A study of the flora and invertebrate fauna of magnesian grassland (of Thrislington plantation SSSI), with particular reference to plant architecture and invertebrates

Jenkins, P.M.

A study of the flora and invertebrate fauna of magnesian grassland (of Thrislington plantation SSSI), with particular reference to plant architecture and invertebrates.

by

P.M. Jenkins.

A Dissertation submitted in partial fulfilment of the requirements for the degree of Master of Science in Ecology

Department of Biological Sciences

The University of Durham

1990

1. Six spot burnet (*Zygaena filipendulae*) emerging from it's coccon on 13/06/90. Site 4.

Abstract.

1/.Relationships between plant architecture and invertebrates have been widely described, (Lawton 1983 and 1986, Southwood, Brown and Reader, 1979). This study aimed to investigate some part of the invertebrate fauna with particular reference to plant architecture and the affects of disturbance.

2/.Thrislington was chosen as the study site as it consisted of a number of transplantated sites (Fig. 1). These represent a series of 8 Magnesian limestone grassland sites of known age and site history. Previous studies of the flora (Shimwell 1968 and Parks 1982 and 1989) and invertebrates (Sheppard, 1987 & 1989 and Woodford and Bruce, 1983) have produced a detailed history of this Grade 1 SSSI prior to it's transplant.

3/.A series of 25 fixed quadrats (2 square metres) were positioned throughout 5 of the 8 transplanted sites i.e. 1,3,4,6,8. Five quadrats were placed randomly within each of the five chosen sites. These quadrats formed the basis of the vegetation, architecture and invertebrate surveys.

4/.The survey yielded 82 plant species occurring within the fixed quadrats and 112 species throughout the 5 sites surveyed. The sites were found to become more homogeneous with increasing age. The diversity of plant species was greatest on site 6 (removed 3 years ago) with 84 species occurring on that site and lowest diversity on site 1 i.e. 59 species and moved 8 years ago.

5/.The architecture survey data and vegeatation data were used to run DCA analyses. The analyses were carried out on the individual quadrat data and both showed a certain degree of separating with respect to the sites they were taken from in that vegetation (in terms of species) and architecture become increasing homogeneous with age, at Thrislington.

The CCA analyses showed that % bare earth and % moisture content were most influencing the biplot along the first and second axes.

6/.A DCA and CCA analyses were carried out on weevils, spiders, carabids and "all invertebrates". The "invertebrate" CCA showed that site age (axis 1) and the height classes 0-2 & 2-5cm (2nd axis) explained the greatest amount of variance. The weevil CCA showed that pitfall position and 10-20cm were the two most important (measured) variables. The spider CCA showed the greatest association with average moss depth and 2-5cm. While the carabids showed the greatest association with 2-5cm and % moss cover.

7/.In addition to the quadrats and pitfalls further invertebrate groups were selected for study by

different techniques - walking transect for butterflies, hand searches for molluscs and counts for Cercopidae nymphs within each of the 25 fixed quadrats.

The butterfly transects revealed that the small heath was the commonest of the 13 species recorded and Site 3 had constantly high counts throughout the study period.

The mollusc survey yielded 8 species (5 snails and 3 slugs). The commonest large snail was *Cepaea nemoralis*. No significant correlation was found between Cepaea numbers and environmental variables measured, using correlation coefficents.

The Cercopidae nymphs counts produced a total of 44 host plant species, five of which accounted for 80% of the total counts. An estimate of density was calculated for each site and an average density per square metre on each of the four sampling occasions.

Multivariate techniques using the DCA and CCA analyses run on the CANOCO programme were found to be a robust and reliable techniques for investigating the interrelationships between species and environmental variables.

Acknowledgements.

Steetly quarries limited gave permission for site access to the transplant site and special thanks to Mr.D.Parks (land management officer) for his help and imformation. I would also like to thank Dr.V.Standen for her supervision and Dr.J.E.C. Buttterfield for checking my Carabid identifications and general computing help. Dr. B.Huntley's advice on vegetation and architecture surveys was greatly appreciated.

I would also like to thank David Coates for access to the geography soil laboratories.

E.

<u>**Contents.**</u>

List of Figures.

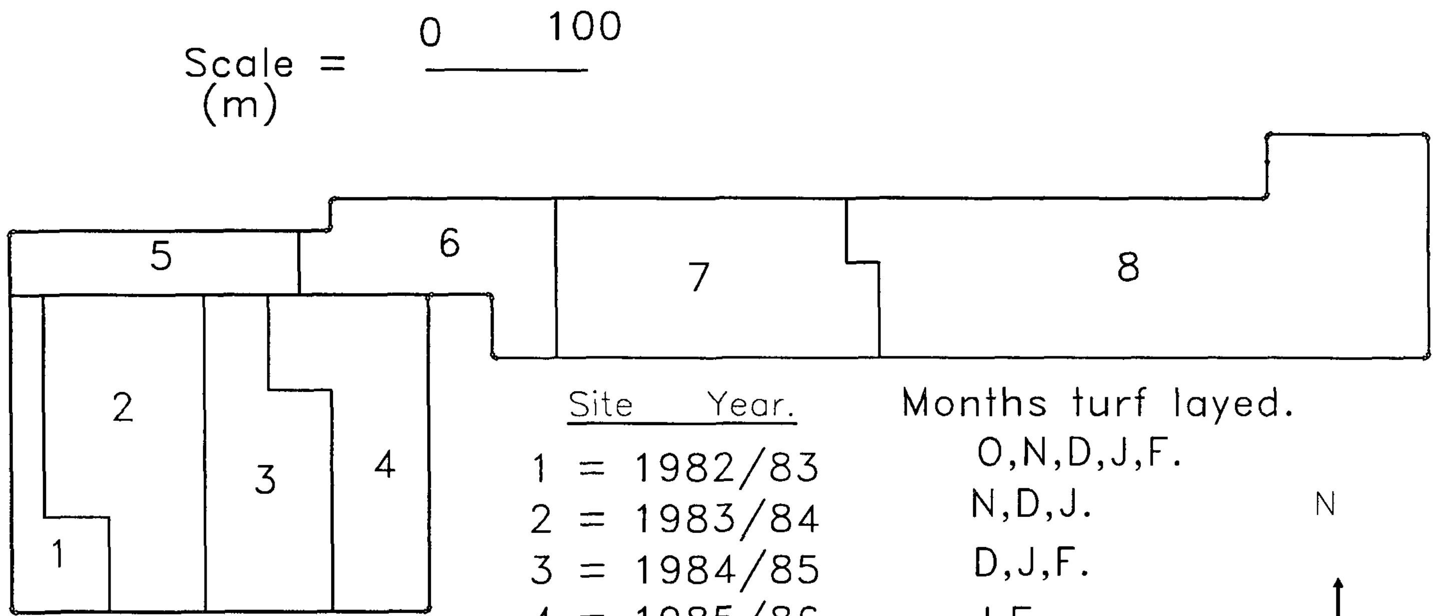
List of Tables.

H.
List of Plates.

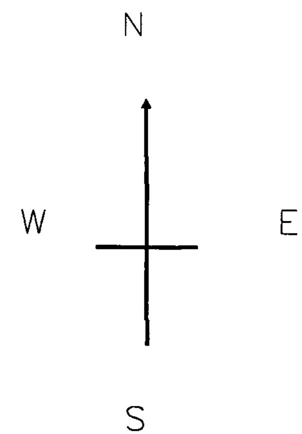
Chapter.1.

Introduction

Figure 1. Thrislington transplant turf year plan.



Site	Year.	Months turf layed.
1 =	1982/83	O,N,D,J,F.
2 =	1983/84	N,D,J.
3 =	1984/85	D,J,F.
4 =	1985/86	J,F.
5 =	1987	F,M.
6 =	1987/88	N,D,J.
7 =	1988/89	N,D,J,F.
8 =	1989/90	N,D,J,F.



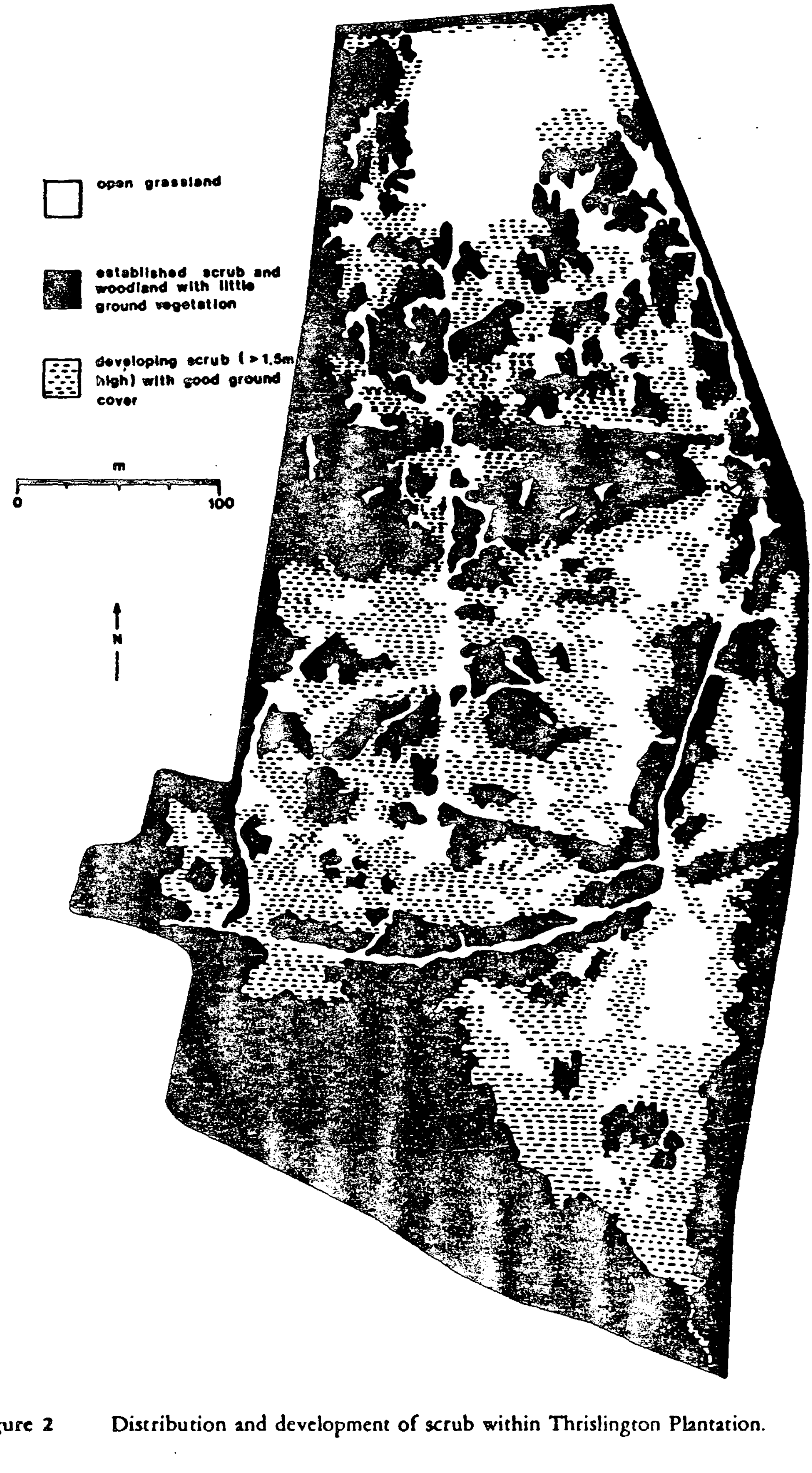


Figure 2 Distribution and development of scrub within Thrislington Plantation.

1 .Introduction.

1.1 .Thrislington Plantation Site of Special Scientific Interest.

Thrislington Plantation (OS ref. NZ 318228) covers an area of 20.5 hectares (roughly 700m x 350m) on the magnesian limestone 12km Southeast of Durham City, County Durham. The underlying lithology of the site is magnesian limestone bed-rock overlain by dolomitic silaceous overburden to a depth of 0.5 - 5.0m. Magnesian limestone extends Northwards from Nottingham to northern County Durham, in a narrow belt 240 km long and has a maximum width of 8 Km in the Pennines (Park 1989). Covering an area of 600 km2 in Britain, (Richardson and Evans 1986).

1.2. The magnesian limestone and associated soils.

The magnesian limestone or dolomite (any magnesian limestone with >15% magnesium content) was formed in tropical seas of the Cretaceous era, (Dunn 1980). Chemical analysis by Richardson and Evans (1986) gave a chemical composition of 59% calcium carbonate, 40% magnesium carbonate, 0.15% alumina, 0.6% ferric oxide and 0.25% silica for Thrislingtons magnesian limestone. A further analysis of the macronutrients essential for plant growth i.e. nitrogen, phosphorus and potassium produced figures of 2.9ppm, 0.6ppm and 4.4ppm respectively, (Booy 1975). These analyses show low levels of macronutrients which give rise to a specialised flora. The high carbonate content favours a flora adapted to alkaline conditions i.e. calcicoles.

