THE DISTRIBUTION OF *HYDRACARINA* IN THE VICINITY OF FLATFORD MILL FIELD CENTRE, EAST SUFFOLK

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I. Introduction

During the years 1959-61 a series of collections were made of Hydracarina inhabiting waters in the lower part of the Stour basin in East Suffolk. From these collections a brief account is given of the distribution of species over the several habitats examined.

The localities are divided into two main categories, lotic and lenitic, listed below.

Lotic (i.e. running water)	Lenitic (i.e. standing or slow-moving)
Helocrenes	Lower reaches of the Stour
Limnocrenes	Drainage dykes on the Stour flood-plain
Brooks	Large borrow pit
Rivers Brett and Box	Small cattle ponds

The inclusion of the River Stour under the second heading requires explanation. Although in the winter months spate water in the lower Stour may reach 1·5 metres/second, its summer character is lenitic with a largely silted bed, an abundant flora, and a fauna showing close relationships with that of the dykes and ponds in its vicinity. At this time of year the water, held back by locks and sluice gates, is almost static.

All these localities were visited many times during the three years and, in addition, quantitative sampling was carried out in 1961 in the four lenitic areas. The equipment used was a pond net of 8 meshes/centimetre and sieves of 8 and 30 meshes/centimetre. The sieves were employed mainly for bottom sampling in running water and for separation of material in the laboratory.

84 species of water mite are listed in Tables 1 and 2 together with the localities in which they were found. The symbols are explained in the legends. Asterisks indicate species common to both lotic and lenitic habitats and therefore listed in both tables.

A number of limnological terms used in this paper are explained below.

Helocrene:	boggy mat of debris with spring oozing through it.
Limnocrene:	clear spring passing over sand and gravel.
Crenophilous:	showing a preference for springs.
Crenobiontic:	confined to springs.
Rheophilous:	showing a preference for streams.
Rheobiontic:	confined to streams.
Eurythermous:	existing through a wide range of temperatures.
Stenothermous:	confined to a narrow range of temperatures.

II. LOTIC HABITATS

A complete description of each locality will not be attempted but, briefly, the physical conditions are as follows. Temperatures in spring waters maintain between 9·5 and 11·5° C. In the brooks the annual temperature range is much wider, 4 to 15° C, and the Rivers Brett and Box in their lower reaches attain summer temperatures up to 18° C. Water flow is nothing more than a trickle in the helocrenes, somewhat in excess of 0·2 metres/second in limnocrenes and 0·7 to 1 metres/second elsewhere. Except in the helocrenes the substrate is generally hard: fine to medium gravel in limnocrenes and brooks, mixed with coarser material in the Brett and Box. Rooted vegetation is absent in the springs, sparse in the brooks, rich in parts of the larger streams. Very little chemical analysis was carried out: calcium values were in all cases higher than 50 mg./litre and alkalinity ranged from 50 to 300 mg./litre except in the springs where values of less than 10 mg./litre were sometimes found. Only certain spring waters showed pH values of less than 7·0, the other waters averaging 7·4 to 7·8.

(1) *Helocrenes*

Two forms of helocrene were examined: (*a*) alkaline spring pools in which woodland debris and silt lay completely submerged; (*b*) wet piles of debris rising above water level fed from slightly acid gravels.

Type (*a*) contained only 1 species, *Thyas rivalis* Koenike, often present in some numbers, while type (*b*) contained 3 species, *Bandakia concreta* Thor, *A-Thienemannia schermeri* Viets and *Arrenurus fontinalis* Viets.

The significance of this difference in fauna may lie in the nature of the substrate in which the mites burrow, that of the spring pools being soft and loose, of the others more firmly packed without the buoyant effect of complete immersion in water. *T. rivalis* of type (*b*) is soft bodied while the species of type (*a*) are hard bodied and better able to penetrate the firmer substrate.

B. concreta, *A-Th. schermeri* and *A. fontinalis* appear to be crenobiontic. *T. rivalis* is known to be partly eurythermous (Lundblad 1927) and although in the present investigation it was found naturally only in conditions of low temperature, eggs and larvae were obtained from individuals kept for several weeks in the laboratory at room temperature.

(2) *Limnocrenes*

8 species were found in limnocrenes but only 3 were confined to this habitat: *Sperchon longissimus* Viets, *Lebertia stigmatifera* Thor and *Hygrobates norvegicus* (Thor). 2 species, *Sperchon glandulosus* Koenike and *Lebertia glabra* Thor, although obviously crenophilous, also occurred less plentifully in brooks of higher summer temperature. *Ljania bipapillata* Thor occurred in both limnocrenes and brooks but mainly in the former. *Sperchon setiger* Thor and *Lebertia celtica* Thor appeared to be casuals in the limnocrene habitat.

(3) *Brooks*

Although the total list of brook Hydracarina contained 14 species, only 4 were at all common or widespread, namely *S. setiger*, *Hygrobates fluviatilis* (Ström),

