THE DIAGNOSTIC MORPHOLOGICAL FEATURES OF BRITISH *SIGARA STRIATA, S. DORSALIS* AND INTERMEDIATE SPECIMENS (CORIXIDAE), WITH A NEW KEY FOR IDENTIFICATION OF ADULT MALES

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Introduction

Waterbugs in the family Corixidae (Hemiptera Heteroptera) are commonly found at the margins of ponds and lakes. There are 34 species of corixids in Britain and Ireland (Savage 1989), of which *Sigara striata* (L.) and *Sigara dorsalis* (Leach) are the only two British representatives of a closely related group of seven European species belonging to the subgenus *Sigara* sensu strictu (Jansson 1986, 1995; Di Giovanni, Rizzotti Vlach et al. 1994; Rizzotti Vlach et al. 1996). The other five species are *S. albiventris* (Horvath), S. *assimilis* (Fieber), *S. basalis* (Costa), *S. janssoni* Lucas and *S. servadeii* Tamanini. Of these, *basalis* has been regarded as a synonym of either *striata* or *dorsalis,* but recent evidence suggests that it is a good species (Rizzotti Vlach et al. 1996).

S. striata is the most widely distributed, occurring throughout Europe except in the extreme west and south. In Britain it is confined to Kent and Sussex in southeast England. In contrast, *dorsalis* is common and widely distributed throughout the British Isles. This species also occurs in Norway, parts of France, northern Italy and Greece. Further south, *dorsalis* is replaced by *janssoni* in the Iberian Peninsula, *servadeii* in Corsica and Sardinia, while *basalis* occurs in Italy. *S. albiventris* and *assimilis* are principally Asiatic species which reach Europe only on the west coast of the Caspian Sea *(albiventris)* and Yugoslavia *(assimilis)* (Jansson 1986). Thus the two British species are well separated, geographically, from the remainder. *S. dorsalis,* although first described by Leach in 1817, was regarded as a synonym of *striata* until Macan (1954a) showed that it was a separate species. He first described it as a new species, *Sigara lacustris* Macan 1954, but soon realised that the new name was a synonym of *dorsalis* (Macan 1954b, 1955). This action was later confirmed (Macan 1961; Macan & Leston 1978; finally confirmed by the International Commission on Zoological Nomenclature - Opinion 1274/1984). Leston (1955) and Waterston (1956) found the true *striata* in Kent and Sussex soon after Macan's separation of *dorsalis.* Further records were added by Lansbury & Leston (1966) which, together with more recent