The underlying bed-rock gives rise to a shallow brown rendzina (the Elm series of the Aberford Association) varying in depth from 100-300mm. Other areas within Thrislington Plantation have brown calcareous soils to a depth of 550-850mm, (Parks 1989).

1.3. Site history.

Thrislington plantation was designated a grade 1 Site of Special Scientific Interest by the Nature Conservancy Council (NCC) in 1968 . Thrislington Plantation had been under threat from colonisation of scrub invasion (photograph 4) mainly hawthorn (*Crataegus monogyna*) and silver birch (*Betula pendula*). The extent of the problem can be seen in the map of the plantation

2/. Steetly Quarries Thrislington Works.

3/. Thrislington transplant, site 8 in top left corner and site 1 in the foreground.

opposite,(from Parks 1989, Fig.2.). In 1979 a planning application was put forward for Steetley Quarry Products Limited for expansion of dolomite quarrying (photograph 2). This would have resulted in the destruction of the Northern half of the site. Opposition from Durham Wildlife Trust and the NCC was on the grounds that Thrislington Plantation represents the most diverse fauna and flora of any calcareous grassland (photograph 5) in the North East of England, (Dunn 1980). This resulted in a compromise, and a plan was produced to relocate 5.5ha of Thrislington plantation under threat, 800m to the South West onto two fallow arable fields.

1.4 .Transplantation of the turfs.

The grassland was transplanted over a period of 8 years from 1982 onwards during the winter months (see turf year plan - Fig.1.) to keep disturbance of the flora and fauna to a minimum the turfs were moved using a specially adapted bucket attached (photograph 7) to an articulated front bucket off-loader. Each turf being 4.75 x 1.75m and a depth of 400 - 500mm - the entire brown renzina profile. These were placed on the new site and overburden was placed between the 100 - 200mm gap between the turfs. This resulted in a patch work of 5000 transplanted turfs (photograph 6) over a period of 8 years of known age, site history and species composition due to a pretransplant vegetation survey by Parks (1982). This was the major consideration for choosing Thrislington for this study.

1.5 The Calcicolous grasslands of Thrislington.

The extensive Calcicolous grassland has developed in East Durham on the Magnesian grassland , the most important being Thrislington plantation, (Graham, 1988 and Parks 1989). Shimwells (1968) phytosociological studies defined Thrislington as a sub- alliance of the Seslerio - Mesobromian community in the Class Festuca-Brometea, this association Seslerio-Helictotrichetum grassland is unique to Eastern Durham, with no counterpart in Western Europe, (Shimwell 1968 and Parks 1989). This association is typical of free draining calcareous soils over the Magnesian Limestone. Shimwells (1968) releves' at Thrislington typically had 90-100% herb cover and 10% moss cover (given in Graham 1988).

Thrislington is important as it is the most northerly site in Britain for Columbine - *Aquilegia vulgaris* and perennial flax *Linum anglicum* (photograph 8) and is the lowland limit of dark red

4/. Thrislington SSSI showing scrub invasion.

5/. Thrislington SSSI. Magnesian Grassland.

helleborine - *Epipactis atrorubens* (see photograph 14), birds eye primrose - *Primula farinosa* and mountain everlasting - *Antennaria dioica*, (Dunn 1980).

Due to open cast mining and agriculture the magnesian grassland are becoming increasingly fragmented and reduced in size, (Dunn 1980). Thrislington is accepted as the most important refugia for the Sesleria-Helictotrichetum association in Western Europe, (Parks 1989), this association supports an equally important invertebrate fauna.

1.6 .Importance of Thrislington for invertebrates.

Thrislington Plantations was designated as a grade 1 Site of Special Scientific Interest as much for its diverse insect fauna as its diverse flora. This site holds the largest inland colony of the Northern Brown Argus butterfly (*Aricia artaxerxes salmacis*) and the largest population of the glowworm (*Lampyris noctiluca*) in the North-East of England. Other rarities include the spider *Tapincyba pygmaea* (known from only 5 sites in Britain), the harvestmen *Odiellus spinosus* and *Mitopis ericaeus* (both being found in less than 100 10 km grid squares) and 3 rare weevils *Alophus triguttatus*, *Brachysomus echinatus* and *Orthochaetes setiger*. A survey conducted pre and post transplant found all these species except glow worm and brown argus to be lost from the transplanted turfs, (Sheppard 1987 and 1988). A total of 194 species of invertebrates were recorded by Sheppard after transplantation.

This invertebrate survey may also provide information on losses or gains in species at Thrislington.

6/. Newly transplanted turf on site 8.

7/. Specially design "bucket" for transplanting turfs.

8/. Perennial flax (*Linum anglicum*) on site 4.

9/. Purple moor grass (*Sesleria albicans*) on site 8.

Chapter. 2.

Methods.

2. Methods.

2.1. The sites used.

Thrislington transplant consists of eight sites of various ages (see Fig.1.). Five of these were used to form the basis of this survey - 1,3,4,6 and 8. These five sites gave a range of ages, plant species, plant architectures and invertebrate faunas on which the surveys were based.

Site.	1	2	3	4	5	6	7	8
Moved	1983/84	84/85	85/86	85/86	86/87	87/88	88/89	89/90
Age(years)	8	7	6	5	4	3	2	1

2.2. The vegetation survey.

The vegetation survey was based on the guidelines set out in the Nature Conservancy Councils botanical survey and monitoring methods for grasslands (Smith et al 1985). The method was followed with one exception in that 2x2m square fixed quadrants were used instead of the recommended 1x1m. The 2m fixed quadrats were used in the N.C.C. monitoring scheme enclosing the 1x1m quadrats at its heart and any new species within the 2m square are recorded with a tick. This method allows other sites to be compared with this current survey. Sites 1,3,4,6 and 8 were used as the basis of the vegetation survey. These represented the most diverse sites in terms of age and plant species composition. In each of the 5 sites 5 randomly placed 2m square quadrats were permanently marked using bamboo canes and individually marked for ease of reference at a later date.

The fixed quadrats were surveyed using the domin scale. (Table.4.) on three occasions. This produced a species list and a record of cover abundance for each quadrat during the season. This data set was the basis for comparison of plant communities within and between sites. It was also used in the multivariate analyses of the flora and/or species and site factors. The Braun Blanquet (see fig.4.) and DAFOR rating (dominant; D, abundant; A, frequent;, F, occasional;, O and rare R) were not used due to the limited time available. These methods are used in the N.C.C. monitoring scheme as an "optional extra".

As the 2x2m square quadrats were to be the basis of subsequent surveys of including snail, slug and froghopper nymph densities and the plant architecture the number was limited to a total of 25 quadrats (Causton 1988). The greater the number of quadrats used the greater the accuracy of the survey, (Clapham 1979 and Southwood 1978, 2nd edition),

Figure. 2a.

Domin and Braun-Blanquet.

	Domin scale.	Braun-Blanquet scale.
99-10%	10	5
75-90%	9	
50-75%	8	4
33-50%	7	3
25-32%	6	
10-25%	5	2
4-10%	4	
<4% frequency.	3	1
<4% ocassional.	2	
<4% 1 or 2.	1	

From Causton (1988).

but due to the constraints of time 5 quadrats were used per site representing 20 square metres per site. In order to obtain a measure of the numbers of plant species represented in these quadrats as a percentage of the plant species per site (table.1.), each site was frequently walked giving an additional species list per site of plants (see part 2 of vegetation list in the appendix). The number of species in the 5 quadrats per site was calculated as a percentage of the total occurring in each site.

Other methods of surveying include line transects where all plants touching the line are recorded and point sampling with a 1x1m frame with 100 points, where the number of contacts with the frame per species is recorded, (Clapham 1979 and Southwood 1979 (2nd edition)). These methods were not used due to the need for fixed quadrats (for the invertebrate survey) and due to limited time the domin scale was considered to be sufficiently accurate.

The vegetation was surveyed during a two day period at 3 week intervals on three occasions. Every species occurring within the quadrats was recorded including Bryophytes and Pteridophytes. The percentage of bare earth was also recorded where it occurred.

Two years before the turfs were transplanted a vegetation survey of the Thrislington area was carried out by Parks, this resulted in a species list of 138 species shown in the appendix.

2.3. Plant architecture.

Architecture, in vegetation terms, describes the structure of a plant it's height, the number and position of leaves, etc. With regards to grassland architecture there is great variation from season to season compared to deciduous woodland, because most species are herbaceous . Their above ground architecture develops from nothing and becomes more complex as leaves, stems and flowers develop. There is often a peak invertebrate diversity associated with a peak in age/architecture of herbaceous plants, (Lawton 1983). The architecture survey was carried out between 17/07/90 - 16/07/90. When the species diversity/architecture was at its maximum. The importance of plant architecture with respect to invertebrates is dealt with in the discussion.

Numerous researchers have found a high correlation between invertebrate diversity and plant architecture. Certain groups have been studied and found to have a high degree of correlation with plant architecture. These groups include spiders (Robinson 1981, Tretzel 1955 and Chew 1961 both in Robinson 1981), froghoppers and leafhoppers or Auchenorhycha - Homoptera (Morris 1969, 1971, 1973, 1979, 1981b and 1983, Walloff and Soloman 1973 and Whittaker 1969) and

(Morris 1969, 1971, 1973, 1979, 1981b and 1983, Walloff and Soloman 1973 and Whittaker 1969) and Carabids - Coloeptera (Butterfield and Coulson 1983).

The correlation between general invertebrate diversity and that of specific species with architecture was investigated in this study.

Numerous methods for sampling plant architecture have been developed by various workers. Murdoch, Evans and Peterson (1972) used a point sampling technique. This involoved placing a metal rod at 45 degrees along a 100 points on a transect and recording all the touches in three height classes. These were 0.0 - 2.4cm, 2.5-7.1cm and < 45cm. Other methods include using a metal rod and "free disc" with a hole in the centre. The disk is then placed on rod and allowed to drop until it rests on the vegetation and the height can be read off on the vertical scale. This method only gives a record of height, (Ellis 1990 personnal communication).

The method employed in this survey was that used by Poissonets bayonet method, (Poissonet 1973). The bayonet method was adopted due to ease of use and accuracy when compared to other methods.

The bayonet consists of an aluminium blade 65cm high, 4.5cm broad and 2mm thick, (see Fig.3.). The upper part being T shaped is used to push the bayonet into the ground, level with the zero on the vertcal scale marked on the bayonet (in 1cm divisions). From one limb of the handle a plum line is suspended to ensure that each measurement is made verticaly.

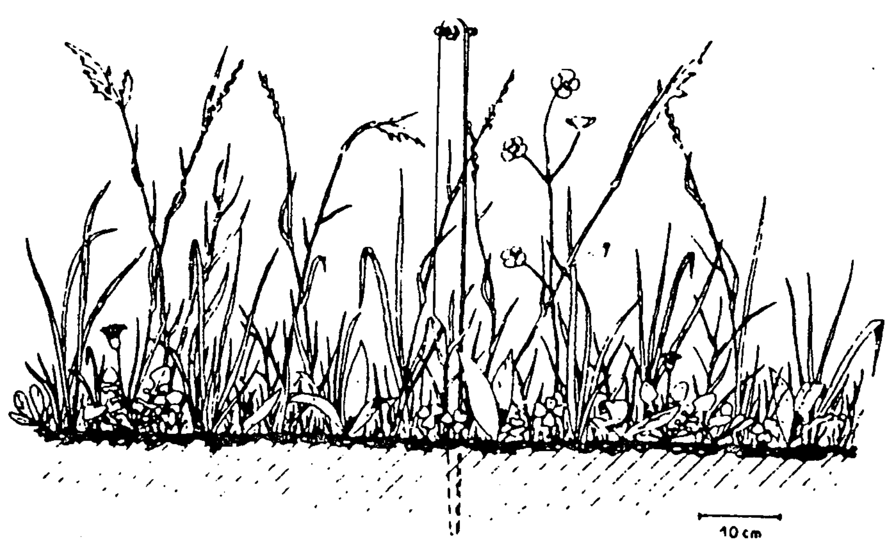


Figure.3. The bayonet method of architecture measurement. (From Poissonet 1973).

The architecture is recorded by counting the number of touches along the right hand bevelled edge of the bayonet in each height class. Number of touches per species can also be recorded but due to the limited time available only the total number of touches were recorded. These height classes are 1cm each between 0-15cm (0-1cm, 1-2cm to 14-15cm) and then ten divisions of 5cm between 15-65cm. These divisions were adopted after a previous field trial using the bayonet.

For each of the 25 fixed 2x2m quadrats 20 randomly placed samples were recorded giving a total of 500 samples. This resulted in the 25 records of the total number of touches for each of the 0-1cm division, 1-2cm, etc, giving a total of 25 totals per quadrat for each of the 25 quadrats. The set of 25 divisions x 25 quadrats were entered into the Canoco programme as one of the environmental variables. The architecture survey is also shown in graph form in Figs 9-13. (environmental variables are given in Fig 6 and 20) . The ordination obtained is shown in Fig 14.