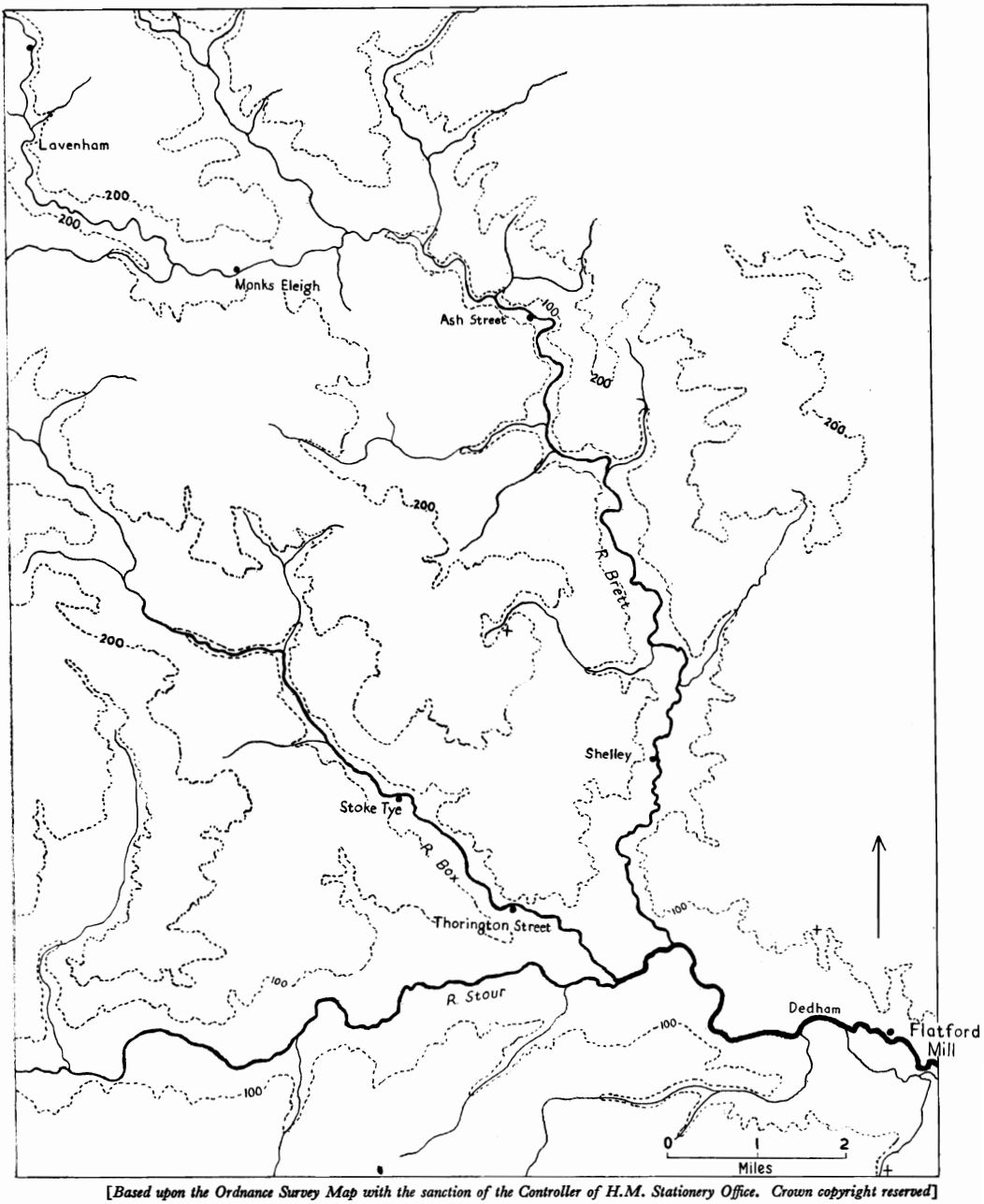


FIG. 1

Rivers Stour, Brett and Box showing sampling stations. Springs investigated are marked +.

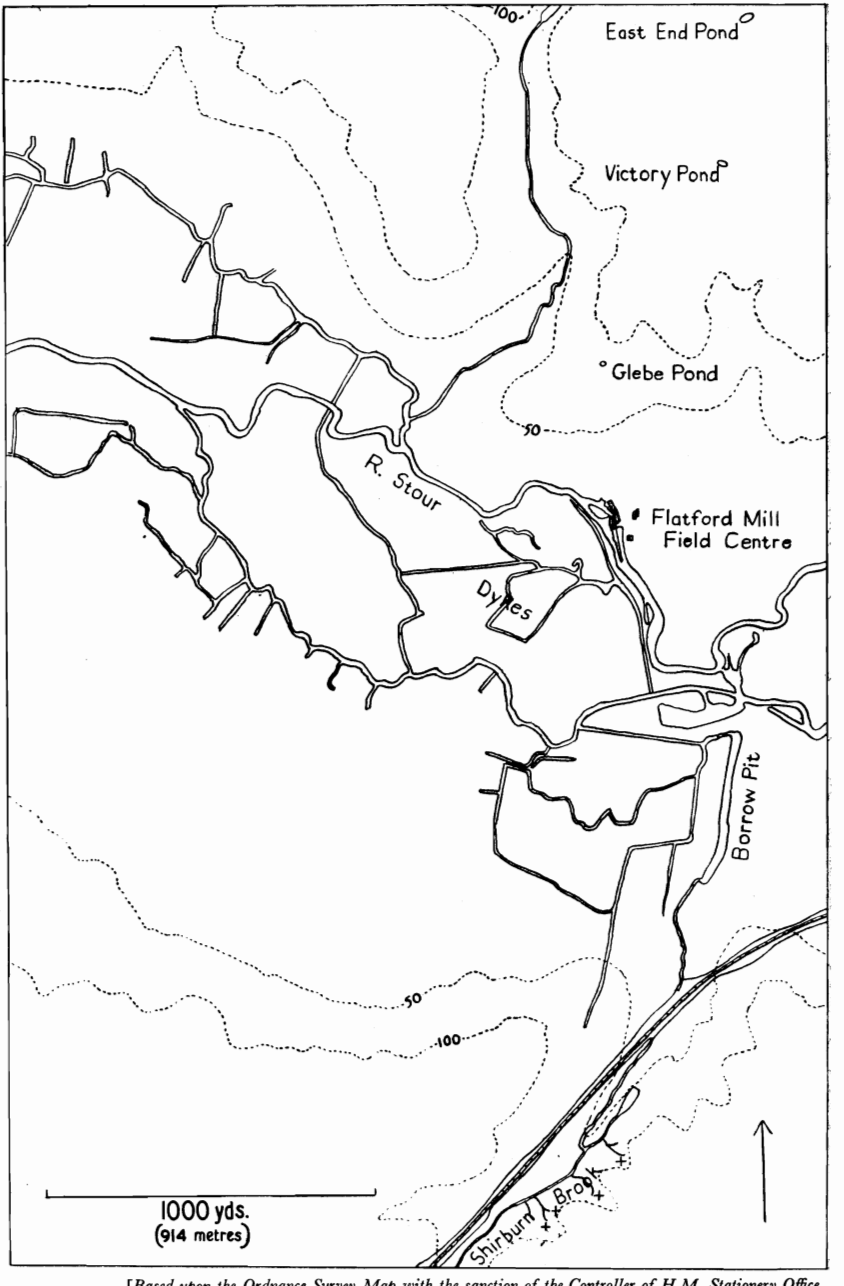


FIG. 2
Area immediately around Flatford Mill showing R. Stour, ponds, dykes and borrow pit.

Atractides nodipalpis (Thor) and *L. glabra*. All the individuals of *A. nodipalpis* belonged to the subspecies *pennata* Viets, supposed by Viets (1936) to be a stenothermous crenobiont.

2 other species of *Sperchon* were found in a few samples, *S. squamosus* Kramer and the crenophile *S. glandulosus*. Viets (1925) assumed the former species to be a crenobiont but its distribution was later shown to be much wider by Lundblad (1927) who discovered it in both mountain and lowland streams in Sweden and even in certain oligotrophic lakes.

Feltria minuta Koenike was taken only in headwaters where temperatures remained lower than in the main courses of the brooks.

The complete list of brook Hydracarina shows a preponderance of eurythermous forms: *S. setiger*, *S. squamosus*, *Sperchonopsis verrucosa* (Protz), *Lebertia porosa* Thor, *L. celtica*, *L. glabra*, *Hygrobates nigromaculatus* (Lebert), *H. fluviatilis*, *Atractides spinipes* (Koch), *A. nodipalpis*, *Wettina podagrica* (Koch) and *Arrenurus cylindratus* Piersig. Several of these occur amongst vegetation in larger streams and some in lenitic habitats. As might be expected in lowland streams the number of predominantly stenothermous species was very small, *S. glandulosus*, *F. minuta* and *Ljania bipapillata* all occurring but rarely.

(4) *Rivers Brett and Box*

These are shallow tributaries of the Stour, considerably larger than the brooks, the Brett 40 kilometres and the Box 20 kilometres long. Both rise on calcareous boulder clay, the first at a height of 100 metres and the second at 60 metres. The Brett was examined more thoroughly than the Box.

Examination of the Brett was carried out in 3 representative reaches, based mainly on the extent of summer vegetation, nature of the substrate and rate of water flow. The Box was treated in the same way but no samples were taken from the upper reaches.

In both streams the lower reaches in summer contained a large variety of aquatic plants growing thickly wherever slack current produced a depositing substrate. In channels free of plants the bed was of medium to coarse gravel with some larger stones. The current varied from 0·3 to 0·7 metres/second, but in winter reached 1 metre/second during times of spate. Higher upstream, the middle reaches, there was considerably less vegetation and a current consistently above 0·5 metres/second producing a bed of coarse gravel mixed with finer material. In the upper reaches of the Brett those parts chosen had a bed of coarse gravel and large stones almost entirely without higher plants; stretches of slow-moving, sedge-choked water also occurred but these were not examined. In this region the Brett approached the size of the larger brooks, though differing from these in its coarser bed.

