# BIONOMICS OF SOME RHYPAROCHROMINAE

# (HETEROPTERA : LYGAEIDAE)

# WITH SPECIAL REFERENCE TO THEIR FEEDING HABITS

by

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ABSTRACT

The life histories of five Rhyparochromine species representing three genera were studied. Some information on four other species (of the same genera) occurring in smaller numbers in the samples are also included.

The stance assumed during feeding is described as also the habit of bending the rostrum and later folding it away from the stylets to allow greater penetration of the stylets into the food.

It is shown that seeds are the essential food for these species as they were reared through the complete life cycle on seeds alone. The vegetative parts of plants and the larvae of a Coleopteron were unsuitable as sole food.

Five species were tested on the seeds of seven different plants. As these were plants with which some of the species were associated they represent the natural food. Growth curves were drawn by plotting weight, taken every two to four days, against time. The survival, preoviposition period, oviposition period, fecundity and adult longevity of insects reared on the different seeds was determined.

The different preference ranking of the seeds by each species revealed that selectivity predominated over the nutritive value of the seeds. The basis of the selection must therefore be on the physical nature of the seed coat, on the detection of differences finer than just the basic constituents of the seed - i.e. perception of slight differences in chemical concentrations, or on the presence or absence of secondary plant substances.

The larval stages of five species are described. As the Scolopostethus larvae were indistinguishable, several body measurements were analysed which showed distinctive species shapes.

Hybridization studies on four Scolopostethus species confirmed their specific status. However, $F_1$ individuals were obtained, though in most cases only of the female sex.

The fertility of the first crosses, the fecundity of the hybrids and the fertility of the unsuccessful backcrosses were determined.

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# INTRODUCTION

Until recently little was known about the biology of the Lygaeidae (Douglas and Scott 1865, Saunders 1892, Butler 1923, Miller 1956, Southwood and Leston 1959) and in particular, of their food. Of the 52 British Rhyparochrominae which are the dominant subfamily of the Lygaeidae, Southwood and Leston (1959) give the food for only five species and two or three associations which indicate a genuine food host. Hence the present study.

Although some records indicate predacious habits in the subfamily (Butler 1923, Thomas 1955) and in Scolopostethus (Woodward 1949) preliminary work showed that the food is seeds. Amongst the literature are a few records of this subfamily feeding on seeds (e.g. Hoffman 1932, Corby 1946) and this led Southwood and Leston (1959) to suggest they are mainly seed feeders. Very recently Ashlock (1958) showed that some members of the subfamily will definitely feed on seeds, but he concludes "It remains to be demonstrated whether seeds are the prime item in the diet of these insects, and if they are what preferences the various species have."

Seed feeding does occur in other subfamilies e.g. Chilacis typhae (Perris) in the Artheneinae (Jordan 1935, Southwood and Leston 1959). In the Lygaeinae the milkweed bug Oncopeltus fasciatus (Dallas) is another example, and is well known in the laboratory. Frings, Frings and Little (1957) showed that a substitute food reduces its fecundity. Johansson (1958) studied the effect of nutrition and hormones on reproduction in O. fasciatus. He showed that the quantity of food (from starvation to excess) and the quality of food (i.e. using different

seeds) markedly affected the pre-oviposition period and fecundity. Beck, Edwards and Medler (1958) ~~showed~~ studied the feeding behaviour in O.fasciatus, and ~~that~~ showed that a synthetic food within a milkweed seed husk supports normal growth but with a 33% mortality near the final moult.

The present study is on the life histories and feeding habits of Scolopostethus affinis (Schilling), Scolopostethus thomsoni Reuter, Scolopostethus decoratus (Hahn), Stygnocoris fuligineus (Geoffroy) and Drymus sylvaticus (Fabricius) with some notes on Scolopostethus grandis Horvath, Stygnocoris rusticus (Fallen), Stygnocoris pedestris (Fallen) and Drymus brunneus Sahlberg. From these common genera the five main species were chosen because they were the most abundant at Silwood Park: they also did well under laboratory conditions.

The present study was with natural foods rather than substitute foods for it is better to know what seeds are fed on in the field especially where two species of a genus often occur together as in Scolopostethus suggesting an ecological difference. In addition to their recorded habitats Scolopostethus species were taken with Stygnocoris fuligineus and Drymus sylvaticus under annual weeds on arable land. Therefore each species was tested on eight different foods, including one of animal, and was reared on five to seven of them. A within species comparison of total development, pre-oviposition period, oviposition period, fecundity and adult longevity on the different foods could then be made.

After the present study had begun Sweet (1960) showed that Rhyparochromines are seed feeders by rearing most of the species from Connecticut on sunflower seeds.

Mortality in his bugs was very high, probably because a substitute food was used.

As the immature stages are not described (Butler 1923) this is done here. There has been a sudden recent interest in the biology of the Lygaeidae and Rhyparochrominae in the appearance of keys to larvae, and the larvae have several valuable taxonomic characters (Slater 1951, Leston and Scudder 1956, Scudder 1957, Putchkov 1958, Slater and Sweet 1961, Sweet and Slater 1961).

As the specific status of some Scolopostethus species is open to doubt on adult characters (Saunders 1892, Southwood and Leston 1959) and as Butler (1923) and the present author found many of the larvae to be indistinguishable in practice, hybridization was attempted with varying degrees of success.

## MATERIALS AND METHODS

The life histories were studied by taking samples each week from the breeding habitats, and at longer intervals from the overwintering sites.

Scolopostethus thomsoni was sampled from three stands of stinging nettle (Urtica dioica L.). Stand 1 under oak (Quercus robur L.) which contributed to the leaf litter, was surrounded by rank grass. Although pure nettle in one portion, this stand was mostly interspaced with grass, notably cocksfoot (Dactylis glomerata L.). Ground elder (Aegopodium podagraria L.) was also present in one portion of the stand. Stand 2 was virtually pure nettle except for two small trees, ash (Fraxinus excelsior L.) and hawthorn (Crataegus monogyna Jacq.) in a damp depression in one corner. Limes (Tilia x vulgaris Hayne) were a few yards from the edge of the stand. The trees contributed little to the thin layer of leaf litter. Stand 3 was also a pure stand under sycamore (Acer pseudoplatanus L.) which contributed considerably to the leaf litter. Southwood and Leston (1959) note that this bug, unlike other members of the genus, is often taken by sweeping, especially amongst rank vegetation. Therefore sweeping was one method of sampling used in all habitats, and very occasionally other species were taken. It was found that Scolopostethus thomsoni could be taken from the ground throughout the year, even during the period from May to October when some of the population was up on the nettle plants. Accordingly the nettle litter was also sampled at the same time. A 1 - foot quadrat was the unit chosen, and all the leaf litter within this unit was examined down to the bare soil surface. For each stand

of nettles a sample consisted of catches from 100 sweeps and from 10 1-foot quadrats of leaf litter taken at random. These were the units of sampling used in all habitats. Scolopostethus affinis was taken less regularly and in smaller numbers from stands 1 and 2, and on two occasions only, from stand 3. Sometimes Drymus sylvaticus and D. brunneus were also taken amongst nettles.

The area of heather sampled for Scolopostethus decoratus was mainly Calluna vulgaris (L.) with a patch of Erica cinerea L. in the centre and some isolated plants around the edge. As regular sweeping of these plants during 1960 yielded only six specimens (from E. cinerea) this was not continued. Sampling amongst the leaf litter under and around the plants was very effective, and it soon became apparent that E. cinerea was the host during the breeding season and C. vulgaris the overwintering quarters. D. sylvaticus and D. brunneus were occasionally found. Stygnocoris pedestris occurred regularly in small numbers under E. cinerea.

Stygnocoris fuligineus and D. sylvaticus were found, together with the Scolopostethus species, in Pond Field on a piece of arable land that had been left after a crop of oats (Avena sativa L. var. Blenda) sown in 1958, and which supported a flora of annual weeds, some grasses, and self sown oats. The nearest nettles, which were on the far side of a damp depression and near a small oak, were at a distance of 20 yards (across dense grass). Twenty-five yards away in the opposite direction, and also across dense grass, were elms (Ulmus procera Salisb.) and nettles. Here also was leaf litter to which the bugs may move by winter. The insects seemed always to be under the plants and never on them, and were often seen crossing patches of bare ground between plants.

Sweep-sampling also showed that the habitat of these bugs is close to the surface of the ground because none was taken. There seemed to be definite associations with chickweed (Stellaria media L.), sheep sorrel (Rumex acetosella agg.), spurrey (Spergula arvensis L.) and Yorkshire fog (Holcus lanatus L.), and accordingly these plants were selected as separate sampling habitats. Unfortunately this piece of land was lightly disced in late September 1960 and so the movement to overwintering quaters could not be ascertained in that season for Stygnocoris fuligineus which up to then was still present. By the following spring the vegetation was a dense, rank growth, mostly grasses. Sampling on four occasions during the season showed that it was no longer a suitable habitat for these species.

In late September 1960 other arable areas on the Field Station were examined, but Stygnocoris fuligineus was found on only one, on Silwood Bottom, under spurrey. It, also, was left untouched after cropping. In the following season the majority of the habitat was unsuitable for these Lygaeid bugs because the vegetation had become a dense sward.

In 1961 the study of Stygnocoris fuligineus and D. sylvaticus was made in two different areas on Silwood Bottom. Specimens associated with spurrey were sampled from an area, approximately 44 yards square, of arable land which had been growing wheat (Triticum aestivum L. var. Eclipse) that season and was overgrown with spurrey. There were patches of bare ground and a few plants of sorrel, chickweed and Yorkshire fog on this area. On one side was dense grass, and the nearest tree, an oak, was in that direction at a distance of 25 yards. On the other three sides were adjacent crops or fallow land for at least 55 yards, and

then dense grass and some trees. Specimens associated with sorrel were sampled from under plants scattered amongst the dense gress. There was no association with the grass.

During winter when the bugs are sluggish, sampling by examining leaf litter in the field was impracticable. Therefore the litter from a known surface area was taken into the laboratory and warmed in a specially designed box which was placed one foot above an electric heating element. The box was built with a metal bottom over which a half-inch layer of sand was placed. A sheet of paper served to prevent the insects from moving into the sand. After warming for one to two hours the bugs were quite active and were readily sorted from the litter.

A proportion of the females collected in 1960 and the majority of those collected in 1961 were dissected to determine, primarily, the state of the ovaries. The study of life histories in the field was supplemented by studies on incubation, development and oviposition in an insectary. Temperatures in the insectary would simulate the field temperatures.

In 1960 a proportion of adults and some late larvae from the field were weighed so that weights taken in the feeding experiments could be related to the natural weights. These insects were first anaesthetized with carbon dioxide and then weighed individually on a five-milligram torsion balance callibrated in 0.01 mg.

Information on the flight activity of the species under study was obtained by examining suction trap catches taken by Dr. T.R.E. Southwood on the Field Station in the years 1959-60. Traps 1 and 3 were the small, 9-inch Vent-Axia type (Johnson 1950, Taylor 1951),

whilst traps 2 and 4 were the large, 18-inch propeller type (Johnson and Taylor 1955). The location of the traps and their distance from the nearest arable land was: trap 1 in a stand of broom (Sarothamnus scoparius (L.) ) 150 yards north west; trap 2 in long grass 20 yards west; trap 3 in an oat crop; trap 4 in 1959 on a short grass headland 10 yards south of an oat crop, and in 1960 on the edge of arable land at a height of 30 feet above ground level. With the exception of trap 4 in 1960 all traps were at a height of four feet above ground level.

Early feeding experiments were conducted in the insectary. Development was very slow and only a single generation was reared in a season. Thus the great duration of any experiment and the variable temperature conditions made this unsuitable for replicated feeding experiments. These were therefore conducted in a heated cabinet at 74 (72 - 76) °F. with constant illumination from a 15-watt lamp.

For rearing containers closed, round, plastic pill boxes $1\frac{1}{2}$ inches in diameter by 1 inch deep were used. A layer, about $\frac{1}{8}$ inch, of plaster of Paris across the bottom was satisfactory for maintaining drinking moisture and relative himidity. Food was placed on a disc of filter paper and both were renewed when the food became mouldy. This was after five to seven days for nettle seed; other seeds could be left longer. A few drops of water were added every two to four days. Although this method of watering takes more time than the gravity supply to an open container from an inverted vial, described by Butt (1949) and Johansson (1958), it has the advantages of permitting (a) closed containers with a high and always adequate relative humidity which is independent of the external environment; and (b) small containers which

facilitate bulk handling of individually reared insects (as distinct from colonies) e.g. 150-300, in a minumum of space. Further, macropterous specimens sometimes flew out when the lids were removed, which obviates the use of closed containers. In the study of oviposition in Stygnocoris fuligineus carried out in the insectary, 6 inch by 1 inch glass tubes stopped with muslin at one end and cottonwool at the other, were used as containers. A sprig of chickweed bearing seeds was added for food, but had to be renewed every two days to maintain moisture and relative humidity. These tubes were not as satisfactory as the pill boxes.

In the feeding experiments, growth rates on the different foods were determined by following the body weights, measured on the torsion balance, of individual insects in addition to their development in time. Twenty newly hatched larvae of each species were started on each food. As the first two instars are small weighings began at the third instar and were conducted every two to four days (according to the rate of development on that food) until adults (males)or oviposition (females). However, the average weight of 20 first instar larvae before feeding was obtained for each species as the basic starting weight for all experiments. The insects were reared separately, at first through all stages, but later from the third larval instar. Each insect was weighed alive in the active state - i.e. not anaesthetized as this might interfere with growth (since Ribbands, 1950, showed that carbon dioxide and nitrogen cause permanent changes in the behaviour of honey bees). Each feeding experiment of this type, including an assessment of longevity, lasted three months or more.

The fecundity of each species on each food was determined by counting the eggs from four to six isolated females at intervals of approximately one week.

As inbreeding of O.fasciatus results in fewer eggs and in some cases lower survival after four generations (Turner 1960) inbreeding was avoided in the present study.

As Frings et al. (1957) showed in O.fasciatus that survival increased with decreasing food renewals, the effect of the regular food renewals made in the present study was investigated.

## (A) BIONOMICS

### I. Scolopostethus thomsoni

RESULTS

Overwintering

Scolopostethus thomsoni overwinters as adults and third to fifth instar larvae. In 1960 equal numbers of males and females overwintered, but twice as many adults as larvae. However in 1961 the numbers of adults taken during winter were low (Table 1).

TABLE 1. Numbers of Scolopostethus thomsoni taken from overwintering quarters.

| | Males | Females | Larval instars 5 | 4 | 3 | 2 |
|---|---|---|---|---|---|---|
| Jan-Apl. 1960 | 28 | 28 | 9 | 15 | 7 | 0 |
| Jan-Mar. 1961 | 8 | 4 | 3 | 17 | 10 | 1 |

The main site was amongst nettle litter, but some specimens were taken from straw, grass tussocks and leaf litter near nettles. Very occasionally an adult was taken from leaf litter under a shelter belt well away from nettles. In the last week of September some adults and late larvae were found sheltering in the base of a cocksfoot tuft growing at the edge of a nettle stand. Over the next two weeks 40 tufts of cocksfoot, some within 15 yards of nettles and some well away from nettles were examined. Only five tufts , right on the edges of stands of nettle yielded specimens (15). In November and January, 20 more cocksfoot tufts mostly well away from nettles were examined, but as no Scolopostethus thomsoni were found this can not be an important over-

wintering site.

In specimens dissected in late January the ovaries were immature, the fat body white and continuous and the gut empty except for solid, granular, orange coloured material on the inside walls. In specimens dissected in early March the ovaries were still immature, the fat body was white and globular, and the gut was full of white granular material in the crop and brown material in the remainder.

In order to determine whether overwintering larvae continue to develop slowly, or are quiescent, some in the third, fourth and fifth instars were placed in the cold insectary and these did not moult during the winter. That this is a quiescence and not a diapause was shown when larvae and females brought into the laboratory in late autumn and early winter continued their development and oviposited. These overwintering females were unfertilized.

Breeding cycle

(a) Nettle habitat 1960.

In the 1960 season earliest ovarian maturity was attained in mid-June. At this time most females still had immature ovaries, but by the last week in June nearly all females contained ripe eggs. The oviposition period continued through to the last week in August after which date all dissected females had immature ovaries. Table 2 summarises the state of the ovaries through the breeding season. From late July until early October

TABLE 2. State of ovaries in Scolopostethus thomsoni during 1960.

| Period | Number dissected | Percentage with ovaries Immature | Mature | Senescent |
|---|---|---|---|---|
| 13.6-18.7 | 57 | 14 | 86 | 0 |
| 25.7-29.8 | 54 | 2 | 85 | 13 |
| 6.9-8.11 | 17 | 88 | 0 | 12 |

small numbers of old females with undeveloped ovaries showing yellow corpora lutea were taken.

The field weights, taken as soon as possible after capture (i.e. within two hours) are given in Table 3.

TABLE 3. Weights of some Scolopostethus thomsoni specimens taken from different habitats in 1960.

| Date | Females Mean weight in milligrams | Number of females weighed | Males Mean weight in milligrams | Number of males weighed |
|---|---|---|---|---|
| Nettles stand 1 | | | | |
| 11.2 | 2.95 | 1 | - | 0 |
| 3.3 | 2.17 | 1 | | |
| 10.5 | 2.83 | 3 | 2.22 | 2 |
| 13.6 | 2.35 | 3 | - | 0 |
| 15.6 | 2.72 | 6 | 1.90 | 7 |
| 27.6 | 2.39 | 8 | 1.99 | 2 |
| 3.7 | 2.74 | 13 | 1.51 | 10 |
| 6.7 | 3.24 | 2 | 2.13 | 3 |
| 12.7 | 2.83 | 17 | 1.71 | 36 |
| 18.7 | 2.74 | 20 | 1.61 | 28 |
| 8.8 | 2.57 | 6 | 1.36 | 3 |
| Nettles stand 2 | | | | |
| 28.6 | 3.25 | 8 | 2.00 | 8 |
| 18.7 | 3.34 | 1 | 1.84 | 2 |
| 12.8 | 3.21 | 5 | 1.94 | 1 |
| 7.9 | 2.99 | 3 | - | 0 |
| 13.9 | 3.43 | 2 | - | 0 |
| Arable land | | | | |
| 16.5 | 3.84 | 7 | 2.27 | 6 |
| 17.5 | 4.02 | 5 | 2.19 | 1 |
| 31.5 | 4.07 | 3 | - | 0 |
| 15.6 | 3.78 | 1 | 2.38 | 3 |

As far as can be determined from this limited data the weight remains fairly constant throughout the breeding season: this contrasts with Stygnocoris fuligineus (Table 15).

The life cycle in 1960 as studied on the three stands of nettle is shown in Fig. 1A. First instar larvae were found in sweepnet catches and on the ground from the last week of June. All instars except the fifth were then present until mid September when the last first instar was taken. The last second instar was taken in the last

week of September. The fifth instar larvae began to appear in late August and the new adults from the first week of September (see Table 2). As none of these adults developed to sexual maturity and as larvae in the third and later instars overwinter, it can be concluded that there is but a single generation a year. Adults were present throughout the year.

In late July the nettles on stand 1 were severely damaged by aphids (Microlophium evansi (Theobald) ). This may have caused the sudden decline in numbers of adults taken and it is assumed that they moved off the stand to another source of food. Although the stand began to recover in early August the setback may have been responsible for the low numbers of new adults taken in September (Fig. 1).

(b) Nettle habitat 1961.

In 1961 the breeding cycle in the nettle habitat was similar to that in 1960 except that it began earlier, consistent with the warmer weather and more sunshine that spring. On 19.4.61 a dissected female had large egg rudiments and one egg, and from 3.5.61 most females contained several eggs. One female dissected on 22.5.61 contained ripe eggs and corpora lutea in the other ovarioles showing that she had already oviposited. The state of the ovaries through the season is summarized in Table 4. Some old females were taken on 19.9.61.

TABLE 4. State of ovaries in Scolopostethus thomsoni during 1961.

| Period | Number dissected | Percentage with ovaries | | |
|---|---|---|---|---|
| | | Immature | Mature | Senescent |
| 19.4-22.5 | 8 | 12.5 | 87.5 | 0 |
| 25.7 | 5 | 0 | 100 | 0 |
| 20.8-6.9 | 29 | 93 | 7 | 0 |
| 19.9-9.10 | 31 | 90 | 0 | 10 |

There was no increase in the number of adults in June (which may have been effected by the nettle damage in 1960) but the newly emerged autumn adults remained amongst the nettles (fig. 1).

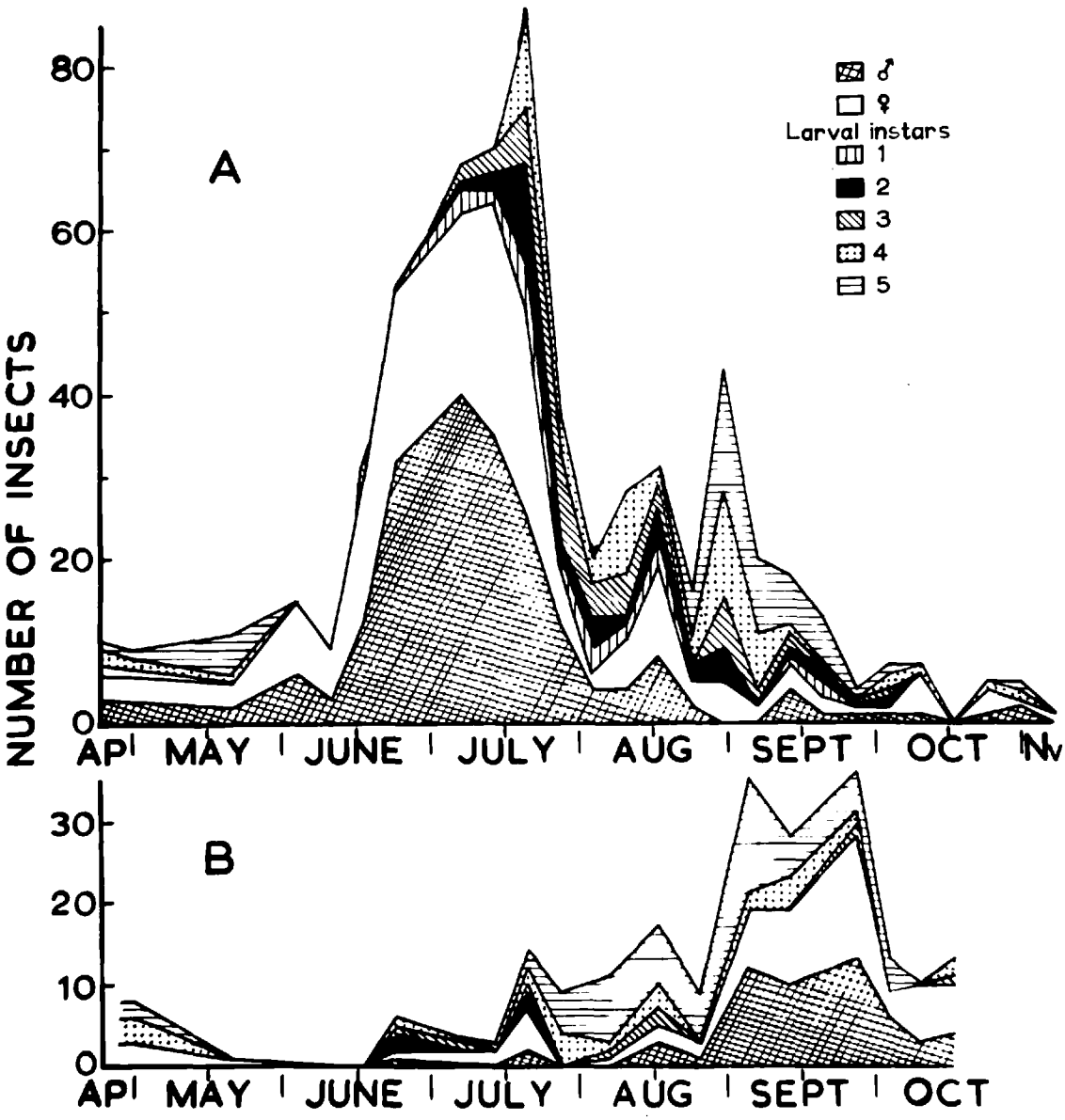



Figure 1. Numbers of Scolopostethus thomsoni taken from nettles in weekly samples. A, in 1960 from stands 1,2 and 3; B, in 1961 from stands 1 and 2. In both years by far the greater number of specimens came from stand 1.

(c) Comparison of numbers on the plants and on the ground.

Although it is difficult to compare directly the catch in 100 sweeps of nettle plants with that obtained by searching 10 square feet of ground around the bases of the plants, the total catches (Table 5) show that in stand 2 more larvae were found on the ground than on the plants.

TABLE 5. Numbers of Scolopostethus thomsoni taken by sweeping nettles, and from nettle litter.

| Stand | Sweepnet catch | | | | | | | Ground catch | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Adult | | Larval instars | | | | | Adult | | Larval instars | | | | |
| | ♂ | ♀ | 5 | 4 | 3 | 2 | 1 | ♂ | ♀ | 5 | 4 | 3 | 2 | 1 |
| 1960 | | | | | | | | | | | | | | |
| 1 | 140 | 113 | 25 | 24 | 28 | 18 | 16 | 14 | 12 | 13 | 12 | 6 | 4 | 3 |
| 3 | 29 | 24 | 7 | 7 | 6 | 3 | 3 | 2 | 5 | 0 | 1 | 0 | 1 | 0 |
| 2 | 26 | 21 | 2 | 2 | 2 | 1 | 1 | 5 | 13 | 8 | 14 | 8 | 6 | 1 |
| 1961 | | | | | | | | | | | | | | |
| 1 | 12 | 24 | 33 | 12 | 6 | 2 | 0 | 18 | 16 | 15 | 0 | 1 | 2 | 0 |
| 2 | 5 | 5 | 11 | 11 | 0 | 0 | 0 | 20 | 18 | 18 | 4 | 0 | 0 | 0 |

Scolopostethus affinis was also breeding on this stand, but when larvae from the ground and from the plants were reared, adults of both species emerged in both cases, which indicates that the two species do not occupy different niches. Thus this discrepancy is unexplained, but may be related to the thinner litter in stand 2.

The young seeds appeared on the nettle plants from early June when the plants were $1\frac{1}{2}$ - 2 feet in height, and in July some plants had reached 5 feet in height. By late August much of the seed was ripe, but some seed remained on the plants until late autumn. The occurence of

the larvae synchronised with the development of the seed (Table 6).

TABLE 6. Showing periods and numbers of Scolopostethus thomsoni on nettle plants on stand 1 during 1960.

| Period | No. of Adults ♂ | No. of Adults ♀ | No. of larval instars 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|
| 13.6 | 1 | 5 | | | | | |
| 5.7 | 21 | 17 | | | | | |
| 12-25.7 | 83 | 51 | 0 | 0 | 5 | 11 | 9 |
| 31.7-14.8 | 23 | 20 | 0 | 9 | 14 | 2 | 4 |
| 22.8-6.9 | 1 | 1 | 15 | 10 | 5 | 4 | 1 |
| 12-27.9 | 2 | 1 | 5 | 2 | 4 | 1 | 2 |
| 3-25.10 | 3 | 2 | 0 | 2 | | | |

(d) Weed habitat 1960.

Scolopostethus thomsoni also occurred in Pond Field under weeds in 1960, but in small numbers. A total of 27 adults was taken, and some larvae. Dissections showed that ovaries were well developed by mid May, and by the end of May contained ripe eggs. First instar Scolopostethus larvae were present by mid June and were followed by small numbers of later instars, but there were no larvae or adults on the area after August.

Oviposition site

In the insectary, females kept in tubes and offered nettle leaves and stems deposited most of their eggs in the cottonwool plug, whilst one or two eggs were laid on the plant. Eggs were deposited singly or side by side in small groups, but when touching were not comented together. No orientation could be noted as some eggs were horizontal,

and others vertical, to the substrate. When green seed from the field was examined, partly incubated eggs were found within the perianth against the fruit. Females kept in the pill boxes deposited their eggs in the same site when provided with green or harvested nettle seed, although some eggs were found on the outside of the perianth and on the filter paper.

During the harvesting of nettle seed on 25.8.60, as the seedheads were shaken out on a sheet of paper many first and second instar larvae and some Scolopostethus eggs were found.

Incubation period

The duration of incubation in the insectary is shown in Table 7. Sixty-five per cent of the eggs, which were laid by five females, hatched.

TABLE 7. Incubation period for Scolopostethus thomsoni in the insectary 1960.

| Incubated during | Number of eggs hatching in the number of days indicated | | | | | | | | | Mean Temperature °C. |
|---|---|---|---|---|---|---|---|---|---|---|
| | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | |
| 19.5-17.6 | | | | | 3 | 2 | 4 | 3 | 4 | 14.0 |
| 7.6-26.6 | 2 | | | | | | | | | 15.1 |
| 2.7-31.7 | 1 | 3 | 1 | | 2 | 1 | | | | 15.0 |
| 13.7-2.8 | | | 1 | 1 | | | | | | 14.8 |

Larval development

The duration of larval development is shown in Table 8. Four other larvae in this group overwintered in the fifth instar. The mean monthly maximum and minimum temperatures in the insectary are shown in Table 26.

TABLE 8. Development of Scolopostethus thomsoni on young nettle seed in the insectary 1960.

| Date laid | Incubation period in days | Duration of larval instars in days 1 | 2 | 3 | 4 | 5 | Date adult emerged |
|---|---|---|---|---|---|---|---|
| 8.6 | 18 | 12 | 7 | 18 | 18 | 23 | 12.9 1♀ |
| 7.6 | | | | | | | 10.9 |
| 6.7 | 19 | 10 | 10 | 12 | 15 | 31 | 29.9 3 |
| 7.7 | (18-20) | (9-12) | (8-11) | (10-15) | (11-17) | (22-45) | 26.10 |

Percentage of the macropterous form

In 1960 a total of 502 adults, 261 males and 241 females, was taken. Of these 4.8% (6.5% of the males and 2.9% of the females) were of the macropterous form with the wing membrane fully developed and reaching, or almost reaching, to the posterior of the abdomen. The majority of the specimens had short wings. In 1961 the percentages of the macropterous form in the specimens taken were 2.5% of all adults, 2.7% of the males and 2.4% of the females.

This low percentage of the macropterous form would account for the very small number collected in the suction traps, only two (macropterous females) on 25.8.59 and 15.6.60, both in trap 2. These records may represent post and pre-hibernation flights.

CONCLUSIONS

Number of generations

Field sampling indicated the duration of the instars (Table 6) and the time intervals approximated those obtained by rearing individual specimens in the insectary (Table 8). These two sources show that

there is a single generation - there is no indication of, or time for a second generation as suggested by Southwood and Leston (1959). There is a long oviposition period which is complicated by late maturing, overwintering larvae. Table 6 shows a cycle of larvae developing from July to September, but the eggs from which they hatched would have been laid in early to mid June. The first eggs oviposited in early to mid May could not develop to new adults before mid to late August. The eggs taken on 25.8.60 would have been laid by old females, for if they were laid by new females one would expect to find some of these with ovaries still maturing during September, but there was no evidence of this (Tables 2 and 4).

Aggregation, and changes in numbers between seasons.

The change in the numbers taken in sampling from one year to the next (Fig. 1) appears to be accounted for by the effects of the aphid attack on the food plant. However, as there were marked differences in the numbers of specimens taken from each stand (Table 5) and the bug sometimes persisted in low numbers, then behaviour alone may be responsible.

In any nettle stand where the bug is known to be present, it sometimes was not found except in a small localized area where several specimens were aggregated. For example, on 8.11.61 a half-hour search amongst leaf litter in stand 2 gave a nil catch but in the next five minutes 28 specimens were taken from within an area of one square foot, and on 9.12.61 22 specimens were taken from grass at the base of nettles in eight minutes, from the same unit area.

Habitat.

On the Field Station this bug was found associated permanently only with nettles, and it will climb the plants, as noted by Southwood and Leston (1959), to feed on the developing seeds.

Although some specimens were found on arable land it is not known what they were feeding on(this problem was further investigated in the feeding studies) and the numbers taken decreased eventually to zero possibly because there was no suitable food. The habitats listed by Southwood and Leston (1959) are meadows, wastelands, woodland clearings, parks and gardens. It would be interesting to know if the species breeds away from nettles in these habitats and if so on what food. In a short trip to Oslo in early June 1961 the author took adults and fifth instar larvae of Scolopostethus thomsoni and Scolopostethus affinis from grass under silver birch, and adults of thomsoni amongst moss, grass and chickweed.

## 2. Scolopostethus affinis

RESULTS.

Overwintering.

Scolopostethus affinis overwinters in nettle litter or in leaf litter near nettles. During two winters 17 males and 11 females were taken from nettle litter, and one male was taken from leaf litter under a shelter belt well away from nettles. When 60 tufts of cocksfoot were examined to determine the number of Scolopostethus thomsoni overwintering in such sites, only one specimen of Scolopostethus affinis was found.

Females taken into the laboratory in January oviposited in 5-15

days. That there is no diapause was shown when larvae taken into the laboratory in late August and also females reared in the laboratory from eggs, completed their development and oviposited.

Breeding cycle

(a) Nettle habitat

Twenty seven males and 20 females were taken amongst nettles in 1960, and 20 males and 20 females in 1961. The earliest females taken in the last week of June in 1960 contained ripe eggs. In the following season, two females taken on 19.4.61 contained eggs; a female taken in late April and placed in the insectary oviposited in the second week of May; and a female taken on 10.5.61 contained one egg and corpora lutea in the other ovarioles. In both seasons oviposition continued through July, but females taken in September and October had immature ovaries. Specimens occurred both on the plants and on the ground.

The mean weights of seven males taken from May to August and eleven females taken from April to July were, respectively 2.49(2.17 - 2.76) mg. and 3.55 (2.87 - 4.48) mg. Two females with immature ovaries taken on 15.5.60 and 19.9.60 weighed 2.65 and 2.76 mg. respectively. One male taken on 3.3.60 weighed 1.88 mg.

The larvae could not be distinguished from those of Scolopostethus thomsoni, but as ovarian maturity in both species was attained at about the same time it is assumed that their larvae also appeared together. The first and second instars were present by the end of June. By rearing some larvae through to adults it was determined that the third and fourth instars of Scolopostethus affinis were present in mid August and the fifth instar throughout August. Most of the larvae were

designated as Scolopostethus thomsoni since the adults of that species were far more numerous.

(b) Other habitats

On 17.5.60 a male and a female were taken under chickweed. Eight males, four females and a fourth instar larva were taken under dandelion (Taraxacum officinale agg.), some in the bases of the plants, on 21.5.60 in an old gravel pit at Newland's corner, Surrey. The occurrence in grass under silver birch in Norway has already been noted under the previous species.

Oviposition site

In the laboratory and in the field eggs were deposited within the perianth against the nettle fruit, and up to three eggs have been found within one perianth. Females kept in the laboratory sometimes laid eggs on the outside of the perianth or on the filter paper. When other seeds were provided as food, eggs were laid amongst the loose seeds. In such cases the eggs would be placed either separately, or in small groups of two to five sometimes touching but not cemented together.

Fecundity

An indication of fecundity at field temperatures was obtained from a female taken in April which laid 51 eggs from 10.5.61 to 20.6.61 in the insectary. The food provided was fresh, green nettle seed. Fecundity was investigated more fully in the feeding studies.

Incubation period

Six of seven eggs laid in the insectary on 1.7.60 hatched in 22 (range 21-22) days.

Percentage of the macropterous form

Over the two years only five macropterous males and four macropterous females were taken. These represent 10.6% and 10% respectively of the total numbers caught. The fully formed membrane extended to, but did not exceed, the posterior of the abdomen.

In the suction traps only two specimens (both from trap 2 and both macropterous) were taken: a male on 7.5.59 and a female on 5.5.60.

CONCLUSIONS

Number of generations

Southwood and Leston (1959) point out that it is unknown if the bug is single or double brooded. The evidence presented here indicates that there is but a single generation. There is a long oviposition period at least until the end of July; no females were dissected in August, but oviposition had ceased by September. The life cycle here is similar to that in Finland where Pfaler (1936) showed that oviposition occurs from May to August, and larvae are present during the same period.

Pfaler (1936) also found evidence of larvae overwintering in Finland. Although no larvae taken during winter were reared to adults to confirm this in England, a fourth instar larva which was taken with twelve adults on 21.5.60 must have overwintered because it could not have developed as far in that season.

Habitat

Douglas and Scott (1865) said this bug is common in hedges, under leaves, and at the roots of grass in dry places, from April to September; Butler (1923) mentioned a habitat of moss and roots of grass in addition

to nettles; and Southwood and Leston (1959) said it is often, but not always, associated with nettles, although this association is only on the ground.

In the present study, although occasionally taken away from nettles, Scolopostethus affinis was mainly sought in nettles from which habitat it was most readily taken. It was found that as in the case of Scolopostethus thomsoni (Southwood and Leston 1959) this species climbs the nettle plants from which it was taken as frequently as on the ground. Thus a definite connection between the bug and the plant is now established, although Thomas (1955) could find none.

The variety of habitats recorded in the literature and in the present work suggests that the bug is adaptable to several foods and this idea is followed up in the next section.

## 3. Scolopostethus decoratus

RESULTS

### Overwintering

Scolopostethus decoratus overwinters as adults in C. vulgaris leaf litter (Fig. 2) where they were found in densities of up to eight per square foot. However, two females were also taken from nettle leaf litter during winter.

Females dissected during winter had immature ovaries and a substantial fat body. The volume of food in the crop was variable and white, but the mid and the hind gut contained yellow or brown fluid, and the rectum orange coloured fluid.

When females caught in January were taken into the laboratory they oviposited in five days and were found to be unfertilized. That

this species overwinters in a state of quiescence and has no diapause was shown when larvae taken into the laboratory in August and also females reared in the laboratory from eggs, completed their development and oviposited.

Breeding cycle

(a) Heather habitat

In the heather habitat this species bred around plants of E.cinerea (Fig. 2). By the last week of April 1960 females contained ripe eggs, and on 18.4.61 a female which emerged in the autumn and overwintered in the insectary began to oviposit. Oviposition occurred through May and June, and one female with mature ovaries was taken at the end of July (Table 9). An old female with senescent ovaries was taken in the third week of August, but from July the majority of the females had immature ovaries. These young females remained immature until the following spring.

The weights of adults from the field are given in Table 10 which shows that the females increased in weight as they became gravid.

In both seasons second to fourth instar larvae were found in June, and third to fifth instar larvae from July to September (Fig. 2) but one fifth instar larva was found as late as 16.10.61.

(b) The association with the two species of heather.

There was a distinct migration of Scolopostethus decoratus from C.vulgaris to E.cinerea in the spring, and vice versa in the autumn, as shown in Fig. 2. There were between-season differences in the time intervals, and fewer specimens returned to C.vulgaris during the winter of 1960-61 than in the preceding and following winters.

TABLE 9. State of ovaries in Scolopostethus decoratus.

| Period | Number dissected | Percentage with ovaries | | |
|---|---|---|---|---|
| | | Immature | Mature | Senescent |
| 30.3.60 | 3 | 100 | 0 | 0 |
| 26.4 | 3 | 67 | 33 | 0 |
| 23.5 | 2 | 50 | 50 | 0 |
| 3-13.6 | 3 | 0 | 100 | 0 |
| 28.6 | 2 | 50 | 50 | 0 |
| 3.8 | 1 | 100 | 0 | 0 |
| 19.8 | 1 | 0 | 0 | 100 |
| 28.9-4.10 | 4 | 100 | 0 | 0 |
| 24.7.61 | 3 | 100 | 0 | 0 |
| 31.7 | 2 | 50 | 50 | 0 |
| 8.8-16.10 | 49 | 100 | 0 | 0 |

TABLE 10. Weights of some Scolopostethus decoratus specimens taken during 1960.

| Date of capture | Females Mean Weight in milligrams | Number of Females weighed | Males Mean weight in milligrams | Number of males weighed |
|---|---|---|---|---|
| Heather habitat | | | | |
| 27.1-15.5 | 1.98 | 24 | 1.70 | 24 |
| 23.5-28.6 | 2.36 | 16 | 1.61 | 21 |
| Weed habitat | | | | |
| 16-31.5 | 3.43 | 10 | 2.14 | 5 |
| 9-16.8 | 2.27 | 6 | - | 0 |

This migration is undoubtedly correlated with the development of the two plants. E. cinerea was in flower at the end of June, and the seeds which were ripe in late August were shed during September. Before the seed was set, however, there was an ample supply of fallen seeds from the previous season. C. vulgaris was later; it was budding when E. cinerea was in flower, and it set seed too late to contribute to the food of Scolopostethus decoratus in the current breeding season. It is noteworthy, however, that the bugs may develop their ovaries fully before moving away from C. vulgaris in the spring. The association with C. vulgaris during winter is probably related to the thicker leaf litter beneath these plants which therefore offer the better shelter.

(c) Weed habitat

In Pond Field this bug was taken mainly under three plants, chickweed, sorrel and Yorkshire fog. Table 11 shows the numbers taken and the period of association with each plant species. Most of the Scolopostethus larvae taken were designated as Scolopostethus decoratus because adults were taken regularly on the area (which was not the case with Scolopostethus thomsoni) and because new females were taken in August which indicates that this species was breeding on the area.

This species was found on arable land in mid May (which was when the bugs dispersed from C. vulgaris leaf litter) and dissected females contained ripe eggs. After 15.6.60 no adults were taken from around chickweed, and by mid July these plants had died. Mature females were present at least until the end of June. An old female with senescent ovaries was taken in mid August after which date all females taken had immature ovaries.

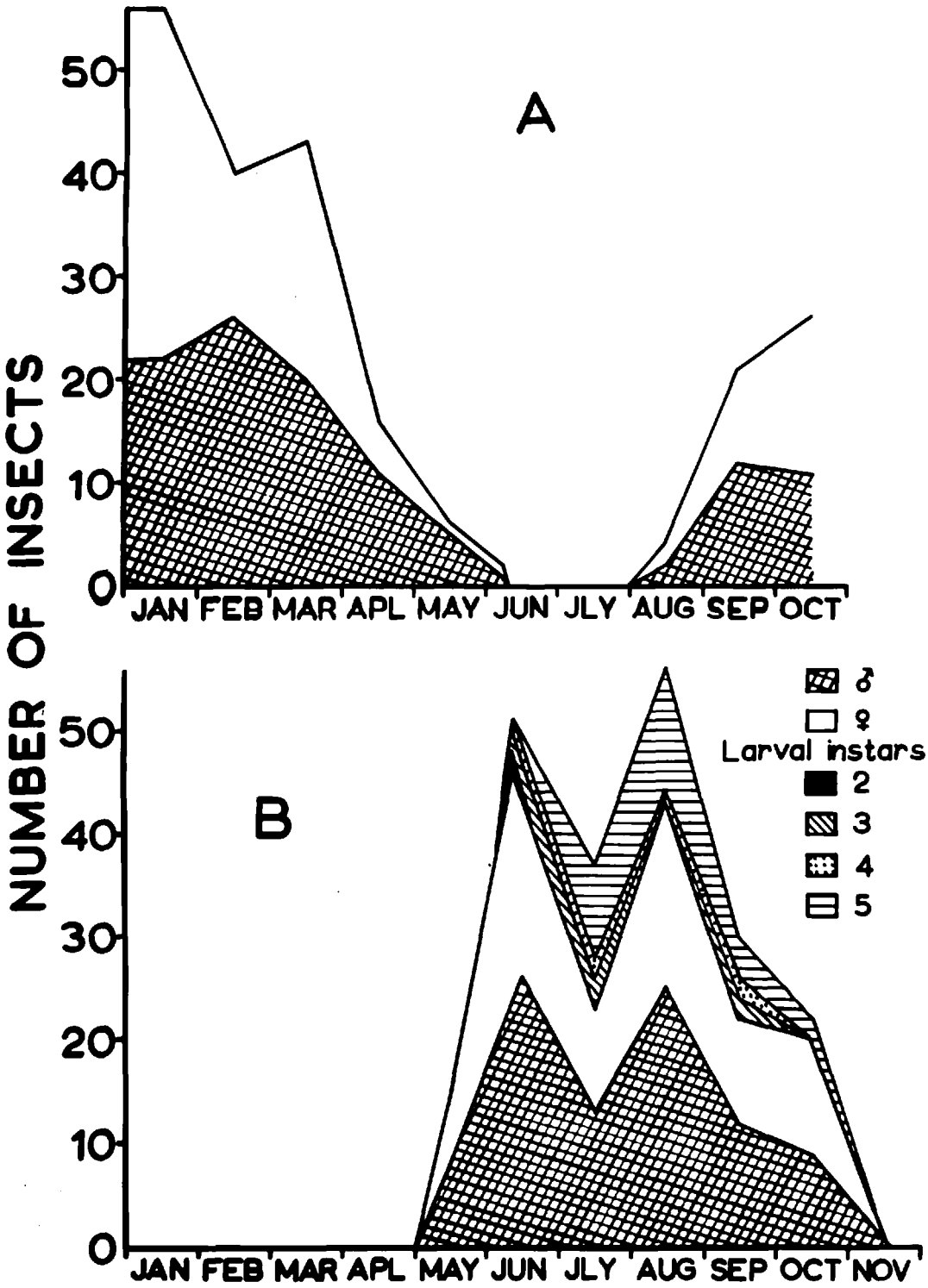



Figure 2. Numbers of Scelopestethus decoratus taken in weekly samples from the heather habitat over two seasons; A, under C.vulgaris (in winter); B, under E.cinerea (in spring and summer).

TABLE 11. Numbers of Scolopostethus decoratus taken on arable land in 1960.

| Taken under | Period | S. decoratus ♂ | S. decoratus ♀ | Scolopostethus larvae 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|
| Chickweed | 16.5-6.7 | 5 | 12 | 0 | 1 | 1 | 3 | 6 |
| Sorrel | 29.6-25.8 | 8 | 4 | 9 | 4 | 1 | 4 | 0 |
| Yorkshire fog | 24.6-31.8 | 5 | 8 | 6 | 1 | 1 | 2 | 2 |
| Spurrey | 31.8-15.9 | 2 | 0 | 1 | | | | |

(d) Occurrence on nettle and broom.

Very occasionally specimens were taken from nettles in the spring and early summer. Lone females were taken from nettle litter on 24.4.61 and 2.5.61, whilst three males were taken in sweepnet catches on 28-29.6.60. On 29.6.60 a male was taken by beating broom.

Oviposition site

In the field an egg of this species was found on a lime seed husk amongst E. cinerea leaf litter on 28.6.60, and two Scolopostethus eggs were found on the surface of arable soil on 24.4.60.

Females kept in glass tubes in the insectary oviposited in the cottonwool stopper. There was no orientation for some eggs were placed vertical, and others horizontal, to the substrate. When the cotton-wool stopper was replaced by muslin, eggs were deposited on the sprig of plant provided for food or on the glass. In the pill boxes the females oviposited mainly on the underside of either the cardboard name tag or the moist filter paper, but some were deposited amongst the seeds provided for food.

The eggs were placed separately or in groups of two to five, and when touching were sometimes stuck one to another although there was no obvious cementing substance.

Fecundity

Three females from the field were placed in pillboxes in the insectary with seeds of E. cinerea as food. They began oviposition on 21.6.60 and laid 21, 50 and 65 eggs in oviposition periods of 4, 25 and 25 days respectively. One to ten eggs were laid in a day, and oviposition occurred on one to seven consecutive days, but there were intervals of one to ten days during which no eggs were laid. A young female which overwintered in the insectary began ovipositing on 18.4.61 and laid 164 eggs over approximately three and a half months. Further information from experiments in the heated cabinet are given in the section on feeding.

Incubation period

The duration of incubation is shown in Table 12. Ninety-three per cent of the eggs, from ten females, hatched.

TABLE 12. Incubation period for Scolopostethus decoratus in the insectary 1960.

| Incubated during | Number of eggs hatching in the number of days indicated. | | | | | | | | Mean temperature °C. |
|---|---|---|---|---|---|---|---|---|---|
| | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | |
| 19.5-11.6 | | | | | | 5 | 9 | 2 | 13.9 |
| 25.5-18.6 | | 4 | - | 1 | 4 | 2 | 3 | | 14.8 |
| 22.6-17.7 | | 1 | 6 | 5 | 10 | | | | 15.4 |
| 6.7-29.7 | 1 | - | 3 | 8 | 3 | 7 | 2 | | 15.0 |
| 10.7-2.8 | | | | | 4 | 9 | | | 14.9 |

Larval development

The duration of larval development is shown in Table 13. The temperatures in the insectary for 1960 are shown in Table 26.

TABLE 13. Development of Scolopostethus decoratus in the insectary 1960 on mixed heather seed. The range is given in Brackets.

| Date laid | Incubation period in days | Duration of larval instars in days 1 | 2 | 3 | 4 | 5 | Date Adult Emerged | |
|---|---|---|---|---|---|---|---|---|
| 18.5 | 22 | 11 | 8 | 13 | 22 | 26 | 28.8 | 1♀ |
| 18.5 | 22 | 11 | 7 | 13 | 11 | 16 | 6.8 | 2♂ |
| 19.5 | (21-22) | (11) | (6-7) | (12-13) | (11) | (16) | 4.8 | |

Percentage of the macropterous form

All specimens taken and all those reared had fully developed wings which extended to the posterior of the abdomen. The numbers of this species taken in the suction traps (Table 22) were the highest for the genus.

CONCLUSIONS

Number of generations

There is a single generation a year, as shown by the duration of development (Table 13) and the failure of the ovaries of the young females emerging in late summer and autumn to mature. The oviposition period is shorter than in Scolopostethus thomsoni (Tables 9, and 2 and 4) and is not prolonged by late maturing, overwintered larvae. The young adults appear earlier which suggests that development is faster than in thomsoni, and larval development is completed before winter.

In Finland Pfaler (1936) reported larvae from early July to early September, and new adults from the end of July to September. On the Field Station the cycle was similar but the larvae were found over a longer period, from 19 June to 16 October.

On feeding during winter

Although Woodward (1949) and Southwood and Leston (1959) state that Scolopostethus decoratus continues to feed throughout the winter, dissections in the present work indicated that in this species and Scolopostethus thomsoni the gut becomes full before winter and then the contents are gradually depleted between late December and late February. That food is not necessary during winter was shown when specimens of Scolopostethus affinis and thomsoni overwintered in the insectary without food. This does not discount the possibility that feeding may occur for short periods on exceptionally warm days during winter.

Habitat

Thomas (1955) reported that this bug is associated with E.cinerea rather than with C.vulgaris. Southwood and Leston (1959) stated that it seldom occurs away from heaths, but Butler (1923) took a few specimens from a marsh.

The present study has shown the summer and winter association, respectively, with E.cinerea and C.vulgaris, and also that the bug can breed around annual weeds well away from heather. However, the patches of heath on the Field Station are small and scattered, which may make it necessary for the bugs to exploit other habitats, whereas on large heaths it may well be that they never need to move far. The few adults taken when sweeping nettles and on broom were probably merely resting

during dispersal.

When larger areas of heath six miles south on Chobham common were sampled, it was found that there also the bug occurred in localized areas, notably around plants of E. cinerea on raised ground. There, greatest numbers were taken in July and August. In Oslo in early June 1961 Scolopostethus decoratus was sought in small patches of C. vulgaris but was not found.

