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# THE DISTRIBUTION OF CORIXIDAE IN LAKES AND THE ECOLOGICAL STATUS OF THE NORTH WEST MIDLANDS MERES

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ABSTRACT

The distributions of Corixidae are described in three meres with differing water chemistry, and differing amounts of organic matter in their substrata. Significant relationships are demonstrated between the distributions, of both individual species and communities, with these environmental factors. The results are discussed in relation to present knowledge on the distribution of Corixidae in lakes. Species successions are suggested for the North West Midlands meres, and for British lakes in general. It is then argued that the generalisations drawn may be used as a basis for the ecological evaluation of lakes. An evaluation is attempted for the North West Midlands meres.

## INTRODUCTION

THERE ARE APPROXIMATELY sixty meres in the lowland glacial drift plain of the English North West Midlands (Fig. 1). With few exceptions, these lakes are eutrophic (productive) and contain base-rich water of high conductivity (Reynolds, 1979; Savage & Pratt, 1976). Superficially, they appear to show little diversity regarding environmental factors or in their plant and animal communities. However, a closer study reveals that they form a series, with distinct differences in chemical concentration of the water, and in the degree of development of marginal vegetation.

In an earlier study of the distribution of Corixidae in twenty-five meres, Savage & Pratt (1976) revealed the probability of considerable ecological diversity. They failed to demonstrate clear associations between the various communities and particular sets of environmental conditions. The two basic hypotheses, derived from studies in the Cumbrian Lake District (Macan, 1938; 1970), were that there would be differences in corixid communities related to water chemistry, and to the degree of development of the marginal vegetation (hydrosere succession). Later, Savage (1982b) demonstrated significant correlations between the distributions of corixid species and water chemistry in British lakes, and argued that they might be used as a basis for lake classification.

The present paper is an attempt to demonstrate the relationships between corixid distribution and environmental conditions by a very limited study of three meres, chosen to represent the range of conditions in the North West Midlands. The results are first discussed in relation to the established patterns of corixid distribution in British lakes, and an attempt is made to develop a general scheme. The conclusions so derived are used to evaluate the ecological status of the meres.

## METHODS

Three collecting stations were envisaged for each mere, at set positions relative to the marginal vegetation. I, in open water on the outer edge of the reeds, or other emergent

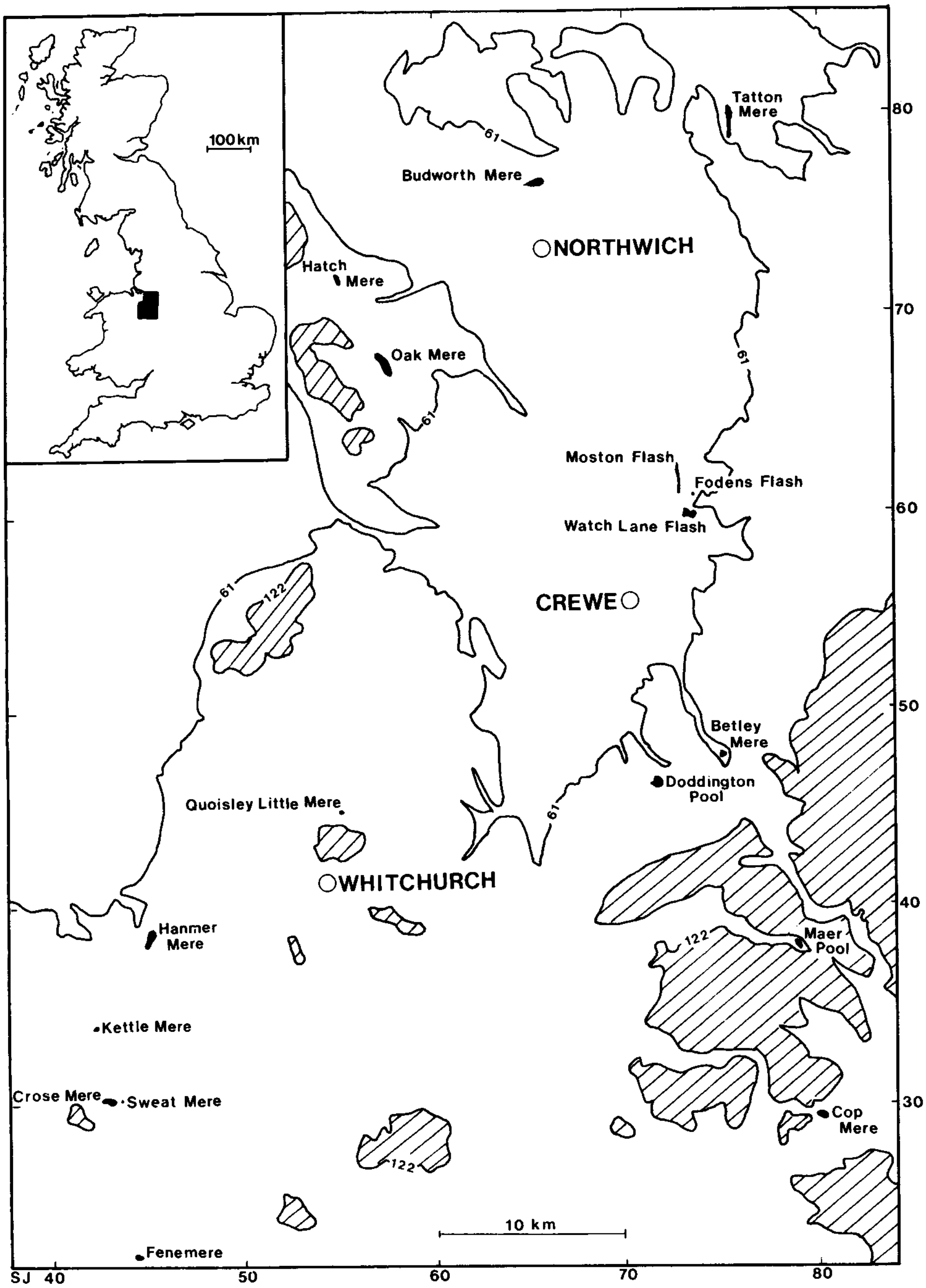



FIG. 1.
A map of the North West Midlands, showing the location of the meres mentioned in the text (adapted from Savage & Pratt, 1976).

plants; II, in the middle of the reed bed; and III, at the back of the reed bed (i.e., on the side nearest to the land) or in submerged fen carr adjacent to the land. In fact, all three stations were possible at only one of the three chosen meres, because the amount of marginal vegetation varied. Nevertheless, the basic designation was retained to facilitate comparisons.

