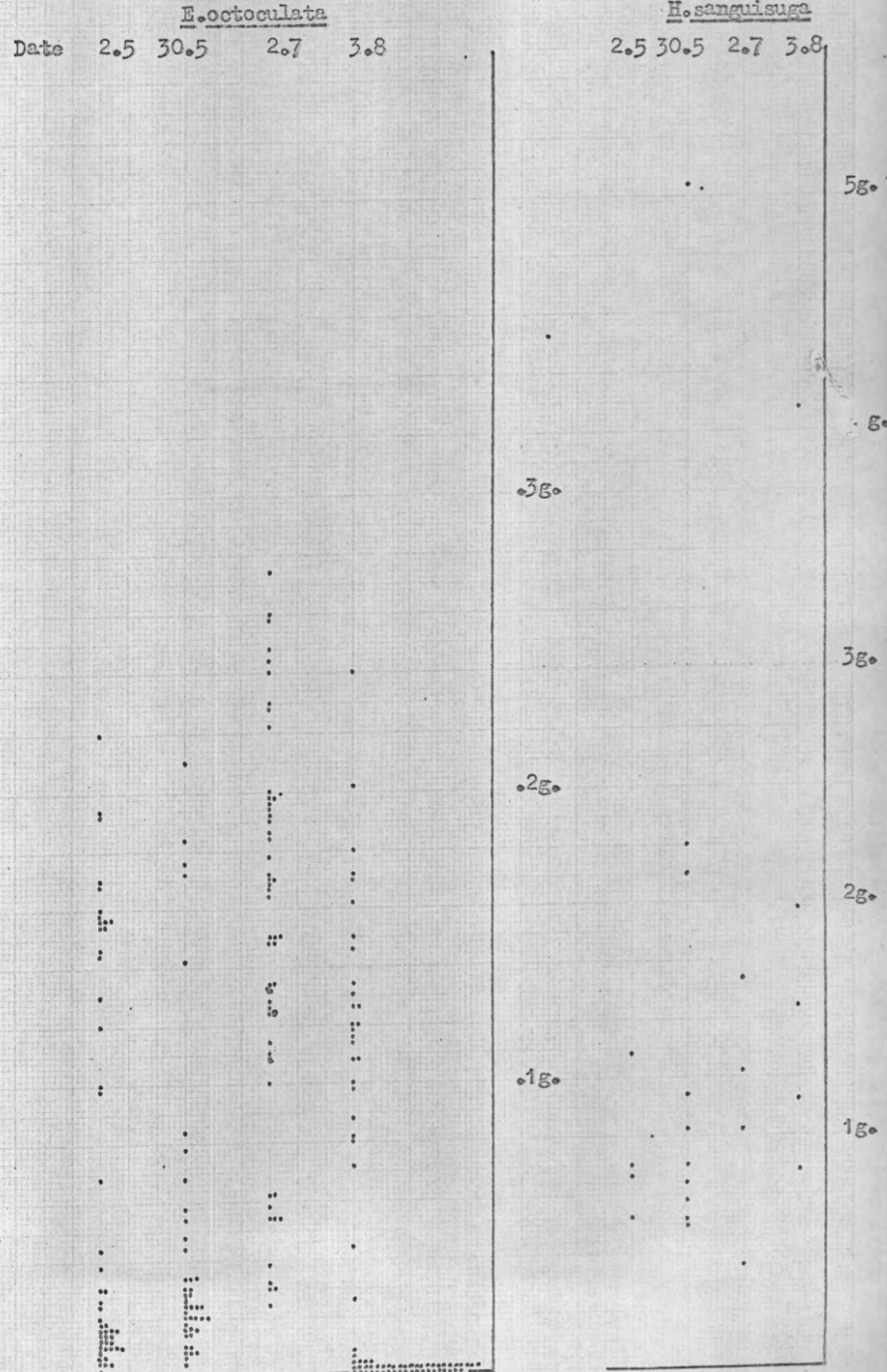


Table 12. Mean numbers per square yard of leeches on substrate type vi, River Wear Croxdale, 5th August

	Haemopis sanguisuga
Mean density (untransformed)	2.2
(transformed)	2.0
Type of calculations used for confidence limits	Normal
95% confidence limits for mean:	
upper	3.3
lower	1.2
95% confidence limits for single areas:	
upper	7.7
lower	.5
Transformation used	log.

Frankland's Farm, below Durham, 27th July

	Trocheta bykowskii	*Haemopis sanguisuga*
Mean density (untransformed)	6.3	3.4
(transformed)	5.7	Not calculated
Type of calculation used for confidence limits	Normal	None
95% confidence limits for mean:		
upper	10.6	Not calculated
lower	2.7	,,
95% confidence limits for single areas:		
upper	22.8	,,
lower	.7	,,
Transformation used	$\sqrt{\ }$	None

Area No.	1	2	3	4	5	6	7	8	9	10
Species :										
G.complanata	0	4.0	0	2.4	0	0	0	0	0	0
E.octoculata	3.0	8.0	6.0	6.0	15.0	16.8	3.0	15.4	7.5	5.1

No weighings were made. The two areas with G.complanata were not typical because they contained a relatively large amount of rotting twigs.

For Erpobdella octoculata the following data were calculated :

Untransformed mean density = 8.6 per sq.yd.
Transformed mean density = 7.2 per sq.yd.
95% confidence limits of the
Mean density = 4.5 - 11.6 per sq.yd.
95% confidence limits for single areas = 1.6 - 32.1 per sq.yd.
Log transformation used.

vi. Stones on muddy sand, just above the water level, with a mat of damp algae covering the surface, Frankland's Farm.

Each area examined on 25th July was about 6 sq.ft. The following numbers per square yard were found in the areas investigated.

Table

	Area no.1	Area no.2
Species:		
H. stagnalis	61.7	82.5
E. octoculata	0	1.5
H. sanguisuga	0	3.0

The following mean weights were found:

Species:	No. weighed	Mean wt. (gm)
H. stagnalis	55	.0031
H. sanguisuga	2	1.1755

Note the difference in the weight distribution for Helobdella stagnalis in substrates type iiiand vi as shown in figure 4.

vii. Exposed shingle banks, with the interstices between the stones filled by mud or sand.

Two sites were searched. The one at Croxdale was exposed except when the river was high after heavy rain; the one at Frankland's Farm was exposed only during one visit when the river was below its normal level. The numbers of each species in each area investigated are shown in table 10. Each area was about one square yard.

The mean population densities and confidence limits for the mean are shown in table 12. Mean weights are shown in table 11, individual weights in figures 7 & 8.

Table 10

Croxdale, 5th August

Area No.	1	2	3	4	5	6	7
T. subviridis	4.2	0	0	0	8.6	0	2.0
H. sanguisuga	2.1	2.0	1.2	2.0	2.9	4.5	1.0

Frankland's Farm, 27th July

Area No.	8	9	10	11	12	13	14
T. bykowskii	2.4	6.3	9.5	11.0	5.6	6.0	3.0
H. sanguisuga	3.2	0	0	4.4	2.2	8.0	6.0

Table 11

Croxdale, 5th August

Species:	No. weighed	Mean wt.
T. subviridis	7	.1695 gm
H. sanguisuga	9	2.1063 gm

Frankland's Farm, 27th July

Species:	No. weighed	Mean wt.
T. bykowskii	17	.1479 gm
H. sanguisuga	14	1.5033 gm

Figure 7. Weights of individual leeches from substrate type vii, Wear, Franklands Farm, below Durham (27 July).

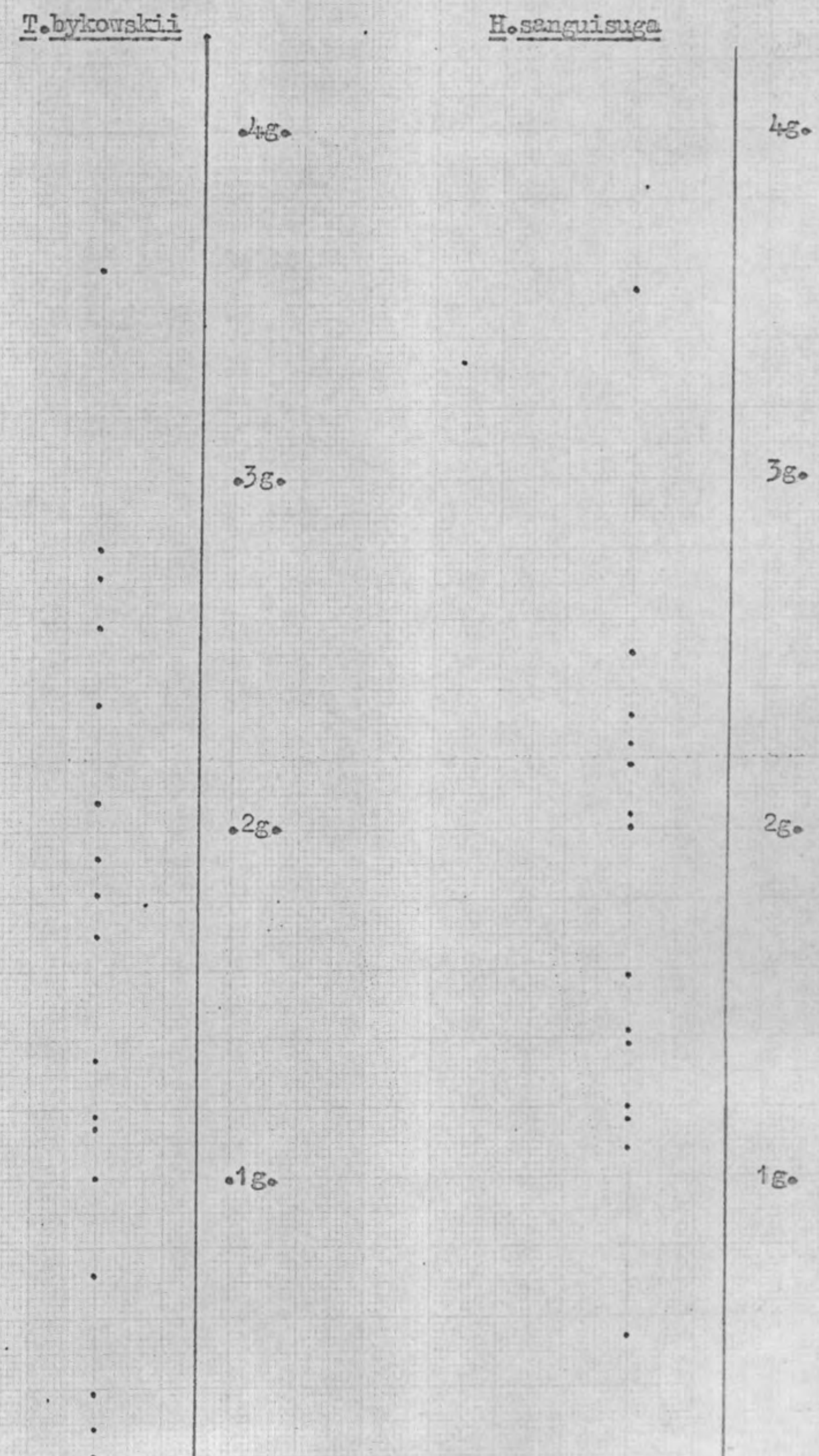
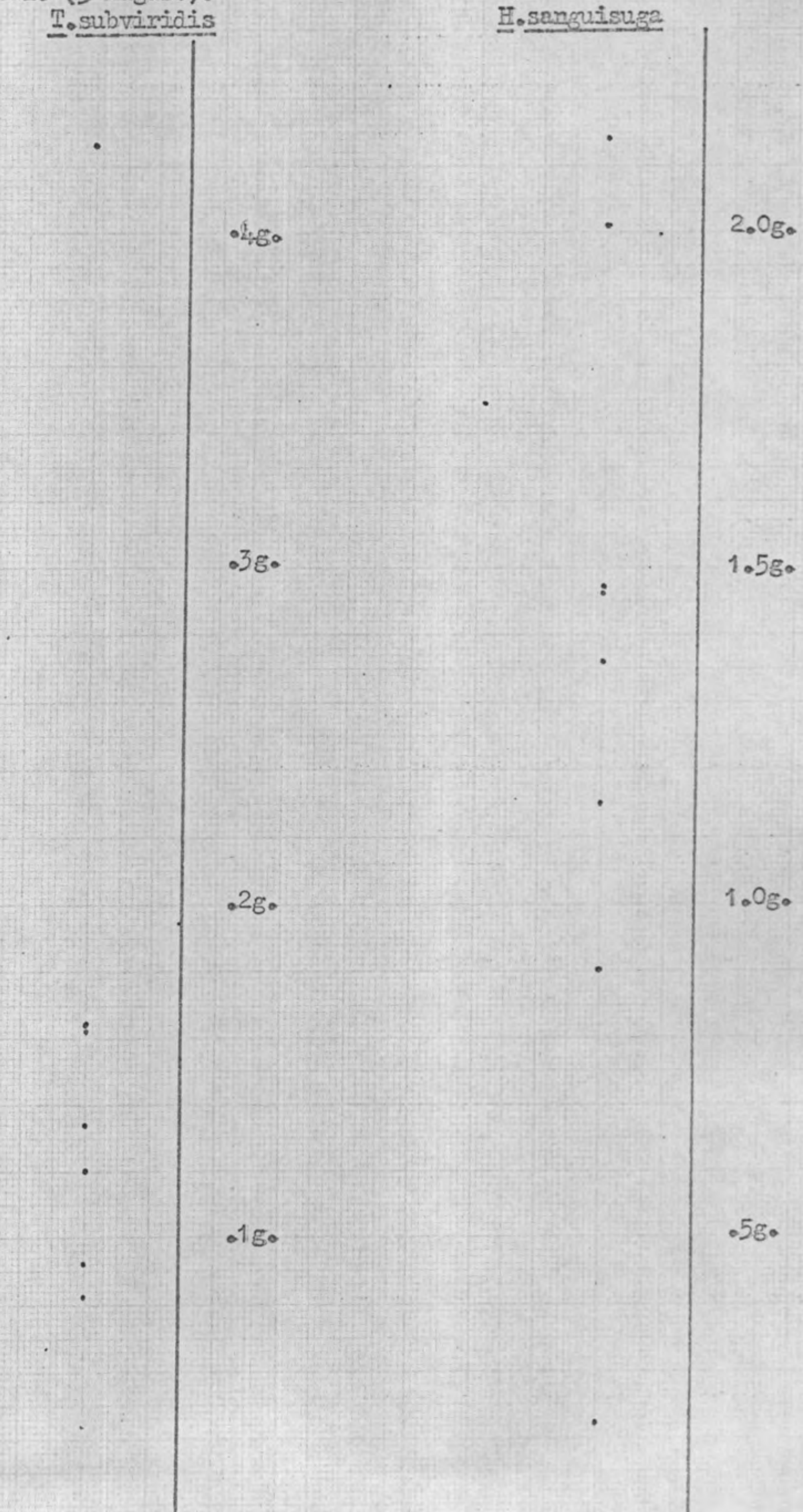
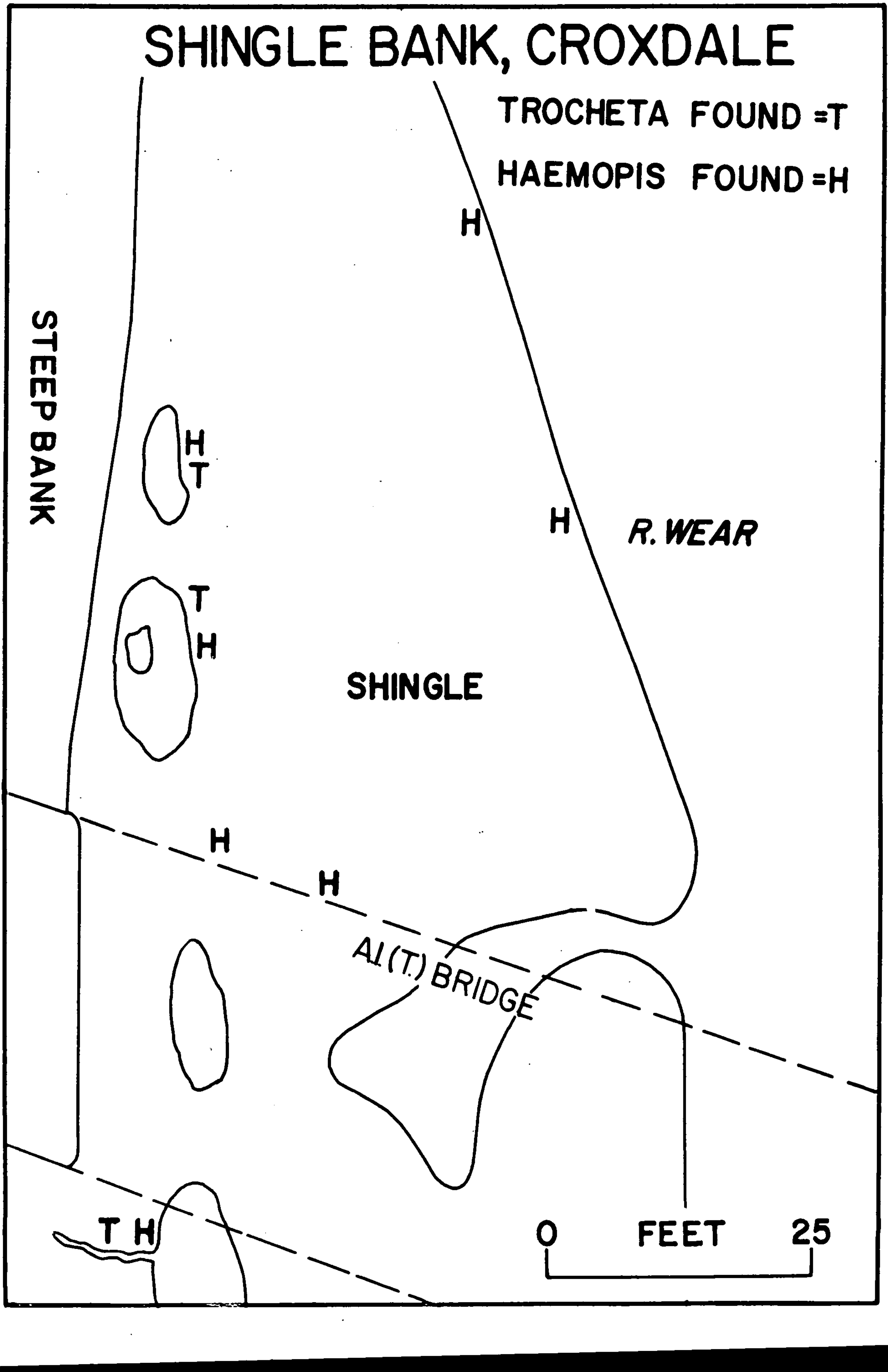


Figure 8. Weights of individual leeches from substrate type 7, We
Croxdale (5 August).




SHINGLE BANK, CROXDALE
TROCHETA FOUND =T
HAEMOPIS FOUND =H
STEEP BANK
H
H
T
T
H
H
R. WEAR
SHINGLE
H
H
A1.(T.) BRIDGE
T H
0 FEET 25

The places where *T. subviridis* were found at Croxdale are shown on the map. All were in places isolated from the main body of the river Wear, either near pools or in a trickle of water from a drain.

The presence of *T. subviridis* here is rather anomalous. None of the specimens found were large anough to be sexually mature, and only one may have been a newly emerged juvenile. This is a completely different population profile from that found above the confluence with the Gaunless. The position of the genital atria (only visible in the larger specimens) corresponded to that of *Trocheta subviridis*.

A single specimen with a clitellum was found in the early spring. It was larger than an adult *T. bykowskii* and had a yellowish colour, similar to that of immature specimens of *T. subviridis*.

Three areas of the site at Frankland's Farm were investigated again on 27th August when they were found to be covered by 3 - 9in of water. These were areas 28, 29, and 30 of substrate type iii, with populations of *H. stagnalis*, *G. complanata*, and *E. octoculata*. *T. bykowskii* and *H. sanguisuga* were completely absent. The leech populations must have moved upwards within the river banks as the water rose. It was not possible to check whether populations of *T. bykowskii* and *H. sanguisuga* were present in the bank because it consists here of large stones held in place by steel bars.

COWSHILL QUARRY, NEAR WEARHEAD

This is a flooded quarry draining into a leechless stretch of the upper Wear. The substrate was stones on sandy mud, with a negligible current. It was investigated once, on 7th July, when the following densities were found.

Table 14

Species:	No. per sq.yd.
H. stagnalis	90
H. stagnalis	333
H. stagnalis	369

None were weighed.

Each area investigated was about 3 square feet.

CROSSTHWAITE BECK

This is a small stream, draining into a leechless part of the upper Tees at Middleton in Teesdale. Two areas with a substrate of stones and a slow current, each measuring about 4½ square feet, were searched on 6th May. The following leech populations were found:

i. No leeches

ii. 36 <u>G</u>. <u>complanata</u> per square yard.

