Fld Stud. (1976), **4**, 465–476

CORIXIDAE (WATER BOATMEN) OF THE NORTH-WEST MIDLAND MERES

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Introduction

The biology of the North-West Midland Meres which lie mainly in Cheshire and Shropshire has been largely neglected. These meres (Fig. 1) are amongst the few lakes lying entirely in a lowland glacial drift plain and, as such, they are a unique group in the British Isles. Little has been published about them. Sinker (1962) surveyed a range of habitats in Shropshire. The phytoplankton of the meres is discussed by Lind (1949, 1951). Reynolds (1973) has presented evidence that the phytoplankton succession is so distinctive and characteristic as to justify its being described as a "regional type". Data on the invertebrate fauna of eight meres and a comprehensive bibliography are to be found in Young and Harris (1974).

This survey describes the distribution of species of Water-boatmen (Corixidae) in the meres in relation to geological, chemical and biological environmental factors during the period 1969–1975. The data are discussed in relation to the habitat preferences of individual species, the distribution of species in the succession from open water to firm ground as the vegetation changes and its dead remains accumulate (the "hydrosere"), and the value of Corixidae as indicators of lake types. Other authors have discussed the same kind of data from other areas, in particular Macan (1938, 1954*a*, 1955, 1970) and Southwood and Leston (1959): we believe our results confirm and extend theirs.

The Nature and Origin of the Meres

The meres are typically small shallow lakes. Their areas vary from 2 to 50 hectares; the maximum depths of those sounded vary from 2 to 30 metres and their surfaces stand at altitudes ranging from 15 to 100 metres above Ordnance Datum. They are fed mainly by water which has percolated through glacial drift to become enriched, especially with bases. The majority are alkaline and have a high conductivity, showing a rough inverse correlation with altitude. The Cheshire meres generally have a higher conductivity than those in Shropshire (Table 1). The most abundant cation is calcium and the most abundant anion bicarbonate (Gorham, 1957*a*, 1957*b*; Savage, 1971). The meres of the Ellesmere group remain thermally stratified for several months during the summer (Reynolds, 1973) as does Petty Pool. The cold, lower layer (hypolimnion) of Petty Pool was devoid of oxygen during the summer of 1967—the only season when measurements were taken—and was in a state for which the term eutrophic is often used. The meres are also eutrophic in the more literal sense; richly supplied with nutrients and capable of high levels of algal production.

The region is almost covered by a thick mantle of glacial drift overlying Triassic rocks, which include notably the Upper Keuper saliferous beds, present in much of