Corixidae were collected by means of five standard net sweeps at each station on each visit. The net was 20cm wide by 25cm deep and with a 0.5mm mesh. A standard net sweep consisted of vigorous scooping movements with the net, forwards in water and backwards in air, over a length of 0.5m for 8 seconds. The technique was practised in the densest reed bed, and subsequently repeated at all stations. Surface water samples were collected in polyethylene bottles at each station. Ten, surface–10cm depth, substratum cores were taken at each station.

Corixidae were identified and counted. Arithmetic mean catches and 95% confidence limits, after logarithmic transformation, were calculated for each set of five standard net sweeps at each station on each visit (see Elliott, 1977). The conductivity, pH, and concentrations of the major ions in the surface water samples were estimated by the methods described in Savage (1982a). Percentage organic matter in the substratum samples was estimated by ignition to constant weight, after acidification to pH 4.5, washing and drying at 105°C.

The relative species compositions of the corixid communities at each station were compared by the calculation of indices of similarity and the construction of a dendrogram (see Mountford, 1962; Savage, 1982b; Savage & Pratt, 1976). The two available dichotomies on the dendrogram were tested for significance (see Mountford, 1971; Shepard, 1984).

Records of rainfall and evaporation at RAF Shawbury (SJ 553220), the nearest appropriate climatological station, were provided by the Meteorological Office.

## THE MERES AND THE COLLECTING STATIONS

Oak Mere contains water of low conductivity (for this region), of low pH, and with very low concentrations of calcium, magnesium and bicarbonate ions (Table 1). It is base-poor. The emergent vegetation is sparse and discontinuous. However, there are marked differences between the substrata at the south and north ends; the former being virtually pure sand whilst the latter is peaty (Savage, 1986). Stations I.1 and I.2 were both in open water and adjacent to the sparse emergent vegetation, but at the south and north ends respectively (Table 2).

Maer Pool and Quoisley Little Mere both contain water of high conductivity and have high concentrations of calcium, magnesium and bicarbonate ions (Table 1). They do not differ from each other significantly but, being base-rich, form a marked contrast to Oak Mere. Maer Pool has narrow, discontinuous, zones of emergent vegetation on a relatively inorganic substratum—except for a dense reed bed, up to 15m wide, at the north east end. Station I was in open water adjacent to sparse emergent vegetation, whilst station III was at the landward edge of the reed bed (Table 2). Initially, an intermediate station (II) was used, but fluctuations in water level prevented a clear distinction between this station and station III. Quoisley Little Mere is completely surrounded by reed beds, up to 30m wide. The substratum is peaty throughout. Station I was in open water on the edge of the reed bed; station II in the reed bed, 5–15m from open water, whilst station III was at the back of the reed bed near to firm ground (Table 2). The fen carr zone, characterised by the presence of the sedge *Carex paniculata* L.,was flooded on one visit, and was accordingly included in station III on that occasion.

The series of stations in the three meres, together, provided significantly different combinations of the two sets of environmental factors (Tables 1 & 2).

Table 1. *The pH, conductivity (μS cm$^{-1}$ k25, i.e. at 25°C) and concentrations (m.equiv $l^{-1}$) of major ions in the three meres (arithmetic means ± 95% confidence limits). Oak Mere data from Savage (1986)*

| | Oak Mere | Maer Pool | Quoisley Little Mere |
|---|---|---|---|
| pH | 4.70 ± 0.40 | 7.20 ± 0.00 | 7.20 ± 0.50 |
| Conductivity | 157 ± 25 | 573 ± 12 | 601 ± 72 |
| calcium | 0.45 ± 0.07 | 3.55 ± 0.08 | 3.58 ± 0.32 |
| magnesium | 0.30 ± 0.07 | 1.55 ± 0.08 | 2.03 ± 1.03 |
| sodium | 0.43 ± 0.08 | 0.85 ± 0.72 | 0.57 ± 0.41 |
| potassium | 0.08 ± 0.02 | 0.45 ± 0.02 | 0.14 ± 0.07 |
| bicarbonate | 0.07 ± 0.02 | 4.27 ± 1.32 | 4.43 ± 0.81 |
| sulphate | 0.54 ± 0.23 | 2.15 ± 0.40 | 1.54 ± 0.65 |
| chloride | 0.72 ± 0.08 | 1.00 ± 0.16 | 1.05 ± 0.14 |
| n | 6 | 4 | 4 |

Table 2. *The percentage of organic matter (arithmetic means ± 95% confidence limits) in the substrata at the collecting stations in the three meres*

| Mere | Station | Percentage of organic matter |
|---|---|---|
| Oak Mere | I.1 | 1.3 ± 0.2 |
| | I.2 | 44.2 ± 3.1 |
| Maer Pool | I | 9.3 ± 5.7 |
| | III | 78.0 ± 7.3 |
| Quoisley Little Mere | I | 54.8 ± 4.0 |
| | II | 66.2 ± 5.4 |
| | III | 81.0 ± 8.2 |

## The Distribution of Corixidae in Relation to Environmental Factors in the Three Meres

The following species were recorded:– *Callicorixa praeusta* (Fieber), *Corixa punctata* (Illiger), *Hesperocorixa sahlbergi* (Fieber), *Sigara concinna* (Fieber), *S. distincta* (Fieber), *S. dorsalis* Leach, *S. falleni* (Fieber), *S. scotti* (Douglas & Scott), *S. semistriata* (Fieber).