WASKERLEY BECK-

This is a shallow, generally fast stream, 4 - 6 feet wide, flowing into a leechless stretch of the Wear at Wolsingham. It was sampled only once, on 2nd August. The substrate was stones on sand. The following densities were found:

Table 14

Species:	Current	No. per sq. yd.
G. complanata	Slow	33
G. complanata	Moderate	9

The mean weight of 16 specimens was .0121 gm.

Both areas examined were about 6 square feet.

RIVER GAUNLESS

The river Gaunless was investigated where it flows through Bishop's Park, Bishop Auckland, just above its confluence with the Wear. All the areas examined were on a substrate of stones on muddy sand. Each area measured approximately 6 square feet.

The numbers of each species per square yard in each area investigated are given in table 15. The mean weights of each species taken at eac h date are shown in table 16.

Individual weights are shown in figure 9.

Estimations of the mean density per square yard of each species, and the probable range of variation, are given in table 17.

Table 15. Population densities of the areas investigated in the River Gaunless

Densities of species found, expressed as nos. per sq.yd.

Date	17th July					18th July					26th August					
Area no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Species densities:																
H. stagnalis	4.7	3.4	0	0	3.2	1.6	0	0	0	7.7	121.5	74.3	25.7	32.3	4.5	21.6
G. complanata	47.3	22.3	19.3	9.0	22.5	25.7	16.8	13.5	24.9	15.8	43.5	43.0	64.3	73.8	85.5	28.8
E. octoculata	7.1	8.6	9.7	11.3	6.4	14.4	7.2	18.0	9.6	10.7	28.5	43.0	32.1	20.8	58.5	40.8

Table 16. Mean weights of leeches from the River Gaunless

	18 July.		26 August	
	No. weighed	Mean Wt. (gm)	No. weighed	Mean Wt. (gm)
Species:				
H. stagnalis	4	.0008	19	.0035
G. complanata	57	.0139	51	.0193
E. octoculata	17	.1116	48	.0798

Table 17. Mean numbers of leeches per square yard, in the River Gaunless.

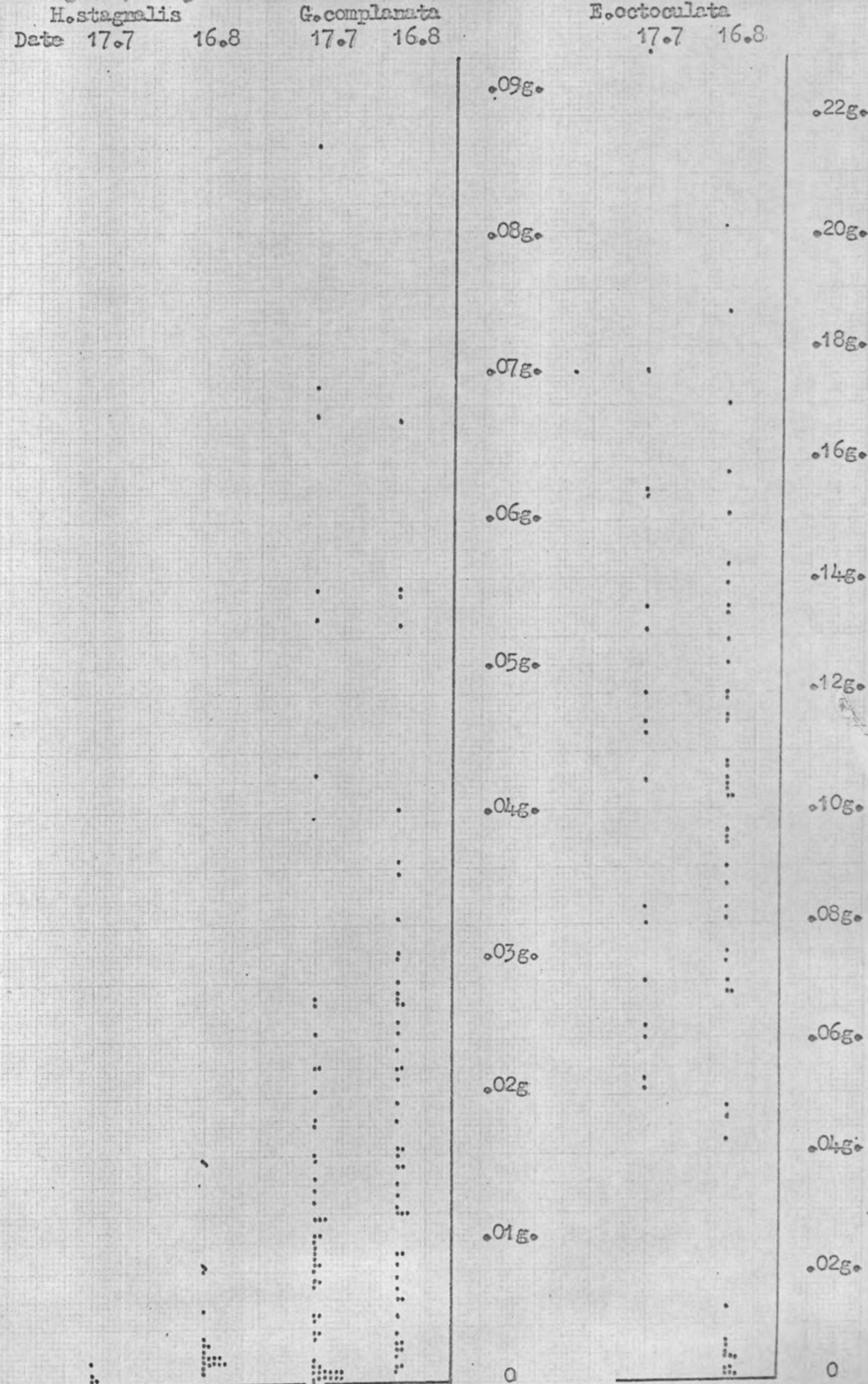
17 - 18 July.

	H.stagnalis.	G.complanata.	E.octoculata.
Mean no. per sq.yd (untransformed)	2.0	21.7	10.3
(transformed)	Not calculated	19.5	9.9
Type of calculation used for confidence limits of mean	Neg.binomial	Normal	Normal
Transformation used	None	$\sqrt{\log.}$	$\sqrt[4]{\ }$
95% confidence limits of mean: upper	3.9	25.6	12.6
lower	0	14.1	7.8
95% confidence limits for single areas: upper	Not calculated	61.9	20.3
lower	Not calculated	7.4	4.1

26 August.

	H.stagnalis.	G.complanata	E.octoculata.
Mean no. per sq.yd (untransformed)	46.6	56.6	37.3
(transformed)	35.5	Not calculated	36.3
Type of calculation used for confidence limits of mean	Normal	Normal	Normal
Tranformation used	$\sqrt[3]{\ }$	None	$\sqrt{\ }$
95% confidence limits of mean: upper	98.3	80.9	52.8
lower	7.5	32.3	22.9
95% confidence limits for single areas: upper	280.0	116.1	127.8
lower	0	0	.6

Figure 9. Weights of individual leeches from the Gaunless.



BRANCEPETH BECK

Brancepeth (Stockley) Beck is a small stream, 3 - 8 feet wide. It can be divided into three parts:

i. An upper part with generally rapid flow, the substrate consisting of stones on eroding clay.

ii. A middle part where it enters the Wear valley plain, with a shingle bottom, and stretches of slow flow.

iii. A lower meandering part, with a substrate of mud on gravel, often lined by <u>Sparganium erecta</u>.

The numbers of each species per square yard in each area investigated are given in table 18. Each area investigated was about 6 square feet. The mean density and probable range of variation are given in table 19. Mean weights are given in table 20.

Individual weights are given in figure 10.

Table 18. Numbers of leeches per square yard in the areas investigated in Brancepeth Beck.

Leeches on S. erecta or nearby gravel, lower part of Brancepeth Beck.

	8th June				9th July				11 August			
Area No	1		2		3		4		5		6	
	Number per Sq.yd	per Plant	Number per Sq.yd	per Plant	Number per Sq.yd	per Plant	Number per Sq.yd	per Plant	Number per Sq.yd	per Plant	Number per Sq. yd	per Plant
<u>G.complanata</u>	31.0	.38	0	No	13.0	No	13.6	.33	14.1	.45	40.5	.38
<u>H.sanguisuga</u>	0	0	17.3	plants	0	plants	1.7	.04	5.6	.18	0	0

Leeches on shingle, middle part of Brancepeth Beck

11th August.

Area No.	7	8	9	10	11
<u>H.stagnalis</u>	1.4	0	0	42.0	6.0
<u>G.complanata</u>	63.5	80.0	99.0	114.0	51.0

Leeches on stones in upper part of Brancepeth Beck.
11th August.

Area No.	12	13	14
<u>G.complanata</u>	3	0	1.5

Table 19. Mean numbers of leeches per square yard in Brancepeth Beck.

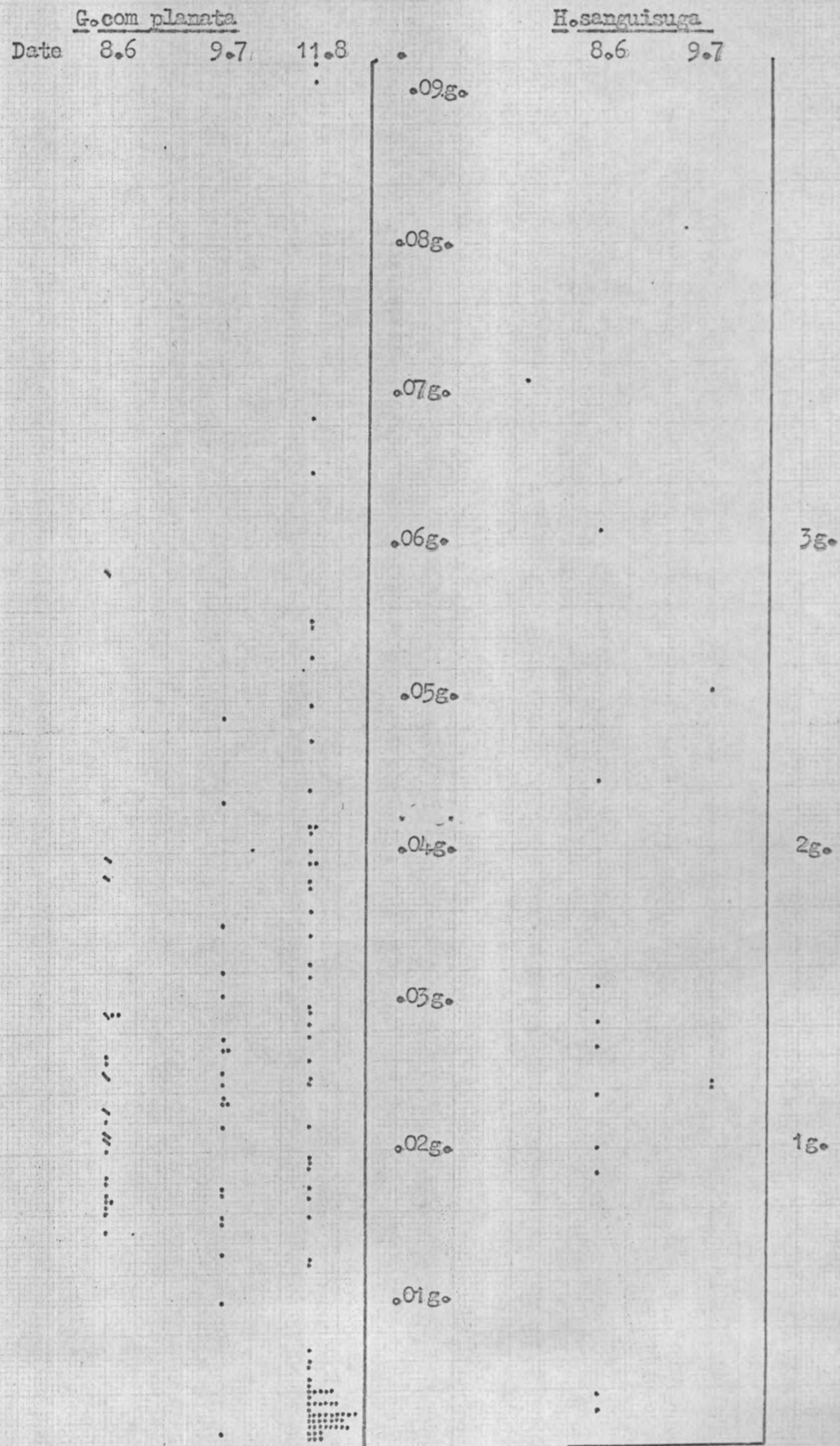
Leeches on stony substrates, slow current, August 11.

		H. stagnalis.	G. complanata
Mean no per. sq. yd	(untransformed)	9.9	81.5
	(transformed)	Not calculated	Not calculated
Type of calculation used for confidence limits.		Neg. binomial	Normal
Transformation used.		None	None
95% confidence limits for mean:	upper	32.1	121.0
	lower	0	50.0
95% confidence limits for single areas :	upper	Not calculated	160.9
	lower	Not calculated	2.1

Table 20. Mean weights of leeches from Brancepeth Beck.

	8 June		9 July		11 August	
	No. weighed	Mean Wt	No. weighed	Mean Wt	No. weighed	Mean Wt.
<u>H. stagnalis</u>	0	-	0	-	1	.0078 gm
<u>G. complanata</u>	21	.0250 gm	22	.0234 gm	86	.0180 gm
<u>H. sanguisuga</u>	10	1.2959 gm	3	1.6465 gm	0	-

Figure 10. Weights of individual leeches from Brancepeth Beck.



HOLYWELL BECK

Holywell Beck is a small stream, 2 - 4 feet wide, and never more than 1 foot deep. The areas investigated all had a slow current and a bottom of shingle.

The numbers of each species per square yard in each area investigated are given in table 21. Each area investigated measured about 6 square feet, except area No.1.

Mean densities and range of probable variation are shown in table 22. Mean weights are shown in table 23, individual weights in figure 11.

Table 21. Numbers of leeches per sq. yd. in the areas investigated in Holywell Beck.

	15 June	11 July			10 August.				
Area No.	1	2	3	4	5	6	7	8	9
H.stagnalis.	5.0	4.4	0	20.8	9.6	7.2	24.9	6.2	21.6
G.complanata	0	0	0	0	1.6	1.4	0	0	0
E.octoculata	5.0	6.3	18.0	3.1	7.7	18.7	20.8	7.0	11.4

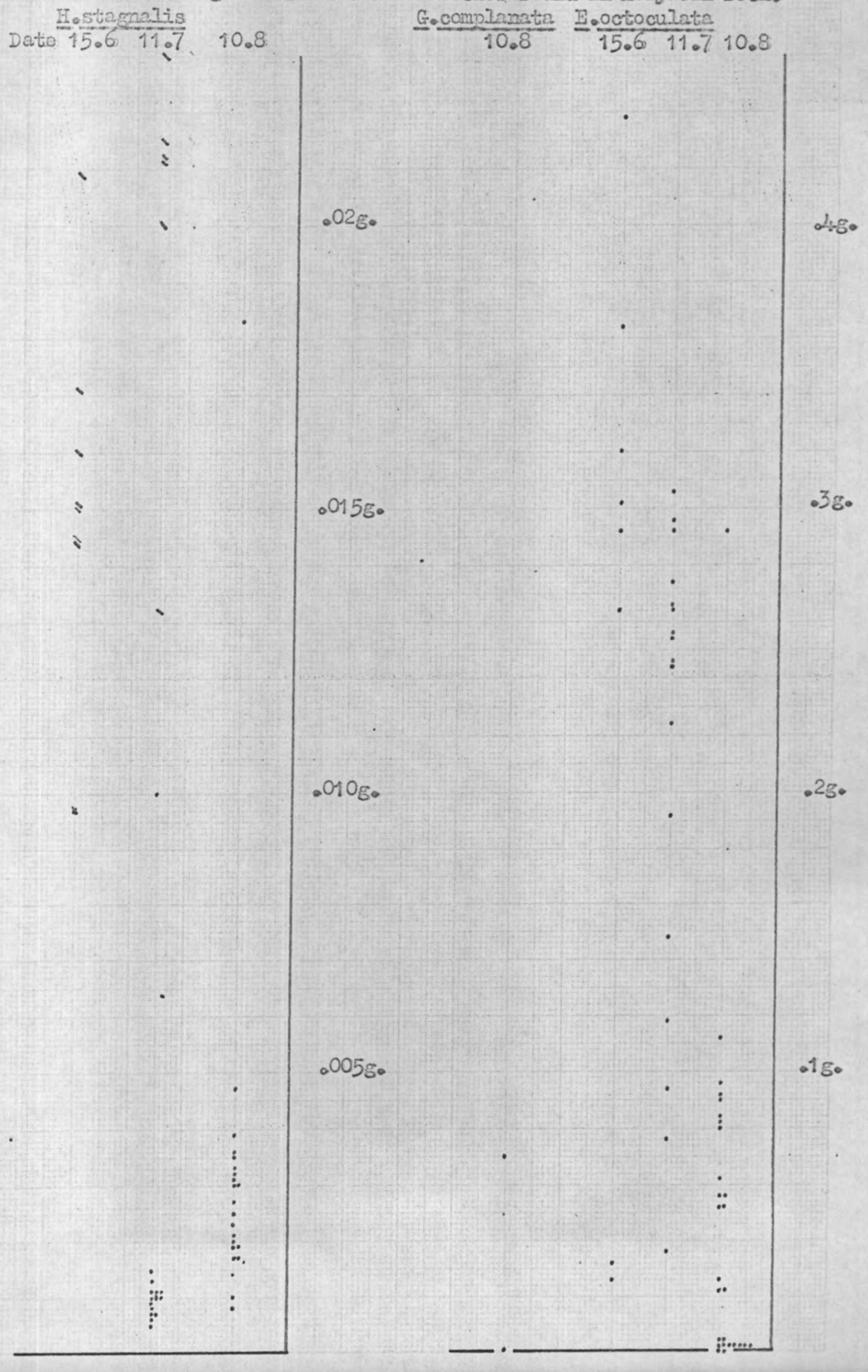
Table 22. Mean numbers of leeches per sq. yd. in Holywell Beck. 10 August.

		H.stagnalis.	G.complanata.	E.octoculata.
Mean no. per sq.yd.	(untransformed)	13.9	.7	13.1
	(transformed)	Not calculated	Not calculated	Not calculated
Type of calculation used for confidence limits.		Neg.binomial	None	None
Transformation used.		None	None	None
95% confidence limits for mean :	upper	23.1	Not calculated	Not calculated
	lower	4.5	Not calculated	Not calculated
95% confidence limits for single areas:	upper	Not calculated	Not calculated	Not calculated
	lower	Not calculated	Not calculated	Not calculated

Table 23. Mean weights of leeches from Holywell Beck.

	15 June		11 July		10 August	
	No.weighed	Mean Wt.	No.weighed	Mean Wt.	No.weighed	Mean Wt.
H.stagnalis	8	.0105 gm	10	.0143 gm	22	.0033 gm
G.complanata	0	-	0	-	2	.0357 gm
E.octoculata	8	.2545 gm	18	.2531 gm	27	.0479 gm

Figure 11. Weights of individual leeches found in Holywell Beck.



RIVER DEERNESS

This is a small river, less than 4 feet deep, and 6 - 15 feet wide. Its bed is of gravel or stones on sandy mud, and shingle banks above the water level occur. Sparganium erectum grows along its banks in places.

Four types of substrate were examined.

i. Sparganium erectum on muddy shingle.

ii. Stones embedded in mud or clay at the edge of the water.

iii. A single large, flat stone at the edge of the water.

iv. Stones on sandy mud, covered by water, slow current.

The numbers of each species found per square yard in each area investigated are given in table 24. Mean weights are given in table 25, individual weights in figures 12 & 13. The mean densities of each species, and the 95% confidence limits of the mean and of pupulations of individual areas are shown in table 26. Each area of stony substrate examined measured about 1 square yard.

Table 24. Numbers of leeches per square yard in the River Deerness.

Substrate type i (*Sparganium erecta*).

Date	5 May		10 June		8 July	
Area No	1		2		3	
Helobdella stagnalis	0 per sq.yd	0 per plant	2.9 per sq.yd	.03 per plant	7.5 per sq.yd	.06 per plant
Glossiphonia complanata	43.7 " "	.52 " "	54.7 " "	.59 " "	56.3 " "	.44 " "
Theromyzon tesselatum	0 " "	0 " "	2.9 " "	.03 " "	0 " "	0 " "
Trocheta bykowskii	2.9 " "	.03 " "	8.6 " "	.09 " "	3.8 " "	.03 " "

Leeches on substrate type ii (stones in river bank).

Date		9 Aug	8 Sept
Area No		4	5
H.stagnalis		0	0
G.complanata		0	4.8
T.bykowskii	(total)	36.0	76.8
	(adult)	36.0	33.6
	(juveniles)	0	43.2

Leeches on substrate type iii (single large flat stone in river bank).

