

The Distribution of Plecoptera and Ephemeroptera in a Lowland Region of Britain (Lincolnshire)

by

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INTRODUCTION

Most of the information concerning distribution and ecology of Plecoptera and Ephemeroptera in Britain, has come from studies of streams in hill and mountain regions, particularly Wales, (HYNES 1961), the English Lake District (See MACAN 1963 p. 20 for refs., GLEDHILL 1960), the Pennines (BROWN, CRAGG & CRISP 1964), Scotland (MORGAN & EGGLESHAW 1965a), and Dartmoor (ELLIOTT 1967).

Very little attention has been paid to the distribution of these insects in lowland regions, though isolated records have been published (HARRIS 1952, HYNES 1958, MACAN 1961). From August 1961 to February 1968, regular biological surveys of streams, rivers and pools in Lincolnshire were carried out, mainly to investigate the natural distribution of invertebrate animals and to assess the effects of polluting discharges on the composition of the invertebrate communities. In these surveys 7 species of Plecoptera (Langford 1964), and 15 species of Ephemeroptera (LANGFORD 1965) were recorded. Of these 22 species, 19 were new records for the region.

This paper describes the distribution and abundance of the species in relation to the topography and chemistry of Lincolnshire streams, rivers and pools, and the Plecoptera and Ephemeroptera faunas of the

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region are compared to those of the mountain regions. The topography and geology of Lincolnshire is described briefly. This paper is the first of a series dealing with the aquatic macro-invertebrate fauna of the region.

DESCRIPTION OF THE REGION

All the river systems and pools surveyed were within the area of the Lincolnshire River Authority as defined by the Water Resources Act (1963). This area (32,174 sq.Km) is somewhat less than that of the whole County of Lincolnshire (42,120 sq.Km.). The major geographical boundaries in the North, South, East and West are, The Humber, The Wash, The North Sea and the Trent watershed – respectively.

The topography and geology of the region were described by SWINNERTON & KENT (1949) and outlined by LANGFORD (1965). The basic characteristics are the very low relief and the soft, calcareous rocks and soils of the North Lincolnshire Wolds (chalk), limestone uplands, coastal plain and fen. The maximum altitude is approximately 182 m (550 ft) and the highest stream reaches to 125 m (375 ft) above Ordnance Datum (Newlyn) (O.D.N.). Much of the land in the coastal plain and fen is below mean tide level (O.D.N.) and protected from sea encroachment by extensive sea defences. This very low land is drained by a network of artificial drainage channels (drains), and water is pumped from these up to the main outfalls. All the major rivers are canalised, artificially maintained and impounded by sea-doors and sluices.

The main industry in the region is arable farming and large amounts of artificial fertilizers, herbicides and pesticides are used. Manufacturing industries are very localised, being mainly around Lincoln, Scunthorpe and Grimsby. The largest number of polluting discharges to rivers originate from small sewage disposal works (S.D.W.'s) and farm premises.

Climate

Lincolnshire has a low rainfall in comparison with the mountain regions. In 1962, 1963 and 1964, the standard averages were 50.2 cm, 55.0 cm and 44.0 cm, which were 84%, 92.7% and 73.4% of the national averages (FINN 1963). Highest rainfall occurs in the wolds and limestone uplands, while the lowest occurs in the eastern coastal plain. In contrast to the Lincolnshire maximum of 70 cm, rainfall in the Lake District reaches up to 508 cm, and in the Pennines to 178 cm.

STREAMS, RIVERS AND POOLS

Size and Topography

All the river systems surveyed are named and numbered in Table I and their locations shown in Fig. 1. (Stippled areas in figure 1 represent high ground. A is the chalk outcrop of the North Lincolnshire Wolds, B is the limestone upland area). The altitude of each stream source (in metres), the length of the watercourse, and the rocks in which the sources rise are also shown in Table I.

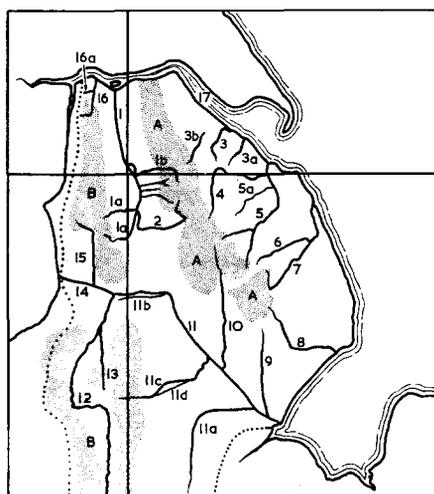


Fig. 1. Outline map of Lincolnshire, showing rivers and streams. (See Table I for names)

Most of the rivers and streams are less than 50 km long from source to outfall and spring sources are at altitudes from 33 m to 125 m above O.D.N. Some of the rivers have sources shown as less than 5 m altitude and in these, most of the water is from land drainage of the fen and alluvial plains. Bed levels at the outfall doors on all Lincolnshire rivers are below mean tide level and often bed levels some miles upstream of the doors are still below this.

Generally, all the river systems rise as very small springs which become grassy trickles on the chalk or limestone uplands. These merge and enlarge to form moderate to swift streams or becks, until they reach the alluvial plain where their character alters fairly sharply and they become long, uniform dredged channels with built up banks. Of the rivers surveyed, only one, the Hobhole Drain, receives

no water from upland areas but is fed entirely by drainage from the fen (Lincs R.B. Report 1965).

In the text, the word "stream" is used to describe the free-flowing upper reaches of river systems and "rivers or drains" to describe the uniform, deeper canalised reaches.

In the fastest becks, current velocities rarely exceed 67 cm/sec and gradients are never as steep as in mountain streams. The overall mean gradient on the River Rase, one of the faster streams, was calculated as $\pm 0.006\%$ from source to outfall, while Ford Wood Beck (MACAN 1957), had a gradient of $\pm 0.03\%$ and the Afon Hirnant (HYNES 1961), $\pm 4.2\%$. As in the mountain streams, the gradients on Lincolnshire becks are not uniform, and short riffles, alternate with slower, sandy reaches. Substrata were mainly coarse sand and only in the faster riffles were stones found in any numbers. The depth of water rarely exceeds 20 cm and in most streams is less than 10 cm.*

In the deeper, uniform drains and rivers, current velocities were much lower, being almost nil at times of drought. Gradients are slight for long distances. For example the overall mean gradient on the New River Ancholme was calculated as $\pm 0.0003\%$, over the first 32 km upstream of the outfall doors. In other drains, gradients are known to be less than this. In comparison, a reach of the Hirnant described by HYNES (1961) as "slowly meandering" had a bed gradient of $\pm 0.03\%$. During summer, and low flow periods, the "rivers" of Lincolnshire assume the general physical characteristics of elongated ponds, with depths from 1 m up to 4 m.

The substrata of the drains and rivers are either alluvium with small amounts of organic mud, clay overlaid with thick black organic mud, or in some cases, bare clay with little or no silt or mud. The basic substrata of each type of watercourse is shown in Table II.

The clear division between streams and rivers may appear oversimplified but, owing to the topography of the region, the placing of weirs and sluices and the dredging operations, there are very few reaches of gradual transition from stream to river and the division is usually quite marked in any one river system.