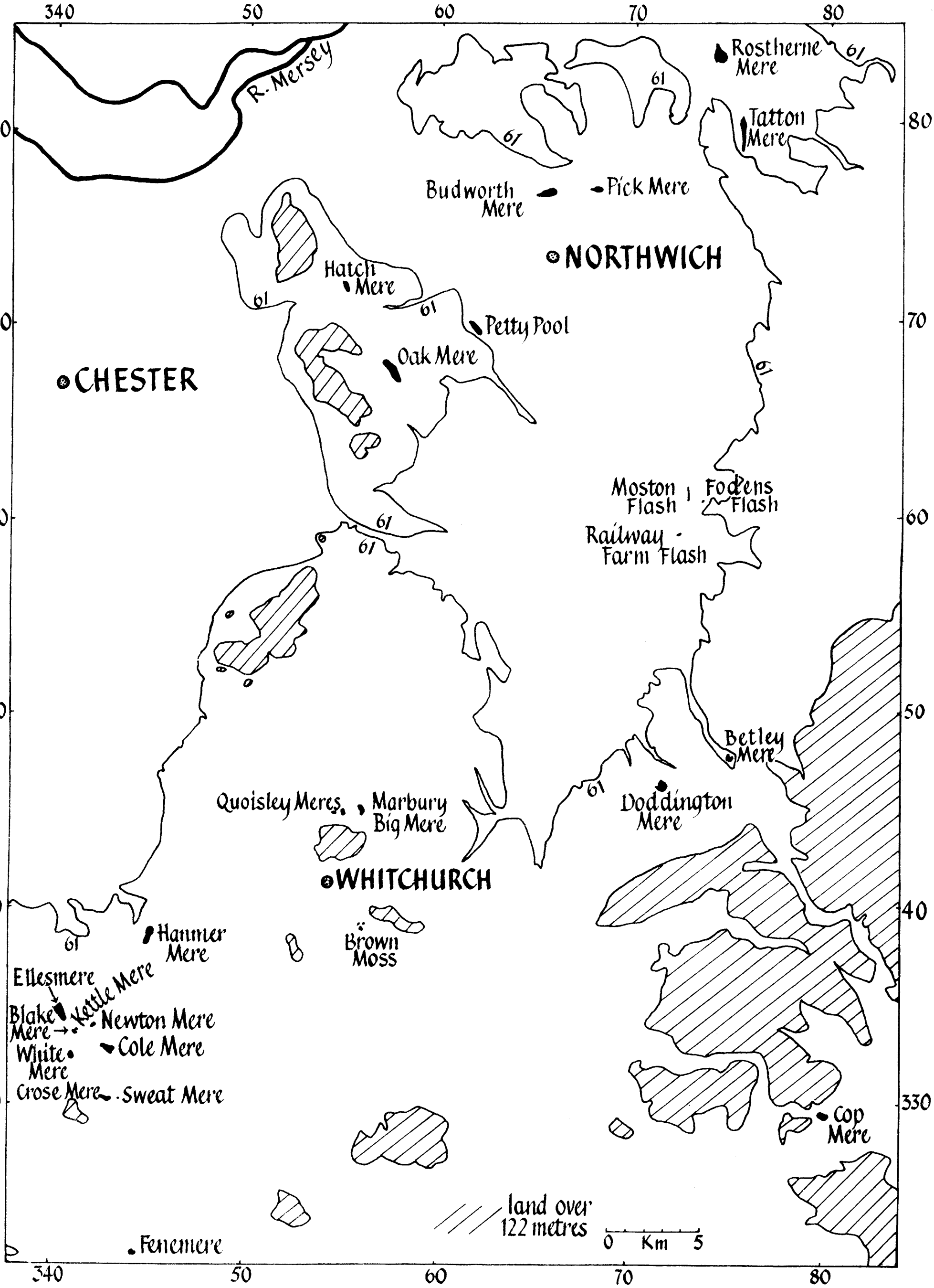

FIG. 1.
Map to show the relative positions of the lakes used in this study.

eastern Cheshire and northern Shropshire. The drift itself consists of a complex mixture of unstratified boulder clay and stratified silts, sands and gravels (Evans *et al.*, 1968; Poole and Whiteman, 1966; Taylor *et al.*, 1963). The clays are impervious to water and a few meres probably lie on "perched" water tables supported by a clay substratum. It seems likely, however, that the majority lie in permeable drift and are in depressions which fall below the level of the general water table. Some of these depressions were originally holes in the drift occupied by iceblocks which melted to form "kettle holes". Some were caused by natural subsidence due to the nature of the drift and the solution of the superficial layers of the salt-containing (saliferous) beds, some by the late glacial drainage systems and a few, known as "flashes", due to the extraction of naturally occurring brine by the chemical industry.

Further details may be found in Shaw (1972), Sinker (1962), Tallis (1973), and Worsley (1970). There are useful brief comments on individual meres in Evans *et al.* (1968), Pocock and Wray (1925), Poole and Whiteman (1966), and Taylor *et al.* (1963).

Methods

Adults and fifth instar nymphs were collected with a pond net, sometimes from the bank, sometimes from a boat, at a number of sampling sites representing the different sets of conditions around the shores of each mere, in each case working intensively for ten minutes. (This is later referred to as a "unit catch".) Many of the sites were visited several times during all months of the year except April and September but mainly in late autumn, winter and mid-summer, when migration is infrequent (Popham, 1964) and the samples were more likely to reflect the indigenous species present. Fifth instar nymphs taken during the summer provide further evidence of breeding populations. The identification of specimens was based on the keys of Macan (1965), Cobben and Pillot (1960) and Jansson (1969). Fifth instar nymphs, particularly of *Sigara falleni* and *Sigara distincta*, were maintained in the laboratory until they moulted to adults.

At each sampling site the nature of the substratum was noted both directly and by consulting drift maps. The proportion of organic matter in the substratum was determined by combustion of a core sample or estimated by inspection. The pH and conductivity of surface water samples were measured, the latter being used as an indicator of the total salt concentration. The most abundant reedswamp plants were recorded.