## 4. Notes on Scolopostethus grandis

RESULTS

### Overwintering

Six males and ten females of this species were taken from February to early April 1960. A group of twelve were taken together from Ash leaf litter, two from nettle litter and two from leaf litter under a shelter belt of several species of trees.

In a female taken on 19.2.60 the crop was empty except for white granular material on the inside walls, the remainder of the gut was full of brown granular fluid, and the rectum was distended with orange coloured fluid. The spermatheca did not contain sperm.

That there is no diapause was shown when young females taken into the laboratory in August completed their development and oviposited; they were not fertilized.

### Breeding cycle

In the habitats sampled this species was rare. A total of 15 specimens (excluding catches during winter) was taken as follows (all larvae were determined by rearing through to adults); on 8.9.60 a female under sorrel; on 18.7.60 a female in a nettle sweepnet catch;

on 24.4.61 a female in nettle litter; on 15.8.61 a fifth instar larva sheltering at the base of Yorkshire fog; and during August 1961 eleven specimens from grass under silver birch (Betula verrucosa Ehrh.). In the first half of the month only fourth and fifth instar larvae were taken, but by the end of the month only adults were taken.

Larval development

The duration of the first and second larval instars at a temperature of 23.3°C. on nettle seed was, respectively, eight, and nine to fourteen days.

Percentage of the macropterous form.

All specimens taken were macropterous. Although the fully developed wing membrane sometimes extended to the posterior of the abdomen, it often did not reach beyond tergite 6. In the suction traps a single female was taken, on 7.9.59 in trap 3.

CONCLUSIONS

Butler (1923) and Southwood and Leston (1959) stated that this species occurs under dead leaves, and that nothing is known of the life cycle. In the present work more specimens were taken from grass under silver birch than from any other habitat, and there the larvae completed their development in August. This, together with the fact that no larvae were taken during winter suggests that the bug overwinters as adults. Unless development is faster than in the preceding three species, which is unlikely, there can be only one generation a year. Both authorities cited above stated that macropters are rare, but all specimens taken in the present work were macropterous. The habitat of this species differed from that of each member of the genus found on the

Field Station.

## 5. Stygnocoris fuligineus

RESULTS

### Overwintering

This species overwinters mostly as adults, for 11 males and 20 females, but no larvae, were taken in two winters mainly from the edge of a dump of straw and leaves under a chestnut (Castanea sativa Mill.). Specimens were still found there in April. However, larvae in the fourth and fifth instars may sometimes overwinter, for two were found on 17.4.61, and in the third winter others were taken up to 18.12.61.

That this bug overwinters in a quiescent state and has no diapause was shown when female larvae in the fifth instar taken into the laboratory in August, and females reared in the laboratory from eggs, completed their development and oviposited.

### Breeding cycle

(a) 1960 Season

As specimens of Stygnocoris fuligineus were found around several species of plants its occurrence with each is discussed (Table 16) although for the life history this information is bulked in Fig 3A and Tables 14 and 15. The bugs were first found in this habitat on 16.5.60, some running across patches of bare ground, and some in cop.; the females contained ripe eggs.

The state of development of the ovaries during 1960 is shown in Table 14, and this data suggests that there is a single generation a year.

TABLE 14. State of ovaries in Stygnocoris fuligineus in 1960.

| Period | Number of females dissected | Percentage with ovaries | | |
|---|---|---|---|---|
| | | Immature | Mature | Senescent |
| 16 May-6 July | 14 | 0 | 100 | 0 |
| 9-25 Aug. | 18 | 44.5 | 44.5 | 11 |
| 31 Aug.-15 Sept. | 21 | 71 | 0 | 29 |
| 21 Sept.-21 Oct. | 4 | 100 | 0 | 0 |

The weights of some specimens taken during 1960 are shown in Table 15, and for females they show a trend that might be expected from the state of the ovaries at the same period.

TABLE 15. Weights of adults of Stygnocoris fuliginous in 1960.

| Period | Females | | | Males | | |
|---|---|---|---|---|---|---|
| | No. of Females | Mean weight in milligrams | Range in milligrams | No. of males | Mean weight in milligrams | Range in milligrams |
| 8 Feb. | 1 | 2.22 | 2.22 | 3 | 1.27 | 1.20-1.32 |
| 16 May-6 July | 28 | 2.65 | 2.04-3.27 | 30 | 1.44 | 1.20-1.73 |
| 9-16 Aug. | 17 | 2.36 | 1.63-2.74 | 0 | - | - |
| 31 Aug.-15 Sep. | 21 | 2.25 | 1.61-2.50 | 1 | 1.47 | 1.47 |

(i) Occurrence under chickweed

First instar larvae were present in the second week of June, third instar larvae were found in mid June, whilst all stages were present in the first week of July (Fig. 3A and Table 16). Gravid females were present into the second week of August after which the population moved because this chickweed had died out, and sampling from it was discontinued after 25.8.60.

Specimens were also found around lesser stitchwort (Stellaria graminea L.) but this weed was not common on the area.

(ii) Occurrence under sorrel

All larval instars were present by the last week in June (Fig. 3A and Table 16) until mid September. New adults were present by mid August and in September, but the last gravid female was taken on 25.8.60. After the area was disced on 20.9.60, sampling in seven consecutive weeks gave only one further specimen, a first instar larva on 18.10.60.

(iii) Occurrence under Yorkshire fog

There seemed to be some association with Yorkshire fog, possibly for shelter. New adults and some larvae were taken in early August; and gravid females on 9.8.60, after which date the females taken had immature ovaries (Table 16).

TABLE 16. Numbers of Stygnocoris fuligineus taken on arable land in 1960.

| Date | Under chickweed | | | | | | | Under sorrel | | | | | | | Under York-shire fog | | | | Under spurrey | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stage | ♂ | ♀ | 5 | 4 | 3 | 2 | 1 | ♂ | ♀ | 5 | 4 | 3 | 2 | 1 | ♂ | ♀ | 5 | 1 | ♂ | ♀ | 5 | 4 | 3 | 2 | 1 |
| 16 May | 10 | 16 | | | | | | | | | | | | | | | | | | | | | | | |
| 31 " | 1 | 2 | | | | | | | | | | | | | | | | | | | | | | | |
| 10 June | | | | | | | 8 | | | | | | | | | | | | | | | | | | |
| 15 " | | | | | 1 | 3 | 6 | | | | | | | | | | | | | | | | | | |
| 24 " | | 1 | | | 1 | 5 | 4 | | | | 1 | 1 | | 2 | | | | | | | | | | | |
| 29 " | Not sampled | | | | | | | | | | | 1 | 1 | 1 | 1 | | | | | | | | | | |
| 6 July | 11 | 4 | 5 | 6 | 7 | 8 | 1 | | | | | | | | | | | | | | | | | | |
| 14 " | 1 | 1 | | | | 3 | | 1 | | | 4 | 1 | 2 | | | | | | | | | | | | |
| 22 " | 2 | 2 | | 1 | | | | 1 | 1 | | | | | | | | | 1 | | | | | | | |
| 27 " | Nil | | | | | | | 1 | 3 | 1 | | | | | | | | | | | | | | | |
| 3 Aug. | | | 2 | 2 | | | 1 | 1 | | | | 1 | | | 1 | | | | | | | | | | |
| 9 " | | 1 | | 1 | | | | Nil | | | | | | | 1 | 5 | 1 | 1 | (1st sample 16th) | | | | | | |
| 16 " | Nil | | | | | | | 2 | 2 | 3 | | | 1 | 1 | | 1 | | | | 2 | 7 | 4 | | 7 | 3 |
| 25 " | Sampling ceased | | | | | | | 1 | 1 | 1 | 2 | | 1 | | | | | | | 3 | | 2 | 1 | 1 | 1 |
| 31 " | | | | | | | | 1 | 6 | 1 | | | | | | 1 | | | | | 2 | 1 | | | |
| 8 Sept. | | | | | | | | | 2 | 3 | 5 | 1 | 1 | 1 | 1 | | | | | 1 | 4 | 8 | 5 | | |
| 15 " | | | | | | | | | | 1 | | 1 | 2 | | | 2 | | 1 | | 1 | 3 | 3 | 3 | 3 | |
| 21 " | | | | | | | | Nil. Area disced | | | | | | | 1 | 1 | | | | Nil | | | | | |
| 29 " | | | | | | | | Nil | | | | | | | | | | | | Sampling ceased | | | | | |
| 6+12 Oct. | | | | | | | | Nil | | | | | | | 2 | 1 | | | | | | | | | |
| 18 Oct. | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| | | | | | | | | Sampling ceased on 12 Dec. | | | | | | | | | | | | | | | | | |

(iv) Occurrence under spurrey

In mid August specimens of Stygnocoris fuligineus were first found under spurrey, a few plants of which were growing on the area. Larvae, and adults (including both young, and senescent females) were present up to mid September (Table 16).

(v) An attempt to continue the study on another piece of land

In late September, after the study area had been disced in error, other arable areas on the Field Station were investigated in the hope that the life history of this species could be traced to the end of the season. Stygnocoris fuligineus was found in only one area, and this suggests that dense populations are localized, although the bug may be widely distributed over the Field Station at a low population density. This area was another patch of spurrey amongst which, in mid September, larvae in all instars except the first, and both young and senescent females, were found. On 21.9.60 only two specimens, larvae in the first and fifth instars, were taken. On 6.10.60 a larva in the second instar and a young female were taken. Thereafter up to the third week in October when sampling ceased, no bugs were taken, and these results indicate a movement to overwintering quarters.

(b) 1961 Season

Both pieces of land sampled in the previous season had become covered by a dense sward, mostly of grasses, which was unsuitable for these bugs. However, on the area examined in the autumn of 1960, some were still found under scattered sorrel plants. As the life cycle of specimens from under sorrel in grassland and from under spurrey on arable land differed, the data from these two habitats are discussed separately.

(i) Occurrence under sorrel

In the period 17.4.61 to 29.5.61 fifth instar larvae and mature and young adults were found, the last mentioned presumably developed from overwintered larvae. No other adults were taken until 17.7.61 and Table 17 shows that the majority of the females taken subsequently had

immature ovaries. Two newly moulted females were taken on 31.7.61.

TABLE 17. State of ovaries in Stygnocoris fuligineus taken under sorrel in 1961.

| Period | Number of females dissected | Percentage with ovaries Immature | Mature | Senescent |
|---|---|---|---|---|
| 15 May | 1 | 0 | 100 | 0 |
| 29 May | 2 | 50 | 50 | 0 |
| 24 July-14 Aug. | 29 | 100 | 0 | 0 |
| 22-28 Aug. | 34 | 94 | 6 | 0 |
| 5 Sept. | 11 | 100 | 0 | 0 |

A first instar larva was taken on 24.7.61, but over the previous four weeks one third, one fourth and two fifth instar larvae were taken. Figure 3B shows that the numbers of adults and late larvae taken increased from the end of July to early September. Earlier instars were scarce; two first and one third instar larvae were taken on 22.8.61. Sampling ceased at the end of September as the bugs seemed to have moved from this habitat.

Samples were taken in the same area amongst the dense grass, mainly Yorkshire fog and Agrostis tenuis Sibth, away from sorrel on 8.8, 14.8, 2.10, and 5.12.61 but no specimens of Stygnocoris fuligineus were taken. However, on the first occasion a few specimens of Stygnocoris pedestris and D. sylvaticus were found.

(ii) Occurrence under spurrey

In the spurrey habitat Stygnocoris fuligineus appeared later than in the sorrel habitat, for no specimens were found on the area from

15.5.61, when sampling began, until 2.7.61. Figure 3C shows that a small population of adults and third to fifth instar larvae increased in numbers which remained high until mid November. The state of the ovaries throughout is shown in Table 18. Some newly moulted females were taken on 31.7.61 and 16, and 23.10.61.

TABLE 18. State of ovaries in Stygnocoris fuligineus taken under spurrey in 1961.

| Period | Number of females dissected | Percentage with ovaries | | |
|---|---|---|---|---|
| | | Immature | Mature | Senescent |
| 31 July | 4 | 50 | 50 | 0 |
| 8-22 Aug. | 11 | 27 | 73 | 0 |
| 28 Aug.-9 Oct. | 32 | 78 | 3 | 19 |
| 16 Oct.-6 Nov. | 57 | 94.8 | 1.7 | 3.5 |
| 19 Nov.-11 Dec. | 10 | 100 | 0 | 0 |

Larvae in the third instar were found up to mid November, and it seemed that some adults and fourth and fifth instar larvae would overwinter on the area (Fig. 3C). From mid November, specimens were less active and were found in aggregations, sheltering under spurrey debris and young sorrel plants, and often immediately below the soil surface in small crevices.

Oviposition site and mating

Eggs were seldom found in the field, but two were found immediately below the soil surface under Yorkshire fog in a spurrey area.

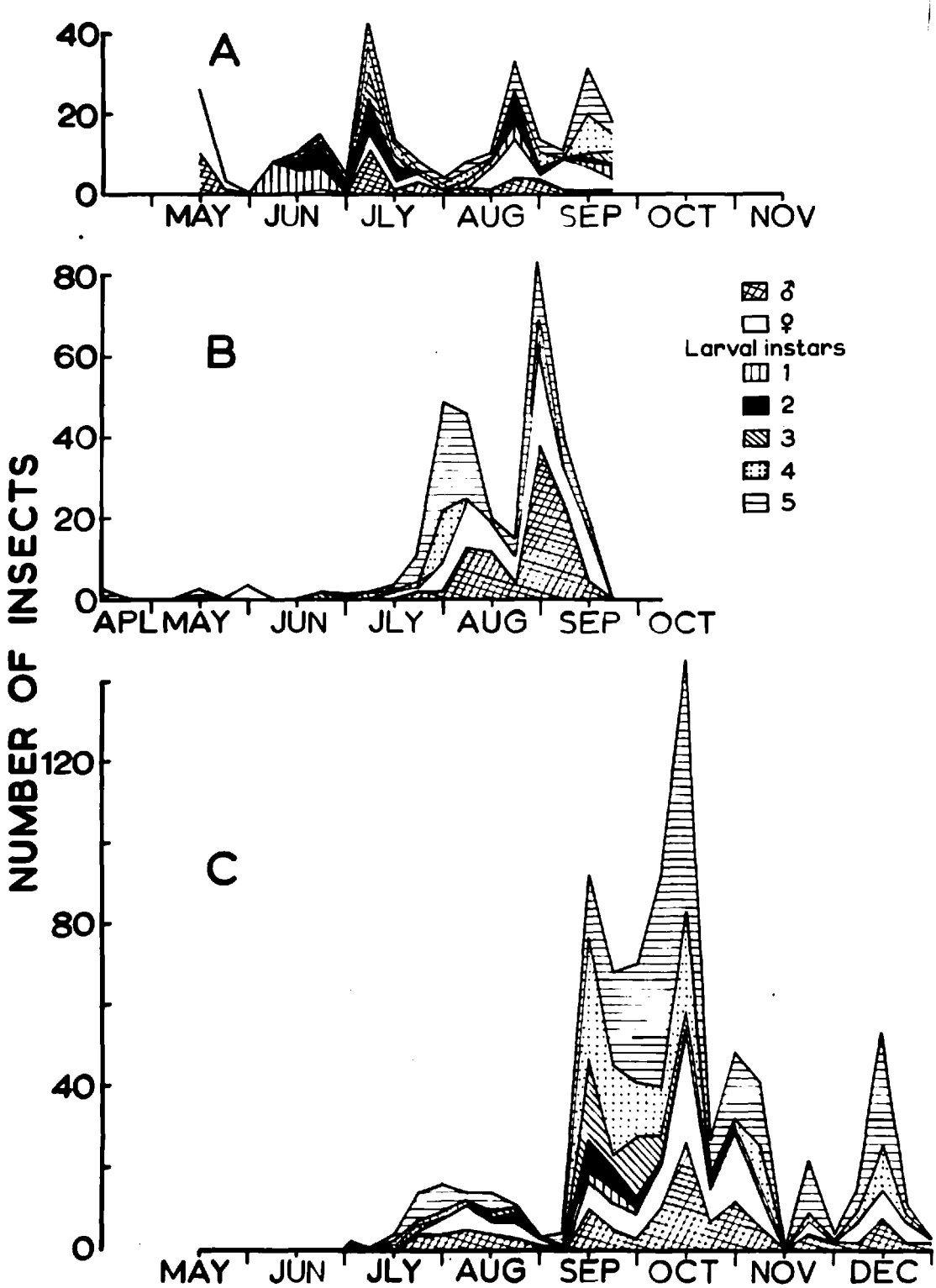



Figure 3. Numbers of Stygnocoris fuligineus taken in weekly samples.
A, in 1960 from an arable habitat of weeds and grasses;
B, in 1961 from under sorrel in grassland;
C, in 1961 from under spurrey on arable land.
A, compared with C, shows the detrimental effect of cultivation, as the area was disced in September 1960.

The identity of these was checked by rearing through to adults. Females kept in the insectary deposited most of their eggs in the cottonwool plug, but several eggs were deposited on the sprig of chickweed. Those oviposited in the cottonwool were generally orientated at right angles to the surface. Eggs laid on one day would be in one or two clusters of one to four, sometimes touching but not cemented together. During four of five days eggs may be oviposited disorderly over other eggs in a heap of about nine. On the food plant single eggs were laid either on the seed within the perianth, or on the outside of the perianth. The females kept in pill boxes laid eggs beside the loose seeds, or on the filter paper.

During oviposition, after a suitable site in the substrate has been selected, the bug takes a firm grip of the substrate with the tarsi and the egg is passed down the ovipositor. The membranes of this organ assume the shape of the egg momentarily and afterwards the ovipositor is waved from side to side four to six times before it is folded away.

In copulation the bugs , after coupling the genitalia, assume the tail to tail position usual in the Lygaeidae for several hours at a time. In the present study this was the only species seen, or taken, in cop. in the field, and the only one that would readily copulate in the laboratory.

Fecundity

The fucundity of nine females studied in the insectary during 1960 is shown in Table 19. They were captured on 16.5.60 and paired with males, and although they may have already laid a few eggs in the field, it is considered that the values in Table 19 are close to,

if not identical with, total fecundity at natural temperatures. The temperatures in the insectary are given in Table 26.

TABLE 19. Fecundity of Stygnocoris fuligineus in the insectary 1960. The food provided was a sprig of chickweed bearing seeds.

| ♀ | Number of eggs laid | Oviposition period in days | Post-oviposition period in days | No. of days on which each ♀ laid | No. of eggs per laying day |
|---|---|---|---|---|---|
| 1 | 88 | 92 | 3 | 37 | 2.4 |
| 2 | 74 | 93 | 21 | 26 | 2.8 |
| 3 | 109 | 79 | 4 | 38 | 2.9 |
| 4 | 20 | 31 | 3 | 9 | 2.2 |
| 5 | 58 | 41 | 2 | 29 | 2.0 |
| 6 | 106 | 69 | 78 | 47 | 2.3 |
| 7 | 25 | 73 | 2 | 13 | 1.9 |
| 8 | 86 | 117 | 47 | 39 | 2.2 |
| 9 | 11 | 30 | 2 | 6 | 1.8 |
| Mean | 64 | 69 | 18 | 27 | 2.3 |

Although the mean number of eggs laid per day is shown in Fig. 4A to be steady, this was not so for individual females. The general rhythm in oviposition shown by seven of the nine females is illustrated in Fig. 4B. Oviposition seldom occurred on more than one or two days in succession, and the intervals of days on which no eggs were laid were often of greater duration. However, females 7 and 8 oviposited more regularly as shown in Fig. 4C.

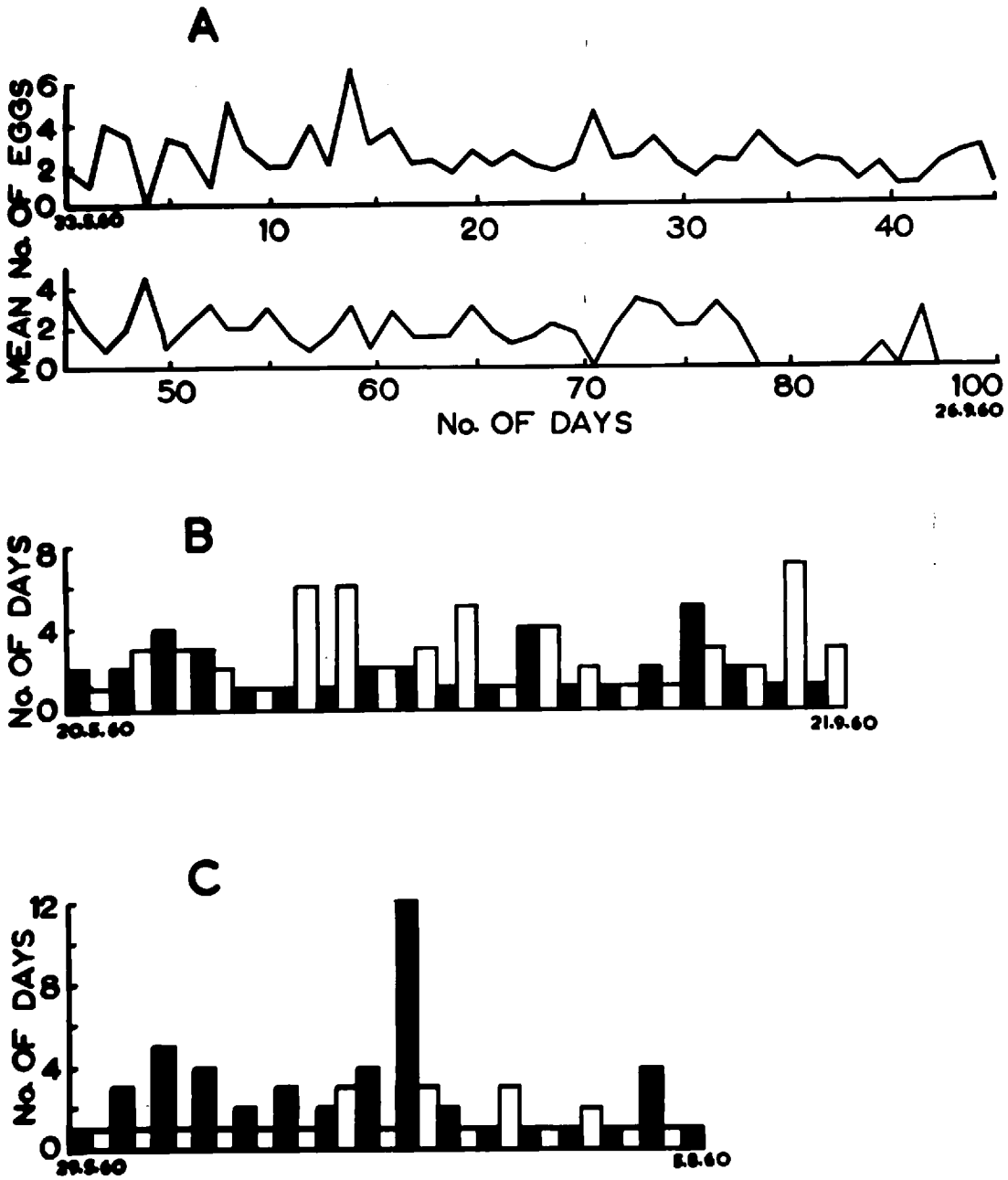



Figure 4. Fecundity of Stygnocoris fuliginous. A, mean number of eggs per day of nine females. B, the general pattern of oviposition as shown for a single female. C, the pattern of oviposition (for a single female) shown by two of the nine females. Black = the number of successive days on which eggs were laid; white = the number of successive days on which no eggs were laid.

Incubation period

The duration of incubation in the insectary is shown in Table 20. Ninety-two per cent (399) of the eggs, from eleven females, hatched.

TABLE 20. Incubation period for Stygnocoris fuligineus in the insectary 1960.

| Incubated during | Number of eggs hatching in the number of days indicated | | | | | | | | | | | | | Mean temperature °C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |
| 18.5-18.6 | | | | | | | 2 | | | 19 | 6 | 2 | 1 | 14.1 |
| 24.5-23.6 | | | | 5 | 2 | 15 | 17 | | 2 | | | | | 15.6 |
| 1-30.6 | 3 | 11 | 36 | 41 | 2 | | | | | | | | | 16.0 |
| 11.6-10.7 | 7 | 33 | 41 | 13 | 2 | | | | | | | | | 15.9 |
| 19.6-25.7 | | | | 12 | 14 | 12 | 15 | 5 | 1 | 1 | 1 | | | 15.5 |
| 2-31.7 | | | | | | 4 | 25 | 5 | | | | | | 15.0 |
| 6.7-5.8 | | | | | | 5 | 15 | 5 | 1 | | 2 | | | 15.0 |
| 6.8-13.9 | | | | | | | 2 | 8 | 2 | 3 | | | 1 | 14.5 |

Larval development

The larval development (Table 21) shows that only a single generation was reared in the season. Of four further fifth instar larvae in the chickweed seed group, two died in September and October, whilst two virtually overwintered, but died in mid February and mid March.

Flight

All adults captured and all those reared from larvae had fully developed wings which extended to the posterior of the abdomen. The suction trap records are given in Table 22. Stygnocoris fuligineus

was taken in traps 2 and 4, but half of the total number of specimens were taken in May 1960 in trap 2. In 1959 eight specimens of this species were taken, all during the period August to October. These records indicate post and pre-hibernation flights.

TABLE 21. Development of Stygnocoris fuligineus in the insectary 1960. The range is given in brackets.

| Date laid | Incubation period in days | Duration of larval instars in days 1 | 2 | 3 | 4 | 5 | Date adult emerged |
|---|---|---|---|---|---|---|---|
| On chickweed seed | | | | | | | |
| 18.5 | | | | | | | 13.9 |
| 20.5 | 27 | 8 | 9 | 12 | 17 | 34 | 11.9 3♀ |
| 20.5 | (27) | (6-9) | (8-10) | (10-13) | (13-19) | (19-44) | 16.8 |
| 18.5 | | | | | | | 3.9 |
| 20.5 | 27 | 7 | 8 | 12 | 24 | 28 | 12.9 3♂ |
| 20.5 | (27) | (6-8) | (8-9) | (11-13) | (21-29) | (20-33) | 22.8 |
| 16.6 | 19 | 11 | 12 | 14 | 13 | 32 | 7.9 & |
| | (19) | (10-12) | (10-15) | (11-18) | (12-15) | (18-58) | 13.9 3♀ |
| On sorrel seed | | | | | | | |
| 7.6 | 19 | 11 | 15 | 13 | 29 | 124 | 2.10 2♀ |
| 10.6 | (18-20) | (11) | (11-18) | (12-14) | (24-34) | (39-209) | 10.3.61 |
| 7.6 | 20 | 13 | 11 | 13 | 15 | 21 | 9.9 2♂ |
| 8.6 | (20) | (10-15) | (11) | (11-14) | (14-15) | (15-27) | 5.9 |

## CONCLUSIONS

### Number of generations

This species was the most abundant of those studied and had the most complex life history to interpret. Southwood and Leston (1959) stated that there are probably two generations a year in southern England, the first generation adults appearing at the end of July, and ovipositing in September. The resulting larvae, they stated, may become adult in late October or overwinter.

TABLE 22. Numbers of the four common Rhyparochromines taken in suction traps in 1959 and 1960.

| Month | Stygnocoris fuligineus | | Drymus sylvaticus | | Scolopostethus decoratus | | Stygnocoris pedestris | |
|---|---|---|---|---|---|---|---|---|
| | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ | ♂ | ♀ |
| Apl. | 1 | 4 | 3 | 1 | 0 | 1 | 0 | 0 |
| May | 12 | 11 | 11 | 3 | 2 | 2 | 0 | 0 |
| June | 5 | 4 | 3 | 2 | 0 | 1 | 1 | 1 |
| July | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| Aug. | 4 | 3 | 1 | 1 | 1 | 2 | 4 | 3 |
| Sep. | 2 | 2 | 1 | 0 | 0 | 1 | 0 | 1 |
| Oct. | 1 | 1 | 2 | 0 | 1 | 0 | 0 | 0 |

The 1960 data (Fig. 3A and Table 16) could indicate two generations, and the 1961 data could also represent two generations - one on sorrel (Fig. 3B) and one on spurrey (Fig. 3C). Figure 3C does show that eggs hatching in September mostly develop to adults by December, and this was the only "batch" of any size found in 1961.

The question now arises, were the larvae which were taken earlier, of a different generation or is there a single generation with a long oviposition period? That there is a long and rather irregular oviposition period (as suggested by Butler, 1923) is shown in Table 19. Adults developing from the earliest eggs may be expected to appear early in the summer, and they did so from the end of July, although the development time in the insectary was found to be longer (Table 21).

If these new females do not lay eggs then there is a single generation. However, this is difficult to determine because both mature and immature ovaries were found in late July and August (Tables 14, 17 and 18).

Nevertheless, because of the absence of senescent ovaries early in the season, and the disappearance of mature ovaries after August (Tables 14, 17 and 18), it is concluded that there is a single generation a year. Thus although there appears to be time for two generations, the eggs hatching in September would have been laid in August by old females (because if the new females matured they would be expected to remain with mature ovaries during September). The oviposition period may be extended by late maturing females emerging from over-wintered larvae.

In Finland Pfaler (1936) noted a single generation thus: old females in May, only larvae in early July and thereafter up to September new adults which remained immature. She showed that this species overwinters as adults thus differing from other members of the genus which overwinter as eggs.

Habitat

The changes in population density both between and within seasons, demonstrates the mobility and adaptability so necessary to the survival of this species. It feeds on the seeds of annual weeds for which the best source is on, or at the edges of, arable land. A great hazard is good cultivation. Often the weeds cannot set seed until the regular cultivations of young crops cease; the bug may then become established, only to be disturbed or destroyed by late season cultivation (Fig. 3A) when the land is prepared for another crop.

If the ground remains untouched after cropping both the weed flora and the bug do well, but if this state of affairs continues into a second season the vegetation may then become too dense for the bug. Thus cultivation both helps and hinders the bug. Often there is wastage e.g. in 1961 the bugs did not move on to the spurrey area until July (Fig. 3C) although seed was set well before this date.

An indication of the habitat of this species is given by Douglas and Scott (1865), Saunders (1892), Butler (1923) and Southwood and Leston (1959) and includes grass and plant roots, moss, heaths, leaf litter, sandpits, rotting grass, and gardens. These further show the adaptability of the species and include places where it may breed undisturbed by cultivation.

## 6. Notes on Stygnocoris pedestris

RESULTS

### Overwintering

In searching during winter for Stygnocoris fuligineus and other species, only one specimen of Stygnocoris pedestris was taken - a female on 6.1.61 from the base of a cocksfoot tuft. On 16.10.61 a male and a female were taken from C. vulgaris leaf litter, but none after that date.

### Breeding cycle

Larvae in the fourth and fifth instars were first found on 19.6.60. A total of 22 larvae (in the third to fifth instars) were found from June to 8 August in the two years around the following plants: buttercup (Ranunculus repens L.), E. cinerea, sorrel, grass and grass under silver birch.

The adults were the last stage to appear, and the first captures were made on 12.7.60 and 2.7.61. Up to 15.9.60 four males and one female were taken singly from under buttercup, E.cinerea and spurrey, and in a nettle sweepnet catch. Between 2,7.61 and 19.9.61 five males and two females were taken from under E.cinerea, and four males and one female from under sorrel; no more than two specimens were taken together.

From the four females dissected it was determined that the ovaries were partly developed by 14.8.61, contained ripe eggs during September (5 and 19.9.61) and that oviposition was completed by 16.10.61.

Flight

The adults captured and those reared through from larvae had fully developed wings which extended to the posterior of the abdomen. The suction trap records in Table 22 show that this species, which was taken in all traps except trap 3, was on the wing in June, August and early September.

CONCLUSIONS

Number of generations

There is a single generation a year. The absence of adults during winter is in agreement with reports by Pfaler (1936) and Southwood and Leston (1959) that this bug overwinters as eggs. Butler1923) reported young larvae in June. The present record of late larvae in June indicates that eggs hatch before June (c.f. Southwood and Leston 1959) and it would be expected that overwintered eggs would hatch before eggs of other species that are laid in the Spring. The adults appear from July, as

shown in Finland by Pfaler (1936), and not late August as suggested by Southwood and Leston (1959). The oviposition period is shorter than in Stygnocoris fuligineus. As the adults die soon after oviposition is completed it is likely that there is no prehibernation flight, and so the total catch of this species in the suction traps (Table 22) represents a preoviposition dispersal.

Habitat

This species, like the preceding, seems also adaptable to a variety of habitats (Butler 1923, Southwood and Leston 1959, and the present study). In fact, it seems that the preferred habitat was not found on the Field Station, unless the bug generally occurs in small numbers as noted by Butler (1923), but this may be because its habitat does not normally overlap that of Stygnocoris fuligineus.

## 7. Notes on Stygnocoris rusticus

No specimens of Stygnocoris rusticus were taken during winter from places sampled for Stygnocoris, Drymus and Scolopostethus species. A larva in the fourth instar was taken under sorrel on 2.7.61 and was reared through to an adult female. On 5.9.61 a male was taken in the same habitat. Both specimens were brachypterous. No specimens were taken in the suction traps.

This species overwinters as eggs and there is a single generation a year (Pfaler 1936, Southwood and Leston 1959). As so few specimens were taken it is concluded that, either the bug is rare on the Field Station, or its habitat does not overlap that of Stygnocoris fuligineus.

## 8. Drymus sylvaticus

### RESULTS

### Overwintering

Fifteen males and eighteen females were taken from leaf litter during the two winters. Half the specimens came from nettle litter, and of the remainder about equal numbers from C.vulgaris litter and from under a shelter belt of several species of trees. In addition three males and two females were taken from cocksfoot tufts growing well away from nettles, but as they were the catch from 60 tufts, this site cannot be favourable for overwintering.

This species has an obligatory diapause because the new generation females emerging in the field in August did not oviposit in the laboratory. However, after subjection to a temperature of 10°C. for six and a half days, oviposition occurred in 15 days. That the period of diapause is short was shown when females taken into the laboratory in early January oviposited in five to fourteen days.

### Breeding cycle

(a) 1960 season

In 1960 ovipositing adults were first taken in mid May under annual weeds in Pond Field and were present until early June. The state of development of the ovaries in specimens taken over two seasons is shown in Table 23.

The mean field weight for three mature females taken in June was 4.85 (4.50-5.55) mg. and for six immature females taken in August and September 3.79 (2.92-3.68) mg.

TABLE 23. State of ovaries in D.sylvaticus

| Period | Number of females dissected | Percentage with ovaries Immature | Mature | Senescent |
|---|---|---|---|---|
| 23.5-10.6.60 | 5 | 0 | 100 | 0 |
| 16.8-27.9.60 | 13 | 100 | 0 | 0 |
| 31.7-9.10.61 | 9 | 100 | 0 | 0 |

The first instar larvae appeared by 10.6.60, and the first eggs incubated in the insectary also hatched in early June. By late June first to fourth larval instars were present, the fifth larval instar appeared in early July, and the young adults from late July. Late instar larvae also occurred until mid September when the species left the area. The numbers taken were relatively small - a total of 102 specimens from this area in the season.

(b) 1961 Season

The earliest catches were a Drymus first instar larva on 21.4.61, and a first and three second instar larvae on 3.5.61 in nettle litter. Under spurrey, and sorrel in grassland, D.sylvaticus was not found until July when all stages were present. During August fourth and fifth instar larvae and young adults were taken. Occasionally specimens were taken in grassland.

Oviposition site

Females kept in glass tubes covered at both ends with muslin cloth oviposited on the sprig of chickweed supplied as food. When cottonwool was used as one stopper, eggs were deposited in

it and not on the plant. This may indicate that eggs are deposited in the soil, and on 24.6.60 an egg of this species was found on the surface of the soil.

Fecundity

The preliminary work on fecundity in the insectary was unsatisfactory because a suitable food had not yet been found for this species. Usually about ten eggs were laid over three days and the bugs died one or two weeks later. Some success was obtained when the seeds of E. cinerea were given as food, for three females laid 16, 17 and 26 eggs in oviposition periods of 6-22 days; one to six eggs were laid per day. Further information on fecundity is given in the section on feeding.

Incubation period

The duration of incubation is shown in Table 24. Of 106 eggs, from ten females, 91.5 per cent hatched.

TABLE 24. Incubation period for Drymus sylvaticus in the insectary 1960.

| Incubated during | Number of eggs hatching in the number of days indicated | | | | | | | | | | | | Mean temperature °C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | |
| 18.5-17.6 | | | | | | 4 | 8 | 13 | 6 | 1 | - | 1 | 13.9 |
| 7.6-26.6 | 3 | 5 | 15 | 2 | | | | | | | | | 15.1 |
| 21.6-18.7 | | | 2 | 4 | 19 | 7 | 1 | | | | | | 15.6 |
| 29.6-24.7 | | | | 2 | 1 | - | - | 1 | 1 | | | | 14.7 |
| 12.7-4.8 | | | | | | | | 1 | | | | | 14.9 |

Larval development

The duration of development is shown in Table 25. One further larva of this group, after 84 days of larval life moulted, not to an adult, but to a sixth instar larva and died nine days later.

TABLE 25. Development of four D. sylvaticus females in the insectary in 1960 on young nettle seed. The range is given in brackets.

| Date laid | Incubation period in days | Duration of larval instars in days | | | | | Date of last moult |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| 9.6 & 21.6 | 19 (17-20) | 13 (12-15) | 14 (13-16) | 15 (14-16) | 17 (12-19) | 26 (21-30) | 20.9<br>18.9<br>7.10<br>30.9 |

The temperatures in the insectary are shown in Table 26.

TABLE 26. Mean monthly temperatures in the insectary 1960.

| Month | Mean maximum °C. | Mean minimum °C. |
|---|---|---|
| April | 10.9 | 6.2 |
| May | 15.7 | 9.3 |
| June | 19.9 | 12.1 |
| July | 17.9 | 12.1 |
| August | 17.6 | 11.6 |
| September | 16.7 | 10.1 |
| October | 14.6 | 6.1 |

Flight

All adults taken in the field and all those reared in the laboratory were macropterous. A total of 21 males and seven females was taken in suction traps 2, 3 and 4 (Table 22) and these records may represent pre- and post-hibernation flights.

CONCLUSIONS

Number of generations

As this species has an obligatory diapause in the late summer and autumn emerging adults, there can be only one generation a year. The three-month larval development period in the insectary (Table 25) is in agreement with the May oviposition and early August emergence of young adults in the field. Although there are records of adults in each month (see also Butler, 1923) there may be a period in late June when there are none. In Finland Pfaler (1936) noted a similar absence of adults in July. New adults appeared from late July but remained immature (Table 23). Thus there is no evidence of a second generation as mentioned by Southwood and Leston (1959), although up to August the life history was found to be similar to their account. Butler (1923) suggested that oviposition occurs at intervals during the summer, but it was found to last four to six weeks in May and June.

Habitat

Douglas and Scott (1865), Saunders (1892), Butler (1923), Thomas (1955) and Southwood and Leston (1959) stated that this species is common in leaf litter, grass roots and moss. These habitats plus those found in the present study suggest that the bug feeds on a variety of seeds.

## 9. Notes on Drymus brunneus

RESULTS

### Overwintering

During two winters 20 males and 20 females were taken, mostly from oak and nettle leaf litter. Five specimens were taken from leaf litter under a shelter belt and two from the base of soft rush (Juncus effusus L.). Females dissected in February and early March had sperm in the spermatheca.

### Breeding cycle

In the two seasons 22 males and 25 females were taken from May to October from nettle litter, grass under silver birch, and under E. cinerea (one specimen). Fourth and fifth instar larvae were taken in late June and July and fifth instar larvae in early August. The state of development of adults taken at the following times is of interest: in mid July a senescent and a young female, in early August a newly moulted male, on 25.8.60 a female with developing ovaries, and from late September to late October all females dissected contained ripe eggs.

Females taken in July and August and those reared from late larvae did not oviposit in the laboratory. There was one exception, a female which laid one egg in December and a further sixteen eggs between 9.2.61 and 12.3.61. Subjection to a temperature of 10°C for seven days did not induce these females to oviposit; the food provided may not have been suitable.

CONCLUSIONS

The number of specimens taken were too few to draw any definite conclusions about the life history of this species although there is some evidence to show that overwintered females complete oviposition about mid July and that new females emerging in August attain sexual maturity before winter. It is interesting to note that in Finland Pfaler (1936) found both young and mature adults up to early August, but in late August and early September (when the study ended) she found only specimens with immature ovaries; larvae were taken from May to September and probably overwinter. Thus the number of generations per year is still unknown (see also Southwood and Leston 1959).

However Putshkova (1956) reported that overwintering eggs are laid. Presumably the females that oviposit in the autumn would not survive the winter. It appears therefore, that there may be but a single generation, with all stages overlapping i.e. the females developing from overwintered eggs will oviposit and die before the next winter, whereas those developing from overwintered females will also overwinter immature and oviposit in the spring; where larvae overwinter, the next generation will also overwinter as larvae. Such timing, however, would not be rigid.

## Natural Enemies

### Dipterous parasites

Cinochira atra Zetterstedt was found to be an occasional parasite of Scolopostethus thomsoni (7 examples), Scolopostethus decoratus (2 examples), D. sylvaticus (1 example), and D. brunneus

(2 examples); and Alophora pusilla Meigen of Stygnocoris fuligineus (1 example) and Stygnocoris pedestris (in the only specimen taken during winter). In all cases the hosts were taken from August to February as late instar larvae or adults. In the laboratory those hosts taken as adults died when the parasite emerged, which was after 11-15 days for C.atra and 9 days for A.pusilla. When hosts were taken as larvae they became adult before the parasite emerged.

The fully grown parasitic larvae emerged through the anus or genital opening; these organs then resumed normal size before the corpse of the host became cold, and thus the path of exit was obscured. The larvae pupated almost immediately and the adult parasites emerged after a further 12-14 days for C.atra and 8 days for A. pusilla. There was one parasite per individual host.

When parasitized adults were dissected during winter a fully grown larva which occupied the whole of the body cavity was found in each. In two females dissected in late July smaller parasitic larvae were found in the abdomen.

The parasite may enter larval hosts, and probably overwinters in the bug to emerge in the spring. The occurence of C.atra in four species suggests that it may be a general, although occasional, parasite of the Lygaeidae. Van Emden (1954) quoted that it is recorded from Eremocoris plebeius Fln, but this is not a British record. He said the fly is rare in England. A.pusilla is a parasite of Chilacis and Cydnus (Cydnidae) and is well distributed in England (van Emden 1954).

Fungi

Some late larvae and adults of Scolopostethus and Stygnocoris fuligineus died twelve hours to five days after being brought into the laboratory and were covered with fungal growth. In other instances bugs were found dead without fungal growth, but saprophytic fungi appeared on them in two or three days.

Dr. M. F. Madelin identified an Entomophthora sp. on Stygnocoris fuligineus and Scolopostethus thomsoni, and identified and isolated a Paecilomyces sp. from two specimens of Stygnocoris fuligineus reared in the laboratory from eggs. The conidia of this fungus measured 4.12 (3.2-5.5) $\mu$ x 1.51 (1.2-2.0) $\mu$.

An attempt was made to infect field larvae and adults of Stygnocoris fuligineus and Scolopostethus spp. with the fungus that had been isolated. The bugs were surface sterilized and placed in sterilized pill boxes which had been smeared with the fungus. A group of control bugs were also surface sterilized. On death the bugs were again surface sterilized and plated out on V8 juice agar. All those exposed to the fungus and two-thirds of the control insects died after two to five days. The general growth form and the appearance of the conidia of the fungus which grew out of the "infected" and of some of the control insects resembled that of the isolated culture.

It can be concluded, tentatively, that there is a definite association of a Paecilomyces fungus with these bugs. Whether or not it is pathogenic has yet to be shown. Because of the high mortality of the controls it is difficult to demonstrate a high

virulence in the fungus; the bugs may have been already contaminated with it in the field. Although the bugs were surface sterilized this does not prove that the fungus was not concealed on the exterior of the insect and became established after death.

The high humidity and temperature conditions provided in the laboratory may enhance development of the fungus which may not become manifest in the field. Further, as the insects may have been wounded when caught an artificial infection site may have been provided.

Spiders

Two dead males of Scolopostethus affinis were found bound in a spider's web on nettle.

## Anomalies in Breeding Cultures

### Larval colour variants

In two batches of Scolopostethus affinis reared in the laboratory approximately 20 per cent of the larvae had yellow instead of orange coloured abdomens; in the fifth instar these were bright orange instead of the usual darker greyish colour, and the wing pads were very pale. The adults produced could not be distinguished from those developing from larvae of normal colour.

Several larvae of Stygnocoris fuligineus had a red instead of a black thorax in the second or second and third instars, and in a few specimens a reddish-brown coloured thorax persisted in the fourth and fifth instars. These colour variants occurred in cultures in the insectary and the laboratory and a few were taken in the field. Some specimens reared on sweet chestnut had a red

head and a fawn coloured thorax. However, the diet has nothing to do with the colour variation. Normal adults were produced.

Anderson (1961) found pale larvae of Anthocoris sarothamni D. & S. in laboratory cultures and in the field, and concluded that this was the effect of high summer temperatures; they also developed into normal adults.

White substance on Stygnocoris fuligineus males

A large number of males brought into the laboratory produced a thick, white "growth" on some abdominal sternites after two or three weeks. This also occurred with many reared males about two weeks after becoming adult. As the substance could be scraped off easily, and as it dissolved readily in xylol and cotton blue in lactophenol it is concluded, tentatively, that it is a waxy exudate and not a fungal growth.

## (B) FEEDING STUDIES

## RESULTS

### Preliminary Work

#### Determination of the general kind of food

During the winter of 1959-60 when the study began, it was necessary to determine the food of the bugs and the best method of rearing them. When Collembola were offered as food, occasionally a dead one was sucked, as were dead bugs; these probably served only as a source of moisture. Several "trial foods" taken from amongst leaf litter where the bugs occurred were offered and included oak twigs with buds, moss, fungi, sycamore seeds, fresh heather leaves and young nettle plants, but they did not support life or oviposition.

A pair of Scolopostethus affinis adults lived for 46 days on water alone at the laboratory room temperature of about 18.6°C.

The insects on the trial foods lived for three to seven weeks, and those given moistened moss appeared to feed on it but were in fact merely taking in moisture. This was further demonstrated by two pairs of D.sylvaticus which showed a continual loss of weight on moist moss until death occurred three to four weeks later. Some females taken in May and June and provided with stems and leaves of nettle (Scolopostethus thomsoni and D.sylvaticus) and of chickweed (Scolopostethus decoratus) oviposited usually on only the first to third days after capture, and died in one to two weeks.

Finally acorns and chestnuts which also occurred in the leaf litter were provided on 22.1.60, and for the first time the bugs were observed feeding vigoursly and for long periods, especially on sweet chestnuts. Although cut surfaces were presented to the bugs, penetration of the case would not be a problem as normally it splits when the nut germinates.

After feeding on sweet chestnut females of Stygnocoris fuligineus, D.sylvaticus and Scolopostethus decoratus taken during winter, oviposited. Oviposition also occurred in Scolopostethus grandis after feeding on germinating ryegrass seeds. Further, a fourth instar larva of Scolopostethus thomsoni completed its development to an adult female on sweet chestnut in 36 days at laboratory room temperature. Its body weight increased during the fifth instar, which lasted 18 days, from 1.22 mg. to 3.09 mg. and the new adult weighed 2.86 mg. However, the first direct proof that seeds support

the growth of these bugs was obtained when larvae of Stygnocoris fuligineus were reared from hatching to adults on sweet chestnut, as shown in Table 27.

TABLE 27. Development of Stygnocoris fuligineus on sweet chestnut.

| Larval instar | No. of larvae | Duration of instar in days | | Mean temperature °C. |
|---|---|---|---|---|
| | | Mean | Range | |
| 1 | 16 | 12 | 8-16 | 18.4 |
| 2 | 7 | 9 | 4-12 | 18.3 |
| 3 | 6 | 9 | 5-15 | 18.4 |
| 4 | 4 | 12 | 11-12 | 18.6 |
| 5 | 3 | 16 | 14-18 | 18.2 |

When the bugs were found breeding in other habitats during the summer it was obvious that chestnut and acorn were not their normal food, and so the seeds of the weeds with which they were associated were tested.

The value of the non-fruiting parts of the plant

When larvae in the fourth and fifth instars were provided with the vegetative parts of plants alone, their life was very short and oviposition did not occur (Table 28). The non-fruiting parts of the plant did not support life as only a very few larvae reached the second instar (Tables 29 and 30).

The apparent poor quality of sorrel seed as a food prompted the testing of the seeds of several weeds in the arable habitat in case specificity existed. Nettle seed was also included for Scolopostethus decoratus, and E.cinerea seeds for the other species.

TABLE 28. Effect of seeds versus vegetative parts of plants on development and fecundity when provided as food to field female larvae taken in the fourth and fifth instars.

| Food given | No. of insects | Mean ♀ weight at emergence in mg. | Mean weight at oviposition in mg. | Mean preoviposition period in days | Mean No. of eggs laid | Mean oviposition period in days | Mean adult longevity in days |
|---|---|---|---|---|---|---|---|
| *Scolopostethus thomsoni* | | | | | | | |
| green nettle seed | 11 | 3.11 | 3.59 | 6 | 3.17* | 52* | 56 |
| Nettle plant No seed | 4 | 2.55 | X | - | 0 | 0 | 7 |
| sorrel seed | 4 | 2.50 | 2.58 | 13 | 4 | 5 | 15 |
| *Scolopostethus affinis* | | | | | | | |
| green nettle seed | 8 | 2.74 | 3.26 | 7 | 370* | 84* | 59 |
| Nettle plant No seed | 1 | X | - | - | - | - | 0 |
| sorrel seed | 2 | X | - | - | - | - | 0 |
| *Stygnocoris fuligineus* | | | | | | | |
| Spurrey seed | 8 | 2.21 | 2.65 | 12 | (not determined) | | 52 |
| Spurrey plant No seed | 4 | 1.91 | X | - | 0 | 0 | 9 |

*Mean of three females: one *S.thomsoni* taken as first instar from field.

The role of animal food

When a bunch of nettle flowers and developing seeds was given to Stygnocoris fuligineus larvae for food at the end of June, one larva was found feeding vigorously on a flower containing a larva of Brachypterus urticae Fabr. This may have been accidental, but it did show that these bugs may occasionally supplement their diet with animal food, and as the larvae of B.urticae feed on nettle flowers they may be prone to predation by Scolopostethus thomsoni.

Furthermore when sprigs of sorrel bearing flowers and developing seeds were given as food to Stygnocoris fuligineus in July it was found that some flowers contained larvae of Contarinia acetosae Kieffer and some of the bugs were feeding on these. However, the bugs could not be reared on these larvae alone and did not develop beyond the first instar. As larvae of Contarinia pulchripes Kieffer were easily obtained from broom pods they were substituted for C.acetosae as a trial bug food, but likewise did not support life (Table 29).

Adults and larvae will suck eggs if starved. If no food is provided to a group of eggs on hatching, some specimens will readily develop to the second instar by sucking eggs alone, and in Scolopostethus affinis direct cannabalism occurs when starved as second and third instar larvae were observed sucking live specimens in the same instar.

Thus it appeared that development on animal food alone might be possible and so the larvae of Carpophilus hemipterus L., a pest of dried fruit, were included as a food for all species in the main feeding study.