Water Temperature

MACAN (1958) showed that single temperature readings at widely spaced intervals are of little value in assessing the temperature regime

*In the upper reaches of some streams e.g. the Rase, calcium carbonate "tufa" deposits are found on the substratum and stationary objects, owing to supersaturation of the water with calcium salts.

TABLE I
Distribution of Plecoptera and Ephemeroptera in Lincolnshire streams and rivers 1961-1967 (35 Rivers/Streams)

Water Course	Altitude of Source	Sources in: -	Length in km.	Taeniopteryx nebulosa	Brachyptera risi	Amphinemura standfussi	Nemoura erratica	Nemoura cinerea	Leuctra fusca	Isoptera grammatica	Ephemera danica	Ephemera ignita	Baetis rhodani	Baetis vernus/tenax	Baetis scambus/bicoloratus	Baetis pumilus	Cloeon simile	Cloeon dipetrum	Centropilum luteolum	Haprophlebia fusca	Paraprophlebia submarginata	Caenis horaria	Caenis moesta	Caenis macrura	Caenis robusta	No. of Surveys	No. of sampling stations
1a New River Ancholme	50	Both	37.0															13	9			3	1			5	19
1a Wressell Beck	10	Lime	2.0										2													1	3
1a Highland Drain	30	Lime	3.3										10													2	3
1a Black Dike	50	Lime	6.5										74													1	7
1a Paunch Beck	50	Lime	6.5																							1	3
1a Hibaldstow Drain	25	Lime	4.0										277									20				1	3
1b Kettleby Beck	10	Chalk	8.0																							1	4
1b North Kelsey Beck	20	Chalk	8.0																							1	3
1b Nettleton Beck	125	Chalk	15.4	3		12	5						249													1	3
1b Thornton Beck	100	Chalk	9.6								12		27													2	9
2 River Rase, East Drain	125	Chalk	9.6	428	47	25	148	16	32	725	6	149	6,936	52		89				5	7					7	25
3 River Freshney, Lacey Beck*	35	Chalk	22.5										118	4												2	8
3 Buck Beck**	20	Chalk	16.0																							1	6
3b Cuxwold Beck**	125	Chalk	9.6																							1	10
4 Wathe Beck, Tretney Drain	117	Chalk	25.6	27		65	69	4	13	15	5	71	3,162	2												2	14
5 River Lud, Louth Canal*	100	Chalk	26.0	21								449	1,616													2	14
5a Lud Tributary, New Dike	8.0																									6	13
6 Long Eau	50	Chalk	11.2	65		5	8					20	677	2												1	4
7 Great Eau	100	Chalk	28.8	83								40	893	2												2	4
8 Lynn and Steeping River	100	Chalk	35.2	83									244													2	4
9 Hobhole Drain	3	Fen	17.6																							4	14
10 River Bain - Horncastle Canal	125	Chalk	36.8	4		4																				1	15
11 Lower Witham	3	Mixed	48.0																							2	4
11a South Forty Foot Drain	3	Lime	24.0																							4	14
11b Sincell Dike*	3	Lime	11.2																							2	4
11c New River Slea*	85	Lime	19.2										2													2	4
11d Old River Slea*	50	Lime	6.4										1													1	5
12 Upper Witham	120	Lime	60.8			5	4																			3	32
13 River Brand	50	Lime	19.2																							2	16
14 Foss Dyke	0	Mixed	16.0	1																						2	10
15 River Till**	50	Lime	19.2																							2	9
16 Winterton Beck**	35	Lime	12.8																							1	5
16a Winterton Beck (Tributaries)	35	Lime	12.8																							1	5
17 Humber Estuary	Free Tidal		60.8																							2	10
18 Pools and Ponds	Various																									2	10
19 River Waring	90	Chalk	8.0																							1	3
20 Other Streams/Drains	Various																									1	6
Number of River Systems Occurring				8	1	6	5	2	2	7	5	7	23	6	2	1	5	9	11	3	2	10	7	1	3	71	332

*Polluted for part of length. **Grossly polluted of source or for most of length.

TABLE II
Aquatic habitats in Lincolnshire

Watercourse	Condition	Substrata	Number of Stations
Flowing streams (Shallow with a moderate to swift current) (128 stations)	Non-polluted (107 Stations)	1. Mainly stones. Sand underneath	47
		2. Mainly sand. Very few stones	48
		3. Small shingle on sand or clay	12
	Polluted (To various degrees) (76 stations)	1. Mainly stones. Sand underneath	19
2. Mainly sand. Very few stones		51	
3. Small shingle on sand or clay		6	
Slow Rivers and Drains (Deeper, slow to static)	Non-polluted (65 stations)	4. Silt with little organic mud.	15
		5. Black mud of organic origin	50
	polluted (29 stations) Seasonally Saline Non-polluted. (29 stations)	5. Black mud of organic origin	29
		4/5. Black mud and/or silt	29
Free Tidal Reaches	Salinity varies with tide.	6. Clay particles and alluvium (Few stones and rocks).	13
Pools and Ponds	Mainly clean (Non-polluted)	4/5. Silt or silt overlaid with black mud. Rarely with sand.	14

in small streams. The temperatures plotted on Fig. 2 were taken during monthly surveys of the River Witham, and are intended to show differences between stream and river reaches at certain times of the year. The temperatures in both stream and river reaches are generally similar during the year but the range is wider in rivers.

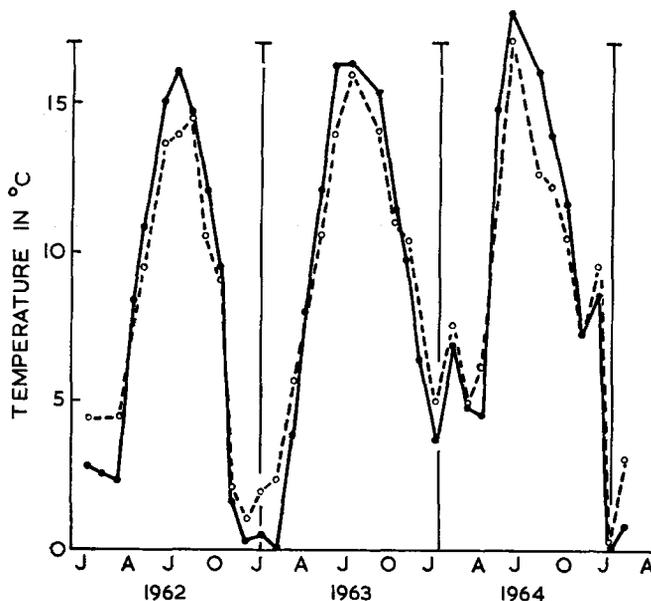


Fig. 2. Monthly temperatures at two stations on river Witham.
 ---- Stream ——— River

Also, rivers normally become ice-covered during part of the winter while stream temperatures usually remain above 0.5°C . The highest temperature recorded in a Lincolnshire stream during 1962–65 was 19.0°C and the highest in a river 22.5°C .

Chemistry

Chemical analyses of water from 50 sampling stations on 4 river systems were carried out regularly during 1961–65 (Lincs. River Board Annual Reports 1961 to 1965). Table III shows the basic chemical characteristics of the streams and rivers, and the stations selected are representative of the types of habitat described in Table II.