Results

For the purposes of presentation an attempt has been made to arrange the meres in an order related primarily to the abundance of reedswamp vegetation and surrounding fen peat. The meres at the beginning of Table 1 show few emergent plants and little or no peat formation; the prominence of these features increases as one proceeds down the table. They have changed very little in their physical, chemical and vegetational characteristics during the last 20 years (Gorham, 1957*a*, 1957*b*; Reynolds, 1973; and personal communication by C. Tait Bowman).

Two sites have been considered separately in Tables 2 and 3. Sweat Mere differs from all the other waters in being extremely rich in types of vegetation, so much so that, in 1962, Macan was able to distinguish several distinct zones of vegetation

Table 2. *Collections at four stations in Sweat Mere (from Macan, 1967). (For description of mere see text.)*

	S. dorsalis	*S. falleni*	*S. distincta*	*H. linnei*	*H. sahlbergi*	*C. praeusta*	*C. punctata*
Edge of *Typha* bed	6	14	3	—	—	2	—
Open bottom and edge of *Carex* bed	5	9	1	—	3	1	—
Middle of *Typha* bed	—	—	—	5	8	2	5
Pools in fen behind *Typha* bed	—	—	—	1	7	—	—

Table 3. *Collections at Fodens Flash 1971–1974. (For description of Fodens Flash see text.)*

Date	Specific conductivity at 25 °C (micromhos/cm3)	*S. dorsalis*	*S. falleni*	*H. linnei*	*C. praeusta*	*S. concinna*	*S. lateralis*	*C. punctata*	*S. stagnalis*
13.9.71	2700	8^n	1	—	—	1	7	—	—
4.10.71	3150	33	—	—	—	—	—	—	1
10.10.72	2050	7^n	1	2	1	—	5	—	—
4.10.73	1680	76^n	122^n	—	60	3	2	—	1
16.10.74	1150	7^n	32^n	—	1	—	—	1	—

n = nymphs also present

(Macan 1967). It is also unusual in that its evolution is still progressing relatively undisturbed. The vegetation is described in Sinker (1962), who gives pH 7.4 and describes the water as having a high base status. Fodens Flash, too, is unusual in that the salinity has been gradually decreasing in the last few years and it has extensive emergent vegetation consisting of *Typha sp.* and *Glyceria maxima*.

Taking the meres as a whole, the trend towards greater development of vegetation is to some extent positively correlated with increasing specific conductivity of the water. Well-developed reed beds are mainly between 5 and 15 metres wide, although at Budworth Mere and Quoisley Small Mere they reach widths of about 30 metres. At many sites the reed beds abut directly on to agricultural land or deciduous woodland. Small patches of true fen carr are present at the western end of Crose Mere and near the outflow at the north west corner of Betley Mere. Several of the Shropshire meres have belts of trees overhanging the water, which must give some shelter from wind, notably at Newton Mere, White Mere, Cole Mere, Blake Mere and Kettle Mere, the last two being almost completely surrounded by trees.

We collected the following species of Corixidae (numbers of specimens taken are shown in each case): *Sigara falleni* (Fieber) 1647, *Sigara dorsalis* (Leach) 370, *Callicorixa praeusta* (Fieber) 262, *Sigara lateralis* (Leach) 78, *Sigara distincta* (Fieber) 50, *Sigara concinna* (Fieber) 22, *Hesperocorixa linnei* (Fieber) 11, *Corixa punctata* (Illinger) 7, *Arctocorisa germari* (Fieber) 5, *Sigara stagnalis* (Leach) 2. One specimen of *Sigara fossarum* (Leach) was taken by Macan in 1962 and he also found *Hesperocorixa sahlbergi* (Fieber) in Sweat Mere. Tables 1, 2 and 3 show their distribution in the meres.

Where different sites in any one lake were sampled, e.g. sandy shore, reed beds, etc., very little variation was found in the species present and their relative numbers, and it was considered justifiable to group such samples together (see also Macan 1967).

Table 1 shows that *Sigara falleni* is the most abundant and successful species in the meres. It was taken in every collection except at Railway Farm Flash where the lowering of the water level and the absence of any emergent vegetation along the shore may have had an important influence.