Early results in the insectary

The list of foods tried is shown in Tables 29 and 30. In the insectary ten insects were started on each food. On the foods which supported growth to the adult stage the times for development have been shown in Tables 8, 13, 21 and 25. On some foods the larvae began to develop, but did not reach the adult stage; the duration of the instars is shown in Table 29. In most cases there was a high mortality in the first and second instars.

TABLE 29. Development of larvae on apparently unsatisfactory foods, in the insectary. None reached adult. The final figure in each case is for the last completed instar.

| Food | No. of larvae developing | Duration of larval instars in days: First Mean | First Range | Second Mean | Second Range | Third Mean | Third Range | Fourth Mean | Fourth Range |
|---|---|---|---|---|---|---|---|---|---|
| *Scolopostethus thomsoni* | | | | | | | | | |
| Sorrel seed | 2 | 13 | 11-14 | | | | | | |
| *Scolopostethus decoratus* | | | | | | | | | |
| Sorrel seed | 5 | 12 | 10-13 | 13 | 12-14 | 15 | 14-15 | 24 | 24 |
| *C. pulchripes* larvae | 1 | 13 | 13 | 15 | 15 | | | | |
| *Stygnocoris fuligineus* | | | | | | | | | |
| Nettle seed | 10 | 12 | 10-16 | 17 | 15-19 | 32 | 26-40 | 23 | 20-25 |
| Fathen seed* | 9 | 11 | 10-13 | 13 | 10-19 | 13 | 12-15 | 27 | 17-35 |
| Ryegrass seed | 1 | 12 | 12 | | | | | | |
| Chickweed plant only | 4 | 19 | 17-21 | | | | | | |
| *C. hemipterous* larvae | 4 | 19 | 17-20 | | | | | | |
| *Drymus sylvaticus* | | | | | | | | | |
| Mixed heather seed | 6 | 10 | 9-10 | 19 | 18-20 | 18 | 18 | | |
| *C. pulchripes* larvae | 2 | 16 | 15-16 | 14 | 14 | 19 | 19 | | |

*Chenopodium album* L.

The duration of the instars on these foods were approximately the same, or in some cases longer, than on foods supporting life to adults.

Although the larvae reared in the insectary were weighed during development the results are not presented here because weight gain was studied more fully on insects reared in the heated cabinet. It was found that development in the insectary was too slow to permit oviposition and thus fecundity, which is important in assessing the value of the foods could not be determined. However, this early work did give some definite pointers on the value of the different foods (Tables 29 and 30) and showed that a diet of animal food warranted further investigation.

TABLE 30. Showing the foods tested in the insectary which were suitable, and those on which there was no survival beyond the first larval instar (c.f. Table 29).

| *thomsoni* | *decoratus* | *fuligineus* | *sylvaticus* |
|---|---|---|---|
| Survived to adults on | | | |
| nettle seed | mixed heather seed | sorrel seed<br>chickweed seed<br>*E. cinerea* seed | nettle seed |
| No development and no survival on | | | |
| chickweed seed | chickweed seed<br>ryegrass seed | | chickweed seed<br>ryegrass seed<br>fathen seed<br>nettle plant |

## Feeding Behaviour

### Feeding stance

As the feeding stance is similar in these species it will suffice to describe it for Stygnocoris fuligineus alone. The mid and hind legs are spread out to the sides to balance the body, and the foretarsi are placed on the surface of the food immediately in front of the head, one on each side of the inserted stylets, parallel one to another and spaced apart a distance approximately equal to the interocular width. At first the rostrum and the stylets are together lowered to the food surface but after one or two minutes as the stylets penetrate, the rostrum is bent backwards between the first and second segments away from the stylets. The stylets penetrate deeper when the bug bends the rostrum so that the tylus touches the third rostral segment. At this stage the third and fourth rostral segments are also withdrawn and the rostrum is folded away under the body. After 8-15 minutes from the commencement of feeding the stylets may be inserted to their full depth with the tylus touching the food surface. The stylets are vigorously moved up and down a distance about half the length of the first rostral segment. The role of the powerful forefemora may be to facilitate this because the head, thorax and forefemora and tibiae move up and down in time with the stylets. The fine, relatively long labrum bends and lies against the surface of the food.

Feeding at the one point of insertion may occupy one and one-quarter hours. After withdrawal the stylets may be brushed down by

the foretarsi and are replaced in the rostrum either by a swinging together of both organs, or if this is unsuccessful by a downward movement of the foretarsi. The above account is largely based on observations of adults feeding on a piece of chestnut.

Larvae similarly feed with the rostrum folded away as at rest. The time interval for full insertion of the stylets by first instar larvae is of the same order as in the adult but the time occupied in feeding is about 15 minutes per meal.

The seeds on which these bugs feed in the field are much smaller than chestnuts and so for adults the stylets would probably not be inserted at full depth, yet even on the seeds of E.cinerea and shepherds purse (Capsella bursa-pastoris (L.) Medik.), the smallest seeds used in this study, the rostrum was at least in the "bent" position. However, when feeding on seeds the rostrum is often folded away even if the stylets are not fully inserted. The larvae were often observed feeding with the stylets inserted at full depth in seeds. Beck etal. (1958) made similar observations on O.fasciatus and noted that the rostrum may be folded away under the insect leaving the stylets unsupported during feeding.

Sometimes adults, if disturbed during feeding, will move with the seed still on the end of the rostrum, but whether this is accidental or not is unknown.

Effect of renewing food at different intervals

As Frings etal. (1957) found that the frequency with which the food was changed affected survival in O.fasciatus, the following experiment was carried out.

Four groups of 10 Scolopostethus affinis were reared from eggs on shepherds purse seed which was changed every 4, 8 and 16 days, and not at all.

TABLE 31. Effect of renewing food at different intervals on the development and survival of Scolopostethus affinis.

| | Duration of total larval development in days | | | |
|---|---|---|---|---|
| | Food changed every | | | Food not changed |
| | 4 days | 8 days | 16 days | |
| Mean ♂ | 36.9 | 31.4 | 36.2 | 34.8 |
| Range | 33-41 | 26-35 | 29.5-35.5 | 29-41 |
| Mean ♀ | 34.5 | 31.0 | 36.3 | 35.0 |
| Range | 33-36 | 25-41 | 30.5-46.0 | 26-42 |
| % survival to adult | 70 | 70 | 80 | 80 |

Table 31 shows that survival was of the same order for all groups but that fastest development occurred when the food was changed every eight days. However, the differences between the means of this and any of the other groups were not significant.

When the food was not changed it went very mouldy and mould also occurred when the food was left as long as 16 days; this could explain the small increase in development time which may not occur if the seed remained uncontaminated.

Thus it is concluded that the practice adopted of changing the food approximately every eight days did not adversely affect survival.

Site of feeding

To obtain an indication of the site of feeding and feeding behaviour the sorrel seeds that had been given as food to five specimens of D. sylvaticus for two to three weeks were examined by cutting them in half.

TABLE 32. Analysis of sorrel seeds offered to D. sylvaticus.

| | No. of seeds not attacked | No. with embryo gone. Rest hard | No. with embryo ½ gone. Rest hard | No. completely hollow | No. ½ hollow. Rest soft |
|---|---|---|---|---|---|
| ♀ | 6 | 41 | - | 1 | - |
| ♀ | 6 | 32 | - | 5 | 3 |
| ♀ | 1 | 11 | 10 | 10 | 1 |
| ♀ | 9 | 24 | - | 5 | 2 |
| ♂ | 15 | 23 | - | 4 | 1 |

Seeds not offered to bugs had an embryo with the remainder of the seed hard. The large number of seeds with the embryo completely sucked out (Table 32) indicates that the bugs concentrate on the embryo and do not completely hollow out one seed before starting on another as in the case of milkweed bugs, which in contrast do not touch the embryo (Beck etal. 1958). However, in some cases seeds were hollowed right out, and in those found half consumed the remaining portion was soft. This may be the direct effect of repeated probings by the stylets, or it may be the result of external pre-digestion.

The seeds of shepherds purse are soft throughout. A quick survey was made of some given to Scolopostethus affinis for food. In some the interior was completely consumed and in others it was half consumed; many seeds were apparently untouched.

## Main Feeding Studies

The eight foods tested were the seeds of nettle, E.cinerea, shepherds purse, sorrel, sweet chestnut, chickweed and spurrey, and the larvae of C.hemipterus.

The growth curves (based on body weights during development) for each species on each food where there was survival to adults are shown in Figs. 5-9. In the case of Scolopostethus affinis and Drymus sylvaticus on C.hemipterus larvae, the results for individual specimens was graphed, even though none survived to adult.

### Growth Curves

The growth curves were all sigmoid, that of both sexes remaining similar until the fourth larval instar (as noted in Nabidids by Fewkes 1958 and in Anthocorids by Anderson 1961). As also noted by these two authors there was a decrease in weight immediately before a moult, and the newly moulted specimen weighed less than the maximum weight attained in the previous instar. Thus the growth curve for each instar was also sigmoid.

### Increase in weight

The increase in weight was studied in some detail and the total gain in milligrams and the gain per instar can be read off from the graphs in Figs. 5-9.

If the new adult weight is divided by the duration of total larval development then the overall daily weight increase is obtained (Table 33).

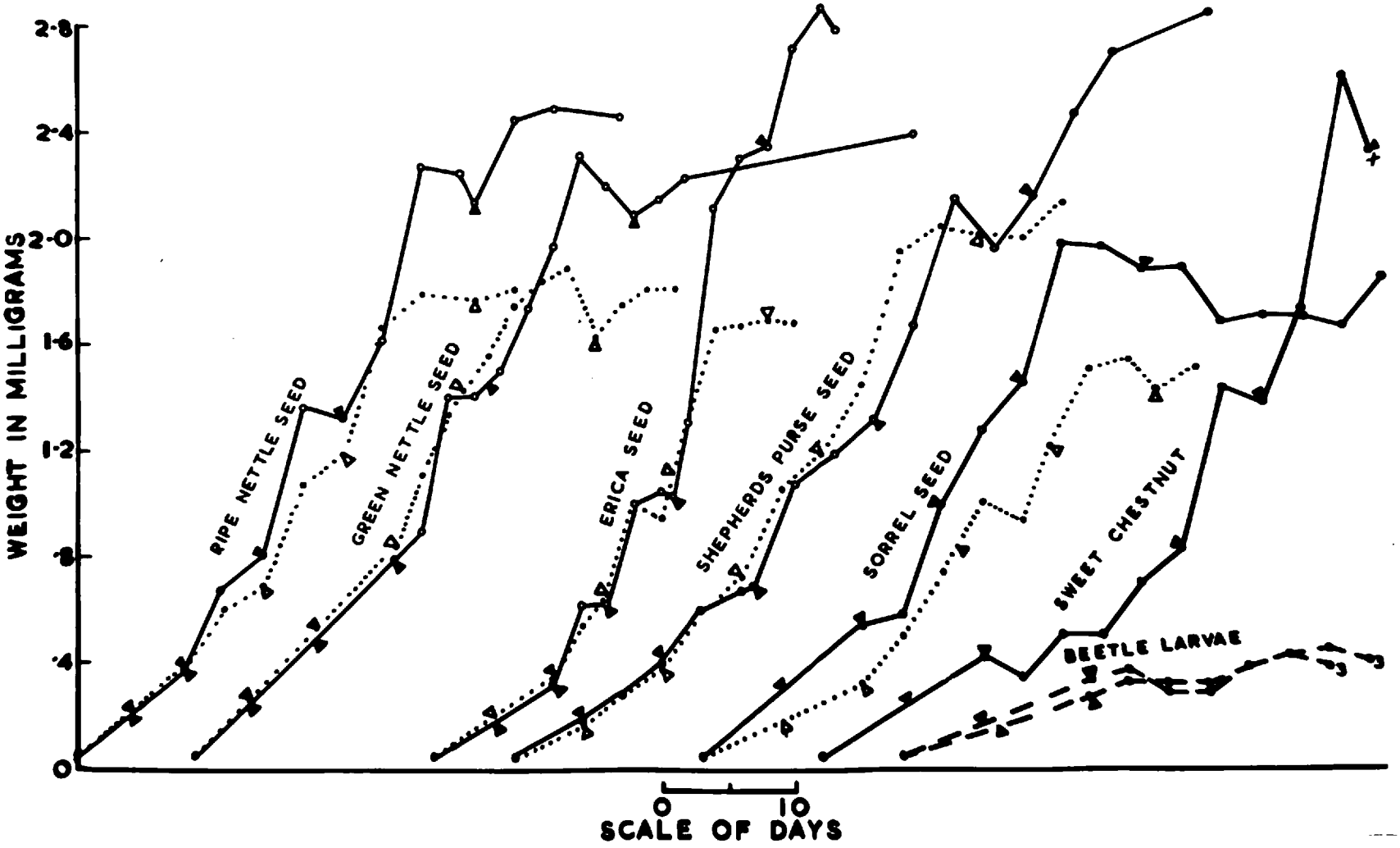



Figure 5. Growth curves, determined by weight, of Scolopostethus affinis reared on different seed diets. Solid lines are for females, until oviposition, - an x indicates that there was no oviposition on that food; dotted lines are for males; the triangles mark the moults. 3 = died in third larval instar.

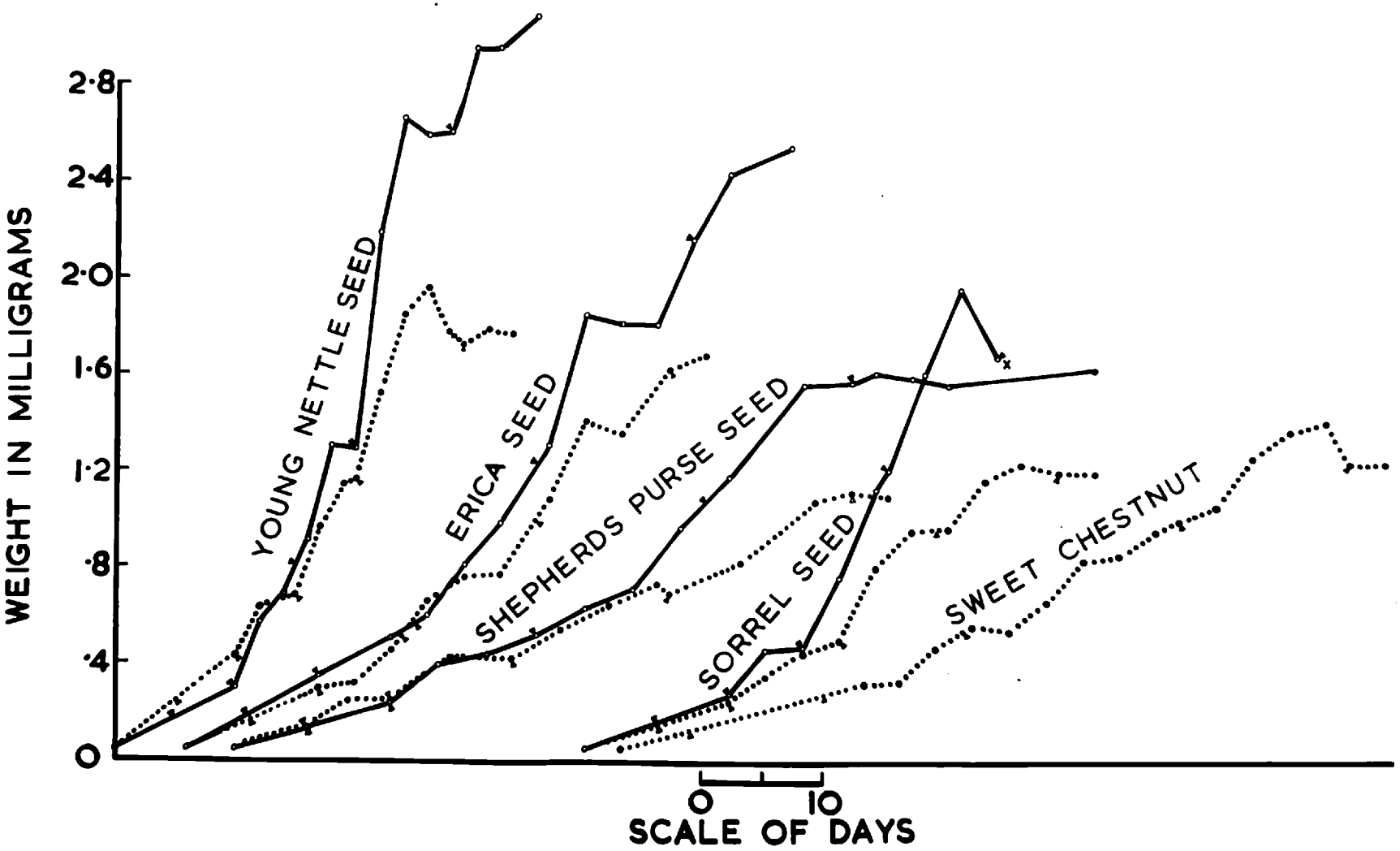



Figure 6. Growth curves, determined by weight, of Scolopostethus thomsoni reared on different seed diets. Legend, as in Fig. 5.

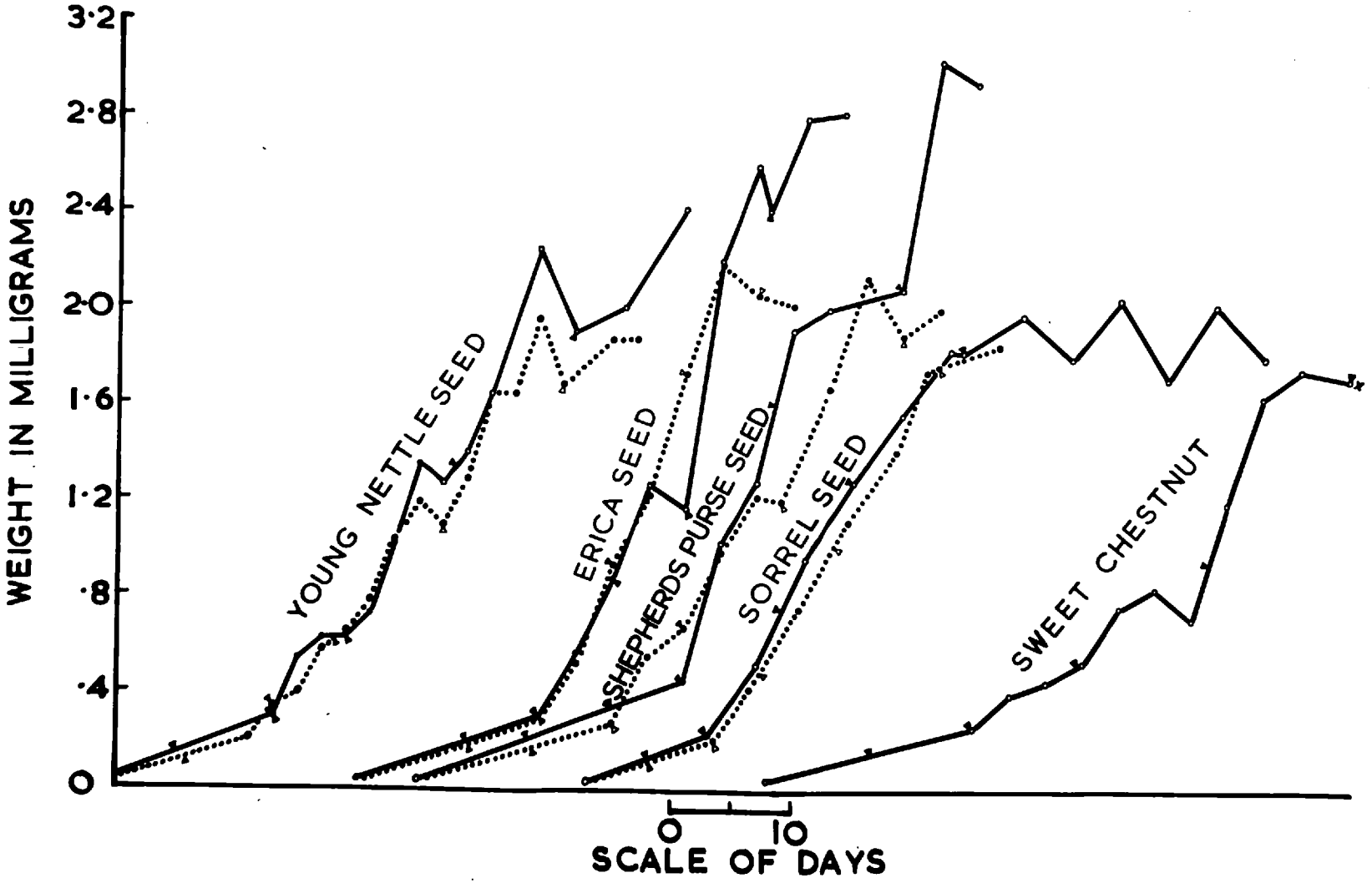



Figure 7. Growth curves, determined by weight, of Scolopostethus decoratus reared on different seed diets. Legend, as in Fig. 5.

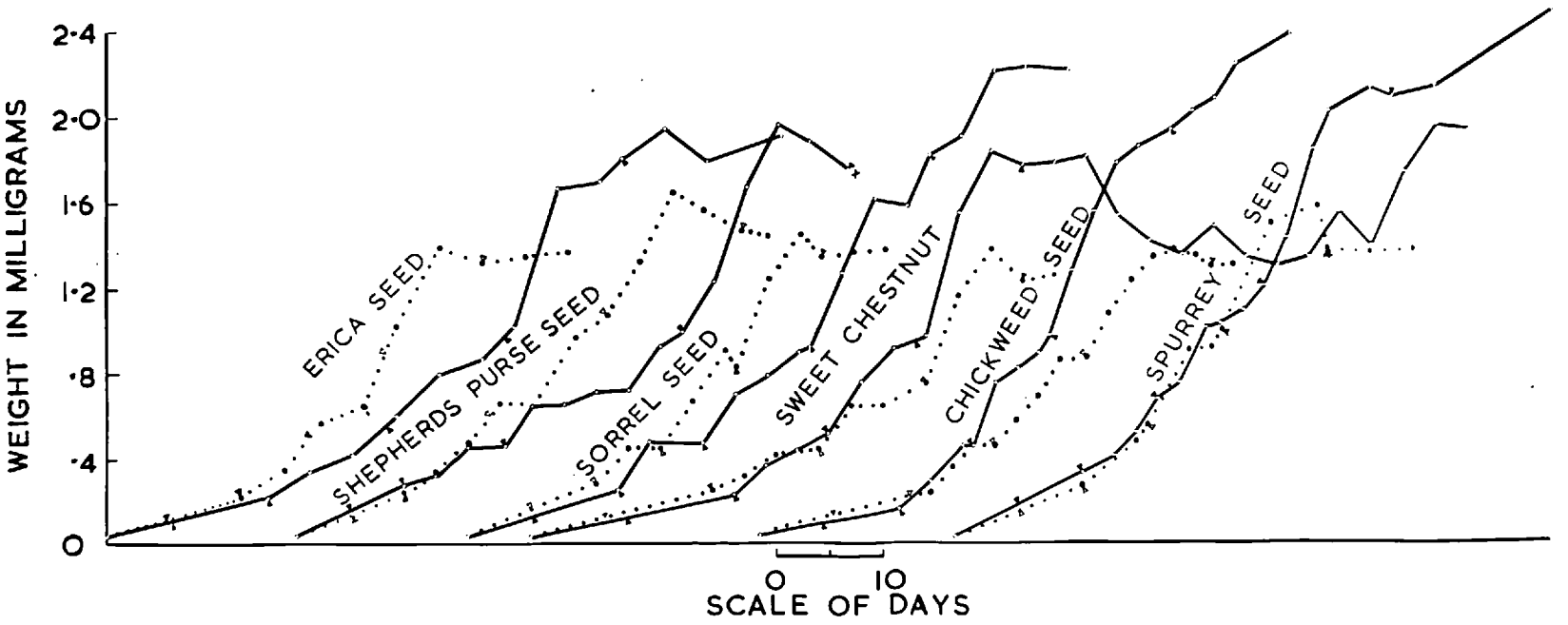



Figure 8. Growth curves, determined by weight, of Stygnocoris fuligineus reared on different seed diets. Legend, as in Fig. 5.

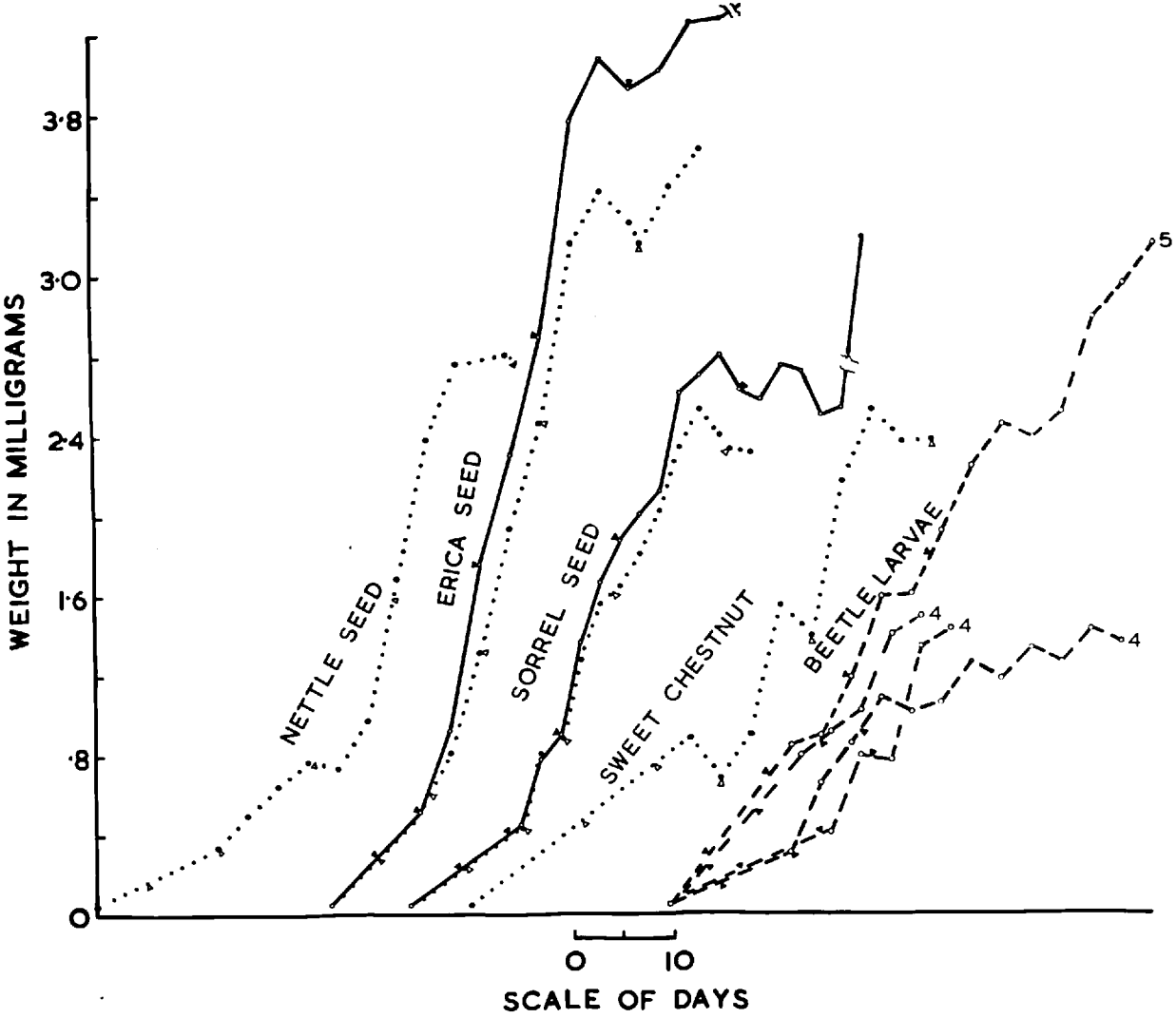



Figure 9. Growth curves, determined by weight, of Drymus sylvaticus reared on different seed diets, and on the larvae of C.hemipterus. Legend, as in Fig. 5. The numbers 4 and 5 indicate the larval instar in which death occurred on the beetle larvae diet.

TABLE 33. Overall daily weight increase in milligrams on the different foods.

| | Green nettle seed | Ripe nettle seed | Erica cinerea seed | Shepherds purse seed | Sorrel seed | Sweet chest-nut | Chick-weed seed | Spurrey seed |
|---|---|---|---|---|---|---|---|---|
| Females | | | | | | | | |
| affinis | .063 | .071 | .097 | .060 | .058 | .053 | | |
| thomsoni | .086 | | .055 | .031 | .046 | - | | |
| decoratus | .051 | | .069 | .048 | .064 | .036 | | |
| fuligineus | | | .037 | .028 | .040 | .038 | .044 | .051 |
| sylvaticus | | | .138 | .043 | .080 | - | | |
| Males | | | | | | | | |
| affinis | .051 | .059 | .067 | .061 | .042 | - | | |
| thomsoni | .055 | | .045 | .023 | .031 | .021 | | |
| decoratus | .044 | | .066 | .043 | .057 | - | | |
| fuligineus | | | .038 | .026 | .041 | .026 | .031 | .040 |
| sylvaticus | | | .105 | .036 | .073 | .052 | | |

However, the rate of actual weight gain was not uniform throughout development as shown in Table 34. The greatest actual weight increase occurred early in the fifth larval instar at a or b in the table which also shows the slowing down in growth before the moults. The adult males did not increase in weight but the females continued to gain weight (though at a slower rate) until sexually mature. These results show that the overall daily weight increase (Table 33) in fact tells us nothing about the growth of the insects, but may be used for comparing one food with another.

TABLE 34. Rate of weight gain (in mg. per day) per instar on the different foods.
The letters a, b and c refer to changes in rate of weight gain within instars.

| Food | Larval instar | affinis ♂ | affinis ♀ | thomsoni ♂ | thomsoni ♀ | decoratus ♂ | decoratus ♀ | fuligineus ♂ | fuligineus ♀ | sylvaticus ♂ | sylvaticus ♀ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3a | .073 | .103 | .100 | .135 | .030 | .120 | | | .053 | |
| | 3b | | | .015 | .060 | .050 | .045 | Insectary | | .050 | |
| | 3c | | | | | -.015 | | exp. not | | | |
| Nettle | 4a | .127 | .187 | .140 | .195 | .065 | .050 | comparable | | .097 | |
| seed | 4b | | | .090 | .065 | .103 | .155 | | | | |
| | 4c | | | | | -.035 | -.040 | | | | |
| | 5a | .160 | .097 | .180 | .445 | .178 | .120 | | | .180 | |
| | 5b | .040 | .217 | .160 | .235 | .155 | .150 | | | .127 | |
| | 5c | | -.007 | -.090 | -.035 | | | | | .020 | |
| Adult | a | .013 | .107 | .030 | .175 | .023 | .045 | | | | |
| " | b | | -.120 | | | | | | | | |
| | 3 | .095 | .145 | .047 | .050 | .073 | .087 | .033 | .030 | .103 | .137 |
| Erica | 4 | .170 | .190 | .030 | .070 | .097 | .130 | .035 | .050 | .207 | .183 |
| cinerea | 5a | .170 | .400 | .140 | .180 | .150 | .343 | .093 | .163 | .300 | .360 |
| seed | 5b | | .100 | -.017 | | | .130 | | .008 | .087 | .103 |
| Adult | a | | .190 | .020 | .090 | | .127 | .008 | .035 | | .080 |
| " | b | | .080 | | .047 | | .007 | | | | .007 |
| | 2 | .037 | .030 | .043 | | | | | | | |
| | 3a | .110 | .077 | .013 | .033 | .093 | .083 | .030 | .017 | | |
| | 3b | | .023 | .030 | .010 | | .073 | | .043 | Not | |
| Shep- | 3c | | | | | | | | .003 | weighed | |
| herds | 4a | .110 | .130 | .030 | .028 | .103 | | .010 | .063 | as | |
| purse | 4b | | .037 | .025 | .020 | .077 | .067 | .110 | .037 | larvae | |
| seed | 5a | .087 | .120 | .046 | .063 | .157 | .210 | .080 | .037 | | |
| | 5b | .170 | .160 | .037 | | .153 | .030 | .110 | .096 | | |
| | 5c | .011 | -.060 | | | | | -.030 | -.027 | | |
| Adult | a | .040 | .100 | | .013 | .037 | .190 | | | | |
| " | b | | .077 | | | | -.030 | | | | |
| | 3a | .060 | .010 | .040 | .060 | .055 | .072 | .057 | .077 | .166 | .165 |
| | 3b | | | .029 | | | | | | | |
| Sorrel | 4a | .120 | .093 | .100 | .097 | .115 | .107 | .073 | .077 | .195 | .230 |
| | 4b | | | .050 | .120 | | | .080 | .037 | .140 | .150 |
| | 5a | .097 | .140 | .067 | .133 | .075 | .070 | .140 | .117 | .117 | .063 |
| | 5b | .010 | | .023 | .117 | .083 | | .070 | .117 | .095 | .245 |
| Adult | | .027 | .050 | | -.037 | .023 | .015 | .007 | .030 | | .075 |

Continued -

TABLE 34 Continued

| Food | Larval instar | affinis ♂ | affinis ♀ | thomsoni ♂ | thomsoni ♀ | decoratus ♂ | decoratus ♀ | fuligineus ♂ | fuligineus ♀ | sylvaticus ♂ | sylvaticus ♀ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3a | | -.027 | .002 | | | .047 | .023 | .047 | | |
| | 3b | | .057 | .048 | | | .017 | .033 | .023 | | |
| | 3c | | .003 | | | | | | | | |
| Sweet | 4a | | .200 | -.007 | | | .077 | .067 | .080 | .073 | |
| chest- | 4b | | | .050 | | | .027 | | .053 | .217 | |
| nut | 4c | | | .003 | | | | | | | |
| | 5a | | .113 | .020 | | | .150 | .137 | .193 | .217 | |
| | 5b | | .293 | .067 | | | .037 | .073 | .097 | .197 | |
| | 5c | | | .013 | | | | .020 | | -.053 | |
| | Adult | | | | | | | .010 | .003 | | |
| | 3 | | | | | | | .060 | .057 | | |
| Chick- | 4 | | | | | | | .083 | .103 | | |
| weed | 5a | | | | | | | .117 | .183 | | |
| seed | 5b | | | | | | | .010 | .060 | | |
| | Adult | | | | | | | .017 | .040 | | |
| | 3 | | | | | | | .052 | .048 | | |
| | 4a | | | | | | | .088 | .076 | | |
| Spurrey | 4b | | | | | | | .007 | .023 | | |
| seed | 5a | | | | | | | .125 | .142 | | |
| | 5b | | | | | | | .016 | .120 | | |
| | Adult | | | | | | | | .027 | | |

When D.sylvaticus fed on beetle larvae the rate of weight gain, although much less than on suitable seeds, was nevertheless positive (Table 35). The general growth curve on this diet (until death in the fourth and fifth instars) was similar to that on seeds (Fig. 9). On the other hand, Scolopostethus affinis, although surviving to the third larval instar on a diet of beetle larvae, scarcely showed any growth (Fig. 5).

TABLE 35. Daily weight gain (in mg.) per instar on C.hemipterus larvae.

| Larval instar | sylvaticus | affinis |
|---|---|---|
| 3 | .067 | .010 - .020 |
| 4a | .083 | |
| 4b | .043 | |
| 5a | .110 | |
| 5b | .070 | |
| 5c | .067 | |

Although the highest value for the actual weight gain per day was generally greater in successive larval instars from the third to the fifth, the gain relative to the body weight at the time was greater in the reverse order of instars. This is shown in Table 36 in which the rate of weight increase per day (from Table 34) is expressed for each instar as the percentage of the previous weight in the same instar. Where the figure was available for the second instar larva e.g. Scolopostethus affinis and thomsoni on shepherds purse seed, it was also high. The data suggests that efficiency in gaining weight is greatest in earlier instars.

This was more noticeable on poor foods than on suitable foods. Thus the larvae may be under an increasing disadvantage in successive instars in the struggle to survive on a poor food: there was late mortality on some foods. However, in the case of D.sylvaticus developing on chestnut the first instar larvae took longer to develop than the second to fourth instars which is suggestive of a short period of habituation to a strange food.

That the female larvae gained weight at a faster rate than the males is also shown in Table 36. There was a temporary loss of weight at oviposition in mature females.

TABLE 36. Rate of weight gain as a percentage of the previous weight in the same instar.
The letters a, b and c refer to changes in % weight gain within instars.

| Food | Larval instar | affinis ♂ | affinis ♀ | thomsoni ♂ | thomsoni ♀ | decoratus ♂ | decoratus ♀ | fuligineus ♂ | fuligineus ♀ | sylvaticus ♂ | sylvaticus ♀ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nettle seed | 3a | 19.2 | 27.8 | 23.3 | 45.0 | 8.8 | 40.0 | | | 15.6 | |
| | 3b | | | 2.4 | 10.5 | 8.0 | 8.3 | | | 10.0 | |
| | 3c | | | | | -2.5 | | Insectary | | | |
| | 4a | 18.4 | 23.4 | 20.6 | 21.4 | 10.0 | 7.9 | exp. not | | 14.1 | |
| | 4b | | | 9.4 | 5.0 | 12.0 | 18.0 | comparable | | | |
| | 4c | | | | | -2.9 | -3.0 | | | | |
| | 5a | 13.6 | 7.3 | 15.5 | 34.5 | 16.2 | 8.6 | | | 10.7 | |
| | 5b | 2.4 | 13.5 | 10.5 | 10.8 | 9.5 | 9.1 | | | 5.3 | |
| | 5c | | -0.3 | -4.6 | -1.3 | | | | | 0.7 | |
| Adult | a | 0.7 | 5.0 | 1.7 | 6.8 | 1.3 | 2.4 | | | | |
| " | b | | -4.8 | | | | | | | | |
| Erica cinerea seed | 3 | 27.1 | 45.6 | 14.4 | 14.3 | 23.5 | 28.1 | 15.0 | 13.6 | 20.2 | 26.2 |
| | 4 | 26.2 | 30.6 | 4.5 | 11.7 | 10.3 | 14.8 | 6.1 | 8.3 | 15.7 | 10.4 |
| | 5a | 12.9 | 30.8 | 13.0 | 13.9 | 8.7 | 29.3 | 9.1 | 16.0 | 12.1 | 12.4 |
| | 5b | 0.3 | 7.7 | -1.1 | | | 5.9 | | 0.5 | 2.6 | 2.6 |
| Adult | a | | 8.2 | 1.2 | 4.2 | | 5.3 | 0.6 | 1.9 | | 1.9 |
| " | b | | 3.4 | | 1.5 | | 2.5 | | | | 0.2 |
| Shepherds purse seed | 2 | 21.8 | 15.8 | 30.7 | | | | | | | |
| | 3a | 28.9 | 19.3 | 5.2 | 12.2 | 33.2 | 16.3 | 12.5 | 6.3 | | |
| | 3b | | 3.8 | 10.0 | 2.5 | | 9.6 | | 13.4 | Not | |
| | 3c | | | | | | | | 0.7 | weighed | |
| | 4a | 15.2 | 19.0 | 7.1 | 5.4 | 15.1 | | 1.6 | 14.0 | as | |
| | 4b | | 3.5 | 4.6 | 3.2 | 7.8 | 5.0 | 17.1 | 5.1 | larvae | |
| | 5a | 7.4 | 9.4 | 6.7 | 5.4 | 13.1 | 16.4 | 7.5 | 3.5 | | |
| | 5b | 11.8 | 9.5 | 4.0 | | 9.2 | 1.6 | 8.4 | 7.8 | | |
| | 5c | 0.6 | -2.4 | | | | | -1.8 | -1.4 | | |
| Adult | a | 2.0 | 4.8 | | 0.8 | 2.0 | 7.7 | | | | |
| " | b | | 3.1 | | | | -1.0 | | | | |
| Sorrel seed | 3a | 18.8 | 1.8 | 20.0 | 21.4 | 26.2 | 30.0 | 20.4 | 30.8 | 42.6 | 36.7 |
| | 3b | | | 8.0 | | | | | | | |
| | 4a | 16.2 | 9.4 | 20.0 | 20.6 | 25.0 | 20.2 | 16.2 | 16.4 | 21.9 | 25.3 |
| | 4b | | | 6.3 | 15.8 | | | 11.9 | 4.7 | 10.9 | 10.9 |
| | 5a | 8.0 | 9.7 | 7.0 | 11.1 | 6.7 | 5.5 | 16.9 | 12.7 | 6.5 | 3.2 |
| | 5b | 0.7 | | 2.0 | 7.3 | 5.9 | | 5.6 | 9.2 | 4.0 | 11.5 |
| Adult | | 1.9 | 2.9 | | -1.8 | 1.3 | 0.8 | 0.5 | 1.6 | | 2.9 |

Continued -

TABLE 36 - continued

| Food | Larval instar | affinis ♂ | affinis ♀ | thomsoni ♂ | thomsoni ♀ | decoratus ♂ | decoratus ♀ | fuligineus ♂ | fuligineus ♀ | sylvaticus ♂ | sylvaticus ♀ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3a | | -5.0 | 0.6 | | | 17.4 | 9.2 | 20.4 | | |
| | 3b | | 16.7 | 14.8 | | | 4.1 | 10.3 | 6.2 | | |
| | 3c | | 0.6 | | | | | | | | |
| Sweet | 4a | | 24.0 | -1.3 | | | 14.3 | 14.9 | 15.4 | 10.6 | |
| chest- | 4b | | | 8.3 | | | 3.5 | | 7.0 | 23.8 | |
| nut | 4c | | | 0.4 | | | | | | | |
| | 5a | | 8.2 | 2.0 | | | 12.5 | 18.0 | 19.7 | 15.5 | |
| | 5b | | 17.0 | 6.3 | | | 2.2 | 6.2 | 6.2 | 10.1 | |
| | 5c | | | 0.9 | | | | 1.4 | | -2.1 | |
| | Adult | | | | | | | 0.8 | 0.2 | | |
| | 3 | | | | | | | 25.0 | 19.7 | | |
| Chick- | 4 | | | | | | | 15.4 | 21.9 | | |
| weed | 5a | | | | | | | 10.3 | 14.9 | | |
| seed | 5b | | | | | | | 0.7 | 3.4 | | |
| | Adult | | | | | | | 1.3 | 2.1 | | |
| | 3 | | | | | | | 19.3 | 14.5 | | |
| | 4a | | | | | | | 15.7 | 11.2 | | |
| | 4b | | | | | | | 0.8 | 2.3 | | |
| Spurrey seed | 5a | | | | | | | 12.4 | 11.6 | | |
| | 5b | | | | | | | 1.1 | 6.3 | | |
| | Adult | | | | | | | | 1.3 | | |

Rate of mortality

The survival of each species on the different foods is shown in Tables 38-42 and is a useful factor in determining the value of the foods to each species. However, it is also of interest to analyse the rate of mortality which is shown in Table 37.

On foods that did not support growth to adults the larvae generally died in the first and second instars. These foods can be regarded as unsuitable. Nettle seed is an exception for D.sylvaticus for in the insectary a survival of eleven per cent was obtained and three further specimens died during the final moult - so for this species this food belongs in the next group - foods that permitted poor survival to adults. Nettle seed may also be an exception for Stygnocoris fuligineus.

TABLE 37. Rate of mortality on the different foods.
The letter m refers to those that died during a moult.

| Food | Number that died in the larval instar indicated | | | | | No. survival based on |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| *Scolopostethus affinis* | | | | | | |
| Green nettle seed | | | | | 1 | 5 |
| Ripe nettle seed | | | | 1 | | 18 |
| *Erica cinerea* seed | 1+1m | | | | 2m | 20 |
| Shepherd's purse seed | | | | 2 | 1+2m | 21 |
| Sorrel seed | | | 2 | 2 | 5+1m | 17 |
| Sweet chestnut | 3+1m | 6+1m | 3 | 7 | 3 | 25 |
| Chickweed seed | 13 | 7 | | | | 20 |
| Spurrey seed | 16 | 2 | | | | 18 |
| *C.hemipterus* larvae | 8 | 7 | 10 | | | 25 |
| *Scolopostethus thomsoni* | | | | | | |
| Green nettle seed | | | | | 2 | 29 |
| *Erica cinerea* seed | 1+2m | | | 1m | 2+3m | 18 |
| Shepherds purse seed | | 1 | 1 | 4+2m | 1 | 20 |
| Sorrel seed | | | 3 | 4 | 3 | 17 |
| Sweet chestnut | 1 | 4+1m | 7 | 2 | 2 | 19 |
| Chickweed seed | 57 | | | | | 57 |
| Spurrey seed | 7 | 6 | | | | 13 |
| *C.hemipterus* larvae | 8 | 8 | 1 | | | 17 |

Continued -

- TABLE 37 continued

| Food | Number that died in the larval instar indicated | | | | | No. survival based on |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Scolopostethus decoratus | | | | | | |
| Green nettle seed | 3 | 1 | 2 | | | 9 |
| Erica cinerea seed | | | | 1m | 3 | 18 |
| Shepherds purse seed | | | | 2+1m | | 10 |
| Sorrel seed | 1 | 5 | 1 | | 4 | 20 |
| Sweet chestnut | 5 | 3 | 3 | | | 13 |
| Chickweed seed | 18 | 2 | | | | 20 |
| Spurrey seed | 20 | | | | | 20 |
| C.hemipterus larvae | 18 | 2 | | | | 20 |
| Stygnocoris fuligineus | | | | | | |
| Green nettle seed* | | 2+1m | 2m | 2+1m | 1 | 9 |
| Erica cinerea seed | 1 | 1m | 1 | 2 | 3 | 16 |
| Shepherds purse seed | | | 1 | 3 | 12+1m | 20 |
| Sorrel seed | | | | 1 | 3 | 20 |
| Sweet chestnut | | 2 | 1 | | 1 | 16 |
| Chickweed seed | 1 | 2 | 1 | 1 | 4 | 35 |
| Spurrey seed | | | 1 | | 1 | 17 |
| C.hemipterus larvae | 20 | | | | | 20 |

* Result from the insectary, not the heated cabinet.

Continued -

- TABLE 37 continued

| Food | Number that died in the larval instar indicated | | | | | No. survival based on |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Drymus sylvaticus | | | | | | |
| Ripe nettle seed | 1 | 1 | 3+1m | 4+1m | 2+2m | 15 |
| Erica cinerea seed | 1+1m | 1+1m | 1m | 1 | 1 | 20 |
| Shepherds purse seed | 13 | 2 | | | | 19 |
| Sorrel seed | | 2 | 2 | 1 | 5 | 19 |
| Sweet chestnut | 6+1m | 5 | 1+2m | 1 | | 18 |
| Chickweed seed | 20 | | | | | 20 |
| Spurrey seed | 20 | 3 | | | | 23 |
| C.hemipterus larvae | 8 | 4+2m | 1 | 3 | 1 | 19 |

On foods on which survival was poor many larvae persisted into the fourth and fifth instars and some of these died during moults (Table 37). In the case of Stygnocoris fuligineus developing on shepherds purse seed the percentage daily weight increase for twelve larvae that died in the fifth instar was 25.8 per cent in the third instar, but in later instars it fell to less than one-third the value for those that survived to adults.

When there was good survival the few deaths generally occurred in the later larval instars, and a number of these during the final moult.

Where survival on a food was poor the mortality rate is of special interest because growth was sometimes completed but more often not quite completed. This suggests that the food in itself may be satisfactory nutritionally (as also indicated when other species do

well on it) yet is largely unaccepted by certain species.

Value of the foods

In determining the value of different foods to each species it is desirable to take several factors into consideration. The nine factors given in Tables 38-42 were included and all are important. Two further factors, the growth rate index (Table 33 x 100) or the growth curve (Figs. 5-9) and the stage in which mortality occurred, were also considered.

However, reliance on growth alone without considering reproductive performance or survival can sometimes be misleading when the few insects that develop on a poor food do so at almost normal rate e.g. the growth curve for Scolopostethus decoratus on nettle seed (Fig. 7) and for Scolopostethus affinis on sorrel seed (Fig. 5).

(a) Scolopostethus species

There was some survival to adults by the three Scolopostethus species on the same five foods. However, the growth curves for affinis (Fig. 5) and for decoratus (Fig. 7) were alike and differed from those of thomsoni (Fig. 6). S.thomsoni did well on nettle seed alone and it was with this plant that it was almost always associated in the field. The other two species both did well on the seeds of E.cinerea and shepherds purse, and affinis also on nettle seed. They are therefore adaptable to certain habitats. These species did not develop at all on chickweed seed, spurrey seed or, except for affinis to the third larval instar, on C.hemipterus larvae.

The foods listed in descending order of merit over all factors (Tables 38-40) are, for each species:

S.affinis the seeds of E.cinerea, shepherds purse, nettle, sorrel and sweet chestnut. Sweet chestnut is not a suitable food, and it is doubtful if this species could develop and then reproduce on sorrel seed alone. The size of the adults produced on all foods was similar.

S.thomsoni the seeds of nettle, E.cinerea, shepherds purse, sorrel and sweet chestnut.

As in the previous species the last two foods seem to be unsuitable and the adults produced were smaller than normal especially on sweet chestnut. S.thomsoni can develop and reproduce on a diet of E.cinerea seeds although this takes longer, and the adults are smaller than on nettle seed (Fig. 6). On a diet of shepherds purse seed development takes longer still and the size of the adults produced is almost half normal. Fecundity is greatly reduced so that this food is scarcely suitable.

S.decoratus the seeds of E.cinerea, shepherds purse, nettle, sorrel and sweet chestnut.

This species showed preferences similar to affinis except that it did not do nearly so well on nettle seed. However, even on this diet it did oviposit, and it was the only one of the three species that seemed capable of reproducing on sorrel seed (although at a much reduced rate). Sweet chestnut seemed an unsuitable food and the adults produced were considerably smaller than normal.

(b) Stygnocoris fuligineus

Stygnocoris fuligineus (Fig. 8) contrasted with the Scolopostethus species in doing well on all the seeds except those of nettle and shepherds purse, and in developing on the seeds of chickweed and spurrey. There were slight differences between the various seed diets as shown in Tables 41 and 33. When reared on a diet of sweet chestnut there was a long preoviposition period and reduced fecundity.

The foods listed in descending order of merit over all factors are: the seeds of spurrey, sorrel, chickweed, E.cinerea, sweet chestnut and shepherds purse.

Table 41 shows that shepherds purse seed was unsuitable for food, and that apart from the disadvantage of sweet chestnut already noted, the suitability of the other five foods was about even. The seeds of E.cinerea, however, fell in the lower end of the group.

(c) Drymus sylvaticus

The foods listed in descending order of merit over all factors (Table 42) are: the seeds of E.cinerea, sorrel, shepherds purse, nettle and sweet chestnut. D.sylvaticus differed from the other species as it did reasonably well on both sorrel and E.cinerea seeds, did not develop at all on spurrey and chickweed seeds, but persisted into the fifth larval instar on beetle larvae (Fig. 9). Its development on nettle seed was very poor, although adults taken in winter and provided with nettle seeds completed their development and oviposited well (Table 47). Further, larvae taken under spurrey developed to adults on spurrey seed.

Although there is considerable variation in the size of field specimens, those specimens reared on diets of chestnut and shepherds

purse seed were very small. Some specimens reared on sorrel seed also tended to be small.