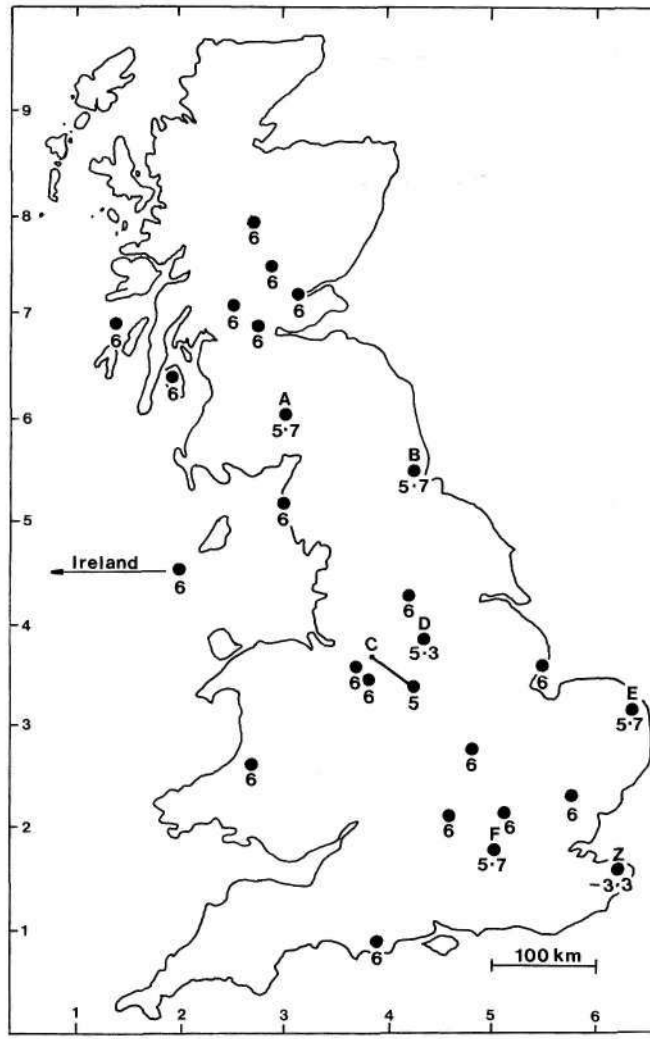

FIG. 1. Locations from which specimens of adult male *Sigara* were collected; those marked with letters A to F, and Z, are mentioned specifically in the text (Map references: A, Earshaig NT (36) 041021; B, Durham NZ (45) 327485; C, Congleton SJ (33) 839622; D, Sheffield SK (43) 335819; E, Norfolk TG (63) 345158; F, Colnbrook TQ (51) 021758; Z, River Stour, Kent TR (61) 231627). The locality in the Republic of Ireland is at Killarney, V 968916. The number adjacent to each locality indicates the score obtained for that population or assemblage (see page 44 for an explanation).

records, were collated by Savage (1989). Lansbury & Leston (1966) experienced difficulty in identifying some individuals of *striata* and *dorsalis* because they were intermediate in form. Later, Jansson (1979) made laboratory crosses of *striata* with *dorsalis* and succeeded in producing hybrids with intermediate morphological features. On the basis of this evidence, Savage (1989) presumed that the intermediate forms found in Kent and Sussex were natural hybrids of *striata* x *dorsalis.* Their characteristics are examined further below.

The present study

In this article we briefly consider a range of diagnostic features that may be used to separate British specimens of *striata* from *dorsalis.* Most of these morphological features have been used in keys to the British species of the subgenus *Sigara* sensu strictu (Macan 1956, 1965; Southwood & Leston 1959; Jansson 1986; Savage 1989, 1990). We have also devised a scoring system to facilitate the identification of individuals from the southeast of England, although it is applicable to the whole of the British Isles, and a new (short) key is presented.

The study is concerned principally with British specimens but it is set in a European context. We examined 313 adult males collected from 26 populations at localities distributed throughout the British Isles (Fig. 1). Of these, 291 males from the 25 populations outside Kent were identified as *dorsalis,* including a population from the Republic of Ireland. The population in Kent (Fig. 1, Z) is a mixed assemblage of *striata* and specimens that are morphologically intermediate between *striata* and *dorsalis.* We examined 22 specimens from this locality, of which five were identified as "pure" *striata* and 17 had intermediate features, some tending towards *dorsalis.* "Pure" *dorsalis* were not found in this particular assemblage but have been noted on previous occasions in adjacent localities (see Fig. 70 on p. 22 in Savage 1989). In addition, we have examined 10 specimens from the continent of Europe (five *striata* from Denmark and five *dorsalis* from France and Italy). All British specimens were dissected and slide preparations made of examples from each population, but the continental specimens were available only for examination.

The description of individuals based on their morphological characters presents certain problems. Throughout the first part of this account, the term "intermediate" is used generically for all specimens that are not "pure" *striata* or *dorsalis.* Later, we shall divide intermediates into "hybrids" and "variants" according to the probable origin of the forms described.

Rizzotti Vlach et al. (1996) describe *basalis* from Italy, and use features on the 8th dextral (right) tergite and the strigil as important diagnostic characters,

as we have done for *striata* and *dorsalis*. Moreover, in *basalis* the left paramere is virtually indistinguishable from that of *striata,* and the right paramere closely resembles that of *dorsalis*. Thus we were aware of the possibility of finding specimens similar to *basalis* among the intermediate forms from the mixed assemblage in Kent, so we examined the diagnostic features. However, although some specimens possessed a left paramere identical to that of *striata,* and an intermediate form of right paramere, none possessed a basal swelling on the 8th dextral tergite nor a very large strigil, both characteristic of *basalis*. Thus, we found no evidence of British specimens resembling *basalis*.

Morphological features considered for identification

Numerous characters are used in keys for identifying corixids (e.g. Savage 1989). Here, we focussed our attention on the following eight morphological features that, for various reasons, seem to be most useful as possible diagnostic characters for identifying *S. striata, S. dorsalis* and intermediate forms.

Body shape

There is a distinct difference in body shape between *striata* from Denmark and British *dorsalis,* the former being narrower and more pointed posteriorly (Macan 1956, 1965; Savage 1989). However, this feature was found to be of little value when examining individuals from the mixed assemblage in Kent, where both species and intermediate forms were present.