Date		8 Sept
Area No		6
H.stagnalis		0
G.complanata		4.0
T.bykowskii	(total)	144.0
	(adult)	60.0
	(juveniles)	84.0

Leeches on substrate type iv (stony river bed, slow current).

Date	10 June	8 July	9 Aug	3 - 5 September														
Area No	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
H.stagnalis	0	0	6.9	0	0	7.2	10.3	4.0	12.8	2.6	0	0	0	0	0	0	0	0
G.complanata	25.2	6.0	20.6	7.4	2.7	14.4	34.4	4.0	22.4	15.4	27.0	9.0	49.5	18.0	5.4	10.0	4.8	6.4
T.bykowskii	18.0	0	13.7	0	0	3.6	0	4.0	6.4	0	14.7	9.0	67.5	18.0	43.2	20.0	28.8	25.6

Table 25. Mean weights of leeches in the River Deerness.

	May 5.		June 7.		July 8.		Aug. 9	
	No.weighed	Mean wt.	No.weighed	Mean wt.	No.weighed	Mean wt.	No.weighed	Mean wt.
H. stagnalis	0	-	0	-	0	-	4	.0063 gm
G. complanata	19	.0141 gm	26	.0187 gm	16	.0152 gm	12	.0287 gm
T. bykowskii	5	.0768 gm	8	.1013 gm	11	.0926 gm	44	.0788 gm

Table 26. Mean numbers of leeches per square yard in the River Deerness, September 3 - 5.

	Areas 10 - 16. H.stagnalis.	Areas 10 - 16. G.complanata.	Areas 10 - 16. T. bykowskii.
Mean no. per sq.yd. (untransformed)	4.7	14.4	2.0
(transformed)	Not calculated	10.9	Not calculated
Type of calculation used for confidence limits.	None	Normal	None
Transformation used.	None	$\sqrt[6]{\ }$	None
95% confidence limits for mean : upper	Not calculated	26.0	Not calculated
lower	Not calculated	4.0	Not calculated
95% confidence limits for single areas : upper	Not calculated	85.9	Not calculated
lower	Not calculated	.5	Not calculated

	Areas 17 - 24. G.complanata.	Areas 17 - 24. T.bykowskii.	Areas 10 - 24. G. complanata.
Mean no. per sq.yd. (untransformed)	16.3	28.4	15.4
(transformed)	11.1	24.8	11.1
Type of calculation used for confidence limits.	Normal	Normal	Normal
Transformation used.	$\sqrt{\log}$	$\sqrt[4]{\ }$	$\sqrt[6]{\ }$
95% confidence limits for mean: upper	23.9	42.4	18.8
lower	5.8	13.4	7.1
95% confidence limits for single areas: upper	119.4	96.4	60.7
lower	2.3	3.1	1.2

Figure 12. Weights of individuals of H. stagnalis & G. com planata from the Deerness.

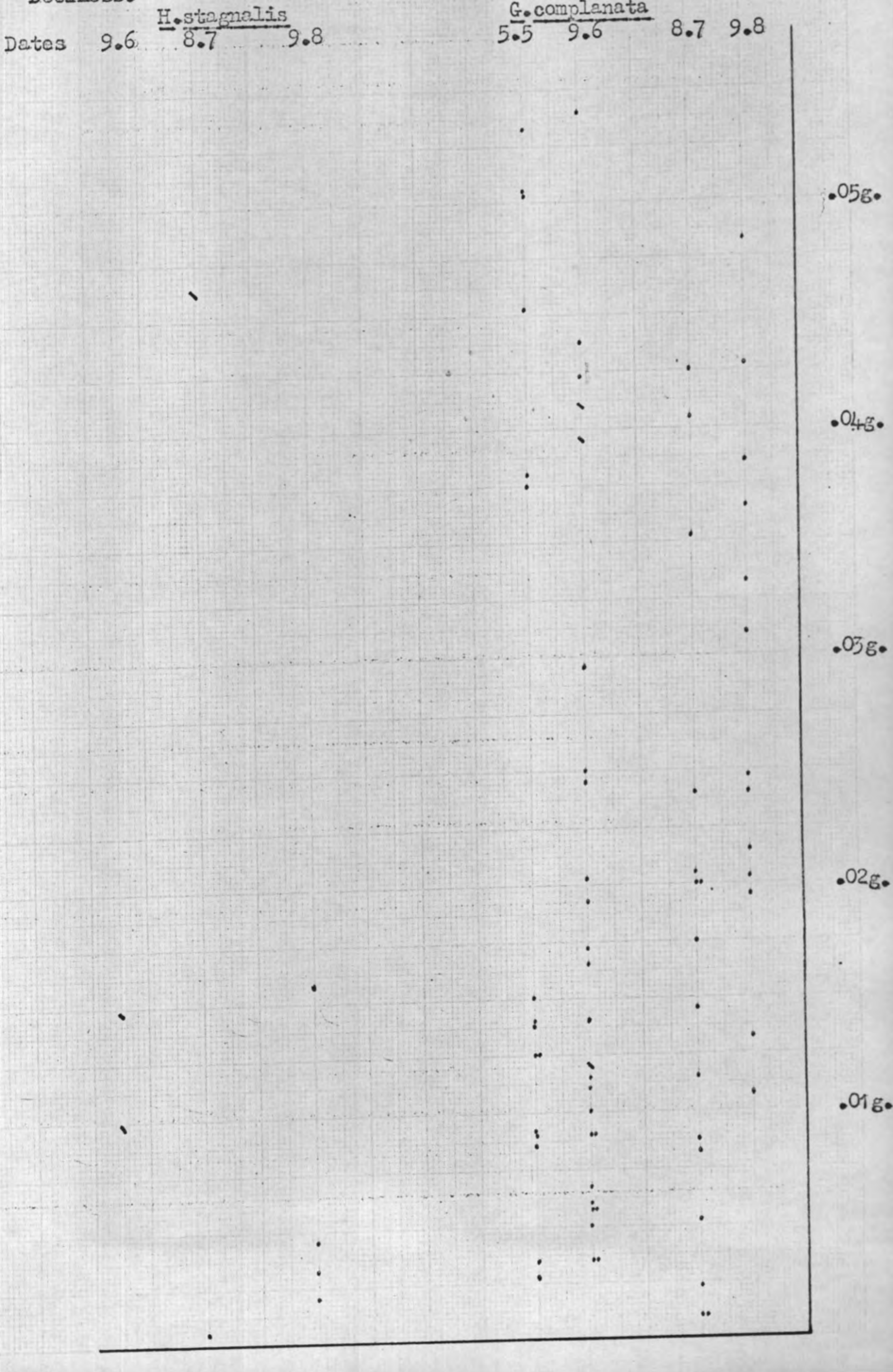
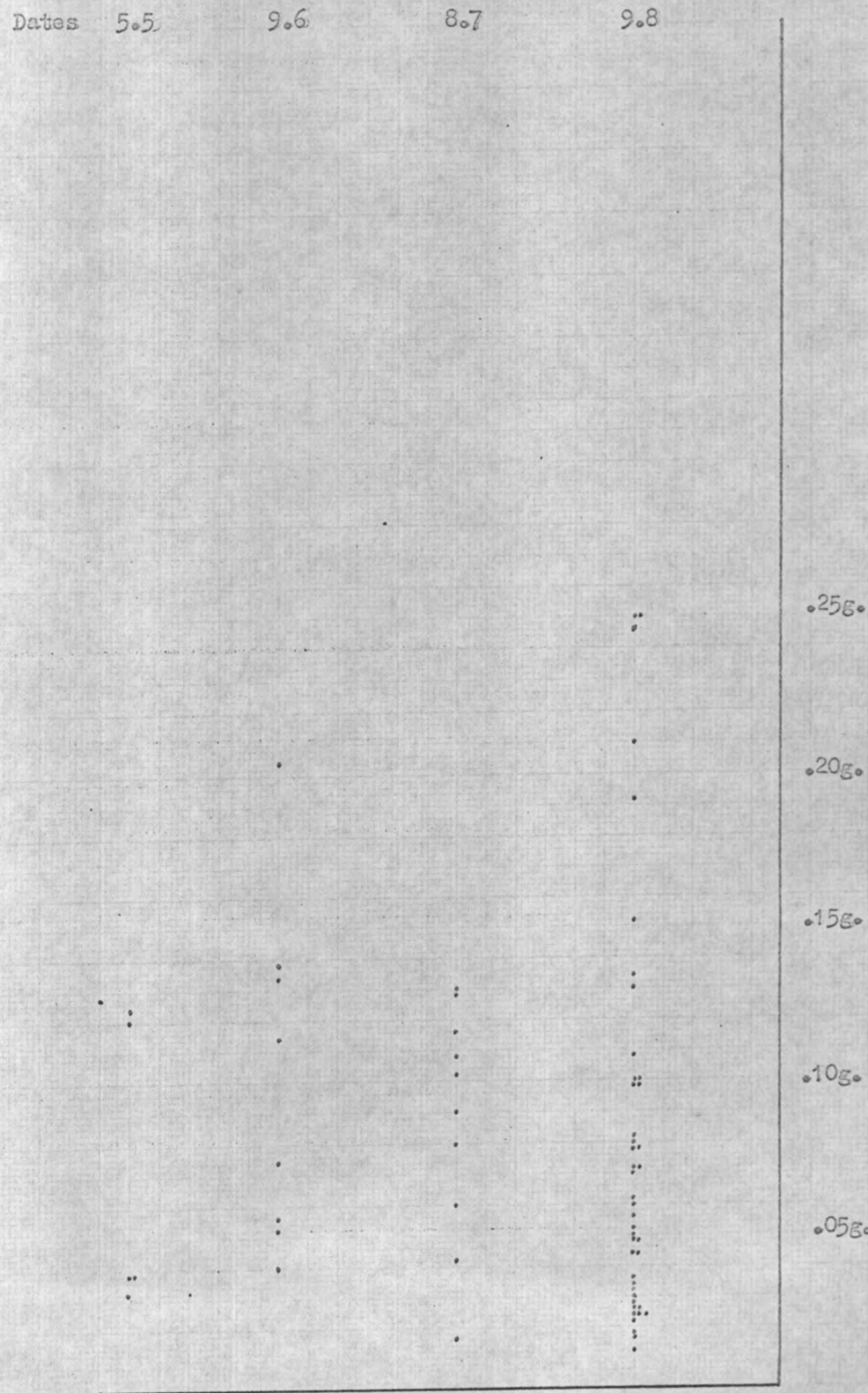


Figure 13. Weights of individuals of T. bykowskii from the Deerness.



RIVER BROWNEY

The Browney is a relatively large river (10 - 20 feet wide). It was sampled below the bridge of the Durham - Bearpark road. The bed consists of solid rock, stones on sandy mud, or mud.

Two areas of mud, each approximately one square yard, were sieved on 22nd August. No leeches were found.

The numbers of each species found per square yard in each area of stones or mud examined are given in table 27. The areas examined on 28th May measured about 2 square yards. All subsequent areas measured about one square yard.

Areas 6, 7, and 8, had been examined previously on 28th May and 30th June. The population densities have been calculated excluding these areas. Mean population densities per square yard and range of probable variation are shown in table 28. Mean weights are shown in table 29, individual weights in figures 14 and 15.

As can be seen from table 27, the *H. stagnalis* populations of areas 6 & 8, and the *T. bykowskii* populations of areas 6, 7, & 8, lie outside the 95% confidence limits for individual areas. It can therefore be concluded that the *H. stagnalis* population of areas disturbed by previous sampling is higher than that of undisturbed areas, and the *T. bykowskii* population is lower than that of surrounding areas. It thus appears that repeated sampling of the same areas is not a reliable method.

The mean density of *G. complanata* in areas 6 - 8 is 16.6 per square yard. This is outside the 80% confidence limits for the mean of areas 9 - 14, but within the 95% limits. It is therefore not possible to say whether the *G. complanata* population was affected by the disturbance caused by sampling.

Table 27. Numbers of leeches per square yard in the areas examined in the River Browney.

	28 May		30 June			30 - 31 July									29 August					
Area No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<u>H.stagnalis</u>	2.7	0	107.4	25.2	3.2	115.7	40.2	52.2	10.3	8.6	26.7	23.4	35.5	28.0	151.2	2.5	25.2	11.5	38.3	9.0
<u>G.complanata</u>	6.0	4.5	16.8	14.4	1.1	15.4	11.1	23.4	10.3	2.74	17.3	6.2	14.7	4.0	18.5	5.0	14.4	0	9.0	3.0
<u>T.bykowskii</u>	6.5	1.5	1.8	9.6	5.4	3.9	0	3.6	18.6	10.7	13.3	13.6	16.0	16.0	6.2	0	18.0	13.5	6.8	45.0

Table 28. Mean numbers per square yard of leeches in the River Browney.

30 - 31 July.

	Areas 9 - 14 H.stagnalis.	Areas 9 - 14 G.complanata.	Areas 6 - 14. T.bykowskii	Areas 6 - 14. G.complanata
Mean no. per sq.yd (untransformed)	22.1	13.4	14.7	14.5
(transformed)	20.8	11.1	Not calculated	13.5
Type of calculation used for confidence limits	Normal	Normal	Normal	Normal
Transformation used	$\sqrt{\quad}$	$\sqrt{\quad}$	None	$\sqrt{\quad}$
95% confidence limits for mean: upper	35.8	19.5	17.8	20.5
lower	10.0	5.1	11.6	7.9
95% confidence limits for single areas: upper	63.8	35.7	22.4	38.9
lower	1.3	.5	7.0	1.2

29 August

	H.stagnalis	G.complanata	T.bykowskii
Mean no. per sq.yd (untransformed)	39.6	8.3	17.9
(transformed)	20.2	Not calculated	Not calculated
Type of calculation used for confidence limits	Normal	None	None
Transformation used	$\sqrt[3]{\quad}$	None	None
95% confidence limits of mean: upper	88.7	Not calculated	Not calculated
lower	3.3	Not calculated	Not calculated
95% confidence limits for single areas: upper	510.9	Not calculated	Not calculated
lower	.1	Not calculated	Not calculated

Table 29. Mean weights of leeches from the River Browney.

	28 May		30 June		30 July	
	No. weighed	Mean wt.	No. weighed	Mean wt.	No. weighed	Mean wt.
H. stagnalis	5	.0095 g	123	.0038 g	129	.0069 g
G. complanata	20	.0520 g	53	.0133 g	28	.0245 g
T. bykowskii	15	.0272 g	21	.0911 g	20	.1353 g

Figure 14. Weights of individuals of *H. stagnalis* from the Browney.

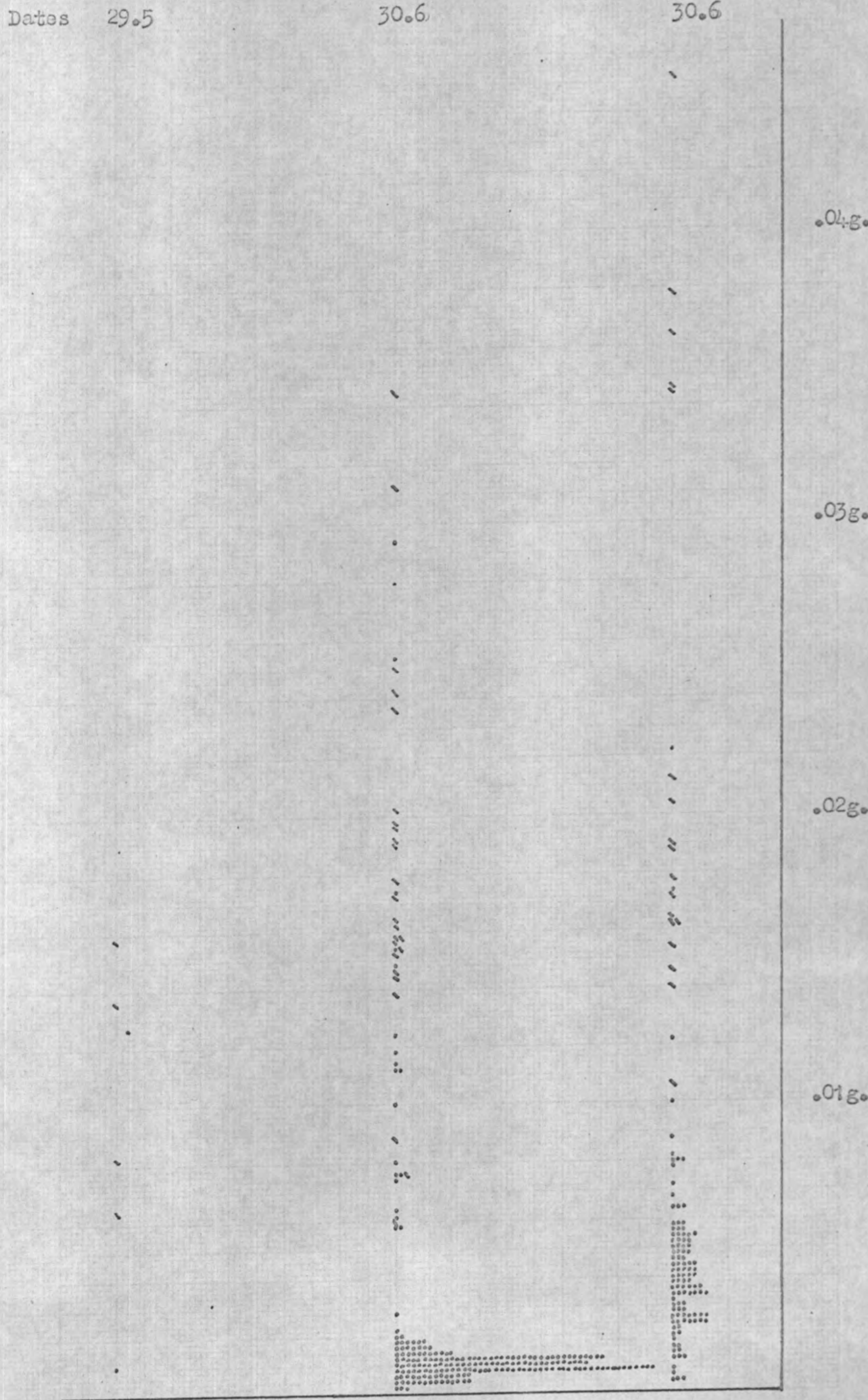
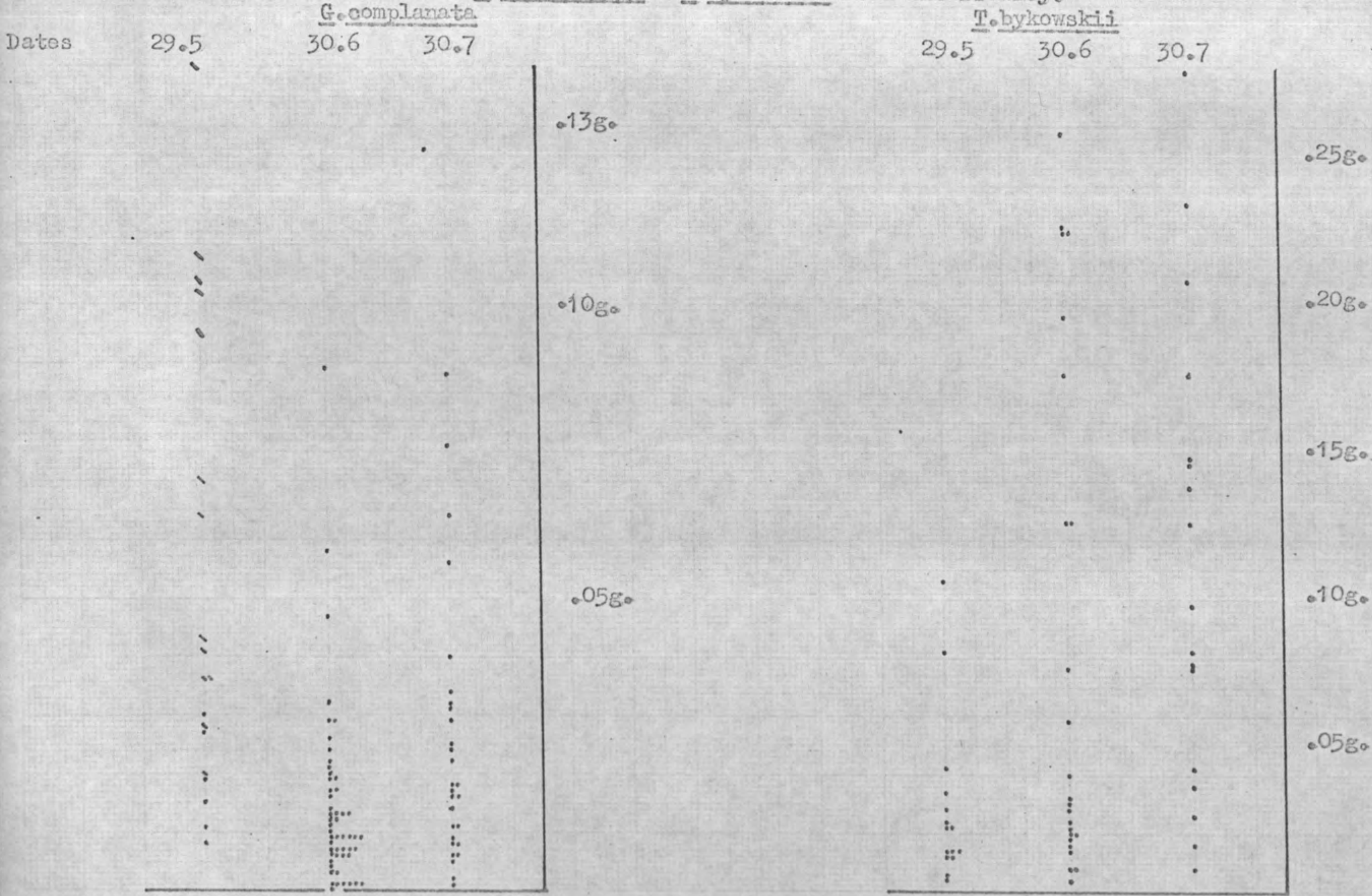


Figure 15. Weights of individuals of <u>G. com planata</u> & <u>T. bykowskii</u> from the Browney.