The obligatory diapause in this species upset the determination of the preoviposition period. The bugs were reared in continuous light but as there is a suggestion that they are nocturnal (Southwood and Leston 1959) some were reared or kept in total darkness. This did not induce oviposition. Although the diapause could be broken by subjection to a temperature of 10°C. for one week, Table 42 shows that when kept in the warmth it was eventually broken after 45-170 days.

When reared on suitable foods the new adult weight and weight of the ovipositing female (Tables 38-42) were in the range of the field weights given in the section on bionomics. In the case of Scolopostethus decoratus on E.cinerea seed some specimens were heavier than the field specimens and this was also the case with newly emerged D.sylvaticus females.

On some poorer foods the new adult weight was sometimes in the range of the field weights, but the ovipositing female was lighter than in the field. Stygnocoris fuligineus on sweet chestnut is also included here. In the case of D.sylvaticus on shepherds purse seed the adults were lighter than in the field.

When reared on unsuitable foods the adults weighed less than field specimens e.g. Scolopostethus thomsoni on shepherds purse seed and Scolopostethus affinis on sorrel seed. Sometimes the males did weigh about the same as field specimens e.g. Stygnocoris fuligineus on shepherds purse seed.

TABLE 38. Overall development and reproductive potential of Scolopostethus affinis on the different foods to show their value. Mean values are given with the range underneath.

| | Ripe nettle seed | Green nettle seed | E.cinerea seed | Shepherds purse seed | Sorrel seed | Sweet chestnut |
|---|---|---|---|---|---|---|
| Larval dvt. in days ♂ | 30<br>24-40 | 30<br>30-34 | 25<br>18-30 | 33<br>26-48 | 34<br>32-36 | - |
| Larval devt. in days ♀ | 30<br>24-34 | 33<br>33 | 24<br>18-27 | 36<br>28-46 | 32<br>25-37 | 43<br>43 |
| % survival to adult | 80 | 94 | 80 | 76 | 39 | 4 |
| Max. 5th wt. in mg. ♂ | 1.92<br>1.58-2.55 | 1.97<br>1.88-2.06 | 1.75<br>1.21-2.21 | 2.05<br>1.49-2.36 | 1.60<br>1.43-1.76 | - |
| Max 5th wt. in mg. ♀ | 2.34<br>1.92 3.23 | 2.30<br>2.18-2.42 | 2.38<br>1.53-3.02 | 2.40<br>1.99-2.85 | 2.10<br>1.96-2.26 | 2.60<br>2.60 |
| Wt. new ♂ adult in mg. | 1.76<br>1.28-2.61 | 1.62<br>1.53-1.70 | 1.68<br>1.11-2.05 | 2.00<br>1.50-2.26 | 1.42<br>1.28-1.52 | - |
| Wt. new ♀ adult in mg. | 2.12<br>1.71-2.96 | 2.07<br>1.97-2.16 | 2.33<br>1.77-2.85 | 2.15<br>1.73-2.75 | 1.87<br>1.73-2.00 | 2.30<br>2.30 |
| Wt. ovipositing♀ mg. | 2.45<br>2.13-3.71 | 2.38<br>2.32-2.43 | 2.76<br>2.27-3.40 | 2.77<br>2.19-3.48 | 1.84<br>1.84 | - |
| Preoviposition prd.days | 11<br>7-17 | 18<br>13-22 | 5<br>5-7 | 13<br>6-25 | 18<br>18 | - |
| Oviposition prd. in days | 34<br>16-52 | Not taken | 45<br>21-68 | 59<br>18-121 | 1<br>1 | - |
| Fecundity Eggs/♀ | 42<br>13-86 | " | 165<br>149-209 | 297<br>15-496 | 1<br>1 | 0 |
| Adult longevity days ♂ | 69<br>19-117 | 19<br>3-35 | 78<br>51-92 | 103<br>52-182 | 17<br>3-30 | - |
| Adult longevity days ♀ | 36<br>6-60 | 56<br>49-63 | 53<br>26-74 | 72<br>29-128 | 7<br>0-29 | 18<br>18 |

TABLE 39. Overall development and reproductive potential of *Scolopostethus thomsoni* on the different foods to show their value.
Mean values are given with the range underneath.

| | Green nettle seed | *E.cinerea* seed | Shepherds purse seed | Sorrel seed | Sweet chestnut |
|---|---|---|---|---|---|
| Larval devt. in days ♂ | 31<br>27-41 | 36<br>28-44 | 49<br>45-61 | 38<br>31-43 | 60<br>58-62 |
| Larval devt. in days ♀ | 30<br>27-38 | 39<br>28-54 | 50<br>44-55 | 36<br>31-41 | - |
| % survival to adult | 93 | 55 | 55 | 41 | 10.5 |
| Max. 5th wt. in mg. ♂ | 2.01<br>1.57-2.52 | 1.68<br>1.17-2.32 | 1.19<br>0.98-1.41 | 1.35<br>1.28-1.51 | 1.51<br>1.41-1.61 |
| Max. 5th wt. in mg. ♀ | 2.83<br>2.28-3.22 | 2.03<br>1.60-2.79 | 1.61<br>1.41-1.83 | 1.95<br>1.74-2.16 | - |
| Wt. new ♂ adult in mg. | 1.72<br>1.34-2.23 | 1.61<br>1.11-2.14 | 1.11<br>1.00-1.22 | 1.18<br>1.06-1.34 | 1.24<br>1.23-1.24 |
| Wt. new ♀ adult in mg. | 2.59<br>1.94-3.17 | 2.15<br>1.56-2.77 | 1.56<br>1.42-1.69 | 1.67<br>1.30-2.04 | - |
| Wt. ovipositing ♀ mg. | 3.07<br>2.26-3.90 | 2.53<br>1.73-3.21 | 1.62<br>1.48-1.74 | - | - |
| Preoviposition prd.days | 7<br>4-11 | 8<br>5-11 | 21<br>15-30 | - | - |
| Oviposition prd.in days | 40<br>7-62 | 51<br>28-67 | 33<br>5-56 | - | - |
| Fecundity Eggs/ ♀ | Not taken | 92<br>5-150 | 15<br>4-45 | 0 | - |
| Adult longevity days ♂ | 49<br>1-93 | 66<br>21-126 | 63<br>32-108 | 5<br>1-13 | 21<br>11-31 |
| Adult longevity days ♀ | 42<br>6-67 | 59<br>39-73 | 69<br>29-108 | 4<br>2-6 | - |

TABLE 40. Overall development and reproductive potential of Scolopostethus decoratus on the different foods to show their value.
Mean values are given with the range underneath.

| | Green nettle seed | E.cinerea seed | Shepherds purse seed | Sorrel seed | Sweet chestnut |
|---|---|---|---|---|---|
| Larval devt. in days ♂ | 38<br>37-39 | 31<br>29-34 | 44<br>40-51 | 31<br>28-37 | - |
| Larval devt. in days ♀ | 38<br>38 | 35<br>29-49 | 43<br>42-44 | 30<br>28-31 | 48<br>43-53 |
| % survival to adult | 33 | 78 | 70 | 45 | 15 |
| Max. 5th wt. in mg. ♂ | 1.88<br>1.81-1.95 | 2.19<br>1.80-2.45 | 2.13<br>1.60-2.55 | 1.65<br>1.33-2.32 | - |
| Max. 5th wt. in mg. ♀ | 2.24<br>2.24 | 2.61<br>1.71-3.22 | 2.11<br>1.77-2.45 | 1.74<br>1.50-1.93 | 1.86<br>1.59-2.13 |
| Wt. new ♂ adult in mg. | 1.68<br>1.58-1.78 | 2.06<br>1.70-2.33 | 1.89<br>1.39-2.42 | 1.76<br>1.55-2.26 | - |
| Wt. new ♀ adult in mg. | 1.95<br>1.95 | 2.41<br>1.61-3.06 | 2.08<br>1.70-2.46 | 1.92<br>1.82-2.13 | 1.72<br>1.38-2.05 |
| Wt. ovipositing mg. | 2.41<br>2.41 | 2.81<br>2.51-3.57 | 2.94<br>2.94 | 1.74<br>1.74 | - |
| Preoviposition prd.days | 9<br>9 | 9<br>7-14 | 6<br>6 | 25<br>25 | - |
| Oviposition prd.in days | 21<br>21 | 60<br>5-91 | 45<br>45 | 19<br>19 | - |
| Fecundity Eggs/♀ | 14<br>14 | 364<br>6-582 | 279<br>279 | 15<br>15 | 0 |
| Adult longevity days ♂ | 36<br>31-40 | 42<br>3-113 | 46<br>2-87 | 10<br>4-17 | - |
| Adult longevity days ♀ | 38<br>38 | 53<br>6-105 | 51<br>51 | 28<br>5-51 | 16<br>2-30 |

TABLE 41. Overall development and reproductive potential of Stygnocoris fuligineus on the different foods to show their value.
Mean values are given with the range underneath.

| | E.cinerea seed | Shepherds purse seed | Sorrel seed | Sweet chestnut | Chickweed seed | Spurrey seed |
|---|---|---|---|---|---|---|
| Larval devt. in days ♂ | 35<br>32-38 | 57<br>55-58 | 33<br>30-36 | 47<br>38-53 | 42<br>37-48 | 35<br>33-39 |
| Larval devt. in days ♀ | 49<br>32-73 | 62<br>55-69 | 46<br>36-59 | 47<br>38-56 | 45<br>35-60 | 41<br>34-59 |
| % survival to adult | 50 | 15 | 80 | 75 | 74 | 88 |
| Max. 5th wt. in mg. ♂ | 1.44<br>1.29-1.57 | 1.69<br>1.55-1.72 | 1.49<br>1.45-1.55 | 1.39<br>1.28-1.48 | 1.50<br>1.29-1.68 | 1.58<br>1.46-1.77 |
| Max. 5th wt. in mg. ♀ | 1.74<br>1.52-1.94 | 1.96<br>1.92-2.00 | 1.96<br>1.67-2.42 | 1.86<br>1.70-2.17 | 2.01<br>1.43-2.50 | 2.22<br>1.79-2.60 |
| Wt. new ♂ adult in mg. | 1.32<br>1.26-1.42 | 1.46<br>1.46 | 1.35<br>1.26-1.45 | 1.24<br>1.17-1.37 | 1.32<br>1.12-1.49 | 1.39<br>1.31-1.49 |
| Wt. new ♀ adult in mg. | 1.81<br>1.59-2.01 | 1.75<br>1.69-1.80 | 1.83<br>1.69-2.21 | 1.79<br>1.66-1.96 | 1.96<br>1.43-2.45 | 2.11<br>1.84-2.45 |
| Wt. ovipositing ♀ mg. | 1.92<br>1.72-2.14 | - | 2.23<br>1.56-2.99 | 1.86<br>1.86 | 2.42<br>1.63-3.00 | 2.52<br>2.30-3.09 |
| Preoviposition prd. days | 15<br>6-36 | - | 13<br>8-15 | 42+<br>26-57 | 11<br>6-18 | 15<br>10-27 |
| Oviposition prd. in days | 38<br>25-54 | - | 44<br>14-66 | 13<br>1-24 | 35<br>11-78 | 58<br>28-90 |
| Fecundity eggs/♀ | 68<br>56-77 | 0 | 118<br>28-238 | 15+<br>6-24 | 91<br>31-225 | 112<br>47-194 |
| Adult longevity days ♂ | 78<br>23-139 | 74<br>18-130 | 49<br>22-72 | 46<br>3-89 | 37<br>8-74 | 29<br>18-40 |
| Adult longevity days ♀ | 58<br>47-65 | 4<br>2-6 | 52<br>6-81 | 51<br>27-81 | 41<br>3-87 | 23*<br>3-39 |

\+ Only two oviposited

* Excluding females in fecundity check.

TABLE 42. Overall development and reproductive potential of *Drymus sylvaticus* on the different foods to show their value. Mean values are given with the range underneath.

| | Ripe nettle seed | *E.cinerea* seed | Shepherds purse seed | Sorrel seed | Sweet chestnut |
|---|---|---|---|---|---|
| Larval devt. in days ♂ | 43<br>43 | 32<br>28-35 | 45<br>41-51 | 32<br>30-33 | 46<br>41-50 |
| Larval devt. in days ♀ | - | 30<br>28-33 | 48<br>48 | 33<br>30-35 | - |
| % survival to adult | Insectary<br>(11) | 65 | 22 | 53 | 11 |
| Max. 5th wt. in mg. ♂ | 2.49<br>1.93-2.97 | 3.64<br>3.03-4.13 | Not taken | 2.55<br>2.41-2.69 | 2.47<br>2.40-2.54 |
| Max. 5th wt. in mg. ♀ | (3.72)<br>3.61-3.85<br>Insectary | 4.31<br>3.31-4.79 | Not taken | 2.92<br>2.36-3.31 | - |
| Wt. new ♂ adult in mg. | - | 3.37<br>2.69-3.77 | 1.60<br>1.56-1.64 | 2.34<br>2.21-2.47 | 2.39<br>2.13-2.64 |
| Wt. new ♀ adult in mg. | (3.65)<br>Insectary | 4.14<br>3.11-4.64 | 2.06<br>2.06 | 2.64<br>2.38-3.14 | - |
| Wt. ovipositing ♀ mg. | - | Not weighed | 2.29<br>2.29 | 3.35<br>3.29-3.40 | |
| Preoviposition prd. days | - | 170<br>170 | 119<br>119 | 64+<br>45-83 | - |
| Oviposition prd. in days | - | 32<br>31-33 | 27<br>27 | 32<br>31-32 | - |
| Fecundity eggs/♀ | - | 67<br>38-93 | 18<br>18 | 12+<br>8-15 | - |
| Adult longevity days ♂ | - | 160<br>57-248 | 107<br>36-160 | 68<br>4-132 | 66<br>4-121 |
| Adult longevity days ♀ | - | 157<br>79-213 | 173<br>173 | 80<br>7-154 | - |

\+ Only two oviposited

Rate of oviposition

The mean total number of eggs laid per female has been shown in Tables 38-42. The numbers of eggs laid per week by individual females reared on the different foods are shown in Tables 43-47. The egg production of most females increased during the oviposition period and then decreased, but this peak was slight and the production of eggs was almost at a uniform rate throughout. The presence of a male (indicated by a + in the tables) seemed to increase the rate of oviposition, and in Scolopostethus affinis to double it so that although the oviposition period was half that of some unmated females the total production was of the same order.

There were differences in the rate of oviposition between females on the same foods and there were often marked differences between foods. For Stygnocoris fuligineus which did well on several foods the differences in the rate of oviposition were not so noticeable. Fecundity is considered to be an important factor in assessing the value of a food for a particular species. As mentioned earlier, even when survival was poor the few insects that did become adult often had a growth curve approximating that on a good food, but in such cases fecundity was low.

Oviposition generally continued until death when one to six eggs may still be present in the abdomen. One Stygnocoris fuligineus female laid 10 eggs in nine days after which the ovipositor became blocked. She lived for a further 26 days by which time the abdomen was greatly distended and projected beyond the hind margin of the wings by a distance equal to the length of the pronotum. The body contained 18 eggs which filled the body cavity; the most anterior egg was found in the anterior

of the prothorax. All the eggs were fully formed - there was only one egg rudiment which was half developed. Ten of the eggs were dark, similar to the colour of eggs several days after oviposition. There was no gut visible and so death probably resulted from starvation. Egg production appeared to continue until death and was not curtailed when pressure built up in the abdomen.

Another case was observed in Scolopostethus affinis. A female laid 139 eggs over 47 days. Death occurred after a further 20 days and the abdomen contained 13 eggs some of which had collapsed. Similar occasional cases occur in O.fasciatus when egg production continues to the extreme (Johansson 1958).

TABLE 43. Rate of oviposition of individual Scolopostethus affinis females reared on different foods.
All females were reared from eggs on the foods except the three on green nettle seed which were taken as 4th and 5th instar larvae from the field. Whole weeks only are included.
A + means that a male was present.

| | | Number of eggs laid on the week number of the oviposition period indicated | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Food | ♀ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Green | 1+ | 42 | 70 | 56 | 63 | 43 | 64 | 51 | 45 | | | | | | | | | |
| nettle | 2 | 25 | 24 | 33 | 27 | 19 | 28 | 25 | 29 | 29 | 31 | 17 | 26 | 34 | 35 | 10 | | |
| seed | 3 | 27 | 26 | 27 | 21 | 18 | 20 | 17 | 16 | 21 | 21 | 22 | 23 | | | | | |
| Har- | 4 | 9 | 14 | 10 | 10 | 7 | 7 | 19 | | | | | | | | | | |
| vested | 5 | 4 | 4 | 2 | 3 | 2 | | | | | | | | | | | | |
| nettle | 6 | 3 | 9 | 3 | 3 | 3 | 8 | | | | | | | | | | | |
| seed | 7 | 17 | 31 | | | | | | | | | | | | | | | |
| | 8 | 12 | | | | | | | | | | | | | | | | |
| Erica | 9 | 20 | 16 | 24 | 26 | 23 | 22 | 14 | | | | | | | | | | |
| cinerea | 10 | 11 | 20 | 16 | 22 | 19 | 23 | 16 | 13 | 9 | | | | | | | | |
| seed | 11 | 18 | 17 | 13 | 33 | 37 | 21 | 40 | 16 | 10 | | | | | | | | |
| | 12 | 20 | 20 | 20 | 23 | 29 | 15 | 12 | | | | | | | | | | |
| Shep- | 13+ | 53 | 34 | 29 | 47 | 60 | 48 | 50 | 39 | 28 | | | | | | | | |
| herds | 14+ | 32 | 69 | 46 | 47 | 20 | | | | | | | | | | | | |
| purse | 15+ | 26 | 24 | 15 | 42 | 52 | 42 | 42 | 31 | | | | | | | | | |
| seed | 16 | 27 | 10 | 12 | 27 | 24 | 41 | 28 | 37 | 32 | 30 | 28 | 40 | 41 | 36 | 29 | 29 | 19 |

TABLE 44. Rate of oviposition of individual Scolopostethus thomsoni females reared on different foods.
The three on green nettle seed were taken as 4th and 5th instar larvae from the field. Whole weeks only are included.
A + means that a male was present.

| | | Number of eggs laid on the week number of the oviposition period indicated | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Food | ♀ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Green | 1+ | 51 | 42 | 64 | 68 | 37 | 51 | 56 | 59 | 35 | 23 | 33 |
| nettle | 2+ | 42 | 30 | 51 | 34 | | | | | | | |
| seed | 3+ | 35 | 48 | 53 | 65 | 43 | | | | | | |
| Erica | 4 | 25 | 22 | 22 | 18 | 16 | 15 | 16 | 14 | | | |
| cinerea | 5 | 17 | 15 | 13 | 13 | 9 | 9 | 9 | 16 | 16 | | |
| seed | 6 | 14 | 10 | 3 | 4 | 34 | 15 | 9 | | | | |
| | 7 | 3 | 1 | | | | | | | | | |
| Shep- | 8+ | 2 | 12 | 11 | 3 | 9 | 2 | 0 | 6 | | | |
| herds | 9+ | 6 | 3 | 4 | 2 | 0 | 1 | | | | | |
| purse | 10 | 2 | 1 | 1 | 0 | 3 | | | | | | |
| seed | 11 | 2 | 0 | 1 | 0 | 1 | | | | | | |
| | 12 | 5 | | | | | | | | | | |

TABLE 45. Rate of oviposition of individual Scolopostethus decoratus females reared on different foods. Whole weeks only are included. A + means that a male was present.

| Food | ♀ | Number of eggs laid on the week number of the oviposition period indicated | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Nettle seed | 1 | 8 | 3 | 3 | | | | | | | | | | |
| Erica cinerea seed | 2+ | 17 | 28 | 28 | 31 | 42 | 57 | 54 | 72 | 52 | 54 | 51 | 48 | |
| | 3+ | 34 | 34 | 45 | 18 | 38 | 33 | 65 | 44 | 74 | 45 | 44 | | |
| | 4+ | 30 | 26 | 35 | 35 | 34 | 39 | 61 | 65 | 66 | 45 | 59 | | |
| | 5 | 18 | 22 | 28 | 25 | 23 | 59 | 53 | 61 | 51 | 62 | 56 | 53 | 55 |
| | 6 | 28 | | | | | | | | | | | | |
| Shepherds purse seed | 7+ | 32 | 31 | 58 | 64 | 65 | 27 | | | | | | | |
| Sorrel seed | 8 | 14 | | | | | | | | | | | | |

TABLE 46. Rate of oviposition of individual Stygnocoris fuligineus females reared on different foods. Whole weeks only are included. A+ means that a male was present.

| Food | ♀ | Number of eggs laid on the week number of the oviposition period indicated | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Erica cinerea seed | 1 | 7 | 8 | 9 | 8 | 14 | 16 | 11 | 3 | | | | |
| | 2 | 13 | 17 | 13 | 11 | 7 | | | | | | | |
| | 3 | 7 | 17 | 14 | 15 | | | | | | | | |
| Sorrel seed | 4+ | 11 | 17 | 16 | 35 | 36 | 30 | 36 | 28 | 34 | | | |
| | 5+ | 11 | 6 | 22 | 11 | 28 | 27 | 32 | | | | | |
| | 6 | 16 | 17 | 15 | 11 | | | | | | | | |
| | 7 | 6 | | | | | | | | | | | |
| Sweet chestnut | 8 | 17 | 7 | | | | | | | | | | |
| Chickweed seed | 9 | 9 | 8 | 17 | 19 | 21 | 23 | 26 | 38 | 31 | 25 | | |
| | 10+ | 13 | 20 | | | | | | | | | | |
| | 11+ | 7 | 8 | 19 | | | | | | | | | |
| | 12+ | 7 | 23 | | | | | | | | | | |
| Spurrey seed | 13 | 3 | 18 | 13 | 16 | 13 | 13 | 16 | 23 | 19 | 23 | 17 | 20 |
| | 14 | 3 | 10 | 10 | 13 | 15 | 15 | 16 | 19 | 15 | | | |
| | 15 | 9 | 14 | 7 | 8 | 10 | 7 | 10 | | | | | |
| | 16 | 7 | 11 | 10 | 13 | 4 | | | | | | | |

TABLE 47. Rate of oviposition of individual *Drymus sylvaticus* females reared on different foods. An exoeption is the four on nettle seed, as they were taken as adults during winter. Whole weeks only are included. A + means that a male was present.

| Food | ♀ | Number of eggs laid on the week number of the oviposition period indicated | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Green nettle seed | 1+ | 36 | 24 | 22 | 24 | 18 | 19 | 16 | 12 |
| | 2+ | 38 | 43 | 64 | 63 | 38 | 29 | | |
| | 3+ | 12 | 21 | 35 | 44 | 40 | | | |
| | 4+ | 34 | 53 | 66 | 53 | | | | |
| *Erica cinerea* seed | 5 | 20 | 25 | 26 | 22 | | | | |
| | 6 | 14 | 15 | 18 | 19 | | | | |
| | 7 | 10 | 9 | 13 | 6 | | | | |
| Shepherds purse seed | 8+ | 8 | 0 | 4 | 3 | 3 | 0 | 0 | |
| Sorrel seed | 9 | 2 | 1 | 1 | 4 | | | | |
| | 10 | 3 | 3 | 7 | | | | | |

# DISCUSSION

## Food Preferences

### Value and preference ranking of seeds

Seeds are the prime item of food in the diet of all five species, which could be reared through the complete life-cycle on seeds alone.

Earlier workers found that O.fasciatus developed on substitute foods (although survival and viability were reduced) but in all cases the seed coat was cracked or removed (Lea and Niswander 1950, Frings and Peissner 1952, Frings et al. 1957). Sweet (1960) in feeding trials with Rhyparochromines on sunflower seeds also hulled the seeds"to provide easier feeding". It is possible that their results do not represent the true response of the species to the food if it had been provided as found in nature.

In the present study the seed coats were not cracked or removed except in the case of sweet chestnuts, and so the results are applicable to the insect-host relationships in the field.

However, the species of seed is important as there were preferences. The word preference is not used in the sense of choice for there was no choice for individual insects, but means that they "do better" on certain seeds and this represents a preference by the species.

These preferences differed with the species so that some species did well on seeds that were unsuitable for others. For example, spurrey seed is an adequate food for Stygnocoris fuligineus but not for the Scolopostethus species, whereas with shepherds purse seed the position is reversed. Exactly the same situation was demonstrated with chickweed seed and nettle seed.

The relationship between species on any two seeds was not always as simple as this for there were gradations of suitability of a food, ranging from very good to entirely unsuitable. An example would be when D.sylvaticus is substituted for one species in either of the above examples. For one seed (spurrey, chickweed) did not permit any development and the other was a poor food.

Another relationship is where two kinds of seeds are good food for one species whereas only one of them is suitable for another. For example E.cinerea seeds and sorrel seeds are suitable for D.sylvaticus, but sorrel seeds are not suitable for the Scolopostethus species. Stygnocoris fuligineus could be substituted for D.sylvaticus in this example.

There were differences between species in the order of seed preference and the degree of suitability. This was so even within the Scolopostethus species, thomsoni differing markedly from the other two in being far less adaptable. However, most of the seeds were suitable for Stygnocoris fuligineus, and it is noteworthy that the seeds of E.cinerea were suitable for all five species.

Host plant selection

The discussion thus far shows that the differences in preferences are due to the insects rather than the seeds. Insects have exacting or complex feeding stimuli requirements. Before an insect will feed the food must provide the feeding stimuli that induce a feeding response which is not inhibited by any other properties or constituents of the food (Thorsteinson 1960). Some important factors involved in food selection are the physical and chemical nature of the seed coat, the constituents of the seed, and the nutritional requirements of the insects. These will

be discussed in detail.

Seed coat: The roughness or smoothness, the presence and size of hairs or spines or their absence, and the thickness and toughness of the seed coat may have some influence. If the physical nature of the seed coat of the seeds used in this study were known it would be interesting to determine if there is any gradation in likeness amongst those suitable, poor and unsuitable for food for any one species. As Stygnocoris fuligineus developed on a variety of seeds it may be that the physical nature of the seed coat alone is not important. This is supported by recent work showing that where insect resistance in plants has been attributed to the nature of the exterior, sensory and nutritional factors are also involved (Thorsteinson 1960).

The chemical nature of the seed coat may play an important role in providing a chemotactic feeding stimulus. Beck et al. (1958) showed that a milkweed seed husk wrapped round a purified diet stimulated the normal pattern of feeding in O.fasciatus and growth was good, whereas on the purified diet alone growth was poor because the duration of feeding was greatly reduced.

Seed constituents and insect nutritional requirements: Seeds differ in their constituents, and insects differ in their nutritional requirements. This may account of the adequacy or inadequacy or partial inadequacy of the seeds as foods, or the restriction to certain seeds may be because the insects are equipped with enzymes capable of digesting some foods but not others.

Because there is such variation in the degree of suitability of different seeds, and because E.cinerea seeds were acceptable to all species and Stygnocoris fuligineus had such a wide range of foods, it seems

unlikely that the actual nutritional values of the different seeds can be the basic reason for the varying preferences of the bugs.

The basis of the selection could, however, be gustatory. Recent work reported by Thorsteinson (1960) has shown that insects possess a gustatory sense of unsuspected dimensions. This coupled with very sensitive chemotactic perception would enable precise selection between seeds having the same constituents but in different concentrations. Stygnocoris fuligineus would therefore be regarded as adaptable to a wider range of concentrations than the other species.

This factor may be of higher significance when valuing a seed for a species that feeds on the endosperm and a species that feeds on the embryo, as the embryo would contain concentrations of growth hormones. These would vary with the kind of seed.

On the other hand, Fraenkel (1959) has suggested that secondary plant substances such as essential oils, glycosides and alkaloids may play an important part in host plant selection by insects, although they are of no nutritional value. Certainly the seeds of some Cruciferae contain mustard oil, one of the substances known to affect feeding responses in some insects (Fraenkel 1959) and it is possible that these substances may act as releasers or inhibitors of the feeding response.

The evolution of such precise restriction to certain seeds would probably involve linking feeding behaviour to all the seed's attributes - nature of seed coat, exact chemical constituents, taste, odour - which now stimulate the optimum feeding response. Other seeds differing in only one character may then be rejected because they no longer stimulate a threshold feeding response. Stygnocoris fuligineus retains the ability to feed on

several kinds of seeds. D.sylvaticus appears to occupy an intermediate position where it retains two of the range of seeds of Stygnocoris fuligineus, and one of them is generally unsuitable for the Scolopostethus species. Yet Scolopostethus affinis did well on three, and decoratus did well on two, different kinds of seeds.

Thus for each species the seeds of at least two plants were suitable, and these plants belonged to different families. This might at first suggest non-restriction of host plants, but in fact there is restriction so therefore one may conclude that either the seeds of the particular plants concerned (although belonging to different families) have similar contents or contain the same secondary plant substance. The overlapping and contrast of acceptable foods among the species may refute this but it may hold for Scolopostethus as the Crucifer seed and seed of Urticaceae suitable for affinis were not suitable for Stygnocoris fuligineus.

Foods other than seeds

Whether or not Rhyparochromines consume foods other than seeds is unknown but if they do the foods cannot be important for survival. The vegetative parts of plants do not support growth but may be a source of moisture. Animal food cannot be important in the diet as it alone did not support life. No attempt was made by the bugs to catch live Collembola which in any case seemed too active for them.

For D.sylvaticus animal food at first appeared to have some value as there was fairly good growth on beetle larvae. This species did well on the seeds of E.cinerea and sorrel alone, so animal food does not appear to be essential to the diet. However, survival on seeds was not

as good as in the other species and the surprisingly poor results on nettle seed (although the insects were caught in that habitat) suggest that some animal food may play a role with certain seed diets.

## Criteria Used to Assess Food Preferences

### The Criteria

The criteria of a suitable food are that it should support good growth and survival from egg to ovipositing adult and maintain high fecundity (after a short preoviposition period) and reasonable adult longevity. The stage in which mortality occurs, the growth rate index, the maximum weight attained in the fifth larval instar, and new and mature adult weights are also taken into account.

For some time now workers have realized that a suitable food for an insect must support larval development and normal oviposition (Johnson 1937, Hodek 1958, Geering and Coaker 1960) and other factors are used as supporting evidence.

There was always an abundant supply of food to ensure that each food had a fair test for Lea and Niswander (1950) found when using milkweed seeds sparingly "If sufficient food is not available there is a decrease in egg production, lack of vigour in the individuals and smaller size of the adults".

Important aspects of some of the criteria are discussed below.

### Increase in weight

Although approximately two-thirds of the total weight is added in the last two larval instars (as also shown by Anderson 1961 for Anthocorids) the percentage daily weight increase was highest in the second larval instar and was progressively less in later instars. It was also much less

in the adult female but this is expected because there is only ovary development and no body growth; in the adult male it was virtually zero. Thus the percentage daily weight increase seems to vary inversely with age (in instars). Adults reared on a poor food were often smaller than normal.

Beck et al. (1958) showed that the larvae of O.fasciatus feed almost continuously. Johansson (1958) by obtaining much reduced fecundity with varying degrees of intermittent feeding showed that the reproducing female also requires constant feeding. These facts are also true for Rhyparochromines.

Rate of mortality

On seeds shown to be a poor food development proceeded until the fourth and fifth larval instars in which there was high mortality, and only a small percentage attained adulthood.

Preoviposition period

D.sylvaticus has an obligatory reproductive diapause normally broken by a short cold period during winter. However, young females kept at 23.3°C. did complete their development after a long time. Egg production was then apparently normal. This is rather an unusual phenomenon, especially when it would normally be considered doubtful if an insect could survive the high metabolic rate of living at that temperature for the long period required to complete diapause development. The ability to do this is of no advantage to the insect in this climate but it might be in the Mediterranean part of its distribution.

Rate of oviposition

The rate of oviposition on a good food was found to be of the order of 20, 40, sometimes as many as 50 eggs per week regularly. This contrasts

with the results of Thomas (1955) and emphasises the effect of inferior foods and rearing conditions; but it bears out a statement by Johansson (1958) that the egg production of the Lygaeidae when better known is likely to be much higher than is thought at present. Johansson also found that a diet of almonds or hazel nuts greatly reduced the fecundity and lengthened the preoviposition period of adult O.fasciatus even though they had been reared on milkweed seeds as larvae.

## Suggestions for Future Work

To follow a modification of the line of Beck et al. (1958) by dehusking a poor seed food and enclosing it in the coat of a good seed food would not provide additional information on the natural food preferences studied here, as such disguising does not occur in nature.

However, in order to understand more fully the real basis of the preferences and the influence of the seed coat, such experiments would be valuable. Further, another important step in determining the effect of the seed coat on feeding would be to compare the development and the duration of the feeding cycle of an insect on a good seed food with these responses on the same seed minus the seed coat. This has not even been done with O.fasciatus and the milkweed seed.

## (C) DESCRIPTIONS OF IMMATURE STAGES

As some features of the eggs and larvae of the five species are similar these will be discussed before the individual descriptions given.

### Eggs

The eggs are of the aphanoid type (Putshkova 1956) which he describes as elongate-cylindrical in form with the posterior and especially the anterior ends broadly rounded and the ventral surface flat or concave. There are three to seven papilliform micropylar processes which curve slightly outwards as described by Southwood (1956) in Scolopostethus decoratus and D. sylvaticus.

In some species at least a portion of the chorion is covered with small processes of varying shape - e.g. truncate in Scolopostethus decoratus (Southwood 1956) - but not within the crown of micropyles. The egg of Scolopostethus grandis has papilliform or hemi-spherical projections over the whole of the chorion. The egg of D. brunneus has a sparse covering of slender processes (Putshkova 1956) and is reported to be smaller than that of D. sylvaticus (Thomas 1955). Five eggs of D. brunneus were measured (1.06-1.11 mm. x 0.44-0.47 mm.) and found to be larger than those of D. sylvaticus.

When first laid the eggs are pale yellow or orange, darkening to a straw yellow or orange colour (see also Thomas 1955). Where the egg of a species has been described previously additional notes are made here in some cases.

## Larvae

Measurements were taken on ten specimens in each instar (ten of each sex in the fifth instar) except in the case of D. sylvaticus of which five specimens were measured in the fourth instar and four of each sex in the fifth instar.

### Antennae

On specimens of Scolopostethus reared in the laboratory the colour of the antennae in the fifth, and to a partial extent in the fourth, larval instars was similar to that of the adult of the species. This was not consistent in field specimens many of which, irrespective of species had the antennal colour as for decoratus. Thus the colour of the antennae, which is a diagnostic character in the adults, can not be used to distinguish the larvae.

### Trichobothria

The numbers and points of origin of the abdominal trichobothria for these genera and other Rhyparochromines have been shown by Scudder (1957). They arise from dark plaques on the ventral surface and five are conspicuous when the insect is viewed from the dorsal surface (Figs. 10, 11 and 12). Although in this aspect the anterior one appears to be coming from abdominal segment IV this is due to the curved boundary between sternites IV and V and it really arises from segment V. Where there are a pair of trichobothria only the more lateral one is evident in dorsal view - hence only five are visible per side in this aspect. They are longest in proportion to the body in the first larval instar.

Y-suture

Putshkov (1958) first described this as the "troughed suture", whilst Slater and Sweet (1961) called it the "Y-suture" which is unique to, and widely distributed amongst, the Rhyparochrominae. This is a very conspicuous and emphasised suture between abdominal tergites III and IV, turning anterad along the lateral margins of tergites III and II with a branch across the posterior of the third pleurite (Figs. 10, 11 and 12). The suture is a wide V-shaped groove with a characteristic hard lining usually of the same general colour as the abdomen. A light coloured strip on each side of the suture emphasises it still more. It is first evident in the second larval instar.

The posterior of the second pleurite often has a light coloured strip on each side and also appears to be double, but does not have the special lining of the Y-suture. Thus the lining is the best indication of the extent of this suture, for in some species e.g. Stygnocoris fuligineus a double, dark suture appears to continue across the anterior of tergite II, and sometimes the lateral arms to continue to the anterior of the abdomen.

Furthermore, the boundaries between sternites II and III, and III and IV stand out very clearly as if two branches of the Y-suture continued right round the venter but neither the lining of the Y-suture nor the light coloured margins are present.

Larval colour changes from instar to instar

According to their basic body colour Lygaeid larvae can be divided into two groups (Putshkov 1958):

(1) those having a pale (grey, yellowish, pinkish, brownish or

rufous) uniform colouration of the whole body, though often with some degree of dark figuring on the head and thorax, and (2) those having a sharply differentiated dark head and thorax (brown, black) and a light (grey, brownish, pink, red) abdomen. The second group is restricted to the majority of the Rhyparochrominae.

The three genera here represented undergo three of the four kinds of colour changes (described by Putshkov 1958) that occur during development in the second group: 1) e.g. Stygnocoris fuligineus - the colours of head and thorax (black) and abdomen (red) remain practically unchanged; 3) e.g. Scolopostethus - pale areas on the head and/or thorax become increasingly conspicuous from stage to stage, while the abdomen changes from a uniform red to a greyish colour with an intricate pattern of pink, crimson, brown or velvety brown stripes and spots; 4) e.g. Drymus sylvaticus - the whole body becomes paler, the head and thorax lose their black or fuscous colour and become brownish, while the abdomen changes from red, first to a dirty pink, and then to an almost uniform greyish colour.

In Scolopostethus the first abdominal tergite and part of the metanotum is always pale, like a yellow band across the body. The first instar larva of thomsoni appeared to be exceptional in having the first abdominal segment concolourous with the rest of the abdomen - although it sometimes went paler when the abdomen stretched after feeding. In Stygnocoris fuligineus and D. sylvaticus the first abdominal segment and most of the metanotum were concolourous with

the rest of the abdomen.

Changes in pilosity

As noted by Putshkov (1958) for Rhyparochromine larvae the nature of the pubescence may vary from instar to instar. Stygnocoris fuligineus larvae have a dense covering of pubescence throughout, but in Scolopostethus the pubescence becomes progressively more sparse in later instars. This is carried further in D. sylvaticus, the fifth instar larva of which is almost devoid of pubescence and contrasts with the conspicuously hairy first instar larva.

Spines on forefemora

The thickened forefemora which are characteristic of the adults are evident in the larvae as also are the spines in some genera. In Scolopostethus the three species have one small spine in the first and second larval instars, and decoratus also in the third instar. S. affinis and thomsoni in the third instar have, in addition, one to three small tubercles on the distal side of the spine. All in the fourth instar have one main spine with up to six small ones distally and occasionally two proximally. In the fifth instar there are usually up to seven smaller spines on the distal side of the large spine and up to three proximally. The spines are arranged in two rows on the inner surface of the forefemora. In Stygnocoris fuligineus there is no evidence of spines until the fifth larval instar, whilst in D. sylvaticus they appear in the third larval instar.

Sexing in the fifth larval instar

The larvae can be sexed accurately in the fifth larval instar.

The females have a modification around the boundary between sternites VIII and IX distinguishing them from the males which are unmodified except that sternite IX is slightly bulged (Figs. 10 and 11). The females have large darkened areas on sternites VII and VIII in the midportion, whereas the males have only a small darkened area on sternite VIII with no or very little darkening on sternite VII, but sternite IX is usually dark.

This has only been shown in two other Lygaeidae, in O.fasciatus (Johansson 1958) and Nysius huttoni White (Eyles 1960) but probably all members of the family can thus be sexed in the fifth larval instar.

Recognition of species

Scolopostethus larvae could not be distinguished in the field and the general body measurements were similar. This led to the measurement of many morphological characters in the hope that some practical distinction could be made between species, but these were all similar for affinis, thomsoni and decoratus (Tables 48, 49 and 50).

However, when the data from ten measurements on fifth instar larvae were analysed for each sex on a modification of Wilks' criterion (Rao 1952), which enables one to assess the similarity of two or more samples in respect of large numbers of characters, the three species were shown to have a different shape which confirms that they are distinct species. This analysis is shown in Appendix I.

Nevertheless, in practice, the larvae of these three species (plus S.grandis) cannot be distinguished and the descriptions, rather than showing any distinguishing characters, emphasise their similarity.

This is why only thomsoni is figured, and is one of the reasons that prompted the hybridization studies discussed in the next section.

The larvae of the different Stygnocoris species can be readily distinguished. With the Drymus species the situation may be complex as in Scolopostethus, at least with D. sylvaticus and D. brunneus.

Scolopostethus affinis

Egg (Thomas 1955): size in mm. (70 eggs): 0.90 (0.81-0.97) x 0.37 (0.34-0.39).

First larval instar: size in mm.: length 1.07 (0.99-1.21); width 0.42 (0.38-0.46); head width 0.31 (0.31-0.32). Head, pro- and mesonota brown or blackish-brown; metanotum yellow with two brown, triangular areas; antennae brown, apical half of fourth segment pale; rostrum grey, extending to hind coxae; legs grey, one small spine on forefemur. Abdomen bright orange - near Marigold orange on the Horticultural Colour Chart (Wilson 1938, 1941); first visible abdominal segment (i.e. segment I) yellow as metanotum; scent gland evaporating areas bounded in white; body covered with fine white pubescence.

Second larval instar: size in mm.: length 1.26 (1.10-1.42); width 0.60 (0.54-0.72); head width 0.39 (0.35-0.40). Colour as in first instar but the abdomen is a darker orange (near Spanish orange on H.C.C.); Y-suture present, bordered with pale coloured strips; abdominal segments II and III within the Y-suture darker - greyish or brownish-orange; scent gland evaporating areas dark, not bounded in white.

Third larval instar: size (see Table 48). Colour of head and thorax as in first instar - dark brown or black; antennae grey or black, distal half of fourth segment pale; pronotum usually pale, yellow, in posterior lateral corners; mesonotum sinuate on posterior margin; mesonotal wing pads now evident; now some smaller spines in addition to large spine on forefemora. First abdominal segment pale; remainder of abdomen darker orange than in the second instar - this is no longer a pure colour but consists of blotches of different intensities; Y-suture as in previous instar; anterior of each pleuron pale, whitish; a brighter orange strip from second scent gland opening to tergite VIII; tergite VIII pale.

Fourth larval instar: size (see Table 49). As in the previous instar but metathoracic wing pads now evident, and mesothoric wing pads usually with some pale blotches; wing pads extend on to abdominal segment I; posterior quarter of pronotum usually mostly pale. Abdomen more greyish than in the third instar, with an overall red-brown colour; tergites II and III within the Y-suture darkest, with the colour becoming progressively lighter towards the posterior.

Fifth larval instar: size (see Table 50). Head black; antennae, first segment black in basal half and pale in apical half, second segment pale throughout (orange or yellow), third segment dark brown or black throughout, fourth segment pale in apical portion. In some specimens the antennae were black throughout, except for the pale apex of the fourth segment. Rostrum dark, third and basal

half of fourth segment pale. Thorax : pronotum black in anterior two-thirds, pale (yellow) in posterior one-third but with two triangular-shaped black portions towards the midline; mesonotum with rudimentary scutellum evident and mostly black, remainder including wing pads pale with grey-black markings roughly in a figure of 8; wing pads extend onto the third abdominal segment; forefemora dark brown or black; mid femora pale but sometimes dark towards apex; hind femora black in mid portion; tibiae darker in basal half, and tarsi pale. The abdomen has lost the basically orange colour of the fourth instar and varies from red-brown to deep red-brown to grey; otherwise as in earlier instars except that tergites V and VI usually have two pale bars across the segment, one each side of the midline (sometimes not as evident on tergite V); pubescence fine, white and sparse.

Scolopostethus thomsoni

Egg (Fig. 10): size in mm. (10 eggs): 0.95 (0.92-1.07) x 0.36 (0.34-0.38). Three to six micropylar processes; chorion smooth.

First larval instar (Fig. 10): size in mm.: length 1.03 (0.93-1.17); width 0.43 (0.30-0.51); head width 0.30 (0.23-0.32). Colour as in affinis except that the abdomen is a reddish-orange (near Nasturtium red on the H.C.C.) approaching the red of Stygnocoris fuligineus, and that the first segment is not pale. The scent gland evaporating areas are black.

Second larval instar: size in mm.: length 1.45 (1.17-1.92); width 0.64 (0.56-0.74); head width 0.38 (0.35-0.40). Colour of head and thorax as in affinis. abdomen now with first segment

yellow, and the remainder darker orange than in the first instar (near Saturn red on H.C.C.); Y-suture present; tergites II and III within the Y-suture darker.

Third larval instar (Fig. 10): size (see Table 48). As for affinis. Sometimes the pronotum has a yellow spot at the posterior on the midline.

Fourth larval instar: size (see Table 49). As in the previous instar but with the slight changes as noted for affinis. Femora and tibiae greyish-black, tarsi pale; abdominal tergite VI sometimes with a pale area on the left and right portions.

Fifth larval instar (Fig. 10): size (see Table 50). As for affinis except the second antennal segment is dark in the apical half; some specimens have the antennae black throughout except for the pale apex of the fourth segment.

Scolopostethus decoratus

Egg (Southwood 1956, Thomas 1955): size in mm. (70 eggs): 0.84 (0.74-0.87) x 0.34 (0.31-0.39). Three to five micropylar processes; small, truncate processes over the remainder of the chorion outside the crown.

First larval instar: size in mm.: length 0.98 (0.93-1.06); width 0.39 (0.32-0.44); head width 0.30 (0.28-0.31). Colour as in affinis; antennae grey, distal half of fourth segment pale; orange colour of abdomen somewhat blotchy or irregularly distributed; scent gland evaporating areas dark, bounded in white; posterior tip of abdomen black.

Second larval instar: size in mm.: length 1.40 (1.14-1.56); width 0.59 (0.52-0.71); head width 0.36 (0.34-0.38). Colour of head and thorax as in affinis; colour of abdomen Orange (on H.C.C.) - darker than in the first instar because of overshadowing with grey, and speckled with yellowish blobs; Y-suture present; tergites II and III within the Y-suture darker; scent gland evaporating areas black; region on midline between anterior and posterior scent gland openings reddish.

Third larval instar: size (see Table 48). As for affinis, but forefemora still with a single spine.

Fourth larval instar: size (see Table 49). As in affinis except that the abdomen is a lighter orange colour. Legs dark brown or grey - black, forefemora darkest.

Fifth larval instar: size (see Table 50). Differs a little from the previous two species in the following ways: antennae black throughout except for the extreme apex of the first and fourth segments and the base of the second segment; pronotum usually with a yellow spot on midline at anterior, and sometimes with varying amounts of black and yellow in posterior portion; scutellum, perhaps the most distinct in the three species is deep maroon or purple in colour; femora and tibiae dark, tarsi pale. Abdomen deep red (near Chrysanthemum crimson on H.C.C.) and more uniformly coloured, although a few specimens were lighter, nearer the dirty orange-grey of the previous species. Other aspects of the abdomen, such as markings, as in affinis.

Stygnocoris fuligineus

Egg (Fig. 11): size in mm. (50 eggs): 0.79 (0.74-0.87) x 0.34 (0.32-0.40). Three to five micropylar processes, although three were rare; most of chorion smooth but there is a region of tiny projections around the crown of micropyles.

First larval instar (Fig. 11): size in mm.: length 0.78 (0.72-0.86); width 0.38 (0.36-0.40); head width 0.32 (0.31-0.32); antennal segments I-IV .0094, .012, .0094, .24. Head, pro and mesonota black or dark brown; metanotum red with two dark triangular areas; antennae light brown, apical half of fourth segment pale - pink or orange; rostrum light brown extending to hind coxae; legs light brown, forefemora unarmed; abdomen bright red (near Mandarin red on H.C.C.); scent gland evaporating areas and posterior tip of abdomen dark; body covered with dense, fine, white pubescence.

Second larval instar: size in mm.: length 1.19 (0.94-1.38); width 0.59 (0.50-0.67); head width 0.40 (0.39-0.40); antennal segments I-IV 0.011, 0.16, 0.13, 0.27. Colour as in first instar but sometimes the thorax is a reddish-brown colour; abdomen a bright reddish-orange (Fire red on H.C.C.); T-suture now present, with slightly lighter red strip on each side.

Third larval instar (Fig. 11): size (see Table 48). As in second instar except that mesonotal wing pads now evident and the darkened portions on the metanotum are semi-elliptical; remainder of metanotum and abdomen bright red (Scarlet on H.C.C.).

Fourth larval instar: size (see Table 49). As in third instar (with abdomen possibly a slightly deeper red) except that metanotal wing pads now evident and metanotum dark throughout; wing pads extend onto abdominal segment I; punctation evident on head and thorax.

Fifth larval instar (Fig. 11): size (see Table 50). As in fourth instar except that the wing pads extend onto or to the posterior of abdominal tergite III; scutellum evident; antennae black, apical half of fourth segment pale; legs blackish-brown, pale at joints; 4-7 small tubercles usually present on forefemora for first time, but sometimes absent; abdomen darker red (near Jasper red on H.C.C.). Sometimes in any instar after the first the thorax or the wing pads only may be reddish-brown.

Drymus sylvaticus

Egg (Fig. 12), also Thomas (1955), Putshkova (1956) and Southwood (1956): size in mm. (70 eggs): 0.92 (0.81-1.03) x 0.39 (0.36-0.44). Three to five micropylar processes; chorion covered with hemispherical projections.

First larval instar (Fig. 12): size in mm.: length 1.05 (0.89-1.17); width 0.42 (0.36-0.47); head width 0.32 (0.27-0.36). Body surface shiny and covered in a long bristly pubescence; head, pro and mesonota dark brown; metanotum red as abdomen with two brown triangular areas; antennae brown, fourth segment red; rostrum grey, reaching a little beyond hind coxae; legs grey, no spines on forefemora; abdomen reddish orange (near Fire red on H.C.C.) throughout including segment I; scent gland evaporating

areas black, ringed in white; posterior tip of abdomen black; in unfed specimens the posterior of the abdomen is straight, not rounded; trichobothria and pubescence on edge of posterior half of abdomen cause this region to be distinctly hairy.

Second larval instar: size in mm.: length 1.32 (1.10-1.50); width 0.59 (0.40-0.66); head width 0.40 (0.36-0.42); antennal segments I-IV 0.13, 0.21, 0.18, 0.33. Varies from the first instar in that the thorax is a lighter brown than the head, the Y-suture is now apparent, the hairiness of the abdomen is less obvious, and the abdomen is distinctly "warted" at the points from which the lateral trichobothria arise. The pleuron of the thorax is pinkish and the abdomen is lighter in colour - a sort of yellowish-orange background colour with deeper, irregularly placed orange blotches. Usually no spines or tubercles on forefemora but occasionally two to three small tubercles with hairs are present.

Third larval instar (Fig. 12): size (see Table 48). As in second instar except that the mesonotum is now a lighter brown than the pronotum and has evidence of wing pads, and the two brown markings on the metanotum are now semi-elliptical in shape. Legs light brown, forefemora occasionally bearing one or two small, tubercle like spines with hairs. Abdomen brownish-orange in colour.

Fourth larval instar: size (see Table 49): As in third instar except that metanotal wing pads now evident and extend half the length of abdominal tergite I, and the abdomen is lighter, a dirty pinkish-orange to light fawn colour; antennae brown, third segment dark brown or black, fourth segment pale at apex but with

a red tinge across the centre; rostrum extending to the mid or hind coxae; forefemora bearing one to three small spines.

