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The ecology of the Corixidae (*Hemiptera*: *Heteroptera*) in the Corrib catchment, Ireland

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Key words: Corixidae, distribution, diversity, water chemistry, substrate

Abstract

Two surveys were carried out in the Corrib catchment (Ireland) to determine the physical and chemical factors that govern the distribution of Corixidae. Of the twenty one species recorded, five species, *Sigara scotti* (Fieber), *S. distincta* (Fieber), *S. fossarum* (Leach), *S. fallenoidea* (Hungerford) and *Cymatia bonsdorffii* (Sahlberg) comprised 82% of the numerical total. Although individual species occurred in chemically diverse sites species assemblages and changes in the relative abundance of the majority of species and in species richness and diversity were evident in the progression from hard to soft water. High altitude soft water sites had a much lower number of species compared with chemically similar low altitude sites. In Lough Corrib, the main body of water in the catchment, most species were abundant only in sheltered areas with mud substrates and high percentage vegetation cover. Species diversity was high in these areas and either *C. bonsdorffii*, *S. fossarum*, *S. fallenoidea* or *Callicorixa praeusta* (Fieber) dominated numerically. However, *S. scotti*, *S. dorsalis* (Leach) and *Arctocorisa germari* (Fieber) were more abundant in exposed areas with sand, gravel or mearl substrates. In temporary ponds and in lotic water species diversity was also high but species composition (mainly *C. praeusta*, *Sigara nigrolineata* (Fieber), *Corixa punctata* (Illiger), *C. panzeri* (Fieber), *C. bonsdorffii*) was different to that of temporally stable lentic habitats.

Introduction

Although numerous synecological studies on the Corixidae have been undertaken (Macan, 1938; Popham, 1943; Walton, 1943; Macan, 1954a, 1954b; Martin, 1970; Bosmans, 1983) little quantitative information has emerged on the factors that govern the distribution of this family of water bugs. The complexity of the freshwater habitat and the dispersal ability and mobility of most species (Brown, 1951) have undoubtedly confounded attempts in this direction. The present work is again an attempt to model the distribution of the group on physical and chemical environmental variables. We are aware that the variables measured may not neccessarily be active niche components controlling distribution. Rather their impact on corixid distribution may act indirectly through effects on fish (Macan, 1965a; Henrikson & Oscarson, 1978, 1981) and invertebrate corixid predators (Eriksson *et al.*, 1980), food supply (Reynolds, 1975) and particularly parasitism of corixids by larval water mites (Scudder, 1983). Nevertheless demonstrating a correlation between species distribution and environmental 'quality' is a useful exercise in that it establishes a baseline from which more interpretative autecological work can proceed.

The Corrib catchment (Ireland) (Fig. 1), which drains an approximate area of 3100 km^2 and ranges in altitude from sea level to 662 m, provides an ideal site for such a study as there is a wide range in the chemical, physical and topographical features of water bodies present (Costello *et al.*, 1984), yet all species recorded would seem, potentially, to be available to all sites sampled. There are numerous oligodystrophic ponds, tarns and corrie lakes in the western mountainous area, whereas mesotrophic and eutrophic loughs and meandering alkaline rivers are characteristic of the eastern plain. Lough Corrib also exhibits a variety of littoral habitats. The northern shores are exposed, with little vegetation or soft substrate. In the shallow (<6 m) southern basin there are extensive *Chara* beds and mearl substrates with well developed stands of *Phragmites* in sheltered bays and inlets.

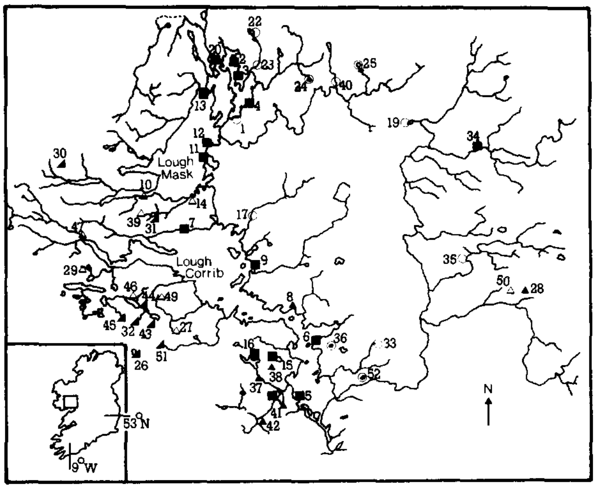

Fig. 1. The Corrib catchment (Ireland inset). Sampling locations for the Corrib catchment survey are indicated. Symbols correspond to five site groups obtained from clustering water chemistry data (See Fig. 3). o = group 1, ■ = group 2, ▲ = group 3, △ = group 4, ◪ = group 5.