No regular temperature measurements were made but there was evidence of a decrease in temperature as the headwaters were approached.

The Hydracarina in the lower reaches were mainly plant-loving species dominated by *Hygrobates fluviatilis* and *Hydrodroma torrenticola* (Walter).

Soar (1900) recorded *H. torrenticola* from running water but assumed it to be a variety of *H.* (=*Diplodontus*) *despiciens* (Müller), a lenitic species. Under its correct appellation it has rarely been recorded from Britain. Halbert (1944)

described it from Ireland and T. Gledhill (personal communication) has found it in the River Winster in Westmorland. It has fewer swimming hairs than *H. despiciens* but more obvious distinctions are (*a*) the absence of swimming hairs on the 2nd. legs, (*b*) the shortness of the outer dorsal spine of palp segment 3 (see Fig. 3) and (*c*) the yellowish colour of the adult.

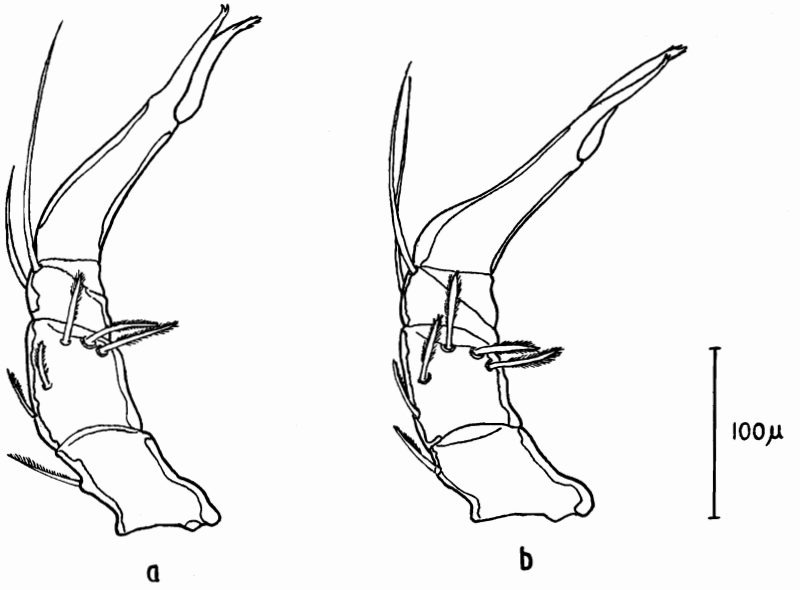


FIG. 3
Left palp of *Hydrodroma:* (a) *H. torrenticola,* (b) *H. despiciens.*

Other species occurring, but much less frequently, were *Lebertia inaequalis* (Koch), *L. porosa, Hygrobates longipalpis* (Hermann), *H. nigromaculatus, Atractides spinipes, Mideopsis orbicularis* (Müller) and *Arrenurus cylindratus.* All are known from lenitic habitats and this region of the Brett and Box might be considered transitional between the lotic and lenitic environment. Characteristically, these Hydracarina were the only lotic species seen to exhibit a large decrease in numbers in the winter months, coinciding with the disappearance of vegetation in late December and January.

Several of the downstream species occurred in the middle reaches, though much less frequently. *H. fluviatilis* was noticeably commoner amongst vegetation than on open gravel where the 2 most abundant species were *Sperchon clupeifer* Piersig and *Hygrobates calliger* Piersig. Neither of these occurred in the lower reaches where, evidently, the extent of suitable gravel was too small.

The upper reaches of the Brett were dominated by *Sperchon denticulatus* Koenike and *Feltria romijni* Besseling. *H. nigromaculatus* was quite common here, but *S. clupeifer* comparatively rare.

(5) *Ecology*

Table 1 shows the distribution of the 30 species taken in lotic habitats. Since no quantitative samples were taken no more than an indication of frequency can be given in the table. However, the distribution is in many cases so sharply delineated that a mere presence and absence list is instructive.

Table 1. *Distribution of lotic Hydracarina.*

Hydracarina	Helocrenes (*a*)	Helocrenes (*b*)	Limnocrenes	Brooks	Brett (upper)	Brett (middle)	Brett (lower)
Thyas rivalis Koenike	+++						
A-Thienemannia schermeri Viets		+++					
Bandakia concreta Thor		++					
Arrenurus fontinalis Viets		+					
Sperchon longissimus Viets			+++				
Lebertia stigmatifera Thor			+				
Hygrobates norvegicus (Thor)			+				
Sperchon glandulosus Koenike			+++	+			
Lebertia celtica Thor			+	+			
Ljania bipapillata Thor			+++	+			
Lebertia glabra Thor			+++	++			
Atractides nodipalpis (Koch)				++			
Sperchonopsis verrucosa (Protz)				+			
Sperchon squamosus Kramer				+			
Feltria minuta Koenike				+			
Wettina podagrica (Koch)				+			
Sperchon denticulatus Koenike					+++		
Feltria romijni Besseling					+++		
Sperchon clupeifer Piersig					+	+++	
Hygrobates calliger Piersig						+++	
Sperchon setiger Thor			+	+++		+	
Hygrobates nigromaculatus (Lebert)				+	+++	+	+
Hygrobates fluviatilis (Ström)				++		++	+++
Atractides spinipes(Koch)				+		+	+
*Lebertia porosa Thor				+		+	+
*Lebertia inaequalis (Koch)						++	+
*Hydrodroma torrenticola (Walter)							++
*Hygrobates longipalpis (Hermann)							+
*Arrenurus cylindratus Piersig							+
*Mideopsis orbicularis (Müller)							+

\+ = species found in less than 25% of samples; ++ = species found in 25-50% of samples; +++ = species found in over 50% of samples.

The larger streams (Brett and Box) provide the richest environment since they contain the greatest variety of habitats—vegetation, coarse and fine gravel, sand, mud, variable current, spatial differences in temperature, etc. Owing to their length they pass through several distinctive regions, each one with its own

typical mite community. Divisions such as these are not as apparent in the brooks which tend to be more uniform, though doubtless a close analysis based on quantitative sampling would again reveal community differences.

Unique amongst the communities examined are those of the helocrenes whose mite fauna appears to be strictly confined to that habitat, even where there is easy access to a neighbouring stream or limnocrene. Since they are burrowing forms requiring a soft substrate they evidently cannot exist on the firm gravel characteristic of limnocrene habitats. Conversely, limnocrene species avoid the silted material of helocrenes. It is conceivable, also, that there are differences in oxygen content between the two habitats, but this was not ascertained. Another factor of importance is that of current. Laboratory experiments, using an artificial stream, showed that *Bandakia* and *Arrenurus fontinalis* were dislodged from stones at current speeds in which limnocrene species (in this case *Sperchon longissimus*, *S. glandulosus* and *Lebertia glabra*) were still fully mobile. *A-Thienemannia*, owing to its flattened shape, was not disturbed, but all 3 helocrene species showed little ability to regain a foothold when artificially dislodged, whereas *Sperchon* and *Lebertia* righted themselves with facility. *Thyas rivalis* was not used in these experiments, but since its larvae hunt their hosts on the water surface it is also excluded from fast moving water.