Fifth larval instar (Fig. 12): size (see Table 50). Head black; antennae, first segment dark brown in basal half, light fawn in apical half; second segment light fawn with dark band at apex (or dark with fawn only at base); third segment black throughout; fourth segment black or dark brown at base, light brown in apical half; rostrum extending to mid or hind coxae, first and fourth segments dark, second and third segments pale; prothorax light brown (the lightest of head and thorax); mesothorax light brown on rudimentary scutellum, dark brown to black on wing pads; metanotum now dark brown throughout; wing pads extend well onto abdominal tergite III, sometimes to tergite IV; legs pale, fawn-yellowish throughout; forefemora with one and sometimes two or three other smaller spines; abdomen dark reddish-brown, but more grey on tergites II and III within the Y-suture; Y-suture narrower than in the preceding species and light coloured margin not always as evident; scent gland evaporating areas and posterior tip of abdomen black; tergite VIII paler than rest of abdomen; very sparse, fine short pubescence.

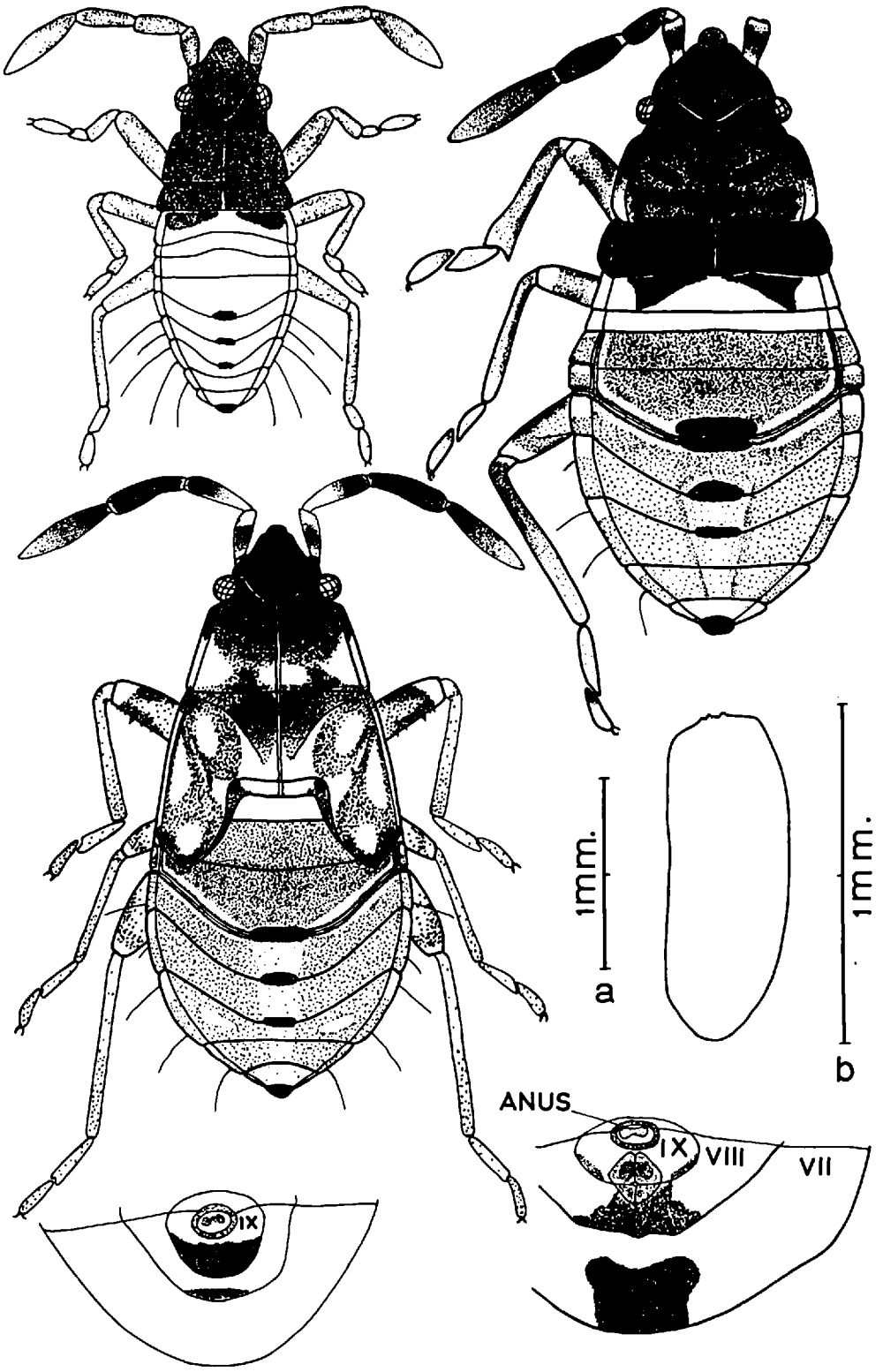



Figure 10. Egg, and first, third and fifth larval instars of Scelopestethus thomsoni. Bottom right: terminal abdominal sternites of female fifth instar larva; bottom left: terminal abdominal sternites of male fifth instar larva. a = scale for full drawing of fifth instar larva; b = scale for the other five drawings.

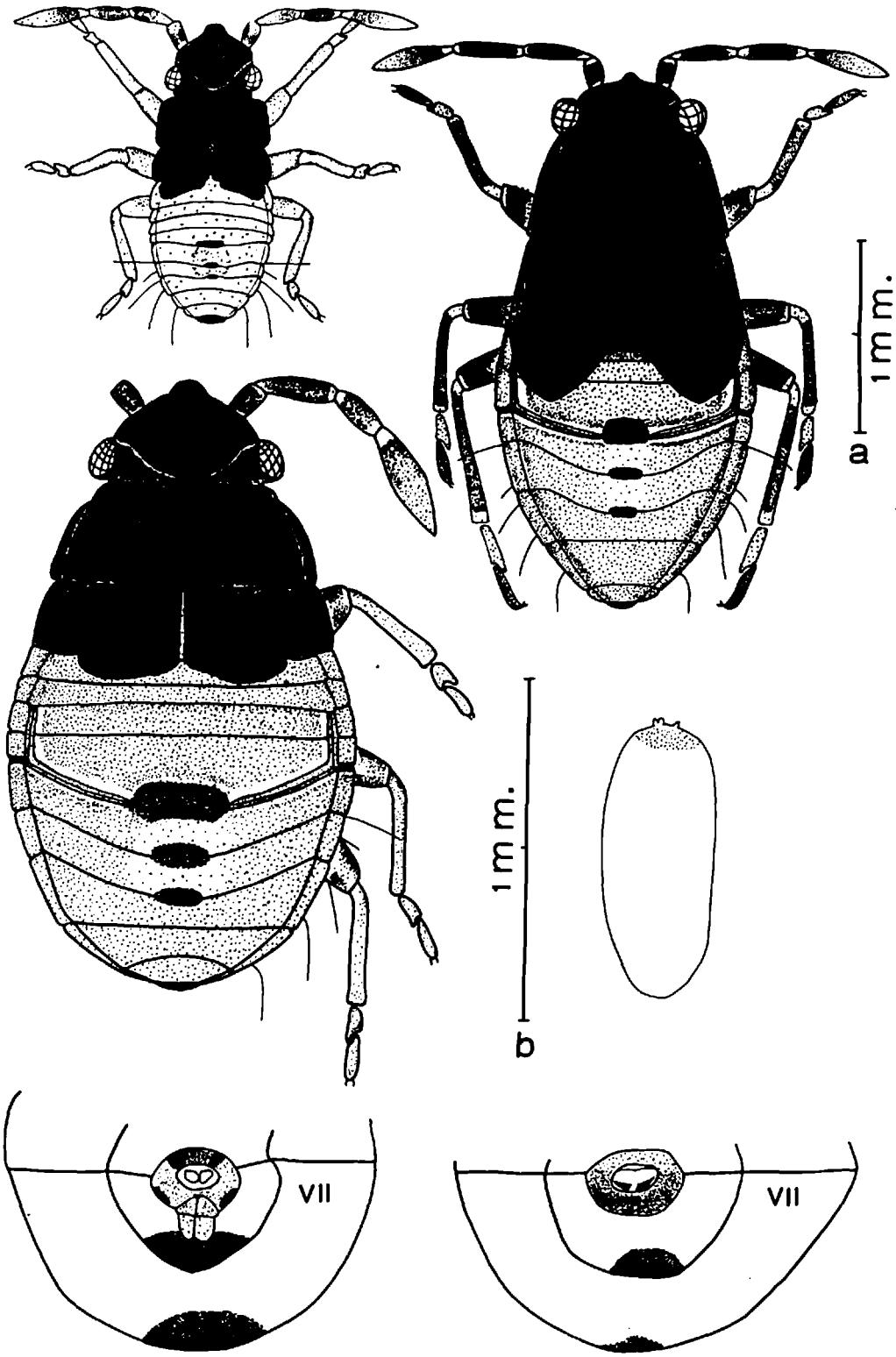



Figure 11. Egg, and first, third and fifth larval instars of Stygnocoris fuligineus. Bottom left: terminal abdominal sternites of female fifth instar larva; bottom right: terminal abdominal sternites of male fifth instar larva.
a = scale for full drawing of fifth instar larva;
b = scale for the other five drawings.

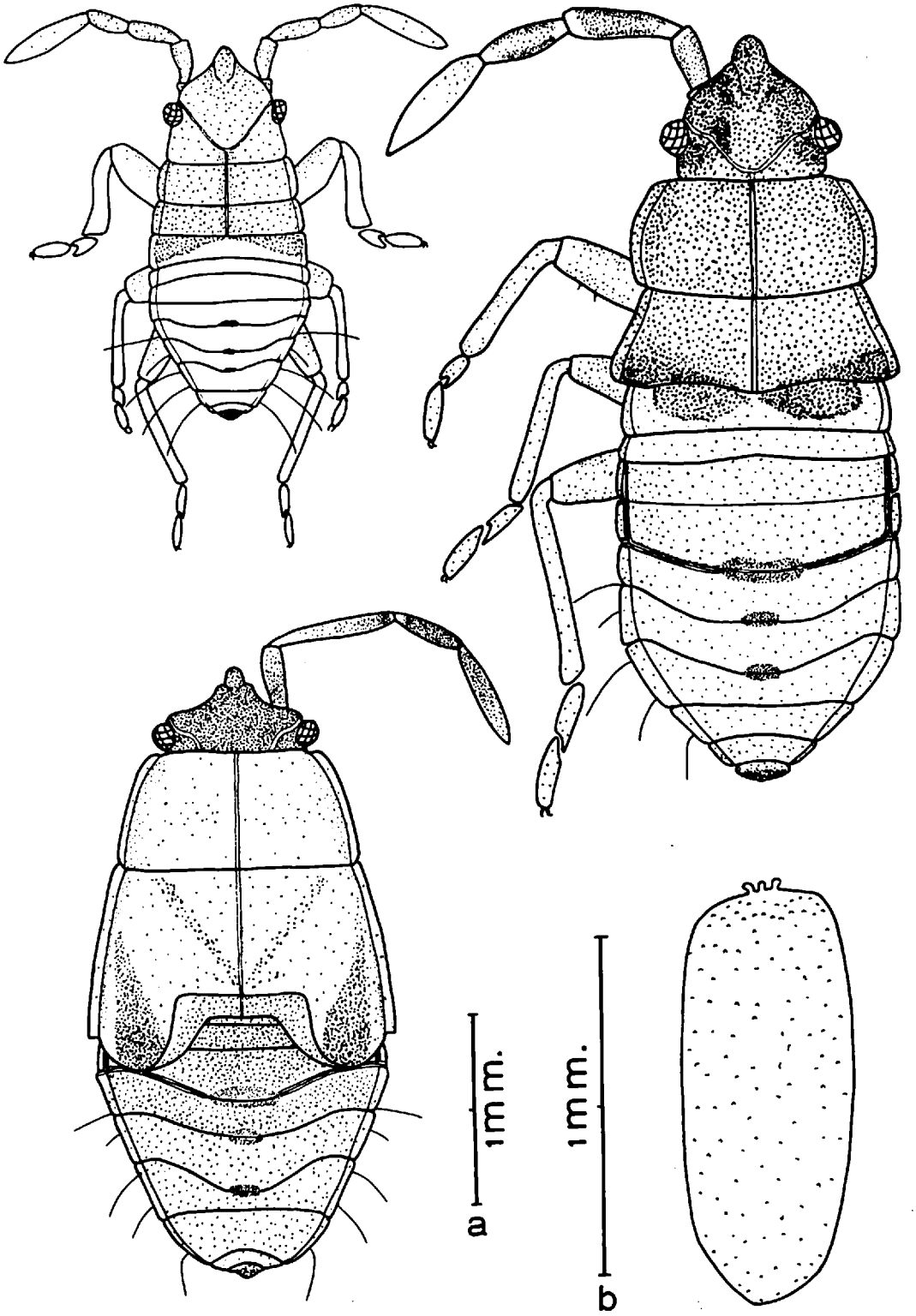



Figure 12. Egg, and first, third, and fifth larval instars of Drymus sylvaticus. a = scale for full drawing of fifth instar larva; b = scale for the other drawings.

TABLE 48. Body measurements in mm. of third instar larvae.

| | Body width | Body length | Head width | Antennal segments 1 | 2 | 3 | 4 | Pronotum width anterior | Pronotum width posterior | Pronotum length |
|---|---|---|---|---|---|---|---|---|---|---|
| Scolopostethus affinis | | | | | | | | | | |
| Mean | 0.78 | 1.77 | 0.48 | 0.19 | 0.28 | 0.31 | 0.43 | 0.47 | 0.60 | 0.31 |
| Range | 0.72-0.91 | 1.58-2.01 | 0.44-0.52 | 0.17-0.21 | 0.27-0.30 | 0.28-0.34 | 0.40-0.44 | 0.42-0.54 | 0.55-0.64 | 0.28-0.34 |
| Scolopostethus thomsoni | | | | | | | | | | |
| Mean | 0.82 | 1.79 | 0.48 | 0.19 | 0.26 | 0.30 | 0.43 | 0.48 | 0.62 | 0.32 |
| Range | 0.77-0.97 | 1.64-2.08 | 0.47-0.51 | 0.17-0.20 | 0.24-0.27 | 0.27-0.32 | 0.42-0.46 | 0.46-0.54 | 0.60-0.66 | 0.30-0.34 |
| Scolopostethus decoratus | | | | | | | | | | |
| Mean | 0.74 | 1.66 | 0.44 | 0.17 | 0.26 | 0.27 | 0.39 | 0.44 | 0.58 | 0.30 |
| Range | 0.60-0.90 | 1.49-2.01 | 0.42-0.46 | 0.15-0.19 | 0.21-0.28 | 0.26-0.28 | 0.38-0.40 | 0.39-0.46 | 0.54-0.62 | 0.27-0.34 |
| Stygnocoris fuliqineus | | | | | | | | | | |
| Mean | 0.82 | 1.64 | 0.53 | 0.13 | 0.20 | 0.16 | 0.30 | 0.50 | 0.69 | 0.30 |
| Range | 0.67-0.99 | 1.45-1.85 | 0.52-0.56 | 0.13-0.15 | 0.19-0.21 | 0.15-0.19 | 0.30-0.31 | 0.43-0.54 | 0.62-0.78 | 0.27-0.32 |
| Drymus sylvaticus | | | | | | | | | | |
| Mean | 0.89 | 1.89 | 0.51 | 0.17 | 0.28 | 0.23 | 0.38 | 0.50 | 0.66 | 0.32 |
| Range | 0.75-1.07 | 1.57-2.26 | 0.48-0.55 | 0.16-0.20 | 0.26-0.31 | 0.20-0.24 | 0.36-0.40 | 0.43-0.60 | 0.58-0.78 | 0.28-0.38 |

TABLE 49. Body measurements in mm. of Fourth Instar Larvae.

| | Body width | Body length | Head width | Inter-ocular width | Antennal segments 1 | 2 | 3 | 4 | 3rd Rostral segment | Pronotum width anterior | Pronotum width posterior | Pronotum length | Mesonotum length mid | Mesonotum length to wing pad | Fore-femur width | Fore-femur length | Hind tibia length |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scolopostethus affinis** | | | | | | | | | | | | | | | | | |
| Mean | 0.94 | 2.12 | 0.56 | 0.41 | 0.24 | 0.38 | 0.38 | 0.50 | 0.26 | 0.56 | 0.77 | 0.42 | 0.23 | 0.36 | 0.20 | 0.60 | 0.75 |
| Range | 0.81-1.05 | 1.81-2.35 | 0.51-0.60 | 0.39-0.44 | 0.23-0.26 | 0.35-0.40 | 0.34-0.40 | 0.44-0.54 | 0.23-0.27 | 0.47-0.62 | 0.63-0.87 | 0.34-0.46 | 0.20-0.30 | 0.27-0.43 | 0.17-0.24 | 0.56-0.66 | 0.67-0.82 |
| **Scolopostethus thomsoni** | | | | | | | | | | | | | | | | | |
| Mean | 0.94 | 2.31 | 0.56 | 0.40 | 0.23 | 0.34 | 0.36 | 0.50 | 0.21 | 0.55 | 0.75 | 0.44 | 0.24 | 0.38 | 0.21 | 0.59 | 0.72 |
| Range | 0.83-1.13 | 2.15-2.48 | 0.55-0.59 | 0.40-0.42 | 0.23-0.26 | 0.31-0.35 | 0.35-0.39 | 0.48-0.54 | 0.17-0.24 | 0.52-0.59 | 0.71-0.81 | 0.40-0.48 | 0.20-0.30 | 0.34-0.42 | 0.19-0.24 | 0.58-0.63 | 0.67-0.77 |
| **Scolopostethus decoratus** | | | | | | | | | | | | | | | | | |
| Mean | 1.05 | 2.40 | 0.56 | 0.40 | 0.23 | 0.35 | 0.35 | 0.48 | 0.27 | 0.55 | 0.79 | 0.46 | 0.27 | 0.39 | 0.21 | 0.60 | 0.72 |
| Range | 0.98-1.11 | 2.17-2.55 | 0.54-0.58 | 0.38-0.42 | 0.20-0.24 | 0.32-0.38 | 0.30-0.39 | 0.44-0.51 | 0.26-0.28 | 0.52-0.58 | 0.72-0.86 | 0.39-0.50 | 0.17-0.35 | 0.32-0.44 | 0.19-0.24 | 0.56-0.63 | 0.66-0.79 |
| **Stygnocoris fuligineus** | | | | | | | | | | | | | | | | | |
| Mean | 1.07 | 2.00 | 0.64 | | 0.18 | 0.27 | 0.21 | 0.35 | | 0.59 | 0.87 | 0.40 | | | | | |
| Range | 0.94-1.21 | 1.50-2.40 | 0.62-0.68 | | 0.16-0.21 | 0.27-0.31 | 0.20-0.24 | 0.34-0.38 | | 0.54-0.62 | 0.82-0.93 | 0.38-0.47 | | | | | |
| **Drymus sylvaticus** | | | | | | | | | | | | | | | | | |
| Mean | 1.12 | 2.61 | 0.64 | | 0.23 | 0.43 | 0.34 | 0.45 | | 0.61 | 0.91 | 0.49 | | | | | |
| Range | 0.94-1.22 | 2.15-2.89 | 0.59-0.70 | | 0.21-0.26 | 0.39-0.46 | 0.32-0.38 | 0.42-0.50 | | 0.54-0.70 | 0.75-1.07 | 0.42-0.52 | | | | | |

TABLE 50. Body measurements in mm. of fifth instar larvae: A. Males.

| | Body width | Body length | Head width | Inter-ocular width | Ante-ocular length | Antennal segments 1 | 2 | 3 | 4 | Rostral segments 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scolopostethus affinis* | | | | | | | | | | | | | |
| Mean | 1.25 | 3.01 | 0.68 | 0.46 | 0.27 | 0.34 | 0.50 | 0.48 | 0.59 | 0.40 | 0.42 | 0.30 | 0.27 |
| Range | 1.01-1.45 | 2.75-3.36 | 0.64-0.71 | 0.43-0.48 | 0.24-0.28 | 0.30-0.35 | 0.44-0.52 | 0.46-0.51 | 0.58-0.62 | 0.38-0.43 | 0.36-0.46 | 0.27-0.34 | 0.27-0.28 |
| *Scolopostethus thomsoni* | | | | | | | | | | | | | |
| Mean | 1.26 | 2.91 | 0.64 | 0.44 | 0.24 | 0.30 | 0.42 | 0.44 | 0.58 | 0.36 | 0.44 | 0.27 | 0.26 |
| Range | 1.02-1.40 | 2.35-3.60 | 0.46-0.71 | 0.35-0.48 | 0.20-0.27 | 0.27-0.34 | 0.34-0.46 | 0.40-0.50 | 0.54-0.63 | 0.32-0.40 | 0.38-0.47 | 0.21-0.31 | 0.24-0.27 |
| *Scolopostethus decoratus* | | | | | | | | | | | | | |
| Mean | 1.05 | 2.60 | 0.62 | 0.42 | 0.24 | 0.28 | 0.44 | 0.43 | 0.56 | 0.39 | 0.44 | 0.32 | 0.28 |
| Range | 0.87-1.21 | 2.35-2.85 | 0.58-0.67 | 0.39-0.47 | 0.17-0.30 | 0.26-0.30 | 0.40-0.48 | 0.40-0.47 | 0.51-0.60 | 0.36-0.40 | 0.40-0.47 | 0.30-0.34 | 0.27-0.28 |
| *Stygnocoris fuligineus* | | | | | | | | | | | | | |
| Mean | 1.32 | 2.53 | 0.74 | 0.47 | | 0.21 | 0.37 | 0.32 | 0.42 | 0.32 | 0.32 | 0.21 | 0.26 |
| Range | 1.26-1.42 | 2.16-2.84 | 0.74-0.79 | 0.47-0.53 | | 0.21-0.26 | 0.26-0.42 | 0.26-0.32 | 0.37-0.42 | 0.26-0.32 | 0.26-0.37 | 0.21-0.26 | 0.26 |
| *Drymus sylvaticus* | | | | | | | | | | | | | |
| Mean | 1.59 | 3.37 | 0.75 | 0.66 | | 0.26 | 0.53 | 0.44 | 0.53 | 0.40 | 0.51 | 0.33 | 0.32 |
| Range | 1.37-1.84 | 3.11-3.58 | 0.74-0.79 | 0.53-0.58 | | 0.26 | 0.53 | 0.42-0.47 | 0.53 | 0.37-0.47 | 0.47-0.53 | 0.32-0.37 | 0.32 |

- continued

TABLE 50. Fifth instar males - continued.

| | Head length | Antenna width 1 | Antenna width 4 | Pronotum width anterior | Pronotum width posterior | Pronotum length | Mesonotum length mid | Mesonotum length to wing pad | Fore-femur width | Fore-femur length | Hind tibia length | Hind tarsus length 1 | Hind tarsus length 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scolopostethus affinis | | | | | | | | | | | | | |
| Mean | 0.46 | 0.13 | 0.15 | 0.62 | 0.95 | 0.59 | 0.42 | 0.82 | 0.30 | 0.79 | 0.98 | 0.38 | 0.32 |
| Range | 0.34- | 0.12- | 0.13- | 0.54- | 0.85- | 0.54- | 0.35- | 0.71- | 0.26- | 0.70- | 0.91- | 0.34- | 0.30 |
| | 0.54 | 0.13 | 0.16 | 0.66 | 1.06 | 0.71 | 0.54 | 0.91 | 0.34 | 0.83 | 1.06 | 0.40 | 0.35 |
| Scolopostethus thomsoni | | | | | | | | | | | | | |
| Mean | 0.40 | 0.13 | 0.15 | 0.63 | 0.91 | 0.56 | 0.43 | 0.78 | 0.26 | 0.74 | 0.90 | 0.38 | 0.28 |
| Range | 0.31- | 0.11- | 0.12- | 0.51- | 0.75- | 0.40- | 0.31- | 0.59- | 0.20- | 0.60- | 0.78- | 0.35- | 0.23- |
| | 0.47 | 0.13 | 0.16 | 0.67 | 1.03 | 0.68 | 0.52 | 0.94 | 0.28 | 0.86 | 1.01 | 0.40 | 0.31 |
| Scolopostethus decoratus | | | | | | | | | | | | | |
| Mean | 0.40 | 0.11 | 0.12 | 0.55 | 0.89 | 0.55 | 0.38 | 0.79 | 0.26 | 0.71 | 0.90 | 0.34 | 0.26 |
| Range | 0.32- | 0.09- | 0.12- | 0.51- | 0.78- | 0.51- | 0.32- | 0.72- | 0.23- | 0.60- | 0.86- | 0.31- | 0.21 |
| | 0.48 | 0.12 | 0.13 | 0.59 | 0.97 | 0.58 | 0.40 | 0.83 | 0.30 | 0.78 | 0.97 | 0.36 | 0.27 |
| Stygnocoris fuligineus | | | | | | | | | | | | | |
| Mean | | | | 0.68 | 1.05 | 0.47 | 0.47 | 0.84 | 0.21 | 0.58 | 0.69 | | |
| Range | | | | 0.63- | 1.00- | 0.42- | 0.37- | 0.68- | 0.21 | 0.58- | 0.63- | | |
| | | | | 0.79 | 1.11 | 0.53 | 0.53 | 0.89 | | 0.63 | 0.74 | | |
| Drymus sylvaticus | | | | | | | | | | | | | |
| Mean | | | | 0.76 | 1.25 | 0.67 | 0.61 | 1.14 | 0.26 | 0.81 | 1.00 | | |
| Range | | | | 0.68- | 1.21- | 0.63- | 0.53- | 1.05- | 0.26 | 0.79- | 1.00 | | |
| | | | | 0.84 | 1.26 | 0.74 | 0.68 | 1.26 | | 0.84 | | | |

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TABLE 50 continued - B. Females: Fifth instar larvae.

| | Body width | Body length | Head width | Inter-ocular width | Ante-ocular length | Antennal segments 1 | 2 | 3 | 4 | Rostral segments 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scolopostethus affinis* | | | | | | | | | | | | | |
| Mean | 1.28 | 3.07 | 0.70 | 0.47 | | 0.35 | 0.51 | 0.52 | 0.62 | | | 0.31 | |
| Range | 1.21- | 2.51- | 0.64- | 0.44- | | 0.32 | 0.47- | 0.50- | 0.60- | | | 0.27- | |
| | 1.34 | 3.49 | 0.72 | 0.52 | | 0.36 | 0.54 | 0.54 | 0.64 | | | 0.36 | |
| *Scolopostethus thomsoni* | | | | | | | | | | | | | |
| Mean | 1.31 | 3.29 | 0.71 | 0.48 | 0.27 | 0.30 | 0.46 | 0.46 | 0.59 | 0.38 | 0.46 | 0.28 | 0.26 |
| Range | 1.14- | 2.85- | 0.66- | 0.44- | 0.23- | 0.27- | 0.42- | 0.43- | 0.55- | 0.32- | 0.43- | 0.27- | 0.21- |
| | 1.49 | 3.76 | 0.74 | 0.52 | 0.35 | 0.32 | 0.51 | 0.50 | 0.63 | 0.42 | 0.47 | 0.31 | 0.27 |
| *Scolopostethus decoratus* | | | | | | | | | | | | | |
| Mean | 1.22 | 2.94 | 0.67 | 0.43 | 0.27 | 0.31 | 0.46 | 0.48 | 0.59 | 0.39 | 0.47 | 0.35 | 0.28 |
| Range | 1.11- | 2.68- | 0.62- | 0.40- | 0.21- | 0.27- | 0.38- | 0.43- | 0.54- | 0.34- | 0.40- | 0.31- | 0.27- |
| | 1.41 | 3.49 | 0.72 | 0.46 | 0.31 | 0.34 | 0.51 | 0.58 | 0.63 | 0.44 | 0.54 | 0.40 | 0.30 |
| *Stygnocoris fuligineus* | | | | | | | | | | | | | |
| Mean | 1.37 | 2.58 | 0.79 | 0.53 | | 0.24 | 0.37 | 0.32 | 0.42 | 0.32 | 0.32 | 0.26 | 0.26 |
| Range | 1.21- | 2.26- | 0.74- | 0.47- | | 0.21- | 0.37- | 0.26- | 0.42- | 0.32- | 0.32- | 0.21- | 0.26- |
| | 1.47 | 3.16 | 0.84 | 0.53 | | 0.26 | 0.42 | 0.37 | 0.47 | 0.37 | 0.37 | 0.26 | 0.32 |
| *Drymus sylvaticus* | | | | | | | | | | | | | |
| Mean | 1.59 | 3.37 | 0.76 | 0.55 | | 0.28 | 0.66 | 0.41 | 0.66 | 0.45 | 0.49 | 0.32 | 0.30 |
| Range | 1.42- | 2.74- | 0.74- | 0.53- | | 0.21- | 0.53- | 0.37- | 0.53- | 0.42- | 0.42- | 0.26- | 0.26- |
| | 1.79 | 4.00 | 0.79 | 0.58 | | 0.32 | 0.58 | 0.47 | 0.58 | 0.47 | 0.53 | 0.37 | 0.32 |

-continued

TABLE 50. Fifth instar females - continued.

| | Head length | Antenna width 1 | Antenna width 4 | Pronotum width anterior | Pronotum width posterior | Length | Mesonotum length mid | Mesonotum length to wing pad | Fore-femur width | Fore-femur length | Hind tibia length | Hind tarsus length 1 | Hind tarsus length 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scolopostethus affinis | | | | | | | | | | | | | |
| Mean | | | | 0.68 | 0.99 | 0.59 | 0.43 | 0.87 | 0.28 | 0.81 | 1.03 | | |
| Range | | | | 0.63-0.72 | 0.91-1.06 | 0.54-0.64 | 0.36-0.47 | 0.77-0.97 | 0.26-0.32 | 0.75-0.87 | 0.94-1.14 | | |
| Scolopostethus thomsoni | | | | | | | | | | | | | |
| Mean | 0.47 | 0.12 | 0.15 | 0.67 | 1.02 | 0.60 | 0.44 | 0.87 | 0.28 | 0.79 | 0.98 | 0.35 | 0.30 |
| Range | 0.36-0.54 | 0.11-0.13 | 0.12-0.17 | 0.63-0.71 | 0.90-1.14 | 0.52-0.67 | 0.34-0.52 | 0.67-0.93 | 0.26-0.32 | 0.67-0.85 | 0.74-1.09 | 0.19-0.40 | 0.19-0.34 |
| Scolopostethus decoratus | | | | | | | | | | | | | |
| Mean | 0.44 | 0.11 | 0.13 | 0.63 | 0.99 | 0.58 | 0.46 | 0.90 | 0.28 | 0.77 | 0.97 | 0.38 | 0.28 |
| Range | 0.35-0.54 | 0.11-0.13 | 0.12-0.16 | 0.54-0.70 | 0.90-1.11 | 0.51-0.64 | 0.40-0.54 | 0.81-1.03 | 0.26-0.34 | 0.71-0.85 | 0.85-1.06 | 0.34-0.43 | 0.26-0.34 |
| Stygnocoris fuligineus | | | | | | | | | | | | | |
| Mean | | | | 0.79 | 1.16 | 0.53 | 0.47 | 0.89 | 0.21 | 0.63 | 0.74 | | |
| Range | | | | 0.74-0.79 | 1.00-1.21 | 0.47-0.58 | 0.32-0.58 | 0.79-1.00 | 0.21 | 0.58-0.68 | 0.68-0.79 | | |
| Drymus sylvaticus | | | | | | | | | | | | | |
| Mean | | | | 0.76 | 1.26 | 0.62 | 0.59 | 1.09 | 0.28 | 0.82 | 1.01 | | |
| Range | | | | 0.74-0.84 | 1.16-1.37 | 0.53-0.68 | 0.47-0.68 | 0.95-1.26 | 0.26-0.32 | 0.74-0.89 | 0.95-1.05 | | |

## (D) HYBRIDIZATION STUDIES

### RESULTS

The crosses tried

Three kinds of interbreeding of Scolopostethus species were tried - within the structural group not having mesosternal spurs (S.decoratus and S.thomsoni), within the structural group possessing mesosternal spurs (S.affinis and S.grandis), and between these two groups.

All combinations were tried except the two decoratus x grandis, the affinis ♀ x decoratus ♂ and the grandis ♀ x thomsoni ♂ crosses. All females were kept separated from males until the commencement of the crossbreeding experiments.

The following crosses were unsuccessful, i.e. no fertile eggs were produced and it is assumed that copulation either did not take place or was unsuccessful:

decoratus ♀ x grandis ♂ 2 pairs,

thomsoni ♀ x grandis ♂ 2 pairs.

Fertility of the parent cross

In the remaining six crosses many of the eggs began developing but in the thomsoni ♀ x decoratus ♂ and thomsoni ♀ x affinis ♂ crosses only half of these hatched. The fertility of the eggs of some females in each cross are shown in Tables 51-55. In some cases there were changes in fertility during oviposition (for a single female). The fertility of the pure species has been given in the section on bionomics, but that of three recently emerged thomsoni females which had received only one copulation is given here (Table 56) for comparison with the data from the crosses.

TABLE 51. Fertility of thomsoni ♀ x decoratus ♂.

| Successive 4-day "batches" of eggs | Number that hatched | No. of eggs that started to develop but failed to hatch | Number of infertile eggs |
|---|---|---|---|
| Pair one | | | |
| 1 | 0 | 0 | 5* |
| 2 | 15 | 13 | 3 |
| 3 | 12 | 3 | 2 |
| 4 | 9 | 11 | 1 |
| 5 | 9 | 7 | 4 |
| 6 | 17 | 8 | 6 |
| 7 | 3 | 4 | 4 |
| Total | 65 | 46 | 26 |
| Pair two | | | |
| 1 | 0 | 0 | 13* |
| 2 | 5 | 8 | 4 |
| 3 | 5 | 10 | 1 |
| 4 | 8 | 9 | 1 |
| 5 | 2 | 5 | 0 |
| 6 | 1 | 2 | 1 |
| Total | 21 | 34 | 7 |
| Pair three | | | |
| 1 | 5 | 4 | 4 |
| 2 | 13 | 5 | 1 |
| 3 | 25 | 30 | 3 |
| 4 | 8 | 5 | 2 |
| Total | 51 | 44 | 10 |
| Pair four | | | |
| 1 | 16 | 2 | 6 |
| 2 | 27 | 5 | 4 |
| 3 | 12 | 6 | 3 |
| 4 | 6 | 1 | 14 |
| 5 | 0 | 0 | 26 |
| Total | 61 | 14 | 53 |

* Excluded from total because they were obviously laid before copulation took place.

TABLE 52. Fertility of *decoratus* ♀ x *thomsoni* ♂.

| Successive 4-day "batches" of eggs | Number that hatched | No. of eggs that started to develop but failed to hatch | Number of infertile eggs |
|---|---|---|---|
| Pair one | | | |
| 1 | 0 | 0 | 7* |
| 2 | 28 | 1 | 3 |
| 3 | 19 | 1 | 1 |
| 4 | 23 | 0 | 0 |
| 5 | 12 | 0 | 0 |
| Total | 82 | 2 | 4 |
| Pair two | | | |
| 1 | 0 | 0 | 2* |
| 2 | 17 | 0 | 1 |
| 3 | 16 | 0 | 0 |
| 4 | 21 | 1 | 2 |
| 5 | 21 | 1 | 2 |
| 6 | 11 | 0 | 0 |
| Total | 86 | 2 | 5 |
| Pair three | | | |
| 1 | 0 | 0 | 8* |
| 2 | 0 | 0 | 7* |
| 3 | 12 | 0 | 2 |
| 4 | 14 | 1 | 11 |
| Total | 26 | 1 | 13 |
| Pair four | | | |
| 1-9 | 0 | - | - |
| 10 | 8 | 0 | 5 |
| Total | 8 | 0 | 5 |

* Excluded from total because they were obviously laid before copulation took place.

TABLE 53. Fertility of *thomsoni* ♀ x *affinis* ♂. The results are for the only "successful" pair.

| Successive 4-day "batches" of eggs | Number that hatched | No. of eggs that started to develop but failed to hatch | Number of infertile eggs |
|---|---|---|---|
| 1-3 | 0 | 0 | 16* |
| 4 | 3 | 3 | 2 |
| 5 | 26 | 13 | 5 |
| 6 | 14 | 6 | 5 |
| 7 | 9 | 9 | 2 |
| 8 | 5 | 7 | 7 |
| 9 | 7 | 10 | 11 |
| Total | 64 | 48 | 32 |

TABLE 54. Fertility of the single *grandis* ♀ x *affinis* ♂ mating tested.

| Successive 4-day "batches" of eggs | Number that hatched | No. of eggs that started to develop but failed to hatch | Number of infertile eggs |
|---|---|---|---|
| 1 | 8 | 0 | 20* |
| 2 | 20 | 0 | 0 |
| 3 | 30 | 0 | 1 |
| 4 | 20 | 0 | 2 |
| 5 | 35 | 0 | 1 |
| 6 | 34 | 0 | 0 |
| Total | 147 | 0 | 4 |

TABLE 55. Fertility of *affinis* ♀ x *grandis* ♂. The results from one pair are given.

| Successive 4-day "batches" of eggs | Number that hatched | No. of eggs that started to develop but failed to hatch | Number of infertile eggs |
|---|---|---|---|
| 1-3 | 0 | 0 | 18* |
| 4 | 16 | 0 | 4 |
| 5 | 25 | 1 | 8 |
| 6 | 24 | 4 | 5 |
| 7 | 11 | 0 | 2 |
| 8 | 23 | 0 | 5 |
| 9 | 11 | 0 | 2 |
| Total | 110 | 5 | 26 |

* Excluded from total because they were obviously laid before copulation took place.

TABLE 56. Normal fertility of pure Scolopostethus thomsoni females that had only one copulation with a thomsoni male.

| Successive 4-day "batches" of eggs | Number that hatched | No. of eggs that started to develop but failed to hatch | Number of infertile eggs |
|---|---|---|---|
| Female one | | | |
| 1 | 17 | 1 | 0 |
| 2 | 15 | 2 | 0 |
| 3 | 3 | 0 | 1 |
| Total | 35 | 3 | 1 |
| Female two | | | |
| 1 | 21 | 1 | 1 |
| 2 | 10 | 0 | 2 |
| Total | 31 | 1 | 3 |
| Female three | | | |
| 1 | 7 | 1 | 1 |
| 2 | 7 | 0 | 2 |
| 3 | 30 | 2 | 3 |
| 4 | 23 | 0 | 1 |
| 5 | 30 | 0 | 0 |
| 6 | 37 | 3 | 2 |
| 7 | 38 | 0 | 1 |
| 8 | 22 | 0 | 2 |
| 9 | 8 | 0 | 5 |
| 10 | 0 | 0 | 9 |
| 11 | 0 | 0 | 3 |
| Total | 202 | 6 | 29 |

S.affinis ♀ x grandis ♂ had a larger proportion of infertile eggs (Table 55) but apart from this and the anomalous egg mortality in the two crosses mentioned above (Tables 51 and 53) the normal proportion of eggs hatched.

When males were put with females of their own species fertile eggs were produced within a day, whilst when put with females of another species there was often a long delay of up to 36 days before the first fertile eggs were produced. This is considered to reflect a delay in copulation.

The hybrid adults produced

A grand total of 173 female and 35 male hybrids was obtained from the six crosses. The numbers from, and the details of each cross are discussed in turn.

(1) thomsoni ♀ x decoratus ♂

Fifty-five females were produced by four out of six pairs. The remaining two pairs did not produce any fertile eggs. Of those that hatched, the number that survived to adult varied (for each four-day "batch" per female) from 11-50 per cent, but the overall mean survival from the four pairs was about 26 per cent.

The mortality was high which indicates a loss of vigour, yet those attaining adulthood seemed normally active. As only females were produced, and as half of the eggs began development but did not hatch, it is likely that only females hatched, and therefore the mortality applies to the females.

The complete failure to produce males suggests that a sex-linked factor is involved and this is incompatible or lethal in this cross.

Most of the females were intermediate in appearance. This was judged on two characters, the colour of the antennae and the wing form. Twenty-seven per cent were like decoratus in appearance, but none like thomsoni. However, there were grades of intermediates as shown in Table 57. Some were intermediate in that they showed one characteristic of each species. Others had a decoratus wing but the second antennal segment was intermediate, i.e. half dark and half pale or sometimes dark at each end and pale in the centre. Still others had both characters intermediate. The macropterous wing form was dominant.

The antennae of one specimen were coloured as in affinis, whilst another had mesosternal tubercles but otherwise appeared like decoratus. Both of these characters belong to the other structural group only.

TABLE 57. Number of hybrid females from the thomsoni ♀ x decoratus ♂ matings possessing the combinations of antennal colour and wing form indicated.

| Wing form as in | Intermediate antennal colour | Antennal colour as in decoratus | thomsoni | affinis |
|---|---|---|---|---|
| decoratus (macropterous) | 17 | 14 | 14 | 1 |
| thomsoni (brachypterous) | | | | |
| Intermediate in form | 5 | 1 | | |

(2) decoratus ♀ x thomsoni ♂

Forty-seven females and eleven males were produced by four, out of six pairs. The remaining two pairs presumably did not mate as no fertile eggs were produced. The number of larvae that survived to adult varied (for each four-day "batch" per female) from 8-39 per cent, but the overall mean survival from the four pairs was about 25 per cent.

As in the case of the reciprocal cross, the high mortality shows a loss in vigour, which this time applies to both males and females (since both hatched - Table 52). This cross was therefore slightly more successful than the reciprocal cross, but the males suffered high mortality. Most had difficulty (and several were assisted) in freeing the old exuvium from the posterior of the abdomen, some had crumpled wings and life was very short, lasting one to nine days. Several males died during the early stages of the final moult.

Most of the females and all of the males examined were intermediate in appearance, having the antennal colour of one species and the wing form of the other (Table 58).

TABLE 58. Number of individual hybrids from the *decoratus* ♀ x *thomsoni* ♂ matings possessing the combinations of antennal colour and wing form indicated.

| Wing form as in | Intermediate antennal colour | Antennal colour as in *decoratus* | Antennal colour as in *thomsoni* |
|---|---|---|---|
| Females | | | |
| *decoratus* (macropterous) | 10 | 5 | 22 |
| *thomsoni* (brachypterous) | | | |
| Males | | | |
| *decoratus* | | | 7 |
| *thomsoni* | 1 | | |

(3) *thomsoni* ♀ x *affinis* ♂

Thirty females were produced by one out of ten pairs - thus there was a high percentage of barren pairs. Yet the loss of vigour was much less for these hybrids, between the structural groups, than for hybrids within the structural groups for 60 per cent of the larvae produced actually survived. The males, however, all died in the egg and had no share in this relatively good survival.

Because of an additional character, the presence or absence of mesosternal tubercles, the hybrids could be classed into more groups (Table 59). Thirty-nine per cent were brachypterous individuals identical in appearance to the pure species (28.6 per cent resembling *thomsoni* and 10.1 per cent resembling *affinis*).

An interesting feature of the intermediates is that they possess the antennal colour of one species and the tubercle character of the other, and both combinations occurred.

TABLE 59. Number of hybrid females from the thomsoni ♀ x affinis ♂ mating possessing the combination of characters indicated.

| Antennal colour as in | With tubercles (as in affinis) | | Without tubercles (as in thomsoni) | |
|---|---|---|---|---|
| | Brachypterous | Macropterous | Brachypterous | Macropterous |
| affinis | 3 | 2 | 7 | 1 |
| thomsoni | 4 | 1 | 8 | 1 |
| decoratus | | | 1 | |

(4) affinis ♀ x thomsoni ♂

Two out of four pairs were "successful" and produced three female and four male hybrids. One female was examined and found to possess the antennal colour for affinis but the mesosternal tubercles were lacking. The four males appeared to be typical affinis although on two specimens the mesosternal spurs were small.

This is the second cross in which some males were produced when the sire is a thomsoni male.

(5) grandis ♀ x affinis ♂

Twenty-six females and four males were produced by the one pair used in this cross. The overall survival was 19 per cent, and as in the case of decoratus ♀ x thomsoni ♂ the males hatched (Table 54) but suffered more severe mortality than the females. A number of males died prior to the final moult.

As macropters were found to be the common form in grandis (see p. 37 ) all the hybrids produced can be regarded as intermediate between the two

species (Table 60). As already noted in crosses where *decoratus* is one partner the macropterous form dominates. It is of interest that within this group which has mesosternal spurs, some hybrids were without tubercles.

TABLE 60. Number of individual hybrids from the *grandis* ♀ x *affinis* ♂ mating possessing the combination of characters indicated.

| | Antennal colour as in | With tubercles or spurs Macropterous (= *grandis*) | With tubercles or spurs Intermediate wing form | Without tubercles Macropterous |
|---|---|---|---|---|
| Females | | | | |
| | *affinis* | 11 | 5 | 2 |
| | *grandis* | | | |
| Males | | | | |
| | *affinis* | 2 | | |
| | *grandis* | | | |

(6) *affinis* ♀ x *grandis* ♂

Fifteen females and twenty males were produced by two out of four pairs. The survival of the larvae was 29 per cent. Although the mortality suffered was still high, the males survived as well as, if not better than the females. Thus in producing even numbers of sexes this cross was the only one with potential success.

The majority of the specimens possessed mesosternal tubercles or spurs (Table 61) and in this respect also they were more "normal". However, the macropterous wing predominated, as did the *affinis* antennal colour.

Fecundity of the $F_1$ females

As the females oviposited normally, their fecundity was determined (Table 62). This can be compared with the performance of the pure females shown in Tables 38-40. The food provided was a mixture of nettle andshepherds purse seeds except for the females shown in the last column which were given only shepherds purse seeds.

TABLE 61. Number of individual hybrids from the *affinis* ♀ x *grandis* ♂ matings possessing the combination of characters indicated.

| | Antennal colour as in | With tubercles or spurs: Macropterous (=*grandis*) | With tubercles or spurs: Intermediate wing form | With tubercles or spurs: Brachypterous | Without tubercles |
|---|---|---|---|---|---|
| Females | | | | | |
| | *affinis* | 11 | 3 | | |
| | *grandis* | 1 | | | |
| Males | | | | | |
| | *affinis* | 12 | 5 | | |
| | *grandis* | | | | |

TABLE 62. Fecundity of the $F_1$ female hybrids of the cross indicated. Mean values are given with the range underneath. The larval development and preoviposition periods are estimated.

| | Within the group without spurs: *thomsoni* ♀ x *decoratus* ♂ | Within the group without spurs: *decoratus* ♀ x *thomsoni* ♂ | Between groups*: *thomsoni* ♀ x *affinis* ♂ | Within the group with spurs: *grandis* ♀ x *affinis* ♂ | Within the group with spurs: *affinis* ♀ x *grandis* ♂ |
|---|---|---|---|---|---|
| Larval devt. days | 32<br>23-42 | 31<br>24-39 | 35<br>34-39 | 32<br>31-34 | 35<br>28-39 |
| Preovip. prd. days | 13<br>7-20 | 10<br>6-15 | 6<br>6-8 | 8<br>6-9 | 11<br>9-12 |
| Ovip. prd. in days | 21<br>0-47 | 26<br>3-59 | 62<br>10-100 | 74<br>25-110 | 34<br>15-65 |
| Fecundity Eggs/♀ | 15<br>0-52 | 57<br>5-115 | 112<br>21-119 | 79<br>40-133 | 50<br>9-79 |
| Postovip. prd. days | 10<br>0-114 | 3<br>0-32 | 30<br>16-52 | 14<br>0-28 | 11<br>0-36 |
| Longevity in days | 42<br>15-151 | 38<br>18-80 | 76<br>16-106 | 88<br>34-126 | 55<br>29-77 |
| No. of females | 38 | 35 | 14 | 8 | 4 |

* One hybrid female of the reciprocal cross laid 159 eggs in 59 days.

The fecundity in all cases was considerably reduced, being only one-sixth to one-third that of the pure females. The hybrids differed from the pure females in having a noticeable postoviposition period. In the decoratus x thomsoni hybrids the oviposition period was reduced by a half and the longevity was slightly reduced. On the other hand, in the affinis x grandis hybrids the oviposition period and longevity were normal. Where males were produced, the longevity was usually less than 15 days, but three affinis ♀ x grandis ♂ hybrids lived for 22, 31 and 90 days respectively.

The duration of larval development and the preoviposition period were normal. Some of the hybrid eggs were white when freshly laid, and many were the normal light straw colour. Frequently some very short eggs half, or less than half normal length were found - e.g. one egg of decoratus ♀ x thomsoni ♂ hybrid measured only 0.54 mm. x 0.31 mm. Five thomsoni ♀ x decoratus ♂ hybrids had blocked ovipositors and two of them did not oviposit at all; the others laid only 1-8 eggs. Their longevity was 19-73 days.

Fertility of the hybrids

As so very few male hybrids were produced the majority of the female hybrids were mated back to one or other of the parent species. The fertility of these matings is tabulated below.

The male hybrids seemed infertile when crossed with hybrid and normal females. Only 2.5 (1.4-4.3) per cent of the eggs laid by the hybrid females were fertile, and 48 per cent of these showed an interesting failure of the embryo to revolve. Only three of the apparently normal eggs hatched, but the larvae soon died.

| | | | |
|---|---|---|---|
| 1) ♀ Hybrids of *thomsoni* ♀ x *decoratus* ♂ | | | |
| (a) Backcrossed to *decoratus* ♂ | | | |
| 8 pairs (1 seen in cop) | 67 total eggs | all infertile | |
| (b) Backcrossed to *thomsoni* ♂ | | | |
| (i) 11♀♀, 8♂♂ (in 2 groups) | 141 total eggs | all infertile | |
| (ii) Group of 4♀♀, 6♂♂ | 70 total eggs | 69 infertile | 1 started development; eyespots at wrong pole. |
| 2) ♀ Hybrids of *decoratus* ♀ x *thomsoni* ♂ | | | |
| (a) Backcrossed to *thomsoni* ♂ | | | |
| (i) 4 pairs | 154 total eggs | all infertile | |
| (ii) 15♀♀, 11♂♂ (4 groups and 1 pair) | 1249 total eggs | 1231 infertile | (5 started development (normally: 10 had eye- (spots at wrong pole; (3 hatched but died - (1 in embryonic cuticle. (1 after 4 days and 1 (in the second instar. |
| (b) Backcrossed to *decoratus* ♂ | | | |
| (i) 6 pairs | 230 total eggs | all infertile | |
| (ii) 4 pairs | 257 total eggs | 246 infertile | (8 started development (normally; 3 had eye- (spots at wrong pole. |
| (c) Crossed to ♂ hybrid of the same cross | | | |
| (i) ♂brother 1 pair | 9 total eggs | all infertile | |
| (ii) ♂ not brother 1 pair | 8 total eggs | all infertile | |
| 3) ♀ Hybrids of *thomsoni* ♀ x *affinis* ♂ Backcrossed to *thomsoni* ♂ | | | |
| 11♀♀, 8 ♂♂ ( 2 groups and 1 pair) | 862 total eggs | 835 infertile | (19 started development (normally; 1 had eye- (spots in middle; 7 had (eyespots at wrong (pole. |
| 4) ♀ Hybrid of *affinis* ♀ x *thomsoni* ♂ | | | |
| (a) Backcrossed to *thomsoni* ♂ | | | |
| 1 pair | 114 total eggs | all infertile | |
| (b) Crossed to hybrid brother | | | |
| 1 pair | 45 total eggs | all infertile | |

5) ♀ Hybrids of *grandis* ♀ x *affinis* ♂
   (a) Crossed to ♂ hybrid brothers
   Group, 4♀♀, 2♂♂ 159 total eggs all infertile

   (b) Crossed to ♂ hybrid of *affinis* ♀ x *grandis* ♂
   1 pair 133 total eggs all infertile

6) ♀ Hybrids of *affinis* ♀ x *grandis* ♂
   Crossed to hybrid brother
   1 pair 72 total eggs all infertile

7) ♂ Hybrids of *affinis* ♀ x *grandis* ♂
   With *grandis* ♀
   3 pairs 49 total eggs all infertile

# DISCUSSION

Saunders (1892) believed that the so-called Scolopostethus species were races of one species. He considered that the colour of the antennae and the form of the pronotum and wing membrane were not reliable as distinguishing characters. He examined the male genitalia, with the exception of Scolopostethus pictus (Schilling), and found only three forms with slight but distinct differences, which he considered were modifications of a common form. On the form of the male genitalia he suggested that affinis and grandis, and thomsoni and Scolopostethus puberulus Horvath, by synonymous, decoratus remaining distinct. Southwood and Leston (1959) consider the specific status of grandis doubtful.