Materials and methods

Field methods

Non-migrating, overwintering corixid populations were sampled from October 1979 to April 1980 at 52 chemically and topographically different sites in the Corrib catchment. A second survey was undertaken in January 1982 at 108 sites on Lough Corrib (Fig. 1).

In both surveys corixids were sampled with a pond net which had a mesh size of 0.125 cm^2 and a mouth area of 625 cm^2. Standard net sweeps, similar to the technique described by Crisp (1962), were performed at each site so that corixid samples were comparable. Twenty such sweeps were taken at each site during the Corrib catchment survey and three at each site in the Lough Corrib survey. For the catchment survey, sites were described chemically by the following variables: pH, conductivity, total alkalinity, calcium hardness, magnesium hardness, chloride, sodium and potassium. Sodium and potassium were measured using an E.E.L. flame photometer, conductivity with a radiometer CMD 3 conductivity meter and pH with a Pye Unicam 292 pH meter. Other chemical variables were estimated volumetrically according to the methods of Golterman & Clymo (1969).

During the Lough Corrib survey each sample was taken from a uniform discrete type of microhabitat. Each site was physically described in terms of substrate type, percentage vegetation cover and whether or not it was exposed to wave action. The type of substrate was redefined in an index form with values from 1–7 being assigned to decaying vegetation (1), mud (2), mearl (3), sand (4), shell fragment (5), gravel (6) and stone (7). In areas of mixed substrate an average of the index values for each substrate present was used, although no quantification of the percentage of each substrate type present was made. The index values from 1–7 represent a progression of decreasing organic content and increasing particle size.

Corixid nomenclature is according to Macan (1965b).

Statistical procedures

A hierarchical fusion clustering procedure was used to chemically classify catchment sites using $\log_e$ transformed water chemistry and altitude data. The chemical similarity between two sites was measured with a squared Euclidean distance dissimilarity coefficient and the distance between clusters was defined by Ward's error sum of squares method (Weishart, 1978).

To isolate relationships between corixid species and water chemistry the proportion of each species (expressed as numerical percentage composition for each species) was calculated for site groupings identified by cluster analysis. For the more common species the species percentage composition was also calculated for different values of the substrate index to detect species successions in relation to substrate type. Possible relationships between species distribution and water chemistry (Corrib catchment survey) and physical variables (Lough Corrib survey) was also investigated by canonical correlation analysis. This procedure detects the relationship or degree of dependance between two sets of data by deriving linear combinations or canonical variates for each set of data so that they maximally correlated with each other. A plot of the canonical variates and the original variables is a graphic representation of the relationship between all variables (Dixon, 1981; Gauch & Whittaker, 1981). In the present analysis the first data set was a $\log_e$ transformed matrix of individual species abundance, species diversity (Shannon-Weiner index) and the total number of species and individuals at each site. The second data set was a matrix of water chemistry and altitude data for each site in the case of the catchment survey and a substrate index, vegetation cover and exposure by site matrix for the Lough Corrib survey. Three of the rarest species in the catchment survey and six in the Lough Corrib survey were excluded from statistical analyses.

Results

Twenty-one and twenty species of corixid were recorded during the Corrib catchment and Lough Corrib surveys respectively (Fig. 2). Overall, the five numerically dominant species were *S. scotti* (26.9% of total), *S. distincta* (17.7%), *S. fossarum* (15%), *C. bonsdorffii* (14.4%) and *S. fallenoidea* (7.9%). *Sigara lateralis* (Leach) and *Corixa affinis* Leach were not recorded in Lough Corrib while *S. fallenoidea* and *A. germari* were not recorded from any other water body. Relatively higher numbers of the less common species were recorded during the Corrib catchment survey.