Stenothermy is an important factor in spring Hydracarina and because of this most spring species tend to be more localized than the more eurythermous forms. Thus, of the 12 species discovered in springs, 7 were found to be crenobiontic and 3 crenophilous.

The remaining lotic communities display less conservatism, but most contain characteristic species rare or absent in the others. This is most noticeable in the brooks with 5 species not found elsewhere, and least noticeable in the thick summer vegetation of the lower Brett and Box to which no single species is confined. Each of these communities contains at least one dominant species: in the brooks *Sperchon setiger*, in the lower Brett and Box *Hygrobates fluviatilis*, in the middle Brett and Box *S. clupeifer* and *H. calliger*, and in the upper Brett *S. denticulatus*. How far they compete with other Hydracarina in the same habitat is unknown, but it is significant that in no locality were 2 species of the same genus found to be equally common.

III. LENITIC HABITATS

All the lenitic habitats investigated support thick summer vegetation.

In the Stour and the deepest flood-plain dykes the vegetation is not fully developed until May and June and consists mainly of *Myriophyllum spicatum* L., *Ceratophyllum demersum* L. and *Hippuris vulgaris* L. growing at depths of 1 to 2 metres. In the Stour there is also a rich growth of *Glyceria fluitans* (L), *Sagittaria sagittifolia* L. and *Nuphar lutea* (L). In those parts of the dykes with less than 0·5 metres of water *Carex riparius* Curtis is common.

The remains of a reedswamp, *Phragmites communis* Trinius, extend along one bank of the 400 metre long borrow pit, with *Elodea canadensis* Michaux growing outside these in water down to 1·5 metres deep.

In the small cattle ponds the flora consists mainly of *Glyceria plicata* Fries and species of *Juncus* in the shallows, *Callitriche stagnalis* Scopoli, *Ranunculus peltatus*

Schrank and *Potamogeton crispus* L. in deeper water. The largest pond has a surface area when full of about 500 sq. metres.

Various species of filamentous algae develop in all these waters.

Winter temperatures from November to March seldom exceed 6° C. Beneath ice, which is rarely continuous for more than a week, temperature varies between 1 and 2° C. The Shirburn Brook (see Fig. 2) has a pronounced effect on temperature conditions in the borrow pit, maintaining relatively high values (4–5° C) at the southern end despite ice coverage elsewhere.

From March the temperature begins to rise, reaching highest values between June and September.

Summer temperature rises very high in the cattle ponds, occasionally reaching 29° C. From June to September temperature minima are rarely less than 15° C and during daylight the water may remain for several hours above 20° C. These small bodies of water suffer a high degree of drought, being reduced by August to odoriferous pools of less than a quarter of their maximum areas.

The remaining waters exhibit a narrower range of summer temperature with maxima between 18 and 20° C and minima around 15° C. Highest readings are found in the borrow pit reedswamp.

Fluctuation of dissolved oxygen is an important factor in lenitic waters. Mann (1958) describes ponds in which the oxygen content falls to 0–10% saturation from June to September. Unfortunately, regular oxygen measurements for the Flatford ponds exist only for the period September to December 1961, with one isolated series made 26–27 July 1953. In 1961 the ponds were found to be completely anoxic (midday readings) beneath the surface from 13th September to 25th October. Probably they had been in this condition since July when the almost complete disappearance of small Crustacea and the die-back of vegetation (except *Lemna*) were first noted.

During the period when readings were taken the Stour, dykes and borrow pit showed high oxygen concentrations (80–90% saturation). It seems doubtful whether these waters become anoxic.

(1) *River Stour*

A striking feature of the Stour populations is the great abundance of *Limnesia maculata* (Müller) which in 1961 frequently made up over 80% of each sample. This species appears to be more voracious than most and in captivity will readily attack other Hydracarina. If this habit persists in its natural environment *L. maculata* may exercise an important influence as a predator on other mites.

Probably rivalling this species in its own restricted environment is the parasitic *Unionicola intermedia* (Koenike) which accomplishes the whole of its life history within large Lamellibranchs. In the Stour its host is *Anodonta cygnea* (Linnaeus). More than 100 specimens of *Anodonta* were examined and very few were found to lack this parasite. The fact that the host is abundant throughout the lower reaches of the Stour suggests a dense population of *U. intermedia*.

2 other species of *Unionicola* were also found in the river :*U. crassipes* (Müller) and *U. aculeata* (Koenike). Both are free-living as adults. *U. crassipes* spends its larval and, to a lesser extent, nymphal life in freshwater sponges. The larvae of

U. aculeata parasitize Lamellibranchs. Probably because of larval competition with *U. intermedia*, *U. aculeata* is scarce in the Stour.

Amongst the most characteristic summer Hydracarina in the Stour are species of *Hydrachna* and *Eylais*. *H. globosa* (de Geer), *H. paludosa* Thor, *E. infundibulifera* Koenike, *E. extendens* (Müller) and *E. soari* Piersig appear to be confined to the river; *H. cruenta* (Müller) and *E. hamata* Koenike also occur rarely in other waters.

Another species confined to the river is *Limnochares aquatica* (Linnaeus), a bottom-living species. Its numbers in this environment may well be greater than was apparent since few samples were taken specifically from the bottom.

The genus *Piona* is well represented, the two large species *P. longipalpis* (Krendowsky) and *P. coccinea* (Koch) being the most frequent. No other genera of the large family Pionidae were found, though several of these are common in neighbouring waters.

Mideopsis orbicularis is a common inhabitant of the river bottom. According to Viets (1928) it burrows in the surface layers of the mud. It is one of the few lenitic species not governed by a preference for vegetation and was frequently taken in areas of bare mud unoccupied by other Hydracarina.

Only 2 species of *Arrenurus* were found: *A. albator* (Müller) and *A. crassicaudatus* Kramer. This genus appears to reach its greatest development in small or shallow waters, especially amongst thick vegetation. Thus, 5 species were recorded from the ponds, 6 from the borrow pit and 10 from the dykes.

(2) *Dykes*

A remarkable variety of Hydracarina were collected in the flood-plain dykes. A majority of the river species occur here, all but 4 of the borrow pit species and one third of the pond species.

Commonest are *L. maculata* and *Brachypoda versicolor* (Müller). The latter is a typical inhabitant of thick algal growths where, according to Meuche (1939), its small flattened shape is advantageous in creeping amongst the close growing filaments. It is found abundantly amongst curtains of filamentous algae growing with *Myriophyllum* in the deeper dykes and, to a lesser extent, in *Cladophora* mats in the borrow pit. In the Stour, algal growths are seldom as concentrated and *Brachypoda* correspondingly less common.

Neumania vernalis (Müller) is common in early spring and in the autumn. Between April and August it is rare during which period, however, *N. deltoides* (Piersig) appears in small numbers.

As in the Stour several species of *Piona* occur and in addition the related genera *Tiphys*, *Pionopsis* and *Forelia*.

Arrenuridae occur in unusual variety with *Arrenurus securiformis* Piersig the most abundant. Less numerous are *A. globator* (Müller), *A. albator* and *A. crassicaudatus*. The remaining 6 are of rare occurrence.