Butler (1923) found that the larvae of all species were very similar and indistinguishable except for pictus. In the previous section it was shown that although the larvae are indistinguishable in practice, those of affinis, thomsoni and decoratus have a distinct shape as disclosed by morphometric analysis.

The important conclusion from the hybridization studies about four of these species is that their status as separate species is confirmed. From the point of view of the species, interbreeding was unsuccessful because no $F_2$ progeny or progeny from the back crosses were produced.

However, the results from this study contribute to our knowledge of hybridization by emphasising the barriers to hybridization which are found to be as follows:

(1) The unwillingness of pairs of different species to copulate: This was shown by the delay which was often considerable, before any fertile eggs were produced. This was further emphasised by the number of

unsuccessful pairs in each trial crossing and these presumably never mated. Sailer (1954) showed with stink bugs that males will mate with females of their own species 17 times more readily than with females of another species in the absence of free choice. Such temporary isolation is probably mainly due to the different courtship behaviour of each species.

In S.decoratus the antennae of both sexes vibrate and often touch the opposite mate; the male puts on a great display shaking the body violently and doing "press ups"; he then pushes his antennae and head against the side of the female thorax and pushes her over on her side; mounting follows.

In S.thomsoni mating eventuates sooner, the antennae vibrate more slowly, there is no display by the male and the female lies herself down exposing one side. When one female exposed her left side a male was observed to cause her to expose her right side by vibrating his antennae on it.

S.affinis males put on a slight display by cleaning the rostrum, during which activity they sometimes lie on one side.

S.decoratus males have been observed performing long and arduous displays in vain before females of other species. The females would sometimes come to the males, which was equally without effect.

It is interesting to note that the courting "song" of the two closely allied Kleidocerys species appears to be an important isolating mechanism (Southwood and Leston 1959).

(2) The heavy mortality of the hybrid females

(3) The severe and almost complete mortality of the hybrid males: This generally occurred in the egg stage, but with some crosses in the larval

stages. Such disturbance in the sex-ratio of the hybrids ensures that there can be no continuation of the hybrid line.

Disturbances in the proper action of the genes is liable to occur in hybrid insects, and where the growth hormones are affected abnormalities of growth may appear (Wigglesworth 1953). In hybrid Lepidoptera it is the female that is affected and in some cases these do not develop beyond the pupal stage (Wigglesworth 1953).

(4) The infertility of the hybrids: The few hybrid males that were produced seemed infertile when put with hybrid females and in back-crosses. The female hybrids were almost completely infertile in back-crosses; disturbances in embryonic development occurred and none of the three larvae that hatched survived.

Point (4) does not always apply to hybrids e.g. Sailer (1954) obtained fertile $F_1$ hybrids of stink bugs, and they exhibited hybrid vigour. However, in later experiments very few $F_1$ hybrids were produced and both sexes were infertile (Sailer 1955).

The Scolopostethus hybrids were mostly intermediate in character between the two parents but there were occasional "throwbacks" possessing a character not possessed by either parent. Even more surprising was the production of affinis x grandis hybrids without mesosternal tubercles.

$F_1$ hybrids were produced from crosses both within and between the structural groups. Thus thomsoni and affinis which belong to different structural groups as well as often occurring in the same habitat, and which might therefore be expected to be incompatible, nevertheless produced $F_1$ hybrids. Again decoratus, although from a different habitat,

is of the same structural group as thomsoni and when crossed with it produced $F_1$ hybrids.

In conclusion it is opportune to state (in contradistinction to the views of Sailer, 1954) that hybridization does not normally occur in nature. The results presented here and in the literatue suggest that when it does occur it is because (or when) one of each sex of two closely related species meet in the absence of their own species. For example, Sailer (1954) reported successful hybridisation of stink bugs but the fertility of the first cross was so low (1.7 per cent and 0.4 per cent in the reciprocal cross) that the hybrid line would be unlikely to continue - especially as species prefer to mate with their own kind.

It could be argued that this latter statement would be the very reason for the continuation of the hybrid - i.e. the hybrid could mate easier with a hybrid than with a pure species. But if this were so one would expect to find hybrids in the field, which rarely occurs. No Scolopostethus hybrids were taken in the field. Lansbury (1956) found one Notonecta (back swimmer) specimen intermediate in appearance between two known species; but no other such specimens have been found. This may indeed be a true hybrid from a chance cross-mating, but if so it has not perpetuated.

Again Clarke and Sheppard (1953) "successfully" crossed related species of Lepidoptera but only after considerable trouble in hand pairing. The hybrids they obtained were incompatible, but they obtained low fertility in backcrosses and this was increased in repeated back-crosses. The chances of this occurring in nature are rather remote and yet they conclude that these forms must be treated as extreme subspecies rather than valid species.

However, when a North African subspecies was crossed with a European subspecies abnormal development occurred among the $F_2$ hybrids, which they consider shows the former is distinct from the European strains (Clarke and Sheppard 1956).

Also with one European subspecies they obtained, on crossing with another strain, an uneven sex ratio in the $F_1$ hybrids and regard this as an indication that it is distinct (Clarke and Sheppard 1956).

This strengthens my conclusions that the Scolopostethus species are distinct.

# GENERAL DISCUSSION

The Scolopostethus species are closely allied and as their habits are similar, previous workers believed that at least some of them may in fact be subspecies. The similarities of these species are summarized here.

The life cycles seemed similar, the larvae abundant in June, and the young adults in early autumn. Because they are ground living species it is difficult to observe any differences between their habitats. That of decoratus is distinct, as it occurs mainly on heaths, but the other species are often found together. The larvae of all species are alike. In the adults, the colour of the antennae is one of the few main distinguishing characters, but their similarity in most other respects cast doubt on the status of some species on virtually colour alone.

The present study, however, has shown that although the Scolopostethus species have close affinities, there are in fact slight but distinct differences between them on several accounts. These are summarized below.

Life cycles: Development in decoratus is faster than in affinis and thomsoni, and overwintering occurs only in the adult stage. The life cycles of affinis and thomsoni are similar and both overwinter as adults and larvae; however, these two species are structurally distinct. The larvae of grandis apparently develop to adult by September and this species probably overwinters as an adult. It is, however, structurally distinct from decoratus.

Habitat: S. decoratus overwinters under C.vulgaris, and in the breeding season is mainly associated with E.cinerea, but also breeds on arable land. S.thomsoni was found to keep entirely to nettles for a breeding

site. Although affinis also occurs on nettles the population density is much less than that of thomsoni, and it occurs in other habitats such as disused gravel pits, grassland, under hedges and amongst moss. S.grandis is probably a grassland species occurring in woods under trees such as silver birch.

Food: The feeding studies showed that the seeds of certain weeds growing on arable land are unsuitable, as food for thomsoni, but are suitable for affinis and decoratus. On the other hand, nettle seed is an excellent food for thomsoni(and affinis)but a very poor food for decoratus.

Larvae: Morphometric analysis showed that the larvae of affinis, thomsoni and decoratus are distinct.

Adults: The colour of the antennae appears to be a reliable diagnostic character, and there are rather striking differences in courtship behaviour.

Hybrids: In most crosses there was a failure to produce $F_1$ hybrid males, and no $F_2$ progeny were produced. The extremely low fertility of the eggs of the $F_1$ hybrid females in backcrosses was coupled with chromosomal disturbance during embryonic development: this was lethal.

From a summation of these differences there can be no doubt that affinis, grandis, decoratus and thomsoni are distinct species.

## SUMMARY AND CONCLUSIONS

1. The life histories of five species were studied in detail whilst some information was obtained on four other species. It is shown that all have a single generation a year.

2. Scolopostethus species and Stygnocoris fuligineus have no diapause but overwinter in a quiescent state. The other Stygnocoris species overwinter as eggs.

3. D. sylvaticus has an obligatory reproductive diapause which is completed in early winter. However, even when kept at a temperature of 23.3°C. this species is able to complete diapause development in three to six months.

4. D. brunneus may overwinter as eggs, larvae and immature adults.

5. Scolopostethus thomsoni was found to be associated permanently only with nettles. This species and S. affinis deposit eggs on the nettle seeds on the plant. The other species (and probably S. affinis in other habitats) oviposit in the soil.

6. The habitat of Stygnocoris fuligineus on arable land is dependent on bad cultivation. Absence of cultivation or good farm practice are both inimical to it.

7. The proportions of the wing forms are given, and in particular no brachypterous speciments of Scolopostethus grandis were found.

8. Cinochira atra was found to be an occasional parasite of four species, and this is the first record from England. Alophora pusilla was found to be an occasional parasite of Stygnocoris.

9. There is a definite association of a Paecilomyces fungus with Scolopostethus and Stygnocoris fuligineus.

10. Occasionally a larval colour variant occurred in Scolopostethus affinis when 20 per cent had yellow instead of orange coloured abdomens. This differs from the larval colour variant found in Stygnocoris fuligineus in which the thorax often did not darken.

11. It has been shown that seeds are the prime item of food in the diet of these insects. The value of the seeds of seven plants representing six plant families and of a beetle larva, was shown for the five species.

12. Stygnocoris fuligineus "did well" on all but two of the seeds; the Scolopostethus species did well on those very two seeds plus E. cinerea seeds but not the others; whilst D. sylvaticus did well on only two seeds, one that was suitable for the Scolopostethus species and one that was not.

13. Those seeds acceptable to the Scolopostethus species varied in order of ranking and/or food value with each bug.

14. It follows that the differences in food value shown are due to the insects and not to the seeds, and therefore a brief discussion is givenof the major factors involved in host plant selection.

15. The total growth curve for these species is sigmoid and the growth curve for each instar is also sigmoid.

16. The actual weight gain is greatest during the fifth larval instar, but the percentage weight gain is least in this instar and progressively greater in earlier instars.

17. As D. sylvaticus were reared to the fifth larval instar on beetle larvae alone with an almost normal growth curve, it is

probable that animal food could play at least a partial role in the diet of this species.

18. The larval stages of five species are described and figured. Further information about the extension of the Y-suture recently described as unique to the Rhyparochrominae is given. It is shown that the larvae can be sexed in the fifth larval instar by modifications on the terminal abdominal sternites.

19. It is shown that although Scolopostethus larvae are indistinguishable in practice, those of affinis, thomsoni and decoratus each have a distinct shape as disclosed by morphometric analysis.

20. Hybridization within the genus Scolopostethus was attempted. Crosses (and their reciprocals) both within and between the two groups of structurally similar species were made.

21. The specific status of the four species involved is confirmed.

22. A low percentage of hybrid females were produced, but no, or very few and short lived, males. The fecundity of the females was greatly reduced, and when crossed with parement males occasional eggs started to develop (some with the embryo orientated at the wrong pole) but only a negligible number hatched and the larvae soon died.

23. The majority of the hybrids were intermediate in appearance between the parent species. Sometimes a character of a member of the genus not possessed by either parent was exhibited.

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# APPENDIX I

Differences between fifth instar larvae of Scolopostethus affinis, thomsoni and decoratus.

Test used: Wilks' Criterion.

A: Females

$$\Lambda = \frac{|W|}{|W+Q|}$$

$$\Lambda = \frac{2.1137}{52.073}$$

$$\Lambda = 0.040591$$

$$\sqrt{\Lambda} = 0.20147$$

p = no. of variables
n = total d.f.
k = no. of species
q = k-1

p = 10
n = 29
k = 3
q = 2

Variance ratio for q = 2 and any p:

$$'F' = \frac{1 - \sqrt{\Lambda}}{\sqrt{\Lambda}} \times \frac{n-p-1}{p}$$ with 2p and 2(n-p-1) d.f.

$$= \frac{0.79853 \times 1.8}{0.20147}$$

$'F' = 7.134^{***}$ d.f. 20, 36.

B: Males

$$\Lambda = \frac{2.7285}{42.3525}$$

$$\Lambda = 0.064423$$

$$\sqrt{\Lambda} = 0.25381$$

$$'F' = \frac{0.74619 \times 1.8}{0.25381}$$

$'F' = 5.29^{***}$ d.f. 20, 36.

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# THE TRANSACTIONS OF THE ROYAL ENTOMOLOGICAL SOCIETY OF LONDON

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# VARIATION IN THE ADULT AND IMMATURE STAGES OF *NYSIUS HUTTONI* WHITE (HETEROPTERA: LYGAEIDAE) WITH A NOTE ON THE VALIDITY OF THE GENUS *BRACHYNYSIUS* USINGER

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With 14 Text-figures

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## I. Introduction

*Nysius huttoni* White, endemic to New Zealand, is the only species of *Nysius* recorded from that country. It was described by Buchanan White (1878) from adult specimens collected by Hutton and Wakefield. Hutton (1897) gave a brief description of the species in a list of Hemiptera then known in New Zealand. A key to the New Zealand Lygaeid genera and species is included in his paper. Myers (1926), unable to identify four species of *Nysius* other than *N. huttoni*, sent specimens to Dr. Bergroth for description, but the outcome does not appear in the literature. Usinger (1943), on examining eleven specimens of *N. huttoni*, noted such variability " in colour and even to some extent in structure that two species may be represented ". Usinger's paper comprises a history of the tribe Orsillini in New Zealand, and descriptions of five new species, including *Brachynysius convexus* Usinger, which genus he here also erected.

Evidence that *N. huttoni* occurs throughout the North and South Islands of New Zealand was given by Myers (1926), Usinger (1943), Gurr (1957) and Cumber (1959).

Alfken (1903) and Kirkaldy (1908) have both recorded it from the Chatham Islands, whilst Woodward (1954) recorded it from the Three Kings Islands.

## II. Descriptions of Stadia

*Definitions of terms used.*—The terminology follows that of Usinger (1942), except that head length and anteocular length were measured from directly above the insect when the latter was in a horizontal position. In addition, the following were measured; *legs*, each segment measured individually; *total length of forewing* and, where possible, *total length of hindwing*; and *length of hindwing exceeding posterior of abdomen*. Adult measurements are given in micrometer units: one micrometer unit = 0·24 mm.

### (1) *Imago*

*Redescription* (based on group I, larger individuals; figures 1 *A* and *B*, 2 *A* and *B*, and Table I).

*Head:* approximately two-thirds broader than long, 3·6 : 2·2; extending well beyond middle of first antennal segment; covered by a fine pubescence; eyes less than half as wide as interocular space, 0·8 : 2·0; length of eye equal to anteocular length, 1·0 : 1·0. Bucculae scarcely decreasing in height posteriorly and suddenly ending before posterior margin of head. Rostrum extending to posterior coxae, and resting in a groove on underside of head, and partially in a shallow groove on ventral surface of thorax; first segment shorter than head, 2·0 : 2·2; segments one to four 2·0 : 1·9 : 1·7 : 1·4. Antennae a little longer than twice width of head, 7·3 : 3·6; as long as head, pronotum and scutellum together, 7·3 : 7·3; segments one to four 1·2 : 2·3 : 1·7 : 2·1.

*Thorax:* pronotum almost one-third longer than head, 2·9 : 2·2; approximately as broad anteriorly as long, 3·1 : 2·9; two-thirds broader posteriorly than long, 4·9 : 2·9; sides straight; posterior edge slightly convex; punctate, but sometimes only in paler, posterior portion. Scutellum broader than long, 3·2 : 2·2; with a triradiate elevation in the centre; sometimes very sparsely punctate. Pronotum and scutellum covered by coarse hairs, but, in the female, only by a fine pubescence.

*Hemelytra:* scarcely to slightly convex; exceeding tip of abdomen by one-fourth length of membrane, 1·5 : 6·2; membrane one-seventh shorter than costal margin of corium, 6·2 : 7·2; the portion of membrane posterior to level of apices of coria approximately as long as the portion anterior to this, 3·2 : 3·0; costal margins straight but diverging almost to apex of scutellum and then arcuate. Three black blotches more or less confluent along suture between corium and membrane; embolium distinct, 0·12 mm. at greatest width; clavus and corium covered by a fine pubescence; membrane veined and opaque, but sometimes clear. Hind wings slightly shorter than fore wings, 9·6 : 10·6; usually extending a little beyond posterior of abdomen.

*Legs:* femora spotted, fore femora shorter than mid femora, mid femora shorter than hind femora, 3·0 : 3·5 : 4·6; fore tibiae shorter than mid tibiae, mid tibiae shorter than hind tibiae, 2·8 : 3·0 : 4·8; second tarsal segment shortest, 0·5; first and third tarsal segments of equal length on fore and mid legs, 0·8; but first segment longer than third on hind tarsus, 1·3 : 0·9.

*Female:* larger in general, and in particular broader across hemelytra; ovipositor cleft more than half length of abdomen.

*Size* (in mm.).—*Male:* mean length 3·74; mean width (head) 0·86; (hemelytra) 1·37. *Female:* mean length 4·00; mean width (head) 0·94; (hemelytra) 1·67.

*Colour.—Head:* black (Ostwald series II, 2 *pn*)[1] sometimes completely, but usually mid-dorsal surface lighter in colour to reddish-brown (varying in extent); eyes reddish-brown (O. IV, 5 *pl*); antennae yellowish-brown (O. VIII, 4 *lc*) on first and second segments, third and fourth segments dark brown (O. IV, 4 *pl*); rostrum black (O. II, 2 *pn*). *Pronotum:* with a densely black (O. series O, *p*) transverse band one-third total length from anterior margin; usually black (O. II, 2 *pn*) in anterior half and mainly pale buff or dull straw yellow (O. IV, 2 *gc*) in posterior half, but sometimes completely black. Scutellum black (O. II, 2 *pn*). *Hemelytra:* usually pale buff or dull straw yellow (O. IV, 2 *gc*) but sometimes variegated with black; membrane varies from pale buff to cloudy white to almost clear; three black blotches along each corial suture. *Legs:* also pale buff, femora spotted black, third tarsal segment dark brown (O. IV, 4 *pl*).

[1] Throughout the descriptions, Ostwald's *Colour Standards* (as arranged by Taylor, 1931) are referred to, and each reference is abbreviated on the pattern (O. II, 2 *pn*).

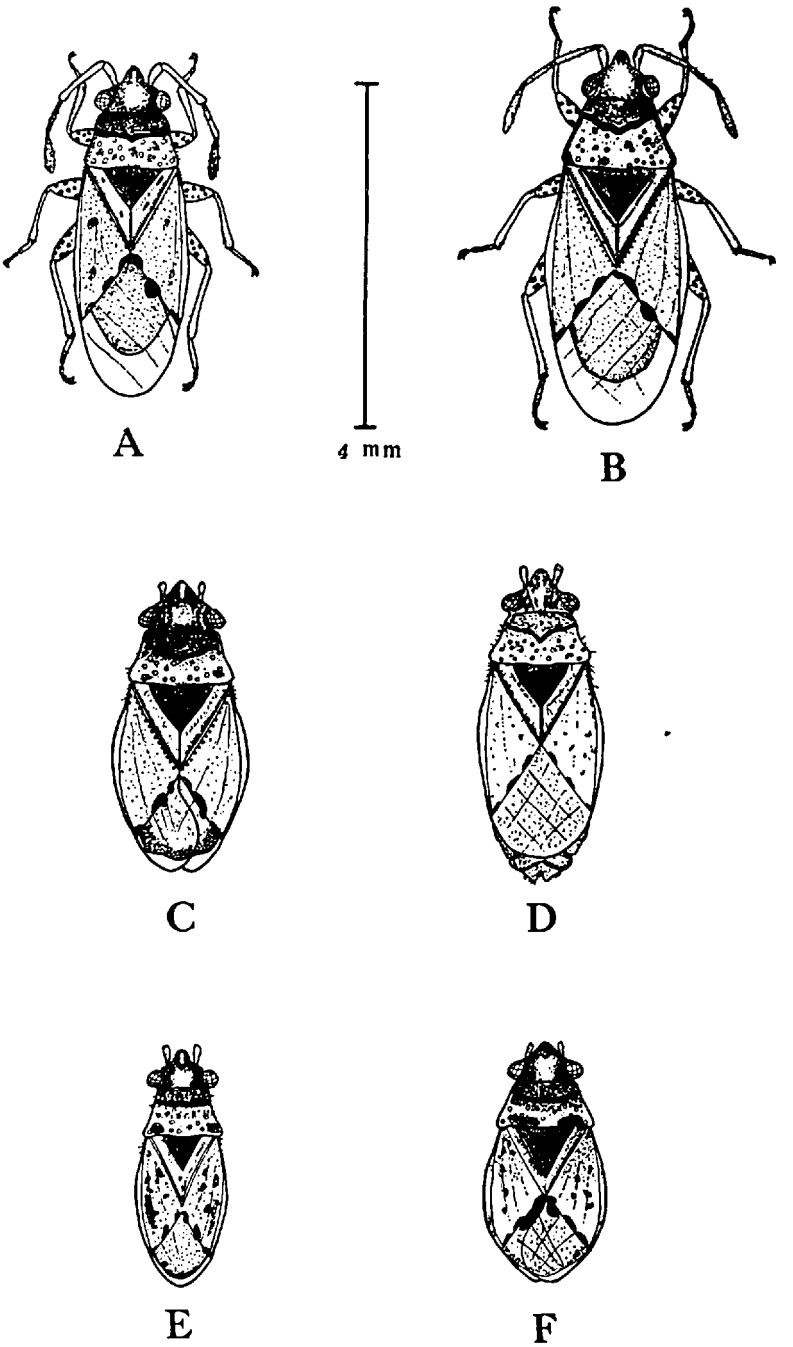



FIG. 1.—*Nysius huttoni*, adults (dorsal): (*A*) macropterous male, group I; (*B*) macropterous female, group I; (*C*) sub-brachypterous female, group II; (*D*) brachypterous female, group II; (*E*) sub-brachypterous male, group III; (*F*) sub-brachypterous female, group III.

*Plesiotype*, male (selected from a series collected by L. Gurr, Nelson, January 1950), lodged at Massey Agricultural College, New Zealand.

*Other Forms*

As no evidence of the various adult forms is given in the original description, it is desirable to mention them at this point. Variation is discussed in detail in Section III.

*N. huttoni* appears to be unique amongst the Orsillini in occurring in three forms in both sexes. These forms are: (1) macropterous, in which the wings extend beyond the posterior of the abdomen; (2) sub-brachypterous, in which the posterior of the wings is level with, or scarcely exceeds, the posterior of the abdomen; and (3) brachypterous, in which the posterior of the wings does not reach the posterior of the abdomen.

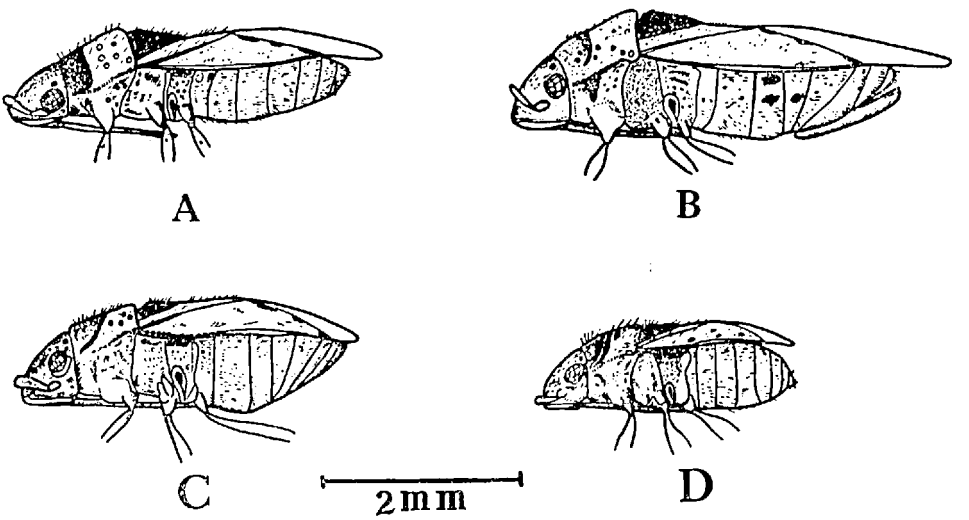



FIG. 2.—*Nysius huttoni*, adults (lateral); (*A*)-(*C*) as in fig. 1; (*D*) sub-brachypterous male, group III.

Further, what is now designated as *N. huttoni* is shown later in this paper to comprise three size groups. From the sizes given in the original description, there can be no doubt that it applies to the larger individuals, and accordingly, the redescription was made on group I individuals. The ranges of size (in millimetres) for the three groups are :—

GROUP I. LARGER INDIVIDUALS—*Male*: length 3·55–3·86; width 1·32–1·39. *Female*: length 3·74–4·34; width 1·61–1·75.

GROUP II. MEDIUM SIZED INDIVIDUALS—*Male*: length 3·00–3·48; width 1·15–1·32. *Female*: length 3·36–3·74; width 1·44–1·53.

GROUP III. SMALLER INDIVIDUALS—*Male*: length 2·38–3·00; width 0·94–1·15. *Female*: length 2·47–3·19; width 1·20–1·32.

In group I (larger individuals), the macropterous form, only, has been observed. In both group II (medium sized individuals) and group III (smaller individuals) the three forms, macropterous, sub-brachypterous and brachypterous occur. Thus there are seven differing "kinds" of individuals within the species (depending on size and wing-form). There is also considerable colour variation.

The sub-brachypterous forms are characterized by distinctly convex hemelytra, reaching or slightly exceeding the posterior of the abdomen. The membrane is

shortened, exceeding level of apices of coria by less than one-fourth the total length of the membrane. The veins on the membrane are sometimes not apparent.

Representatives from each size group are illustrated in figures 1 and 2, which also depict the three wing-forms over the total species, but not all wing-forms from each size group. Sub-brachypterous and brachypterous forms of *N. huttoni* have been lodged, by the author, at the British Museum (Nat. Hist.) and at Massey Agricultural College, New Zealand.

### (2) *Egg* (Fig. 3)

Longer than broad, ratio length to width, 3 : 1 ; slightly concave ventrally, convex dorsally and laterally ; blunt anteriorly, pointed posteriorly. Four to six papilliform micropylar processes surround cephalic pole ; no operculum or pseudoperculum ; external chorionic surface sculptured in anterior third with longitudinal grooves, almost converging at cephalic pole. *Size :* mean length 0·77 mm.; mean width 0·28 mm. *Colour* (soon after oviposition) : straw yellow (O. X, 2 *la*), darker area at cephalic pole marigold orange (O. XIV, 4 *pa*).

During incubation, the grooves or wrinkles in the chorion may extend. The colour of the freshly laid egg has been described by Gurr (1957) as " creamy white " and that of *Nysius coenosulus* Stål by Usinger (1942) as " almost water white or colourless and shining. " *N. huttoni* eggs observed at the moment of oviposition were very pale and were either (*a*) almost water white, or (*b*) a very pale yellowish-orange. The (*b*) type of colouring probably resulted from retention of the egg within the abdomen for a longer period before oviposition.

### (3) *Nymphal instars*

Table II shows the measurements from which the descriptions are taken. All nymphal measurements are in eyepiece scale divisions : one scale division = 0·063 mm. The means are from 11 first stage nymphs, 17 fifth stage nymphs (including both sexes) and 10 nymphs from each of the second, third and fourth instars.

*First nymphal instar* (fig. 3 and Table II)

*Head :* broader than long, 4·5 : 3·4 ; eyes one-fifth as wide as interocular space, 0·64 : 3·2, and approximately one-third as long as head, 1·0 : 3·4. Rostrum extending beyond posterior coxae, the first segment approximately two-thirds length of head, 2·0 : 3·4 ; total length over two-thirds length of body, 7·4 : 10·4 ; segments one to four 2·0 : 1·9 : 1·4 : 2·1. Antennae almost one and a half times as long as width of head, 6·4 : 4·5 and approximately two-thirds length of body, 6·4 : 10·4 ; segments one to four 1·0 : 1·0 : 1·6 : 2·8.

*Thorax :* pronotum almost five times broader than long, 4·5 : 1·0, slightly longer than mesonotum. Mesonotum slightly longer than metanotum. A narrow strip extending slightly on both sides of midline on pronotum, and more so on mesonotum, lacks black pigmentation. Metanotum devoid of black pigmentation except for a narrow, oblique line extending full length of segment on each side. Pleura of thorax narrow, flattened, transparent.

*Abdomen :* shorter than head and thorax together, 4 : 6 ; slightly wider than head, 5·4 : 4·5. Two distinct mid-dorsal abdominal scent gland openings intersegmentally disposed between segments four and five, and five and six. Pleura narrow, flattened, opaque. Eight abdominal segments.

*Tarsi :* two-segmented, distal segment longer than proximal, 1·8 : 0·7 (hind tarsus).

*Size* (in mm.) (when fed) : mean length 0·84 ; mean width (head) 0·28 ; (abdomen) 0·34.

*Colour*[2]*: Head :* brownish-black (O. 1V, 4 *pl*) ; seven head stripes and ecdysial suture of head, orange (O. XII, 3 *pc*) giving impression of portions not darkened ; eyes red (O. XIV, 7 *pa*) ; antennae and rostrum grey-black (O. II, 1 *li*) ; distal rostral segment black (O. series O, *n*). *Thorax :* pro- and mesonota brownish-black (O. IV, 4 *pl*), the undarkened, mid-dorsal strip, orange (O. XII, 5 *na*). Metanotum basically orange as abdomen ; two narrow, oblique, lateral, black markings extend length of segment. Pleura undarkened, as abdomen. Ventral thorax :

[2] At eclosion, the nymph is pale orange in colour, but darkening occurs gradually over a period of seven hours until definitive coloration (as described above) is assumed.

TABLE I.—*Body Measuremen*

(All measurements are in micrometer units : one micrometer unit = 0·24 mm

| | Head length | Head width | Inter-ocular width | Eye width | Ante-ocular length | Eye length | Rostral segments 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Males* | | | | | | | | | | |
| Mean . | 2·2 | 3·6 | 2·0 | 0·8 | 1·0 | 1·0 | 2·0 | 1·9 | 1·7 | 1·4 |
| Range . | 2·0–2·4 | 3·5–3·8 | 1·9–2·0 | 0·8–0·9 | 1·0–1·1 | 1·0–1·1 | 1·9–2·1 | 1·8–2·0 | 1·5–1·8 | 1·2–1 |
| S.D. . | 0·18 | 0·12 | 0·05 | 0·05 | 0·07 | 0·07 | 0·07 | 0·10 | 0·14 | 0·20 |
| *Females* | | | | | | | | | | |
| Mean . | 2·2 | 3·9 | 2·4 | 0·8 | 1·2 | 1·1 | 2·1 | 1·7 | 1·5 | 1·5 |
| Range . | 2·0–2·5 | 3·8–4·0 | 2·3–2·4 | 0·8 | 1·0–1·3 | 1·0–1·1 | 2·0–2·2 | 1·5–2·0 | 1·4–1·7 | 1·4–1 |
| S.D. . | 0·21 | 0·11 | 0·07 | 0 | 0·07 | 0·07 | 0·01 | 0·20 | 0·13 | 0·10 |

| | Hemelytra: Length of membrane: Total | Beyond apices of coria | Beyond abdomen | Length of corium | Total wing length | Hindwings: Total wing length | Length beyond abdomen | Femora: Fore | Mid | Hi |
|---|---|---|---|---|---|---|---|---|---|---|
| *Males* | | | | | | | | | | |
| Mean . | 6·2 | 3·2 | 1·5 | 7·2 | 10·6 | 9·6 | 0·4 | 3·0 | 3·5 | 4·6 |
| Range . | 5·8–6·6 | 2·5–3·7 | 0·8–1·9 | 6·8–7·8 | 9·9–11·0 | 9·4–9·7 | 0·3–0·4 | 2·8–3·1 | 3·2–3·6 | 4·2–5 |
| S.D. . | 0·31 | 0·50 | 0·38 | 0·41 | 0·46 | 0·31 | 0·31 | 0·11 | 0·16 | 0·28 |
| *Females* | | | | | | | | | | |
| Mean . | 6·9 | 3·6 | 1·7 | 8·3 | 11·5 | 10·3 | 1·0 | 3·2 | 3·5 | 5·2 |
| Range . | 6·5–7·8 | 3·0–4·2 | 1·4–1·9 | 7·9–9·0 | 10·2–12·8 | 9·7–10·8 | 0·7–1·3 | 3·0–3·5 | 3·2–3·7 | 4·9–5 |
| S.D. . | 0·50 | 0·49 | 0·20 | 0·41 | 1·05 | 0·55 | 0·44 | 0·21 | 0·19 | 0·24 |

subcoxal plates, only, darkened ; rest orange. Legs lighter than head, grey-black (O. II, 1 *li*). *Abdomen :* basically orange (O. XII, 5 *na*) ; abdominal scent gland openings dark ; three red (O. XIV, 6 *pa*) spots occur on dorsum, two laterally, and one towards anus ; anus black (O. series O, *n*).

*Second nymphal instar* (fig. 3 and Table II)

*Head :* broader than long, 6·4 : 5·0 ; eyes approximately one-fourth as wide as interocular space, 1·0 : 4·4, and approximately one-third as long as head, 1·5 : 5·0. Rostrum extending beyond posterior coxae, the first segment one half length of head, 2·5 : 5·0 ; total length almost half length of body, 9·8 : 19·5 ; segments one to four 2·5 : 2·5 : 2·0 : 2·8. Antennae one and a third times as long as width of head, 8·4 : 6·4 ; less than half length of body, 8·4 : 19·5 ; segments one to four 1·6 : 1·7 : 1·8 : 3·3.

*Thorax :* pronotum slightly longer than mesonotum ; broader than long ; broader posteriorly than anteriorly ; sides straight or slightly arcuate, rounded posteriorly. Metanotum approximately same length as mesonotum ; black pigmentation slightly extended on first stage, two semi-lunar patches visible on each side, reaching to one half to two-thirds length of metanotum. Black pigmentation absent from narrow strip on midline of pro- and mesonota. Pleura of thorax narrow, flattened, transparent. Femora longer than tibiae, 4 : 3 ; tarsi two-jointed, possessing bi-lobed ampullae ; proximal segment shorter than distal, 1·0 : 1·9 (hind tarsus).

*Abdomen :* same length as head and thorax together, 10 : 10 ; one and a half times as wide as head, 9·8 : 6·4. Two distinct mid-dorsal scent gland openings intersegmentally disposed between segments four and five, and five and six. Pleura narrow, flattened, opaque. Eight abdominal segments.

Nysius huttoni *Adults*

ıe measurements were taken on 5 males and 5 females)

| Antennal segments | | | | Pronotum | | | Scutellum | | Body | Body |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Width | | | | | |
| 1 | 2 | 3 | 4 | Length | An-terior | Pos-terior | Length | Width | length | width |
| ·2 | 2·3 | 1·7 | 2·1 | 2·9 | 3·1 | 4·9 | 2·2 | 3·2 | 15·6 | 5·7 |
| ·0–1·4 | 2·0–2·5 | 1·6–2·0 | 1·8–2·3 | 2·6–3·0 | 3·1–3·2 | 4·8–5·0 | 2·0–2·5 | 3·0–3·4 | 14·8–16·1 | 5·5–5·8 |
| ·14 | 0·19 | 0·17 | 0·24 | 0·17 | 0·10 | 0·10 | 0·20 | 0·19 | 0·50 | 0·12 |
| ·2 | 2·3 | 1·8 | 2·2 | 3·1 | 3·6 | 5·7 | . | . | 16·7 | 6·9 |
| ·2–1·3 | 2·0–2·6 | 1·7–1·8 | 2·2–2·3 | 3·0–3·4 | 3·3–3·9 | 5·4–5·9 | . | . | 15·6–18·1 | 6·7–7·3 |
| ·07 | 0·22 | 0·07 | 0·07 | 0·20 | 0·25 | 0·20 | . | . | 0·90 | 0·24 |

| Tibiae | | | Tarsi | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fore | | | Mid | | | Hind | | |
| Fore | Mid | Hind | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 8 | 3·0 | 4·8 | 0·8 | 0·5 | 0·8 | 0·8 | 0·4 | 0·7 | 1·3 | 0·5 | 0·9 |
| 3–3·3 | 2·7–3·5 | 4·0–5·4 | 0·7–0·8 | 0·4–0·5 | 0·7–0·9 | 0·7–0·9 | 0·4–0·5 | 0·5–0·8 | 1·1–1·5 | 0·4–0·6 | 0·8–0·9 |
| 40 | 0·32 | 0·52 | 0·05 | 0·05 | 0·10 | 0·10 | 0·05 | 0·12 | 0·17 | 0·071 | 0·071 |
| 0 | 3·4 | 5·5 | 0·8 | 0·4 | 0·7 | 0·8 | 0·4 | 0·8 | 1·6 | 0·5 | 0·9 |
| ·9–3·2 | 3·0–3·7 | 4·9–6·0 | 0·6–1·0 | 0·4–0·5 | 0·5–0·9 | 0·7–1·0 | 0·4–0·5 | 0·7–0·9 | 1·2–1·8 | 0·5–0·7 | 0·7–1·3 |
| ·11 | 0·28 | 0·46 | 0·17 | 0·05 | 0·19 | 0·12 | 0·071 | 0·10 | 0·26 | 0·10 | 0·24 |

*Size* (in mm.): mean length 1·23; mean width (head) 0·40; (abdomen) 0·62.

*Colour :* anterior half of body similar to first stage except that black pigmentation on metanotum has extended. Pleura transparent to pale grey (O, IV, 1 *ea*), flattened. *Abdomen :* dorsal surface basically dirty orange (O. XIV, 3 *pa*), offset by markings of red and white; red spots arranged irregularly; scent gland openings black; pleura grey. Ventral surface lacks markings except for lateral red streaks, black edges of two segments anterior to anus, and portions of viscera showing through cuticle. Anus black (O. II, 2 *pn*).

*Third nymphal instar* (fig. 3 and Table II)

*Head :* almost one-third again as broad as long, 8·0 : 5·6 ; eyes a little more than one-fourth as wide as interocular space, 1·4 : 5·1, and a little longer than one-third length of head, 2·0 : 5·6. Rostrum reaching posterior coxae, the first segment approximately two-thirds length of head, 3·3 : 5·6 ; total length approximately half length of body, 11·8 : 23·0 ; segments one to four 3·3 : 3·0 : 2·3 : 3·2. Antennae longer than width of head, 10 : 8 ; not quite half length of body, 10 : 23 ; segments one to four 2·0 : 2·0 : 2·1 : 3·9.

*Thorax :* pronotum broader than long ; broader posteriorly than anteriorly ; strongly convex dorsally ; sides straight, rounded anteriorly and posteriorly. Pronotum longer than mesonotum, mesonotum longer than metanotum, 3 : 2 : 1. A dark black line now present across centre of pronotum. Black pigmentation absent from narrow strip on midline of pro-and mesonota. First signs of wing pad development appear as slight, rounded, laterally disposed projections on posterior margins of meso- and metanota, but less obvious on metanotum. Black pigmentation on metanotum further extended than in second stage, now bicornuate and almost reaching posterior of segment. Pleura narrow, flattened, opaque.

TABLE II.—*Body Measurement*

(All measurements are in eyepiece scale divisions

| | Head length | Head width | Inter-ocular width | Eye width | Ante-ocular length | Eye length | Rostral segments 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| *First stage nymphs* | | | | | | | | | | |
| Mean . | 3·4 | 4·5 | 3·2 | 0·64 | . | 1·0 | 2·0 | 1·9 | 1·4 | 2·1 |
| Range | 3·0–4·0 | 4·2–5·0 | 3·0–3·5 | 0·5–0·8 | . | 1·0 | 1·7–2·1 | 1·5–2·0 | 1·0–1·7 | 2·0–2· |
| S.D. . | 0·42 | 0·18 | 0·21 | 0·10 | . | 0 | 0·13 | 0·16 | 0·20 | 0·20 |
| *Second stage nymphs* | | | | | | | | | | |
| Mean . | 5·0 | 6·4 | 4·4 | 1·0 | . | 1·55 | 2·5 | 2·5 | 2·0 | 2·8 |
| Range | 4·0–5·9 | 6·0–6·6 | 4·0–4·6 | 1·0 | . | 1·2–1·9 | 2·4–2·7 | 2·0–2·6 | 1·8–2·0 | 2·5–3· |
| S.D. . | 0·60 | 0·21 | 0·21 | 0 | . | 0·22 | 0·075 | 0·31 | 0·082 | 0·17 |
| *Third stage nymphs* | | | | | | | | | | |
| Mean . | 5·6 | 8·0 | 5·1 | 1·4 | . | 2·0 | 3·3 | 3·0 | 2·3 | 3·2 |
| Range | 4·7–6·5 | 7·8–8·1 | 5·0–5·5 | 1·2–1·6 | . | 1·8–2·2 | 3·0–3·6 | 2·8–3·2 | 2·0–2·5 | 3·0–3· |
| S.D. . | 0·59 | 0·11 | 0·21 | 0·16 | . | 0·11 | 0·25 | 0·12 | 0·24 | 0·25 |
| *Fourth stage nymphs* | | | | | | | | | | |
| Mean . | 6·9 | 10·6 | 6·5 | 2·0 | 3·9 | 2·7 | 4·8 | 4·0 | 3·0 | 4·0 |
| Range | 6·0–8·5 | 10·0–11·3 | 6·0–7·0 | 2·0–2·2 | 3·5–5·0 | 2·5–3·0 | 4·0–5·0 | 3·5–4·4 | 3·0–3·3 | 3·5–4· |
| S.D. . | 0·90 | 0·52 | 0·50 | 0·082 | 0·53 | 0·23 | 0·33 | 0·23 | 0·10 | 0·30 |
| *Fifth stage nymphs* | | | | | | | | | | |
| Mean . | 8·3 | 12·4 | 7·9 | 2·2 | 4·5 | 3·1 | 6·0 | 5·3 | 4·1 | 4·7 |
| Range | 6·0–11·5 | 11·2–13·0 | 7·0–9·0 | 1·8–2·8 | 4·0–5·8 | 2·9–3·5 | 5·2–7·0 | 4·0–6·0 | 3·5–5·0 | 4·0–5· |
| S.D. . | 1·76 | 0·65 | 0·60 | 0·33 | 0·62 | 0·197 | 0·40 | 0·51 | 0·38 | 0·38 |

*Fifth stage*—continued

| | Mesonotum width | Metanotum length at middle | Pronotum Length | Pronotum Width (posterior) | Length of foreleg Femur | Tibia | Tarsus 1 | Tarsus 2 |
|---|---|---|---|---|---|---|---|---|
| Mean . | 20·0 | 1·3 | 7·0 | 15·7 | 7·4 | 7·7 | 2·0 | 4·0 |
| Range | 14·6–24·0 | 1·0–1·8 | 6·0–8·0 | 13·5–19·0 | 6·0–8·0 | 7·0–8·4 | 1·8–2·5 | 3·8–4· |
| S.D. . | 2·27 | 0·27 | 0·57 | 1·52 | 0·65 | 0·45 | 0·15 | 0·087 |

*Abdomen :* slightly shorter than head and thorax together, 10·8 : 12·1 ; one-third again as wide as head, 11·8 : 8·0. Dorsal abdominal scent gland openings, and pleura as in first stage. Eight abdominal segments.

*Tarsi :* proximal segment to distal segment, 1·5 : 2·5 (hind tarsus).

*Size* (in mm.): mean length 1·5; mean width (head) 0·5; (abdomen) 0·74.

*Colour. Head :* black (O. II, 2 *pm*) ; seven head stripes and ecdysial suture of head, orange (O. XII, 3 *pc*) ; eyes dark red ; antennae, rostrum and underside of head, lighter than dorsal surface of head, brownish-black (O. IV, 2 *pl*). *Thorax* : pro-and mesonota and pigmentation on metanotum, black (O. II, 2 *pm*) ; a dense black line across centre of pronotum ; undarkened mid-dorsal strip, orange (O. XII, 3 *pc*) ; remainder of metanotum as abdomen ; pleura pale grey (O. IV, 1 *ea*) ; coxae and subcoxal plates black (O. II, 2 *pm*) ; remainder of ventral thorax, pale orange to grey (O. II, 1 *ge*) ; legs brownish-black, (O. IV, 2 *pl*). *Abdomen :* white spots surrounded by red (O. XII, 7 *pc*) spots, extending almost length of segment, are regularly arranged in a row across each segment. Background colour, still orange, is paler than these markings. Dorsal pleura marked by one red (O. XII, 7 *pc*) bar along centre of each segment, whilst two parallel red bars occur ventrally on each segment. Dorsal scent gland openings black ; two light

f Nysius huttoni *Nymphs*

ne scale division = 0·063 mm.)

| Antennal segments | | | | Body length | | Abdomen width | | Length of mesonotum | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | Unfed | Fed | Unfed | Fed | At middle | To tip of wing pad |
| ·0 | 1·0 | 1·6 | 2·8 | 10·4 | 13·4 | 5·0 | 5·4 | . | . |
| ·0 | 1·0–1·1 | 1·5–1·7 | 2·5–3·0 | 9·5 – | 14·5 | 4·0 – | 6·0 | . | . |
| | 0·045 | 0·071 | 0·16 | 0·66 | 0·82 | 0 | 0·82 | . | . |
| | | | | | Fed | | Fed | | |
| ·6 | 1·7 | 1·8 | 3·3 | | 19·5 | | 9·8 | . | . |
| ·4–1·8 | 1·6–1·8 | 1·7–1·9 | 3·0–3·7 | | 18–22 | | 9–11 | . | . |
| ·14 | 0·094 | 0·057 | 0·25 | | 1·44 | | 0·86 | . | . |
| ·0 | 2·0 | 2·1 | 3·9 | | 23·0 | | 11·8 | . | . |
| ·8–2·0 | 1·8–2·5 | 2·0–2·5 | 3·4–4·1 | | 18–25 | | 10–14 | . | . |
| ·067 | 0·19 | 0·18 | 0·21 | | 2·55 | | 1·51 | . | . |
| ·7 | 3·5 | 3·0 | 5·3 | | 32·5 | | 17·4 | 3·8 | 6·0 |
| ·4–3·0 | 3·0–4·0 | 2·5–3·6 | 5·0–5·9 | | 28–38 | | 15–20·5 | 3·0–4·5 | 5·0–7·2 |
| ·22 | 0·41 | 0·31 | 0·33 | | 3·00 | | 1·62 | 0·51 | 0·75 |
| ·8 | 5·1 | 4·0 | 6·5 | | 40 | | 19·7 | 6·5 | 13·3 |
| ·0–4·0 | 4·5–6·0 | 3·5–4·5 | 6·0–7·7 | | 36–47 | | 15–27 | 5·1–8·0 | 11·7–16·0 |
| ·32 | 0·46 | 0·26 | 0·45 | | 2·95 | | 2·74 | 0·75 | 1·01 |

| Length of midleg | | | | Length of hindleg | | | |
|---|---|---|---|---|---|---|---|
| emur | Tibia | Tarsus 1 | Tarsus 2 | Femur | Tibia | Tarsus 1 | Tarsus 2 |
| ·9 | 7·8 | 2·2 | 3·9 | 10·0 | 10·9 | 3·0 | 4·2 |
| ·0–9·0 | 7·0–9·0 | 2·0–3·5 | 3·8–4·0 | 9·0–12·0 | 9·8–12·0 | 2·6–4·0 | 4·0–4·8 |
| ·68 | 0·54 | 0·39 | 0·10 | 0·77 | 0·72 | 0·27 | 0·28 |

fawn areas approximately one segment in diameter surround them; a dark line on each side of anterior scent gland opening. Anus black (O. II, 2 *pn*); two segments immediately anterior to anus, blackened on mid-ventral edges.

*Fourth nymphal instar* (fig. 3 and Table II)

*Head :* more than one-third again as broad as long, 10·6 : 6·9 ; eyes almost one-third as wide as interocular space, 2·0 : 6·5 ; eye length approximately three-fourths anteocular length, 2·7 : 3·9 and approximately one-third length of head, 2·7 : 6·9. Rostrum extending to posterior coxae, and resting, partially, in a very shallow groove on ventral surface of head and thorax ; the first segment a little over two-thirds length of head, 4·8 : 6·9 ; total length almost half length of body, 15·8 : 32·5 ; segments one to four 4·8 : 4·0 : 3·0 : 4·0. Antennae almost one and a half times as long as width of head, 14·5 : 10·6 ; less than half length of body, 14·5 : 32·5 ; segments one to four 2·7 : 3·5 : 3·0 : 5·3.

*Thorax :* pronotum broader than long ; broader posteriorly than anteriorly ; sides arcuate, rounded posteriorly ; posterior edge may be slightly sinuate or straight ; slightly convex. Mesonotum at middle, four-fifths length of pronotum, 3·8 : 4·8 ; posterior margin between hemelytral

pads at middle, arcuate. Length of mesonotum laterally to tip of mesonotal wing pad, one half as long again as mesonotum at middle, 6·0 : 3·8. Wing pad development considerably advanced on third stage ; mesonotal pads overlap metanotal pads except at inner bases and sides ; extending usually one-third to one half length of first abdominal segment. Metanotum very short at middle, black pigmentation extended over wing pads but absent at middle.

*Abdomen :* slightly shorter than head and thorax together, 16·0 : 16·4 ; almost one and three-fourths times width of head, 17·4 : 10·6. Scent gland openings and pleura as in earlier stages. Eight abdominal segments.

*Size* (in mm.) *:* mean length 2·05 ; mean width (head) 0·67 ; (abdomen) 1·10.