There are significant differences in species and/or numbers of individuals for adults at all stations (Table 3) except Maer Pool III and Quoisley Little Mere III. Interpretation of the data for nymphs is less certain, owing to my inability to distinguish between *S. falleni* and *S. distincta*, but they show that all species (except *S. scotti* and *S. semistriata*) were breeding at some stations. In general, there are significant relationships between the distributions of nymphs and adults.

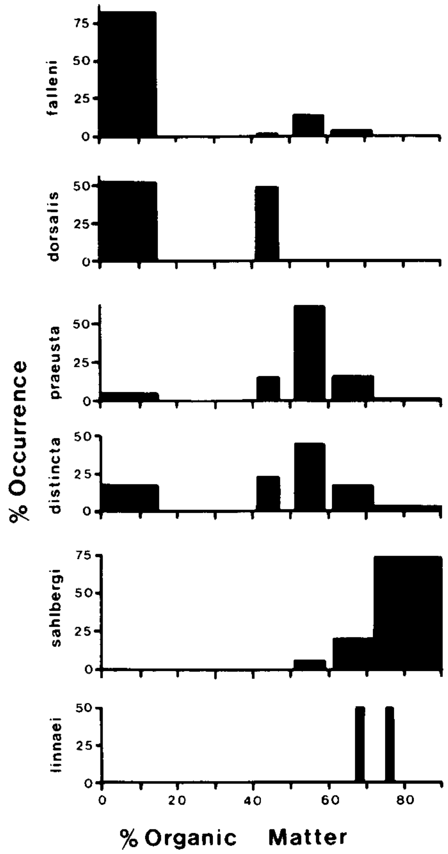



FIG. 2.

The percentage (%) occurrence (unit collecting effort$^{-1}$ mere$^{-1}$) of five corixid species (*Sigara falleni, S. dorsalis, Callicorixa praeusta, S. distincta and Hesperocorixa sahlbergi*) in relation to percentage organic matter (arithmetic means plus or minus 95% confidence limits at each station) in Oak Mere, Maer Pool and Quoisley Little Mere. Data for *Hesperocorixa linnaei* are from Fodens Flash and Hatch Mere.

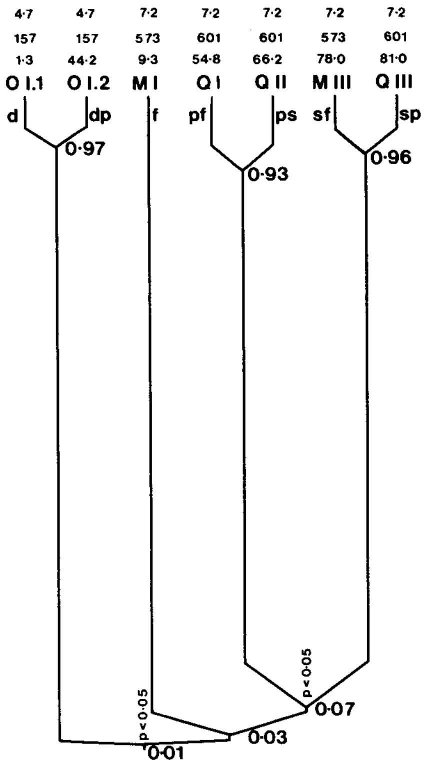



FIG. 3.

Dendrogram showing the relationships of the corixid communities at the stations in Oak Mere (O), Maer Pool (M), and Quoisley Little Mere (Q) together with pH, (top line) conductivity (μS cm$^{-1}$ k 25) and percentage (%) organic matter (bottom line). Species comprising approximately 10%, or more, of the community at each station are indicated. Key: d, *Sigara dorsalis*; f, *S, falleni*; p, *Callicorixa praeusta*; and s, *Hesperocorixa sahlbergi*. Significance from the dendrogram is shown at the two available dichotomies but note the significant differences described in the text.

Of the commoner species, *S. falleni* and *H. sahlbergi* are clearly associated with base-rich waters, and *S. dorsalis* with base-poor waters. *C. praeusta* and *S. distincta* show less well-marked differences. Some species, found in small numbers, were exclusive to particular chemical conditions: *S. concinna* in base-rich waters and *S. scotti* and *S. semistriata* in base-poor. *C. punctata*, normally a pond species but frequently found in sheltered meres, occurred in both types of water.

*S. dorsalis* and *S. falleni* are associated with low to moderate concentrations of organic matter (Oak Mere I.1, I.2, Maer Pool I). *S, distincta* and *C. praeusta* are associated with moderate concentrations (Oak Mere I.2, Quoisley Little Mere I) whilst *H. sahlbergi* is associated with high concentrations of organic matter (Maer Pool III and Quoisley Little

Table 3. *The distribution of Corixidae in the three meres. Arithmetic mean catches ( ×/÷ 95% confidence limits) per standard net sweep*