Cluster analysis of Corrib catchment water chemistry data isolated five site groups at a level of 1.08–2.03 on the dissimilarity index (Fig. 3). Water hardness decreased from group 1–5 (Table 1) and reflected an east to west trend in the catchment (Fig. 1). Group 1 sites were medium sized lakes east of Lough Corrib. Group 2 sites were on Lough Corrib and Lough Mask in the centre of the catchment. Group 3 sites were primarily stream and lake sites west of lower Lough Corrib. Softer water sites were mainly low (group 4) and high altitude (group 5) ponds and corrie lakes west of upper Lough Corrib.

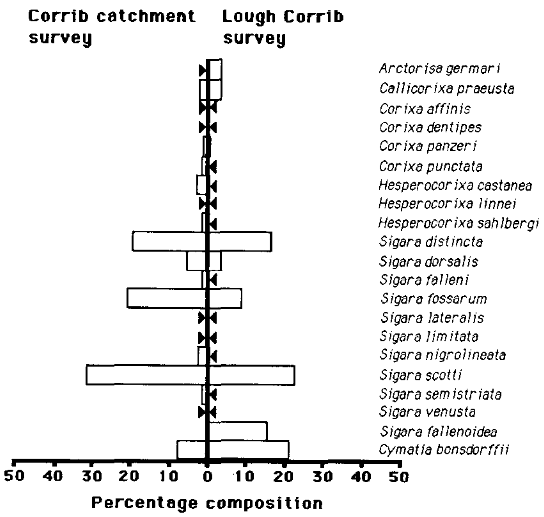

Fig. 2. The species percentage composition of corixids recorded during surveys in the Corrib catchment and Lough Corrib. ◂ = less than 1%.

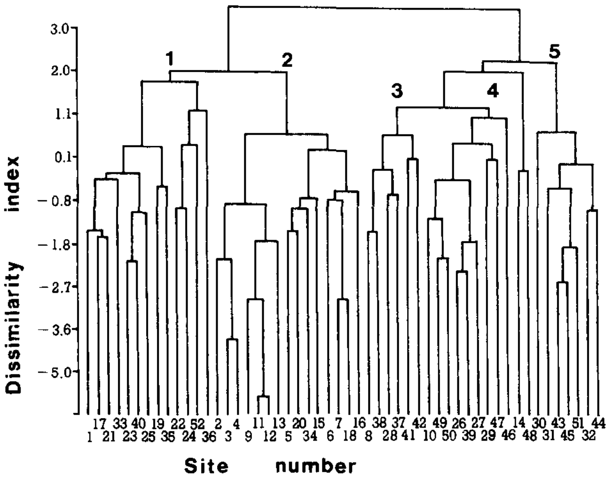

Fig. 3. Site groupings obtained from cluster analysis of water chemistry data at 52 sites in the Corrib catchment. See Fig. 1 for site locations.

Results of canonical correlation analysis showed that two canonical variates were sufficient to express the correlation between the chemical and biological data sets of the Corrib catchment survey at the 0.01 significance level (Table 2). The loadings of the original variables on these two canonical variates is shown in Fig. 4. Water hardness variables are positively loaded on the second canonical variate and are negatively correlated with altitude. The first canonical variate seems to represent a gradient, (positive to negative) of decreasing potassium levels. The biological variables (species) and population statistics (H, S and N) are distributed diagonally from medium negative to medium positive loadings on both canonical variates. *C. affinis*, *Coria dentipes* (Thoms.), *S. semistriata*, *S. distincta* and *S. nigrolineata* which are most closely correlated with high diversity, number of species per site and water hardness variables did actually occur mainly in hard water sites although they were not confined to these sites (group 1, Fig. 5). At the opposite end of the scale are *S. scotti*, *Hesperocorixa sahlbergi* (Fieber) and *H. castanea* (Thoms.) which, along with *S. nigrolineata*, were the only species recorded at high altitude soft water sites (group 5, Fig. 5). These species also occurred in hard water sites. Single species of these four were frequently found in isolation, at group 5 sites eg. only *H. castanea* occurred at site 43, a deep pool covered in *Sphagnum*. At site 44, which was a shallow water (20 cm) pool with decaying grasses only *H. sahlbergi* occurred, while *S. scotti* was the only species at sites 31 and 32 which were steep banked barren loughs. Other species occupy an intermediate position on the second canonical variate suggesting that water hardness was less important in affecting their distribution. *C. praeusta*, *C. panzeri*, *S. fossarum* and *C. bonsdorffii* are grouped together and have high positive loadings on the first canonical variate which is interpreted as a gradient in potassium concentrations. Only four species, *A. germari*, *C. dentipes*, *S. limitata* (Fieber) and *S. semistriata* which were recorded in hard water sites were not recorded in soft water (Fig. 5 groups 1–3 compared with groups 4–5).