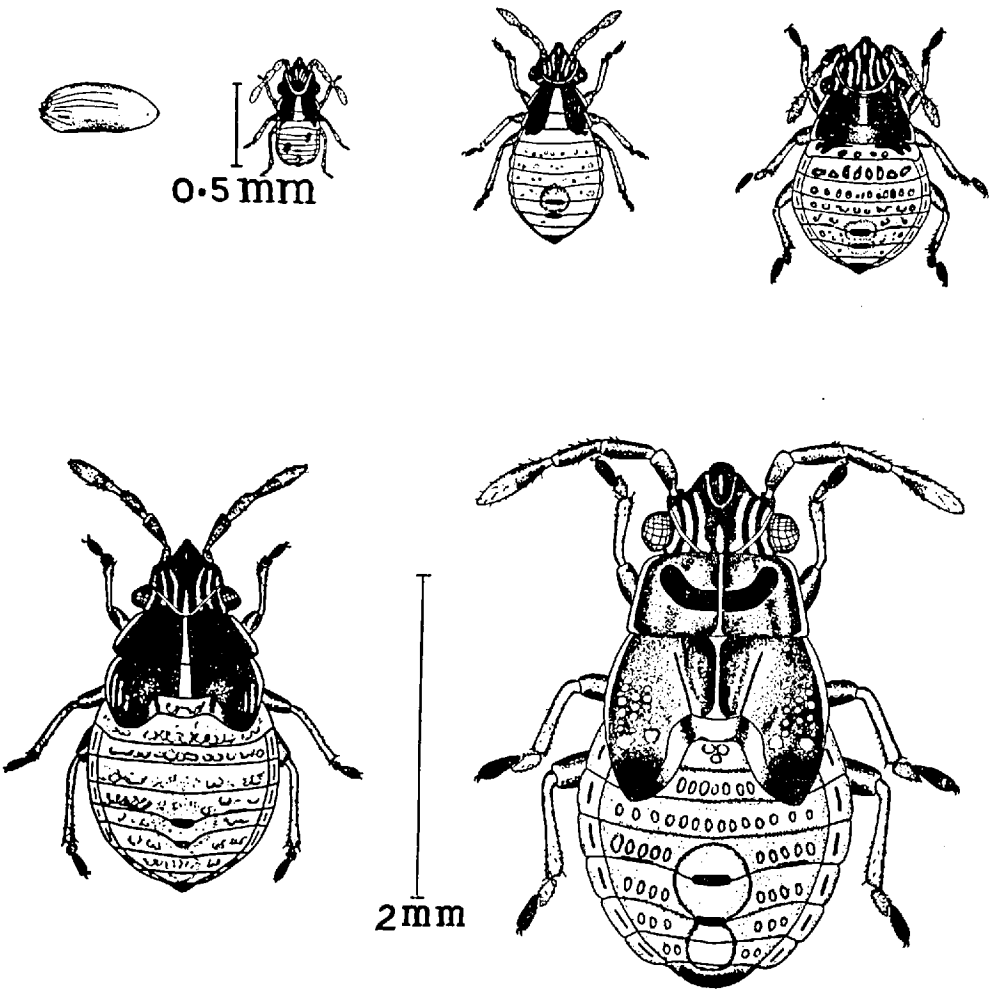



FIG. 3.—*Nysius huttoni* : egg and nymphal instars.

*Colour : Head :* black (O. II, 2 *pn*) ; seven head stripes and ecdysial suture of head, pale orange to yellow (O. VI, 3*ic*) ; eyes brownish-red (O. VIII, 6 *pg*) ; antennae black, white bands at joints, distal half of fourth segment brown. Rostrum orange-brown (O. X, 4 *pc*), fourth segment black. *Thorax* : except for mid-dorsal strip and portion of metanotum between wing pads, black (O. II, 2 *pn*) ; dark band across centre of pronotum densely black (O. series O, *p*) ; narrow, pale orange (O. VI, 3 *ic*) mid-dorsal strip on thorax ; two or three similar coloured lengthwise strips on mesonotal wing pads, and one on each metanotal wing pad ; pleura pale grey, almost transparent (O. series O, *e*) ; legs dark brown. *Abdomen :* mainly a dirty orange (O, X, 3 *nc*) ; red (O. XII, 7 *pc*) markings;

many have extended laterally to enclose parts of the whitish or pale grey background colour, resulting in a row of white spots with red borders; such markings confined to posterior half of each segment. Dorsal abdominal scent gland openings black; a dark line on each side of anterior opening (as in third and fifth instars). A circular area, reddish throughout, radiates from anterior scent gland opening to middle of third segment anteriorly, and anterior of sixth segment posteriorly; a smaller brown-edged circular area extends from posterior scent gland opening to anus. Pleura flattened, each segment marked by one red (O. XII, 7 *pc*) bar dorsally, and two parallel red bars ventrally. Ventral abdominal surface now marked similar to dorsal surface, but sometimes the red markings are orientated lengthwise across, and not along, the segments; anus black; segments six to eight black on ventral edges.

*Fifth nymphal instar* (fig. 3 and Table II)

*Head:* half again as broad as long, 12·4 : 8·3; eyes a little more than one-fourth as wide as interocular space, 2·2 : 7·9; length of eye almost three-fourths anteocular length, 3·1 : 4·5, and more than one-third length of head, 3·1 : 8·3. Rostrum extending to posterior coxae, and resting, partially in a shallow groove on ventral surface of head and thorax; the first segment three-fourths length of head, 6·0 : 8·3; total length half length of body, 20 : 40; segments one to four 6·0 : 5·3 : 4·1 : 4·7. Antennae one and a half times as long as width of head, 19·4 : 13·0; a little less than half length of body, 19·4 : 40·0; segments one to four 3·8 : 5·1 : 4·0 : 6·5.

*Thorax:* pronotum more than twice as broad at posterior as long, 15·7 : 7·0; sides straight, rounded anteriorly and flaring posteriorly to humeral angles; posterior edge may be sinuate or straight; slightly convex. Mesonotum at middle a little shorter than pronotum, 6·5 : 7·0; posterior margin between hemelytral pads at middle, arcuate. Length of mesonotum laterally to tip of mesonotal wing pad, twice as long as mesonotum at middle, 13·3 : 6·5. Mesonotal pads overlay metanotal pads, except at inner bases and sides, so that tips of both are level and extend, usually, to posterior of second or third abdominal segment. Metanotum at middle short, one fifth as long as mesonotum at middle, 1·3 : 6·5. Legs: forefemora shorter than midfemora, midfemora shorter than hindfemora, 7·4 : 7·9 : 10·0; foretibiae shorter than midtibiae, midtibiae shorter than hindtibiae, 7·7 : 7·8 : 10·9; tarsi two-jointed, second segment longer than first; foretarsus one shorter than midtarsus one, midtarsus one shorter than hindtarsus one, 2·0 : 2·2 : 3·0; foretarsus two longer than midtarsus two, but shorter than hindtarsus two, 4·0 : 3·9 : 4·2.

*Abdomen:* approximately three-fourths length of head and thorax together, 16·9 : 23·1; one and a half times width of head, 19·7 : 12·4. Two mid-dorsal abdominal scent gland openings intersegmentally disposed between segments four and five, and five and six; a dark line occurs laterally on each side of anterior scent gland. Pleura narrow, flattened, opaque. Eight abdominal segments, the eighth tergum platelike, projecting slightly beyond anus. *Ventral abdomen (male):* sternites seven and eight darkened on mid-ventral line; external genitalia not evident. *Ventral abdomen (female):* sternites six, seven and eight darkened on mid-ventral region, sternite six sometimes darkened on one border only; external genital rudiments evident as more heavily pigmented area on mid-ventral line of segments seven and eight.

*Size* (in mm.): mean length 2·52; mean width (head) 0·78; (abdomen) 1·24.

*Colour: Head:* black (O. II, 2 *pn*), seven dorsal head stripes and ecdysial suture of head pale orange to pale grey (O. II, 1 *ca*); eyes reddish-brown (O. IV, 6 *pl*); ventral surface of head dark brown to black except for white bases of antennae and a light grey (O. series 0, *e*) area under eyes; antennae dark brown almost black, white bands at joints of segments, distal half of fourth segment lighter brown. Rostrum dark brown almost black, fourth segment black. *Thorax:* black (O. II, 2 *pn*), not a deep black but denser on tips of wing pads; dark band across centre of pronotum densely black (O. series 0, *p*); in places lighter pinkish to pale grey (O. II, 1 *ca*) markings on wing pads; narrow mid-dorsal, thoracic ecdysial suture line, white to pale grey (O. II, 1 *ca*)—this strip, wider in earlier instars, is here reduced to a line; pleura pale grey (O. II, 1 *ca*). Legs: coxae and subcoxal plates black (O. II, 2 *pa*); trochanters dark brown; femora dark brown, tibiae lighter brown, proximal tarsal segment dark brown, distal tarsal segment black. *Abdomen:* to naked eye appears grey-brown but on closer examination appears mainly red; background colour of dorsal segments greyish-blue (O. II, 14 *ge*); white spots in a row across each segment, each spot surrounded by a red (O. XII, 7 *pc*) border; abdominal scent gland openings black (O. II, 2 *pn*); a dark line on each side of anterior scent gland; a dark edged circular area lighter in interior, encircles anterior scent gland opening and extends from segment four to segment six; a similar coloured but smaller circular area extends from posterior scent gland opening to terminal segment; eighth tergite black (O. II, 2 *pn*); pleura flattened, white to grey (O. II, 1 *ca*), each

segment marked by one red (O. XII, 7 *pc*) bar dorsally and two parallel red bars ventrally. Ventral surface of abdomen similar in colour to dorsal surface except that background more of a bluish or greenish tinge, and white spots and red markings not as regular. Mid-ventral markings on segments six to eight in females, and seven and eight in males, dark brown to black.

From the foregoing descriptions it is seen that each nymphal instar is readily distinguished by size, by characteristic black pigmentation on the metanotum in the first three instars, and by wing pad development in the fourth and fifth instars.

## III. Variation within the Species

### (1) *Immature stages*

(a) *Egg dimensions*

A total of 176 eggs were measured under a Zeiss low power stereoscopic microscope, using an eyepiece scale (one scale division = 0·063 mm.). Because of the shape

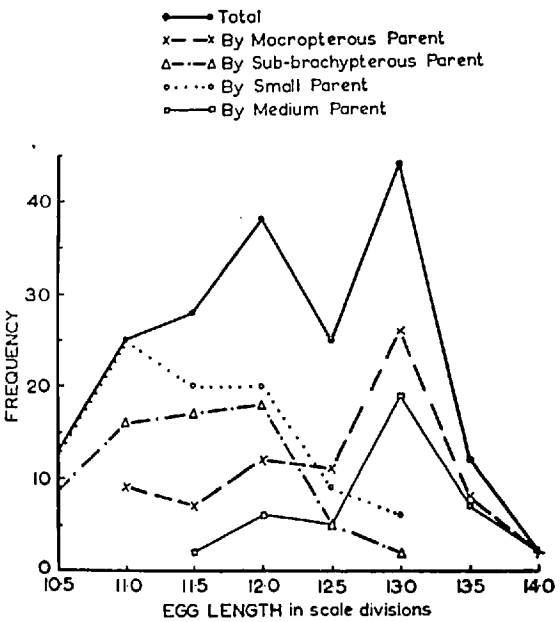



Fig. 4.—*Nysius huttoni*: distribution of egg length.
(Measurements are in eye-piece scale divisions: one scale division = 0·063 mm.)

of the egg, it was necessary to take three measurements of length and width on each. Most of the eggs were measured either on the day of oviposition or the following day, but it was found that even after one week there was no change in egg dimensions.

*Length.*—The mean length, 0·77 mm., was obtained by averaging the means of the three measurements taken on individual eggs. The distribution of egg length is shown in figure 4.

The total distribution was not normal. As macropterous and sub-brachypterous, and medium sized and smaller individuals were present among the females which laid the eggs, this then prompted two reclassifications of the data into (i) wing-form, and (ii) body size, of the maternal parents.

(i) *Individuals differing in wing-form.*—The eggs laid by the sub-brachypterous females seemed, in the main, to be smaller than those laid by macropterous females, but the latter's eggs still showed a bimodal distribution which overlapped the sub-brachypterous distribution. The means of these (so called) two groups differed

by one scale division, or 0·063 mm. The mean length of eggs laid by the sub-brachypterous females was (in scale divisions), 11·5 ± 0·75, whereas the corresponding figure for eggs laid by the macropterous females was 12·5 ± 0·63. However, this arbitrary division into two groups differing in wing-form is unsatisfactory because of the overlap, and does not explain the bimodality.

(ii) *Individuals differing in size.*—The eggs laid by the smaller females fell into a separate group from those laid by the medium sized females. There was less overlap, and a more marked modal peak for each population. The means of the two groups differed by 1·4 scale divisions, or 0·088 mm. The mean egg length (in scale divisions) of the smaller and medium sized females was, respectively, 11·4 ± 0·67, and 12·8 ± 0·60. The division into two groups according to size of adults compared with the division into two groups according to wing-form, gave a greater difference between the group means, a lesser difference between their standard deviations, and a better explanation of the bimodal graph for total eggs.

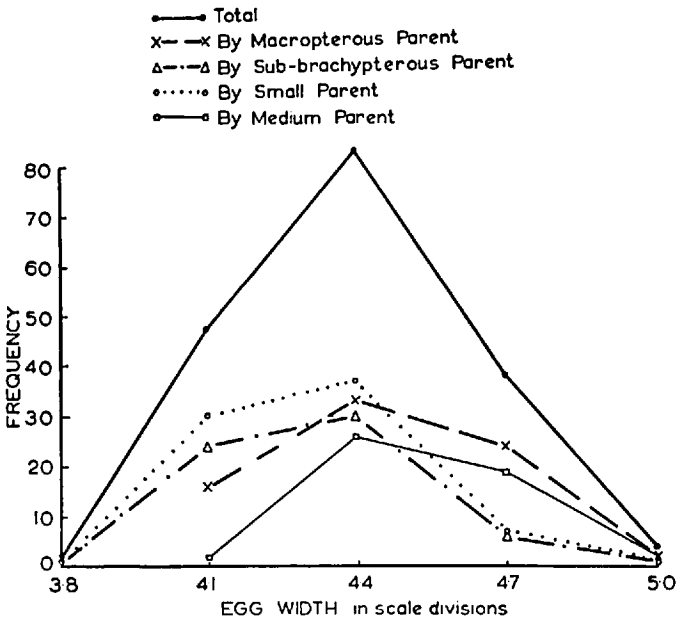



FIG. 5.—*Nysius huttoni :* distributions of egg width.
(Measurements are in eye-piece scale divisions : one scale division = 0·063 mm.)

*Width.*—The mean egg width, 0·28 mm., was obtained by averaging the means of the three measurements taken on individual eggs. The data on egg width (*see* fig. 5) received the same treatment as that on egg length. The total distribution was normal, and the mode of all five graphs was the same, but the graphs for eggs laid by the smaller and medium sized females tended to separate out, thus supporting the more noticeable difference shown in egg length. Because of the small width of an egg (mean 0·28 mm.) and the small total range (3·5–5·0 scale divisions) it is considered that the difference shown, which seems slight, has some importance.

(b) *Progression in Growth*

Dyar (as mentioned by Usinger, 1942) suggested that the sclerotized parts of the insect body increase in size in a more or less regular geometrical progression during successive instars, there being a growth factor for each species representing the

increase in size at each moult. Przibram (Przibram and Megusar, 1912) has extended this principle and gives a theoretical progression factor of 1·26 (the cube root of 2) for insects in general.

Head widths of 100 nymphs of each instar were measured, and the frequency distributions are shown in figure 6. The five instars were shown to be distinct, but there was some overlapping of the third and fourth, and fourth and fifth instars. There was more spread in the fourth instar and still greater spread in the fifth instar which exhibited a trimodal curve. A sex difference was expected because in the adults males are smaller than females, but clearly more than a sex difference is represented. For *N. coenosulus*, a bimodal distribution in the fifth nymphal instar was demonstrated by Usinger (1942). Although he could not distinguish their sex, he attributed the double peak to a sex difference. The author was able to distinguish the sex of fifth stage *N. huttoni* nymphs and considers that the trimodal curve may indicate three size groups.

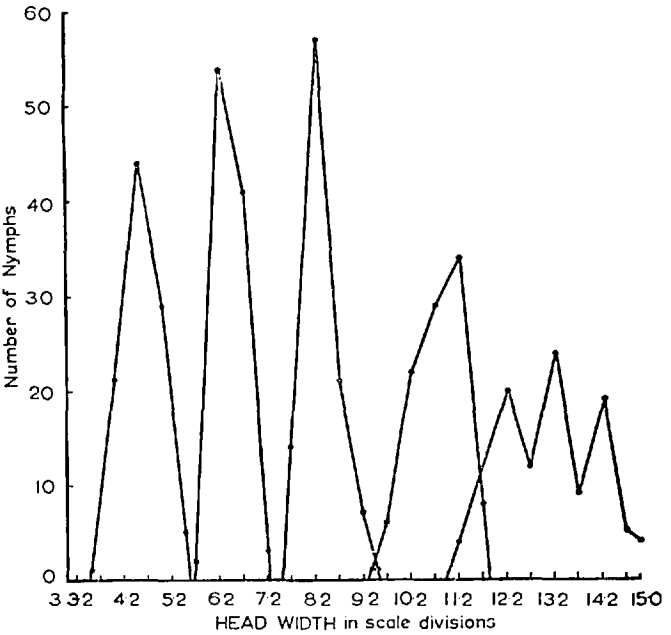



FIG. 6.—*Nysius huttoni*: distribution of head width showing the five nymphal instars. (Measurements are in eye-piece scale divisions: one scale division = 0·063 mm.)

At this stage it was necessary to determine whether or not a sex difference was involved. For the fifth nymphal instar description, body measurements were taken on nine males and eight females. There were slight size differences between the sexes in most characters. To elucidate this, analyses of variance were applied to four main characters, *viz.* head width, length of mesonotum at middle, width of mesonotum and width of pronotum. In the first three characters no significant differences between the sexes could be demonstrated. For width of pronotum there was a difference between the sexes, significant at the 5 per cent. level. The trimodal graph (which was drawn on head width data) is clearly not influenced by a sex difference and is regarded as representing three size groups.

By dividing the mean head width for each instar by that of the previous instar, the growth ratio between any two successive instars was obtained. The calculation of the mean growth ratio for *N. huttoni* is shown in Table III. Usinger (1942),

TABLE III.—*Calculation of mean growth ratio for* Nysius huttoni

(One scale division = 0·063 mm.)

| Instars | Mean head widths (in scale divisions) | | Growth ratio |
|---|---|---|---|
| 2nd / 1st | 6·3 / 4·5 | | 1·40 |
| 3rd / 2nd | 8·2 / 6·3 | | 1·30 |
| 4th / 3rd | 10·7 / 8·2 | | 1·30 |
| 5th / 4th | 13·1 / 10·7 | | 1·22 |
| Mean growth ratio for nymphal stages | | | 1·31 |
| Adult / 5th | Adult ♂ / 5th ♂ | 13·3 / 12·1 = 1·10 | 1·11 |
| | Adult ♀ / 5th ♀ | 14·0 / 12·6 = 1·11 | |
| Overall mean growth ratio from first instar to adult | | | 1·266 |

working on *N. coenosulus* nymphs, obtained a mean growth ratio of 1·38 which is near Przibram's theoretical progression factor of 1·26. With *N. huttoni* the mean growth ratio for the nymphal stages was 1·30. Head width measurements of 50 adult males and 50 adult females were used in calculating the growth ratio between the fifth stage and the adult. The ratios obtained, 1·10 and 1·11, were also in reasonable agreement with Przibram's factor and showed that there was the same relative increase in growth in males and females. The overall mean growth ratio, from first instar to adult, came to 1·266 correct to three decimal places, and this almost equals Przibram's factor.

## (2) *Adults*

### (a) *Effect of Temperature on Wing Form*

Wigglesworth (1952) showed, with nymphs of *Rhodnius prolixus* Stål, that a high temperature (34° C.) in the fourth stage produced larger than normal wing pads in the fifth stage, whereas a low temperature (18° C.) produced smaller than normal wing pads. He showed that the optimum temperature for nymphal development was 28–30° C.

Accordingly, fourth stage nymphs of *N. huttoni* were subjected to one of three temperature ranges, to test the possibility that high temperature favoured macroptery, and low temperature, brachyptery. The temperatures chosen were: high, 34° C., in a controlled temperature cabinet; low, minimum 9·4–15·6° C., maximum 17–21° C., under a Dutch barn in December; normal, minimum 6·7–13·9° C., maximum 27·8–34·4° C., in a greenhouse. The nymphs were kept in glass tubes (6 in. × 1 in.), covered at one end by butter muslin and stoppered at the other with cotton wool plugs. A sprig of twin cress (*Coronopus didymus* (L.) Sm.) was replaced daily for food. In the high temperature group, relative humidity was maintained by the presence of a bowl of water in the temperature cabinet. Five nymphs were placed in each tube. The results are summarized in Table IV.

TABLE IV.—*Effect of temperature on wing form of adults reared from fourth to fifth stage nymphs*

| | High temperature 34° C. | Normal temperature 6·7–34·4° C. 1 | Normal temperature 6·7–34·4° C. 2* | Low temperature 9·4–21° C. |
|---|---|---|---|---|
| Number of insects reared through to adults | 23 | 19 | 90 | 9 |
| Macropterous | 8·7% | 10·5% | 17·8% | . |
| Sub-brachypterous | 91·3% | 73·7% | 67·8% | 44·4% |
| Brachypterous | . | 15·8% | 14·4% | 55·6% |

* These insects were reared from eggs over a complete breeding season (September–March 1957–8) and hence were kept separate from the remainder which were reared from fourth and fifth stage nymphs.

It is clear that the sub-brachypterous form was the most common at normal temperatures, and this was so in both sexes. This form was also the most common in field samples. Of the macropterous form there were twice as many males as females, but of the brachypterous form there were twice as many females as males.

High temperature did not favour macroptery (as the sub-brachypterous form was still the most common) but tended to suppress it, and also suppressed the brachypterous form. In *N. huttoni* moulting was not retarded at high temperatures (34–42° C.) as it is in nymphs of *R. prolixus* (Wigglesworth, 1952), but rather hastened.

Subjection to low temperatures caused some increase in the brachypterous form, but suppressed the macropterous form. However, the number of insects used in this case was rather small.

When it was discovered that there were three size groups in *N. huttoni*, all the insects included in this experiment were examined and found to belong to groups II and III. Therefore, the above results and conclusions apply to these two groups, and may not necessarily apply to group I. Temperature is probably not a major factor in the determination of wing form in this species.

(b) *Crossing of Forms*

Crossing was necessary to determine whether or not the three wing-forms were merely different forms of one and the same species. The forms intercopulated freely. Later examination of field specimens, preserved *in copula*, showed that intercopulation occurred in all (*i.e.* nine) combinations.

Eleven experimental matings were made. The 22 insects had each been kept separate as fifth stage nymphs. Five sub-brachypterous females were mated with macropterous males, one brachypterous female was mated with a macropterous male, and five macropterous females were mated with sub-brachypterous males.

All eleven matings were successful, for eggs were laid, which later hatched, and the progeny also mated and bred. All three wing-forms were produced, but there was a majority of the sub-brachypterous form, thus: macropterous 17 per cent., sub-brachypterous 70 per cent., brachypterous 13 per cent. These percentages approximate the normal occurrence of forms in the species, as shown in Table IV. There was no noticeable reduction in fertility (hatchability) in comparison with a normal breeding experiment in which pairing was random.

When it was discovered that there were three size groups in *N. huttoni* (*see* (*c*) variation in size) the insects used in the above experiment were examined and found to fall mainly within group II. Three were of group III, and one was of group I.

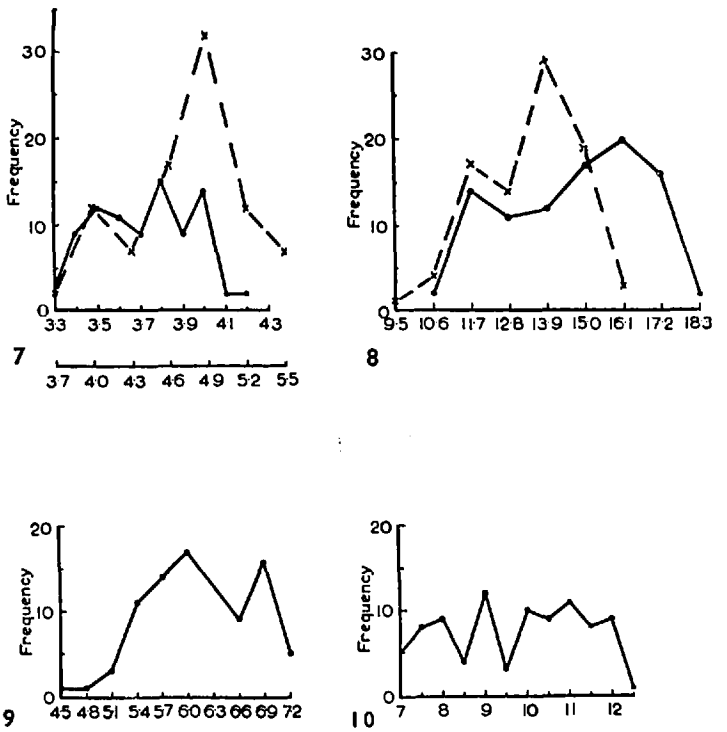
The experiment clearly demonstrated that the three wing-forms are members of one and the same species. There are a few Hawaiian Orsilline species which have relatively short wings, but in almost every case one form only occurs (Usinger, 1942).

The appearance of even two forms in the one species is very rare amongst the Orsillini ; there are about two cases in the Hawaiian species (*Nysius terrestris* Usinger, 1942, and *Nysius longicollis* Blackburn), but in both it is a sex difference, there being a somewhat shorter wing in the female. Therefore *N. huttoni* appears to be unique amongst the Orsillini in occurring in three wing-forms in both sexes.

(c) *Variation in Size*

The *N. huttoni* specimens examined differed in size, and there seemed to be three size groups. It was now clear that if any divisions were to be made, they would be on size and not wing-form.

Body measurements were taken on 164 specimens, including both sexes, from the following localities: Kaimai, Taumarunui, Horotiu, Westshore, Havelock North, Maraekakaho, Marton, Foxton, Waitarere, Hokowhitu, Massey Agricultural College,




FIGS. 7–10.—*Nysius huttoni :* Adult females. Distribution of: (7) head width (solid line and upper scale) and length of head plus pronotum ; (8) body length to wing tip (solid line) and body length to posterior of abdomen ; (9) width across hemelytra ; (10) wing length. (All measurements are in micrometer units : one micrometer unit = 0·24 mm.)

Blenheim, Nelson, Tuamarino, Seddon and Leefield. Six characteristics were measured, namely :

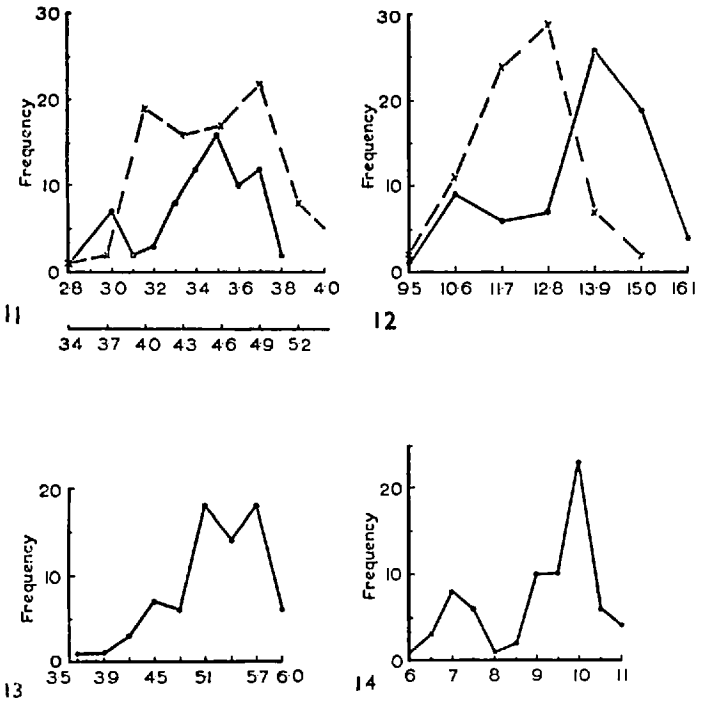
| | |
|---|---|
| *head width* (including eyes) | *body length* (to posterior of abdomen) |
| *total wing length* | *width across hemelytra* |
| *body length* (to wing tip) | *length of head plus pronotum* |

The two measurements of body length were taken to counteract the tendency for sub-brachypterous forms to fall into a smaller size group for this character. The

results are shown graphically in figures 7–10 for females, and in figures 11–14 for males. All measurements are in micrometer units : one micrometer unit = 0·24 mm.

A trimodal graph was obtained for head width and wing length in both females and males, and for width across the hemelytra in males. Six of the remaining graphs showed bimodal distributions, *i.e.* for body length (to wing tip) and length of head plus pronotum in both sexes, and for width across hemelytra and body length (to posterior of abdomen) in females. The distribution of this latter measurement in males was monomodal.

On all characters, except the one in males mentioned above, a group of small sized individuals (group III) was shown to be distinct. The fact that half of the graphs are merely bimodal may be interpreted as showing that there was no clear distinction between groups I and II. However, closer study should be made of




FIGS. 11–14.—*Nysius huttoni :* Adult males. Distribution of: (11) head width (solid line and upper scale) and length of head plus pronotum; (12) body length to wing tip (solid line) and body length to posterior of abdomen; (13) width across hemelytra; (14) wing length. (All measurements are in micrometer units : one micrometer unit = 0·24 mm.)

figures 8 and 9. In the graph of body length (to wing tip) in females, group III was shown to be distinct, but the second peak showed greater spread and an overlapping of groups I and II. On the other hand, in the graph of width across hemelytra in females, group I was shown to be distinct, but the first peak showed greater spread and an overlapping of groups II and III. These two graphs combined, therefore, point to three size groups. This conclusion is supported by figure 13, a trimodal graph for width across the hemelytra in males. Therefore in the summation of all the graphs the balance was moved to over half, *i.e.* 7 out of 12 (4 characters out of 6) showed three distinct size groups.

The above conclusion is further supported by the trimodality of head width in

adults and fifth stage nymphs, and by the bimodality of egg length. What status should be assigned to these size groups has yet to be tested by interbreeding.

## IV. Validity of *Brachynysius*

Sub-brachypterous forms of *N. huttoni* seemed similar to the *B. convexus* description. Using the *N. huttoni* redescription (which was made on group I individuals) it is seen that the two species are similar (except for the wings). In both species antennal proportions are similar, the ratio width of scutellum to length of scutellum is similar, the length of the first rostral segment is similar, the bucculae are similar, and the antennae are as long as head, pronotum and scutellum together. Of the *Brachynysius* head, Usinger (1943) said " Head as in typical *Nysius* . . . "

Thus the proportions of the group I *N. huttoni* individuals are very similar to those of *B. convexus*, although actual measurements are slightly larger. In all three *N. huttoni* groups the proportions are similar. Sub-brachypterous forms (which were reared from macropterous forms) of group II were found to conform to the *B. convexus* description. But all forms of group II were proved by interbreeding experiments to be members of one and the same species. Examination of a paratype of *B. convexus* showed it to be identical to these specimens.

Usinger (1943) in a " key to the genera and species of Orsillini in New Zealand ", gave the following condensed description of *Brachynysius* :

> " Hemelytra distinctly convex, costal margins strongly rounded beyond basal fourth. Membrane small, exceeding level of apices of coria by less than one-fourth the total length of membrane, without apparent veins . . . *Brachynysius convexus* n. gen. and sp. "

Usinger had seen only 14 specimens of this complex—11 *N. huttoni* specimens (which would have been macropterous) and 3 sub-brachypterous specimens which he described as *B. convexus*. It seems that he had in fact studied two extremes of *N. huttoni* which were so different that he separated them. The author found that extremes went from macroptery, beyond sub-brachyptery to brachyptery, and there were all grades in between. As all forms appear to occur in the localities sampled, this represents simply variation within the species, and thus is not even a cline.

It follows then, that Usinger's key to the genera and species of Orsillini in New Zealand should be amended so that *Brachynysius* is sunk, and *Nysius* is extended to include all forms (this would then include the brachypterous form here first recorded, and the sub-brachypterous form which was formerly designated as *B. convexus*).

## V. Summary

The imago of *Nysius huttoni* White is redescribed, the immature stages are described, and all stages are illustrated for the first time.

The variation exhibited in wing-form and body size is discussed, and appears to be unique amongst the Orsillini.

*Brachynysius convexus* Usinger is shown to be identical to the sub-brachypterous form of *N. huttoni*.

## VI. Acknowledgments

This paper records part of a study for a M.Agr.Sc. thesis presented at Massey Agricultural College, New Zealand. I gratefully acknowledge the assistance of Mr. L. Gurr in supervising the study, and in providing access to specimens of *N. huttoni* collected by him in the South Island of New Zealand.

I am also indebted to Professor R. L. Usinger, University of California, for the loan of a paratype of *B. convexus* ; to Dr. R. A. Cumber, Entomology Division of

the Department of Scientific and Industrial Research, for access to specimens from the North Island of New Zealand, and to Mr. H. Drake of the same Division for reproducing the drawings and graphs.

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* Not consulted in original.

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# INSECTS ASSOCIATED WITH THE MAJOR FODDER CROPS IN THE NORTH ISLAND

## I. THE GENERAL PICTURE

By A. C. EYLES,* Entomology Division, Department of Scientific and Industrial Research, Palmerston North

(*Received for publication, 16 August 1960*)

**Summary**

A survey of insects associated with fodder crops in the North Island was carried out during the summer of 1959. The 129 crops studied comprised mainly chou moellier, swedes, turnips, maize, and lucerne. Information on techniques used, location, and condition of crops, and the numbers of insect species associated with the various crops, is given.

### INTRODUCTION

The purpose of the present survey, which is one of a series aimed at covering the non-forestry agricultural crops, is to provide up to date information on species and their abundance on specific crops.

Fodder crops play an important part in the seasonal production of some 65% of New Zealand dairy farms (N.Z. Dairy Board 1955) and on a great number of sheep farms. They aid in maintaining stock-carrying capacities during winter and summer pasture growth shortages, and assist in preparation of land for pastures. Table 1 shows, by land districts (1956-57), the areas sown and relative importance of the fodder crops sampled in the survey. The major crops studied were lucerne, maize, chou moellier, swedes, and turnips, limited samples of mangels, rape, and pampas also being taken.

In the New Zealand literature some 80 species of insects, of which about 15 are presumed to be beneficial, have been associated with crops—about 60 with crucifers, 15 with lucerne, and 10 with maize. The more important papers are those by Myers (1921), concerning lucerne in the Marlborough seed-growing areas, swedes (Cottier 1932), and cruciferous crops (Todd 1957, 1958, 1959; Lowe 1958). Most of the records, however, concern specific outbreaks rather than attempts at assessing the complex as a whole.

### TECHNIQUES

The technique used in the collection of samples was similar to that described by Cumber (1958), which involved a sweep-net equipped with detachable end-socks. A sample consisted of 20 sweeps, the net being reversed for successive sweeps of approximately 6ft in progressing forward, and covering in all about 15 sq. yd. In the case of maize, sweeps were taken up the full height of a plant and down another, and sometimes across the tops of plants.

* Present address: Imperial College of Science and Technology, London, S.W.7.

TABLE 1. DOMINION AREAS FOR MAJOR FODDER CROPS AND PERCENTAGE GROWN IN NORTH ISLAND DISTRICTS, 1956–57*

| Crop | Dominion Area (acres) | Percentage of Dominion Area | | | | | |
|---|---|---|---|---|---|---|---|
| | | Northland | South Auckland | Gisborne | Hawke's Bay | Taranaki | Wellington |
| Lucerne for hay and silage | 137,908 | 0.6 | 8.4 | 0.5 | 3.5 | 0.7 | 2.5 |
| Maize for green feed | 4,953 | 16.3 | 37.9 | 6.0 | 6.1 | 5.8 | 19.8 |
| Maize for grain | 5,486 | 4.9 | 23.0 | 67.5 | 4.1 | 0.07 | 0.3 |
| Chou moellier | 110,722 | 3.0 | 11.6 | 0.4 | 17.5 | 4.4 | 27.9 |
| Soft turnips | 166,319 | 4.3 | 13.0 | 0.4 | 2.9 | 1.1 | 5.4 |
| Yellow turnips | 57,604 | 1.4 | 5.9 | 0.2 | 1.6 | 0.9 | 4.8 |
| Swedes | 179,599 | 2.1 | 15.1 | 0.4 | 1.5 | 3.2 | 5.9 |
| Rape | 147,532 | 0.4 | 1.0 | 0.2 | 4.8 | 0.1 | 4.2 |

* Source: N.Z. Farm Production Statistics.

On removal, the detachable end-sock was closed with a rubber band and placed in a killing jar to which a few drops of ethyl acetate had been added. Samples were transferred to 2-oz holding jars at least one hour, and preferably not longer than four hours, later, since transpiration from crop leaves often present tended to dampen and adversely affect the materials. To facilitate transfers, a wide-mouthed (9 in. diameter) funnel adapted to screw on to holding jars, and a small brush, were used. To assist the further drying out of samples, a hole about $\frac{1}{2}$ in. diameter was drilled in the screw-on lids. This was covered with fine muslin. Pieces of absorbent paper were also added to samples. Insects likely to damage the rest of the sample, e.g.,

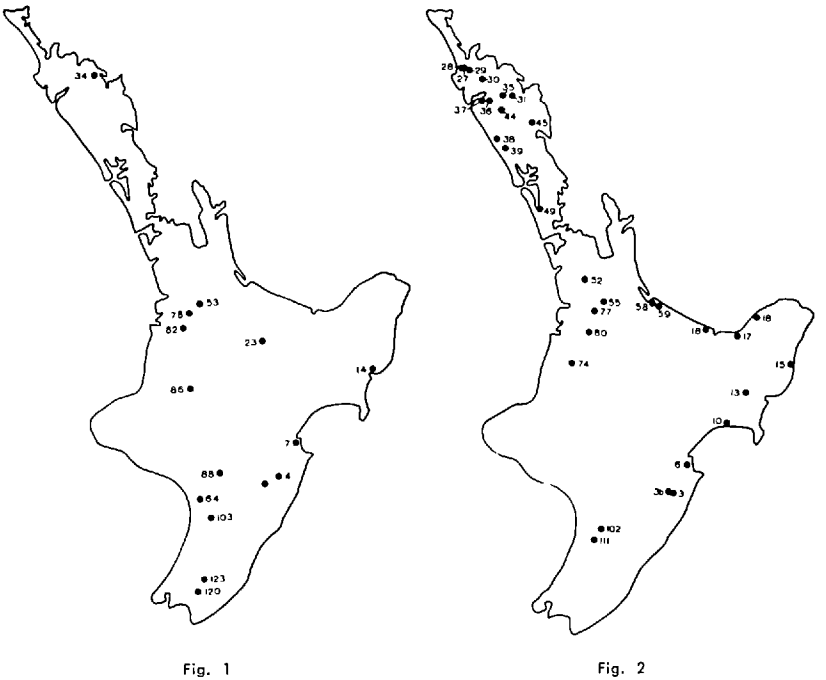



Fig. 1 Fig. 2

Fig. 1.—Map showing location of lucerne crop sampling stations.

Fig. 2.—Map showing location of maize crop sampling stations.

soft-bodied caterpillars and *Nezara* adults and nymphs, were discarded after counting at the time of transferring samples to holding jars. Thus the insect materials were kept in good order. On arrival at headquarters 1-2 weeks later they were transferred to petri dishes and held on filter papers, together with a little flake naphthalene.

Soil samples were studied on the spot, and the insect materials were collected and recorded. Most of these samples were six random spade-square samples, including actual plants; they were taken to a depth of about 6 in.

The sampling periods were as follows: East Coast areas, 9.2.59-13.2.59; Northland and Auckland, 23.2.59-5.3.59; West Coast, 16.3.59-20.3.59; Manawatu, 24.3.59; Wellington, 25.3.59; and Wairarapa, 8.4.59. Weather conditions were adequately fine. It was found desirable to delay morning samplings usually till about 9 a.m., by which time the dew had dried off the crops.

Crops were sampled in order of sighting, usually with a minimum distance of 20-30 miles between similar crops, and were numbered consecutively. In all, 129 crops were studied (Table 2), and the distributions of these are shown in Fig. 1 (lucerne), Fig. 2 (maize), Fig. 3 (chou), Fig. 4 (turnips), and Fig. 5 (swedes, mixed chou and swedes). Mangels were sampled at Sanson, Kimbolton, Tiakitahuna, and Ashhurst, rape at Feilding, pampas at Kotemaori, and mixture of rape, swedes and turnips at Feilding and Awahuri-Sanson. At each sampling site details of topography, time of day, weather, soil moisture, height of crop, and weeds present, were recorded. This information is summarised in the Appendix.

## RESULTS

This first paper gives only a general picture of the survey. Subsequent papers will discuss details of identity, distribution, and frequency of occurrence, of individual species. The crops considered together yielded in sweep-sampling the following numbers of species: Coleoptera 42, Diptera 50, Hemiptera 50, Hymenoptera 73, Isoptera 1, Lepidoptera 14, Neuroptera 1, Odonata 1, Orthoptera 7, Psocoptera

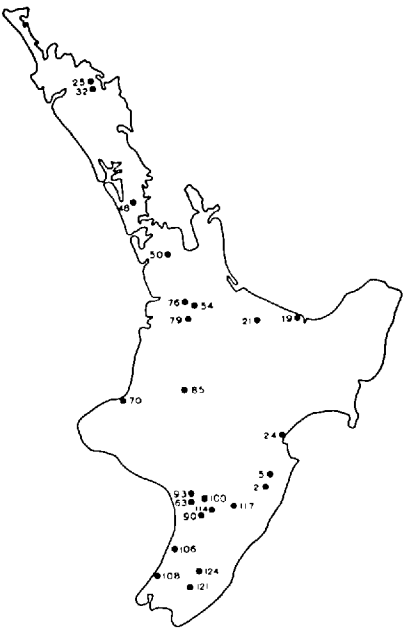



Fig. 3.—Map showing location of chou moellier crop sampling stations.

TABLE 2. NUMBERS OF SPECIES TAKEN SWEEPING

| Crop | No. Crops Studied | Coleoptera | Diptera | Hemiptera | Hymenoptera | Isoptera | Lepidoptera | Neuroptera | Odonata | Orthoptera | Psocoptera | Thysanoptera | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chou, Swedes mixed | 19 | 11 | 23 | 12 | 23 | — | 8 | 1 | 1 | 2 | 1 | 3 | 85 |
| Chou | 24 | 10 | 23 | 17 | 32 | — | 7 | 1 | — | 1 | — | 5 | 96 |
| Lucerne | 15 | 19 | 21 | 18 | 28 | — | 8 | — | — | 3 | 1 | 6 | 104 |
| Maize | 34 | 21 | 23 | 28 | 41 | — | 9 | 1 | 1 | 4 | 2 | 7 | 137 |
| Mangels | 4 | 2 | 15 | 3 | 9 | — | 3 | — | 1 | 1 | 2 | 1 | 37 |
| Pampas | 1 | — | — | 2 | — | — | — | — | — | — | — | — | 2 |
| Rape | 1 | — | 6 | 3 | 10 | — | 2 | — | — | 1 | — | 1 | 23 |
| Swedes | 8 | 8 | 25 | 7 | 21 | — | 3 | 1 | — | — | 1 | 2 | 68 |
| Turnips | 21 | 17 | 35 | 22 | 38 | 1 | 8 | 1 | 2 | 4 | 2 | 7 | 137 |
| Rape, Swedes, Turnips mixed | 2 | 1 | 2 | 4 | 4 | — | 2 | 1 | — | — | 1 | — | 15 |

3, and Thysanoptera 11—a total of 253 species. The figures do not differ greatly either in numbers of species or in the relative magnitude of order representation from the data shown in the pasture survey (Cumber 1958). Many of the species taken, as in the pasture survey, have occurred in small numbers only. Many of such species are common to both surveys, and are to be regarded as casual associates.

Table 2 shows the numbers of species in each order taken during the sampling of pure and mixed crops. The figures should be examined in the light of the varying numbers of crops of each category studied.

## DISCUSSION

While the limitations set by available facilities are fully realised, nevertheless this survey represents a considerable advance in the understanding of the complex. It is only by seeing repeated occurrences or absences over widespread areas that the full significance of individual species may be gauged. The precise importance of each species, however, must await the results of detailed studies.

The majority of the species encountered were present in small numbers, and many will prove to be only casual associates. However, numerical representation is not necessarily an index of importance.

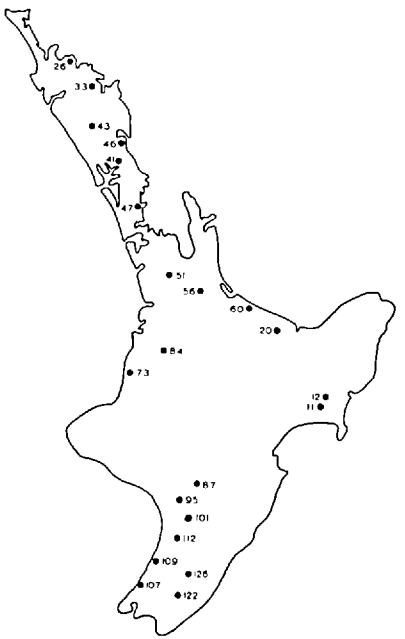



Fig. 4

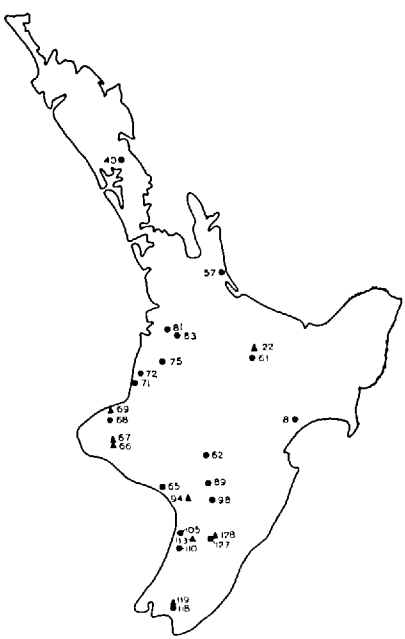



Fig. 5

Fig. 4.—Map showing location of turnip crop sampling stations.

Fig. 5.—Map showing location of mixed chou moellier and swedes (black circles), and swede (black triangles), crop sampling stations.

The complex involves an order majority in that group of insects which is largely parasitic, and parasite and host often balance at relatively low populations.

It would seem apparent that surveys such as this will become increasingly affected by the more widespread use of insecticides and that future investigations may possibly show declining insect populations. In the present survey no attempt was made to obtain information on any such treatments which crops had received.

## ACKNOWLEDGMENTS

Assistance with field work given by the staff of the Entomology Division sub-station at Palmerston North is gratefully acknowledged; assistance of particular importance was given by Dr R. A. Cumber, who also helped in the planning of the survey and in the presentation of findings.