(3) *Borrow pit*

The borrow pit was the largest body of enclosed or semi-enclosed water examined, with a surface area of some 6,000 sq. metres. Most of the samples were taken in shallow water in the thin fringe of reedswamp extending along

the east bank. There appeared to be few planktonic animals in the open water beyond the swamp but a rich fauna at the bottom amongst *Elodea*. A number of bottom samples were taken from deeper water at various times of year.

5 species of Hydracarina predominated: *Limnesia undulata* (Müller), *L. koenikei* Piersig, *Hygrobates longipalpis*, *Piona variabilis* (Koch) and *Arrenurus cylindratus*. All of these were of fairly long-term appearance, occurring in most months of the year. Quantitative sampling in 1961 showed an increase in the numbers of *H. longipalpis* and *A. cylindratus* in the autumn.

Hydrochoreutes krameri Piersig appeared for a short period extending from May to September with a maximum in June. It is interesting that no males were ever found; Halbert (1944) states that there is usually a great disparity in numbers between the sexes.

2 other common species were also of short-time appearance, namely *Tiphys torris* (Müller) and *Piona rotunda* (Kramer). In 1961 some numbers of *L. maculata* appeared suddenly in August. Since this species is usually rare in the borrow pit it is assumed that the phenomenon was due to immigration of Chironomidae from the river carrying larval *Limnesia*.

(4) *Cattle Ponds*

Probably owing to high temperature and anoxia in the summer months, the largest number of pond Hydracarina are found in the early part of the year, especially between March and June. The tendency for short-term appearance is pronounced amongst these species.

Hydrachna leegei (Koenike) and *Eylais hamata* Koenike merit special comment, although not found commonly. Most species of *Hydrachna* and *Eylais* are active during the summer, at a time when conditions in the ponds are most rigorous. *H. leegei* and *E. hamata*, however, occur early in the year and for this reason are the only members of the two genera able to utilize this habitat.

Other common spring species are *Hydryphantes ruber* (de Geer), *Tiphys latipes* (Müller), *Pionopsis lutescens* (Hermann) and *Piona nodata* (Müller).

Few mites are found commonly in the summer months, *Piona carnea* (Koch) and *Arrenurus buccinator* (Müller) being often the only species in samples taken during July and August. Curiously, *P. carnea* reaches its maximum numbers in June and July during the period of high temperatures and semi-drought.

A. buccinator was the only species found commonly in all months of the year. From November to February no other mites were taken as adults, though Pionid nymphs occurred sporadically. Its maximum numbers occur in early autumn, a characteristic which has been found in many other Arrenuridae (Sparing 1959).

(5) *Ecology*

The information gained from lenitic areas is augmented by the results of quantitative sampling carried out between January and December 1961. These samples were taken (*a*) in emergent vegetation in the River Stour, (*b*) amongst *Carex* and *Myriophyllum* in the dykes, (*c*) in the reedswamp of the borrow pit, and (*d*) from various points in three cattle ponds. These are all shown in Fig. 2. The method employed for each sample was to sweep a pond net for half a minute in such a way as to pass it through all the water within reach from a

standing position on or near the bank. Figs. 4-7 show the annual cycle of adult activity assessed from these samples.

Table 2 shows the distribution of Hydracarina found in lenitic habitats.

Table 2. *Distribution of lenitic Hydracarina.*

Hydracarina	River Stour	Dykes	Borrow Pit	Cattle Ponds
*Hydrodroma torrenticola (Walter)	+			
Eylais extendens (Müller)	+			
Limnesia connata Koenike	+			
Unionicola aculeata (Koenike)	+			
Hydrachna globosa (de Geer)	+			
Hydrachna paludosa Thor	+			
Limnochares aquatica (Linnaeus)	+			
Eylais infundibulifera Koenike	+			
Eylais soari Piersig	++			
Eylais hamata Koenike	++			+
Unionicola intermedia (Koenike)	+++			
Hydrachna cruenta (Müller)	++	+		
Neumania deltoides (Piersig)	++	++		
Piona longipalpis (Krendowsky)	++	++		
*Mideopsis orbicularis (Müller)	++	++		
Arrenurus albator (Müller)	+	+		
Piona coccinea (Koch)	++	++		+
Piona circularis (Piersig)	+	+		
Piona rotundoides (Thor)	+	++		
Unionicola crassipes (Müller)	+	+	+	
Limnesia maculata (Müller)	+++	++	++	+
Limnesia koenikei Piersig	+	+	+++	
Arrenurus crassicaudatus Kramer	+	++	++	
Neumania vernalis (Müller)	+	+++	+	
Brachypoda versicolor (Müller)	+	+++	++	
Eylais rimosa Piersig	+	+		+
*Lebertia porosa Thor		+	+	
*Lebertia inaequalis (Koch)		+		
Forelia liliacea (Müller)		+		
Forelia variegator (Koch)		+		
Arrenurus sinuator (Müller)		+		
Arrenurus mediorotundatus Thor		+		
Arrenurus cuspidifer Piersig			+	
Limnesia fulgida Koch		+	+	
Arrenurus securiformis Piersig		++	++	
Tiphys torris (Müller)		++	++	
*Arrenurus cylindratus Piersig		+	+++	
Piona variabilis (Koch)	+	+	+++	+
Piona rotunda (Kramer)	+	++	+	+
Limnesia undulata (Müller)		++	+++	+
Pionacercopsis vatrax (Koch)			+	
Hydrochoreutes ungulatus (Koch)			+	
Hydrochoreutes krameri Piersig			++	
Arrenurus inexploratus Viets		+		+

Hydracarina	River Stour	Dykes	Borrow Pit	Cattle Ponds
Pionopsis lutescens (Hermann)		++		+++
Arrenurus globator (Müller)		+	+	++
Piona nodata (Müller)		+	+	+++
*Hygrobates longipalpis (Hermann) ..	++	++	+++	
Arrenurus cuspidator (Müller)		+		+
Piona conglobata (Koch)		+	+ +	++
Tiphys latipes (Müller)		+		++
Arrenurus buccinator (Müller)		+	+	+++
Tiphys ornatus Koch			+	+
Piona carnea (Koch)	+	+		+++
Hydryphantes ruber (de Geer)				++
Hydrachna leegei (Koenike)				+
Piona uncata (Koenike)				++
Euthyas truncata (Neumann)				+
Thyopsis cancellata (Protz)				+
Arrenurus novus George				+

Symbols as in Table 1 but allowance is made for periodicity by estimating the frequency of each species only for its season of greatest abundance.

All told, 60 species were taken, with at least a third of this number recorded from every habitat. With such large numbers involved there arises the possibility of serious interspecific competition. This is aggravated by two factors. Firstly, Hydracarina appear to prey on a very small variety of animals, mainly Cladocera, Ostracoda and Chironomid larvae. Secondly, many species parasitize, as larvae, the same hosts, e.g. Chironomidae are parasitized, with little specificity, by *Hydryphantes*, *Lebertia*, *Limnesia*, *Hygrobates*, *Neumania*, *Hydrochoreutes*, *Pionopsis*, *Tiphys*, *Piona* and several species of *Arrenurus* (Sparing 1959).