The strigil

The strigil is an oval-shaped organ located dorsally on the right-hand side of the 6th and 7th abdominal tergites (see Fig. 35 on p. 67 in Savage 1989). We measured the length of the strigil in five male specimens from each of the following populations: Durham (Fig. 1, B), Colnbrook (Fig. 1, F), France and Italy for *dorsalis;* Kent (Fig. 1, Z) and Denmark for *striata;* five specimens of intermediate forms from Kent (Fig. 1, Z). The strigil of *S. basalis* (three specimens) was measured from photographs in Rizzotti Vlach et al. (1996).

We found some statistically significant differences (t-test) between mean strigil length in British and Continental specimens from different populations of *striata* and *dorsalis,* but the ranges overlap (Table 1) and we conclude that strigil length can not be used to separate these two species. However, although we were able to measure only three specimens of *basalis,* the mean (905 μm) is substantially and significantly greater ($p<0.001$) than the means for *dorsalis* and *striata* (Table 1).

Table 1. The mean lengths (µm) ± 95% confidence limits and ranges for the strigil in three species of *Sigara* from localities in Europe and Britain. Five adult males were measured from each locality, except for *basalis* (3 specimens; see the text).

Species	Locality	Mean ± 95% CL	Range
S. striata	Europe (Denmark)	571 ± 89	450-650
	Kent (Fig. 1, Z)	613 ± 53	555-667
	Intermediates (Kent Fig. 1, Z)	627 ± 41	574-667
S. dorsalis	Europe (France and Italy)	707 ± 67	655-803
	Colnbrook (Fig. 1, F)	719 ± 62	648-796
	Durham (Fig. 1, B)	740 ± 27	711-778
S. basalis	Italy (Rizzotti Vlach et al. 1996)	905 ± 69	879-943

The eighth dextral tergite

The right-hand (dorsal) tergite of the 8th abdominal segment appears to be of particular diagnostic importance in *basalis,* where there is a marked swelling on the proximal inner margin (Rizzotti Vlach et al. 1996). Jansson (1986) illustrated a similar swelling on a specimen of *dorsalis* but it should be remembered that he regarded *basalis* as a synonym of *dorsalis.* British specimens of both *striata* and *dorsalis* have relatively straight inner margins with no sign of a swelling (Fig. 2 sr a, ds b).

The middle posterior lobe of the seventh tergite

European mainland specimens of *striata* and *dorsalis* may be separated by the presence or virtual absence, respectively, of long hairs on the middle posterior lobe of the 7th tergite (Jansson 1986, 1996; Rizzotti Vlach et al. 1996). British specimens of *striata,* together with specimens of intermediate form, possess long hairs (Fig. 2 sr c, arrow). However, British *dorsalis* show an intergrading series, from virtual absence to many long hairs, although the hairs are usually somewhat shorter than in *striata* (Fig. 2 ds d, ds e, arrows).

Pale lines on the pronotum

This feature was examined in a large number of specimens by Macan (1956), who showed that there was an overlap in the number of lines found in Continental *striata* and British *dorsalis.* In our study we compared specimens from a population in Durham (Fig. 1, B), consisting exclusively of *S. dorsalis,*