2.4. Soil variables.

A 10g soil sample from each quadrat was removed and taken back to the laboratory for analysis of moisture content, organic content, carbonate content and pH). All formulae for calculating percentages are shown in Fig.4.. These variables were used in the CCA vegetation analyses.

2.4.1. Soil moisture content.

A soil core was taken randomly within the boundary of each quadrat using 1/1000 m\2 corer. The soil was cored to a depth of 10cm in each quadrat. The samples were labelled and placed in sealed bags. The humus layer and any vegetation were removed and the top 6cm was separated and mixed thoroughly, (Chapham 1976). From this a 10g sample was taken and placed in a crucible in an oven at 110 degrees C to dry. The sample was weighed every hour until a constant weight was obtained. The dry weight was then recorded and the percentage moisture content calculated (Fig.4.). This was repeated for each of the 25 samples.

2.4.2. Soil organic content.

The sample used for content analysis was reweighed before placing in the muffle furnace at a 550 degrees C for 4 hours. The percentage organic contents of the samples are shown in Fig.6.

Figure .4.

Soils - calculation of losses on ignition.

5 weights.

A - crucible weight

B - crucible weight + sample

C - crucible weight + sample after drying at 105°C

D - crucible weight + sample after ignition at 550°C

E - crucible weight + sample after ignition at 950°C

Calculate:

Sample wet weight = B - A = WW

Sample dry weight = C - A = DW

$$\% \text{ loss on drying} = \frac{(WW - DW)}{WW} \times 100 = WL$$

Sample wt. after ignition at 550°C = D - A = IW
Sample wt. after ignition at 950°C = E - A = SW

$$\% \text{ loss on ignition at } 550°C = \frac{(DW - IW)}{DW} \times 100 = OL$$

$$\% \text{ loss on ignition at } 950°C = \frac{(IW - SW)}{DW} \times 100 = CL$$

WL provides an estimate (very rough) of water content

OL provides an estimate of organic content

CL provides an estimate of carbonate content.

2.4.3. Soil carbonate content.

The sample was reweighed before placing in a muffle furnace at 950 degrees C for 4 hours. The percentage weight loss giving the percentage carbonate content. The carbonate content of each sample are shown in Fig.6..

2.4.4. Soil pH.

The vegetation layer from the top of each soil core was removed. The horizons of the top 6cm of each core were then mixed and from this a 10g sample was taken. The 10g sample was added to 25ml of distiled water and mixed thoroughly. The resulting 1 : 2.5 suspension was left to equilibriate for 1 hour. The pH meter (a 7020 Electric Instrument Limited) was calibrated using buffers to pH 7 and pH 4 and 9. The electrodes were placed in each suspension and left for 2 minutes before the reading was taken to 1 decimal place. The electrodes being washed with distiled water after each measurement (Hesse 1971). See Fig.6.. for pH's. .

2.5. Population estimates of invertebrates (within the 25 2x2m quadrats).

The invertebrate density surveys were based on material collected within the 2x2m fixed quadrats. The plots were used to sample the populations of 3 herbivore groups - froghopper nymphs, snails and slugs. Different techniques were employed for each group as described below.

2.5.1. Cercopidae nymphs - froghoppers.

The total number of Cercopidae nymphs on each plant species was recorded separately giving a total per quadrat and per plant species over time. The Cercopidae were counted fortnightly allowing the change in population density to be monitered over time.

2.5.2. Mollusc density survey.

The density of snails per quadrat was sampled after rain and/or during rain. In all the counts the vegetation was always wet. As *C.nemoralis* appeared to be the most common large snail by far this species was counted. Other species densities such as *Cepaea hortensis* were not recorded whilst searching due to their low density or small size and difficulty in obtaining a accurate density using the hand searching method. These large, upto 22x25mm in diameter (Cameron and Kerney 1979) snails are ease to find during wet weather giving a more accurate population density per m than is possible for the smaller species. A population estimate can be obtained for the smaller species by sieving vegetation and leaf litter,(Cameron and Kerney 1979) but due to the limited time available and as this method is highly destructive, it was not used in this study.

Each quadrat was hand searched for 10 minutes and all *C.nemoralis* recorded. A total of 100 searches were made within the 25 quadrats (4 per quadrat).

The same method was used in the slug survey with a 10 minute search time. A total of 100 counts were conducted in the 25 quadrats (4 per quadrat) simultaneously with the snail hand searches.

2.6. The Lepidoptera survey.

Lepidoptera comprise both the butterflies and moths of which there are 2313 species in Britain, (Hello 1947). Butterflies and moths were surveyed separately. The moths were mainly recorded as and when they were encounted and are given in a species list in the appendix. The butterflies were surveyed using fixed line transects. The transect method has recently been modified to use for population estimates for day flying moths by Erhardt (1985). During this survey any moth disturbed or seen during the butterfly monitoring was also recorded.

The method of surveying butterfly populations adopted was the Institute of Terrestrial Ecologys (I.T.E.) butterfly scheme, (Hall 1981). This involves the use of a series of permanent posts (set up Sam Ellis in 1990) a set distance apart. This method was first used by the I.T.E. in 1973 by the staff at Monks Wood research station. It involved simply counting the number of butterflies within 2.5m either side of the transect line 2.5 in front of the observer whilst walking at a fixed pace. Each individual is recorded. This is repeated on a weekly basis ideally from the 1st April to 30th September. In this survey recording was from 30/04/90 - 18/08/90 . The time of the recording was carried out was kept as constant as possible every Thursday morning whenever the weather conditions were suitable. The limits on weather are:-

A/. A Transect should not be walked at temperatures below 13 degrees C.

B/. At temperatures between 13-17 degrees C, there must be at least 60% sunshine.

C/. Above 17 degrees C, the amount of sunshine is not critical, Hall 1981.

This method gives an indication of declining populations and/or areas which harbour high populations of butterflies such as the Durham Argus (*A.artaxerxes salmocis*)

As the transects are of a set length and the numbers of each species are known within 2.5m each side of the transect then a population estimate can be calculated. This however does not provide information on wether the butterflies are breeding or, passing through or feeding in that site, (Hall 1981). Nevertheless as all the sites at Thrislington are roughly rectangular then this method is ideal for estimating butterfly populations. The width x length of each site gives the total area in square metres. The densities of each species of butterfly are calculated by dividing the number of butterflies observed in the 5m wide transect by the length and converting this figure to densities per square metre. This density is then multiplied by total area to give a population density per species per site over time.

A picture of the population dynamics of the separate species can be obtained using this quick and easy method. Mark and recapture methods were then used to re-survey the butterflies by I.T.E. researchers and a there was a high correlation between the two techniques, (Hall 1981). Mark and recapture was not used in this survey.

2.7. Pitfall trapping.

A pitfall trap was positioned at the Northern most corner of each fixed quadrat . They were placed flush with the soil surface. In order that invertebrates remained in the pitfall 4% formalin solution was used to a depth of 3cm. A 1% teepol solution (wetting agent) was added to reduce the surface tension of the formalin reducing the likelihood of invertebrates escaping. The catch is directly related to the edge length of the trap (Luff 1975) and standardize this a constant size was used. The pitfalls consisted of a plastic cup with a internal diameter of 68mm and a depth of 90mm. These were collected every fortnight and new traps set.

Initially a series of 10 pitfalls were layed along a transect line in each site. This transect line was in use from 16/04/90 - 25/05/90 . Due to the length of time required to sort each pitfall (average of one and a half hours) the number was reduced to 5 per site and relocated at the fixed quadrats. The pitfalls were placed on the fixed quadrats on 25/05/90 - 18/07/90.

The majority of invertebrates caught in the pitfalls were counted and placed in order, family or species. Numbers per quadrat were kept separate on all occasions. The exceptions being- mites below 2mm long springtails (except for Orchellia sp) due to the limited time and large numbers collected.

Pitfalls have a number of drawbacks which will be dealt with in greater depth in the discussion. Pitfalls have a tendency to trap larger numbers of active species and catches of carabids (Greenslade 1963) and spiders (Robinson 1981) are reduced in dense vegetation.

The four categories that comprise the environmental variable (used in the invertebrate CCA'S) pitfall position are given in Fig.20.

2.8. CANOCO programme - introduction.

Many ecologists are faced with samples containing a multitude of species and environmental variables, (Ter Braak 1987) and with interpreting their significance. Previous statistical methods assumed linear relationships between species. If analysis of non-linear, community or species is required then ordination and cluster analysis, cannot be used. These are indirect analysis which are less powerful than "direct" regression analysis. This has lead to the technique of multivariate techniques from regression and ordination analyses. These new methods are called Canonical (or constrained analysis). The more powerful technique known as canonical ordination is capable of explaining the specific effects between data sets. Canonical correspondence analysis does not assume linearity in data and is able to detect relationships between environmental variables and species.

The programme known as CANOCO is an extension of DECORANA, (Hill, 1979).

The two options on the CANOCO programme used is this dissertation study are DCA (detrended correspondence analysis) and CCA (Coninical correspondence analysis). DCA analysis is an ordination expressed as a scatter plot of the eigenvector scores or sample scores (either environmental, site or species scores). The CCA analysis is an extension of the weighted averaging ordination, (Whittaker 1967, Hill 1973 in Ter Braak 1987) which arranges the species along axis of environmental variables. CCA distributes the species along the axis with maximal separation, the eigenvalues (these represent the % variance accounted for by the biplot of species-environment relations i.e. an eigenvalue of 0.28345 for axis 1 shows that 28% of the variance is explained by that axis e.g. pH, site age) produced by CCA measure this separation. The output is an ordination diagram which shows the pattern of community variation and the main features of the distributions of species along the environmental variables, hence species-environmental relationships can be detected.

The species are represented by points and those showing the strongest correlation with the environmental variables are labelled with the latin name or a code number. The environmental variables are shown on the biplot, with arrows. Both the relative lengths and directions of the arrows are important, (thus the arrows can be reduced or increased to fit in the bipolt, (Ter Braak 1986)). The greater the length of the arrow the greater it's importance with respect to the other environment variables. Directionally, each arrow represents an axis which can be extended backwards through the biplot. A line can then be extended at 90 degrees to this axis from each species or site to show relative position of each with respect to the variable.

The eigenvalues obtained in the four CCA analyses are given in Table 4.

Chapter. 3.

Results.

3. Results.

3.1. The vegetation.

3.1.1. Plant species composition.

Twenty five fixed 2x2m quadrats formed the basis of a vegetation survey. The final species list for the quadrats was 82 species in 100m/2 surveyed representing total species counts in each quadrat from 02/06/90, 26/06/90 and 14/07/90. The species list for the quadrats is given in part 1 of the vegetation list in the appendix. Latin names are given on a presence/absence basis for the 5 sites and histograms showing total number of species per quadrat are given in Fig.5.

Additional species outside the quadrats but found within the site were also recorded for each site and are given in part 2 of the vegetation list in the appendix. The total number of additional species was 31 or 28 % of the total flora including the additional species. All species recorded within the quadrats were also recorded throughout the site, results are given below:-

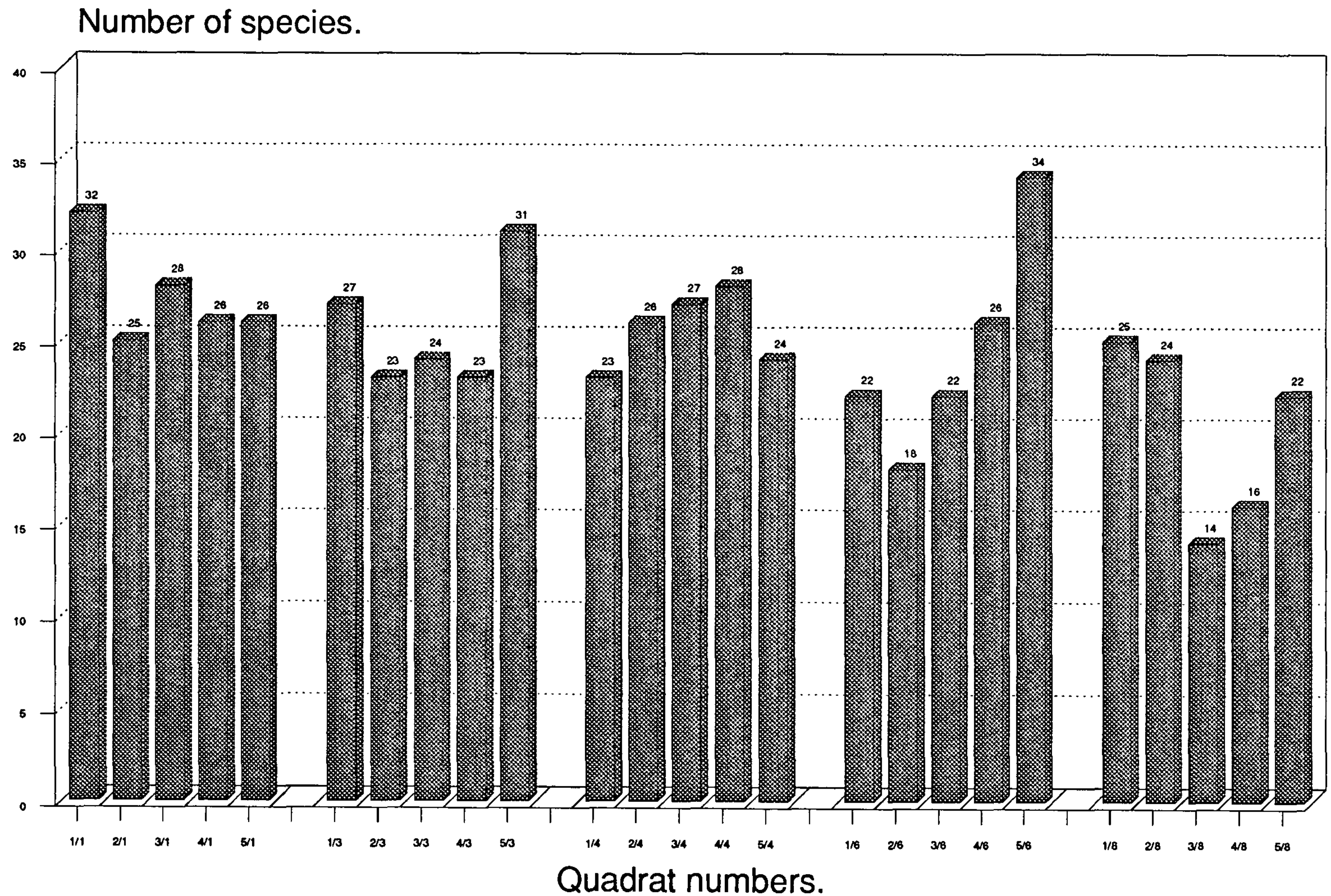
Table.1. Vegetation survey results.