However, the position is seen to be less acute when it is realized that many common species exhibit periodicity in activity so that, in fact, few are abundant in the same habitat at the same time of year. Where related species do occur abundantly together they are frequently of dissimilar size, an indication of different food-size preferences. Examples of this are *Limnesia undulata* and *L. koenikei* in the borrow pit, *Tiphys latipes* and *T. ornatus* in the cattle ponds, *Arrenurus securiformis* and *A. crassicaudatus* in the dykes. Conversely, related species in the same size group tend not to coincide in time, e.g. *Arrenurus globator*, *A. crassicaudatus* and *A. albator* follow each other in consecutive months in the dykes (Fig. 6), and *Piona nodata* and *Pionopsis lutescens* show a similar pattern in the cattle ponds (Fig. 4).

It is difficult to discern which factors are primarily concerned in limiting the distribution of lenitic Hydracarina. Little work seems to have been done on the extent to which predation may control water mite populations. The possibility of heavy predation by *Limnesia maculata* on other Hydracarina has already been mentioned: one may suspect some correlation between the great abundance

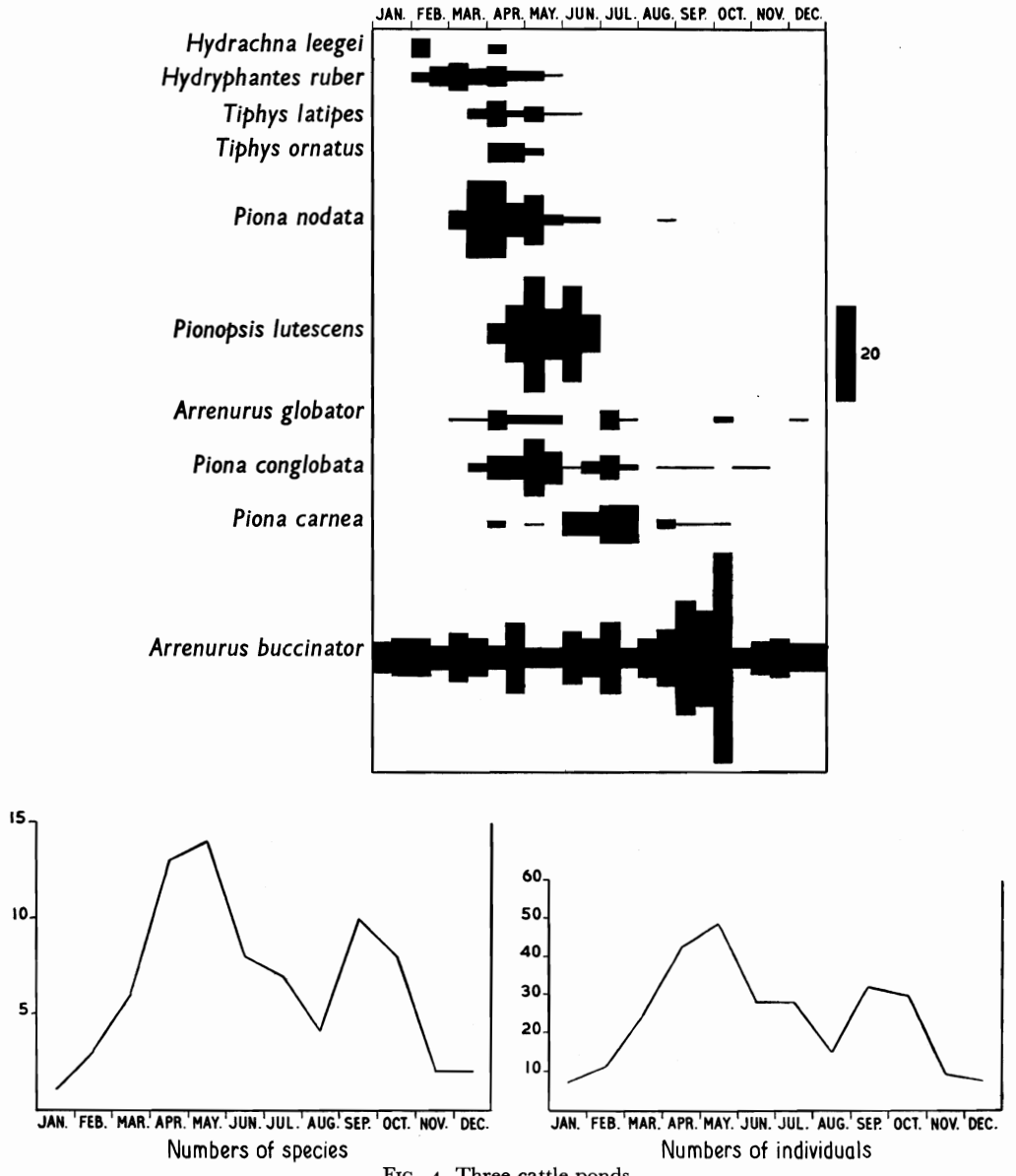


FIG. 4. Three cattle ponds.

FIGS. 4-7. The seasonal cycle, 1961, of adult Hydracarina in four sampling areas near Flatford Mill. In each figure the histogram shows the individual cycles of selected species and the other two diagrams show the changes in total numbers of Hydracarina through the year.