| Mere | Station | Date | *Sigara falleni* | *Sigara dorsalis* | *Callicorixa praeusta* | *Sigara distincta* |
|---|---|---|---|---|---|---|
| Oak Mere | SJ 576677 | | | | | |
| | I.1 | 20/6/78 | | 0.6 ×/÷ 1.8 | | |
| | | | | (3.0 ×/÷ 1.5) | | |
| | | 26/3/79 | | 7.6 ×/÷ 1.9 | | |
| | | 9/4/79 | | 2.8 ×/÷ 1.7 | | 0.6 ×/÷ 1.8 |
| | | 14/5/79 | | 15.6 ×/÷ 1.8 | | |
| | | 11/6/79 | | 0.8 ×/÷ 2 | | |
| | | | | (5.4 ×/÷ 1.4) | | |
| | | 19/9/79 | | 4.6 ×/÷ 1.5 | | |
| | | 10/9/79 | 0.6 ×/÷ 1.5 | 23.4 ×/÷ 1.8 | | 0.8 ×/÷ 1.7 |
| | Total Adults | | 3 | 277 | 0 | 7 |
| | I.2 | 10/7/78 | | 3.8 ×/÷ 2.4 | 1.4 ×/÷ 2.6 | |
| | | | (0.6 ×/÷ 2.0) | | | (0.6 ×/÷ 2.0) |
| | | 14/5/79 | | 8.2 ×/÷ 2.1 | 1.4 ×/÷ 0.6 | |
| | | 17/9/82 | 0.2 ×/÷ 1.4 | 11.2 ×/÷ 2.2 | 1.2 ×/÷ 1.4 | 1.2 ×/÷ 1.4 |
| | Total Adults | | 1 | 116 | 20 | 6 |
| Maer Pool | SJ 789385 | | | | | |
| | I | 20/10/80 | 5.0 ×/÷ 1.9 | 0.2 ×/÷ 1.5 | 0.4 ×/÷ 1.7 | 0.4 ×/÷ 1.7 |
| | | 14/12/80 | 7.8 ×/÷ 1.8 | 0.6 ×/÷ 1.9 | 0.6 ×/÷ 2.0 | |
| | | 7/6/81 | | | 0.4 ×/÷ 1.7 | |
| | | | (10.5 ×/÷ 1.9) | | (1.0 ×/÷ 2.2) | (10.5 ×/÷ 1.9) |
| | | 2/8/81 | 7.0 ×/÷ 1.6 | | 0.6 ×/÷ 1.9 | |
| | | | (1.6 ×/÷ 1.8) | | | (1.6 ×/÷ 1.8) |
| | Total Adults | | 99 | 4 | 10 | 2 |
| | III | 20/10/80 | water level very low | | | |
| | | 14/12/80 | 0.2 ×/÷ 1.4 | | | |
| | | 7/6/81 | | | | |
| | | | (0.3 ×/÷ 1.9) | | | (0.3 ×/÷ 1.9) |
| | | 2/8/81 | | | | |
| | Total Adults | | 1 | 0 | 0 | 0 |
| Quoisley Little Mere | SJ 550456 | | | | | |
| | I | 20/10/80 | 0.6 ×/÷ 1.9 | | 8.2 ×/÷ 1.8 | 1.6 ×/÷ 2.7 |
| | | | | | (9.6 ×/÷ 1.6) | |
| | | 16/11/80 | 0.2 ×/÷ 1.5 | | 21.2 ×/÷ 2.1 | 0.8 ×/÷ 1.7 |
| | | 1/3/81 | 0.2 ×/÷ 1.5 | | 3.8 ×/÷ 2.5 | 2.6 ×/÷ 2.3 |
| | | 5/5/81 | 0.4 ×/÷ 1.7 | | 0.2 ×/÷ 1.5 | |
| | | 14/5/81 | 0.2 ×/÷ 1.5 | | 1.4 ×/÷ 2.5 | |
| | | 15/6/81 | (1.4 ×/÷ 1.5) | | (8.2 ×/÷ 1.7) | (1.4 ×/÷ 1.5) |
| | | 31/10/81 | 4.2 ×/÷ 1.8 | | 5.4 ×/÷ 1.8 | 0.4 ×/÷ 1.7 |
| | Total Adults | | 29 | 0 | 201 | 27 |
| | II | 20/10/80 | | | 0.4 ×/÷ 1.5 | |
| | | 16/11/80 | | | 2.2 ×/÷ 1.7 | 0.6 ×/÷ 1.9 |
| | | 1/3/81 | | | 1.0 ×/÷ 1.6 | 0.2 ×/÷ 1.5 |
| | | 5/5/81 | 0.2 ×/÷ 1.5 | | 2.0 ×/÷ 1.7 | 0.2 ×/÷ 1.5 |
| | | 14/5/81 | 0.2 ×/÷ 1.5 | | 1.4 ×/÷ 1.7 | |
| | | 15/6/81 | | | | |
| | | 31/10/81 | 0.6 ×/÷ 2.0 | | 2.8 ×/÷ 1.6 | 0.4 ×/÷ 1.5 |
| | Total Adults | | 5 | 0 | 49 | 7 |
| | III | 20/10/80 | | | | |
| | | 16/11/80 | | | 0.6 ×/÷ 1.9 | 0.2 ×/÷ 1.5 |
| | | 1/3/81 | | | 0.2 ×/÷ 1.5 | |
| | | 5/5/81 | | | | |
| | | 14/5/81 | | | | |
| | | 15/6/81 | | | | |
| | | 31/10/81 | | | | 0.2 ×/÷ 1.5 |
| | Total Adults | | 0 | 0 | 4 | 2 |

Notes Numbers in parentheses indicate nymphs
Nymphs of *S. falleni* and *S. distincta* could not be separated and are shown in both columns.