CROXDALE BECK

Croxdale Beck is 5 - 12 feet wide, and seldom more than two feet deep. Where investigated, the current was mainly moderate to fast. The bottom is of stones on sandy mud, and many shingle banks occur. The water is very turbid, and contains much coal dust.

The following substrates were investigated:

i. Stones on sand, with a slow to moderate current. Four areas were examined on 27th June. No leeches were found.

ii. Stones on muddy sand in very sheltered places, current slow to negligible.

iii. Shingle banks rising above the water level.

iv. Single large stones on the shingle banks.

v. Soil of the river bank, including stones and rotten wood.

The areas examined measured about 2 x 3 feet, except for those of substrate type iv, which were about 3 - 4 square feet.

The numbers of each species found per square yard in each area examined are given in table 30. Mean densities per square yard for each species, and range of variation, are given in table 31. Mean weights are shown in table 32,

Table 30. Numbers of leeches per square yard in the areas examined in Croxdale Beck.

Substrate type ii (stony river bed, slow current).

Date	27 April	26 May	28 June				
Area No	1	2	3	4	5	6	7
G.complanata	10.0	17.3	10.5	9.0	6.0	36.0	9.6
T.bykowskii	1.0	4.0	6.0	0	0	1.1	0

Substrate type iii (shingle banks).

Date	27 April		27 May					28 June				28 July								
Area No.	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
G.complanata	1.5	0	0	7.5	2.0	0	0	4.3	0	0	0	0	0	0	0	0	0	0	0	0
T.bykowskii	15.0	21.0	19.7	9.0	8.0	6.0	13.5	25.2	7.7	12.6	15.6	17.6	14.1	15.4	7.2	5.1	9.6	4.8	24.0	15.0

	Substrate type iv (single large stones in shingle bank).		Substrate type v (stony soil from river bank).
Date	28 June		28 June
Area No.	28	29	30
G.complanata	0	0	0
T.bykowskii	58.2	44.0	10.0

Table 31. Mean numbers of leeches per square yard in Croxdale Beck.

Substrate type ii 26 May

		G.complanata	T.bykowskii
Mean no. per sq.yd.	(untransformed)	15.8	2.2
	(transformed)	12.9	Not calculated
Type of calculation used for confidence limits.		Normal	None
Transformation used.		Logarithmic	None
95% confidence limits for mean :	upper	33.4	Not calculated
	lower	4.9	Not calculated
95% confidence limits for single areas :	upper	109.1	Not calculated
	lower	1.5	Not calculated

Substrate type iii

		27 May T.bykowskii	28 June T.bykowskii	28 July T.bykowskii	27 April-28 July T.bykowskii
Mean no. per sq.yd	(untransformed)	11.2	15.3	12.5	13.2
	(transformed)	10.2	14.6	11.2	12.4
Type of calculation used for confidence limits.		Normal	Normal	Normal	Normal
Transformation used		$\sqrt{\text{logarithm}}$	$\sqrt{}$	$\sqrt[8]{}$	$\sqrt[3]{}$
95% confidence limits for mean :	upper	19.7	30.7	17.4	15.2
	lower	5.5	4.4	7.0	10.0
95% confidence limits for mean:	upper	47.7	52.7	39.7	28.3
	lower	2.7	.1	2.5	3.9

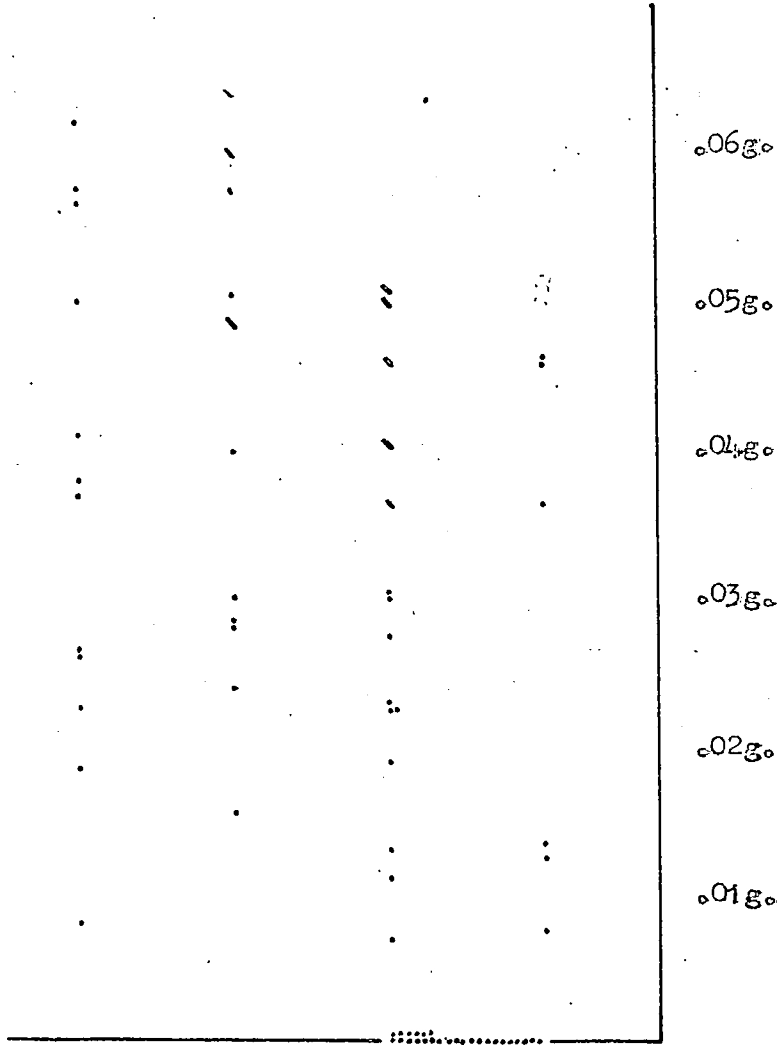
individual weights in figure 16.

Because the population of *T. bykowskii* is practically constant from April 27th to 28th July, and because figure 16 shows a constant population profile, accompanied by a steady increase in individual weight, it was concluded that the mean densities had not changed during the period of this research. The mean was then re-calculated, using the densities of all the areas of substrate type iii which had been investigated.

Figure 16. Weights of individual leeches from Croxdale Beck.

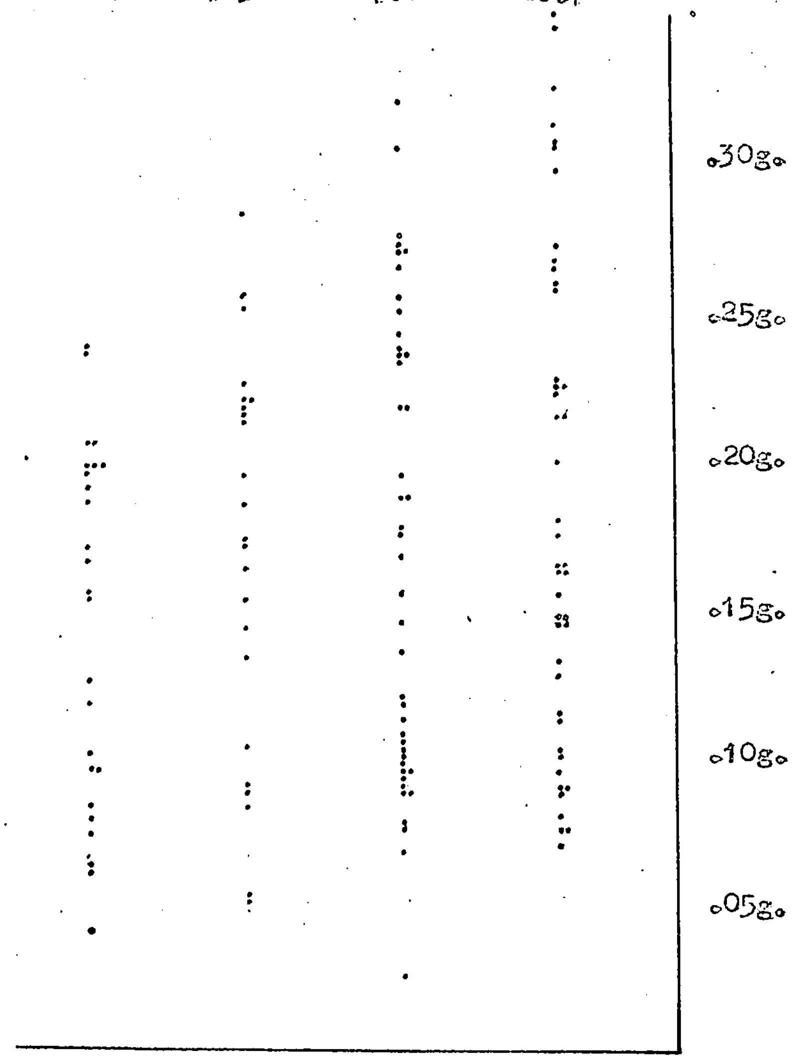
G. complanata

Dates 28.4 27.5 27.6 28.7



T. bykowskii

28.4 27.5 27.6 28.7



WHITEWELL BECK

Whitewell Beck is a small stream 4 - 8 feet wide. The bottom is mainly of large stones on clay. The site investigated was below the bridge of the A.180 near Shincliffe. This includes two pools, one of which is about 4 feet deep. Only Glossiphonia complanata was found. The numbers found in each area investigated are given in table 33. Each area examined measured about 4.5 square feet. In areas 11 - 15 mud was being deposited on the stones, and the current was slow to negligible, in areas 6 - 10 no mud was being deposited, and the current was slow to moderate. Mean populations, and range of variation, are shown in table 34.

Mean weights are given in table 35; individual weights in figure 17.

Above the A.180 road bridge, Whitwell Beck, and its tributary, Chatman Beck, have a generally fast current, with no large continuous areas of slow or moderate current. The substrate is largely unstable, consisting of gravel and eroding clay.

Small isolated areas with a moderate current and a stony bottom do occur. Seven of these with areas varying from 3 - 6 square feet were investigated on 15th - 16th January. The numbers of G. complanata found in them were: 0, 0, 0, 1, 1, 2, 4.

Table 33. Numbers of leeches per sq.yd. in the areas investigated in Whitewell Beck.

	21 May.	24 July.				24 August.									
Area No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
G.complanata	33.3	47.1	7.2	14.5	10.4	0	7.7	8.5	2.3	0	28.5	36.5	46.5	41.1	33.1

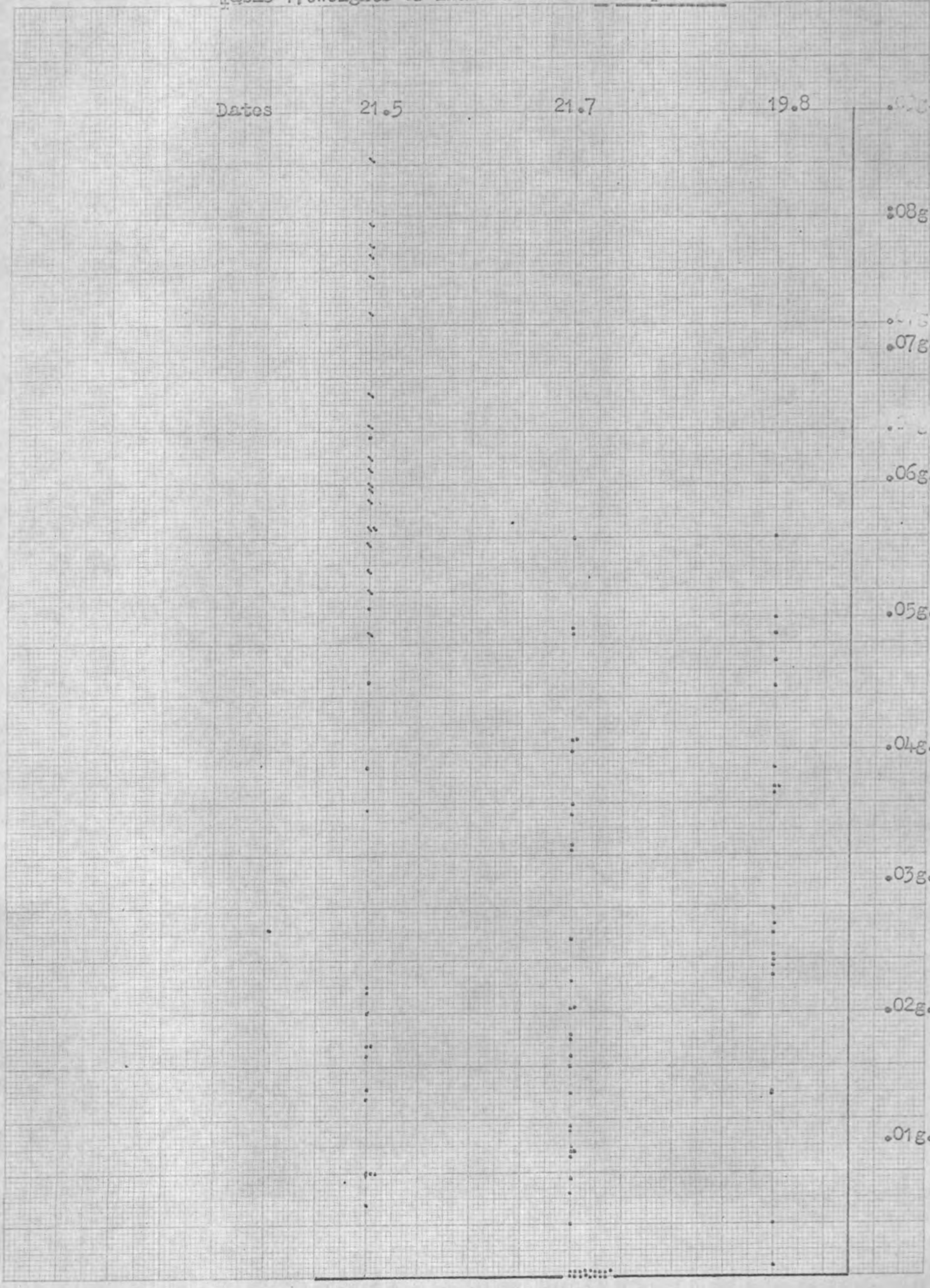
Table 34. Mean numbers of leeches per sq.yd. in Whitewell Beck.

	Areas 6-10. G.complanata	Areas 11-15. G.complanata
Mean no. per sq.yd. (untransformed)	3.7	37.1
(transformed	Not calculated	Not calculated
Type of calculation used for confidence limits of mean	None	Normal
Transformation used.	"	None
95% confidence limits of mean:		
upper	Not calculated	46.7
lower	Not calculated	27.5
95% confidence limits from single areas :		
upper	Not calculated	58.7
lower	Not calculated	15.5

Table 35. Mean weights of G.complanata from Whitewell Beck.

Date	Number	Mean Wt (gm).
21 May	37	.0451
24 July	45	.0150
24 August	19	.0277

Table 17. Weights of individuals of G. complanata from Whitewell Beck.



COW POND, COCK OF THE NORTH, DURHAM.

This pond has a diameter of about 15 feet, and is about 1 foot deep. It is situated opposite the garage at the Cock of the North, Durham, about a mile from the Wear, and 100 feet above it. It has neither inflow nor outflow.

The substrate was mud, with a dense covering of *Glycena* sp.

One area of approximately 3 square feet was searched on 28th May. The following population densities were found :

Species.	No. per sq. yd.
Batracobdella paludosa (total)	84
Batracobdella paludosa (with young)	18
Helobdella stagnalis	9
Dina lineata	45
Dina lineata (cocoons)	99

STREAMS WITHOUT LEECHES

Upper Tees

This was investigated at two sites, Moorhouse and Middleton in Teesdale.

At Moorhouse it is 4 - 6 feet wide. Four areas, each about 3 square feet, were searched on 7th July. The substrate was of stones on mud in a slow current.

At Middleton in Teesdale it is about 30 feet wide. The areas searched had a stony substrate and a slow current. Five areas, each about three square feet, were searched on 6th May.

Upper Wear

Areas in the river Wear above Witton le Wear were searched and found to lack leeches, as already described.

Saltwell Gill

This is 2 - 6 feet wide, and receives treated sewage from the Durham colleges. Seven areas, each 2 - 3 square feet were searched. The substrate was stones on mud, with a slow to moderate current.

Nickynack Beck

This is 2 - 4 feet wide, and receives sewage from Croxdale village, and drainage water from a coal tip. Three areas each about 3 square feet were searched. The substrate was stones on rotten wood on mud, with a slow current.

Goat's Beck, Langley Moor

This is 3 - 4 feet wide. It receives drainage water from a coal tip, and also shows signs of detergent pollution. The stones were covered with a greyish gelatinous deposit. Four areas, each 3 square feet, with a slow to moderate current, were investigated.

POPULATIONS FOUND BY OTHER WORKERS

I have only been able to find one record (Mann, 1965), of the numbers of leeches per unit area on a given substrate. The substrate below a depth of 3m in the river Thames at Reading is stony; above 3m it consists of mud with water lilies (*Nuphar* sp.) and sweet rushes (*Acorus* sp.)

The populations found are given in table 36.

Bennike gives the population density found on an unspecified substrate in a brook beneath a mill-pond.

The population densities per square yard are given in table 37.

Bennike also counted the turbellarians, gastropods, oligochaets, isopods, water mites, and insects. He found that leeches formed c. 25% of the total number of animals counted.

The total population (654 leeches per square yard) is comparable to that found in the more heavily populated parts of the river Wear. The difference between the ratio of *H. stagnalis* to *E. octoculata* found here, and that found in the river Wear, may be due to the fact that Bennike based his estimate on the numbers found in three small areas, each 450 sq.cm.

Table 36. Numbers of leeches per square yard in the Thames (Mann 1965).

	Above effluent		Below effluent	
Species	3 m deep	3 m deep	3 m deep	3 m deep
Helobdella stagnalis	16.2	41.1	0	2.2
Batracobdella paludosa	0	2.2	0	0
Glossiphonia complanata	2.1	3.0	0	3.0
Erpobdella octoculata	16.2	4.4	.5	11.2
Erpobdella testacea	2.0	0	0	0
Trocheta bykowskii	1.6	0	.9	0

Table 37.

Species	No. per square yard.
H. stagnalis	246
G. complanata	7
G. heteroclita	137
Hemiclepsis marginata	7
Theromyzon tesselatum	7
Erpobdella octoculata	226
E. testacea	7
Haemopis sanguisuga	7

EFFECTS OF SUBSTRATE

Figure 18 shows the mean densities of leech populations in different substrates in the river Wear. Densities are expressed as numbers per square yard. Table 38 shows the percentage of each population formed by each species. Newly emerged specimens of Trocheta subviridis are excluded.

Mean densities of the leech populations in different substrates in Brancepeth Beck, Croxdale Beck, and the river Deerness, are given in figure 19. The percentages of each population formed by each species are given in table 39.

Populations of Helobdella stagnalis and Trocheta bykowski can vary greatly within apparently uniform substrates. Examples of this are given in table 40.

Since the comparison of transformed and untransformed means would be of doubtful value, untransformed means are used throughout tables 38 - 40 and figures 18 & 19.

Mann (1955) gives the percentage compositions of leech populations on stones and reeds (reed species not named) in some lakes. Bennike (1943) gives the percentage composition of the leech fauna of plants of Sparganium erecta in a lake. He noted the presence, but not the relative numbers, of leech species in the stony parts of the lake.

Table 38. Percentage composition of the leech populations of the River Wear.