Species diversity and the number of species per site are associated with hard water and high

Table 1. Mean, standard deviation and range of total alkalinity and pH and altitudinal range for each group of sites isolated by cluster analysis (see Fig. 3).

Site group	Total alkalinity (meq.L)			pH			Altitude range
	mean	s.d.	range	mean	s.d.	range	
1	4.4	1.1	2.2–5.8	8.1	0.5	7.1–9.1	15–45
2	2.6	0.8	1.4–4.1	8.2	0.6	7.3–9.5	15–45
3	1.3	0.8	0.5–2.3	7.2	0.5	6.2–7.6	15–75
4	0.6	0.3	0.1–1.1	6.9	0.4	6.1–7.3	15–165
5	0.6	0.4	0.1–1.0	5.7	1.1	4.4–7.7	165–285

Table 2. The canonical correlation between biological and chemical data matrices (Corrib catchment survey) and biological and physical matrices (Lough Corrib survey). The canonical correlation is the degree of correlation between each corresponding pair of canonical variates. The eigenvalue, which is the square of the canonical correlation, indicates the amount of variance shared by each pair of canonical variates. This is significant (*) only for the first two canonical variates.

Eigenvalue	Canonical correlation	Number of eigenvalues	Bartletts test for remaining eigenvalues		
			X^2	d.f.	probability
Corrib catchment survey					
–	–	–	332.98	207	0.0000*
0.95736	0.97845	1	224.14	176	0,.0083*
0.87325	0.93448	2	152.88	147	0.3530
Lough Corrib survey					
–	–	–	224.66	110	0.0000*
0.65210	0.80750	1	126.45	84	0.0019*
0.43016	0.65587	2	74.15	60	0.1035

potassium levels in Fig. 4. The hardest water sites (group 1, Fig. 5) had the highest mean number of species and species diversity per site and the highest total number of species per site group. These population statistics decreased, along with water hardness, from site groups 1 to 3 although

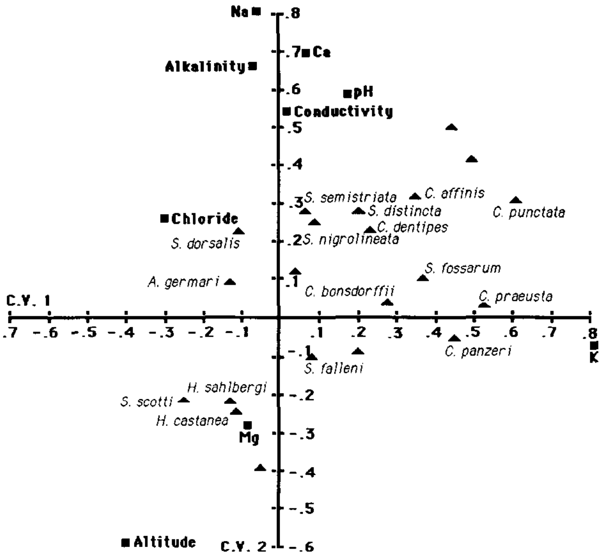

Fig. 4. Canonical correlation analysis. Biotic variables (▲) and chemical environmental variables (■) from the Corrib catchment survey, plotted on canonical variates 1 and 2. H = species diversity per site, S = total number of species per site, N = number of individuals per site, Na = sodium, Ca = calcium, K = potassium, Mg = magnesium.

the soft water group 4 sites (Table 1) had a higher total number of species and mean number of species per site (Fig. 5) than harder water group 1 and 2 sites (Table 1). Species diversity mean number of species per site and the total number of species in the site group was much lower in the higher altitude soft water group 5 sites. The mean number of corixids per site was not correlated with hardest water sites or with species diversity (Fig. 4). In fact this statistic was highest at the soft water group 4 sites.