Site.	1	3	4	6	8
Quadrat totals.	55	58	53	67	59
Site totals.	59	64	66	84	81
% occuring in quadrats as % of site total.	93%	90%	80%	80%	73%
% occurrence per site as % x% of all sites i.e. 112	49%	57%	47%	60%	53%
Average number of species per quadrat i.e. 2 square metres.	27.4	25.6	25.6	24.4	20.2
Range of species numbers per quadrat.	25-32	23-31	23-28	18-34	14-25

The number of species per quadrat is shown in Fig.5

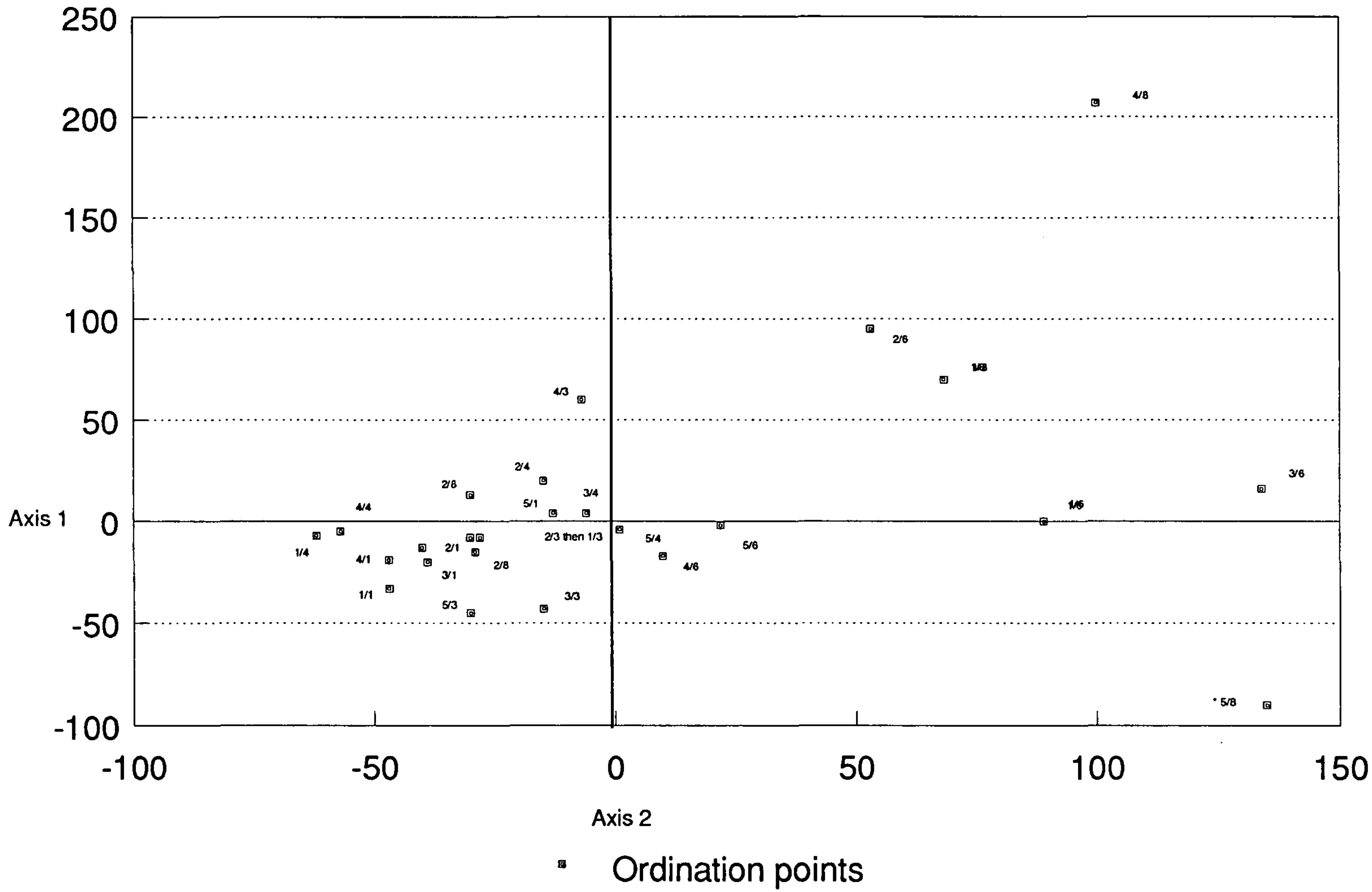
113 species of plant were recorded from the whole transplant site and the range in number of species per quadrat was 14-34. The average number per species per site ranged from 20.2 for site 8 to 27.4 for site 1 and there was a steady increase in average number of per quadrat with

Fig.5. Total number of plant species per
fixed quadrat from 17/05/90-12/07/90.



DCA of vegetation quadrats.

Figure.15.



site age. However the total number per site showed the reverse trend with highest numbers per site in sites 6 and 8. Graminiae were the most abundant in terms of cover within the quadrats including sheeps fescue *Festuca ovina* and False brome *Brachypodium sylvaticum* recording the having domin values. *F.ovina* was particularly common often having domin values of 5 or more (10-25%). High domin values were also recorded for common rockrose *Helianthemum chamaecistus* (<8 domin value), *Lotus corniculatus* (<5), *Sanguisorba minor* (<5), *Plantago lanceolata* (<5) and *Centaurea scabiosa* (<5). Many species recorded domin values of 4 or less including cowslip, *Primula veris* (<4), yellow rattle, *Rhinanthus minor* (<3), selfheal, *Prunella vulgaris* (<3), common milkwort, *Polygala vulgaris* (2), lady's bedstraw, *Galium verum* (<2) and yellow oat grass, *Trisetum flavescens* (<2). The data set for the CCA analysis is also given in the appendix, with domin values on a quadrat basis.

Six species of orchid were recorded on the transplant, given here in order of abundance, Twayblade *Listera ovata* (photograph 15), early purple orchid *Orchis mascula*, common spotted orchid *Dactylorchis fuchsli* (photograph 17), fragrant orchid, *Gymnaadenia conopsea*, Northern marsh orchid, *Dactylorchis purpurella* and heath spotted orchid *Dactyylorchis mascula*. Other species recorded prior to the transplant - frog orchid *Coeloglossum viridae* and dark red helleborine *Epipactis atrorubens*

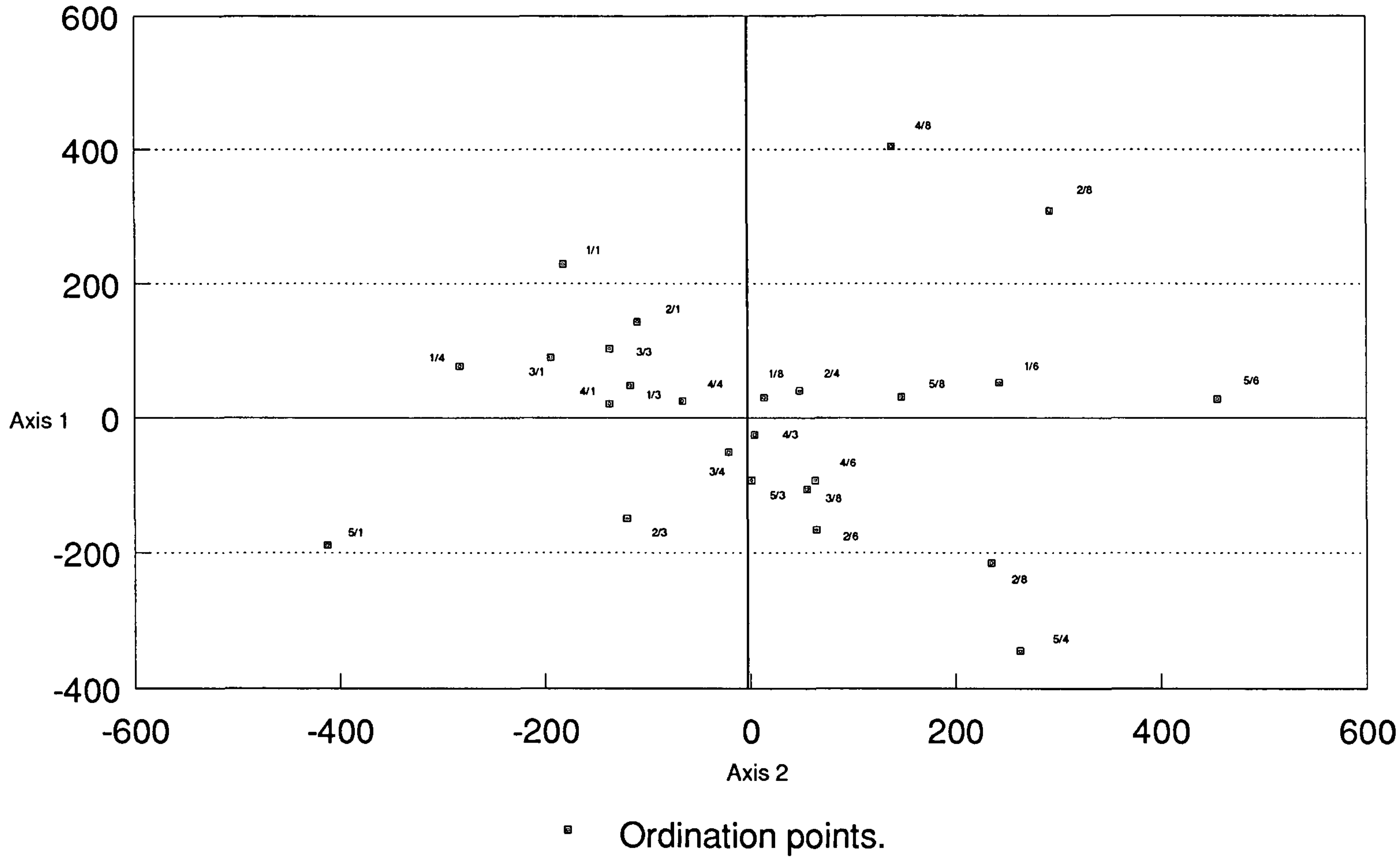
(photograph 14) were not found during this study. Photograph 14 of *E.atrorubens* was taken at Raisby quarry, which supports a large population of this species. Many orchids are abundant in open disturbed ground especially limestone overburden (photograph 10) i.e. *D.maculata* and *G.conopsea*.

A large number of rare species that occur in Thrislington plantation including mountain everlasting *Antennaria dioica*, birds eye primrose *Primula farinosa* and burnett rose *Rosa pimpinellifolia* were not recorded in this survey. It is assumed that the absence of these species is due to disturbance caused by the transplantation of the turfs.

The majority of the species however have survived the transplant and continue to flourish in a dense herb rich sward especially in sites 1-4. Park (1989) cites a species list for the pretransplant area of 150+ species for Thrislington plantation. However scrub was removed prior to the transplant (predominantly *C.monogyna*) and this has changed the nature of the grassland, removing many niches for birds and invertebrates, giving rise to

Figure. 14.