Place.	Substrate.	Date.	H.stagnalis.	G.complanata.	E.octoculata.	T.bykowskii.	T.subvinidis	H.sanguisuga	N
Above Gaunless	Stones, moderate current	15 July	0	30.6	4.1	0	30.6	34.7	2
		21 Aug	14.9	43.1	3.8	0	38.2	0	5
Croxdale	Stones, slow current	12-26 July	77.7	6.9	14.6	0	0	.8	6
	Stones, moderate current	30 April	1.4	14.1	83.9	0	0	.6	2
		1 June	7.2	19.1	68.4	0	0	5.3	2
	"	4 July	18.8	34.8	43.8	0	0	2.6	5
	"	6 Aug	10.6	32.3	55.6	0	0	1.5	5
Frankland's Farm	Stones, slow current	24 June	69.0	16.9	13.9	0	0	.2	3
		25 July	58.0	16.3	25.7	0	0	0	6
	"	27 Aug	71.1	11.2	17.4	.1	0	.1	5
Bishop Auckland	"	30 Aug	50.9	14.9	34.2	0	0	0	6
	Reeds	2 May	4.8	9.5	79.4	0	0	6.3	1
Croxdale	"	30 May	4.8	11.1	68.2	0	0	15.9	1
	"	2 July	3.7	28.4	63.0	0	0	4.9	1
	"	3 Aug	25.8	23.3	47.9	0	0	3.0	1
Croxdale	Mud	6 Sept	0	6.5	93.5	0	0	0	10
Frankland's	Algal Mat	25 July	96.9	0	1.1	0	0	2.0	2
Farm	Shingle Bank	27 July	0	0	0	61.4	0	38.6	7
Croxdale	" "	5 Aug	0	0	0	12.4	50.0	37.6	7

N = Number of samples on which percentage is based.

Table 39. Percentage composition of the leech populations of Brancepeth Beck, Croxdale Beck, and the River Deerness.

Stream.	Substrate	Date.	H.stagnalis.	G.complanata.	T.bykowskii	H.sanguisuga	N
	Reeds.	8 June	0	64.2	0	35.8	2
Brancepeth Beck	"	9 July	0	84.8	0	15.2	3
	"	11 Aug	0	100.	0	0	1
	Stones slow current	11 Aug	10.8	89.2	0	.0	5
	Stones moderate current	11 Aug	0	100.	0	0	3
Deerness	Reeds	5 May	0	93.8	6.2	0	1
	"	10 June	4.2	79.2	12.4	0	1
	"	8 July	11.1	83.3	5.6	0	1
	Stones slow current	10 June	0	58.3	41.7	0	1
		8 July	0	100.0	0	0	1
		9 Aug	16.7	50.0	33.3	0	1
		3 Sept	22.2	68.2	9.6	0	7
		5 Sept	0	36.5	63.5	0	8
	Stones in bank approx at water level	12 June	4.0	40.0	56.0	0	1
		9 Aug	0	0	100.0	0	1
		8 Sept	0	8.6	91.4	0	1
Croxdale Beck	Stones moderate current	27 June	0	0	0	0	4
	Stones slow current	27 April	0	90.9	9.1	0	1
	"	26 May	0	87.9	12.1	0	5
	"	28 June	0	100.0	0	0	1
	Shingle bank	27 April	0	4.0	96.0	0	2
	"	27 May	0	14.5	85.5	0	5
	"	28 June	0	6.7	93.3	0	4
	"	28 July	0	0	100.0	0	9
	Stones in bank at water level	28 June	0	0	100.0	0	1

N = number of samples on which the mean is based.

Table 40. Variations in leech populations within apparently uniform substrates.

River	Date	Mean Density of *H. stagnalis* (per sq.yd).	Percentage of population formed by *H. stagnalis.*
Gaunless	17-18 July	2.0	5.9
	29 Aug	40.6	33.4
Deerness (areas 17-24)	3-5 Sept	0	0
(areas 10-16)	3-5 Sept	4.7	22.3
Browney (areas 9-14)	30-31 July	22.1	43.8
(areas 6-8)	30-31 July	69.4	78.4
		Mean Density of *T. bykowskii* (per sq.yd)	**Percentage of population formed by *T. bykowskii.***
Deerness (areas 17-24)	3-5 Sept	28.4	63.5
(areas 10-16)	3-5 Sept	2.0	9.5
Browney (areas 9-14)	30-31 July	15.0	29.7
(areas 6-8)	30-31 July	2.5	2.8
		Mean Density of *G. complanata* (per sq.yd)	**Percentage of population formed by *G. complanata.***
Gaunless	17-18 July	21.7	63.8
	29 Aug	56.6	40.6
Deerness (areas 17-24)	3-5 Sept	16.3	36.5
(areas 10-16)	3-5 Sept	14.4	68.2
Browney (areas 9-14)	30-31 July	13.4	26.5
(areas 6-8)	30-31 July	16.6	18.8

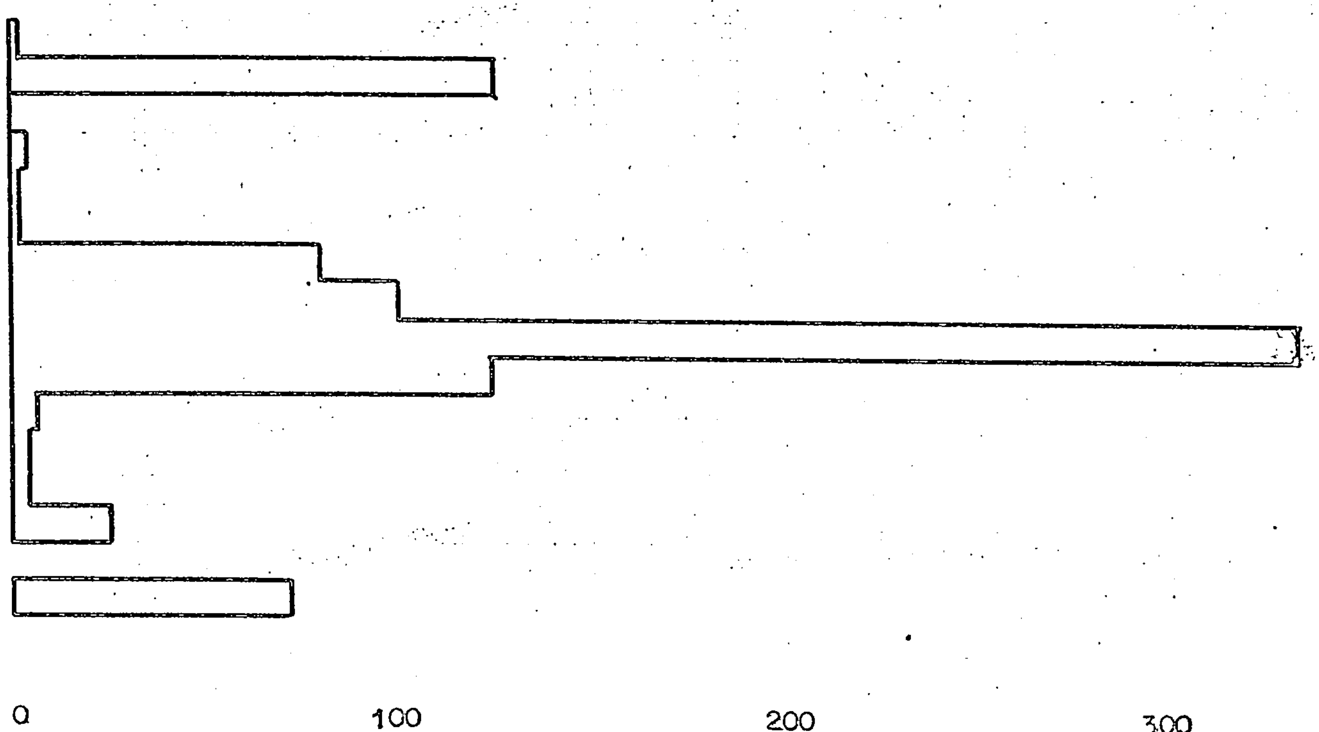
Table 41. Comparison of populations on stones and reeds.

Source of information.	Leech species	% of leech population on reeds formed by species.	% of leech population on stones formed by species.
Bennike (1943)	_H.stagnalis_	71	+
	G.complanata	0	+
	E.octoculata	25	+
	H.sanguisuga	0	+
	Other species	4	+
Mann (1955)	_H.stagnalis_	76-80	0 - 45
	G.complanata	0	14 - 20
	E.octoculata	14-18	43 - 82
	H.sanguisuga	+	+
	Other species	+	+
Present work	_H.stagnalis_	4[illegible]-26	51-71 (slow current) 1-19 (moderate current)
	G.complanata	10-28	11-17 (slow current) 14-35 (moderate current).
	E.octoculata	48-79	14-34 (slow current). 44-84 (moderate current).
	H.sanguisuga	3[illegible]-16	0-2 (slow current). .6-2.6 (moderate current).

+ means species is present, but frequency is not given.

Figure 18a. Mean numbers of H. stagnalis per sq. yd. in various substrates in the Wear.

Place.	Substrate type.	Date.
Above Gaunless	ii	15.7
"	"	21.8
Above Gaunless	iii	26.7
Croxdale	ii	30.4
"	"	1.6
"	"	4.7
"	"	6.8
Franklands Farm	iii	24.6
"	"	25.7
"	"	27.8
Below Gaunless	iii	30.8
Croxdale	iv	2.5
"	"	30.5
"	"	2.7
"	"	3.8
Croxdale	v	16.9
Franklands Farm	vi	25.7
Franklands Farm	vii	27.7
Croxdale	vii	5.8



N
2
5
6
2
2
5
5
3
6
5
6
1
1
1
1
10
2
7
7

Substrate types:

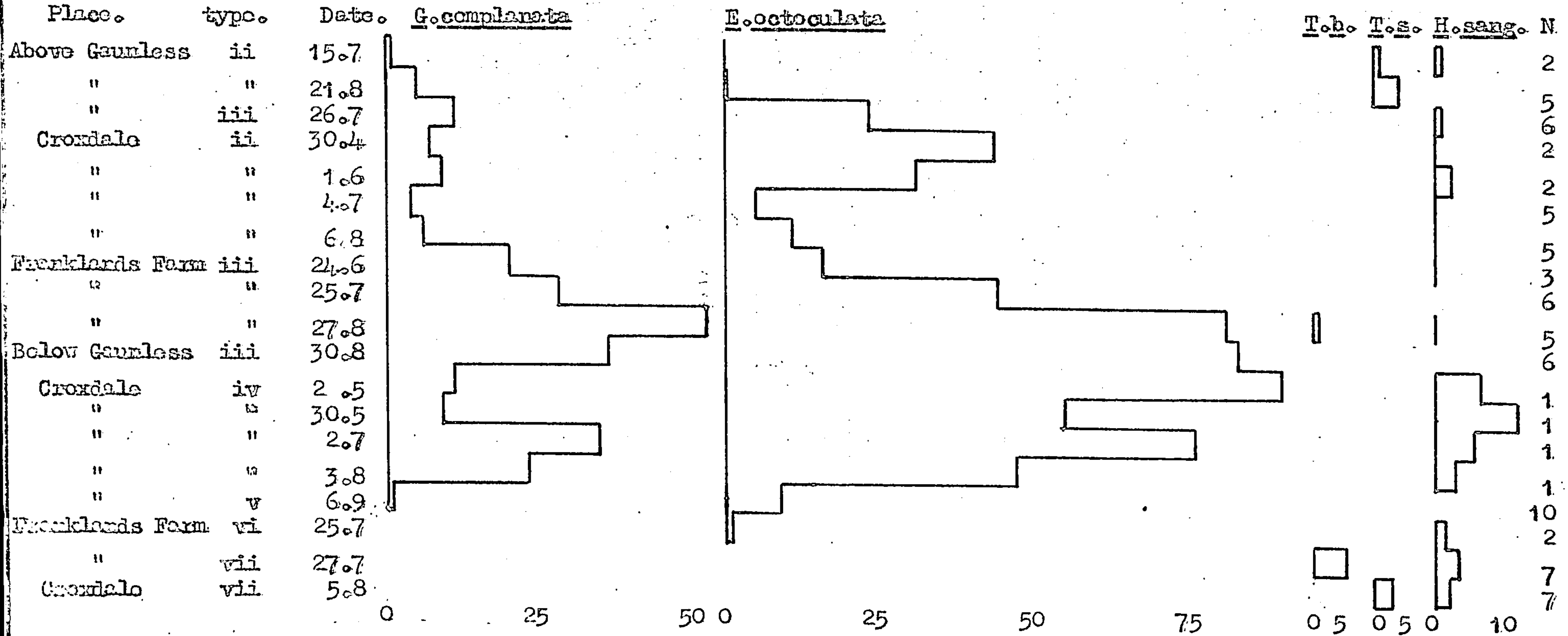
ii Stones, moderate current.
iii Stones, slow current.
iv Reeds.

v Mud covered by water.
vi Stones level with water surface, covered by algal m at.

vii Exposed shingle banks.

N = number of samples on which mean is based.

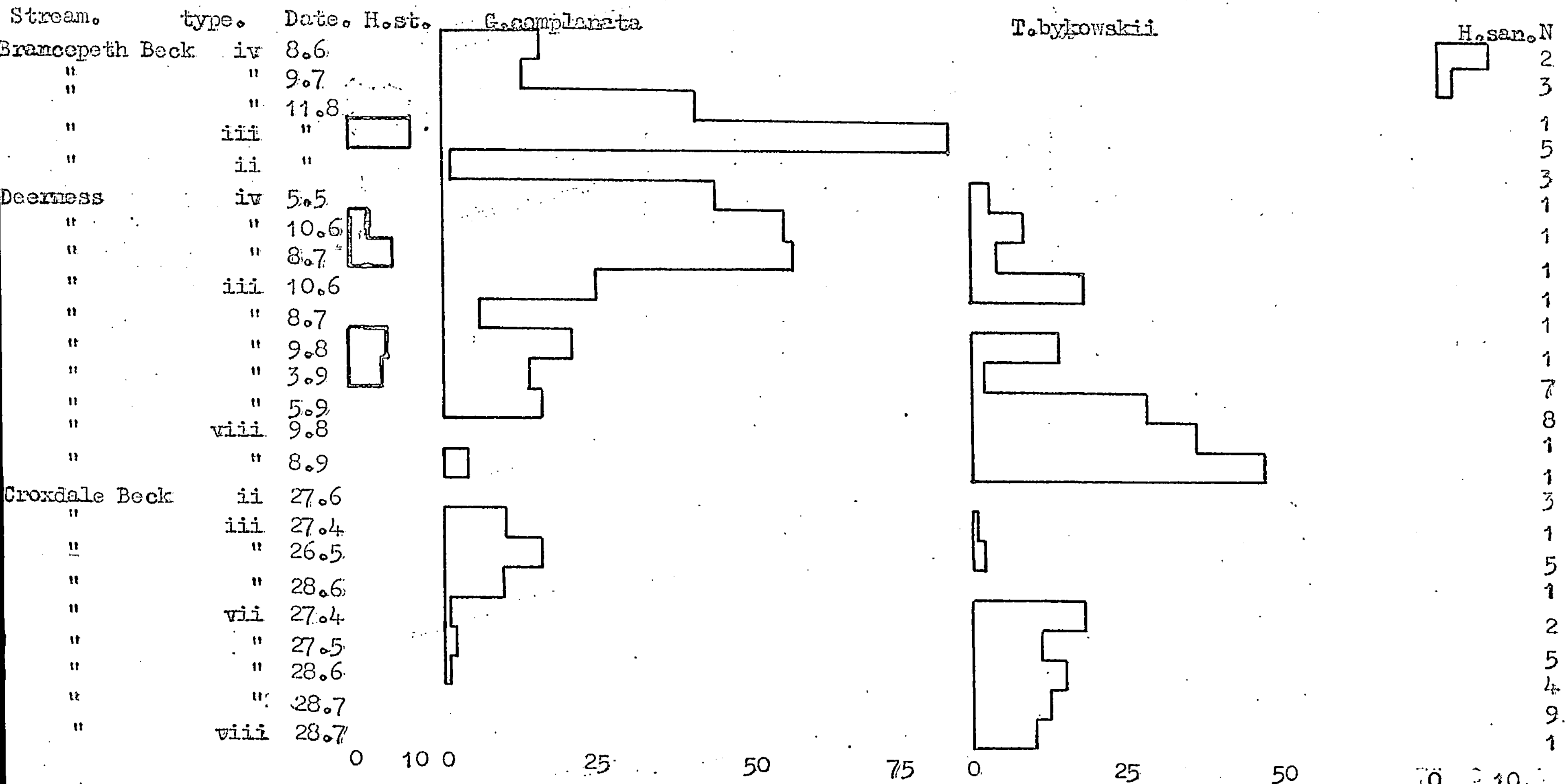
Figure 18b. Mean numbers of G. complanata, E. octoculata, T. bykowskii, T. subviridis, & H. sanguisuga per sq. yd. in various substrates in the Wear.



Substrate types:
ii Stones, moderate current.
iii. Stones, slow current.
iv Reeds.
v Mud, covered by water.
vi Stones level with water surface, covered by algal mat.
vii Exposed shingle banks.

Abbreviations used:
T.b. = T. bykowskii
T.s. = T. subviridis
H.sang. = H. sanguisuga
N = number of samples on which the mean is based.

Figure 19. Mean nos. of leeches per sq. yd. in various substrates in Brancepeth Beck, Croxdale Beck, & the Gaunless.



Substrate types:
ii Stones, moderate current.
iii Stones, slow current.
iv Reeds.
vii Exposed shingle banks.
viii Stony soil in river banks.

Abbreviations used:
H. st. = Hellobdella stagnalis
H. san. = Haemopis sanguisuga
N = number of sam ples on which m ean is based.

These results are compared with those of the present work in table 41.

CHEMICAL PROPERTIES OF THE WATERS INVESTIGATED

The calcium concentrations found are shown in table 42; magnesium concentrations in table 43, total resistivity at $0^{o}C$ and pH in table 44. In cases where no determination has been made, a blank is left in the table.

The relationship between the densities of the leech populations and the calcium concentrations of the waters in which they were found in shown in figure 20; the relationships of the densities of the leech populations to mean Mg^{++} concentrations and total resistivities are shown in figures 21 and 22 respectively.

In each case the figure for the leech population is the highest untransformed mean population found in the river on a stony substrate. Only means of five or more samples (where available) were used. The numbers of H. stagnalis are shown on half the scale of the other species. Streams without leeches are not included. Only calcium concentration appears to be correlated with the leech population.

Figure 20. Relationship between the highest mean number of leeches per sq. yd. in stony river beds, and mean calcium concentrations.

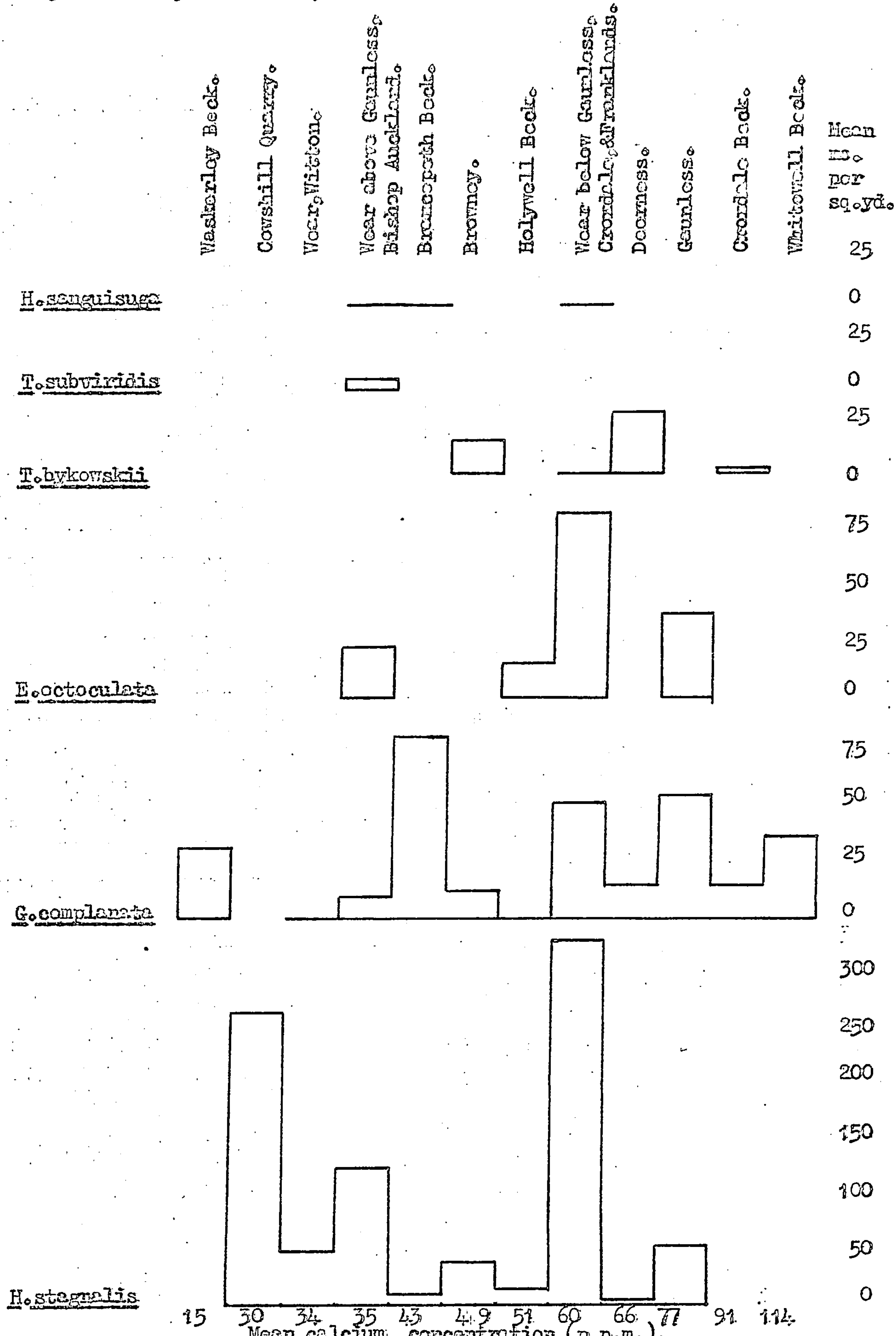


Figure 21. Relationship between the highest m ean number of leeches per sq. yd. found in stony river beds , and mean magnesium concentration.