The plot of the physical and biological variables of the Lough Corrib survey on the two significant ($p < 0.01$) canonical variates (Table 2) is shown in Fig. 6. All species, have negative values on the first canonical variate. No species was recorded on stone substrates which were the most exposed areas sampled. The abundant species *C. bonsdorffii*, *C. praeusta* and *S. fossarum* and also *C. panzeri*, which were grouped together in Fig. 4, are again associated in Fig. 6 and are correlated with a high percentage vegetation cover and fine substrates. Two other dominant species, *S. scotti* and *S. dorsalis* (Leach) were, however, common in more exposed areas with little vegetation (Fig. 6). The actual species percentage composition of eight common species in Lough Corrib, recorded at different values of the substrate index indicated that two distinct groups exist (Table 3).

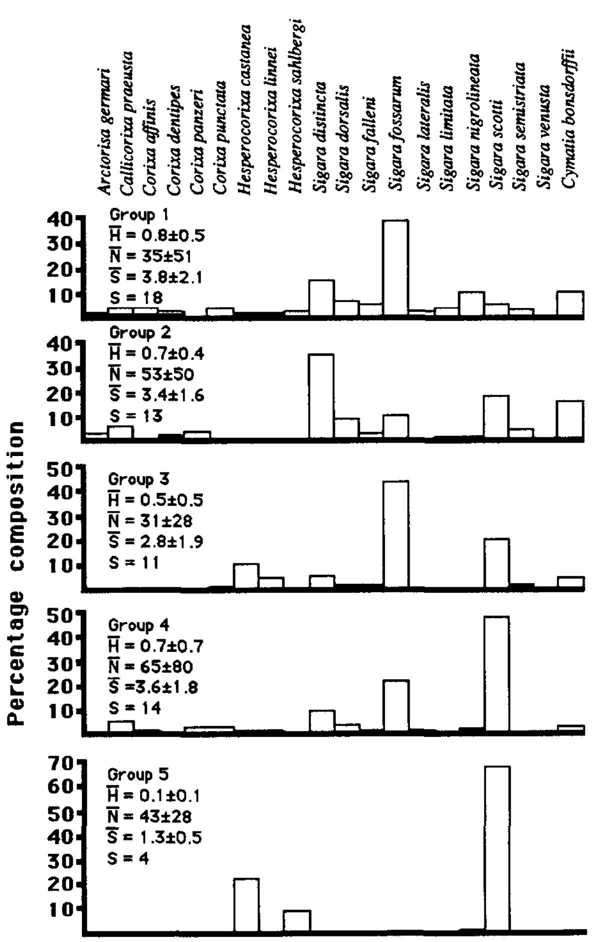

Fig. 5. Corixid species percentage composition in each of five site groups isolated by cluster analysis of water chemistry data for the Corrib catchment survey (See Figs. 2 and 3). H = mean species diversity per site (± standard deviation), N = mean number of individuals per site (± s.d.), S = mean number of species per site (± s.d.), S = total number of species in each site group.

C. praeusta, *C. bonsdorffii*, *S. fallenoidea* and *S. fossarum* were abundant only on mud substrates. *S. scotti*, *A. germari* and *S. dorsalis* also occurred on mud but were more abundant on mearl, sand and gravel substrates. *S. distincta* occurred on most substrates and is intermediate in position to the two groups described. The distribution of these 8 species on the substrate index in Table 3 agrees relatively well with their plot positions in Fig. 6. Species diversity, mean number of species per site and the mean number of individuals per site are all closely correlated with each other and with fine grained substrates and percentage vegetation cover.

Corixid communities also seem to be regulated by such physical characteristics as the size and stability of their habitats. Sites sampled during the catchment survey are categorised in Table 4, based primarily on size, water flow characteristics and altitude. Temporary ponds and rivers sampled during the catchment survey had a higher species diversity and number of species per site than lakes and ponds. Nine species occurred in one temporary pond, which was the highest number of species recorded at any site. The species composition in temporary ponds was *C. praeusta* (32.2%), *C. punctata* (14.8%), *S. nigrolineata* (13.2%), *C. panzeri* (13.2%), *C. affinis* (9.9%), *C. bonsdorffii* (7.4%), *S. semistriata* (3.3%), *S. limitata* (1.6%), *H. castanea* (0.8%), *S. fossarum* (0.8%), *S. lateralis* (0.8%) and *S. scotti* (0.8%).