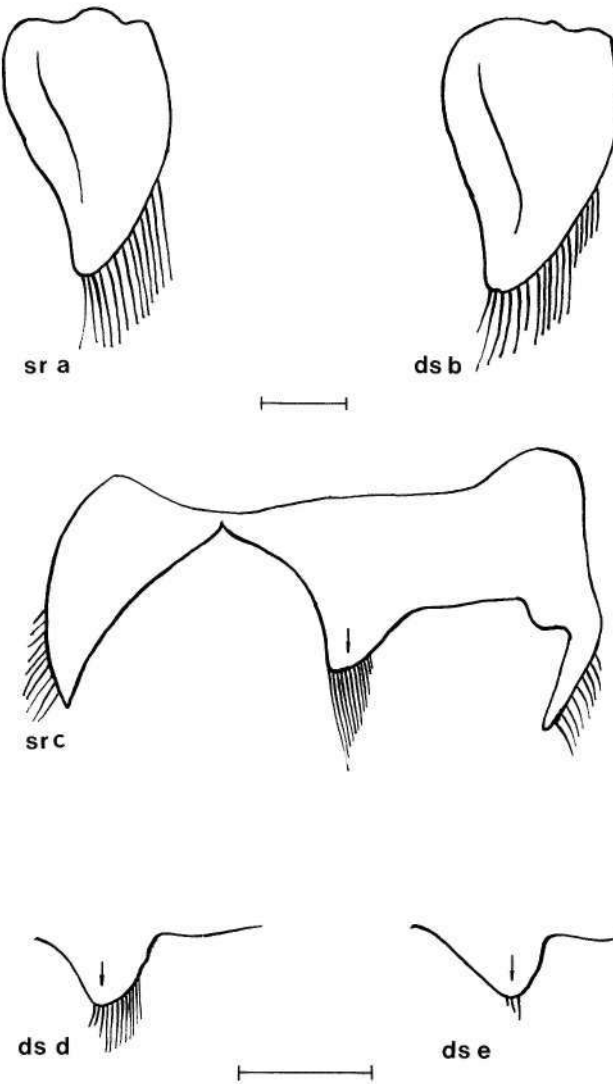

FIG. 2. *Top row:* dorsal views of the 8th dextral tergites of *S. striata* (sr a) and *S. dorsalis* (ds b). *Middle row:* dorsal view of the 7th tergite of *striata* (sr c) showing the posterior mid-lobe (arrow). *Bottom row:* two examples (ds d, ds e) of the mid-lobe (arrows) on the 7th tergite of *dorsalis*. (Scale lines 0.5 mm).

and specimens from the mixed population in Kent (Fig. 1, Z), comprised mainly of *striata* and intermediate forms. These two geographically distinct British populations also showed an overlap in the number of pronotal lines (Table 2). However, the modal numbers are different and there was a significant difference ($p<0.01$) between the mean numbers of pronotal lines in *dorsalis* and *striata*.

Table 2. The number of pale lines on the pronotum of adult males in a population of *S. dorsalis* from Durham (Fig. 1, B), a population of *S. striata* from Kent (Fig. 1, Z) and intermediate specimens from the same locality. The table gives mean numbers ± 95% confidence limits, ranges and modal numbers for n specimens.

Species	Locality	Mean ± 95% CL	Range	Mode	n
S. dorsalis	Durham	6.1 ± 0.3	5-7	6	18
S. striata	Kent	6.8 ± 0.5	6-7	7	5
Intermediates	Kent	6.7 ± 0.4	6-8	7	9

Palar pegs

On the anterior pair of legs, the tarsus is broad and forms the pala, on which there are two rows of palar pegs on the anterior surface (Fig. 3 sr a, ds b). We found no significant difference between the number of palar pegs in the distal row on British examples of *striata* and *dorsalis*. There was a significant difference ($p<0.01$) in the mean numbers of palar pegs in the proximal row, but the ranges overlap, so the numbers of pegs cannot be used to separate the two species. However, the marked proximal curve in the distal row of pegs, characteristic of *striata*, proved to be a most useful diagnostic feature (Fig. 3 sr a, ds b). Only four (1.4%) of 291 specimens identified as *dorsalis* from the 25 British populations outside Kent, had palar pegs characteristic of *striata;* these four specimens were from populations C, E and F (Fig. 1). In 15 specimens from Kent (Fig. 1, Z) the curvature of the distal row of palar pegs was totally characteristic of *striata*, while seven specimens were intermediate in form.

The right paramere

The parameres are attached to the genital capsule of corixids (see Fig. 35 on p. 67 in Savage 1989). Normally, the right paramere of *dorsalis* has a distinct distal constriction or step (Fig. 3 ds h, arrow) while in *striata* it proceeds in a smooth curve (Fig. 3 sr d, arrow). The distinctness of the constriction or step