Ordination of quadrats based on plant architecture.



a more open vegetation (see photograph 3 and Fig.2. for pretransplant map). Nevertheless this high scrub/tree component which was present formally is reflected by the presence of ten such species including ash *Fraxinus excelsior*, pendunculate oak *Quercus robur*, blackthorn *Prunus spinosa* and holly *Ilex aquifolium*, the majority occurred on sites 6 and 8 (see part 2 of the vegetation list in the appendix). The colonisation of these species is being halted by annual mowing in September, (Park 1989) some individuals continue to grow as coppice while other appear as seedlings

All sites show colonisation by ruderal species, decreasing with increasing age since transplantation. Disturbance to the soil occurred during the transplant operation premoting a diverse ruderal flora in sites 6 - 8. The majority of ruderals are early pioneers species including dandelion, *Taraxicum officinalis*, coltsfoot, *Tussilago farfara* and rosebay willowherb, ~~*Epilobium angustifolium*~~ Chaemenarion angustifolium. There are also a number of atypical grassland species including *I.aquifolium*, *Geranium robertianum* and honeysuckle *Lonicera periclymenum* on site 4. Site 4 has the lowest average pH of any site and this may explain the presence of this species but a more likely explanation is that it was on turf which has had it's tree cover prior to transplanting. As the herb rich sward colonizes the overburden infill the majority of ruderal species are out competed and restricted to areas of bare ground.

The overall effects of transplantation on the vegetation are discussed in section 4.3.

3.1.2. DCA of quadrats on the basis of plant species.

The DCA uses the domin values of the plant species survey of the 25 quadrats, sampled on 14/07/90.

Sites 1, 3 and 4 are positioned in the bottom left of the ordination and sites 6 and 8 are widely dispersed and mostly to the right of the second axis. (Quadrats 2/8 and 3/8 are positioned to the left of the second axis).

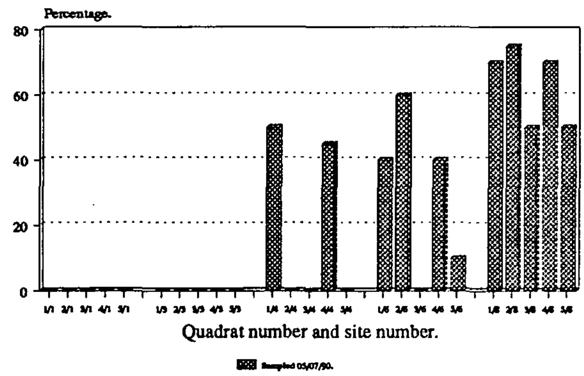
As in the architecture ordination (section 3.1.5) quadrats 1/1-4/1 are clumped in the bottom left of the ordination with 5/1 as an outlier. The quadrats from site three also show a clumping of 4 quadrats along the first axis but to the left of the second with 4/3 as an outlier above the cluster.

Four quadrats for site 4 lie in a narrow band along the first axis and to the left of the second

Graphs showing the 5 soil variables used in the CCA analysis.

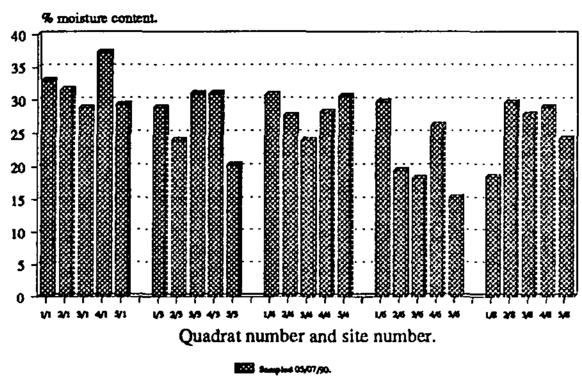
Figure.6.

% bare soil.
% bare soil from each of the 25 quadrats



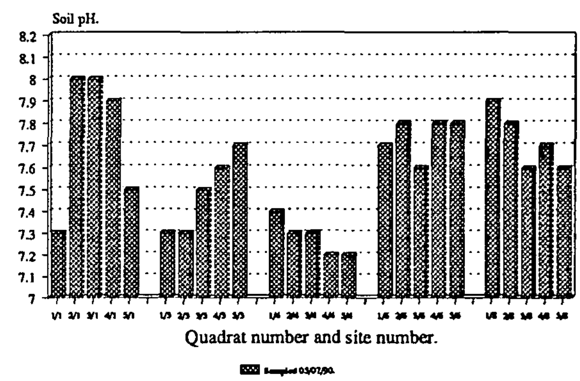
1/1 = Quadrat 1 - site 1, etc.

Percentage soil moisture.
1 sample from each of the 25 quadrats.



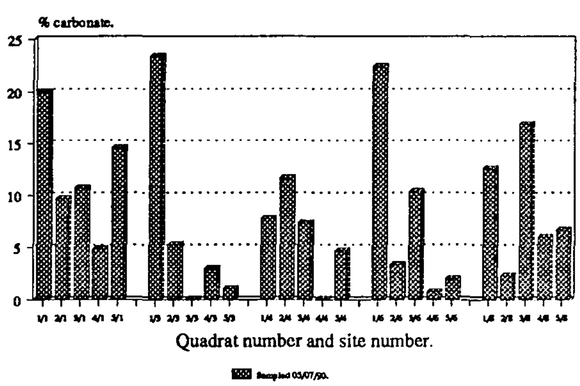
1/1 = Quadrat 1 - site 1, etc.

Soil pH.
Soil pH from each of the 25 quadrats.



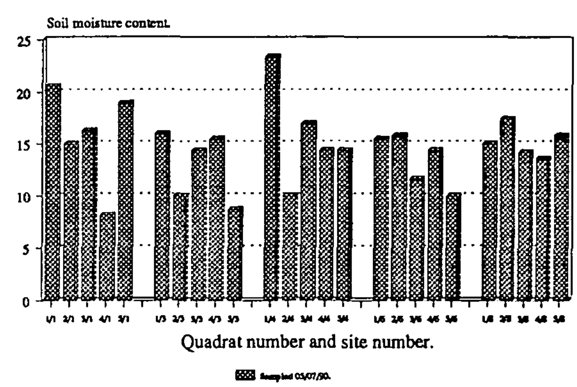
1/1 = Quadrat 1 - site 1, etc.

Percentage carbonate content.
1 sample from each of the 25 quadrats.



1/1 = Quadrat 1 - site 1, etc.

Percentage soil organic content.
1 sample from each of the 25 quadrats.



1/1 = Quadrat 1 - site 1, etc.

axis, with 5/4 close to the origin.

Four quadrats from site 6 lie in a narrow band along the first axis and 2/6 is positioned as an outlier above the first axis. Site 8 show the greatest dispersion through the ordination.

From the ordination it can be seen that there is a gradient of sites from 1-8 with respect to clumping, the older the site the greater the degree of clumping and it is possible to infer that as site age increases (since transplantation) the plant communities become increasingly similar and hence show a greater degree of clumping.

No DCA analyses was carried out using plant species due to the limited time available.

3.1.3. CCA of plant species and environmental variables.

A CCA analysis was run using five environmental variables -
percentage bare earth, percentage soil moisture content, percentage soil carbonate content, percentage soil organic content and soil pH (listed in order of importance with respect to the biplot) and the 82 plant species within the fixed quadrats. The species are represented by points and those showing the strongest correlation with the environmental variables are labelled with a number, which is described in the key. The environmental variables are shown on the biplot, with arrows.

Both the relative lengths and directions of the arrows are important, the arrows can be reduced or increased in length to fit in the bipolt, (Ter Braak 1987). The greater the length of the arrow the steeper the gradient in association between species and a variable and the greater it's importance with respect to the other environment variables. The direction of each arrow represents an axis which can be extended backwards through the biplot. For ease of interpretation the axis will be referred to as positive from the origin to the arrow tip and negative from the origin backwards. A line can be extended at 90 degrees to this axis from each species or site and the species nearest the line can br related to this gradient. In this analyses the species show a wide spread and the most influential variables were % bare earth, % moisture and % carbonate.

All references to plant habitat requirement, autecology, etc are taken from Grime, *et al* (1988) unless an alternative reference is given.

Figure.7.

CCA analysis using plant species
and environmental variables.

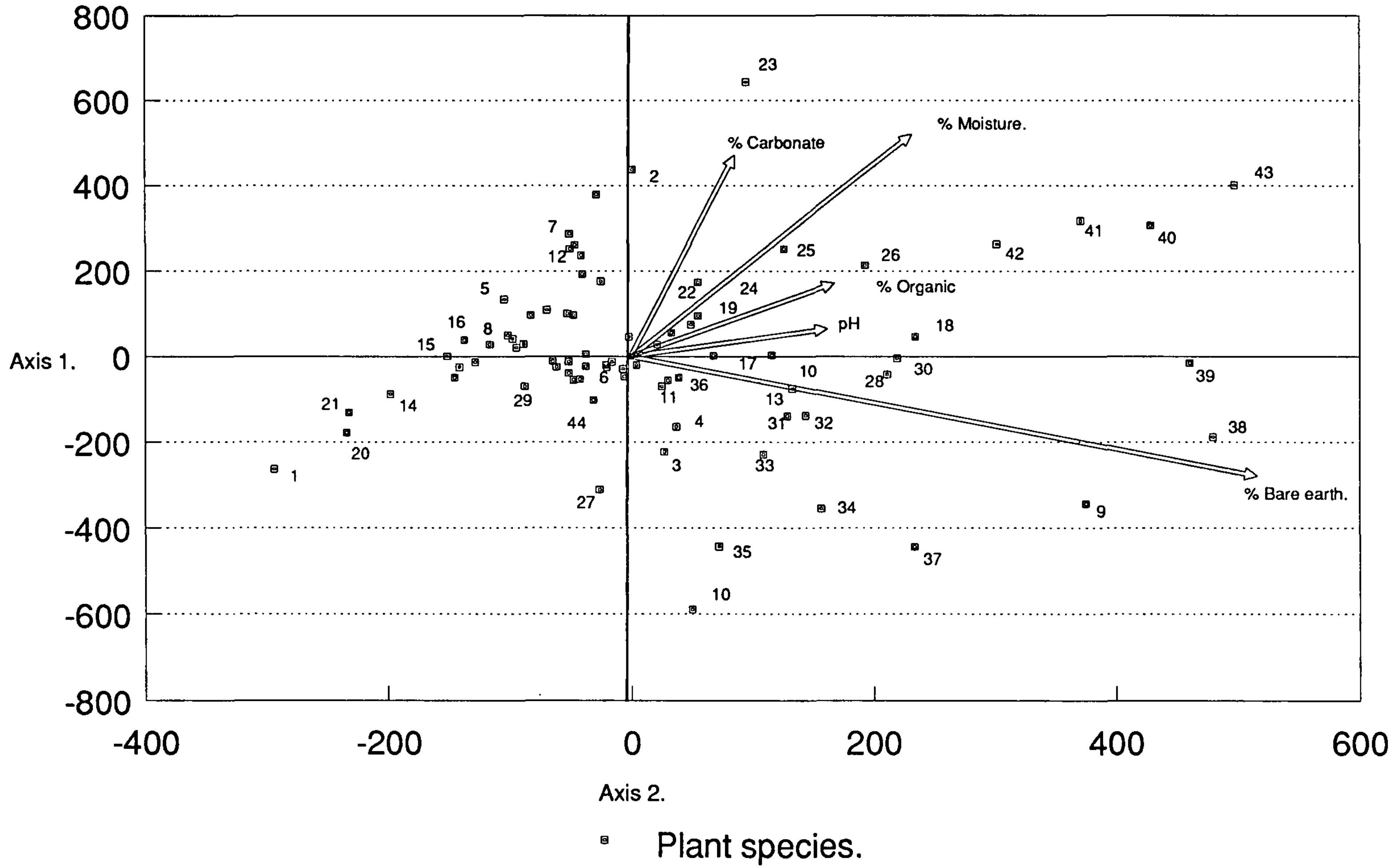


Figure.8. Plant species CCA legend.

Achillea millefolium	28	Festuca ovina	17	Silaum silaus	12
Agrostis stolonifera	1	Festuca arundinacea	38	Stachys sylvatica	27
Anthylus vulneraria	3	Koelaria cristata	30	Trisetum flavescens	10
Arrhenatherum elatius	13	Linum anglicum	20	Trifolium pratense	33
Arenaria serypllifolia	4	Plantago lanceolata	6	Veronica chamaedrys	34
Agrostis tenuis	2	Plantago media	39	Veronica officinals	23
Brachypodium sylvaticum	5	Polygala vulgaris	22	Vicia septum	43
Bromus erectus	7	Potentilla reptans	19	Viola variata	26
Campanula rotundifolia	37	Primula veris	18	Moss 1	36
Centaurea nigra	8	Prunella vulgaris	24	Moss 2	29
Centaurea scabiosa	11	Ranunculus auricomus	40	Medicago lupulina	32
Chamaenerion angustifolillum	9	Ranunculus bulbosus	35	Briza media	44
Chrysanthemum leucanthemum	18	Rumex acetosa	15	Rhinanthus minor	25
Dactylorhiza fuchsii	27	Sanicula europea	14	Ranunculas repens	16
Dactylorhiza purpurella	12	Sesleria caerulea	12		

The impact of the environmental variables of the analyses of plant species is described in turn.