Discussion

In the Corrib catchment survey three main corixid species assemblages were evident. *C. affinis*, *C. dentipes*, *S. semistriata*, *S. distincta* and *S. nigrolineata*, forming one group, were all more abundant in the hardest water sites. These sites also supported the highest species diversity. High altitude soft water sites had an impoverished corixid fauna where only *S. scotti*, *H. sahlbergi*, *H. castanea* and *S. nigrolineata* were recorded. The occurrence of *H. sahlbergi* in these areas is surprising as Macan (1954b) included it in the species succession of lime rich ponds that evolve into fen. This impoverished fauna was in contrast to low altitude soft water sites where 14 species were recorded and where species diversity was only slightly lower than that of any hard water site group. A third species group containing *C. bonsdorffii*, *C. praeusta*, *S. fossarum* and *C. panzeri* was identified in both surveys and was associated with sites having a high percentage vegetation cover, fine substrates and apparently high potassium levels.

Most species were found over a wide range of

Table 3. Percent numerical composition of eight numerically dominant corixid species in Lough Corrib on each value of the substrate index (see text for details)

Species	Substrate index										
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
Callicorixa praeusta	89.9	–	5.0	–	0.7	–	4.3	–	–	–	–
Cymatia bonsdorffii	82.9	–	2.9	0.4	1.6	5.7	3.9	1.4	0.9	0.9	0.2
Sigara fallenoidea	82.8	–	2.3	7.0	2.5	1.3	2.2	0.5	–	0.6	–
Sigara fossarum	81.6	–	1.4	–	0.6	4.2	2.5	–	8.8	–	0.8
Sigara distincta	51.5	–	5.3	2.1	–	15.4	7.6	5.8	6.6	3.1	–
Sigara scotti	26.0	–	11.7	28.4	0.5	2.5	7.2	13.1	–	10.1	–
Arctocorisa germari	22.9	0.6	3.6	16.8	4.2	3.6	21.7	9.0	1.8	11.4	1.2
Sigara dorsalis	17.6	–	2.8	3.5	4.9	8.4	9.1	49.6	4.2	2.8	–

the chemical environmental variables measured. Changes in the relative abundance of the majority of species were evident however in the progression from hard to soft water. In addition two chemically similar soft water site groups had very different corixid species composition which seemed to be related to altitude. The four species recorded in the high altitude sites were also segregated. Previous work on corixid distribution have shown them to be tolerant to acidification (Henrikson & Oscarson, 1978, 1981) and their osmoregulatory ability in saline lakes has been demonstrated by Scudder (1976). In some of these lakes the absence of particular species was shown by Scudder (1983) to be entirely due to effects of parasitism by water mites rather then any direct limiting effects of salinity. In the present surveys *S. scotti* was numerically dominant both in soft water pools and in many alkaline harder water areas in Lough Corrib. Macan (1938) recorded *S. scotti* mainly in base poor conditions where organic matter had accumulated. Evidently, it is not restricted to these habitats.

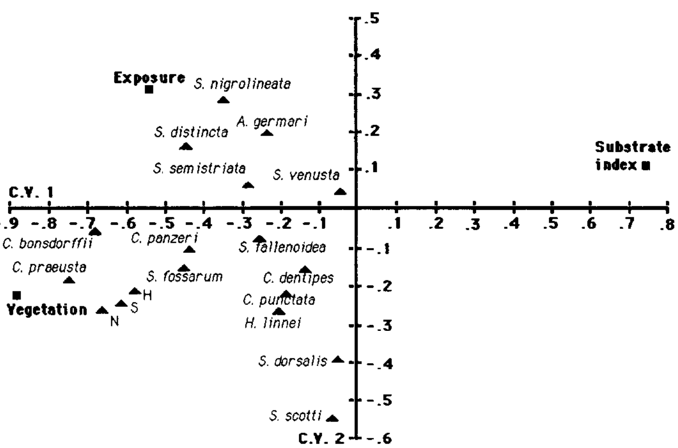

Fig. 6. Canonical correlation analysis. Biotic variables (▲) and physical environmental variables (■), from the Lough Corrib survey, plotted on canonical variates 1 and 2. H = species diversity per site, S = total number of species per site, N = number of individuals per site.