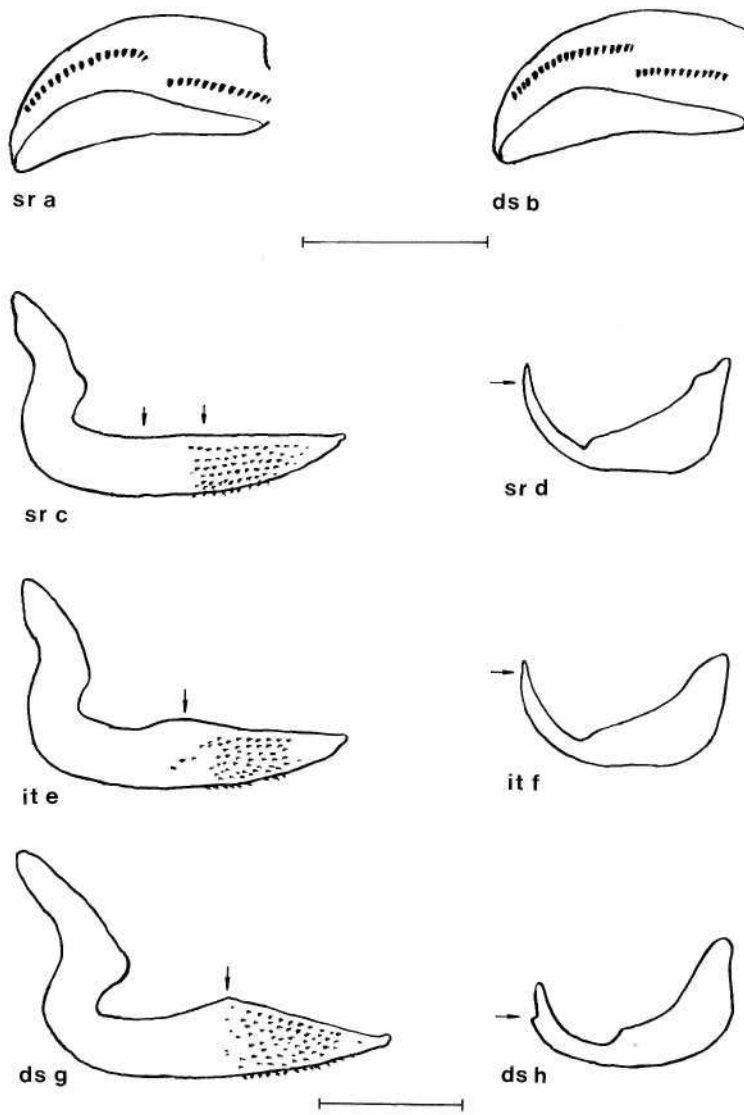

FIG. 3. *Top row:* anterior view of right pala of *S. striata* (sr a) and *S. dorsalis* (ds b). *Other rows:* left and right parameres respectively of *striata* (sr c, sr d), intermediate forms of *striata* and *dorsalis* (it e, it f), and *dorsalis* (ds g, ds h). (Scale lines 0.5 mm).

varies in all populations of *dorsalis* and is sometimes so indistinct that it may be regarded as intermediate between the two species (Fig. 3 it f). Only six (2.1%) of 291 specimens identified as *dorsalis* from the 25 British populations outside Kent, showed the smooth curve characteristic of *striata;* these six specimens were from populations A, B, C and D (Fig. 1). However, 13 specimens from a population in Cheshire (Fig. 1, C) possessed right parameres that were intermediate in form (Fig. 3 it f). In 13 specimens from Kent (Fig. 1, Z) the right parameres were characteristic of *striata* (Fig. 3 sr d), but eight other specimens were intermediate in form (Fig. 3 it f) and another one resembled *dorsalis* (Fig. 3 ds h). Further illustrations of variation in the right paramere may be found in Savage (1989) and Savage & Feakes (1991). Like the palar pegs considered above, the right paramere is usually a reliable diagnostic feature in most British populations.

The left paramere

The left paramere of *dorsalis* rises to a point on its proximal dorsal surface when examined in *precise* lateral view (Fig. 3 ds g, arrow). All 291 specimens, from all of the 25 British populations we have sampled outside Kent, showed this feature. The left paramere of *striata* has a smooth, flat proximal dorsal surface (Fig. 3 sr c, arrows). In Kent (Fig. 1, Z), the left parameres of 13 specimens were characteristic of *striata* while seven were intermediate in form, with a slight proximal dorsal swelling when examined in *precise* lateral view (Fig. 3 it e, arrow). Two specimens possessed left parameres characteristic of *dorsalis* (Fig. 3 ds g, arrow). Thus the left paramere is the most reliable diagnostic feature for separating *striata* from *dorsalis.*

The main differences between *striata, dorsalis* and intermediates

The morphological features summarised above all show variations between species, and may have some validity for identification. No single character is totally reliable to identify every male specimen encountered in Continental Europe and the British Isles, but the left and right parameres, together with the palar pegs, are certainly the best. When these features are used in combination, all undoubted individuals of *striata* and *dorsalis,* and their intermediate forms, may be identified reliably. A procedure for doing this is presented below, comprising a scoring system for a combination of characters, and a short dichotomous key.