3.1.3.1. Percentage bare earth.

The range of % bare earth was 0-75% (see Fig). It can be inferred from the biplot that since *R.repens* occurs at the extreme negative end of the axis, that it occurs in areas of no/minimal bare earth i.e. in a dense sward. However *R.repens* is found generally on open ground and most commonly at 20% occurrence on 76-100% bare soil, (Grime et al 1988). This is a species often associated with disturbed habitat. According to the biplot *Festuca arundinacea* occurring at the opposite end of the axis to *Ranunculus rupens)* is most common on bare earth and is in just common on sites 6-8 (see Fig.7.). Thus both these species occur on the transplant with respect to the % bare earth present as described by the CCA analysis. Willowherb *Chamaenerion angustifolium*, also shows a strong association with percentage bare earth. It's numerous seeds disperse widely allowing colonisation of relatively inaccessible niches such as pockets of bare earth and is rarely found in long established communities, (Grime, et al 1988).

There is a gradient along the axis of species with decreasing association with percentage bare earth - black medick *Medicago lupulina*, false oat grass *Arrhenatherum elatius*, Moss 1, greater knapweed *Centaurea scabiosa*, and lesser knapweed or hardheads *Centurea nigra. C.scabiosa* is most commonly associated with ungrazed calcareous grassland with relatively small exposures of bare earth, (Grime, et al 1988). This species is positioned on the positive "arm" of the axis for percentage bare earth, but it's position close to the origin indicates it's loose association with % bare earth.

C.nigra is most common on low to moderate bare earth and associated with intermediate to high floristic diversity. It is able to colonise and is associated with herb rich species hence it's general independence from bare earth.

3.1.3.2. Percentage moisture.

The percentage moisture content ranged from 16 - 37% (see Fig.6.). The CCA biplot demonstrates an important gradient in species with respect to moisture content from yellow rattle, *Rhinanthus minor* on the wettest areas to *Brizamedia* occurring on the driest soils.

According to Grime et al (1988) *R.minor* is often found in meadows which have a tenancy to become waterlogged in winter and is generally absent from dry soils. This is supported by it's strong association with the axis for percentage moisture content in the present study.

Selfheal - *Prunella vulgaris* is typical of moist soils, even occurring in soligenous mires. Most commonly associated with short turfs or open swards, often occurring in gaps within them before being out competed by other species.

On the other hand *B.media* which occurs at the negative at the end of the moisture axis is characteristic of dry mineral soils.

3.1.3.3. Percentage carbonate content.

The axis for carbonate has two strongly associated species, heath speedwell - *Veronoica officinalis* at the positive end of the axis and *Stachys sylvatica* at the negative end of the axis. *V.officinalis* often occurs on dry soils but there is no evidence in the literature to suggest that this species is highly associated with high carbonate content, other than occurring in calcareous grassland.

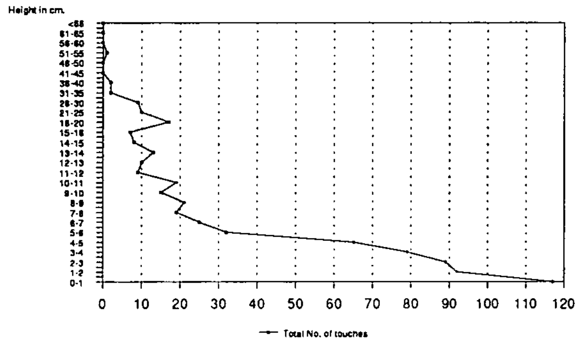
S.sylvatica is not especially associated with low carbonate soils but the range of percentage carbonate content was 1-23 (see Fig.6.). It should be remembered that % carbonate content of all the samples is relatively high.

Common milkwort - *Polygala vulgaris* lies midpoint between the axes for % moisture and % carbonate content. This species is common on soils of high carbonate content (pH 7-8) and is regarded as an indicator of ancient grassland, (Wells et al 1976 in Grime et al 1988). This species is also associated with moist soils (Grime et al 1988).

3.1.3.4. Architecture DCA.

The 25 original height classes were reduced to 6 classes to accommodate late analysis by CCA. The results of the architecture survey were used in order to test the hypothesis that - plant

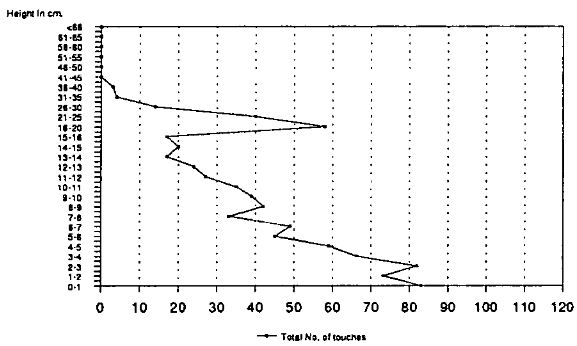
Vegetation architecture results.
20 samples - site 1,quadrat 1.



Measured on 17/07/90.

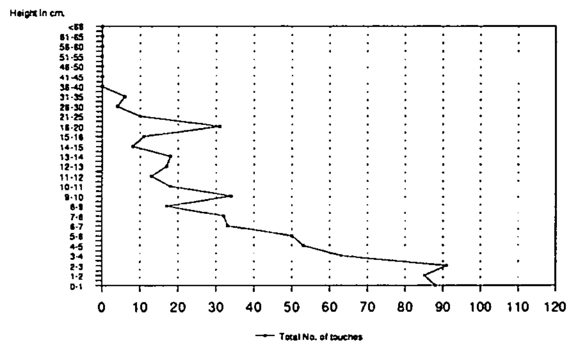
Plant architecture
profile diagrams
site 1.

Vegetation architecture results.
20 samples - site 1,quadrat 2.



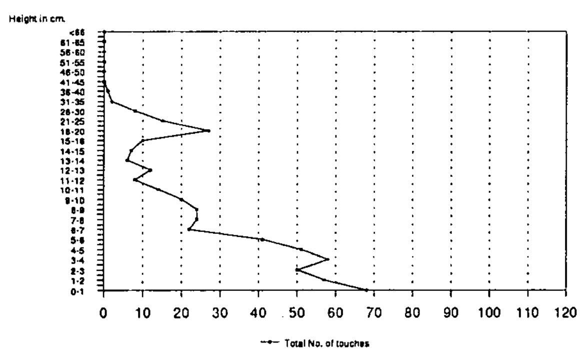
Measured on 17/07/90.

Vegetation architecture results.
20 samples - site 1,quadrat 3.



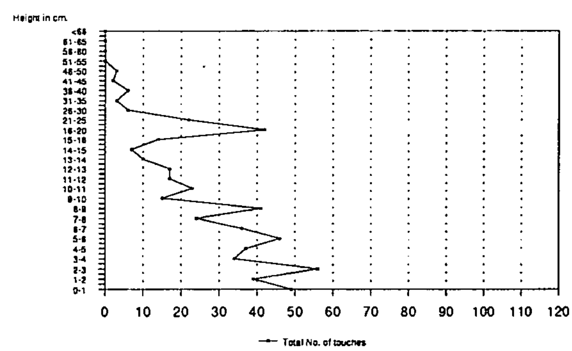
Measured on 17/07/90.

Vegetation architecture results.
20 samples - site 1,quadrat 4.



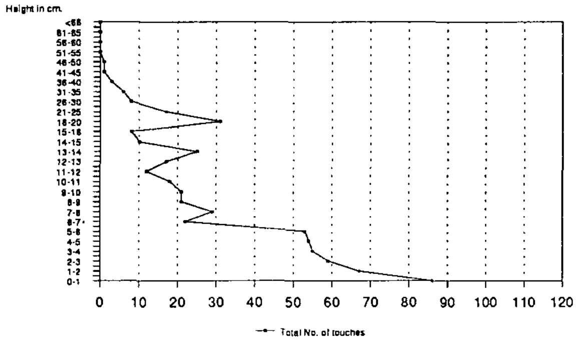
Measured on 17/07/90.

Vegetation architecture results.
20 samples - site 1,quadrat 5.



Measured on 17/07/90.

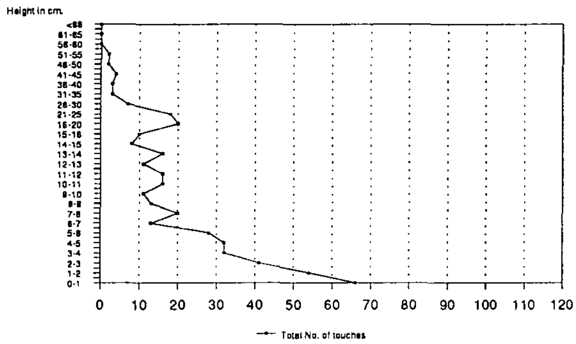
Vegetation architecture results.
20 samples - site 3,quadrat 1.



Measured on 17/07/90.

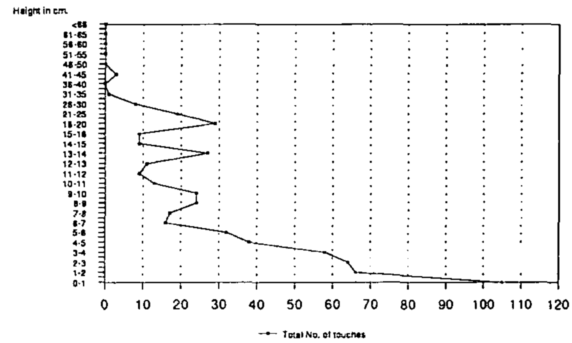
Plant architecture
profile diagrams
site 3

Vegetation architecture results.
20 samples - site 3,quadrat 2.



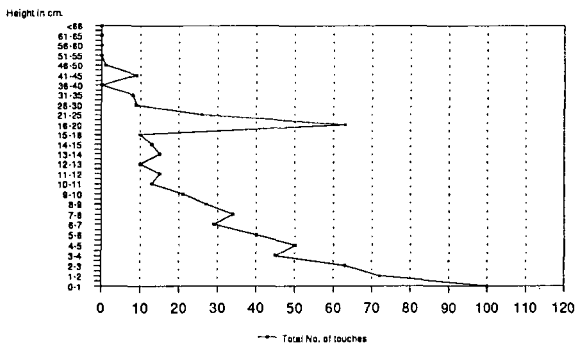
Measured on 17/07/90.

Vegetation architecture results.
20 samples - site 3,quadrat 3.



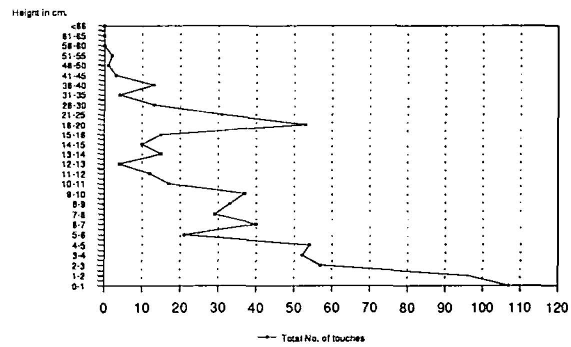
Measured on 17/07/90.

Vegetation architecture results.
20 samples - site 3,quadrat 4.



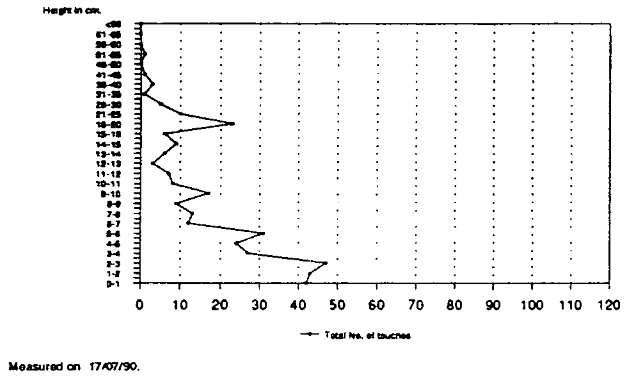
Measured on 17/07/90.

Vegetation architecture results.
20 samples - site 3,quadrat 5.



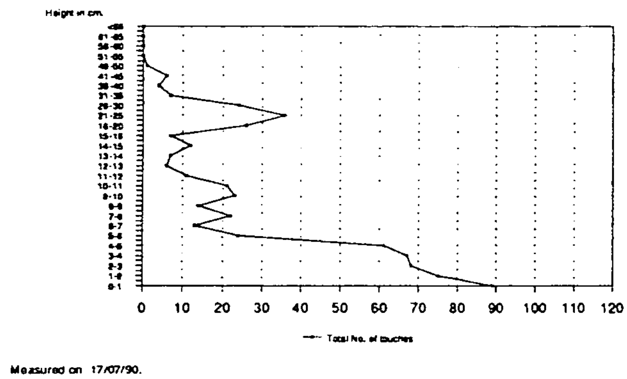
Measured on 17/07/90.