Clean streams and clean rivers are chemically similar. Rivers showed slightly higher degrees of hardness and B.O.D.'s than streams and dissolved oxygen (saturation) were often over 120% in rivers,

TABLE III

Results of chemical analyses of Lincolnshire stream and river waters to illustrate the general chemical characteristics of the sampling stations in the various types of habitat

Type of Water	Described Condition		Ca ⁺⁺ (p.p.m.)	PH	Cl- (p.p.m.)	Amm. Nit (NH ₃ ⁺) p.p.m.	Nitrate NO ₃ p.p.m.	B.O.D. p.p.m.	% Satn. O ₂	Total hardness p.p.m.
Flowing Streams	Non-polluted	H	201	8.0	30	0.70	8.55	3.1	137	283
		L	125	7.4	26	0.00	3.3	0.4	90	256
	Polluted (Various degrees)	H	145	8.3	115	4.3	8.0	45.0	149	362
		L	118	7.9	48	1.5	1.32	2.0	10	288
	Non-polluted	H	157	8.2	60	1.07	8.96	6.6	115	416
		L	155	7.8	42	0.00	1.69	1.1	66	508
Slow Rivers and Drains	Polluted (Various degrees)	H	244	8.6	86	4.5	7.1	19.0	154	850
		L	192	7.4	42	0.0	0.0	1.1	7	380
	Seasonally saline (Non-polluted)	H	176	8.0	3,000	0.90	8.58	4.5	145	794
		L	112	7.9	74	0.0	0.96	0.9	79	504
Free Tidal	Tidal salinity changes	H			12,000					
		L			1,700					
Pools and Ponds	Mostly non- Polluted	H		9.2						
		L		7.9						
Other Rivers in Other Regions	River Sawdde*	H	22	7.6	9					
		L			7					
	Afon Hirnant*	H								
		L								
	River Wharfe*	H	18	8.5	30					
		L			25					

*Data from other rivers in other regions are included for comparison

species of macrophyte, though the most common and abundant were *Nuphar lutea*, *Ceratophyllum demersum* and *Potamogeton* spp. Pools and ponds contained most of the species found in these reaches.

Where saline infiltration occurred regularly *Ceratophyllum* was absent and *Potamogeton* spp. generally sparse. Of the more easily recognisable algae, *Cladophora* spp. were common and very abundant in rivers during summer and *Enteromorpha* spp. were common in the seasonally saline reaches.

METHODS

Collections of aquatic invertebrates were taken from both streams and rivers with a triangular-framed hand-net of 8 meshes/cm, the standardised methods outlined by LANGFORD (1965) being used. In the wadeable streams, the net was held downstream of an area of substratum and animals were washed into the net when the substrate was disturbed.

In rivers and drains, collections were usually carried out from the bank using the net on a longer pole (2—3 m). Sweeps were made through weed beds and a section of the substratum was sampled. Surveys of the major river systems were carried out at least twice during the programme, though many of the smaller feeder streams were only surveyed once. The timing of single surveys is taken into account when the distribution of species is discussed.

In the original surveys, 577 collections were taken from 274 stations on 24 rivers and streams. For this account additional data have been used, from surveys in 1966, 1967 and 1968 and, in all, 644 collections from 332 stations have been analysed. The stations cover 504 km of streams and rivers, 61 km of estuary and 15 pools.

DISTRIBUTION AND ABUNDANCE OF SPECIES

Of the 644 collections, 622 were taken from non-tidal waters. The total number of macro-invertebrates sorted and counted was 317,559, of which 1,904 (0.6%) were Plecoptera nymphs and 25,441 (8.0%) were Ephemeroptera.

PLECOPTERA

The distribution and habitats of Plecoptera have been described by other authors, notably by HYNES (1941) and BROWN, CRAGG & CRISP (1964) in Britain, BRINCK (1949) in Sweden and AUBERT (1946)

in Switzerland. It is of value to compare the Lincolnshire habitats of the 7 species recorded with their habitats in other regions.

Family Taeniopterygidae

Taeniopteryx nebulosa (LINNÉ)

This was the most widely distributed, though not always the most abundant stonefly species. It occurred in 8 river systems at 41 stations (Table IV) and of the 635 nymphs collected only 1 was from a limestone stream. The altitude range was normally + 3 m to + 117 m (ODN) and nymphs were mainly collected in flowing stream on sand, amongst stones or amongst plants such as *Carex* spp. at the stream margins. On two occasions fully grown nymphs were collected from a canalised river but both times the reach was just below a stream confluence and collections followed a heavy spate. Most nymphs were found during the period, October to February though tiny nymphs were collected among moss on stones in the Upper Rase and Waithe Beck during July 1964. Very few nymphs were taken during the period March to July.

TABLE IV

Relative abundance of Plecoptera and Ephemeroptera in Lincolnshire habitats

Habitat	Total Inverts.	Total Plecopt.	% Plecopt.	Total Ephems.	% Ephems.
Clean Streams	137,736	1,574	1.1	17,942	13.0
Polluted Streams	86,034	70	0.001	3,508	14.1
Clean Rivers/Drains	48,882	14	0.0003	3,682	7.5
Polluted Rivers/Drains	20,494	—	—	130	0.8
Seasonally Saline	17,648	—	—	66	0.08
Pools and Ponds	6,697	—	—	103	1.02

In general the habitat of *T. nebulosa* in Lincolnshire corresponds with that found by BROWN, CRAGG & CRISP (1964) in the Pennines, though they found the species up to altitudes of 670 m. HYNES (1941) considers the species to be characteristic of slow streams and rivers but in Lincolnshire nymphs were found in faster reaches (up to 70 cm/sec) and in slower sandy reaches (30 cm/sec). The greatest concentrations of tiny nymphs were found among the moss *Eurhynchium riparioides* (HEDW.) on stones in the Upper Rase. The distribution of nymphs varied with their development. Very young nymphs were found only in the upper reaches of streams, but, during the

growth period (autumn, winter) older nymphs were found further and further downstream until, just prior to emergence, full grown nymphs could be found over a wider altitude range. The species was not recorded from the Afon Hirnant (HYNES 1961) or from Ford Wood Beck (GELDHILL 1960) and only from 1 stream in the Scottish Highlands (MORGAN & EGGLESHAW 1965b).

T. nebulosa was recorded from Lincolnshire streams which were mildly polluted by organic effluents but never where pollution was severe.

Brachyptera risi (MORTON)

Nymphs were rare and never abundant, only collected from 6 stations on 1 stream, (Tables I and VII) the River Rase. Large nymphs were found in July, December, February and April, mainly among moss in faster reaches. This species has been found up to 490 m in Britain (BROWN, CRAGG & CRISP 1964) and up to 900 m in the Alps (AUBERT 1946). Its Lincolnshire range was + 50 m to + 125 m (ODN).

TABLE V

Relative abundance of Plecoptera and Ephemeroptera in streams from different regions of Britain

Stream	Region	%* Plecoptera	%* Ephemeroptera	
All Lincolnshire Clean Streams	Lincolnshire	1.1	13.0	
All Scottish Streams	Scottish Highlands	11.8	25.2	MORGAN & EGGLESHAW (1965a)
Afon Hirnant	N. Wales	51.0	28.0	HYNES (1961b)

*as % numbers of all invertebrates.