The intermediate forms found in the Kent locality (Fig. 1, Z) are indistinguishable from the text-figures of laboratory hybrids of *S. striata* and *S. dorsalis* produced by Jansson (1979). The evidence is now very strong to suggest that these British intermediates from Kent are natural hybrids.

A scoring system for identifying *S. striata, S. dorsalis* and intermediates

Our system depends upon the use of a three-point weighted scale for each of three diagnostic features on adult males: the proximal curvature of the distal row of palar pegs, and the right and left parameres. Each of these features is given a particular value according to its perceived diagnostic validity and whether it is typical of *striata, dorsalis* or an intermediate form (Table 3). For a given specimen, the values are added to give a score for that individual.

Table 3. Values adopted for a scoring system to aid identification of British specimens of *S. striata, S. dorsalis* and intermediate forms

Morphological feature	*S. striata*	Intermediates	*S. dorsalis*
Palar pegs	–1 (Fig. 3 sr a)	0	+1 (Fig. 3 ds b)
Right paramere	–2 (Fig. 3 sr d)	0 (Fig. 3 it f)	+2 (Fig. 3 ds h)
Left paramere	–3 (Fig. 3 sr c)	0 (Fig. 3 it e)	+3 (Fig. 3 ds g)

For example, a specimen with all three diagnostic features typical of *dorsalis* would score +6 (i.e. the sum of +3 +2+1), while one with palar pegs and a left paramere typical of *striata* but a right paramere typical of *dorsalis* would score -2 (i.e. the sum of -1 -3 +2). Individuals wholly typical of *striata* and *dorsalis* will score -6 and +6 respectively. Since a few individuals score only +2 but appear to be *dorsalis* on the basis of other diagnostic features, particularly the pointed left paramere (Fig. 3 ds g), and their geographical location, we suggest that individuals with scores of -1, 0 and +1 should be regarded as true hybrids, while those with scores of -5 to -2 and +2 to +5 should be regarded as *striata* and *dorsalis* respectively, but with intermediate features, and may be called variants. However, the matter is complex and needs some explanation.

Intermediate forms: variants and hybrids *of striata* and *dorsalis*

Amongst the specimens of *dorsalis* from the 25 British populations outside Kent, a few scored +2 to +5. These variants are not likely to have been produced by natural crosses between *dorsalis* and *striata,* as the latter species is known only from southeast England. However, in Kent and Sussex, similar variants of *dorsalis* were found with variants of *striata* (scoring -2 to -5), and it is quite likely that these are in fact natural hybrids between the two species, especially when the left paramere is intermediate in form (Fig. 3 it e). Jansson (1979) showed that hybrids of *striata* x *dorsalis* occurred in mixed assemblages under laboratory conditions, although survival to the adult stage

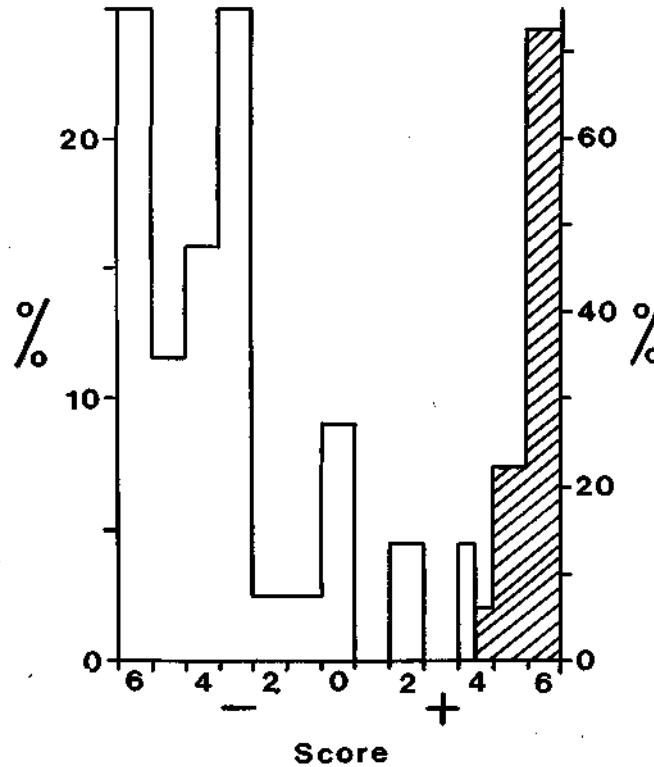

FIG. 4. The percentage distributions of average scores obtained from: *left* (unshaded) 22 adult males from a mixed assemblage in Kent (Fig. 1, Z); *right* (hatched) 18 adult males from a population of *dorsalis* in Durham (Fig. 1, B). Specimens were scored independently by the two authors and then averaged; results are expressed as percentage scores for each species.