Table 3. *The distribution of Corixidae in the three meres. (Continued)*

| Mere | Station | Date | *Sigara concinna* | *Sigara scotti* | *Corixa punctata* | *Sigara semistriata* | *Hesperocorixa sahlbergi* |
|---|---|---|---|---|---|---|---|
| Oak Mere | SJ 576677 | | | | | | |
| | I.1 | 20/6/78 | | 0.2×1.5 | 0.2×1.5 | | |
| | | | | | (0.6×1.9) | | |
| | | 26/3/79 | | 0.4×1.5 | | | |
| | | 9/4/79 | | | | | |
| | | 14/5/79 | | | 0.4×1.7 | 0.4×1.5 | |
| | | 11/6/79 | | | | | |
| | | 19/9/79 | | | | | |
| | | 10/9/79 | | 0.4×1.7 | 0.2×1.5 | | |
| | Total Adults | | 0 | 5 | 4 | 2 | 0 |
| | I.2 | 10/7/78 | | | | | |
| | | | | | (0.4×1.5) | | |
| | | 14/5/79 | | | 0.2×1.5 | 1.0×2.0 | |
| | | 17/9/82 | | 0.2×1.5 | | | |
| | Total Adults | | 0 | 1 | 1 | 5 | 0 |
| Maer Pool | SJ 789385 | | | | | | |
| | I | 20/10/80 | | | 0.4×1.5 | | |
| | | 14/12/80 | | | 0.2×1.5 | | |
| | | 7/6/81 | 0.2×1.5 | | 0.2×1.5 | | |
| | | | (0.2×1.5) | | | | |
| | | 2/8/81 | 0.2×1.5 | | 0.2×1.5 | | |
| | Total Adults | | 2 | 0 | 5 | 0 | 0 |
| | III | 20/10/80 | | | | | |
| | | 14/12/80 | | | | | 0.6×1.8 |
| | | 7/6/81 | | | | | 1.0×2.2 |
| | | | | | | | (0.6×1.9) |
| | | 2/8/81 | | | | | 0.8×1.7 |
| | | | | | | | (0.6×1.8) |
| | Total Adults | | 0 | 0 | 0 | 0 | 12 |
| Quoisley Little Mere | SJ 550456 | | | | | | |
| | I | 20/10/80 | | | | | 0.2×1.5 |
| | | 16/11/80 | | | | | |
| | | 1/3/81 | | | | | 0.4×1.5 |
| | | 5/5/81 | | | | | |
| | | 14/5/81 | | | | | |
| | | 15/6/81 | | | | | |
| | | 31/10/81 | 0.4×1.5 | | | | 0.2×1.5 |
| | Total Adults | | 2 | 0 | 0 | 0 | 4 |
| | II | 20/10/80 | | | | | 1.0×1.6 |
| | | 16/11/80 | | | | | 0.2×1.5 |
| | | 1/3/81 | | | | | 1.0×1.6 |
| | | 5/5/81 | | | | | |
| | | 14/5/81 | | | | | 0.2×1.5 |
| | | 15/6/81 | | | | | (1.0×1.6) |
| | | 31/10/81 | | | | | 0.4×1.5 |
| | Total Adults | | 0 | 0 | 0 | 0 | 14 |
| | III | 20/10/80 | | | | | 1.0×1.7 |
| | | 16/11/80 | | | | | 0.8×1.7 |
| | | 1/3/81 | | | | | 1.0×2.2 |
| | | 5/5/81 | | | | | 0.6×1.8 |
| | | 14/5/81 | | | | | 0.8×2.0 |
| | | 15/6/81 | | | | | (1.6×1.8) |
| | | 31/10/81 | | | | | 1.4×1.8 |
| | Total Adults | | 0 | 0 | 0 | 0 | 28 |

Notes Numbers in parentheses indicate nymphs
Nymphs of *S. falleni* and *S. distincta* could not be separated and are shown in both columns.

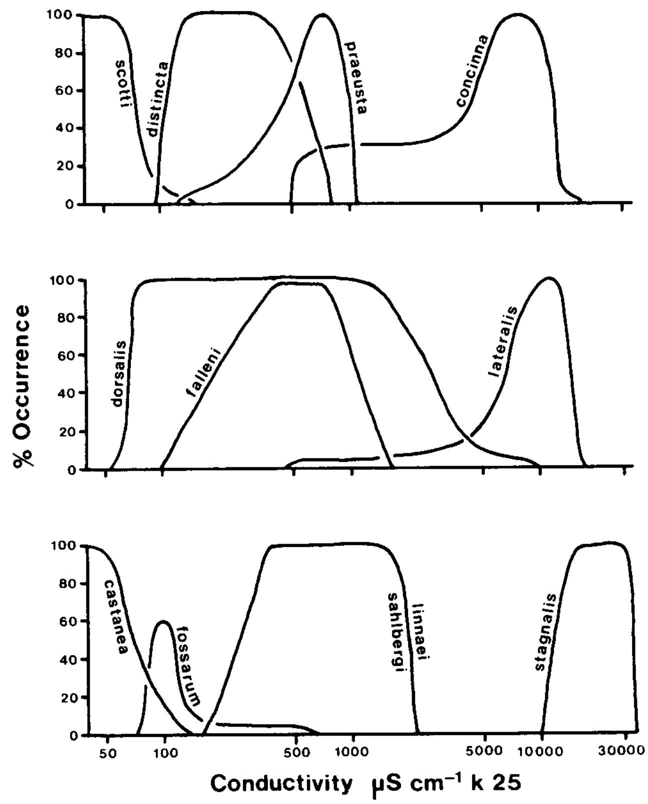



FIG. 4.
A semi-schematic representation of the maximum probable percentage (%) occurrence of some corixid species in relation to conductivity (μS $cm^{-1}$ k 25) of lakes. Data from Carrick & Sutcliffe (1982), Macan (1938, 1954, 1970), Martin (1970), Savage (1971, 1979, 1981, 1982b), Savage & Pratt (1976) and Walton (1943). The species are (top) *Sigara scotti, S. distincta, Callicorixa praeusta* and *Sigara concinna.* (middle) *S. dorsalis, S. falleni* and *S. lateralis* (bottom) *Hesperocorixa castanea, S. fossarum, H. sahlbergi, H. linnaei,* and *S. stagnalis.*

Mere III). The less well-marked differences in corixid distributions between the stations in Quoisley Little Mere correspond to the greater similarity in environmental factors. In general, there is a statistically significant relationship between the corixid distribution and the concentration of organic matter in the substrata (Tables 2 & 3 : Fig. 2). Corixid communities, as opposed to particular species, show significant associations with the combined environmental conditions at the different stations (Fig. 3).