Family Nemouridae

Amphinemura standfussi (RIS.)

A. standfussi was the third most widespread species, being found in 6 river systems (Table I). Nymphs were collected mainly from streams over an altitude range of + 17 m to + 125 m. The largest single collections came from small grassy trickles in the headwaters of tiny streams among leaf debris and shingle, where the water was only 2—3 cm deep and the stream less than 0.5 m wide. Some

TABLE VI

Total numbers of each species collected in Surveys
(Results from 622 Collections at 319 stations)

Species	Total Number of Nymphs	Number of Stations Occurring ()	Average Number per Collection	Main Season Occurrence
<i>Taeniopteryx nebulosa</i>	635	41 (8)	8.4	Aut. — Wint.
<i>Brachyptera risi</i>	47	6 (1)	4.0	Wint. — Spt.
<i>Amphinemura standfussi</i>	116	14 (6)	6.4	
<i>Nemoura erratica</i>	224	17 (4)	7.7	
<i>Nemoura cinerea</i>	20	5 (2)	3.3	
<i>Leuctra fusca</i>	45	8 (2)	3.5	Summer
<i>Isoperla grammatica</i> (Poda)	817	25 (7)	13.9	All.
Total (All Plecoptera)	1,904	—	—	—
<i>Ephemera danica</i>	27	9 (5)	2.3	
<i>Ephemerella ignita</i>	783	34 (7)	21.7	Summer
<i>Caenis horaria</i>	629	32 (10)	16.4	
<i>Caenis moesta</i>	7,555	28 (7)	198.8	
<i>Caenis macrura</i>	127	3 (1)	42.3	
<i>Caenis robusta</i>	50	4 (3)	12.5	
<i>Baetis rhodani</i>	14,869	118 (23)	67.5	(All.)
<i>Baetis vernalis/tenax</i>	109	18 (6)	4.7	Summer
<i>Baetis scambus/biocularis</i>	628	14 (2)	39.3	Summer
<i>Baetis pumilus</i>	89	6 (1)	11.1	Summer
<i>Cloëon simile</i>	105	12 (5)	7.5	
<i>Cloëon dipterum</i>	131	23 (9)	6.5	
<i>Centroptilum luteolum</i>	322	29 (11)	10.7	
<i>Haprophlebia fusca</i>	9	3 (3)	3.0	
<i>Paraleptophlebia submarginata</i>	8	4 (2)	2.0	
Total (All Ephemeroptera)	25,441	—	—	—
Total Invertebrates in 622 Collections	317,559	—	—	—

nymphs were found regularly in very mildly polluted reaches, but never where pollution was severe enough to encourage sewage fungus. In other regions the species is recorded up to 670 m (KIMMINS 1943), and HYNES (1941) describes its habitat as "silt and leaf packets in a small stony stream", which corresponds closely to its Lincolnshire

habitat. It was found by BRINCK in all types of running water and in lakes in Sweden, and is common in the Pennines and North Wales (HYNES 1958).

Nemoura erratica (CLAASEN)

Fairly common, and occasionally abundant in Lincolnshire streams, mainly on the chalk. The species was often collected together with *A. standfussi* in the small trickles but was more abundant in the lower reaches than the former species. The altitude range was + 3 m to + 125 m, and it was not recorded where pollution was severe. Its Lincolnshire habitat corresponds closely with those described by BRINCK for Sweden and by HYNES for the Lake District. HILL (1946) recorded *N. erratica* from a pond in Scotland but none were taken from Lincolnshire ponds or drains.

Nemoura cinerea (RETZIUS)

Rare, 20 nymphs collected from 5 stations on 2 streams (Tables I and VII) in the Wolds. All nymphs came from the 17 m to 33 m range and small numbers were collected from a mildly polluted reach. At all 5 stations, there was leaf and twig debris among the stones and between "ripples" on the sandy substrate. The species is widely distributed in other regions of Britain (HYNES 1941, BROWN, CRAGG & CRISP 1964) and has been recorded from trickles, stony streams and tarns. BRINCK described it as ubiquitous in Sweden. Altitude records are up to 915 m in Scotland (CORBET 1959) and 1500 m in the Alps (AUBERT 1946).

Family Leuctridae

Leuctra fusca (LINNÉ)

Rare and scarce. Nymphs were collected from 8 unpolluted stations on 2 streams (Tables I, VII and VIII) in the North Lincolnshire Wolds, over an altitude range of + 17 m to 117 m. Like *B. risi* and *N. cinerea* nymphs were only collected in small numbers, mainly among stones and on rippled sand where debris had accumulated. Its altitude range in other places goes up to + 600 m in the Alps, + 650 m in the Lake District and + 700 m in the Pennines. Nymphs were collected mainly during July - October and one adult was collected in October 1964. BRINCK records *L. fusca* from high mountain lakes in Sweden and the species is common and fairly abundant in the hill streams of Britain (HYNES 1958).

TABLE VII

Numbers of each species collected from each main type of habitat and the number of stations at which the species occurred

Species	STREAMS		RIVERS AND DRAINS				POOLS	
	No. Stations	No. Nymphs	Fresh No. Stations	Fresh No. Nymphs	Seas No. Stations	Saline No. Nymphs	No. Stations	No. Nymphs
ebulosa	39	622	2	13	—	—	—	—
si	6	47	—	—	—	—	—	—
tandfussi	13	115	1	1	—	—	—	—
rratica	17	224	—	—	—	—	—	—
inerea	5	20	—	—	—	—	—	—
asca	8	45	—	—	—	—	—	—
ammatica	25	817	—	—	—	—	—	—
al Plecoptera	—	1,867	—	14				
anica	8	26	1	1	—	—	—	—
gnita	33	781	1	2	—	—	—	—
oraria	9	150	16	444	2	16	5	19
noesta	20	4,774	6	2,775	2	11	1	15
nacrura	2	127	—	—	—	—	—	—
obusta	—	—	1	29	2	3	1	18
hodani	107	14,778	11	81	—	—	—	—
ernus/tenax	14	78	4	31	—	—	—	—
cambus/biocularatus	14	628	—	—	—	—	—	—
umilus	6	89	—	—	—	—	—	—
ëon simile	2	48	5	37	1	2	4	18
ëon dipterum	1	1	16	79	3	28	3	23
troptilum luteolum	1	8	23	161	3	6	1	10
rophlebia fusca	3	9	—	—	—	—	—	—
aleptophlebia submarginata	4	8	—	—	—	—	—	—
al Ephemeroptera		21,518		3,640		66		103
al invertebrates		223,770		69,384		17,652		6,697
al Stations veyed		183		94		28		14

TABLE VIII

Numbers of Plecoptera and Ephemeroptera collected from chalk and limestone river systems 1961—1965