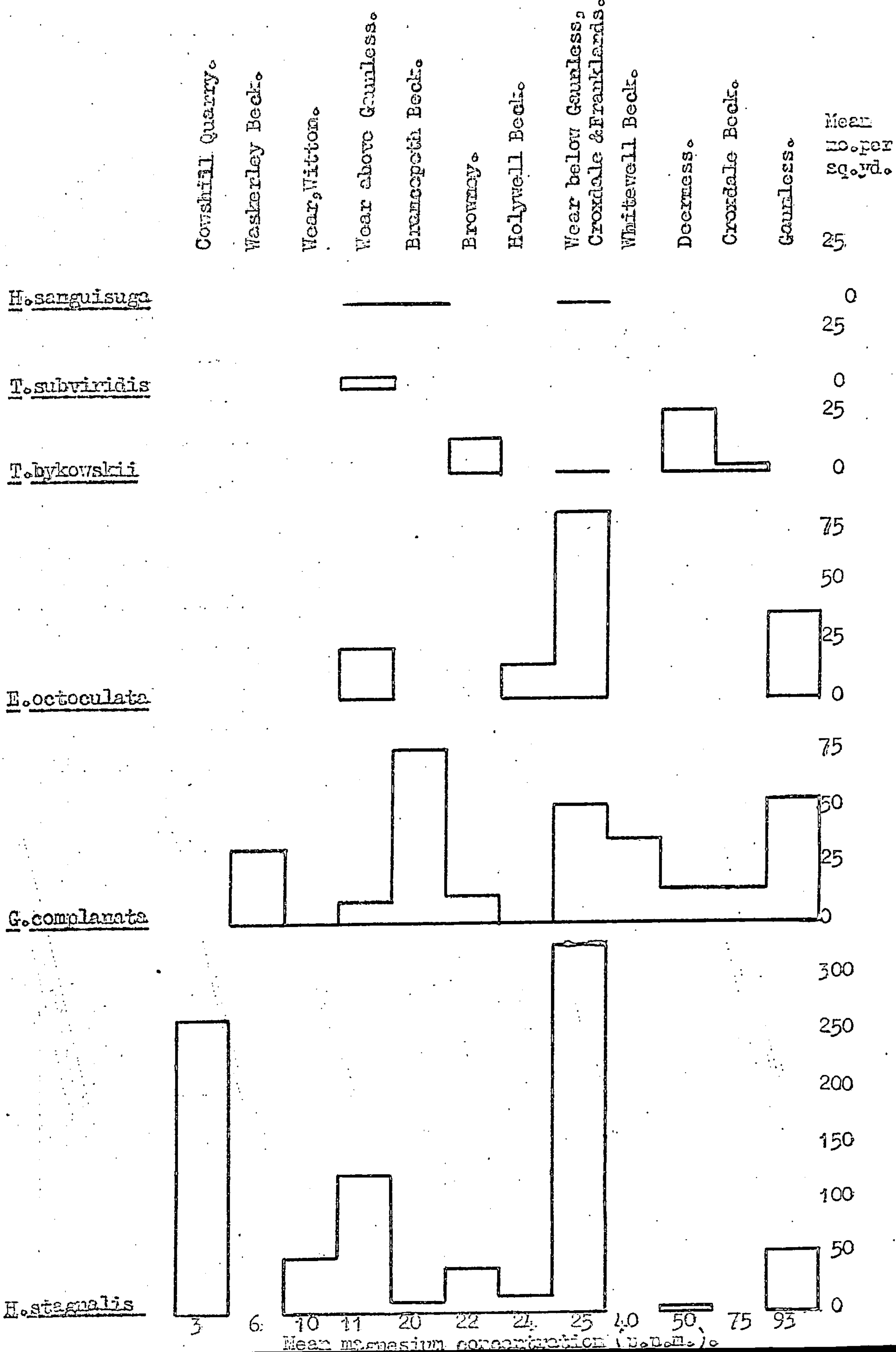


Figure 22. Relationship between the highest mean number of leeches per sq. found in stony river beds, and mean total resistivity of the water.

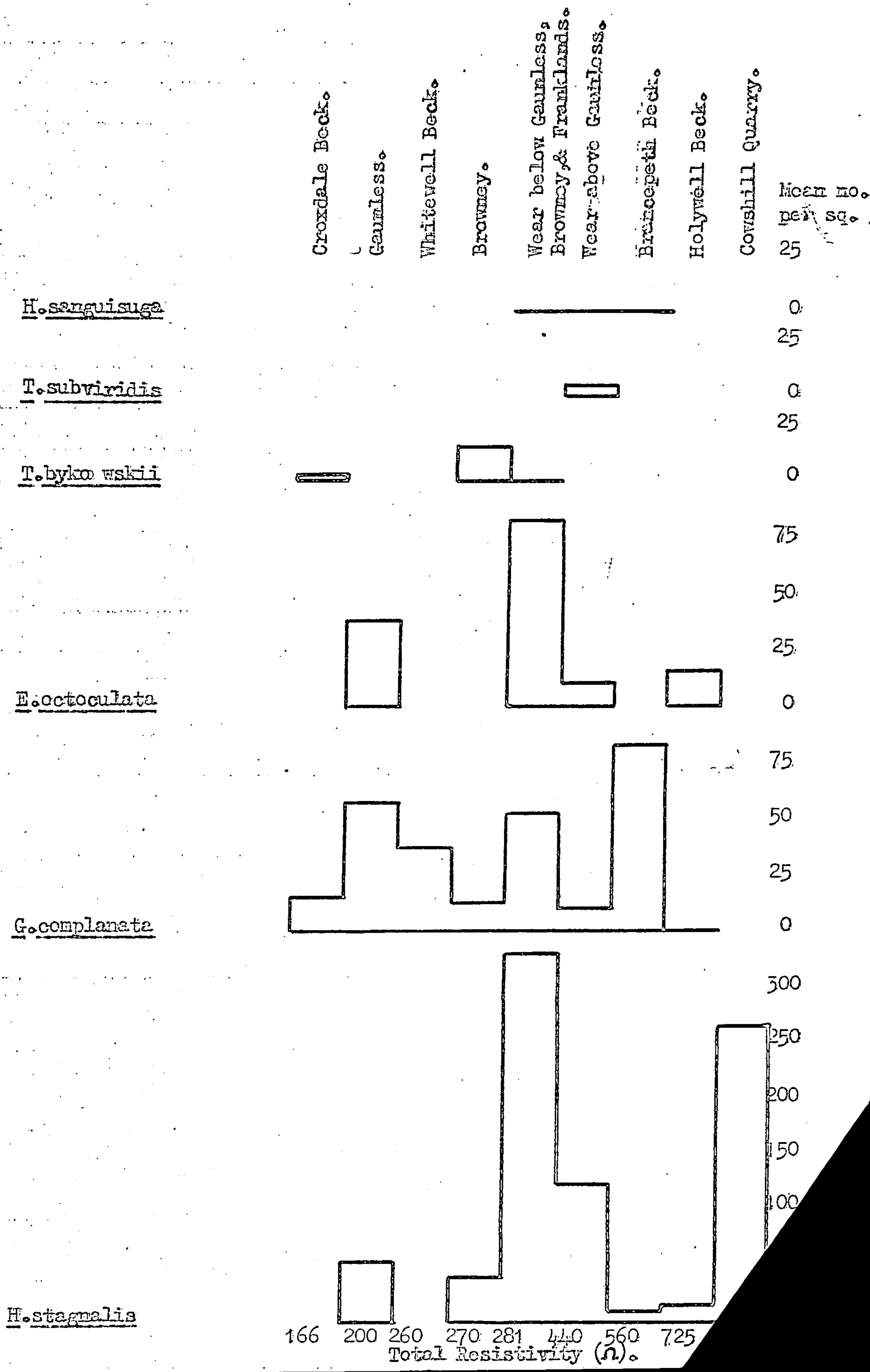


Table 42.

Calcium concentrations in waters investigated.

Stream	Ca++(ppm)	Date	Ca++(ppm)	Date	Ca++(ppm)	Date
Tees, Moorhouse			13.0	7 July	6.0	3 Aug.
Wear, Wearhead			30.0	"		
Wear, Stanhope			48.0	"		
Wear, Wolsingham					27.0	3 Aug.
Wear, Witton					34.0	22 Aug.
Wear above Gaunless			40.0	15 July	30.0	21 Aug.
Wear below Gaunless			54.0	26 July	49.0	30 Aug.
Wear, Croxdale	60.0	30 April	66.0	1 June	63.5	4 July.
Wear, Croxdale pool					66.0	5 Aug.
Wear, Durham	64.5	24 May	58.5	24 June	64.0	26 July.
Holywell	56.0	15 June	36.0	11 July	60.5	10 Aug.
Gaunless			90.0	17 July	64.5	16 Aug.
Brancepeth	49.0	8 June	45.0	9 July	33.5	11 Aug.
Browney	45.0	29 May	58.5	30 June	45.0	30 July.
Deerness	70.0	9 June	70.0	8 July	58.5	9 Aug.
Croxdale	92.5	27 May	95.0	27 June	86.0	28 July.
Deerness Tributary	55.5	9 June				
Quarry			30.0	7 July		
Waskerley			14.5	3 Aug		
Whitewell	118.0	21 May	123.0	14 July	102.0	24 Aug.
Saltwell	58.5	4 June			32.0	4 Aug.
Nickynack	163.0	30 May			104.0	4 July.
Goats Burn					190.0	11 Aug.

Table 43.

Magnesium concentrations in waters investigated.

Stream	Mg++ppm	Date	Mg++ppm	Date	Mg++ppm	Date
Tees, Moorhouse			.8	7 July	1	3 Aug.
Waskerley					5.5	3 Aug.
Wear, Wolsingham					10	3 Aug.
Wear, Wearhead			5	7 July		
Quarry, Wearhead			2.5	"		
Wear, Witton					10	22 Aug.
Wear above Gaunless			9.2	15 July	12	21 Aug.
Brancepeth	29	8 June	14	9 July	18	11 Aug.
Saltwell	12	4 June			21	4 Aug.
Wear, Stanhope			6.5	7 July		
Browney	21	29 May	20	30 June	24	30 July.
Holywell	22	15 June	13	11 July	38	10 Aug.
Wear below Gaunless			21	15 July	26	30 Aug.
Deerness Tributary						
Wear, Croxdale	31	30 May	25	2 July	30	4 July.
Deerness	52	9 June	52	8 July	45	9 Aug.
Gaunless			90	17 July	96	16 Aug.
Croxdale Beck	86	27 May	76	27 June	74	28 July.
Whitewell	27	21 May	40	14 July	52	24 Aug.
Nickynack	210	30 May			150	4 July.
Goats Burn					170	11 Aug.
Wear, Durham	27	24 May	23	24 June	20	26 July.
Wear, Croxdale soil Water					36	26 July.

Table 44.

Total resistance and p^H of the waters investigated.

Stream	Date	p^H	Resist ( )	Date	p^H	Resist ( )	Date	p^H	Resist ( )
Wear, Durham	21 May	8.3		24 June	8.5	214	26 Jly	8.3	262
Croxdale Beck	27 May	8.8		27 "	8.0	132	28 "	7.8	200
Browney	29 May	8.3		30 "	7.8	270	30 "	8.3	
Deerness	3 Jne	8.6		8 Jly	8.6		9 Aug	6.9	
Brancepeth	8 Jne	8.4		9 Jly	7.6	360			
Wear: Croxdale	7 Jne	8.6		2 "	8.2	288	3 "	7.8	
Holywell	15 "	7.8		11 "	7.6	725	10 "	7.9	
Moorhouse				7 "	6.9	1900			
Wear, Wearhead				7 "	8.1	918			
Quarry				7 "	8.7	990			
Stanhope				7 "	8.2	1145			
Whitewell				14 "	7.6	260	24 "	7.9	
Wear above Gaunless				15 "	8.7	440	21 "	8.4	
Wear below Gaunless				15 "	8.7	360			
Gaunless				17 "	8.2	200	16 "	8.2	
Waskerley							2 "	7.5	
Wear, Wolsingham							2 "	7.4	
Wear, Croxdale pool							5 "	8.1	
Witton le Wear							22 "	8.1	

All except three of the sites examined had mean pH values between 7.8 and 8.2. pH therefore does not seem likely to have had a great effect on leech populations.

The range of calcium content within which a species occurs, and the percentage of streams within the range where it is present, are shown in table 45. Leechless streams are not included in this table.

Table 45

Species	Range of mean Ca^{++} concentration within which species is found	% of streams within range where species is present
H. stagnalis	30 - 77 p.p.m.	100
G. complanata	14 - 114 p.p.m.	92
E. octoculata	35 - 77 p.p.m.	57
I. bykowskii	49 - 91 p.p.m.	67
H. sanguisuga	35 - 60 p.p.m.	60

The calcium and magnesium concentrations, and the presence of possibly toxic substances in the leechless streams, are shown in table 46.

Tucker (1958) relates the populations of leeches and other invertebrates to calcium concentration.

Table 46. Chemical Properties of leechless streams.

Name of stream.	Mean Mg^{++} concentration	Mean Ca^{++} concentration	Poisonous organic or other substances present.
Upper Tees	.9 p.p.m.	9.5 p.p.m.	Peat effluents
Upper Wear	3.8 p.p.m.	35.0 p.p.m.	" "
Saltwell Gill	16.5 p.p.m.	45.3 p.p.m.	Treated sewage
Nickynack Beck	180.0 p.p.m.	133.5 p.p.m.	Treated sewage. Coal wastes.
Goat's Burn	170.0 p.p.m.	190.0 p.p.m.	Coal wastes. Detergents.

The range of calcium concentrations at which he found *H. stagnalis*, *G. complanata*, and *E. octoculata* is given in table 47.

Table 47

Species	Range of mean Ca^{++} concentrations within which the species was found (p.p.m.)	% of sites within the range where the species is found
H. stagnalis	8 - 88	90
G. complanata	15 - 45	50
E. octoculata	10 - 88	66.7

Only ponds containing leeches were considered in table 47. Both species of Trocheta were absent while *H. sanguisuga* was present in only one pond.

The relationship between the mean calcium concentration and the presence of leeches and numbers of leech species present is shown in table 48.

Table 48

	Ponds with less than 20 p.p.m. Ca^{++}	Ponds with more than 20 p.p.m. Ca^{++}
% of ponds with leeches	45	100
Number of leech species per pond	1, 1, 1, 2, 5	3, 4, 4, 5, 8

Only one pond lacked *H. stagnalis*.

Two other workers (Mann, 1955), Bennike, 1943), relate the numbers of leeches to the total alkalinity. Total alkalinity can be defined as the total concentration of weak acid ions. It is measured by titration with .02 N sulphuric acid, using methyl orange as an indicator. Thus, though it is related to the total anion concentration, it is inevitably lower.

Total alkalinity was expressed by Bennike as the number of parts per million of CaO equivalent to the amount of acid used; by Mann as the number of p.p.m. of $CaCO_3$ equivalent to the amount of acid used; and by Tucker as the number of p.p.m. of Ca^{++} equivalent to the amount of acid used. The latter form has been used throughout the present work, and all figures have been adjusted accordingly.

The relationship between calcium concentration and total alkalinity in the ponds examined by Tucker is shown in figure 23. 94% of the readings lie between the two lines. Mann (1955) investigated 11 streams in the Lake District and Berkshire, with total alkalinities varying from 3 to 112 p.p.m. The number of leeches found per hour, the total alkalinity, and the rate of flow, are given in table 49. The rates of flow are not defined in the article, but probably do not correspond to those used in the present work.

Table 49. Leech Populations of Rivers investigated by K.H.Mann (1955).

Speed of stream	Total Alkalinity (p.p.m).	Numbers caught per hour of : Helobdella stagnalis	Glossiphonia complanata	Hemiclepsis marginata	Theromyzon tesselatum	Piscicola geometra	Erpobdella octoculata	Erpobdella testacea	Haemopis sanguisuga
Fast	3	0	1	0	0	3	16	0	0
"	5	1	5	0	0	0	11	0	0
"	8	2	0	0	0	0	34	0	0
"	10	2	4	0	0	0	104	0	0
"	31	3	3	0	0	0	46	0	0
Slow	38	10	1	0	0	1	2	4	0
Fast	52	4	4	0	0	0	84	12	0
Very slow	52	30	0	2	0	0	2	0	64
Moderate	74	18	2	4	0	0	18	0	0
"	97	0	86	0	5	4	31	0	0
Very slow	112	0	11	0	0	0	15	2	0

Figure 23. Relationship between total alkalinity and calcium concentration, based on Tucker (1958).