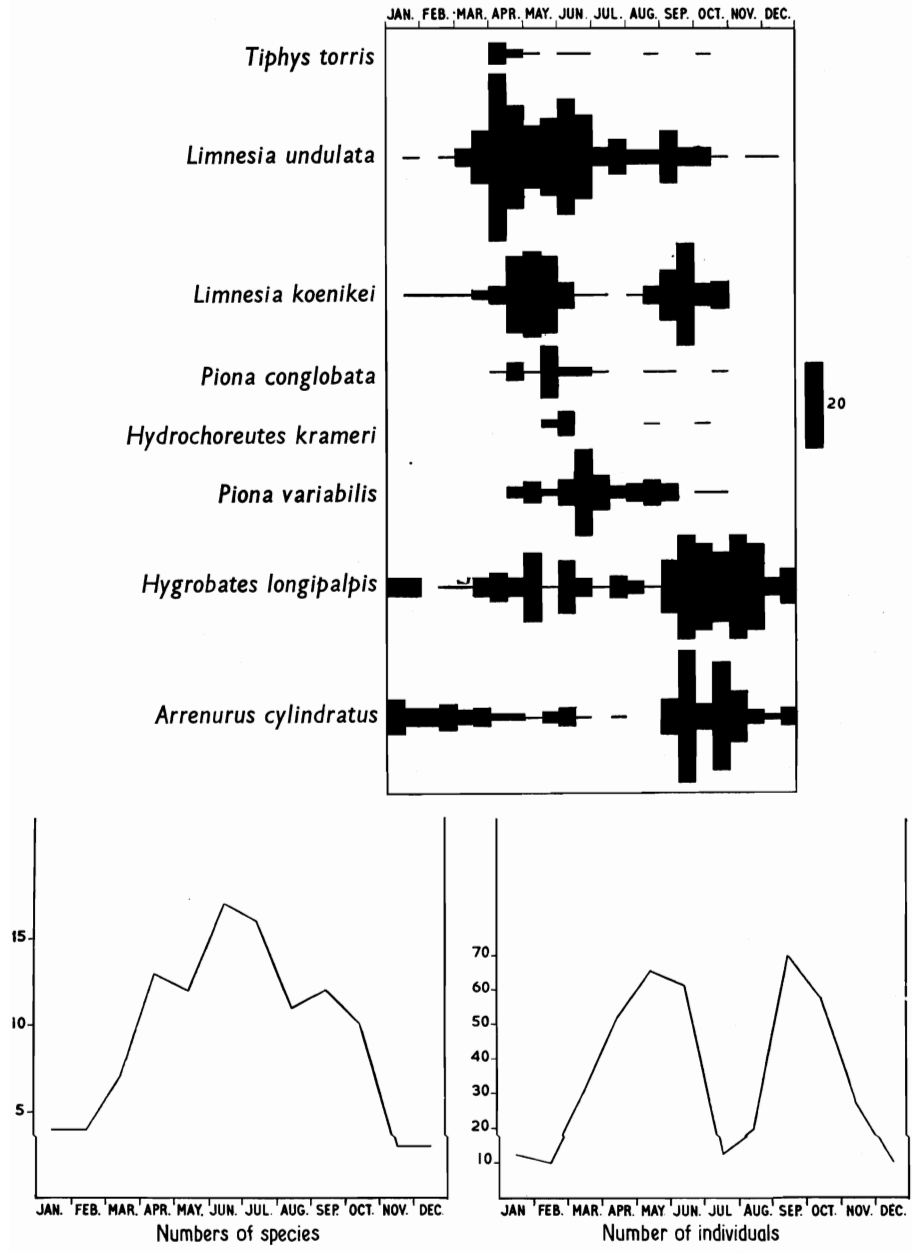


FIG. 5. Borrow pit (reedswamp).

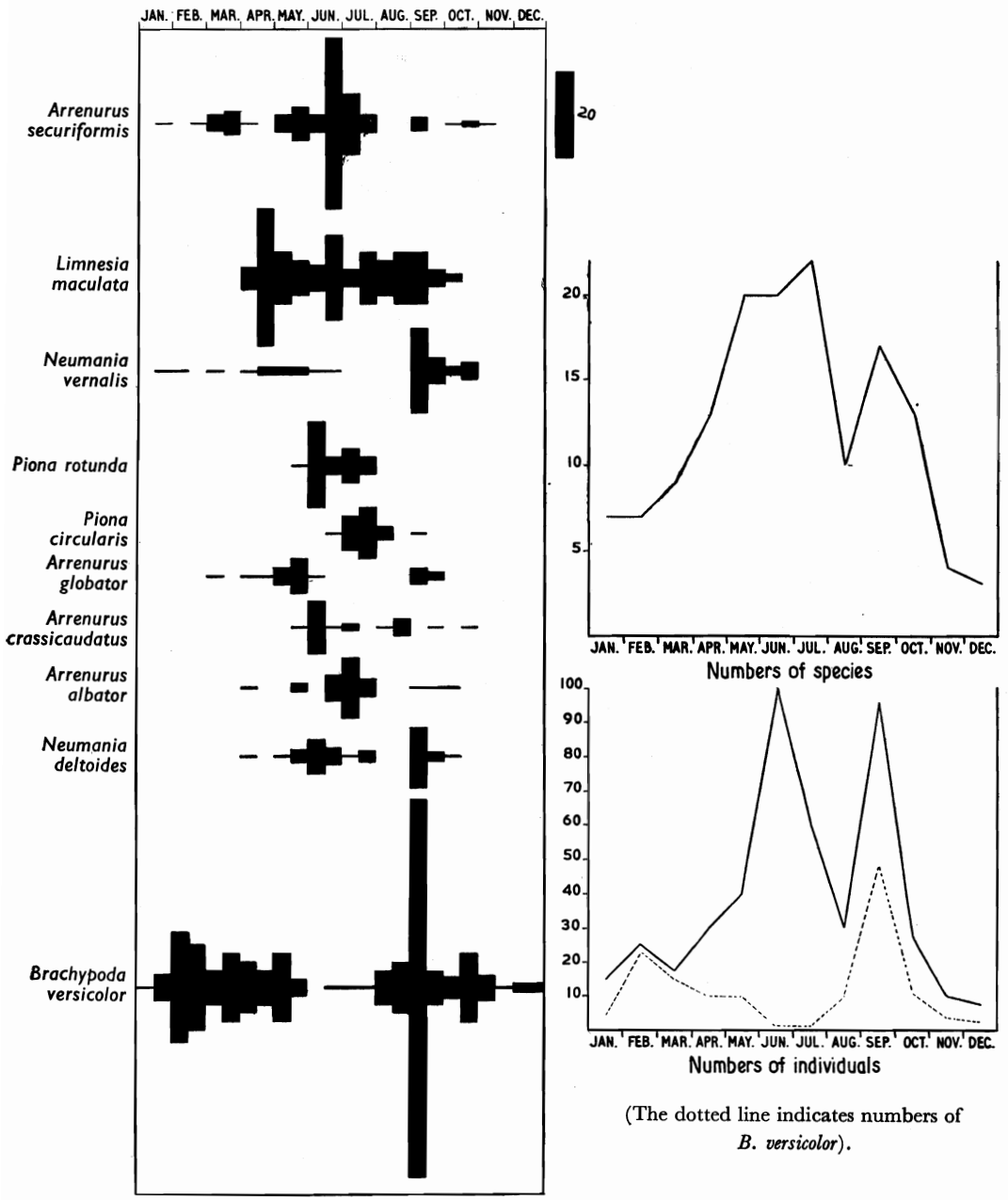
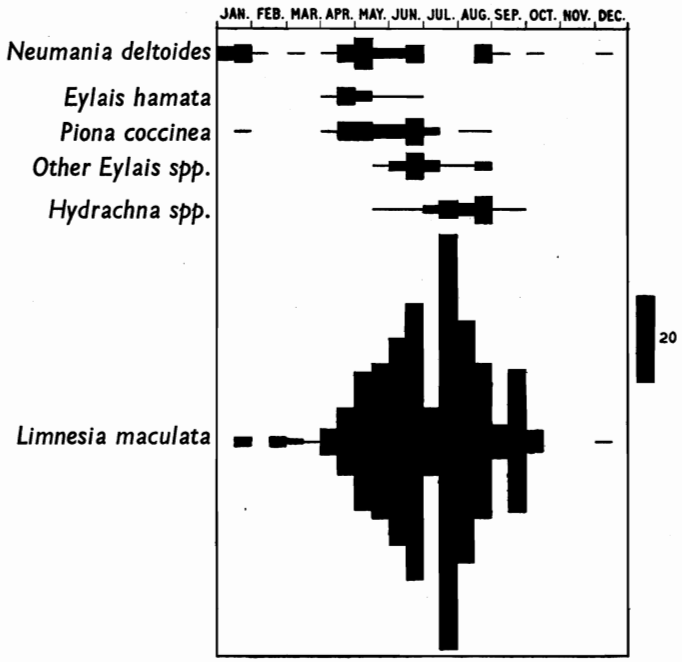
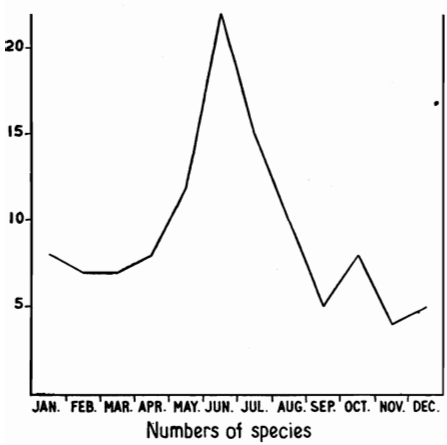
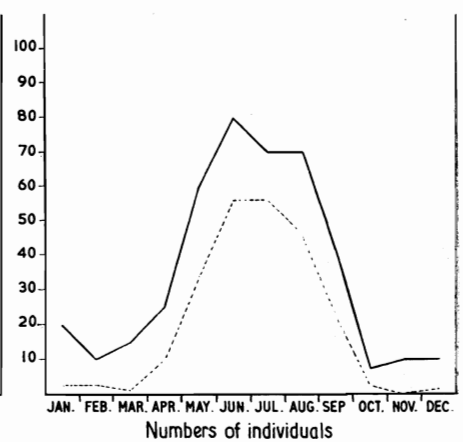


FIG. 6. Dykes (amongst *Carex* and *Myriophyllum*).