Species	Limestone Systems (14)		Chalk Systems (15)		Rivers with Sources from both (4)	
	No. Occurred	No. Specimens	No. Occurred	No. Specimens	No. Occurred	No. Specimen
<i>Taeniopteryx nebulosa</i>	1	1	7	631	—	—
<i>Brachyptera risi</i>	—	—	1	47	—	—
<i>Amphinemura standfussi</i>	1	5	5	111	—	—
<i>Nemoura erratica</i>	1	4	3	225	—	—
<i>Nemoura cinerea</i>	—	—	2	20	—	—
<i>Leuctra fusca</i>	—	—	2	45	—	—
<i>Isoperla grammatica</i>	1	1	6	817	—	—
<i>Ephemera danica</i>	1	1	4	24	—	—
<i>Ephemerella ignita</i>	1	38	6	745	—	—
<i>Baetis rhodani</i>	11	757	11	14,107	2	12
<i>Baetis vernus/tenax</i>	1	51	5	66	—	—
<i>Baetis scambus/bioculatus</i>	2	618	—	—	—	—
<i>Baetis pumilus</i>	—	—	1	89	—	—
<i>Cloëon simile</i>	2	54	1	33	1	3
<i>Cloëon dipterum</i>	3	29	3	55	2	24
<i>Centroptilum luteolum</i>	5	155	3	183	2	29
<i>Haprophlebia fusca</i>	—	—	3	9	—	—
<i>Paraleptophlebia submarginata</i>	1	1	1	7	—	—
<i>Caenis horarja</i>	3	478	3	303	2	63
<i>Caenis moesta</i>	2	8,295	3	66	1	1
<i>Caenis macrura</i>	1	129	—	—	—	—
<i>Caenis robusta</i>	—	—	—	—	1	1
No of species (Plecoptera)	4	—	7	—	—	—
No. of species (Ephemeroptera)	12	—	12	—	7	—
<i>Common Species</i>	<i>Lime/Chalk/Mixed</i>				P	E
	<i>Lime/Chalk</i>				0	6
					4	10

TABLE IX

Numbers of Plecoptera and Ephemeroptera collected from

Species	Habitat	Streams and Becks			
		Clean Stones/Moss (47)	Polluted Stones (19)	Clean Sand (48)	Polluted Sand (51)
<i>Taeniopteryx nebulosa</i>		16 (355)	1 (30)	20 (223)	2 (14)
<i>Brachyptera risi</i>		3 (24)	—	2 (21)	1 (2)
<i>Amphinemura standfussi</i>		4 (27)	—	4 (12)	2 (3)
<i>Nemoura erratica</i>		4 (97)	1 (5)	7 (34)	1 (1)
<i>Nemoura cinerea</i>		2 (7)	1 (7)	2 (6)	—
<i>Leuctra fusca</i>		6 (32)	—	2 (13)	—
<i>Isoperla grammatica</i>		11 (533)	—	12 (252)	2 (8)
<i>Ephemera danica</i>		3 (5)	—	4 (18)	1 (3)
<i>Ephemerella ignita</i>		16 (618)	1 (4)	10 (94)	1 (65)
<i>Baetis rhodani</i>		44 (7374)	6 (1832)	32 (4731)	15 (589)
<i>Baetis vernus/tenax</i>		5 (18)	4 (13)	5 (35)	1 (7)
<i>Baetis bioculatus</i>		3 (163)	5 (147)	4 (305)	1 (3)
<i>Baetis pumilus</i>		3 (33)	—	2 (41)	—
<i>Centroptilum luteolum</i>		2 (8)	—	—	—
<i>Cloëon simile</i>		—	—	2 (48)	—
<i>Cloëon dipterum</i>		—	1 (1)	—	—
<i>Paraleptophlebia submarginata</i>		1 (5)	1 (1)	2 (2)	—
<i>Haprophlebia fusca</i>		1 (2)	—	2 (7)	—
<i>Caenis moesta</i>		3 (3454)	3 (677)	6 (551)	7 (92)
<i>Caenis horaria</i>		—	2 (49)	5 (46)	—
<i>Caenis macrura</i>		1 (15)	—	2 (112)	—
<i>Caenis robusta</i>		—	—	—	—

Family Perlodidae

Isoperla grammatica (PODA)

The second most common stonefly species in Lincolnshire, occurring at 25 stations in 7 river systems (Tables I & VII). Though less widespread than *T. nebulosa*, *I. grammatica* was generally more abundant and an average of 13.9 individuals per station were collected compared with 8.4 for *T. nebulosa*. Only 1 specimen was collected from a limestone stream, the rest being from the chalk streams of the Lincolnshire Wolds. Nymphs were found on sand and among stones and moss in all months of the year, and the largest numbers were taken from among *Eurhynchium riparioides* (HEDW.) in the Upper

different substrata in Lincolnshire streams and rivers 1961–1967

		Rivers and Drains					
Clean Shingle (12)	Polluted Shingle (6)	Clean Clay/Silt (15)	Clean Silt/Mud (50)	Polluted Mud	Seasonally Saline Clay (15)	Pools Ponds (15)	
—	—	—	2 (13)	—	—	—	
—	—	—	—	—	—	—	
3 (73)	—	1 (1)	—	—	—	—	
4 (87)	—	—	—	—	—	—	
—	—	—	—	—	—	—	
—	—	—	—	—	—	—	
1 (1)	—	—	—	—	—	—	
<hr/>							
—	—	1 (1)	—	—	—	—	
—	—	1 (2)	—	—	—	—	
6 (237)	4 (25)	3 (38)	4 (21)	4 (22)	—	—	
1 (5)	—	—	4 (31)	—	—	—	
—	—	—	—	—	—	—	
1 (15)	—	—	—	—	—	—	
—	—	7 (151)	15 (142)	1 (5)	3 (6)	1 (10)	
—	—	2 (24)	3 (13)	—	1 (2)	4 (18)	
—	—	5 (18)	8 (54)	2 (7)	3 (28)	3 (23)	
—	—	—	—	—	—	—	
—	—	—	—	—	—	—	
—	—	1 (47)	5 (2708)	—	2 (11)	1 (15)	
—	—	6 (270)	11 (133)	1 (96)	2 (16)	5 (19)	
—	—	—	—	—	—	—	
—	—	—	1 (29)	—	2 (3)	1 (18)	

Rase, in April and July. The altitude range of the species was + 8 m to + 125 m (ODN) but most nymphs were taken above 67 m contour. *I. grammatica* was never found in a river.

HYNES did not collect *I. grammatica* above 330 m (ODN) in the Lake District but BROWN, CRAGG & CRISP recorded it up to 670 m (ODN) in the Pennines, CORBET to 735 m in Scotland, and AUBERT to 1400 m in the Alps. BRINCK considered it to “have the widest ecological amplitude of all Swedish Plecoptera”.

HYNES (pers. comm.) compared nymphs of *I. grammatica* from Lincolnshire with his specimens from a calcareous stream in Hampshire and noted that both showed the same light colouration, not found in the mountain streams.