## DISCUSSION

There is now a considerable body of evidence showing clear relationships between the occurrence of particular species of Corixidae and particular combinations of environmental factors in British lakes (Macan, 1938; 1954; 1967; 1970: Savage, 1971; 1982b: Savage & Pratt, 1976). Two sets of factors appear to be of special importance; variations in the water chemistry associated with the oligotrophic—eutrophic series, and the accumulation of organic matter in the substratum associated with the hydroseral succession. For *S. dorsalis* and *S. falleni*, there is an additional factor related to lake size and shape; perhaps associated with the amount of available shelter. Furthermore it is possible to distinguish between "open water species", occurring along the outer edge of reed beds, and "reed bed species," found within them.

Savage (1982b), by development of Macan (1938; 1954; 1967; 1970) and Savage & Pratt (1976), showed highly significant correlations to exist between the distribution of open water species and the concentrations of major ions in lake water (as expressed by measurement of conductivity) (Fig. 4). The relationship may be expressed by:–

*S. scotti* — *S concinna*
*S. distincta* — *C. praeusta*
*S. dorsalis* — *S. falleni*

→ Increasing conductivity

*S. fossarum* is omitted from the scheme because it occurred in only three lakes (Windermere, Esthwaite Water and Blelham Tarn—Macan, 1938; 1970). Similarly, *S. lateralis* was an open water species only in a moderately saline lake (Watch Lane Flash) and *S. stagnalis* was confined to saline waters (Savage, 1971; 1979; 1981).

In the present study, all six species were found in the three meres. Oak Mere is characterised by *S. dorsalis—S. distincta—C. praeusta*: Maer Pool by *S. falleni*: and Quoisley Little Mere by *S. falleni—C. praeusta*. However, it is important to include the information about the organic content of the substratum.

Macan (1938) proposed a species succession in relation to a developing hydrosere and the accumulation of organic matter in the substratum based on studies of, essentially oligotrophic (conductivity 40–110µS $cm^{-1}$ k 25), Cumbrian lakes (Fig. 5), namely–

*S. fossarum*
*Micronecta poweri* — *S. dorsalis* / \ *S. scotti* — *S. castanea*
*S. distincta*

The succession in Oak Mere is clearly related to this proposal:–

*S. praeusta*
*S. dorsalis* / \ *S. scotti*
*S. distincta*

It is, perhaps, surprising that *M. poweri* is absent, since the organic content of the substratum at station I.1 is the same as in the places where it occurs in Windermere. In contrast, *H. castanea* is found in dense vegetation, and this does not occur in Oak Mere. *C. praeusta* replaces *S. fossarum*. *C.praeusta* is associated with waters of higher conductivity (300–900µS $cm^{-1}$ k 25) and suggests that Oak Mere, although base-poor, has associations with eutrophic waters. This opinion is supported by its relatively high conductivity (Table 1) and the fact that phytoplankton production is high (Swale, 1968).

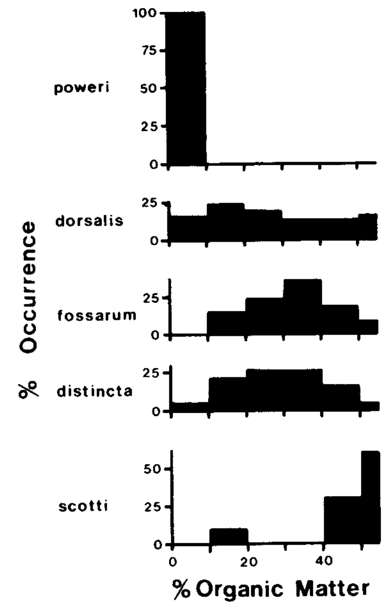



FIG. 5.

The percentage occurrence of five corixid species (*Micronecta poweri, Sigara dorsalis, S. fossarum, S. distincta* and *S. scotti*) in relation to percentage organic matter in Windermere. Redrawn from data in Macan (1970).

Macan (1967) proposed a comparable succession for the North West Midlands meres, based on a study of Crose Mere and Sweat Mere (conductivity c. 400μS $cm^{-1}$ k 25), namely;

*S. falleni — H. linnaei — H. sahlbergi*

Savage & Pratt (1976), in a survey of 25 meres, failed to confirm this succession, and concluded that only open water species were common. *S. falleni* was the most abundant species but *C. praeusta, S. distincta,* and *S. concinna* were also important open water species in these lakes of high conductivity (130–870μS $cm^{-1}$ k 25). Macan's succession was thus an oversimplification which would apply only to Maer Pool and some of the Group B meres of Savage & Pratt (1976). Savage (1982b) showed that *S. distincta* and *C. praeusta* occupy comparable positions in waters of lower and higher conductivity, respectively, but overlap in waters of intermediate conductivity (Fig. 4). Here it is shown that they are found at similar concentrations of organic matter. Thus, the succession in waters of higher conductivity (300–900μS $cm^{-1}$ k 25) should be:–

*S. falleni — C. praeusta — H. linnaei — H. sahlbergi*

and in waters of intermediate conductivity (200–300μS $cm^{-1}$ k 25)

*C. praeusta*

*S. falleni* *H. linnaei — H. sahlbergi*

*S. distincta*

These two successions would account for the majority of the corixid species associations occurring in the North West Midlands meres (Savage & Pratt, 1976). The data strongly suggest that each of these successions is related to particular combinations of conductivity and organic matter concentrations.

In addition, *S. dorsalis* (rather than *S. falleni*) is common in large meres of high conductivity (300–900μS $cm^{-1}$ k 25). The same is true in very small meres and ponds (Savage, 1982b). Indeed, *S. falleni* seems to be most numerous in waters of high conductivity but moderate size (Fig. 6).