(The dotted line indicates numbers of *L. maculata*).

FIG. 7. River Stour.

of this one species throughout the year in the Stour and the comparative rarity of most of the others. At least a few species are distasteful, e.g. stickleback and young roach and dace refuse *Limnesia*, *Hygrobates* and *Unionicola*, Odonata initially refuse *Eylais*, *Limnochares* and *Limnesia*.

A number of experiments were designed with a view to determining how extreme conditions in the hottest months might prejudice the survival of adult Hydracarina in the cattle ponds, since it was evident that in July and August the population was much less than in spring and autumn. Lundblad (1927) suggests that the appearance of several species common to temporary waters is timed so that the maximum of adult activity takes place before the summer drought.

Resistance to drought seemed to be effective in all species tried provided they were allowed to burrow into damp mud. Survival occurred in most individuals even after several weeks in drying mud. Curiously, samples taken from mud bordering the shrunken ponds in August and September, 1961, yielded only 4 mites: 2 *A. buccinator* and 2 *Thyopsis cancellata* (Protz). A greater number was expected after laboratory experiments had demonstrated the long period over which Hydracarina could resist desiccation.

Experiments were also made to gauge the effects of high temperature. Individuals were put in containers of river water and, as a rough approximation to the hottest periods in the summer, temperature was maintained at 25-27° C for 12 hours, followed by a fall to 17-19° C for the next 12 hours. This pattern was repeated for 120 hours, the mites being examined every 8 hours. The results appear in Table 3. The majority of the species seem capable of surviving this treatment except for *H. longipalpis*, *N. deltoides*, *B. versicolor* and the males of *A. cylindratus*.

A further set of experiments was carried out to investigate reactions to oxygen starvation. Various Hydracarina were kept in river water with an oxygen content of less than 0·4 mg./litre (>4% saturation) obtained by boiling. The results, laid out in Table 4, show that most species survived 100 hours—the duration of the experiments. Only in 5 species did the majority of individuals fail to survive. *A. buccinator* and *A. cylindratus* provide an interesting case in which the males are more prone to oxygen starvation than the females. Even the lowest survival rate is enough to ensure continued activity for, whatever the state of the bottom water, the surface layers remain oxygenated and mites can swim into this zone at intervals. However, not all lenitic species are habitual swimmers. *Lebertia*, *Hygrobates*, *Hydrochoreutes* and *Brachypoda*, for instance, tend to crawl, either on the bottom or on vegetation. In the absence of vegetation they probably remain on the bottom. Since under summer anoxic conditions the pond vegetation largely dies back these species could hardly survive in this habitat.

In general these experiments indicate that the more obvious summer extremes obtaining in the ponds are not hostile to adult Hydracarina apart from predominantly crawling forms. However they may be inimical to active development of eggs since in most species these are laid on water plants which collapse in the summer, thus exposing the eggs to the foul conditions of the bottom. It is therefore advantageous for the adults to be in active breeding condition early in the year. Sparing (1959) states that some Pionidae, amongst them *Tiphys ornatus* and *Pionopsis lutescens*, die after egg deposition. The rapid decline of

Table 3. *Reactions of Hydracarina to high temperature.*

Species	Number used	Number dead or immobilized after *x* hours													
		12	20	28	36	44	52	60	68	76	84	92	100	108	116	120+
Lebertia porosa	10									2						8
Limnesia undulata	20			1												19
L. koenikei	20															
Hygrobates longipalpis ..	25	1		4	3	11		2	2	1	1					
Unionicola crassipes	10						1					1	1			7
Neumania vernalis	10															10
N. deltoides	10			3		1	3			1	2					
Piona conglobata	10															10
P. coccinea	5															5
P. rotundoides	10															10
Brachypoda versicolor ♂♂ ..	20			4	5	4	2	1	4							
B. versicolor ♀♀	20			2				3	4	2	2	2			3	2
Arrenurus crassicaudatus ♀♀ ..	10															10
A. cylindratus ♂♂	10		3				2	2		3						
A. cylindratus ♀♀	20							1					1			18
A. buccinator ♀♀	20					1										19

Table 4. *Reactions of Hydracarina to oxygen starvation.*

Species	Number used	Number dead or immobilized after *x* hours											
		12	20	28	36	44	52	60	68	76	84	92	100+
Libertia porosa	6												6
Limnesia undulata	10						1				1		8
L. koenikei	20			1	2	1					4		12
Hygrobates longipalpis	20		7	6	2	5							
Unionicola crassipes	6	2						2			2		
Neumania vernalis	10										1		9
Hydrochoreutes krameri	5	1	3	1									
Tiphys torris	5											1	4
Brachypoda versicolor	12		2				6						4
Mideopsis orbicularis	6												6
Arrenurus buccinator ♂♂	6	3	1	2									
A. buccinator ♀♀	20												20
A. cylindratus ♂♂	8	3	3		2								
A. cylindratus ♀♀	20												20

Tiphys latipes and *Piona nodata* in May and June suggests that these, too, die after laying.

It will be seen from Figs. 5-7 that most of the common species in other localities attain maximum numbers later in the year. Ovigerous females can be found as late as July and August, existing as they do under less rigorous summer conditions. But there is a distinct drop in numbers in the borrow pit reedswamp during July and August. Samples taken in these months from deeper water in the borrow pit revealed large numbers of mites so that probably during periods of high temperature there is a general retreat from the shallows into cooler regions. An even sharper drop is shown in Fig. 6 for the dykes. Only the river population maintains a high density throughout the summer.

The lenitic mites are plant-loving forms with the exception of the mud-burrowing *Mideopsis* and parasitic *Unionicola intermedia*. It is therefore scarcely surprising that the winter populations of active Hydracarina are considerably less than the summer. The numbers of Hydracarina drop to very low values between October and February. The majority of species appear to overwinter in a dormant state, as eggs (*Eylais*), as nymphochrysalids (*Hydrachna*, attached to the host) or as nymphs (most of the others). But some species remain active throughout the winter, though in small numbers. Various Pionidae are found as nymphs. Adult Hydracarina found in samples between November and February are: *Limnesia maculata*, *L. undulata*, *L. koenike*, *Hygrobates longipalpis*, *Unionicola intermedia*, *U. crassipes*, *Neumania deltoides*, *N. vernalis*, *Piona coccinea*, *P. rotundoides*, *Brachypoda versicolor*, *Mideopsis orbicularis*, *Arrenurus crassicaudatus*, *A. globator*, *A. securiformis*, *A. cylindratus and A. buccinator*.

In addition to these *Piona rotunda* (by Viets 1928) and *P. longipalpis* (by Sparing 1959) are stated to overwinter as adults.

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