TABLE X

Distribution of Plecoptera and Ephemeroptera 1961—65, based on the numbered 10 Km. Squares in which each species occurred

<i>Plecoptera</i>	
Taeniopteryx nebulosa	TS20, TF-08, 18, 18, 27, 28, 29, 37, 38, 46, 47, 48.
Brachyptera risi	TF19.
Amphinemura standfussi	SK. 91, TF-19, 28, 37, 38.
Nemoura erratica	SK. 19, TF-08, 18, 19, 28, 37, 38, 46.
Nemoura cinerea	TF. 08, 18.
Leuctra fusca	TF. 18, 19, 28, 38.
Isoperla grammatica	TF. 18, 19, 27, 28, 29, 36, 37, 46.
<i>Ephemeroptera</i>	
Baetis rhodani	SK09-83, 84, 85, 91, 92, 93, 94, 97, 98, 99; TA. 20, TF-04, 09, 19, 27, 28, 29, 36, 37, 38, 46, 47, 48.
Baetis vernus (tenax*)	TA. 20- SK. 29, 48, 85, 96, TF-08, 18*, 19*.
Baetis pumilus	TF. 19
Baetis bioculatus	SK. 84, 85, 94, 96.
Centroptilum luteolum	SE-91, 90, 96; TF. 07-09, 15, 16, 25, 26, 45, 48, 49, 55.
Cloëon dipterum	TF-09, 15, 25, 26, 39, 45, 48, 55.
Cloëon simile	SK. 96; TF-07, 15, 48.
Empherella ignita	SK. 92, 93; TA. 20; Tf-18, 19, 28, 29, 36, 37, 38, 47, 48.
Ephemera danica	TF. 08, 09, 18, 19, 29.
Haprophlebia fusca	TF. 08, 18, 38, 47.
Paraleptophlebia submarginata	TF. 18.
Caenis moesta	SE. 91; TF. 07, 45, 48.
Caenis horaria	SE. 90, 91; SK. 84, 85; TF. 09, 12, 34, 35, 48.
Caenis macrura	SK. 84, 85.
Caenis robusta	SK. 97+; TF. 35.

*Indicates that this species could be "tenax"

+This refers to a pool near Lincoln.

In Lincolnshire, *I. grammatica* was found regularly below a very mildly polluting organic discharge but no nymphs were collected in grossly polluted reaches.

EPHEMEROPTERA

Distribution and habitat preferences have been described mainly by KIMMINS (1954) and MACAN (1961) and comparisons are drawn between these previously described habitats and those in Lincolnshire. Data from other surveys notably of Scottish streams (MORGAN

& EGGLESHAW 1965a) and Pennine streams (CRISP & NELSON 1965) are also used for comparison.

Family Ephemeridae

Ephemerella danica (MULLER)

Nymphs were collected from 9 stations on 5 streams (Table IV), mainly from sandy substrata, over an altitude range of + 50 m to + 100 m. One nymph was collected from the sandy margin of a river, during 1967. *E. danica* was described by KIMMINS (1954) as common and abundant on sandy substrata in lakes, streams and rivers with a preference for alkaline waters. The species was not recorded by MORGAN & EGGLESHAW in their Scottish streams, nor by CRISP & NELSON in Pennine streams. In Lincolnshire, nymphs were usually collected singly or in very small numbers and were absent from grossly polluted reaches.

Family Ephemerellidae

Ephemerella ignita (PODA)

Fairly common and often abundant in summer, mainly in streams. Nymphs were found on bare sand, among moss and higher plants and also among the lower stems of *Carex* spp. at stream margins. This species occurred in 7 chalk streams and 1 limestone stream, but was found rarely where pollution was present. This species appears to have preference for places where there was a good, fairly fast flow of clean water with a depth of more than 10 cm, and some emergent vegetation.

The altitude range was + 33 m to + 100 m (ODN), and the species was absent from the uppermost trickles and from the very small, shallow becks (0.3 m wide/5 cm deep) at lower altitudes. In other regions nymphs were recorded up to altitudes of 500 m (HYNES 1961) and 550 m (CRISP & NELSON 1965). Very few nymphs were collected from Lincolnshire rivers. Most specimens were found during June to September, though a few large nymphs were collected in both November 1962 and November 1963.

Family Caenidae

Caenis horaria (LINNÉ)

This was the most widespread species of the Caenidae, occurring in rivers, streams and pools (Tables I & VII). It was rarely abundant in any habitat, though it was most common in rivers on substrata of clean silt, or organic mud. Nymphs were recorded in small num-

bers from 2 seasonally saline reaches, and from 7 stations on flowing streams in both sandy and stony substrata. The altitude range was — 3 m (ODN) to + 30 m. In 2 stony reaches where pollution by sewage caused silting between the stones, nymphs were regularly recorded.

Caenis moesta (BENGTTSS)

This species was more locally abundant than *C. horaria* but was less widespread. The habitat range was wide and nymphs were recorded from streams in clean sand, and among stones where pollution resulted in some silting, as well as in rivers among clean silt and organic mud. Its altitude range was 0 m to + 80 m. MACAN (1961) describes the habitat of *C. moesta* as gravel or stones with finer material between in rivers, lakes or ponds and KIMMINS (1954) records it from acid and alkaline streams with sandy substrata. In Lincolnshire *C. moesta* has a wide habitat range and was equally distributed between chalk and limestone rivers and streams.

Caenis macrura (STEPH)

Rare, being found only at 3 sampling stations on the River Witham, in flowing reaches with sandy substrata, a few large stones and emergent vegetation. KIMMINS (1954) records it as preferring more alkaline waters and it is not recorded from the Lake District (MACAN 1961) or from the Pennines (CRISP & NELSON 1965). It was absent from the chalk streams in Lincolnshire and its apparent altitude distribution was from + 25 m to + 50 m.

Caenis robusta (EATON)

Rare and scarce. Nymphs were taken from 3 stations on rivers and in 1 pool. The substrata were mainly organic mud and 1 reach was brackish at the time of collection. All stations, except the pool had bed altitudes below mean tide level (+ 0 m ODN).

Family Baetidae

Baetis rhodani (BURMEISTER)

This species was by far the most common and abundant of the Ephemeroptera in Lincolnshire. Nymphs were collected from 23 streams and rivers in all habitats except seasonally saline reaches and ponds. It was most abundant in clean streams on both sandy and stony substrata (Table VI), and was recorded regularly in 24 mildly polluted reaches, below S.D.W. effluents. In rivers and drains nymphs were found to occur regularly, but usually in small numbers. The normal altitude range was + 3 m to + 117 m (ODN) but some nymphs were found in reaches at 0m and at + 125 m (ODN).

The species is common and widespread in Britain and has been recorded up to altitudes of 350—730 m by CRISP & NELSON, in the Pennines and down to + 30 m by MORGAN & EGGLISHAW in Scotland.

Some nymphs, usually large ones, were recorded from grossly polluted reaches of Lincolnshire streams but the occurrences were sporadic which led us to believe that the nymphs were not resident but had drifted in from cleaner reaches upstream.

Baetis pumilus (BURMEISTER)

Nymphs were found only at 6 stations on 1 river, the River Rase. The largest numbers were collected above the 100 m contour line, although a few full-grown nymphs were collected at about + 75 m. This is one of the species found in the tiny, grassy trickles in the headwaters of Lincolnshire streams. CRISP & NELSON give an altitude range of + 350 m to 660 m for *B. pumilus* in the Pennines, and MACAN records it from larger rivers. This latter finding is supported by LANGFORD (In prep.), who has collected nymphs regularly during recent work on the middle reaches of the River Severn.

Baetis vernus/tenax (CURTISS)

Nymphs of these two species are physically indistinguishable although MACAN (1961) considers that there is a clear ecological distinction. Nymphs were collected in streams and rivers from both chalk and limestone areas, at 16 sampling stations, over an altitude range of 0m to + 125 m (ODN). It is probable that nymphs from the higher streams were *B. tenax* (i.e. over 50 m ODN), while those from the larger drains and rivers were almost certainly *B. vernus*.