Sigara falleni comprised two-thirds or more of the catch in the majority of situations (an analysis being made wherever the total specimens taken at a site were more than 10). These meres are designated Group B (see later). Group A, by contrast, comprises those sites (Doddington Mere, Moston Flash, Budworth Mere, Crose Mere, Quoisley Small Mere, Hanmer Mere, Kettle Mere and Brown Moss) where the other species associated with *S. falleni* occur in fairly large numbers and together represent more than one-third of the total. Table 4 shows that in Doddington Mere, Moston Flash and Budworth Mere *S. dorsalis* is of importance; in Crose Mere and Quoisley Small Mere *Callicorixa praeusta* is the main additional species; and in Hanmer Mere, Kettle Mere and Brown Moss both of them and *S. distincta* are important.

S. dorsalis is characteristic of nutrient-poor (oligotrophic) waters where the substratum has a low content of organic matter (Macan 1954*a*) and its close relative *S. striata* (Linnaeus) is characteristic of large nutrient-rich (eutrophic) lakes (Macan, 1954*b*). *S. dorsalis*, recorded in ponds by Macan (1954*a*), and common in ponds in the North West Midlands (personal observations), is commonest in the meres which are placed near the beginning of Table 1. Doddington, Hanmer and Budworth meres are relatively exposed whilst Kettle and Sweat Meres are small and perhaps have more in common with ponds. Moston Flash was formed during the present century. The distribution of *S. dorsalis* seems to be related therefore to meres in which the hydrosere has not yet reached the late stages, except in Sweat Mere which is very small.

Table 4. *Percentages of* Sigara dorsalis, Callicorixa praeusta *and* Sigara distincta *present in Group A meres (i.e. those in which* Sigara falleni *comprises less than two-thirds of the total. Totals given are of the open water species* S. dorsalis, S. falleni, S. distincta, S. concinna C. praeusta, A. germari.

Name of mere	Total no. specimens	*S. dorsalis*	*C. praeusta*	*S. distincta*
Doddington	80	50	16	—
Moston	400	29	4·8	—
Budworth	67	33	12	—
Crose	249	8·0	30	—
Quoisley Small	36	—	39	—
Hanmer	75	19	17	27
Kettle	46	30	28	20
Brown Moss	24	—	17	30

S. distincta generally occurred in small numbers but its proportion of the catches was greatest in the meres placed near the beginning of Table 1. Nymphs of corixids were recorded from a total of eleven meres but those of *S. distincta* from the two acid meres only. These findings are in accord with others already published.

Callicorixa praeusta is reported to frequent moderate sized bodies of water which may be tainted by slight organic pollution (Macan, 1954*a*). We have no evidence to support this; indeed the distribution of this species within our area cannot be satisfactorily correlated with any of the environmental factors measured. It occurs in the majority of places in at least small numbers and fifth instar nymphs were found in three meres. Conditions must be generally favourable but nowhere has it built up a large population.

Although *S. falleni* is the most successful species in the meres, Table 3, which shows data for Fodens Flash, a body of water which has changed in its chemical nature over the past few years, suggests that it is adversely affected by a total salt concentration giving a specific conductivity of above about 2000 micromhos. A pH in the region of 8 may be optimal for *S. falleni* (Walton, 1943), but it seems to be able to tolerate a pH of just below 7 in the meres (e.g. Newton Mere and Kettle Mere).

Sigara lateralis is well documented as being associated with the presence of cattle fouling and trampling; the sites where we found it were like that. *Arctocorisa germari*, *Sigara concima* and *Corixa punctata* all occur in very small numbers and this is to be expected. *A. germari* seems to be a species of deep water (Southwood and Leston, 1959) and lays its eggs on stones (Crisp, 1962). *S. concinna* is successful in slightly saline water (Savage, 1971), though the occurrence of two nymphs in Marbury Mere indicates that it can breed in non-saline water. *C. punctata* is a species of ponds (Macan, 1954*a*).