Water chemistry variables measured in this study are important indicators of productivity at all trophic levels. Calcium concentration is positively correlated with the rate of turnover of plant

Table 4. Mean (standard deviation) diversity (*H*), number of species (*S*) and number of individuals (*N*) and the dominant species at each of 7 site groupings. Sites are categorised primarily on size, altitude and whether lotic or lentic.

Site category	*H*	*S*	*N*	Dominant species
Temporary ponds	1.32(0.45)	6.00(3.00)	37.3(33.3)	*C. praeusta*
Rivers	1.07	3.50	29.5	*S. falleni*
Large lakes	0.65(0.40)	3.20(1.50)	52.8(63.7)	*S. scotti*
Low altitude	0.78(0.41)	3.50(1.60)	30.9(41.3)	*C. bonsdorffii*
peat ponds	0.76(0.54)	3.50(1.70)	18.7(16.7)	*S. scotti*
Streams				
High altitude	0.72(0.42)	3.50(2.00)	56.0(74.8)	*S. fossarum*
peat ponds				
	0.05(0.10)	1.40(0.90)	38.6(28.7)	*S. scotti*

material (Egglishaw, 1968) and with population densities of species in streams (Macan, 1963). Corixid species diversity and the mean number of species per site in the Corrib catchment was highest in hard water areas. Soft water sites however, also supported a substantial number of species and species diversity and the number of corixids per site was also uncorrelated with water hardness. The absence of a correlation between corixid biomass and calcium concentration (or other interrelated chemical variables) in this study suggests that there is no simple relationship between corixid biomass or the biomass of individual species and habitat productivity. In Swedish lakes corixid biomass increases rather than decreased with acidification and reduced overall productivity. This is primarily due to niche expansion in the absence of fish predation (Henrikson & Oscarson, 1981).

Individual species showed preference for certain types of substrate and amount of vegetation cover and two distinct groups, with *S. distincta* occupying an intermediate position, were identified along a substrate gradient in Lough Corrib. Macan (1938) suggested a species succession along a similar gradient and later split the succession into that characteristic of soft water areas, ultimately developing into bog and hard ware areas evolving into fen (Macan, 1954b). Species diversity and the total number of species and individuals per site were positively correlated with soft substrate, vegetated, sheltered habitat types in Lough Corrib. These relationships are probably not reflective of a correlation with habitat productivity given the absence of a correlation between water hardness and corixid abundance as discussed above. Habitat physical structure and stability (which will be reflected in the substrate index) may be directly important in sustaining high corixid diversity and biomass. *S. scotti*, *S. dorsalis* and *A. germari* were however, generally more abundant in more exposed areas.

Unpredictable habitats, such as temporary ponds and lotic water also favoured high species diversity. Environmental conditions in unpredictable habitats vary more on a temporal scale than do stable productive areas which may be more complex and diverse spatially. The state of equilibrium between immigration and emigration rates and the dispersal ability of each corixid species will be important factors in determining the species composition of temporally unstable areas (Brown, 1951). The common species in temporally unstable habitats such as *C. praeusta*, *S. nigrolineata* and *C. panzeri* have the ability to colonise new areas rapidly (Brown, 1951). In contrast numerically dominant species in Lough Corrib are dominated by predominantly non-flying forms eg. *C. bonsdorffii* is primarily brachypterous and consequently does not migrate (Southwood & Leston, 1959). Also, histological analysis of the flight muscles of *S. distincta* and direct observations of the flight muscles of *S. fallenoidea* from Lough Corrib revealed only non-flying morphs (Tully, unpublished).

The range in water chemistry variables measured in this study did not directly restrict the distribution of the majority of corixid species. Observed changes in the relative abundance of corixid species along water chemistry gradients may be due to altered biotic relations in chemically different habitats (e.g. Scudder, 1983). Numerically dominant species were segregated on a substrate gradient in Lough Corrib. Corixid biomass and diversity did not seem to be directly related to habitat productivity in the Corrib catchment. Habitats of different physical size, structure, stability and altitude seemed to be important for corixid distribution. Both transient and resident corixid species groups, characteristic of temporally unstable and temporally stable but spatially variable habitats respectively, may exist in the Corrib catchment. Both of these habitat types also sustain high corixid species diversity.

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