Vegetation architecture results.
20 samples - site 4,quadrat 1.

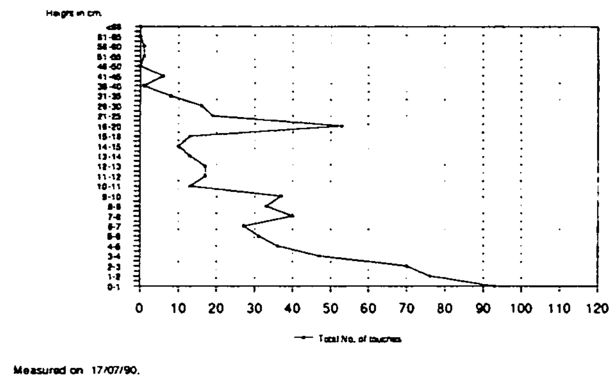


Plant architecture
profile diagrams
site 4

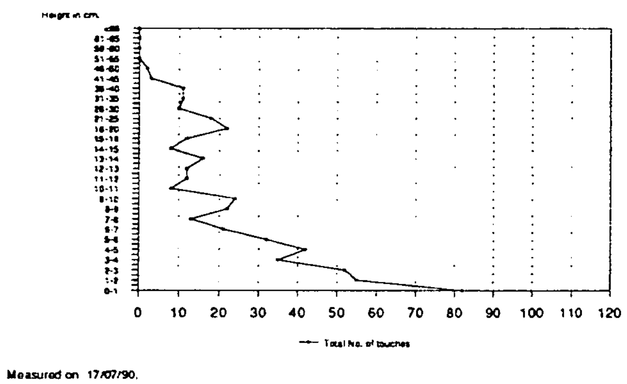
Vegetation architecture results.
20 samples - site 4,quadrat 2.



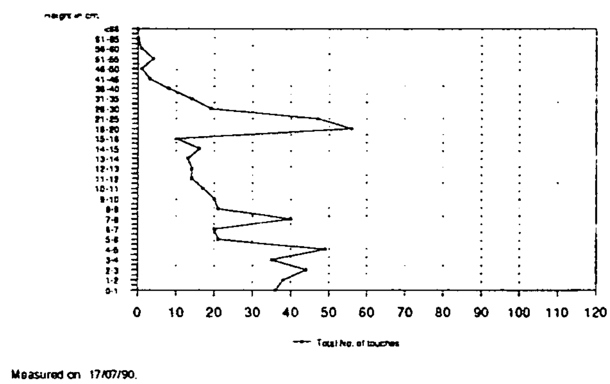
Vegetation architecture results.
20 samples - site 4,quadrat 3.



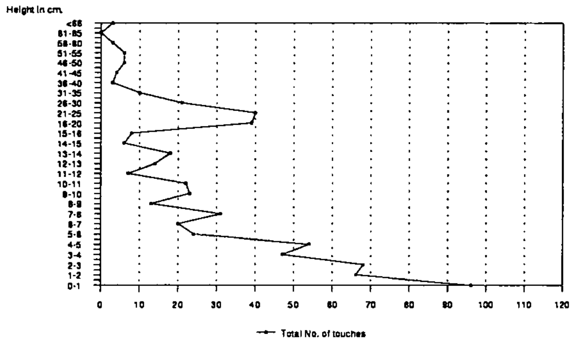
Vegetation architecture results.
20 samples - site 4,quadrat 4.



Vegetation architecture results.
20 samples - site 4,quadrat 5.



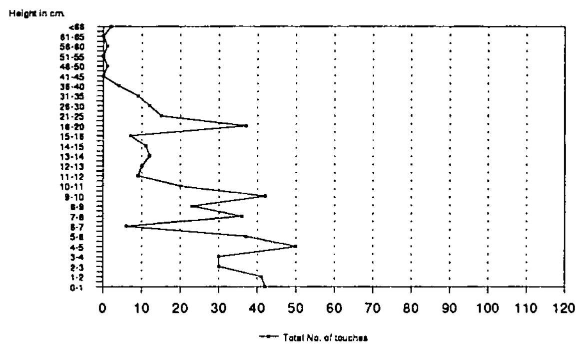
Vegetation architecture results.
20 samples - site 6 quadrat 1.



Measured on 17/07/90.

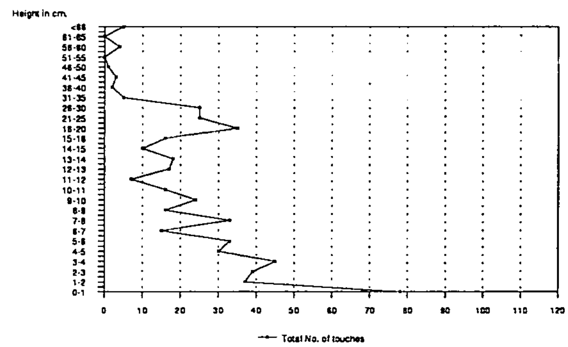
Plant architecture
profile diagram.
Site.6.

Vegetation architecture results.
20 samples - site quadrat .



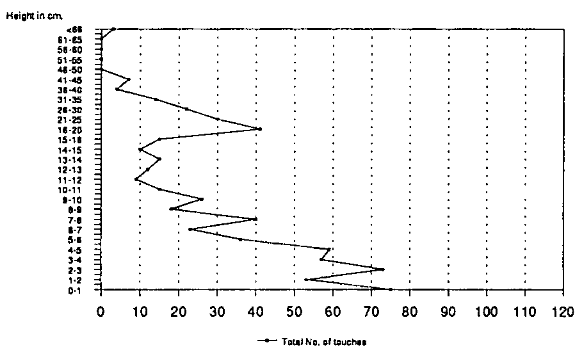
Measured on 17/07/90.

Vegetation architecture results.
20 samples - site 6, quadrat 2.



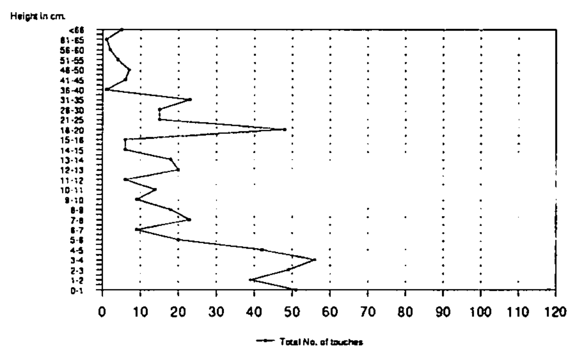
Measured on 17/07/90.

Vegetation architecture results.
20 samples - site 6,quadrat 4.



Measured on 17/07/90.

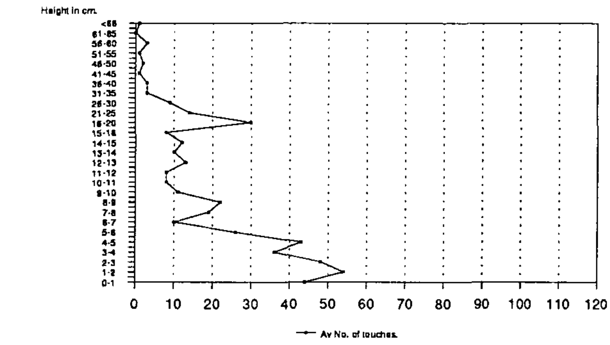
Vegetation architecture results.
20 samples - site 6,quadrat 5.



Measured on 17/07/90.

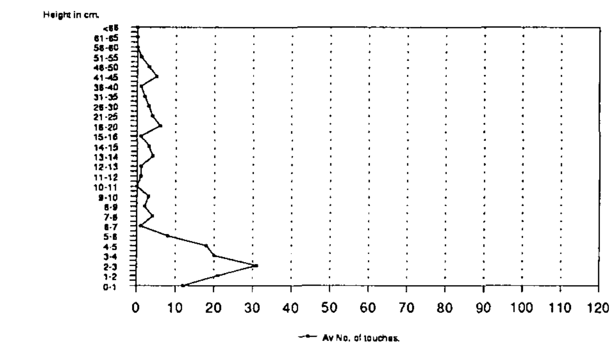
Plant architecture profile diagrams.
Site. 8.

Vegetation architecture results.
Average of 20 samples site 8 quadrat 1.



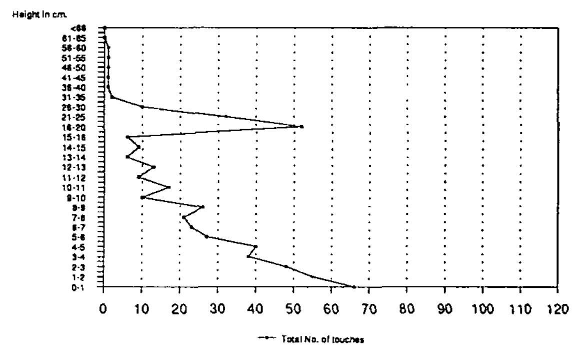
Measured on 17/07/90.

Vegetation architecture results.
Average of 20 samples site 8 quadrat 2.



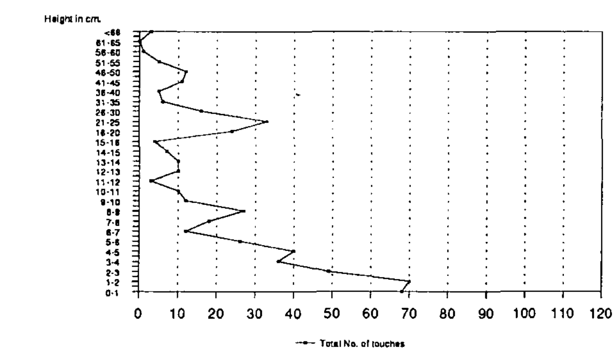
Measured on 17/07/90.

Vegetation architecture results.
20 samples from site 8 quadrat 3.



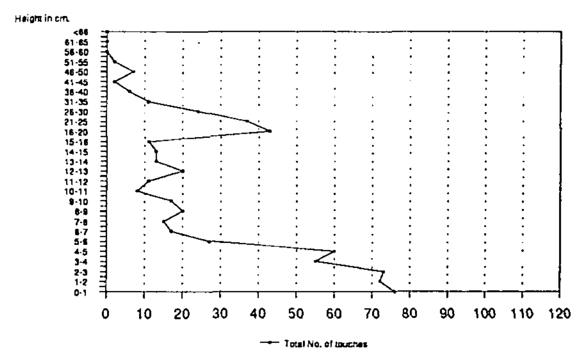
Measured on 17/07/90.

Vegetation architecture results.
20 samples from site 8 quadrat 4.



Measured on 17/07/90.

Vegetation architecture results.
20 samples from site 8 quadrat 5.



Measured on 17/07/90.

architecture can be used to classify sites.

The ordination places the points along the first axis (probably site age) and equally above and below the second axis. The general trend of the ordination is that sites 1,3 and 4 are positioned on the left of the axis and sites 6 and 8 on the right of the axis. The architecture ordination is shown in Fig.14.

Site 1 shows the greatest degree of clumping with quadrats tightly grouped - especially 1/1 - 4/1 with 5/1 as on outlier. A visual explanation based on the architecture profiles (in the architecture profile diagrams in Figs 9 - 13) , seems to be the large number of touches represented by 4 plateaus at 3-4cm, 6-7cm, 9-10cm and 21-25cm.

The quadrats for site 3 lie to the left of the second axis or just on, it in a fairly tight clump.

The quadrats for site 4 lie in a band at roughly 45 degrees from the first axis - from top left through the origin to the bottom right of the ordination.

The quadrats of sites 6 and 8 are spread widely along the first axis and all quadrats lying to the right of the second axis. This distribution indicates that these quadrats vary widely both in the species composition and architecture. Architecture is a function of the species that comprise the sward.

The ordination places 4/8 as an outlier in the top right of the ordination and the architecture profile of 4/8 shows a high number of touches above 40cm. These are probably due to the grass tall festuca, *Festuca arundinacea* in this quadrat which reaches heights of 200cm (Grime, et al 1988).

3.1.3.5. Conclusions of vegetation analysis.

The vegetation CCA analysis revealed that site age and % carbonate explained the greatest variation within the plant species (eigenvalues of 0.28760 and 0.23765 respectively). It seems likely that transplantation has altered the original mosaic of the magnesian grassland species, with an increase in the ruderal element and competive species.

The uniqueness of Thrislington both in terms of it's diverse flora and fauna and it's transplantation 800m to a new site make it an important site for research. It's associations of rare flora and fauna made this site important in it's own right but it's subsequent transplantation also allows the affects of disturbance, extinction, colonisation and recolonisation to be investigated. It is hoped that this study has contributed in some way to this greater understanding. Ongoing research by Sheppard and Parks should yield more information in the coming years.

3.1.3.6. Summary of vegetation analysis.

A/. There is a tendency for the vegetation to become increasingly homogeneous with site age.

B/. Site age is the most important overall variable for both plant species and plant architecture.

C/. The two environmental variables % bare earth and % moisture represent the greatest influence on the plant species.