The data from each site where more than 10 specimens of *S. falleni*, *S. dorsalis*, *C. praeusta* and *S. distincta* were taken have been looked at mathematically. The indices of similarity for each site compared with all the remaining sites were calculated. These indices were then used to construct a dendrogram (Fig. 2) after the method of Mountford (1962). Each index of similarity was calculated using the equation:

$$\frac{(a_1 \cdot b_1 + a_2 \cdot b_2 + \ldots\ldots\ldots a_n \cdot b_n)^2}{(a_1^2 + a_2^2 + \ldots\ldots\ldots a_n^2) \cdot (b_1^2 + b_2^2 + \ldots\ldots\ldots b_n^2)} = \text{Index of Similarity}$$

where a_1 is the percentage of individuals of a given species at a particular site and b_1 the percentage of individuals at another site; a_2 and b_2 are the respective percentages for the second species and so on up to any number of species. For example:

	S. dorsalis	*S. falleni*	*S. distincta*	*C. praeusta*
Moston Flash	29% (a_1)	65% (a_2)	0% (a_3)	5% (a_4)
Kettle Mere	30% (b_1)	22% (b_2)	20% (b_3)	28% (b_4)

$$\frac{(29 \cdot 30 + 65 \cdot 22 + 0 \cdot 20 + 5 \cdot 28)^2}{(29^2 + 65^2 + 0^2 + 5^2) \cdot (30^2 + 22^2 + 20^2 + 28^2)} = 0{\cdot}46$$

The validity of the method of course depends on the assumption that the samples are a true representation of the proportions of species present. This assumption was justified by calculating indices of similarity for successive unit catches obtained from one station on Betley Mere and one on Moston Flash, both of which were visited on several occasions over a period of 4 years. The mean indices were 0·99 and 0·86 respectively, indicating that successive relatively small catches were closely similar to each other. This suggests that the sampling method was reliable and that there is sufficient validity for carrying out a comparison of the meres on this basis. The indices have been calculated to only two places of decimals because the data did not justify further mathematical refinement. It should be noted that if the same species are present in identical proportions in two places then their index of similarity is 1; if there are no species in common then the index is 0.

The dendrogram is a classification of the meres based on their indices of similarity calculated from the corixid data. The number indicated at each division of the dendogram is the index of similarity between the separate groups of meres encompassed by that division. For example, the index of Budworth and Moston compared with the thirteen meres to the right is 0·80.

This analysis (Fig. 2) agrees well with the separation of the meres based only on the proportions of *S. falleni*. Thirteen of the meres (coincident with Group B) form a homogeneous group characterized by the presence of *S. falleni* in large numbers. These thirteen show a common index of similarity of 0·93, and it may be argued that there is no case for attempting to distinguish between them at all on the available data. They have expanses of open water from 4–48 hectares surface area. With the exception of Newton Mere and White Mere they show fairly well-developed emergent vegetation and some active peat formation. It is perhaps significant that the two which do not have fringing emergent vegetation do have belts of overhanging trees, and one might tentatively suggest that shelter is an important factor whether provided by reed beds or trees. The majority also show considerable evidence of peat formation in the past. These features in eutrophic alkaline lakes perhaps provide optimum conditions for *Sigara falleni.*

Group A meres are not so closely related in their corixid faunas (see Table 4 and those placed to the left of a line between Budworth Mere and Petty Pool in Fig. 2) and can be placed in categories already described according to the relative importance of the three species *Sigara dorsalis*, *Sigara distincta* and *Callicorixa praeusta.*

Discussion

Fig. 2 shows that the meres do not form a homogeneous group. The meres forming our Group B, in which *Sigara falleni* is the species occurring in largest numbers, nearly all have well-developed reed beds and areas of fen peat. The varied patterns in Group A show a number of species apparently competing for numerical supremacy and Table 4 shows that this group may be further subdivided into several categories. Fodens Flash and Sweat Mere are exceptional. Thus it seems that there are a number of distinct types of mere. Indeed a division into two groups based on vegetation has already been made by Sinker (1962). Further comparative studies should prove rewarding.