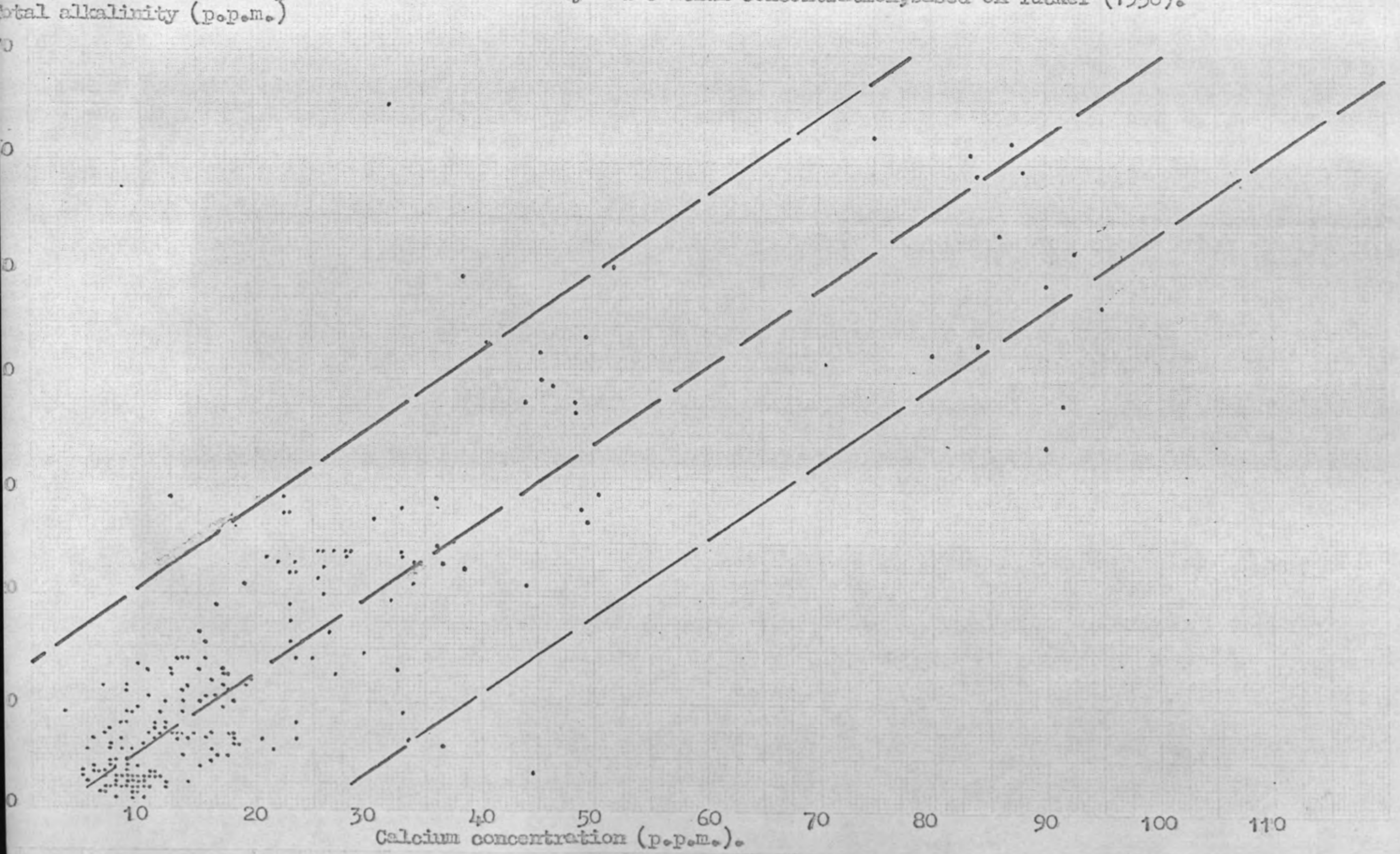
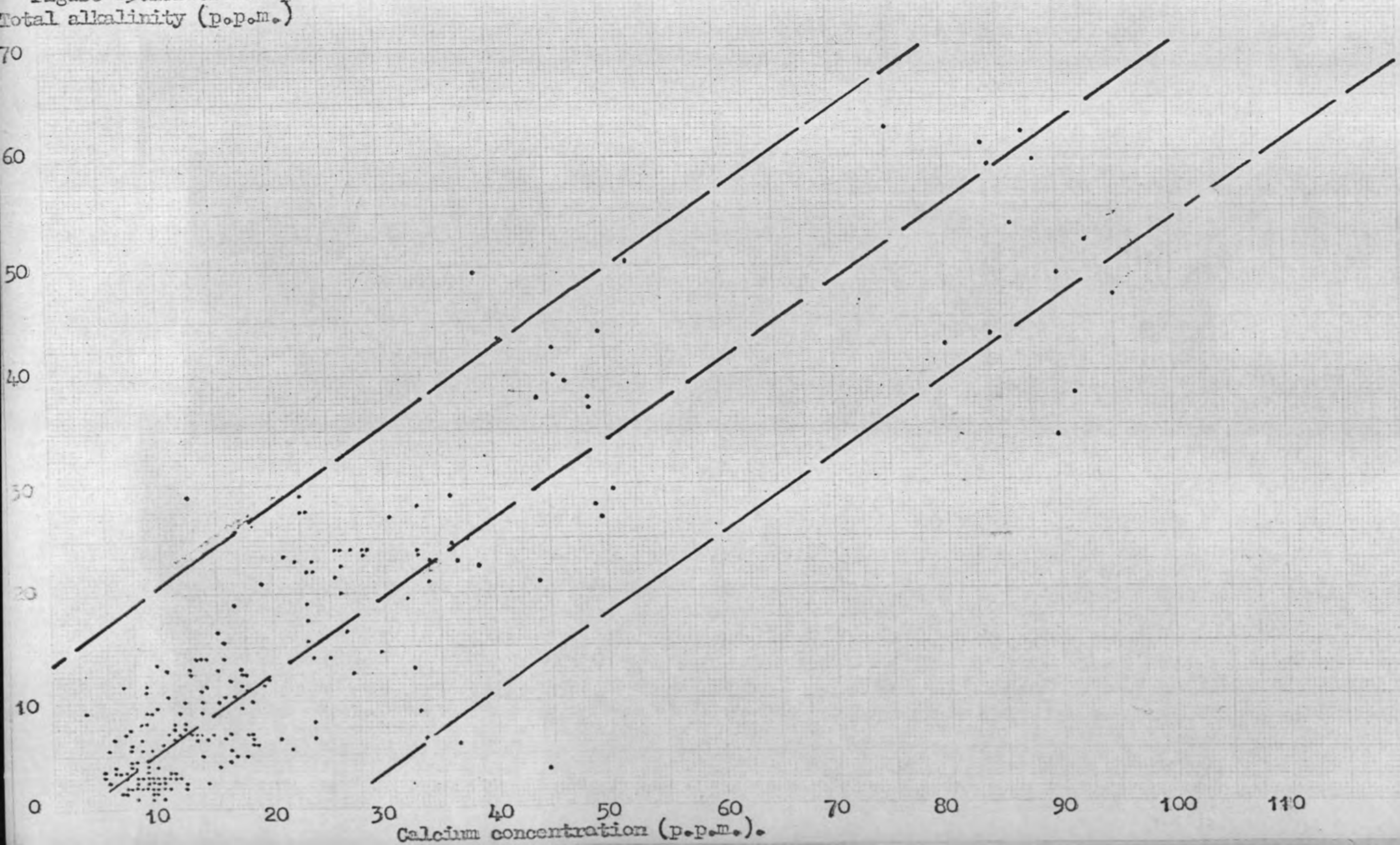


Figure 23. Relationship between total alkalinity and calcium concentration, based on Tucker (1958).



Mann also examined 47 lakes or ponds. The results are summarized in table 50. It is worth noting that _H. stagnalis_ was not found in any body of water with more than 96 p.p.m. total alkalinity.

The three most eutrophic sites examined by Mann were a stream and a pond with total alkalinities of 97 p.p.m. and a stream with 112 p.p.m. total alkalinity. If the relationship between total alkalinity and calcium concentration based on Tucker (1958) is valid, then the calcium concentrations in these waters are probably 113 to 172 p.p.m. and 132 to 195 p.p.m. respectively.

The relationship between the total alkalinity and the number of leech species present (based on Bennike, 1943 and Mann, 1955) is shown in table 51.

Table 52 shows the maximum and minimum calcium and magnesium concentrations at which various leech species have been found. The figures for _T. bykowskii_ are based entirely on the present work.

Two figures are given for calcium. The upper one is an approximation, derived from the figures for total alkalinity given by Mann (1955); the lower one is the highest or lowest figure found in the present work and Tucker (1958).

Table 50. Relationship between total alkalinity and leech population in lakes, based on Mann, 1955.

Range of total alkalinity		*Helobdella stagnalis*	*Glossiphonia complanata*	*Erpobdella octoculata*	*Haemopis sanguisuga*
3-7 p.p.m.	% of lakes where species is :				
	present	58	58	83	33
	dominant	0	0	83	
8-24 p.p.m.	% of lakes where species is :				
	present	68	42	47	37
	dominant	37	5	16	
24-100 p.p.m.	% of lakes where species is :				
	present	94	63	88	6
	dominant	75	6	6	

Table 51. Relationship between the number of leech species in ponds on lakes and the total alkalinity.

Source of information.		Range of total alkalinity. 0 - 10 ppm	10 - 100 ppm
Bennike 1943	Number of leech species present	9	10
	% of ponds on lakes without leeches	33.3	0
	Mean number of leech species per leech - bearing pond.	3.0	6.3
Mann 1955	Number of leech species present.	11	12
	% of ponds on lakes without leeches	16.0	0
	Mean number of leech species per leech bearing pond.	3.6	4.7

Table 52. Range of Ca^{++}, Mg^{++}, total alkalinity and p^H tolerated by various leech species.

	Ca^{++} (p.p.m)		Mg^{++} (p.p.m)		total alkalinity (p.p.m)		p^H	
	minimum	maximum	minimum	maximum	minimum	maximum	minimum	maximum
<u>H.stagnalis</u>	<3 (8.6)	112-169 (88.3)	1.5	93.0	3.3	96	6.4	9.6
<u>G.complanata</u>	<3 (14.5)	132-195 (114.3)	2.1	93.0	6.5	112	6.8	9. 4
<u>E.octoculata</u>	<3 (10.2)	132-195 (88.3)	1.9	93.0	3.3	112	6.4	9.6
<u>T.bykowskii</u>	49.3	90.9	21.7	75.3	Not measured			
<u>H.sanguisuga</u>	<3 (35.0)	76-123 (60.0)	3.1	25.4	4.0	67	6.9	8.5

Trocheta bykowskii and Erpobdella octoculate seem not to exist together. T. bykowskii is found in four streams, E. octoculata in three. In the Wear, E. octoculata was found exclusively in the river bed below the water level, T. bykowskii was almost always found in the shingle bank above the water level. No specimens of T. bykowskii were found in the shingle bank after it was covered by water (Wear, Frankland's Farm, 27th August). In the other rivers T. bykowskii lives both in the bed and in the banks. Competition with E. octoculata is not a likely explanation for the absence of T. bykowskii from the bed of the Wear, since the elimination of a species would certainly take more than a month. The most likely explanation is that the specimens of T. bykowskii moved upwards in response to some chemical factor in the water.

From the report of the Wear and Tees River Board (1965) it was found that Croxdale Beck, and the Browney below its confluence with the Deerness (Trocheta bearing rivers), have a consistently higher chloride content and biological oxygen demand than the Wear or Gaunless. This is shown in table 53.

Table 53

River	Mean Cl^-.	Mean B.O.D.
Wear above Gaunless	14 p.p.m.	1.3
Gaunless	26 p.p.m.	1.8
Wear below Gaunless to Durham	16 - 26 p.p.m.	1.5 - 4.1
Browney & Deerness	47 p.p.m.	7.4
Croxdale Beck	207 p.p.m.	5.5

Bennike (1943) investigated five *Sphagnum* bogs with total alkalinities of 0 - 5 p.p.m. and 13 marshes with 15 - 100 p.p.m. total alkalinity. (Marshes may be defined as having higher total alkalinities than *Sphagnum* bogs, and a vegetation not dominated by *Sphagnum*).

Leeches were present in all the marshes, but absent from all the *Sphagnum* bogs.

Herten (1937) states that water containing dissolved substances from peat is poisonous to leeches, and that *Helobdella stagnalis* is more resistant to this form of poisoning than *Erpobdella octoculata*.

It was thought that *Trocheta bykowskii* might be absent from the bed of the river Wear because of higher sensitivity to peat effluents than *E. octoculata* and *G. complanata*.

To test this hypothesis, the following experiment was carried out:

8 specimens of _G. complanata_, 47 specimens of _E. octoculata_, and 11 specimens of _T. bykowskii_ were put into water from a moorland stream which completely lacks leeches. The water was replaced every day.

At the end of five days all were alive, and appeared perfectly healthy.

A stronger solution of peat effluent was made by soaking some peat in water from the same stream for 12 hours and filtering the resultant solution.

The immediate reactions to immersion in this solution were:

G. complanata. The suckers failed to hold on to the glass. The animals continued to make unsuccessful crawling movements, flexing and straightening their bodies.

E. octoculata. The animals lost the power to grip the substrate. Most of them made very rapid, convulsive swimming movements, which lasted up to 30 minutes. A few of the larger specimens managed to attach the rear sucker, after a few minutes, but could not attach the front one.

T. bykowskii. The animals lost the power to grip with their suckers. Most made convulsive swimming at first; after 5 - 10 minutes this stopped. Many small pieces of grit stuck to their bodies, possibly due to some disturbance of the slime glands.

Death was presumed to occur when the animal no longer moved spontaneously or responded to touch. The animals may in fact have been moribund well before this stage was reached.

The time taken for the leeches to die is shown in figure 24. The relationship between the individual weight and the length of survival is shown in figure 25.

Figure 24. Survival of leeches in water containing peat effluents.

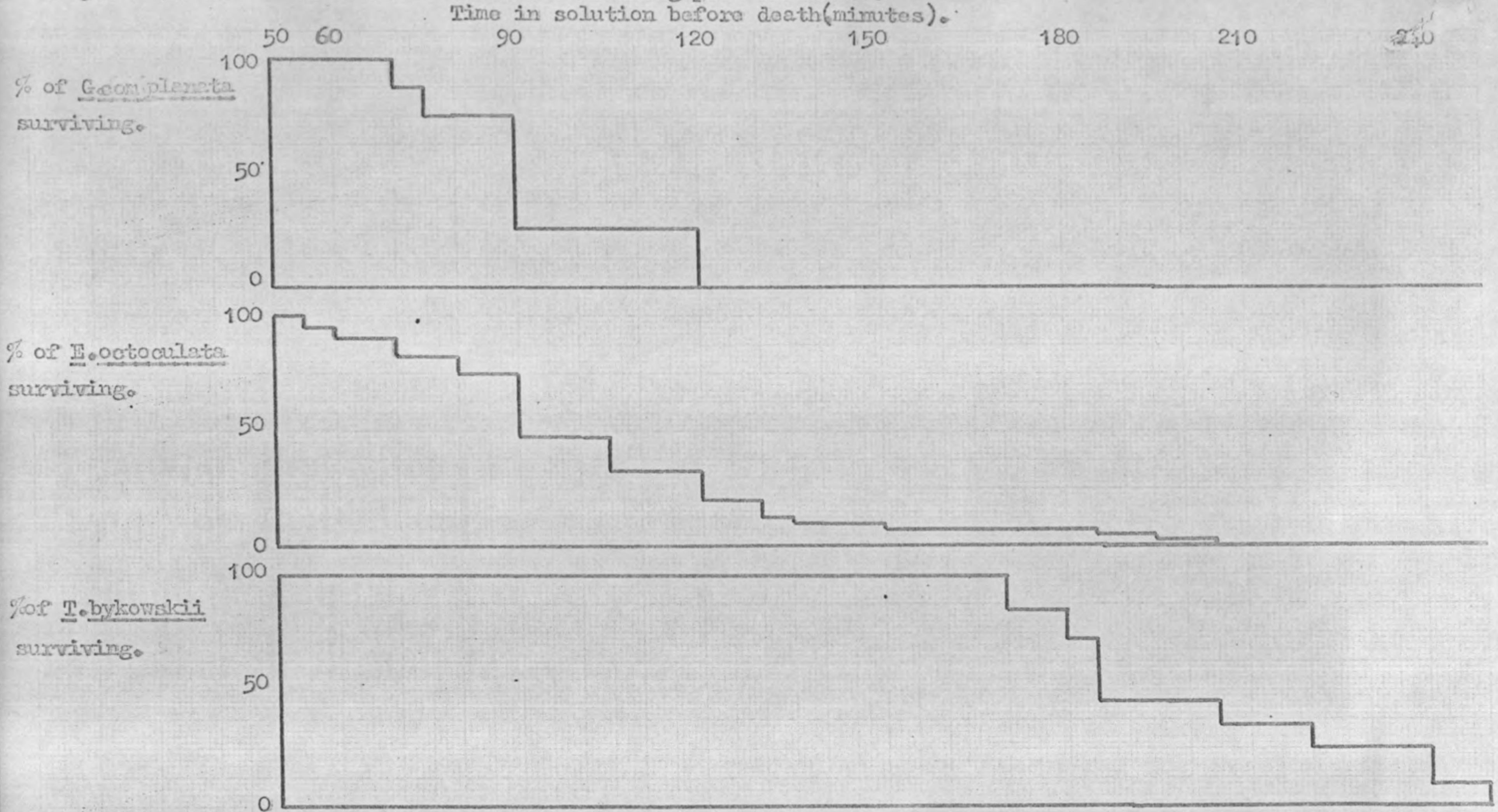
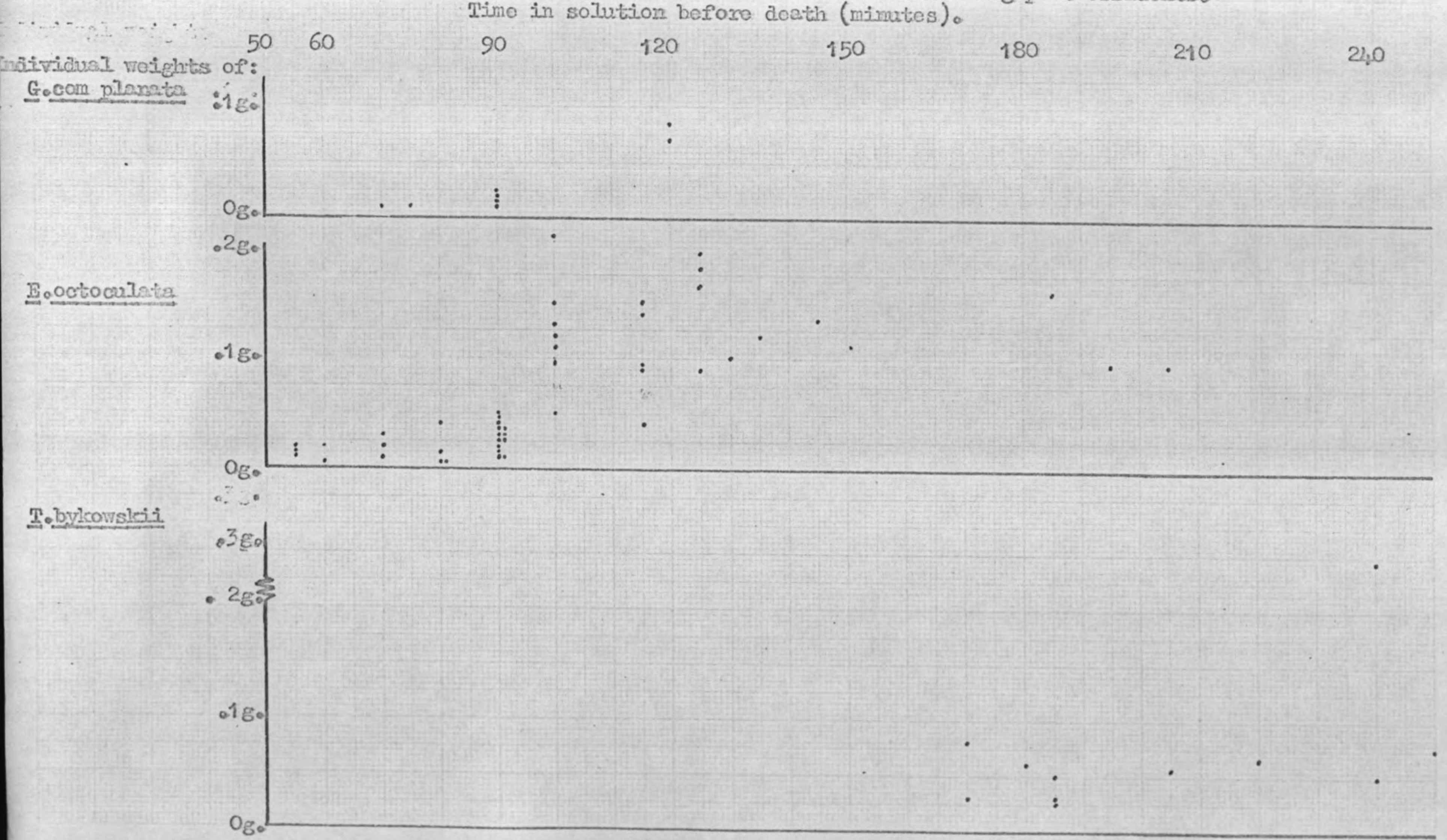


Figure 25. Relationship between weight and length of survival in water containing peat effluents.



FEEDING HABITS

The gut contents of 20 specimens of Trocheta bykowskii were examined under the microscope. It was found that:

10 contained setae of small oligochaets (mainly Naidae)

3 contained chironomids

3 contained terrestrial cyclorrhaphous larvae

2 contained ostracods

1 contained insect tracheae

1 contained legs of a probably terrestrial insect

1 contained large setae, probably from a lumbricid

All contained a considerable amount of grit and amorphous matter; many contained live or dead algal unicells.

Table 54 shows the feeding habits of the leeches found in the river Wear and its tributaries. It is based partly on observations, partly on Herter 1937 and Mann 1962. Several details are not given in the table. For instance, only the young of G. complanata (weighing less than .0050gm) attack E. octoculata, T. bykowskii and E. octoculata, when they feed on large oligochaets, attack only immature specimens, or dead or injured adults.

Table 54. Feeding habits of the leeches found.

	Prey									
	Molluscs	Oligochaets small	Oligochaets large	Erpobdella	Trocheta	Ostracods	Copepods	Asellus	Insect larvae	Birds
Leeches:										
<u>Helobdella stagnalis</u>	*	-	-	o	o	-	-	*	*	o
<u>Glossiphonia complanata</u>	*	-	-	*	o	-	-	-	*	o
<u>Theromyzon tesselatum</u>	o	o	o	o	o	o	o	o	o	*
<u>Erpobdella octoculata</u>	o	*	*	o	-	-	-	-	*	o
<u>Trocheta bykowskii</u>	o	*	*	-	-	*	*	-	*	o
<u>Trocheta subviridis</u>	-	*	*	-	-	-	-	-	*	o
<u>Haemopis sanguisuga</u>	-	*	*	*	*	-	-	-	*	o

* = leech is known to prey on this animal.

\- = it is not known whether the leech preys on this animal.

o = leech probably or definitely does not prey on this animal.

Phoresy

It was observed that the young of <u>Helobdella stagnalis</u> have a strong tendency to attach themselves to other leeches. In one sample, 111 out of 148 specimens of <u>H. stagnalis</u> weighing less than .0020 gm had attached themselves to the lower surface of 10 specimens of <u>Glossiphonia complanata</u>. Six had attached themselves to seven specimens of <u>Trocheta bykowskii</u>.

To test the possibility of one form of phoresy, groups of 10 young <u>Helobdella stagnalis</u>, 10 young <u>Glossiphonia complanata</u>, and 3 young <u>Batracobdella paludosa</u> were each put into a glass container, diameter 6", containing a large specimen of <u>Theromyzon tesselatum</u>. The following reactions were observed:

<u>H. stagnalis</u>. All had attached themselves to the ventral surface of the <u>Theromyzon</u> within four hours. They were attached by the near sucker, and did not appear to be feeding on the <u>T. tesselatum</u>.