The species were not recorded by Crisp and Nelson from Pennine streams, but Hynes recorded *B. tenax* above 230 m in the Afon Hirnant.

Baetis bioculatus (LINNÉ)

Nymphs were collected at 14 stations on 2 limestone rivers both in the Witham watershed. Most nymphs were collected from the Upper Witham itself and none were found in streams on the chalk wolds. All nymphs were collected during summer and early autumn. Nymphs of *B. bioculatus* are not distinguishable from those of *B. scambus* (MACAN 1961) but *B. bioculatus* is considered to be more common in alkaline waters and *B. scambus* more common in acid, mountain streams. CRISP & NELSON recorded *B. scambus* from the Pennine streams.

In Lincolnshire the habitat of *B. bioculatus* was mainly sluggish streams with sandy substrata and emergent vegetation, over an altitude range of + 10 m to + 75 m (ODN).

Centroptilum luteolum (MULLER)

Common in rivers. Nymphs were collected at 28 stations from 10 rivers, 1 pool and 1 stream. The species was most common and abundant in clean drains among weed beds on substrata of clean silt or organic mud. MACAN (1957) considers the species as characteristic of slow rivers and pools and it is recorded from lakes in the Lake District by KIMMINS (1954).

Cloëon dipterum (LINNÉ)

Nymphs were collected at 23 stations from 9 river systems (Tables I & VII). The species was more common in clean rivers among weed beds, often taken together with the previous species and/or *Cloëon simile*. Nymphs were also regularly recorded in seasonal saline reaches and ponds. The altitude range was 0m to + 5 m ODN in rivers but was found in pools up to 20 m (ODN). MACAN (1957) describes *Cloëon* spp. as typical pond dwellers and KIMMINS (1954) describes *C. dipterum* as common in ponds with a high summer temperature. In Lincolnshire *C. dipterum* was equally common in chalk and limestone rivers.

Cloëon simile (EATON)

Generally less common than *C. dipterum*. Nymphs were collected mainly in rivers (Table VII), though a few were taken in pools and at 2 stations on a stream. The species was usually found together with *C. dipterum* and/or *C. luteolum* among weed beds on substrata of clean silt or organic mud, in chalk and limestone rivers and in pools. The altitude range was 0 m to + 5 m (ODN), in Lincolnshire though in other regions it has been recorded from tarns at higher altitudes (KIMMINS 1954).

Family Leptophlebiidae

Haprophlebia fusca (CURTISS)

Rare and scarce. 9 Nymphs were collected at 3 stations from 3 chalk streams, usually from sandy substrata where dead leaves and twigs had accumulated in ripples. KIMMINS described the habitat of this species as slow streams where the substratum was sand with packets of leaves. The altitude range was + 12 to + 100 m.

Paraleptophlebia submarginata (STEPH.)

Rare and scarce. Only 8 nymphs were collected in 6 years, from 4 stations on 2 streams. Substrata were similar to those in which *H. fusca* were found. KIMMINS states that the species is "common in small moderately fast streams" and MACAN records it from the slow

upper reaches of a small stream and from stony rivers in the Lake District. The altitude range was + 10 m to + 100 m (ODN).

COMPARISONS

Streams and Rivers in Lincolnshire

Plecoptera totalled only 0.0003% of the invertebrates collected from rivers and 1.1% of those collected from streams, Ephemeroptera totalled 7.5% and 13.0% respectively (Table IV).

Small numbers of Plecoptera, mainly *Taeniopteryx nebulosa* were found in rivers after particularly heavy spates in early spring but no species of Plecoptera was resident in these reaches (Table VII).

Of the Ephemeroptera *E. danica*, *E. ignita*, *B. rhodani*, *B. vernus/tenax*, *B. bioculatus*, *B. pumilus*, *H. fusca*, *P. submarginata*, *C. macrura* and *C. moesta* were far more common in streams than in rivers.

Those most common in rivers were *C. horaria*, *C. robusta*, *C. simile*, *C. dipterum*, *C. luteolum*. These 5 species, plus *Caenis moesta* were also common in pools and ponds. This indicates to some extent, the physical similarities between the long impounded rivers and the pools and ponds in the region.

Seven species of Plecoptera and 14 species of Ephemeroptera were recorded from Lincolnshire streams while 2 species of Plecoptera, and 10 species of Ephemeroptera were recorded from rivers.

In "seasonally saline" reaches, 6 species of Ephemeroptera were found, but the total was only 0.08% of the total fauna, and all the species were common to the freshwater rivers. No Plecoptera were recorded.

CLEAN AND POLLUTED REACHES

In polluted streams, Plecoptera formed only 0.001% and Ephemeroptera 4.1% of the total invertebrate catch (Table IV). Five species of Plecoptera occurred in mildly polluted reaches but never where the pollution load was heavy. *T. nebulosa*, *I. grammatica* and *A. standfussi*, the commonest species, appeared to be the most tolerant to pollution (Table VII). Nine species of Ephemeroptera were recorded in polluted streams but only *B. rhodani*, and *C. moesta*, were found where pollution was continuous and severe. Where growths of sewage fungus occurred Plecoptera were absent and Ephemeroptera scarce.

Of the rarer Ephemeroptera, *Baetis bioculatus* appeared to be tolerant of the organic pollution, in the River Witham. In the Buck Beck, Cuxwold Beck and Winterton Beck (Table I), which are grossly polluted from the source downwards, Plecoptera and Ephemeroptera were absent.

Chalk and Limestone River Systems

Plecoptera were more common and abundant in chalk streams, i.e. from the Lincolnshire Wolds (Table VIII). All 7 species occurred on the chalk but only 4 species on the limestone area, and all these were found only in the Upper Witham.

Twelve species of Ephemeroptera occurred in both chalk and limestone streams and 10 species were common to both. *Baetis bioculatus* and *Caenis macrura* were found only in the Upper Witham catchment (limestone), while *Haprophlebia fusca* and *B. pumilus* only occurred in the chalk streams.

Two rivers received water from both chalk and limestone areas and both were long, uniform channels. Six of the seven species of Ephemeroptera which occurred were in the "river" group. *Baetis rhodani* occurred rarely and sporadically.

The scarcity of Plecoptera in the limestone streams is difficult to explain as there are few basic chemical or physical differences between chalk and limestone streams. One possible explanation is that, of the streams surveyed, more chalk streams had sources above 75 m (OD), and generally spring flows were larger and more consistent. Most Plecoptera nymphs were collected above 75 m (ODN), even in chalk streams and only *Taeniopteryx nebulosa* was common below 50 m (OD). In the limestone area, the Upper Witham was the only stream with a source at (125 m) and all 4 Plecoptera recorded, occurred in this stream.

Sampling Stations with different Substrata

Table IX shows the distribution of Plecoptera and Ephemeroptera on different substrata. All Plecoptera species occurred on sand and stones only 3 occurred on shingle. The shingly substrata were almost all in tiny, very shallow trickles in the headwaters of streams, at altitudes from 50 m to 125 m (OD) *A. standfussi*, and *N. erratica* occurred, usually together in these places.