This study attempts to relate the distribution of corixid species in small eutrophic lakes to the present state and past history of the hydrosere as shown by the occurrence of emergent vegetation and fen peat. Macan (1954*b*) has shown that in the Danish Lakes the corixid succession *striata–linnei–sahlbergi* is correlated with the hydrosere

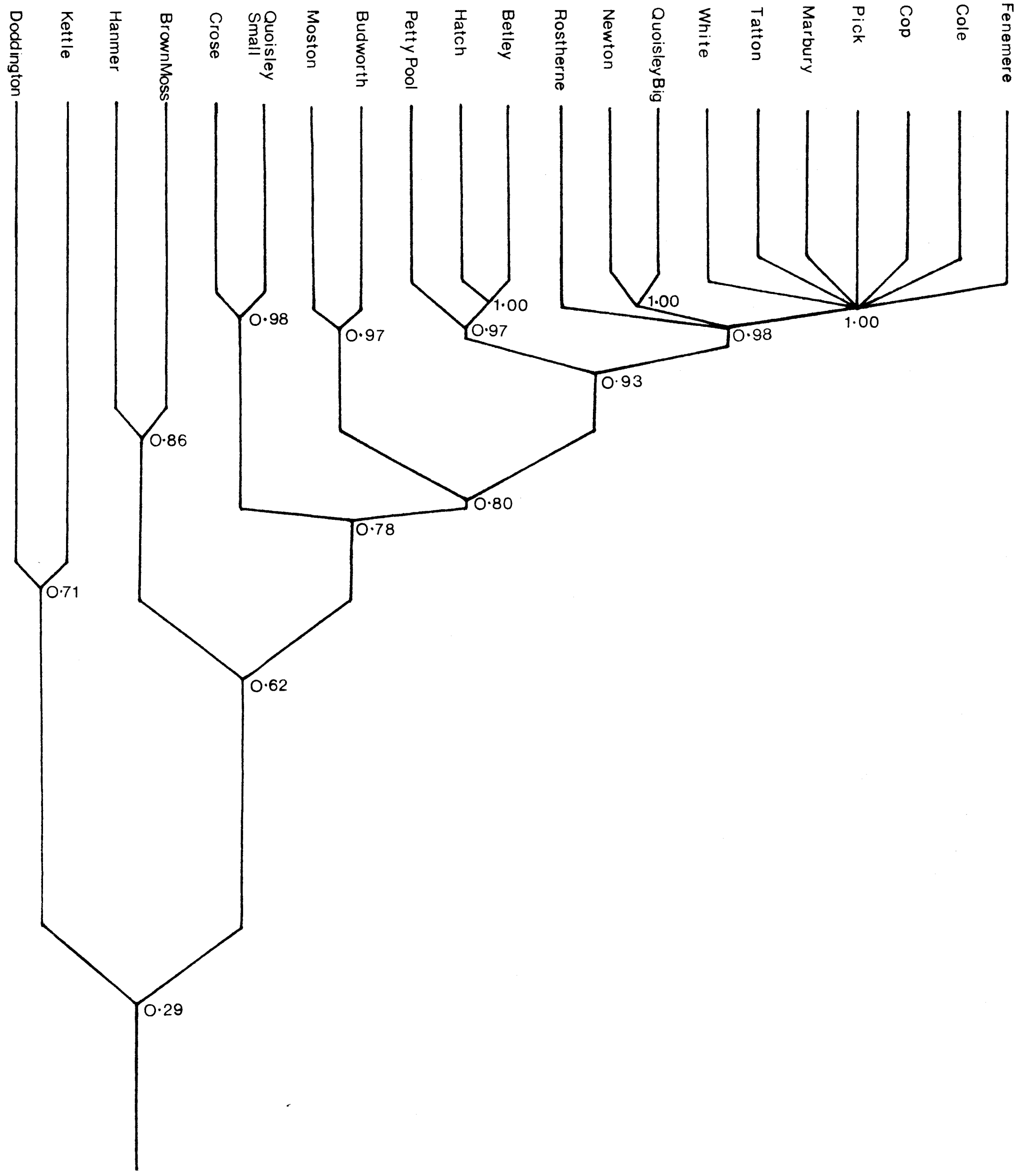

FIG. 2.

Dendrogram to show the relationships of some lakes based on an analysis of their corixid faunae.

succession from open water to alder carr. Similarly Macan (1967) in Sweat Mere (Shropshire) showed that the succession *dorsalis*–*falleni* > *linnei–sahlbergi* occurred. Later Macan (1970) suggested that the succession in small eutrophic lakes is likely to be *falleni–linnei–sahlbergi*. If the meres in Table 1 are regarded as having either progressed only a very small way along the hydrosere succession or if it is considered that the intensive human activity around them, particularly the reclamation of fen peat, has in some way inhibited or interfered with their evolution, as indeed seems the case when they are compared with the Danish lakes (Macan, 1954*b*) and Sweat Mere, then Macan's (1970) placing of *Sigara falleni* is confirmed by the results of our survey.