<u>G. complanata</u> showed no response to <u>T. tesselatum</u>.

<u>Batracobdella paludosa</u>. These attached themselves by the anterior sucker to the edge of the dorsal surface of the <u>T. tesselatum</u> within two days. They appeared to be feeding on it.

<u>Glossiphonia complanata</u> has been observed attached to the legs or feathers of aquatic birds (Herten). I have often found that up to ten specimens had attached themselves to my feet while I was collecting.

I observed no tendency towards phoresy in any other species.

According to Herter, leeches or their cocoons may be carried accidentally along with algae and debris by birds and mammals.

DISCUSSION

The following aspects of the present work are discussed:

i. The influence of other animals on leeches.

ii. The influence of chemical factors on leeches.

iii. The influence of the nature of the substrate on leeches.

iv. The ability of leeches to disperse themselves.

v. The methods used in the present work.

vi. Possible future research suggested by the present work.

i. Influence of other animals on leeches

From table 54 it can be seen that all the species found, except *Theromyzon tesselatum* eat a fairly wide range of prey. Almost all the sites examined were found to have large populations of snails, insect larvae, and oligochaets. These sites are therefore able to support any of the species found, except possibly *T. tesselatum*.

The main exception is Croxdale Beck, which has comparatively few snails. In spite of this it supports a population of *Glossiphonia complanata*. It was therefore concluded that the distribution in the streams examined is not caused by the presence or absence of suitable prey.

Mann (1959) states that T. bykowskii is unable to establish itself where Haemopis sanguisuga is present. This seems unlikely, in view of the fact that both species were associated in quite large numbers in a shingle bank in the Wear at Frankland's Farm, Durham.

ii. Effects of Chemical factors on leeches

From the results of the present work it appears that Glossiphonia complanata is the most widespread species, and tolerates the widest range of Ca^{++} concentrations. The other species appear to tolerate only a relatively narrow range of Calcium concentrations (see table 45, figure 20).

This result differs from the observations of Tucker (1958) who found that H. stagnalis and E. octoculata occurred at calcium concentrations much higher and lower than the apparent upper and lower limits found in this work (see table 46).

K.H. Mann (1955) gives total alkalinity, not calcium concentration. If the relationship between total alkalinity and calcium concentration given by Tucker (1958) is valid (see figure 23), G. complanata and E. octoculata occur in waters which vary from an extremely low to an extremely high calcium concentration. Though extremely high or low concentrations of calcium may affect these species, there is in spite of the results of the present work no sign that calcium may be a limiting factor in nature. _Helobdella stagnalis_, on the other hand, is absent from the two tributaries of the Wear with the highest calcium concentrations, and from the three bodies of water investigated by Mann (1955) with the highest total alkalinities. It is possible that high calcium concentrations are a limiting factor for _H. stagnalis_. The level at which calcium becomes limiting might itself be affected by other factors. _T. bykowskii_ may occur only within a fairly narrow range of calcium concentrations (49 - 91 p.p.m.), but it was not possible to confirm this by reference to other work. It was only found in waters with a low total resistivity (less than 300 (see figure 22), i.e. with a high concentration of dissolved ions.

Bennike (1943) and Mann (1955) found that _Haemopia sanguisuga_ appears not to occur above calcium concentrations of c. 76 - 123 p.p.m., and total alkalinities of c. 70 p.p.m. (see table 52).

There seems to be little difference in the minimum total alkalinities on calcium concentrations tolerated by _H. stagnalis_, _G. complanata_, _E. octoculata_, and _H. sanguisuga_.

Tucker (1958) determined the magnesium contents of the ponds investigated. His results seem very low, ranging from .2 to 6.8 p.p.m., while those of the present work range from .8 to 210 p.p.m. Only 17% of the streams found in the present work to contain leeches had magnesium concentrations within the range found by Tucker. There is no evidence that magnesium concentrations influenced the leech populations.

Of the leechless streams found in the present work, two are rivers draining off moorlands, thus containing peat effluents; three are small streams polluted by sewage, coal wastes, or detergents (see table 46). It is thus quite likely that the absence of leeches is not due to the calcium and magnesium concentrations present.

The frequent absence of leeches from waters with low calcium concentrations or total alkalinities (see tables 48 & 51) may be because such waters are often found in moorlands, and therefore contain peat effluents.

The upper reaches of the Wear, draining off moorlands, lack leeches. Helobdella stagnalis is found in large numbers higher up the Wear (Witton-le-Wear) than any other species. This is probably due to its greater tolerance of peat effluents.

It was thought that T. bykowskii might be absent from the bed of the Wear because of the effects of peat effluents. The experiment with peat waters, however, showed that Trocheta bykowskii is in fact less sensitive to water containing peat effluent than either E. octoculata or G. complanata. Specimens of G. complanata and E. octoculata of equal weight were roughly equally sensitive. The specimens of G. complanata did in fact die sooner because of their smaller size. The experiment was not entirely satisfactory, since the smallest, and therefore presumably most sensitive, stages were not available.

It is stated (p.75) that Trocheta bykowskii is probably absent from the beds of the Wear and Gaunless because of some chemical factor. These rivers have consistently lower chloride concentrations and biological oxygen demands than the rivers with T. bykowskii in their beds (see table 53). However, the Wear and Tees Water Board quoted about 25 different chemical and physical factors for each river that they examined. The fact that these two factors were consistently higher for rivers with T. bykowskii in their beds is therefore not statistically significant. No conclusions should be drawn from table 49 unless the results are confirmed by other work.

iii. Effects of Substrate

The relationship between the numbers of leeches per square yard and the nature of the substrate is given in figures 12 & 13; the relationship between the percentage each species forms of the leech population, and the nature of the substrate, is given in tables 38 & 39.

The various species found appear to show the following substrate preferences:

Helobdella stagnalis.

In every river where this species occurs, it is commonest on stony substrates with a slow current, where it may exist in very large numbers. It is much less common among reeds, and is completely absent from mud, and from shingle banks above the water level.

The population density and the percentage of H. stagnalis in the total leech population both decrease rapidly in areas with a moderate current. This is shown in the river Wear where mean population in stony areas of slow current vary from 80 to 332 per square yard (51 - 78% of the total leech population), which in areas of moderate flow means populations vary from 0 to 3.3 per square yard (0 - 18% of the total leech population). This decrease is also confirmed by Mann's results as shown in table 49. This shows that, of the rivers with less than 80 p.p.m. total alkalinity, three were described as "very slow" to "moderate"; the remaining six were described as "fast". In all the "fast" rivers, H. stagnalis is absent, or present in very low numbers; in the "slow" and "very slow" rivers it is the commonest species; in the one "moderate" river it occurs in equal numbers to E. octoculata.

Populations of H. stagnalis vary greatly within apparently uniform areas. The clearest examples of this are shown in table 40. In the river Browney, areas 6 - 8 which had been disturbed by previous sampling had a mean population of 69.4 H. stagnalis per square yard, while areas 9 - 15 which had not been disturbed had a mean population of 22.1 H. stagnalis per square yard.

After an area has been examined it is impossible to replace all the stones exactly. The crevices between the stones and the underlying mud will therefore be wider than before. H. stagnalis was never found on those surfaces of stones which were actually touching the mud, and appears to be unable to burrow into the mud. Widening the gaps between the stones and mud would therefore make more space available for this species. The numbers of this species are probably to a large extent determined by the degree to which the crevices between the stones are filled by mud. This factor is difficult to measure exactly. It may, however, be significant that four of the areas with very large populations of H. stagnalis (Gaunless, 29th August, Wear, Frankland's Farm, Wear below Gaunless, Bishop Auckland, and the Quarry at Wearhead) had largely artificial substrates, including much broken brick and slate. Such areas might tend to have high populations of H. stagnalis until the crevices are silted up.

Glossiphonia complanata is commonest on stones in areas of slow current. In the river Wear it forms only 7 - 28%

of the total leech population on this substrate because of the presence of very large numbers of H. stagnalis and E. octoculata. In other rivers it occurs in roughly similar numbers, but usually forms a larger proportion of the population on this type of substrate. It is also fairly common on reeds.

G. complanata becomes less common as the current increases. The density decreases less rapidly than that of H. stagnalis and E. octoculata, so that it forms a higher proportion of the total leech population in regions with a moderate current. Thus in four out of six groups of samples from regions of moderate current from the river Wear G. complanata forms 30 - 43% of the population.

G. complanata does not show as much variation within an apparently uniform substrate as H. stagnalis or T. bykowskii (see table 40). It appears to respond to differences in substrate less than other species.

A few specimens of G. complanata were found on sticks among the mud of the Wear, or in the edge of the shingle banks in Croxdale Beck. These few can be considered as strays from nearby reeds.

G. complanata is practically confined to solid substrates beneath the surface of the water.

Erpobdella octoculata

This species is commonest on stony substrates with a slow current, and among reeds. On the stones in slow parts of the Wear it has mean densities of 23 - 81 per square yard (14 - 34% of the total leech population). The numbers on reeds are approximately similar (47 - 90 per square yard), but this species forms 48 - 80% of the total leech population because of the scarcity of H. stagnalis.

The populations of Erpobdella octoculata are lower in areas with a faster current (5 - 44 per square yard). This decrease is slower than that of H. stagnalis so that it tends to form a larger proportion (44 - 84%) of the total leech population. This tendency is shown in Mann's results (Table 49). In the two slow flowing streams with less than 80 p.p.m. total alkalinity E. octoculata forms only a small percentage of the total leech population; in the seven remaining streams it is dominant, or co-dominant. Unlike the Wear, there seems to be a decrease in actual numbers of E. octoculata in the slow streams.

Both the numbers of E. octoculata and the percentage it forms of the total leech population taken from the Wear at Croxdale on 30th April and 4th June are much higher than those of the areas sampled on 4th July and 6th August. The areas sampled on the latter two dates appear to have been less sheltered from the current than those sampled on 30th April and 1st June. It is possible that the lower proportion of E. octoculata and the higher proportion of G. complanata on 4th July and 6th August were due to E. octoculata being less resistant to current than G. complanata.

The extremely low numbers and proportions of E. octoculata in areas with a moderate current above the confluence with the Gaunless may be due to the combined effects of current and predation by Trocheta subviridis.

E. octoculata is almost never found above the water level. It seems to be the only species found that can live in mud without any firm substrate.

Trocheta bykowskii

Most specimens of T. bykowskii were found in well marked burrows under stones. In the river Wear almost all the specimens were found in an exposed shingle bank; in Croxdale Beck and the river Deerness the highest numbers were found in shingle banks, or in stony parts of the river bank. It thus seems that T. bykowskii is most common in stony soil (the interstices in the shingle banks were all filled with soil) at or just above the level of the water table. It is also quite common on river beds consisting of loose stones, as in the Deerness and Browney. It is not known how far T. bykowskii penetrates into river banks. It shows a definite tendency to accumulate under large flat stones (see tables 24 & 30).

Like those of H. stagnalis, populations of T. bykowskii may vary greatly within an apparently uniform substrate, as can be seen from the samples from the river Deerness on September 3rd - 5th (see table 40).

Trocheta subviridus

This species was found in fairly large numbers in the parts of the Wear with a moderate current above the Gaunless at Bishop Auckland.

According to Herter (1937) there are two "ecological races" of this species. One lives in fast mountain streams and is confined to the water, the other lives in stagnant or sluggish and often polluted waters, and is amphibious. The specimens from Bishop Auckland were of the former type.

It is noteworthy that not one specimen of T. subviridus was found in the slow flowing parts of the Wear at Bishop Auckland.

Specimens of T. subviridis were also found near or in a small pool sheltered from the main body of the river Wear at Croxdale. During the winter when the river is higher this pool is joined to the river. They are thus living in a completely different habitat from those found at Bishop Auckland. The single adult specimen found here also differed in appearance, being yellow, not green like those at Bishop Auckland. The population profiles (c.f. figure 2 and figure 8) are also completely different.

<u>Haemopis</u> <u>sanguisuga</u> seems to be commonest among reeds and in stony banks just above water level. Occasional specimens were found in stony parts of the river bed.

The difference between the results obtained by K.H. Mann (1955) and those of the present work when comparing leech faunas of stones and reeds (see table 41) may be due to three possible factors:

i. The reed beds examined by Mann may not have consisted of <u>Sparganium</u> <u>erecta</u>.

ii. The reed beds examined by Mann were in still, not flowing, water.

iii. The reed beds examined by Mann may have been on a stony, not a muddy, substrate. The aerial shoots of <u>S</u>. <u>erecta</u> die down during the winter. Since there are no stones near these reed beds, the leeches would have to burrow in the mud among the rhiyomes of <u>S</u>. <u>erecta</u>. If, as has been suggested, <u>H</u>. <u>stagnalis</u> has no ability to burrow in mud, then almost the whole population would be exterminated during the winter. <u>E</u>. <u>octoculata</u>, on the other hand, can survive in mud without any solid substrate. Its numbers would therefore not be so drastically reduced when the reeds die down in the autumn.

If the reed beds examined by Mann were on a stony substrate, then a far higher proportion of the <u>H</u>. <u>stagnalis</u> population would survive the winter.

Dispersal

Glossiphonia complanata or *Helobdella stagnalis* were present at every site where leeches were found. This includes four sites which are isolated from leech bearing waters; Waskerley Beck and Cowshill Quarry, which drain into leechless stretches of the river Wear, Crossthwaite Beck, draining into a leechless stretch of the upper Tees, and the cow pond at the Cock of the North, Durham, which has neither inflow nor outflow. The specimens of *G. complanata* found in the upper parts of Brancepeth and Whitewell Beck can also be described as isolated since this species cannot be expected to crawl upstream from the heavily populated areas, over an unstable clay substrate.

One possible explanation of the presence of leeches in such isolated places is phoresy.

The experiment with *Theromyzon tesselatum* (Results, part 5) was carried out because *T. tesselatum* enters the nasal cavities and pharynx of birds, and sucks their blood. According to Herter, it usually spends 4 - 5 days in its host, and emerges while the bird is drinking. If young specimens of *H. stagnalis* and *B. paludosa* are carried in this way, the chances of being returned to the water would be great, the chances of dessication would be slight, and the distance over which they would be carried might be considerable.

From the experiment it seems very likely that these two species are carried by *T. tesselatum*, though further experiments would be needed to prove it.

G. complanata and *H. stagnalis* may be present in isolated sites because they have greater powers of dispersal by phoresy than the erpobdellids or *Haemopis*.

Methods

Animal numbers are estimated by two main methods; marking and recapture; and direct counting of individuals. The first method was not applicable here. Leeches are moist skinned animals, and therefore difficult to mark. They are slow moving animals and would take a long time to randomize.

It was therefore decided in the present work to estimate the density from samples of the population. This has been done either by noting the number of individuals caught within a given period, or the number caught within a given area.

The first method has been much used, e.g. Mann 1955. It was not used in the present work for the following reasons:

i. Areas with a moderate current tend to have small leech populations living on a substrate of large stones. Areas with a slow current tend to have a large leech population living on a substrate of small stones. The population of a given area with a slow current would therefore be counted much more slowly than that of an equal area with a moderate current. The differences between the two types of substrate would therefore be underestimated.

ii. There may be considerable differences between the speeds of different workers. There may also be great differences in the speed at which one individual works on different occasions; for instance a person will work more clumsily and therefore more slowly when his hands are cold.

iii. If a population is described as numbers caught per unit time, then it is not possible to estimate the mean population of an area, or to make a comparison with animals caught by another method, e.g. dredging.

For this work, the choice had to be made between searching for leeches in a large number of small areas or in a small number of large areas. Since a stony river bed is a very irregular substrate, samples of an exact area or volume, like soil cores, cannot be taken. Supposing that, owing to these irregularities, the lengths of the sides of the quadrats examined may vary by as much as one inch, then the actual areas of foot square quadrats will be 11^2in to 13^2in. Thus the maximum quadrat will be 40% larger than the minimum. If the quadrat size is increased to 6 sq.ft., the difference is only 15%.

Leeches in general have a strong tendency to aggregate together. A small quadrat size would tend to give a large number of zero readings and very high values. It was thought that larger quadrat sizes would give samples with smaller variances relative to the mean, and a variability tending to approximate to a Poisson distribution.

A further difficulty about using small quadrats is that when the sand or mud beneath the stones is taken out for sieving, sand or mud flows into the area from outside. It is thus not known whether the leeches caught in the sieve were originally within the quadrat area or not. This source of inaccuracy is made less important by using large quadrats.

The ideal solution to the problem of quadrat size would of course be to use large numbers of large quadrats. It took an average of 1 - 1½ hours to examine each of the large quadrats which were used. It would be impossible to use twenty or more such quadrats at each site without greatly reducing the number of sites examined.

It was therefore decided to use small (5 - 10) numbers of large quadrats. Unfortunately, this means that the statistical results are often very vague. The upper 95% confidence limit for the mean, for instance, is often ten times larger than the lower limits. This means that only the most extreme differences between mean population densities at different sites can be shown to be statistically significant. If larger numbers of smaller areas were used, the confidence limits for the mean would be narrower, but would be based on less accurate samples.

The inaccuracy in one group of 20 - 30 samples is likely to be as great as that in another such group. The two groups of samples would therefore be statistically comparable. Thus using large numbers of small quadrats would probably give better results.

Proposals for future research

Two possible lines of research were suggested by the present work.

In general, animal populations are sampled from supposedly uniform substrates. The differences between quadrats are supposed to reflect tendencies of the animals towards aggregation on under-dispersal. It is quite likely, however, that most stony river beds are not uniform at all, and that the distribution of leeches is complicated both by their tendency to aggregate and by irregular differences in the substrate. The accuracy of the present work has been greatly decreased because it has not been possible to judge the nature of the substrate at all exactly.

A series of accurate measurements of factors within the substrate would therefore be very useful.

Possibly important factors include:

the speed of water over the surface of the substrate, and in the crevices between the stones;

the degree to which the crevices between the stones are filled by mud or sand;

the relative size of the stones in the substrate;

the proportions of mud, sand, and organic matter within the substrate;

the oxygen content of the water between the stones;

the presence of toxic substances, such as hydrogen sulphide, in the mud.

Though some of these factors might be hard to measure, they would probably give a clearer explanation of the variations in numbers of leeches.

The toxicity of peat effluents to leeches is not yet understood. It is not caused by either low pH or high organic content of the water. Presumably it is caused by some specific compound or compounds. These have not been identified. If these toxins could be identified and isolated, the susceptibilities of the various species could be compared exactly. It would also be possible to distinguish between the effects of low calcium or other anion concentrations and the effects of peat effluents.

CONCLUSIONS

i. None of the species appear to be limited by a shortage of prey.

ii. Calcium and peat effluents are the only chemical factors which were shown to influence the presence and species composition of leech populations.

Helobdella stagnalis and Haemopis sanguisuga seem to be unable to inhabit waters with high calcium concentrations. Helobdella stagnalis may be able to tolerate higher calcium concentrations (c.112-169 p.p.m.) than Haemopis sanguisuga (c.76-123 p.p.m.).

Helobdella stagnalis and Trocheta bykowskii are less susceptible to poisoning by peat effluents than Glossiphonia complanata and Erpobdella octoculata. For this reason, H. stagnalis is found higher up the river Wear than G. complanata or E. octoculata.

iii. In the rivers investigated:

H. stagnalis is commonest on stony areas with a slow current, where it may be the commonest species, and is rare on reeds or stony places with a moderate current.

G. complanata is commonest on stony areas with a slow current, and on reeds. It may be the commonest species on either of these substrates if large numbers of H. stagnalis and E. octoculata are not present. It is less common in stony areas with a moderate current.

E. octoculata is commonest in stony areas with a slow current, and among reeds, where it is the commonest species. It is less frequent in stony areas with a moderate current, but is the commonest species on this substrate, in the absence of *Trocheta subviridis*. *E. octoculata* is the only species found that inhabits mud without any solid substrate.

Trocheta bykowskii is commonest in stony river banks or shingle banks just above the water level. It is less common (in one case nearly absent) in stony river beds.

Trocheta subviridis was found in two very different habitats;

a stony area with moderate flow at Bishop Auckland.

a small pool, separated from the river by a shingle bank at Croxdale.

Haemopis sanguisuga is commonest among reeds (*Sparganium erecta*) and in stony parts of the river bank just above water level. It is occasionally found in the river bed.

iv. Phoresy may play an important part in the distribution of the Glossiphorids found. In the case of *H. stagnalis* and *Batracobdella paludosa* the "carrier" is *Theromyzon tesselatum*; in the case of *G. complanata*, the "carriers" are warm blooded vertebrates.

SUMMARY

Areas in the river Wear, some of its tributaries, and four nearby waters were searched for leeches. Mean densities and, where possible, confidence limits for the means were calculated. The calcium and magnesium contents, pH, and total resistivity were measured. These factors, and the nature of the substrate, were related to the densities of the leech populations.

Experiments were performed to test the possibility of phoresy occurring using Theromyzon tesselatum as a carrier and to find the relative survival times of H. stagnalis, E. octoculata and T. bykowskii in water containing peat effluents.

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