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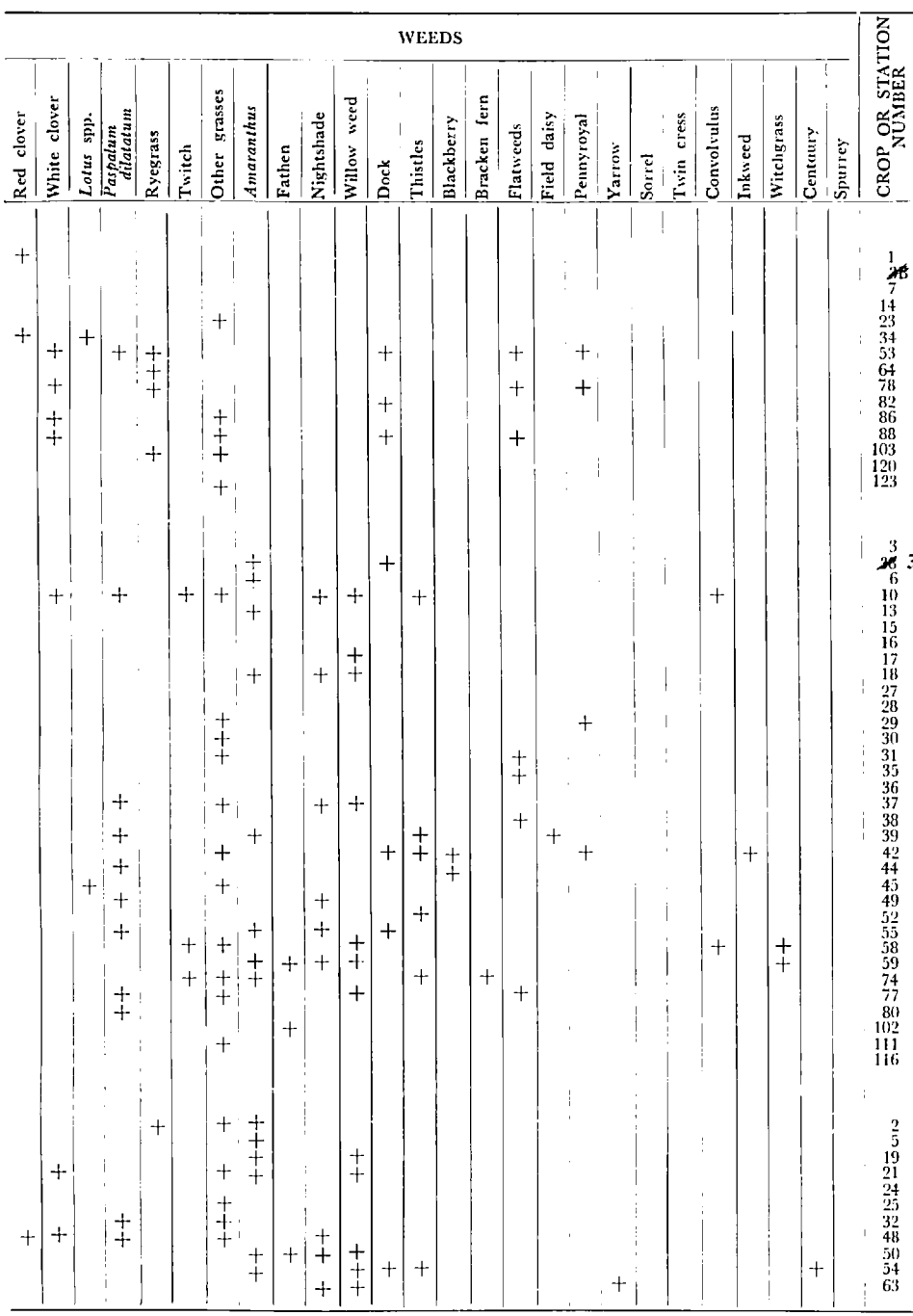
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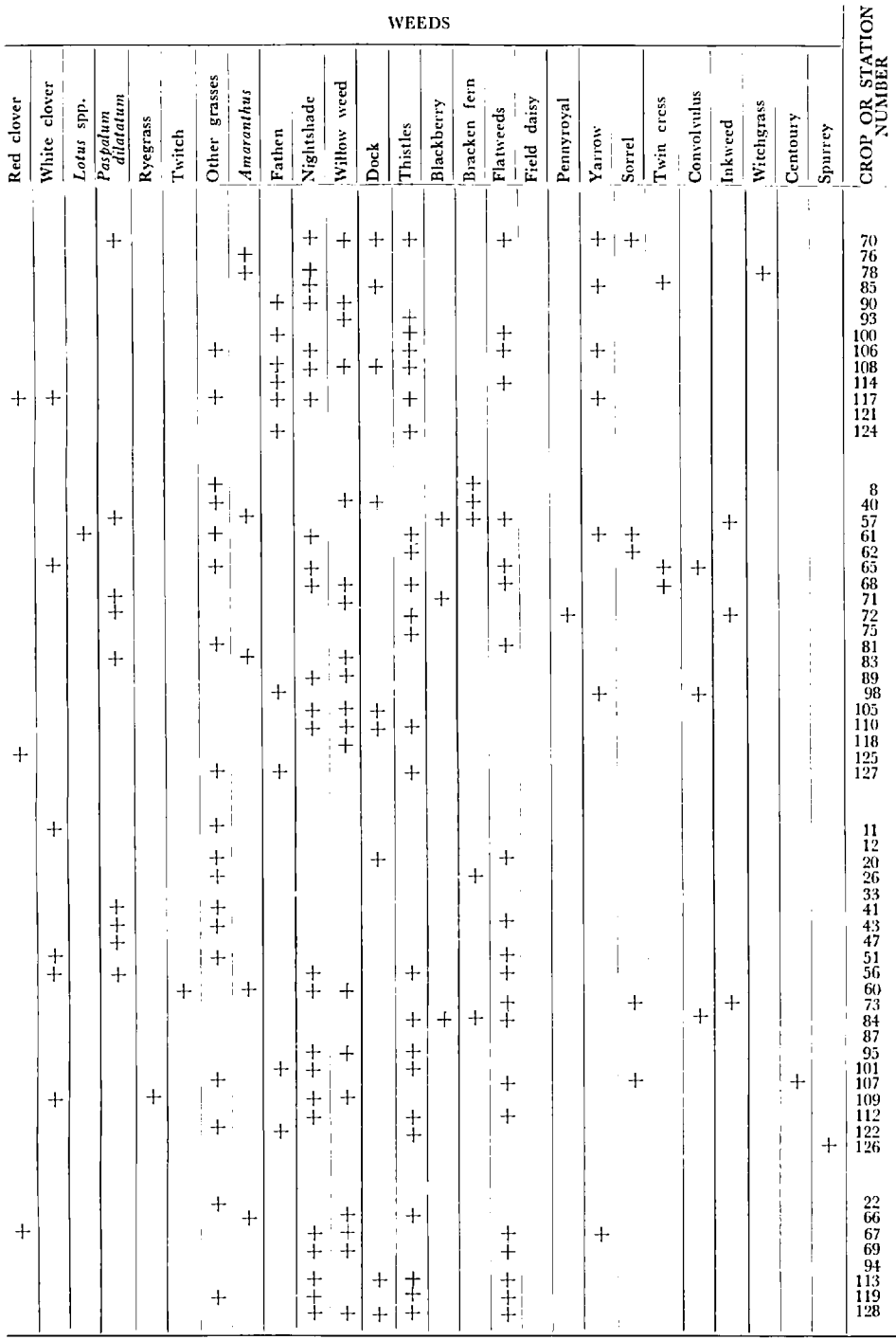
## APPENDIX

### DETAILS OF SAMPLING STATIONS

| CROP OR STATION NUMBER | LOCATION | DATE (1959) | TIME Nearest daylight hour | WEATHER A, Sunny; B, Cloudy; C, Strong Wind | TOPOGRAPHY F, Flat; H, Hilly; R, Rolling | SOIL MOISTURE D, Dry; M, Moist; W, Wet | GRAZING C, Cattle; H, Horses; S, Sheep | Height of Crop |
|---|---|---|---|---|---|---|---|---|
| **Lucerne** | | | | | | | | (in.) |
| 1 | Takapua plains | 9.2 | 10 | A | F | D | | 18 |
| 4 | Waipawa, Argyle Road | 9.2 | 12 | A | F | D | | 6–12 |
| 7 | Greenmeadows | 9.2 | 12 | A | F | D | | 18 |
| 14 | Gisborne, 6M. South | 10.2 | 2 | B | F | M | | 18–24 |
| 23 | Waiotapu | 12.2 | 4 | B | F | M | | 6–12 |
| 34 | Kapiro (Waipapa) | 24.3 | 11 | A | F | M | | 12–18 |
| 53 | Cambridge | 3.3 | 1 | A | F | M | | 15 |
| 64 | Bulls, 4M. West | 16.3 | 10 | B | R | M | | 12–15 |
| 78 | Te Awamutu, 5M. West | 19.3 | 12 | A | F | M | | 18 |
| 82 | Otorohanga, 2M. West | 19.3 | 6 | B | H | M | | 12 |
| 86 | Taumarunui, East | 20.3 | 11 | B | R | M | | 18 |
| 88 | Ohingaiti, 1M. South | 20.3 | 4 | B | R | M | | 12–15 |
| 103 | Longburn | 24.3 | 4 | A | R | D | | 15 |
| 120 | Martinborough, 7M. South | 8.4 | 12 | A | F | D | C | 3–4 |
| 123 | Greytown | 8.4 | 2 | A | F | M | S | 6–8 |
| **Maize** | | | | | | | | (ft) |
| 3 | Waipawa, 2M. North | 9.2 | 11 | A | F | D | | 9 |
| 38 | Waipawa, 2M. North | 9.2 | 11 | A | F | D | | 2½ |
| 6 | Taradale, 3M. South | 9.2 | 2 | A | F | D | | 10 |
| 10 | Wairoa, 1M. North | 10.2 | 10 | V | F | M | | 9 |
| 13 | Hangaroa | 10.2 | 2 | V | R | M | | 9 |
| 15 | Tolaga Bay | 10.2 | 4 | BC | F | M | | 7 |
| 16 | Te Kaha, 2M. North | 11.2 | 6 | A | F | M | | 2½ |
| 17 | Torrye | 12.2 | 10 | A | F | M | | 4 |
| 18 | Whakatane | 12.2 | 11 | A | F | D | | 8 |
| 27 | Kaitaia, 4M. North | 23.2 | 3 | AC | F | M | | 5 |
| 28 | Kaitaia, 4M. North | 23.2 | 3 | AC | F | M | | 8 |
| 29 | Kaitaia, 6M. South | 23.2 | 3 | AC | F | W | | 6–8 |
| 30 | Mangamuka | 23.2 | 5 | B | F | M | | 5–7 |
| 31 | Pakaraka, 5M. South | 24.2 | 9 | A | R | M | | 9 |
| 35 | Ngawha | 25.2 | 9 | B | F | M | | 7–9 |
| 36 | Taheke | 25.2 | 11 | B | F | M | | 6–8 |
| 37 | Whirinaki | 25.2 | 12 | A | F | D | | 8 |
| 38 | Dargaville, 6M. North | 25.2 | 5 | A | F | M | | 3–8 |
| 39 | Dargaville, 5M. South | 26.2 | 10 | A | F | D | | 2–7 |
| 42 | Whangarei, 3M. South | 26.2 | 3 | B | H | D | | 4 |
| 44 | Awarua | 26.2 | 6 | B | F | M | | 6–9 |
| 45 | Kamo | 2.3 | 12 | A | F | D | | 9 |
| 49 | Heteusville | 2.3 | 5 | A | F | M | | 9 |
| 52 | Ohinewai | 3.3 | 12 | A | F | D | | 9 |
| 55 | Eureka | 3.3 | 3 | A | F | M | | 10 |
| 58 | Tauranga | 4.3 | 11 | A | F | M | | 6–8 |
| 59 | Papamoa | 4.3 | 12 | A | R | D | | 7 |
| 74 | Pio Pio | 16.3 | 6 | A | H | D | | 4–6 |
| 77 | Rukuhia | 19.3 | 12 | A | F | D | | 10 |
| 80 | Te Kawa | 19.3 | 2 | A | R | M | | 6 |
| 102 | Longburn | 24.3 | 4 | A | F | M | | 10 |
| 111 | Shannon, 3M. North | 25.3 | 4 | A | F | W | | 5 |
| 116 | Dannevirke | 26.3 | 11 | B | F | M | C | 5 |
| **Chou moellier** | | | | | | | | (ft) |
| 2 | Waipukurau | 9.2 | 10 | A | R | D | | 2 |
| 5 | Waipawa, 5M. North | 9.2 | 12 | A | R | D | | 3–4½ |
| 19 | Whakatane, 4M. South | 12.2 | 2 | A | F | M | | 3–4 |
| 21 | Rotorua | 12.2 | 3 | A | F | M | | 4 |
| 24 | Bay View | 13.2 | 1 | A | F | D | S | ½–1 |
| 25 | Puketona | 23.2 | 9 | B | H | W | | 1 |
| 32 | Pakaraka | 24.2 | 10 | A | R | D | S | 3–4 |
| 48 | Waitoki | 2.3 | 4 | A | R | D | | 2 |
| 50 | Mercer | 3.3 | 11 | A | F | D | S | 3 |
| 54 | Cambridge | 3.3 | 2 | A | R | M | | 3 |
| 63 | Bulls, 3M. West | 16.3 | 9 | A | R | W | | 2 |


WEEDS
Red clover
White clover
Lotus spp.
Paspalum dilatatum
Ryegrass
Twitch
Other grasses
Amaranthus
Fathen
Nightshade
Willow weed
Dock
Thistles
Blackberry
Bracken fern
Flatweeds
Field daisy
Pennyroyal
Yarrow
Sorrel
Twin cress
Convolvulus
Inkweed
Witchgrass
Centaury
Spurrey
CROP OR STATION NUMBER

| CROP OR STATION NUMBER | LOCATION | DATE (1959) | TIME Nearest daylight hour | WEATHER A, Sunny; B, Cloudy; C, Strong Wind | TOPOGRAPHY F, Flat; H, Hilly; R, Rolling | SOIL MOISTURE D, Dry; M, Moist; W, Wet | GRAZING C, Cattle; H, Horses; S, Sheep | Height of Crop |
|---|---|---|---|---|---|---|---|---|
| **Chou moellier**—Cont. | | | | | | | | (ft) |
| 70 | Urenui | 16.3 | 3 | A | F | M | | 4 |
| 76 | Rukuhia | 19.3 | 11 | A | F | M | | 5 |
| 78 | Kihikihi | 19.3 | 2 | A | F | M | | 5 |
| 85 | Taumarunui, 6M. North | 20.3 | 10 | B | R | M | | 1 |
| 90 | Palmerston North, 1M. West | 24.3 | 9 | A | F | M | | 6 |
| 93 | Marton, 2M. South | 24.3 | 10 | A | R | M | | 2½ |
| 100 | Cheltenham | 24.3 | 3 | A | F | D | | 4 |
| 106 | Manakau, 7M. South | 25.3 | 11 | B | R | M | | 2 |
| 108 | Pahautanui | 25.3 | 2 | A | F | M | | 2½ |
| 114 | Ashhurst, 1M. South | 26.3 | 10 | B | F | D | | 1 |
| 117 | Dannevirke | 26.3 | 11 | B | F | M | | 4 |
| 121 | Greytown, 5M. South | 8.4 | 1 | A | F | W | | 1 |
| 124 | Carterton, 4M. North | 8.4 | 2 | A | F | M | | 4 |
| **Chou moellier plus swedes** | | | | | | | | (ft) |
| 8 | Kotemaori, 3M. South | 9.2 | 5 | A | H | D | | ½ |
| 40 | Maungaturoto | 26.2 | 12 | B | H | D | | ½ |
| 57 | Waihi, 3M. South | 3.3 | 5 | A | H | M | | 1½ |
| 61 | Wharepaina | 4.3 | 3 | A | F | M | | 2 |
| 62 | Irirangi | 5.3 | 11 | AG | H | M | S | ½–1 |
| 65 | Wanganui | 16.3 | 10 | B | F | M | | 3 |
| 68 | Inglewood | 16.3 | 2 | B | H | M | | 1½ |
| 71 | Mokau | 16.3 | 4 | A | R | D | | 1 |
| 72 | Mahoenui, 2M. South | 16.3 | 5 | A | H | M | S | 1 |
| 75 | Pio Pio, 4M. North | 16.3 | 6 | A | R | M | | 4 |
| 81 | Te Rauroa, 2M. West | 19.3 | 5 | A | H | M | | 1½ |
| 83 | Otorohanga, 2M. West | 19.3 | 6 | A | H | M | | 2 |
| 89 | Ohingaiti, 1M. South | 20.3 | 4 | B | F | M | | 4½ |
| 98 | Kimbolton | 24.3 | 2 | A | R | M | | 2 |
| 105 | Foxton, 3M. North | 25.3 | 10 | A | F | W | | 4 |
| 110 | Levin | 25.3 | 4 | A | F | M | | 4 |
| 118 | Pirinoa | 8.4 | 12 | A | F | M | | 2 |
| 125 | Masterton | 8.4 | 3 | A | F | D | | 1½ |
| 127 | Konini, 5M. South | 8.4 | 4 | A | F | M | | 1½ |
| **Turnips** | | | | | | | | (in.) |
| 11 | Marumaru | 9.2 | 10 | B | H | M | S | — |
| 12 | Tiniroto | 9.2 | 12 | B | F | M | | 8 |
| 20 | Te Teko | 12.2 | 2 | A | R | M | | 10 |
| 26 | Oruaiti | 23.2 | 12 | A | R | M | | 6 |
| 33 | Puketona | 24.2 | 10 | A | H | M | | 4 |
| 41 | Maungaturoto | 26.2 | 12 | B | H | D | | 12 |
| 43 | Parakao | 26.2 | 4 | B | R | D | | 3 |
| 47 | Silverdale | 2.3 | 3 | A | H | D | | 8 |
| 51 | Rangiriri | 3.3 | 11 | A | F | D | S | — |
| 56 | Waitoa | 3.3 | 4 | A | F | M | | 12 |
| 60 | Te Puke | 4.3 | 12 | A | F | M | | 12 |
| 73 | Mohoenui | 16.3 | 5 | A | H | M | | 12 |
| 84 | Te Kuiti | 20.3 | 9 | B | H | M | | 10 |
| 87 | Ohingaiti | 20.3 | 4 | B | F | M | | 12 |
| 95 | Marton, 4M. East | 24.3 | 12 | A | F | M | | 12 |
| 101 | Te Arakura | 24.3 | 3 | A | F | M | S | — |
| 107 | Pukerua Bay | 25.3 | 12 | A | H | D | | 8 |
| 109 | Otaki | 25.3 | 3 | A | F | D | | 10 |
| 112 | Makerua | 25.3 | 5 | A | H | D | | 10 |
| 122 | Greytown | 8.4 | 1 | A | F | M | | 12 |
| 126 | Masterton, 5M. North | 8.4 | 3 | A | F | D | | 12 |
| **Swedes** | | | | | | | | (ft) |
| 22 | Waimangu | 12.2 | 4 | B | F | M | | 1½ |
| 66 | Eltham | 16.3 | 1 | A | F | M | | 1½ |
| 67 | Ngaere | 16.3 | 2 | A | R | M | | 2 |
| 69 | Waitara | 16.3 | 3 | B | F | M | | 2 |
| 94 | Marton, 4M. East | 24.3 | 11 | A | F | M | | 1½ |
| 113 | Makerua | 25.3 | 5 | A | H | D | | 1½ |
| 119 | Pirinoa | 8.4 | 12 | A | R | D | | 1½ |
| 128 | Pahiatua | 8.4 | 4 | A | R | W | | 1½ |


WEEDS
Red clover
White clover
Lotus spp.
Paspalum dilatatum
Ryegrass
Twitch
Other grasses
Amaranthus
Fathen
Nightshade
Willow weed
Dock
Thistles
Blackberry
Bracken fern
Flatweeds
Field daisy
Pennyroyal
Yarrow
Sorrel
Twin cress
Convolvulus
Inkweed
Witchgrass
Centoury
Spurrey
CROP OR STATION NUMBER

| CROP OR STATION NUMBER | LOCATION | DATE (1959) | TIME Nearest daylight hour | WEATHER A, Sunny; B, Cloudy; C, Strong Wind | TOPOGRAPHY F, Flat; H, Hilly; R, Rolling | SOIL MOISTURE D, Dry; M, Moist; W, Wet | GRAZING C, Cattle; H, Horses; S, Sheep | Height of Crop |
|---|---|---|---|---|---|---|---|---|
| **Mangels** | | | | | | | | (ft) |
| 92 | Sanson | 24.3 | 9 | A | F | D | | 1½ |
| 99 | Kimbolton | 24.3 | 12 | A | F | D | | 1½ |
| 104 | Tiakitahuna | 25.3 | 9 | A | F | M | | 1½ |
| 115 | Ashhurst bridge | 26.3 | 11 | B | F | M | | 1½ |
| **Rape** | | | | | | | | (ft) |
| 97 | Feilding, 4M. West | 24.3 | 12 | A | H | D | | 2 |
| **Pampas** | | | | | | | | (ft) |
| 9 | Kotemaori | 9.2 | 5 | A | H | M | | 5 |
| **Rape, Swedes, Turnips, mixed** | | | | | | | | (ft) |
| 91 | Awahuri-Sanson | 24.3 | 9 | A | F | M | | 2 |
| 96 | Feilding, 5M. West | 24.3 | 12 | A | R | M | | 2 |

| WEEDS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | CROP OR STATION NUMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Red clover | White clover | *Lotus* spp. | *Paspalum dilatatum* | Ryegrass | Twitch | Other grasses | *Amaranthus* | Fathen | Nightshade | Willow weed | Dock | Thistles | Blackberry | Bracken fern | Flatweeds | Field daisy | Pennyroyal | Yarrow | Sorrel | Twin cress | Convolvulus | Inkweed | Witchgrass | Centoury | Spurrey | | | | | | |
| + | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 92 |
| | | | | | | ++ | | | | ++ | ++ | | | | | | | + | | + | | | | | | | | | | | 99 |
| | | | | | | | | + | ++ | | | ++ | | | | | | | | | | | | | | | | | | | 104 |
| | | | | | | | | | + | + | + | + | | | | | | | | | | | | | | | | | | | 115 |
| | | | | | | + | | + | + | + | + | + | | | | | | | | | | | | | | | | | | | 97 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| | | | | + | + | | | | + | + | | | | | | | | | | | | | | | | | | | | | 91 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 96 |

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# INSECTS ASSOCIATED WITH THE MAJOR FODDER CROPS IN THE NORTH ISLAND

## II. HEMIPTERA

By A. C. EYLES,* Entomology Division, Department of Scientific and Industrial Research, Palmerston North

(*Received for publication, 16 August 1960*)


### Summary

A survey of fodder crops in the North Island, carried out during 1959, revealed 50 species of Hemiptera. Two are new records for New Zealand. The identity, distribution, incidence, and possible economic importance of each species are discussed. A list of the species occurring on each crop is appended.


### INTRODUCTION

A survey of the insects associated with fodder crops in the North Island was carried out during the summer of 1959. A general account of this survey has already been presented (Eyles 1960). The major fodder crops sampled were lucerne, maize, chou moellier, swedes, mixed chou moellier and swedes, and turnips. There were, in addition, minor samplings of mangels, rape, pampas, and mixtures of crucifers.

The present paper lists the species of Hemiptera taken in the survey, and gives information on their distribution, incidence on the various crops, habits (where not covered in Cumber's pasture survey 1959), and economic significance.**

The majority of species were represented by few specimens. Distribution maps for the seven species most commonly encountered are given, a black square indicating at least one occurrence within the area.

### RESULTS

### HEMIPTERA-HOMOPTERA

Fam. CICADIDAE

The cicada larval stages are spent below the surface of the soil, where nymphs feed upon roots of various plants. Here they may be regarded as damaging, but they may be more obviously damaging as adults when they affect aerial portions by feeding, and, more especially, with their oviposition scars.

He. 58. *Melampsalta muta* (Fabr.)

This indigenous species is widely distributed in both North and South Islands, and is present in the Chatham Islands (Myers 1929). In the present survey two adults were taken from pampas at Kotemaori on 9.2.59. Myers states that *M. muta* occupies a mesophytic but open

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** Where further information is contained in Cumber's pasture account it is indicated by an asterisk after the species.

country habitat. The species is of no economic importance on fodder crops.

He. 57. *Melampsalta sericea* (Walk.)

Myers (1929) shows that this endemic species is restricted to the North Island. In the present survey, a single adult was collected from maize at Dargaville on 26.2.59. Myers records the ecological habitat of this species as dry open spaces and exposed banks. *M. sericea* is of no economic importance on fodder crops.

Fam. JASSIDAE (Leaf-Hoppers)

This is a very extensive family of economically important insect species. Cereal and fodder crops, and fruit and forest trees, are commonly affected; injury results from direct mechanical means, production of toxins, or spread of virus diseases.

He. 5. *Erythroneura zealandica* Myers*

This species is widely distributed in New Zealand. The distribution shown by the present survey is given in Fig. 1, which indicates

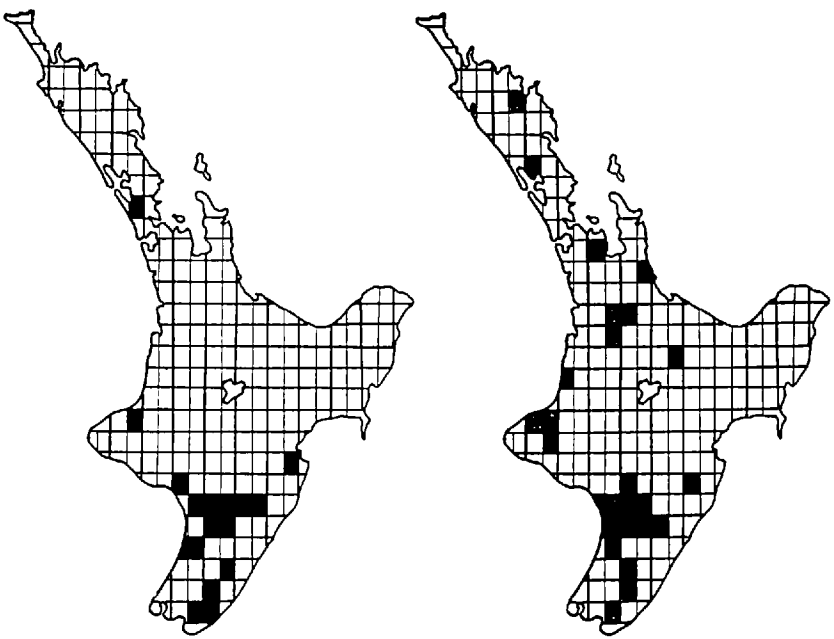



Fig. 1.—Distribution map for the jassid *Erythroneura zealandica* He. 5.

Fig. 2.—Distribution map for the aphid *Brevicoryne brassicae* He. 8.

a mainly southern distribution in the North Island. It was taken on lucerne (5 crops), maize (6), chou (4), chou plus swedes (1), turnips (1), swedes (1), and rape (1). It was never taken in large numbers, however—seven on lucerne (Greytown 8.4.59) and five on maize

(Shannon 25.3.59) being the greatest catches. This situation contrasts strongly with that met in pastures, where very considerable numbers were taken. This species is not considered to be important in fodder crops, except perhaps in possible virus transmission in lucerne and maize.

He. 19. *Deltocephalus* sp.*

Only one specimen (maize, Taradale 9.2.59) of this widely-distributed species, which is commonly present in pastures, was taken.

He. 13. *Thamnotettix* sp.*

This species is widely distributed south of Auckland in the North Island. In the present survey a single specimen was taken from maize at Taradale on 9.2.59. Damaging members of this genus occur on cereals in North America (Osborn 1939). This species occurred commonly in pasture sweeping.

He. 14. *Thamnotettix* sp.*

A single specimen of this species, which is widely distributed in the North Island, was collected from turnips at Makerua on 25.3.59.

He. 11. *Xestocephalus* sp.*

The genus is cosmopolitan. Cumber (1959) shows that the distribution of this species in pastures is south of the Bay of Plenty. Two specimens were collected in the present survey—one from lucerne at Bulls and one from maize at Pio Pio (both on 16.3.59).

He. 54.? *Idiocerus* sp.

The genus *Idiocerus* occurs in Australia and New Zealand (Tillyard 1926). In the present survey an adult and nymphal exuvium were collected from mangels at Ashhurst on 26.3.59. This was probably associated with Lombardy poplars at one end of the field rather than with the crop.

He. 55. Undetermined.**

One adult and a nymph of this as yet undetermined species were collected from lucerne at Greenmeadows on 9.2.59. The habits of the species are not known.

Fam. DELPHACIDAE

The family includes many species which are injurious to agricultural crops.

He. 7. *Delphacodes tasmani* Muir*

This species occurs throughout the North Island. In the present survey one adult was taken from lucerne at Greenmeadows (9.3.59), and a nymph from maize at Tauranga on 4.3.59.

He. 4. *Delphacodes* sp.*

This species occurs in the North Island on pastures from widely-separated localities. A single adult was taken from turnips at Te Puke on 4.2.59.

** Undetermined species are held under the numbers shown, in the collections of the Entomology Division sub-station, Palmerston North.

Fam. DICTYOPHARIDAE

The family is of minor economic importance.

He. 21. *Thanatodictya tillyardi* Myers*

Cumber (1959) records this species in pastures from four widely separated North Island areas. In the present survey small numbers were taken from turnips at Te Teko on 12.2.59, and from maize at Whangarei on 26.2.59. Myers (1923) and Cumber both record bracken fern (*Pteridium esculentum* Hook) as host plant. The turnip crop referred to above was bounded on one side by manuka (*Leptospermum scoparium* Forst.); while the maize crop, on a small hillside area, was surrounded by rough grasses and weeds which included blackberry (*Rubus* sp.), dock (*Rumex* sp.), inkweed (*Phytolacca octandra* L.), pennyroyal (*Mentha pelegium* L.), and thistles. The species was probably associated with these attendant weeds.

Fam. FLATIDAE

The family is of minor economic importance.

He. 35. *Sephena cinerea* Kirk*

This introduced Australian species is widely distributed in the North Island and the north of the South Island. A small number of adults were taken from lucerne at Bulls (16.3.59) and Ohingaiti (20.3.59), maize at Mangamuka (23.2.59), chou at Cheltenham (24.3.59), and pampas at Kotemaori (9.2.59). The species is known to attack a wide variety of plants in New Zealand, but no detailed studies have been made. It is unlikely to prove of importance in fodder crops.

Fam. RICANIIDAE

The family is of minor economic importance.

He. 28. *Scolypopa australis* (Passion-vine Hopper)*

This Australian species is widespread in the North Island and in the north of the South Island. Single adults were collected from maize at Kaitaia and Mangamuka (23.2.59), from turnips at Te Teko (12.2.59), and from chou plus swedes at Wailii (3.3.59) and Mahoenui (16.3.59). This occasionally associated species is not important in fodder crops. The heavy populations encountered on native vegetation must cause considerable harm, however.

Fam. PSYLLIDAE

The family includes some important pests of agricultural crops.

He. 31 ? *Ctenarytaina pollicaris* Ferris and Klyver*

This species occurs in North and South Islands. A single adult was taken from lucerne at Te Awamutu on 19.3.59. There was no *Leptospermum*, which is regarded as the usual host plant (Tuthill 1952), in the vicinity.

He. 59. *Trioza* sp.

A single adult was taken from mixed chou and swedes at Te Raumoa on 19.3.59.

He. 63. *Psylla* sp.

Three adults were collected from chou at Whakatane on 12.2.59. These were probably associated with the gross weeds rather than with the crop.

Fam. APHIDIDAE

This is an extensive family. Although there are only a limited number of endemic species, many overseas introductions are present in New Zealand.

He. 42. *Aulacorthum solani* (Kltb.)*

This species was taken from a mixed chou and swede crop at Konini on 8.4.59. It has a great number of host plants, and its occurrence is widespread in both Islands.

He. 8. *Brevicoryne brassicae* (L.)*

This world-wide species, commonly a series pest of cruciferous crops, is of widespread occurrence in both Islands. It occurred in 35 cruciferous crops (Fig. 2), being taken from chou, rape, swedes, and turnips, during February, March and April.

He. 41. *Capitophorus elaeagni* (Del Guerc.)*

This world-wide species is known to occur in both Islands, on a number of host plants. In the present survey it was taken from lucerne at Takapau 9.2.59, Otorohanga 19.3.59, and Longburn 24.3.59; from chou mixed with swedes at Pio Pio 16.3.59 and Rauamoa 19.3.59; and from turnips at Masterton 8.4.59.

He. 6. *Hyperomyzus lactucae* (L.)*

This world-wide species is apparently of widespread occurrence in the North Island. The present survey yielded specimens from maize at Dargaville 26.2.59 and Whangarei 26.2.59.

He. 46. *Lipaphis erysimi* (Kltb.)*

This species, which is of world-wide occurrence, was taken from chou at Cambridge 3.3.59 and Urenui 16.3.59; from chou mixed with swedes at Wharepaina 4.3.59; and from turnips at Ohingaiti 20.3.59. It is widely distributed in the North Island, and is known on occasion to be damaging to cruciferous plants.

He. 44. *Macrosiphum avenae* (F.)*

This world-wide species is widely distributed in the North Island. It was taken from turnip crops at Puketona 24.2.59 and Silverdale 2.3.59.

He. 45. *Macrosiphum euphorbiae* (Thos.)*

This world-wide species has been reported from many host plants in both Islands. It was taken from maize at Pakaraka 24.2.59.

He. 47. *Macrosiphum sonchi* (L.)*

This world-wide species is found on thistles. It was taken probably from the associated weeds, in crops of chou at Ashurst 26.3.59; chou mixed with swedes at Maungaturoto 26.2.59 and Konini 8.4.59; maize at Waipawa 9.2.59; swedes at Makerua 26.3.59 and Pahiatua 8.4.59; and turnips at Marton 24.3.59, Te Arakura 24.3.59, and Tokomaru 25.3.59.

He. 65. *Myzus ornatus* Laing

This species was taken from lucerne at Te Awamutu on 19.3.59. Cottier (1953) records it from *Trifolium subterraneum* L., *Lavatera arborea* L., *Primula* sp., *Anemone* sp. and *Bellis perennis L.*, at Palmerston North.

He. 37. *Myzus persicae* (Sulz.)*

This is a world-wide species that is widely distributed in New Zealand. In the present survey it was taken on 35 occasions during February, March, and April, mainly from chou, rape, swedes, and turnips (Fig. 3). It is known to have a great number of host plants and may often reach damaging proportions.

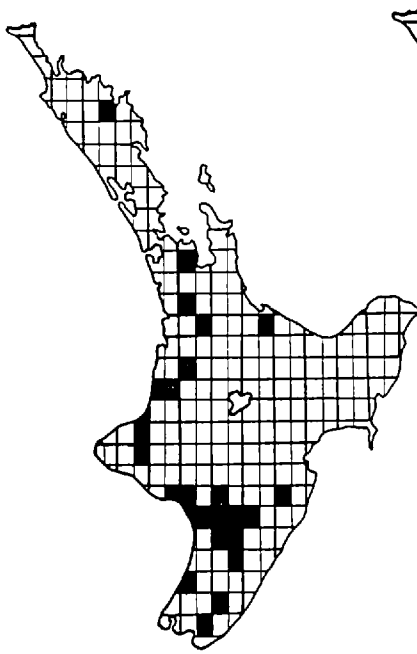


Fig. 3

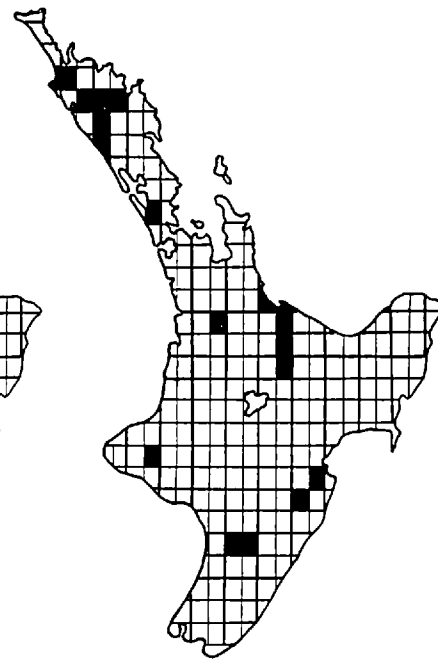


Fig. 4

Fig. 3.—Distribution map for the aphid *Myzus persicae* He. 37.

Fig. 4.—Distribution map for the aphid *Rhopalosiphum padi* He. 39.

He. 64. *Rhopalosiphum maidis* (Fitch)

This species was taken from maize at Kaitaia 23.2.59, Whirinaki 25.2.59, and Ngawha 25.2.59, and from chou at Pakaraka 24.2.59. Cottier (1953) records it from maize at Auckland and Palmerston North, and from *Avena sativa* at Palmerston North. He remarks upon its occasional occurrence and non-economic importance.

He. 39. *Rhopalosiphum padi* (L.)*

This world-wide species is of widespread occurrence in New Zealand. At times it is troublesome in grain crops (Cumber and Todd 1959). In the present survey it was taken on 18 occasions (Fig. 4), during February, March and April. It occurred for the most part on maize crops.

He. 38. *Rhopalosiphum splendens* (Theo.)*

This world-wide species is of widespread occurrence in the North Island. In the present survey it was taken from chou at Martinborough-Greytown 8.4.59, and from turnips mixed with chou at Greytown 8.4.59.

## HEMIPTERA-HETEROPTERA

Fam. NABIDIDAE

The majority of species in this family are predacious, many being regarded as highly beneficial insects.

He. 12. *Nabis capsiformis* Germar*

This species, now nearly cosmopolitan, is widely distributed in New Zealand. In the present survey it was taken in most North Island districts (Fig. 5).

A total of 56 adults and 29 nymphs was collected from lucerne (10 crops), maize (7), chou (7), mixed chou and swedes (1), turnips (4), and swedes (2). Numbers in excess of 3 were taken in 5 lucerne crops, in one swede crop, and one turnip crop. Higher numbers included 9 adults on lucerne at Gisborne (10.2.59), and 8 adults on swedes at Pirinoa (8.4.59).

Adults and nymphs were present from early February to early April. This species is actively predacious on other insects and must be regarded as beneficial.

He. 16. *Nabis maoricus* F. Walker*

This endemic species occurs throughout New Zealand. In the present survey it was taken from lucerne at Bulls (3 adults 16.3.59) and Longburn (2 adults 24.3.59). In testing sampling techniques, single adults were taken at Palmerston North from turnips and mature chou late in January 1959. This species must be regarded as beneficial.

Fam. MIRIDAE

This very large family of insects contains many pests that damage agricultural crops. A few beneficial predacious species are known.

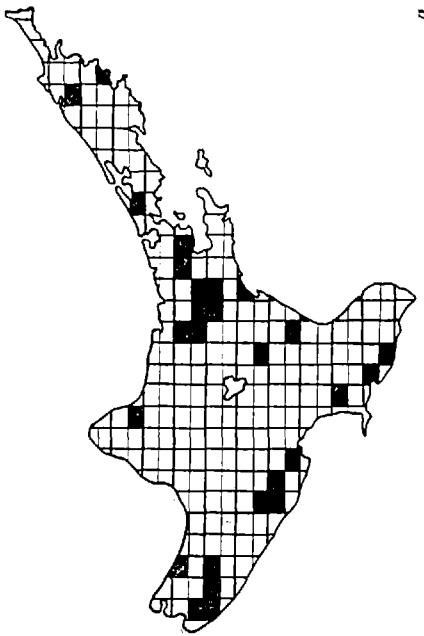


Fig. 5

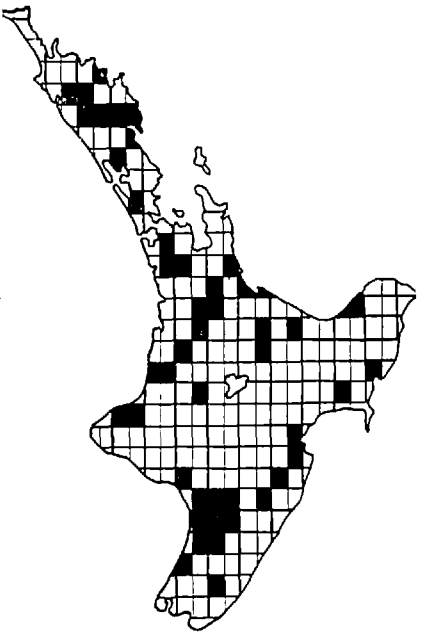


Fig. 6

Fig. 5.—Distribution map for the nabidid *Nabis capsiformis* He. 12.

Fig. 6.—Distribution map for the mirid *Eurystylus australis* He. 17.

He. 27. *Calocoris norvegicus* (Gmelin)*

This European species is now well distributed in the North Island. A single specimen was taken from chou at Cheltenham on 24.3.59. It is probable that this species, if shown to be damaging, will be important in the early part of the season.

He. 26. *Deracocoris maoricus* Woodward*

This species is widely distributed in the North Island, and occurs in the north of the South Island. In the present survey it was taken in small numbers from turnips at Marumaru (10.2.59) and Rangiriri (3.3.59), and from maize at Shannon (25.3.59). This species, which was taken in greater numbers in pastures, is not considered to be important in fodder crops.

He. 17. *Eurystylus australis* Poppius*

This Australasian species occurs throughout the North Island, and in the north of the South Island. In the present survey it was taken in all North Island districts (Fig. 6).

A total of 82 adults and 36 nymphs was taken from 67 crops, the species being present on lucerne (10 crops), maize (16), chou (12), chou plus swedes (7), turnips (12), swedes (3), mangels (4), rape (1), and mixed rape, swedes and turnips (2). The insect occurred

in excess of 3 individuals in 17 crops, of which 7 were turnips (apparently a major host). The greatest catch, however, was from chou at Mercer on 3.3.59 (18 adults and 6 nymphs).

Adults were taken for the duration of the survey, i.e., from early February to early April. The species occurred far more frequently on fodder crops than in pastures, being the most common hemipteron taken. Although crop damage by this insect was not evident, the species may prove to be more important than is at present realised: its feeding habits make it a potential transmitter of virus or fungus disease, or a potential pest through causing mechanical injury.

He. 18. *Halticus tibialis* Reuter*

This widespread Javanese species is well distributed in northern North Island districts. In the present survey small numbers were taken from lucerne at Te Awamutu (19.3.59); maize at Kamo (2.3.59), Eureka (3.3.59), and Paparoa (4.3.59); and turnips at Te Teko (12.2.59) and Waitoa (3.3.59). This species, which occurred in far greater numbers in pastures, does not appear to be of importance in fodder crops.

He. 50. *Lygus* sp.

Two specimens taken from maize at Hangaroa on 10.2.59 have been determined by Dr T. E. Woodward as *Lygus* sp. He indicates (pers. comm.) that it is impossible to give specific names to New Zealand *Lygus* until the genus in this part of the world has been revised. He believes that New Zealand probably has several undescribed species.

He. 10. *Megaloceroea reuteriana* White*

This species is widespread in Australia and New Zealand. Cumber (1959) collected it in moderate numbers from pastures and showed that it is well distributed in the North Island on such herbage. In the present survey it was taken only from maize—one adult and one nymph at Awarua on 26.2.59, and one adult at Helensville on 2.3.59.

Fam. ANTHOCORIDAE

The members of the family are predacious, for the most part upon small arthropods.

He. 51. *Lyctocoris campestris* Fabr.

This predacious species is now almost cosmopolitan (Dr T. E. Woodward, pers. comm.). In the present survey a single adult was taken from maize at Taradale on 9.2.59. If beneficial, this species plays a very minor role.

He. 52. *Poronotellus whitei* Reuter

This species is widespread in Australia and at least the North Island of New Zealand (Dr T. E. Woodward, pers. comm.). In the present survey single adults were taken from maize at Taradale (9.2.59) and Ohinewai (3.3.59). The species is unimportant in fodder crops, but, being predacious, could play a minor beneficial role.

Fam. LYGAEIDAE

The family includes many pests that damage agricultural crops.

He. 9. *Nysius huttoni* White*

This endemic species is widely distributed in the North and South Islands. Single adults were collected from lucerne at Waipawa (9.2.59), Te Awamutu (19.3.59), and Martinborough (8.4.59), and a nymph was taken from chou at Cambridge (3.3.59).

This species, which lives close to the ground surface, prefers areas where vegetation is sparse and where the sunlight strikes through to the ground. Myers (1921) records it on lucerne, and Gurr (1952, 1957) records it as damaging crucifer seedlings in the South Island. It appears that the population does not build up to pest proportions in the North Island. The dry and sparse "edge" vegetation which favours the insect may be a more common feature of the South Island crops. Detailed information on the biology and ecology of this insect is given by Eyles (1958).

He. 23. *Pachybrachius nigriceps* (Dallas)*

This species is widespread in the Pacific area, and is well distributed in the North Island. In the present survey it was taken from maize at Dargaville (1 adult 26.2.59) and Papamoa (2 adults 4.3.59). It is unlikely to prove of importance on fodder crops.

He. 34? *Rhypodes clavicornis* (F.)

The genus is endemic. In the present survey a single adult was taken from lucerne at Greytown on 8.4.59. Although this species is commonly found on some garden plants there is no evidence that it is important in crops.

Fam. PENTATOMIDAE

The family includes many important agricultural pests and some predacious species which must be regarded as beneficial.

He. 61. *Antestia orbona* Kirkaldy

This species is an introduction from Australia. Woodward (1953) recorded material collected near Hastings in March 1950. In the present survey a specimen was taken from the vicinity of a turnip crop at Masterton on 8.4.59. Other adults have recently been collected from bush at Palmerston North (27.9.58, J. M. Esson, and 30.4.59, A.C.E.). These records indicate a wide distribution, at least in the southern part of the North Island. The species is unlikely to prove of importance in fodder crops.

He. 1. *Dictyotus caenosus* (Westwood)*

This species occurs in Australia, and throughout the North Island and northern portion of the South Island. In the present survey small numbers were taken from 11 crops, namely, lucerne at Waipapa (24.2.59), Greenmeadows (9.2.59), Waipawa (9.2.59), and Martinborough (8.4.59); maize at Papamoa (4.3.59); chou at Masterton (8.4.59); and turnips at Maungaturoto (26.2.59), Ruakaka (2.3.59),

Silverdale (2.3.59), Waitoa (3.3.59), and Masterton (8.4.59). It occurred more frequently on lucerne and turnip crops. This species, which was commonly taken in pastures (Cumber 1959), may prove of some importance where crops are being held for seed production.

He. 62. *Cermatulus nasalis* (Westwood)

This species occurs in Australia and New Zealand (Tillyard 1926). Five nymphs were taken from chou at Waipawa on 9.2.59. Nymphs were observed at the time on a seedhead of *Amaranthus retroflexus* L. Tillyard records the species as attacking the pear slug (*Caliroa limacina* de Geer). It must be regarded as a beneficial species of minor importance.

He. 56. *Cuspicona simplex* Walk.

This species, which was first recorded from New Zealand by Spiller and Turbott (1944), is well distributed in the North Island, and occurs on the Three Kings Islands (Woodward 1953b). In the present survey one adult was collected from mangels at Ashhurst on 26.3.59. Woodward records this insect in association with solanaceous plants. The species is not important in fodder crops.

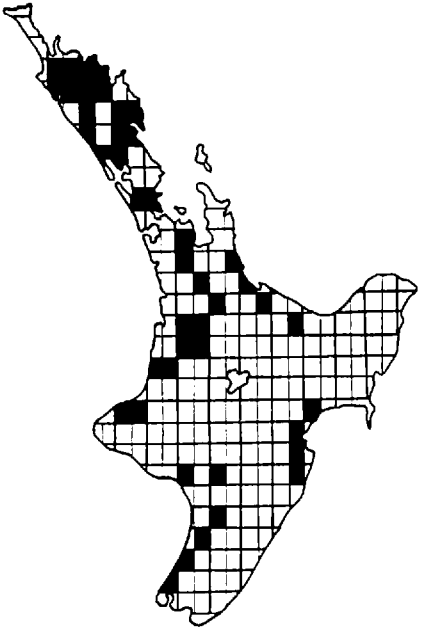


Fig. 7.—Distribution map for the pentatomid *Nezara viridula* He. 22.

He. 22. *Nezara viridula* (L.)*

This cosmopolitan species is distributed throughout the North Island, and occurs in the northern portions of the South Island. In the present survey it was taken in most North Island districts (Fig. 7) —128 adults and 28 nymphs being collected from lucerne (3 crops),

maize (17), chou (11), chou plus swedes (9), turnips (10), and swedes (1). It occurred in greatest numbers in Northland, irrespective of the type of crop. It also occurred in large numbers south of Auckland, e.g., turnips—Te Kuiti (22 adults) and Tauranga (9 nymphs); maize—Pio Pio (5 adults); chou plus swedes—Kotemaori (6).

Accounts of the habits of this species are given by Cumber (1949, 1951). Adults and nymphs were present for the duration of the survey (early February till early April).

It is interesting to note that maize crops in seven Northland areas showed only low infestations. It would seem that either this insect reaches pest proportions only in localised areas, or that its egg parasite, *Microphanurus basalis* Woll., is effective in local areas only.

*N. viridula* is a major pest of maize in Northland, occurring in such numbers as 11, 12, 15, 17, 20, and 26 per plant, and 7, 11, and 12 per cob. Damage to the plants is quite evident. Reddish-purple spots on the stems and cob sheaths mark the feeding punctures. Examination of cobs showed that the rostrums penetrated the sheath and pierced the grains. Many grains were split and many cobs malformed.

Chou was also found to suffer damage from this pest. At Waitoki, the insect occurred in recorded numbers of 4, 8, 11, and 20 per plant. The insects tend to congregate, groups of about 10 being quite common. Damage was evident as extensive puncturing on the stems. At Pakaraka, 28 adults and an empty egg-raft (no evidence of parasitism) were taken. Heavy infestations of chou and swedes were seen at Maungaturoto and Kotemaori, but no such infestations of swedes alone were encountered. Heavy infestations, with feeding on bulbs of turnips, were observed at Ruakaka and Te Kuiti. Lucerne did not appear to be heavily infested.

He. 53. *Oechalia schellembergii* (*Guérin-Ménville*)**

This species occurs in Australia and New Zealand (Tillyard 1926). In the present survey 5 specimens were collected from lucerne (Gisborne 10.2.59), maize (Mangamuka 23.2.59), chou (Puketona 23.2..59), mixed chou and swedes (Waihi 3.3.59), and turnips (Te Kuiti 20.3.59). An egg-raft was taken from chou at Waipawa on 9.2.59.

This is to be regarded as a beneficial species, since it is predacious on lepidopterous larvae etc.; but the numbers taken suggest that it plays a minor role in fodder crops.

He. 60. *Philapodemus australis* (Erichson)

This species occurs also in Australian and Oriental regions (Woodward 1953). A single adult was taken from lucerne at Waipawa on 26.3.59.

** Previously known as *O. consocialis* (Boisd.)

## DISCUSSION

Some 50 species of Hemiptera have been taken during this fodder crop survey. As was to be expected, many were taken in small numbers and probably represent casual associates as individuals of dispersions or associates of attendant weeds.

The following remarks concern the Hemiptera-Homoptera. The cicada species are casual associates, except in the case of pampas. Nymphal stages occupy several seasons, so that they are unlikely to be of importance in annual crops. *Erythroneura zealandica* would appear to feed on a large number of plants and must be regarded as a potential virus transmitter. The same potential exists for the remaining jassids and delphacids, but they were present in small numbers and on a limited number of occasions, as were *Thanatodictya tillyardi, Sephena cinerea, Scolypopa australis,* and the two psyllids. In the aphids, the majority of the species are casual associates. The importance of *Brevicoryne brassicae* and *Myzus persicae* in cruciferous crops is well known, however. It seems probable that *Rhopalosiphum padi* is of more importance in maize crops than is generally realised; perhaps its importance occurs during establishment, rather than at later stages.

Turning now to the Hemiptera-Heteroptera, there are a number of interesting considerations. The two *Nabis* species occurred commonly, and in their predacious capacities are doubtless useful biological control agents. *Calocoris norvegicus* did not appear in significant numbers, and perhaps prefers a cooler climate than is generally encountered in the North Island. Amongst the mirids the introduced species *Eurystylus australis* was consistently present, and warrants study to determine its precise importance. There is no evidence for important species among the lygaeids, although *Nysius huttoni* is known to be damaging to crops in some South Island areas. Amongst the pentatomids only *Nezara viridula* would appear to be important. It is still a serious pest of many crops in Northland—especially of maize and chou moellier—and warrants further attention in the biological control field.

## ACKNOWLEDGMENTS

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## APPENDIX

SPECIES OF HEMIPTERA ASSOCIATED WITH FODDER CROPS

| | Lucerne | Maize | Chou Moellier | Chou Moellier, Mixed Swedes | Turnips | Swedes | Mangels | Pampas | Rape | Rape, Swedes, Turnips, Mixed |
|---|---|---|---|---|---|---|---|---|---|---|
| *Melampsalta muta* | | | | | | | | * | | |
| *Melampsalta sericea* | | * | | | | | | | | |
| *Erythroneura zealandica* | * | * | * | * | * | * | | | * | |
| *Deltocephalus* sp. He 19 | | * | | | | | | | | |
| *Thamnotettix* sp. He 13 | | * | | | | | | | | |
| *Thamnotettix* sp. He 14 | | | | | * | | | | | |
| *Idiocerus* sp. He 54 (?) | | | | | | | * | | | |
| undetermined jassid He 55 | * | | | | | | | | | |
| *Xestocephalus* sp. He 11 | * | * | | | | | | | | |
| *Delphacodes tasmani* | * | * | | | | | | | | |
| *Delphacodes* sp. He 4 | | | | | * | | | | | |
| *Thanatodictya tillyardi* | | * | | | * | | | | | |
| *Sephena cinerea* | * | * | * | | | | | * | | |
| *Scolypopa australis* | | * | | * | * | | | | | |
| *Ctenarytaina pollicaris* | * | | | | | | | | | |
| *Trioza* sp. He 59 | | | | * | | | | | | |
| *Psylla* sp. He 63 | | | * | | | | | | | |
| *Aulacorthum solani* | | | | * | | | | | | |
| *Brevicoryne brassicae* | | | * | * | * | * | | | * | * |
| *Capitophorus elaeagni* | * | | | * | * | | | | | |
| *Hyperomyzus lactucae* | | * | | | | | | | | |
| *Lipaphis erysimi* | | | * | * | * | | | | | |
| *Macrosiphum avenae* | | | | | * | | | | | |
| *Macrosiphum euphorbiae* | | * | | | | | | | | |
| *Macrosiphum sonchi* | | * | * | * | * | * | | | | |
| *Myzus ornatus* | * | | | | | | | | | |
| *Myzus persicae* | | * | * | * | * | * | | | | * |
| *Rhopalosiphum maidis* | | * | * | | | | | | | |
| *Rhopalosiphum padi* | | * | * | | * | * | | | | |
| *Rhopalosiphum splendens* | | | * | | * | | | | | |
| *Nabis capsiformis* | * | * | * | * | * | * | | | | |
| *Nabis maoricus* | * | | * | | * | | | | | |
| *Calocoris norvegicus* | | | * | | | | | | | |
| *Deraeocoris maoricus* | | * | | | * | | | | | |
| *Eurystylus australis* | * | * | * | * | * | * | * | | * | * |
| *Halticus tibialis* | * | * | | | * | | | | | |
| *Lygus* sp. He 50 | | * | | | | | | | | |
| *Megaloceroea reuteriana* | | * | | | | | | | | |
| *Lyctocoris campestris* | | * | | | | | | | | |
| *Poronotellus whitei* | | * | | | | | | | | |
| *Nysius huttoni* | * | | * | | | | | | | |
| *Pachybrachius nigriceps* | | * | | | | | | | | |
| *Rhypodes clavicornis* (?) | * | | | | | | | | | |
| *Antesia orbona* | | | | | * | | | | | |
| *Dictyotus caenosus* | * | * | * | | * | | | | | |
| *Cermatulus nasalis* | | | * | | | | | | | |
| *Cuspicona simplex* | | | | | | | * | | | |
| *Nezara viridula* | * | * | * | * | * | * | | | | |
| *Oechalia consocialis* | * | * | * | * | * | | | | | |
| *Philapodemus australis* | * | | | | | | | | | |