It is surprising, however, that only 11 specimens of *Hesperocorixa linnei* and not a single *H. sahlbergi* were among the 2454 taken in these meres which, in several cases, do have well-developed reed beds and extensive surrounding areas of fen peat which indicate an advanced evolutionary state at some time in the past. We particularly searched the surrounds of the meres, especially any pools in the small patches of fen carr which sometimes exist, but without finding specimens of *Hesperocorixa linnei* and *H. sahlbergi*. The only body of water, other than small ponds, in which both specimens have been taken is Fodens Flash (Savage, 1971). Thus virtually no positive evidence has been found to support the later stages of the corixid succession proposed by Macan. Either Macan's scheme is not of general application, or as has already been suggested, each of the North-West Midland meres represents the hydrosere succession held back at a very early stage by human interference such as drainage of surrounding wetlands and trampling by cattle. The latter explanation is difficult to accept in some cases, particularly at Quoisley Small Mere, where the surrounding plant community, though perhaps not quite so extensive and rich, is similar to that of Sweat Mere. A comparison between the extent of reed beds and fen carr associated with the English meres and the Danish lakes may help to resolve this anomaly. Whereas in the meres the maximum width of reed beds is some 30 metres, in the Danish lakes, in particular Lake Fure, where Macan found *H. linnei* and *H. sahlbergi* in large numbers, reed beds are as much as 100 metres wide. Only a very few small patches of relatively undisturbed fen carr up to 20 metres wide are found around the meres whereas around parts of Lake Fure the fen carr is of the order of 1000 metres wide. It seems reasonable to conclude therefore that the meres investigated in this survey provide largely open water conditions since they generally lack highly developed examples of the later stages of the hydrosere succession and associated species of Corixidae. If this is the case then Macan's hypothesis would still stand.

As for open water sites, Table 5 shows an analysis of our results for Groups A and B (where the total number of individuals of the relevant species are higher than 10) compared with others for the Lake District lakes, the Danish lakes and lakes in Wales and Scotland. The percentage of the total sample (number of specimens) at each site assignable to each species represented in the table was calculated. The sites were then grouped as shown, and the species percentages re-calculated for each group as a whole, giving equal weight to every site in a group whatever its proportional contribution to the total number of specimens in the right-hand column.

Macan (1955) made a similar comparison using the data then available but based his analysis on the presence or absence of a species. In both cases the lakes are arranged in order in a series beginning with extremely oligotrophic lakes and ending with highly eutrophic ones. A purely linear arrangement is no longer possible, since the large eutrophic Danish lakes have a different corixid fauna from the small eutrophic lakes of the English North-West Midlands, Llyn Coron, Llyn Hendref (Anglesey), and the relatively small sheltered and isolated Møllebugt section of Lake Esrom. *Sigara striata* (*dorsalis*) remains as the most successful species in the large lakes whilst *S. falleni* is the most successful in small lakes.

Table 5. *The distribution of some species of Corixidae in lakes. Data collected from Macan (1955), Savage (1971) and authors' collections. Figures are percentage numbers of specimens in total catch calculated to not more than two significant figures (see also text) and values below 0·1% have been omitted.*

Name of water and grid reference	pH	Sp. conductivity	*S. scotti*	*S. dorsalis*	*S. distincta*	*S. falleni*	*S. concinna*	*C. praeusta*	*S. fossarum*	*H. linnei*	*H. sahlbergi*	No. of specimens
Llyn Cwm Bychan SH 640313 Loch a'Bhaillidh NR 755633	6·4	56	**100**									68
Ennerdale NY 105150 Crummock NY 158188 Derwent NY 260210 Bassenthwaite NY 215295	6·5	42* 59* 70*	41	50	*7·0*			*2·7*				418
Coniston SD 305945 Ullswater NY 430205 Tal y Llyn SH 718100	 6·7	69* 63* 60	*0·2*	**100**								481
Windermere SD 390970		N67* S74*		**57**	27	*2·9*			12		*1·0*	769
Esthwaite SD 360965		101*	*1·6*	29	32	27		*0·8*	10			825
Blelham NY 365005	7·5	105*		49	*8·4*	13		14	15		*0·5*	215
Llyn Hendref SH 398766 Llyn Coron SH 378700	7·2 8·4	390 355		27	*0·4*	**59**	*0·5*	11	*0·5*		*2·1*	537
N W Midlands Meres Group A	6·8 to 8·4	158 to 790		21	*9·8*	46	*1·4*	21		*1·2*		973
N W Midlands Meres Group B	6·8 to 8·6	130 to 870		*3·0*	*1·7*	**87**	*2·5*	*5·4*				1258
Esrom Møllebugt				*9·0*		**89**		*1·8*				54
Esrom Fure (Main basins open water)				**72**		23		*0·6*	*0·6*	*2·8*	*2·3*	651
Watch Lane Flash SJ 728606	8·4	3000 to 7000		*7·7*		*0·5*	**89**	*2·7*				414