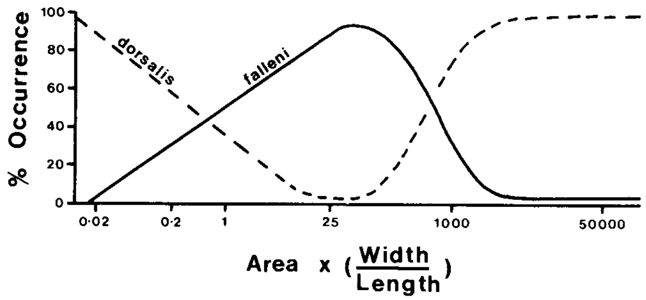
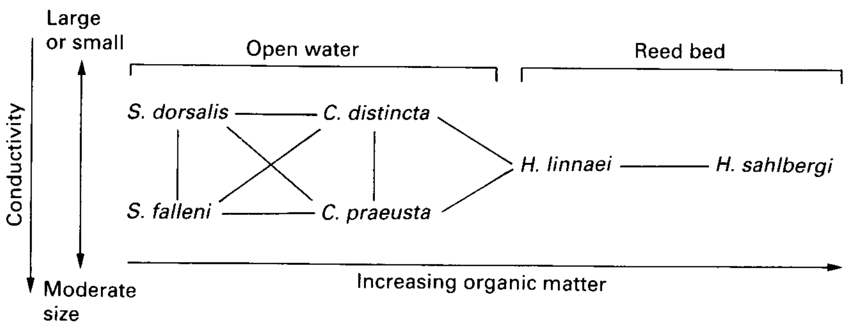


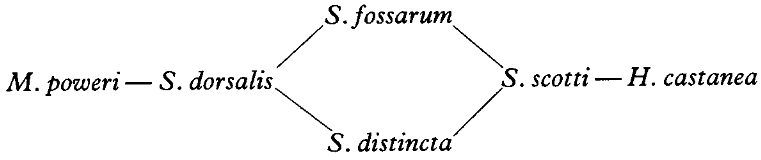

FIG. 6.
A semi-schematic representation of the possible percentage occurrence of *Sigara falleni* and *S. dorsalis* in relation to the "Shelter factor" in lakes and ponds, where the overall conductivity range is 300-1000μS $cm^{-1}$ k 25. Data from Savage (1982b).

So, a more comprehensive model, for the North West Midlands meres, would be



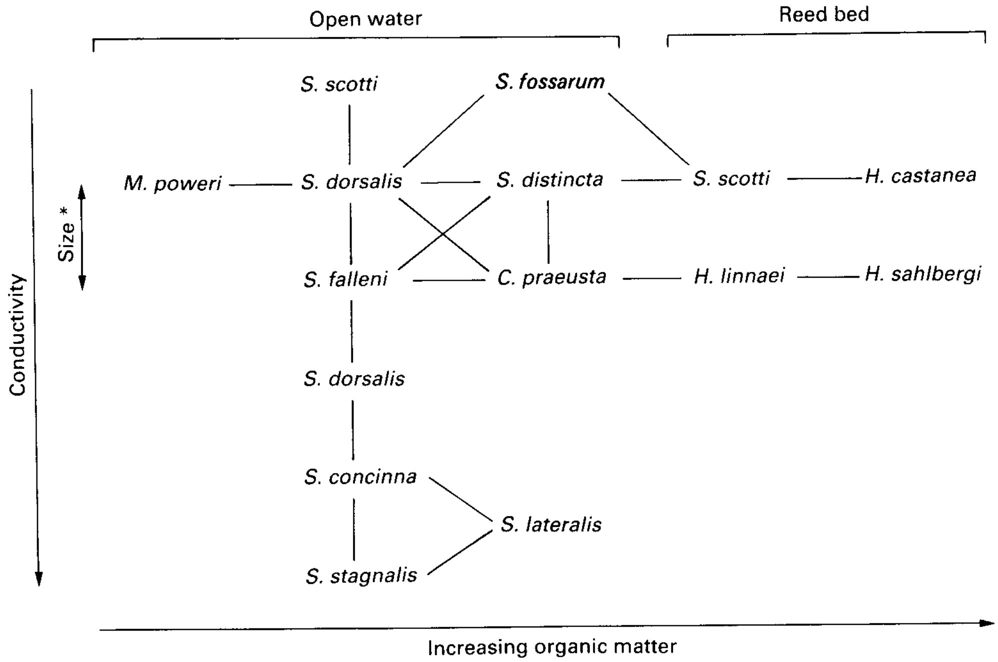

*S. scotti* and *S. concinna* are omitted because they occurred in small numbers; the former only in Oak Mere, while the major habitat of the latter is in highly calcareous (Walton, 1943) and saline waters with a conductivity of between 4000–9000μS $cm^{-1}$ k 25 (Savage, 1971; 1979).

The model may be extended to encompass all the major types of lake in the oligotrophic-eutrophic series, together with inland saline lakes. It has already been shown that the main successions in waters of low and high conductivity are respectively:–




*S. falleni* — *C. praeusta* — *H. linnaei* — *H. sahlbergi*

*S. scotti* is an open water species at very low conductivities (<80μS $cm^{-1}$ k 25) while *S. dorsalis* again replaces *S. falleni* in very slightly saline water (c. 2000–4000μS $cm^{-1}$ k 25) (Savage, 1971; 1982b ). *S. concinna* is common in moderately saline waters (4000–9000μS $cm^{-1}$ k 25) but, in turn, is replaced by *S. stagnalis* at high salinities (9000–30,000μS $cm^{-1}$ k 25) (Savage, 1971; 1979; 1981). There is also evidence that *S. lateralis* replaces *S. concinna* when plants decay and the organic matter in the substratum rises (Savage, 1979; 1981). Furthermore, *H. linnaei* and *H. sahlbergi* have been taken in the, slightly saline, Fodens Flash (c. 2000μS $cm^{-1}$ k 25) (Savage, 1971). Thus a final scheme for British inland lakes would be :




* applies only to *S. dorsalis* and *S. falleni*. *S. semistriata* is omitted because it occurred, in small numbers, in only two lakes—Esthwaite Water and Oak Mere.

It is clear that the corixid communities in the open water of North West Midlands meres show considerable ecological diversity (Table 4). The saline lakes of the region contribute further environmental diversity.