was low. Backcrosses of hybrid males with females of *striata* or *dorsalis* showed that either fertility was low or the males were sterile. In backcrosses of hybrid females with *striata* males, fertility was low, but it was almost normal in backcrosses with *dorsalis* males. Furthermore, laboratory hybrids are morphologically nearer to the female parent species. Thus, in natural populations, intermediates are likely to exhibit a wide range of morphological variation, as is indicated by the scoring system adopted here (Fig. 4). Intermediate individuals with scores of -5 to +4 have been found in the Kent locality. However, although it may be possible to separate hybrids from variants (as defined below) in the Kent assemblage, on purely morphological criteria, it is not always possible to deduce their mode of origin; i.e.

hybridisation or intraspecinc variation. On this basis, Fig. 4 shows that the Durham population (Fig. 1, B) is principally composed of "pure" *dorsalis*, with a few variants. In contrast, the assemblage in Kent (Fig. 1, Z) contains a range of individuals varying from "pure" *striata*, through variants of this species, to (natural) hybrids and variants of *dorsalis*.

In summary, the usual definition of "hybrid" is applicable here. The term "variant" may be defined as a tendency for an individual of either species *(striata* or *dorsalis)* to have intermediate morphological features that are not due to immediate hybridisation between the two species, but rather intraspecific variation reflecting their evolutionary relationships.

Mean scores may be calculated for populations or assemblages, shown in Fig. 1. It will be seen that all of the populations outside the locality in Kent have scores of+6 or approaching +6, and therefore contain individuals of *S. dorsalis*. In contrast, the mixed assemblage in the Kent locality scores -3.3.

A key to separate *S. striata, S. dorsalis* and intermediates

Couplet 1 of the key given below, for adult males, is an alternative for couplet 21 of the key to family Corixidae on page 90 of the FBA key to adults, by Savage (1989).

1 Males*— 2

– Females— [these cannot be identified except by association with known males]

* Males may be separated from females by reference to pages 68-69 of Savage (1989).

2 Left paramere†, in *precise* lateral view, forming, proximally, a straight cylinder (Fig. 3 sr c); proximal end of distal row of palar pegs forming a sharp curve (Fig. 3 sr a); right paramere tapering gradually to a point (Fig. 3 sr d); score –6 (Table 3)— **Sigara striata** (L.)

– Left paramere, in *precise* lateral view, rising, dorsally, to a point (Fig. 3ds g) or with a slight to moderate swelling in that position (Fig. 3 it e); distal row of palar pegs with or without a proximal sharp curve (Fig. 3 sr a, ds b); right paramere usually with, at least, a slight constriction before the apex (Fig. 3 it f, ds h)— 3

† The morphology of the parameres and palar pegs, together with notes on dissection, may be found on pages 66-69 of Savage (1989). Until experience is gained, it is wise to dissect the relevant structures, place them on a slide in 50% ethanol, and examine them at magnification x100.

3 Left paramere, in *precise* lateral view, rising, dorsally, to a point (Fig. 3 ds g); distal row of palar pegs usually* forming a smooth slight curve (Fig. 3 ds b); right paramere usually* constricted abruptly before the apex (Fig. 3 ds h); score +6 (Table 3)— **Sigara dorsalis** (Leach)

* Unusually (very rarely) a specimen may be found with palar pegs and/or a right paramere more characteristic of *striata*. Such specimens are variants of *S. dorsalis* with scores of +2 to +5.

- Left paramere, in *precise* lateral view, only slightly swollen dorsally (Fig. 3 it e); proximal end of distal row of palar pegs usually forming a sharp curve (Fig. 3 sr a); right paramere either proceeding smoothly to a point (Fig. 3 sr d) or with a slight constriction before the apex (Fig. 3 it)— **S. striata x S. dorsalis** hybrids or variants*

*Score -1, 0 or +1: natural hybrids
Score -5 to -2: variants of *S. striata*
Score +2 to +5: variants of *S. dorsalis*
(See Table 3 and accompanying text for details).

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