Of the "stream" group of Ephemeroptera only 3 species, *B. rhodani*, *B. (vernus) tenax* and *B. pumilus* were found on the shingle substrata in the uppermost trickles.

In the clean, freshwater rivers, the species in the "river" group

appeared to be as common in clean silt as in substrata containing large amounts of 'organic' mud.

LINCOLNSHIRE AND OTHER REGIONS OF BRITAIN

The Plecoptera fauna of Lincolnshire is poor. Seven of the 35 British species were found, compared with 25 in the Pennines, (BROWN, CRAGG & CRISP 1964), 25 in the Lake District (HYNES 1958), 19 in the Afon Hirnant (HYNES 1961b), and 19 in the richer Scottish streams (MORGAN & EGGLISHAW 1965b). This paucity of species in Lincolnshire is almost certainly due to the uniformity of the substratum and habitat in the streams. All the Lincolnshire Plecoptera are also found in the mountain regions and obviously have a wide range of tolerance to calcium. However, the most common species in Lincolnshire, *Taeniopteryx nebulosa*, is rare in the Lake District and North Wales and was absent from Ford Wood Beck (MACKERETH 1957) and the Afon Hirnant. *A. standfussi* was also described by HYNES (1941) as rare, but both this species and *T. nebulosa* were found to be quite common in the Pennines (BROWN, CRAGG & CRISP 1964). The remaining 5 species found in Lincolnshire are common and fairly widespread over the other regions of Britain.

Of the Ephemeroptera in Lincolnshire, at least two species *B. vernus* and *Baetis bioculatus* are described by KIMMINS (1954) as having a preference for calcareous streams. *E. danica*, *E. ignita*, *B. rhodani*, *B. pumilus*, *H. fusca* and *P. submarginata*, are on the other hand also found in mountain streams with very low calcium concentrations (HYNES 1961, MACAN 1961).

The species found in the rivers of Lincolnshire are also common to the margins of rivers, weedy streams and ponds in other parts of Britain (MACAN 1957).

There are no Ecdyonuridae in Lincolnshire streams, even those known to be tolerant of fairly high calcium concentrations, e.g. *Heptagenia sulphurea* (GEIJSKES 1935, MACAN 1961). The reason for their absence is almost certainly the lack of suitable stones and stony substrata. Among the Plecoptera, Perlidae and Chloroperlidae, which are common in mountain regions, are absent from Lincolnshire, and again the uniformity of the habitat is no doubt the reason.

The overall distribution of species in Lincolnshire follows a very similar pattern to that in other regions. For example, a few species, *B. rhodani*, *E. ignita*, *T. nebulosa* and *I. grammatica*, are widespread, while a few species viz. *B. pumilus*, *B. bioculatus*, and *B. risi* are found in only one stream. This basic pattern is common to the streams of the Lake District (MACAN 1957), the Pennines (BROWN,

CRAGG & CRISP 1964) and Scotland (MORGAN & EGGLESHAW 1965), though the species which are the least or the most abundant differ from region to region. In Scotland for example *B. risi* occurred in 38 out of 50 streams, and *T. nebulosa* in 1 stream, In Lincolnshire *B. risi* occurred in only 1 stream and *T. nebulosa* in 8 streams, out of the 24. *Haprophlebia fusca* on the other hand was rare and scarce in all regions, while *B. rhodani* and *E. ignita* were equally common to all.

It is evident from Table V, that both Plecoptera and Ephemeroptera form a very minor proportion of the invertebrate fauna of Lincolnshire streams when compared with those of other regions.

One of the phenomena most difficult to explain was the sporadic distribution of species within the region. For example, *B. rhodani*, the most common mayfly, occurred in only 76 of the 95 clean stony or sandy reaches of streams, while *T. nebulosa*, the most common stonefly occurred in only 36 of the 95 reaches. Also, only 1 stream, the River Rase, contained all 7 species of stonefly. The greatest number of species found in any other stream was 5, yet all of the streams on the chalk Wolds started around 125 m (OD) within a few miles of each other. The distribution of the "river mayfly" species was even more sporadic and though such "rivers reaches" were widespread in the region, the most common species *C. luteolum* occurred at only 23 out of the 122 stations.

MACAN (pers. comm.) suggested that where a species does not occur, it is prevented from establishing itself by predators. This is a possibility for some species in Lincolnshire streams and rivers, but no evidence of an abundance of flatworms or other known predators has been produced. One animal which occurs in very large numbers in Lincolnshire streams is, however, *Gammarus pulex* and it may be that competition with this species for the few niches available is an important factor. One further factor which may account for the paucity of the mayfly and stonefly fauna is the presence of pesticides and artificial herbicides in streams and rivers due to the intensely agricultural nature of the region. It is perhaps significant that the upper reaches of the River Rase, where all Plecoptera species occurred were not surrounded by arable crops, but by poorly drained areas in which pesticides and herbicides were not used.

SUMMARY

1. Biological Surveys of rivers and streams were carried out in Lincolnshire during 1961—67.
2. Lincolnshire is a lowland region, with calcareous rocks and soils intensively farmed. Pollution is mainly from small sewage disposal works and farms.

3. The rainfall is low, up to 27.5" (70 cm) annually.
4. Most river systems are less 50 km long and have sources from + 33 m to 125 m above Mean Tide Level (ODN). There are two main types of watercourse
 - a. Free flowing "streams" with sandy or stony substrata
 - b. Canalised impounded "rivers" with clay banks and silt or mud substrata.
5. The temperature of the streams is less variable throughout the year than that of rivers.
6. The two types of watercourse are chemically similar, but the rivers have higher B.O.D.'s and some reaches are affected by salt water during low freshwater flows.
7. The vegetation of streams differs from that of rivers. Plant species common in rivers are also found in pools and ponds.
8. Collections of invertebrates were made with a hand net in two standardised methods depending on the type of watercourse.
9. The distribution and habitat of each species is described and habitats are compared with those in other regions. Altitude ranges are higher in other regions but basic habitats are very similar.
10. Comparisons are drawn between the Plecoptera and Ephemeroptera faunas of
 - a. Clean Lincolnshire streams and clean rivers
 - b. Clean and polluted reaches
 - c. Chalk and limestone river systems
 - d. Stations with different substrata
 - e. Lincolnshire and other regions of Britain
- 10a. Plecoptera are not usually found in rivers. Two groups of Ephemeroptera are defined - a "river" group and a "stream" group.
 - b. Plecoptera are rare as pollution occurs. *T. nebulosa*, *I. grammatica* and *A. standfussi* are most tolerant. Ephemeroptera are also suppressed by pollution. *B. rhodani*, *C. moesta* and *B. bioculatus* are fairly tolerant.
 - c. Plecoptera were more common in chalk streams. Of the mayflies, *B. pumilus* and *H. fusca* were only found in the chalk streams, *B. bioculatus* and *C. macrura* were only found in limestone streams.
 - d. Few differences were found between the distribution of species in sandy and stony substrata, though only 3 species of Plecoptera and 3 of Ephemeroptera occurred in small, shingly headwaters.
 - e. The Plecoptera fauna of Lincolnshire is sparse compared to the mountain regions. Of the Ephemeroptera, Ecdyonuridae were notable absentees, owing to the lack of suitable substrata.

Distribution of species is in many cases inexplicably sporadic within the region as it is in other regions.

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