The reed bed species associated with high conductivity are *H. linnaei* and *H. sahlbergi* (Macan, 1954; 1967). However, the complete sequence has been found at the same time in

Table 4. *The open water species associations of Corixidae in relation to some environmental factors in selected North West Midlands meres. Data from the present study, miscellaneous collections, and Savage & Pratt (1976)*

| Mere | | Species association | pH | Conductivity | Organic matter | Shelter factor |
|---|---|---|---|---|---|---|
| Oak | SJ 576677 | *S. dorsalis—C. praeusta—S. distincta* | 4.7 | 157 | L–M | N |
| Hanmer | SJ 453394 | *S. falleni—S. distincta* | 7.4 | 330 | L–M | N |
| Kettle | SJ 418342 | *S. falleni—S. dorsalis—C. praeusta—S. distincta* | 6.8 | 158 | L–M–H | S |
| Budworth | SJ 596657 | *S. falleni—S. dorsalis—C. praeusta* | 8.4 | 790 | M | E |
| Doddington | SJ 714465 | *S. falleni—S. dorsalis—C. praeusta* | 8.0 | 550 | L | E |
| Moston Flash | SJ 718620 | *S. falleni—S. dorsalis* | 7.4 | 550 | L | S |
| Betley | SJ 748479 | *S. falleni—C. praeusta* | 7.5 | 640 | M | N |
| Crose | SJ 430305 | *S. falleni—C. praeusta* | 8.0 | 400 | M | N |
| Hatch | SJ 553722 | *S. falleni—C. praeusta* | 7.2 | 450 | L–M–H | N |
| Quoisley Little | SJ 550456 | *C. praeusta—S. falleni* | 7.2 | 600 | M–H | N |
| Cop | SJ 802297 | *S. falleni* | 7.7 | 364 | L–M | N |
| Fenemere | SJ 445228 | *S. falleni* | 7.8 | 487 | L–M | N |
| Maer | SJ 789385 | *S. falleni* | 7.2 | 570 | L | N |
| Tatton | SJ 755800 | *S. falleni* | 8.3 | 496 | L–M | N |

Key: Organic matter: L, Low; M, Moderate; H, High.
Shelter factor: N, Normal; S, Sheltered; E, Exposed.

only three places in the North West Midlands:– Sweat Mere, Hatch Mere and, the slightly saline, Fodens Flash (Fig.2) (Macan, 1967; Savage, 1971). Savage & Pratt (1976) found a few specimens of *H. linnaei* only, in spite of intense searching in reed beds. *H. sahlbergi* (alone) was found in Maer Pool and Quoisley Little Mere during the present survey. Both species have been taken in annual collections at Hatch Mere, but seldom on the same occasion.

An examination of the rainfall data suggests that low catches of *H. linnaei*, and the absence of *H. sahlbergi*, was associated with a number of increasingly-dry years. Then there was a sudden increase in net annual precipitation, starting in the autumn of 1976. *H. sahlbergi* was found during this latter period (Fig. 7). Only six individual corixids were caught in Oak Mere, prior to 1976, despite an intense collecting effort (Savage & Pratt, 1976), compared with 448 during the present study. Records of water level were kept at Oak Mere (Savage, 1986), and corixids were uncommon until the sparse marginal vegetation was flooded. Precise records were not kept for the other meres, but it was clear that water levels were higher after 1976. However, *H. sahlbergi* was not found at Maer Pool on 20 October 1980, after two dry months. It may be concluded that the extensively-

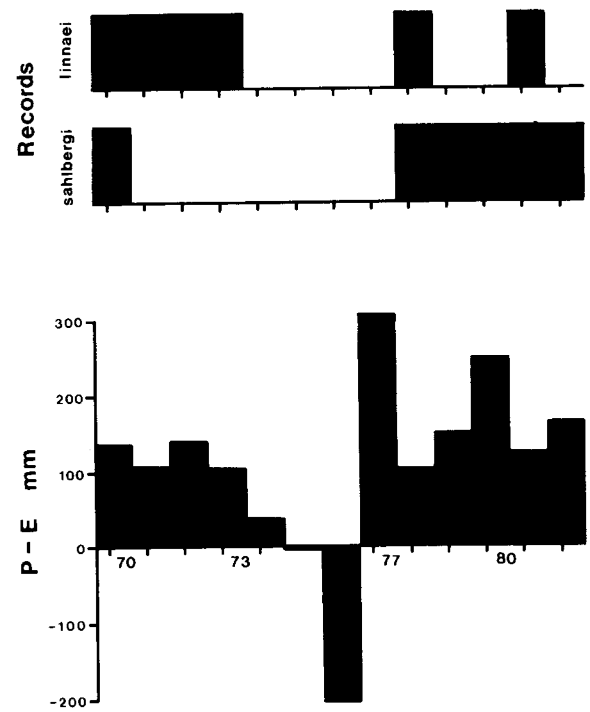



FIG. 7.

The net annual rainfall (Precipitation minus Evaporation, September to August) 1969–1982, together with the records for *Hesperocorixa linnaei* and *H. sahlbergi* in North West Midlands meres. Climatic data from RAF Shawbury (SJ 553220). Faunal data from the present study, Savage (1971), Savage & Pratt (1976) and the author's annual collections in Hatch Mere.

developed reed beds around many meres do not provide appropriate conditions for the full development of later stages in the corixid succession.

The North West Midlands meres lie in intensively-used agricultural land, that has been subject to drainage "improvement" during recent centuries. Records of higher plants on the mosses and around the mere margins, show that many species have become extinct in these habitats (Newton, 1971; Sinker, 1962). Reed beds appear well-developed, but it is clear that the more terrestrial zones around the meres are not developing their full potential. At the same time, the visual similarity of many meres fails to reveal their rich ecological diversity.

The phytoplankton, and the gastropod molluscan fauna, are just as diverse as are the corixid communities (Reynolds, 1978: Savage & Gazey, 1987). The North West Midlands meres are more varied and, at the same time, more threatened than is suggested by their general appearance.

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