* = Sp. conductivity measured at 20 °C, all others being at 25 °C.
Map references for the Danish lakes are as follows:
Esrom Lat. 56°0′, Long 12°22′; Fure Lat. 55°48′, Long 12°24′.
Precise values for pH for the lakes Crummock, Derwent, Bassenthwaite, Coniston, Ullswater, Windermere and Esthwaite have not been indicated in the table. The values range from about 6·5 to about 7·5 in increasing order down the list. (Personal communication J. F. Talling.)

A further point of interest is the distribution of *Sigara fossarum* which occurs in considerable numbers only in Windermere, Esthwaite and Blelham. *S. dorsalis* is also present in large numbers in all three but the distributions of *S. distincta*, *S. falleni* and *Callicorixa praeusta* prevent them from being presented as a single figure in Table 5.

Windermere is regarded as a lake towards the end of the oligotrophic series; Esthwaite and Blelham are eutrophic (Macan, 1970), but probably relatively unproductive when compared with the North-West Midland meres. An examination of Table 5 suggests that *Sigara distincta* is associated with the end of the oligotrophic series whilst *Callicorixa praeusta* and *S. falleni* are associated with the beginning of the eutrophic series.

The species present in the more oligotrophic lakes are those one would expect, whether in England, Wales or Scotland. The species found in the North-West Midland meres suggest a division into two groups, of which Group A is closely similar to two lakes in Anglesey. We cannot demonstrate any detailed relationship between corixid species and chemical factors or productivity within these eutrophic waters. Rather, other factors such as degree of hydrosere development and peat formation or shelter by overhanging trees may be important.

In conclusion, Fig. 3 derived from Table 5, suggests how corixids might be used to indicate lake types. We also hope it may stimulate further investigation into the causes of their distribution.

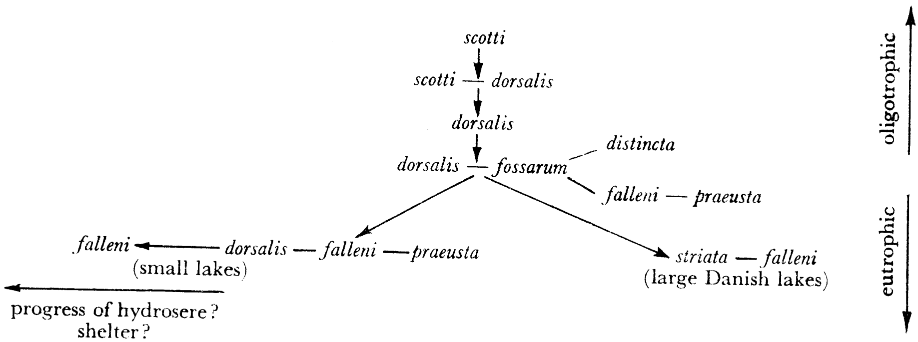

FIG. 3.
A suggested scheme for the relationships of species of Corixidae and lake types.

ACKNOWLEDGEMENTS

We are grateful to the many landowners who allowed access to the meres. Thanks are also due to Miss R. M. Badcock, the Biology Department of Keele University, for encouragement and laboratory facilities for M. M. Pratt, to Dr. T. T. Macan who confirmed some of our identifications, to Dr. J. F. Talling for data on specific conductivities of Lake District lakes, to staff of the Institute of Geological Sciences for data on drift distribution, and to Mrs. C. Tait Bowman for some of her unpublished results.

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