D/. Plant architecture gives a more reliable measure of site age than do plant species in the DCA analyses.

3.2. Invertebrate survey.

3.2.1. Invertebrate survey - general conclusions.

The invertebrate fauna collected in pitfalls totalled 16518 individuals and 3559 from counts and observations giving a total of 20067 individuals (Table.2. and table.3.).

The pitfall catches show that Araneae were the most abundant group in terms of individuals caught with 4308 individual or 26% of the total catch. A total of 19 species of Araneae were identified.

Coleoptera were the next commonest group with 2884 indiviuals representing 17.37% of the total and 19 species.

The remaining orders represented by low numbers as shown in table.2 and 114 species were recorded in this survey full species list is given in the appendix, with distributions, numbers caught and notes on abundance, etc.

A series of bar charts of invertebrate distribution are also given in the appendix together with total number per quadrat and the including table beneath each gives details of numbers collected on each of the four sampling dates. The reason for including the bar charts are to aid in the interpretation of the CCA analyses and as a data base for further studies into the invertebrate fauna of this grade.1. SSSI.

10/. **Fragrant orchid (*Gymnadenia conposea*) and common spotted orchid (*Dactylorhiza maculata*) on overburden at Thrislington.**

11/. **Weld (*Reseda luteola*) on site 6.**

12/. Tufted vetch (*Vicia Cracca*) and yellow rattle (*Rhinanthus minor*) on site 1.

13/. Rockrose (*Helianthemum nummularium*)- site 3.

14/. Dark red helliborine (*Epipactis atrorubens*) at Raisby quarry.

15/.Twayblade orchid (*Listera ovata*)- site 1

16/.Fragrant orchid (*Gymnadenia conopsea*) on site 1.

17/.Common spotted orchid (*Dactliorhiza fuschii*) on site 1.

20/. Wild thyme (*Thymus preacox*) and sheeps fescue (*Festuca ovina*) in centre of photograph.

21/. Typical view of Raisby Quarry, County Durham. Note - sparse vegetation when compared with Thrislington (photo 6).

3.2.2. Changes in the invertebrate fauna of Thrislington transplant.

Thrislington is the largest site that has ever been "successfully" transplanted in Britain and the ongoing study by Sheppard (NCC) will show the affect of the transplant with respect to the invertebrates. Of the 66 species reported to be lost from the transplanted turfs by Sheppard (1989), (see

Sheppard 2 page (1989) report given in the appendix) 8 (12%) have been found in this survey, so have apparently recolonised since 1986. They are 6 species of Coleoptera:- *Apion virens*, *Bembidion lampros*, *Ceutorhynchus quadridens* *Ceuthorhynchidius troglodytes*, *Leistus rufescens* and *Orthocheates setiger*. Also the spider *Enoplognatha ovata* and the harvestman *Nemastoma bimaculatus*. It is likely that many other species have also recolonised, as a total of 1407 Coleoptera, 703 Araneae, 732 Opilines and 454 Auchennorhyncha, etc, were not identified to species level due to the limited time available.

Losses are based on previously recorded species that did not occur after transplantation. The number of new species that have colonised the transplant is not known since a full species list was not available for the pretransplant site.

The total number of species at Thrislington is not known but it is likely to be close to a 500-700 breeding species including Acari, Collembola, etc and over a thousand transitory visitors, (such as the common blue damselfly, *Enallagma cyayhigerum*). This is not an excessive number as 529 species of ichneumon wasps have been recorded by Owen and Owen (1974 in Golley 1983 p95-99) in one suburban garden in Leicester during trapping over a number of years.

3.3. Invertebrate DCA and CCA analyses.

3.3.1. Invertebrate DCA and CCA using all invertebrate groups.

A total of 19436 invertebrates were used in both the DCA and CCA analysis, Fig.14 & 15 and Fig.16 & 17 respectively.

Both DCA and CCA analysis used 32 species or groups of invertebrates representing all the major groups collected in pitfalls (see Table.2.), hand searches and counts (see Table.3.). The CCA analysis was run with 11 environmental variables. These were plant architecture with 6

Table.2. **Invertebrate pitfall catches.**

Family or Order.	Total.	% of total.
Acari.(>1mm).	978	5.92
Auchennorhyncha. (total).	454	(2.75)
" nymphs.	313	1.89
" imagos.	141	0.85
Araneae.	4308	26.1
Acrididae.	28	0.17
Chilopoda.	30	0.18
Coleoptera. (total).	2884	(17.46)
Carabidae	664	4.0
Chrysomelidae	195	1.18
Curculionidae	362	2.19
Staphylinidae (total).	837	(5.07)
" 0-5mm	79	0.48
" 5-10mm	670	4.06
" >10mm	88	0.51
" larvae	409	2.48
Other Coleoptera larvae	47	0.28
Other Coleoptera.	370	2.24
Collembola (*Orchella* sp only)	1236	7.44
Dermaptera	8	0.048
Diploda	641	3.88
Diptera	1216	7.36
Formicidae	1352	8.18
Parasitic Hymenoptera	444	2.69
Isopoda	1972	11.94
Lepidoptera (total).	84	0.5
" caterpillars	37	0.22
Miridae	24	0.14
Molluscs	110	0.60
Oligochaetes	8	0.048
Opiliona (total).	732	(4.43)
" juvieniles	390	2.36
" imagos	342	2.07
Pseudoscorpiones	3	0.02
Siphonaptera	7	0.04
Total =	16,519	100%

Invertebrate table 3. Counts and hand searchs.

Invertebrate group.	Method.	Totals.
Auchenorhyncha nymphs	Sweep netting	199
C.nemoralis	Pitfalls	326
C.nemoralis	Hand seaches	1279
Butterfly transects	Counts	249
Cercopidae nymphs	Counts	2738
	Total =	3359

Table.4. CCA analyses Eigenvalues.

	Weevils	Plants	Inverts	Araneae	Carabidae
Axis 1	0.26	0.14053	0.10	0.051	0.04
Axis 2	0.23	0.11204	0.08	0.034	0.03
Axis 3	0.17	0.08074	0.05	0.021	0.002
Axis 4	0.10	0.07608	0.03	0.01	0.001

Figure.16.Invertebrate DCA.

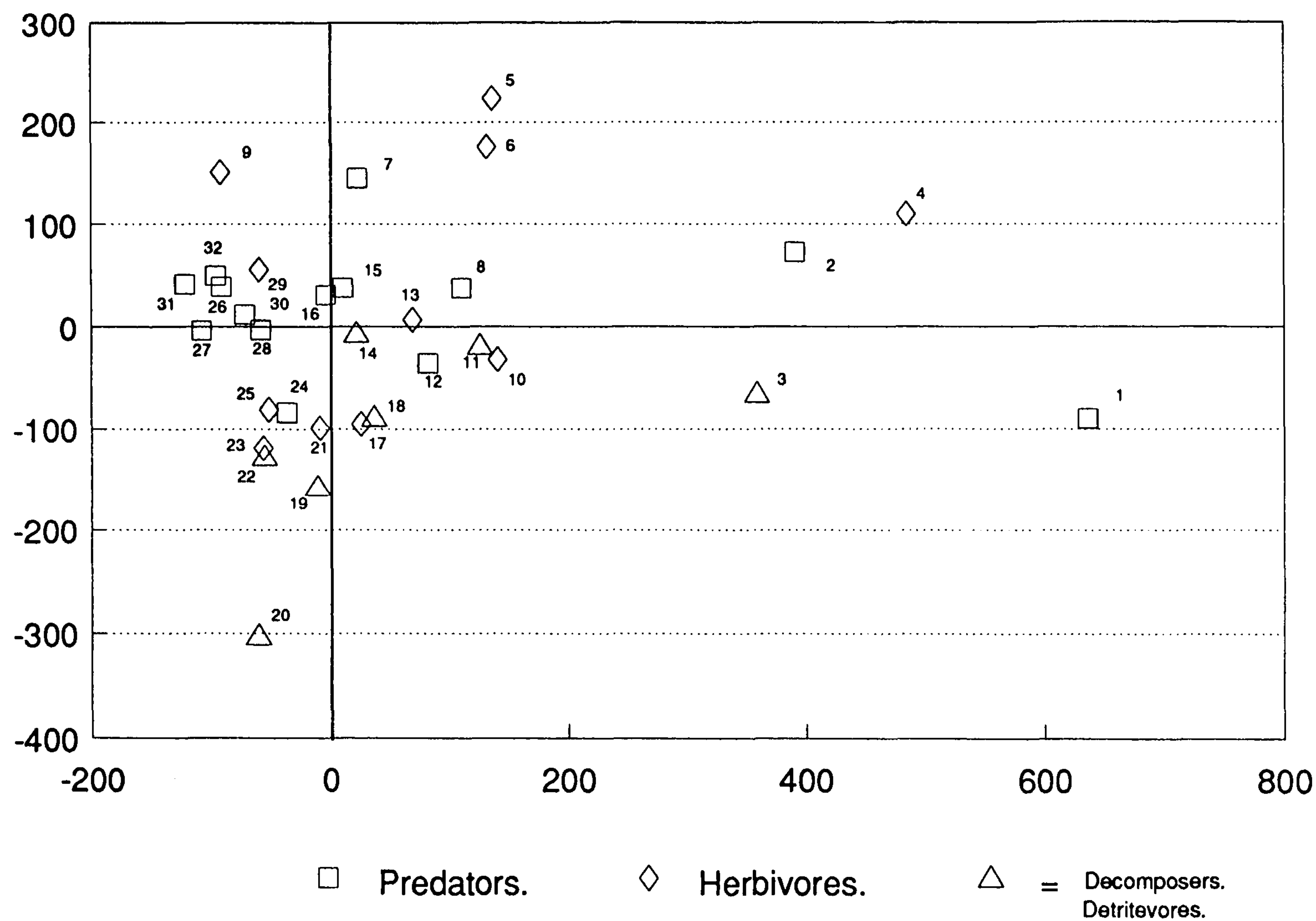


Figure.16.
DCA. Invertebrate legend.

Herbivores

4 P.undulata
5 Pollen beetles
6 Auch. nymphs
20 Rhagonycha fulva
10 Auch. imagos
13 Curculionidae
17 Elateridae
23 Crep. transversa
25 Cercopidae counts
29 Crep. ferruginea
21 Auch nymphs
3 Crep. transversa

Decomp/detritovores

11 T.niger
14 P.angustus
18 Orchellia sp
19 P.muscorum
22 C.nemoralis (PF)
8 C.nemoralis (HS)

Others:-
31 Diptera
20 Acari

(PF) Pitfall catchs
(HS) Hand searchs

Predators.

1 L.forficatus
2 N.bimaculatum
7 Araneae
8 Beetle x
12 Staphylinidae >10
15 Opilione imagos
16 Staphylinidae <5
24 Opilione juv.
26 Formicidae
27 Carabidae
28 Staphs - 5-10mm
30 Parasitic wasps
32 Lamprus noctiluca

and Fig.16 & 17 respectively.

Both DCA and CCA analysis used 32 species or groups of invertebrates representing all the major groups collected in pitfalls (see Table.2.), hand searches and counts (see Table.3.). The CCA analysis was run with 11 environmental variables. These were plant architecture with 6 height classes, 0-2cm, 2-5cm, 5-10cm, 10-20cm, 20-40cm and >40cm. Pitfall position was used with the four following categories:- 1. bare earth, 2. vegetation with ocassional bare earth, 3.vegeatation overhanging pitfall, but not enclosing it and 4. pitfall totally enclosed, often not visiable from above. These four categories were entered into CANOCO to produce the one variable "pitfall position". The moss flora was represented % moss cover and average moss depth. Percentage moss cover was recorded during the vegetation survey and average moss depth was an average of the 20 measurements taken as part of the architecture survey. The % bare earth and site age (all quadrats within each site being of the same age) in years since transplantation, (Fig 1) were also used. Soil characteristics were not used. The % bare earth, % moss depth, average moss depth, pitfall position and site age on a quadrat basis are presented diagramatically in Fig.20.

A further 3 DCA and CCA analyses were run with Araneae - spiders (13 species), Carabidae - ground beetles (15 species) and Curculionoidae - weevils (13 species). These three groups were selected to determine any trends in distribution with respect to the environmental variables and to explain the position on the biplot with respect to individual species habitat requirements. All rare species were down weighted in the four CCA's.

Due to the large numbers of species, genera, families, etc in this analysis only selected invertebrates will be discused with respect to their position on the biplots and habitat requirements. To aid in interpretation of the biplot the invertebrates have been divided into three cateogories based on their feeding habits 1/.decomposers/detritovores, 2/.herbivores and 3/.predators (including Diptera and parasitic Hymenopterla). Each invertebrate is given a code number explained in the legend accompanying each biplot.

Any invertebrate with an asterix in brackets and number, (*1) after the first reference indicates the presence of a histogram of pitfall total catches for this group, (see the appendix contents list at beginning of this dissertation).

Figure.18.

C.C.A of all invertebrates and pitfall position, plant architecture, site age, % moss, % earth and average moss depth.

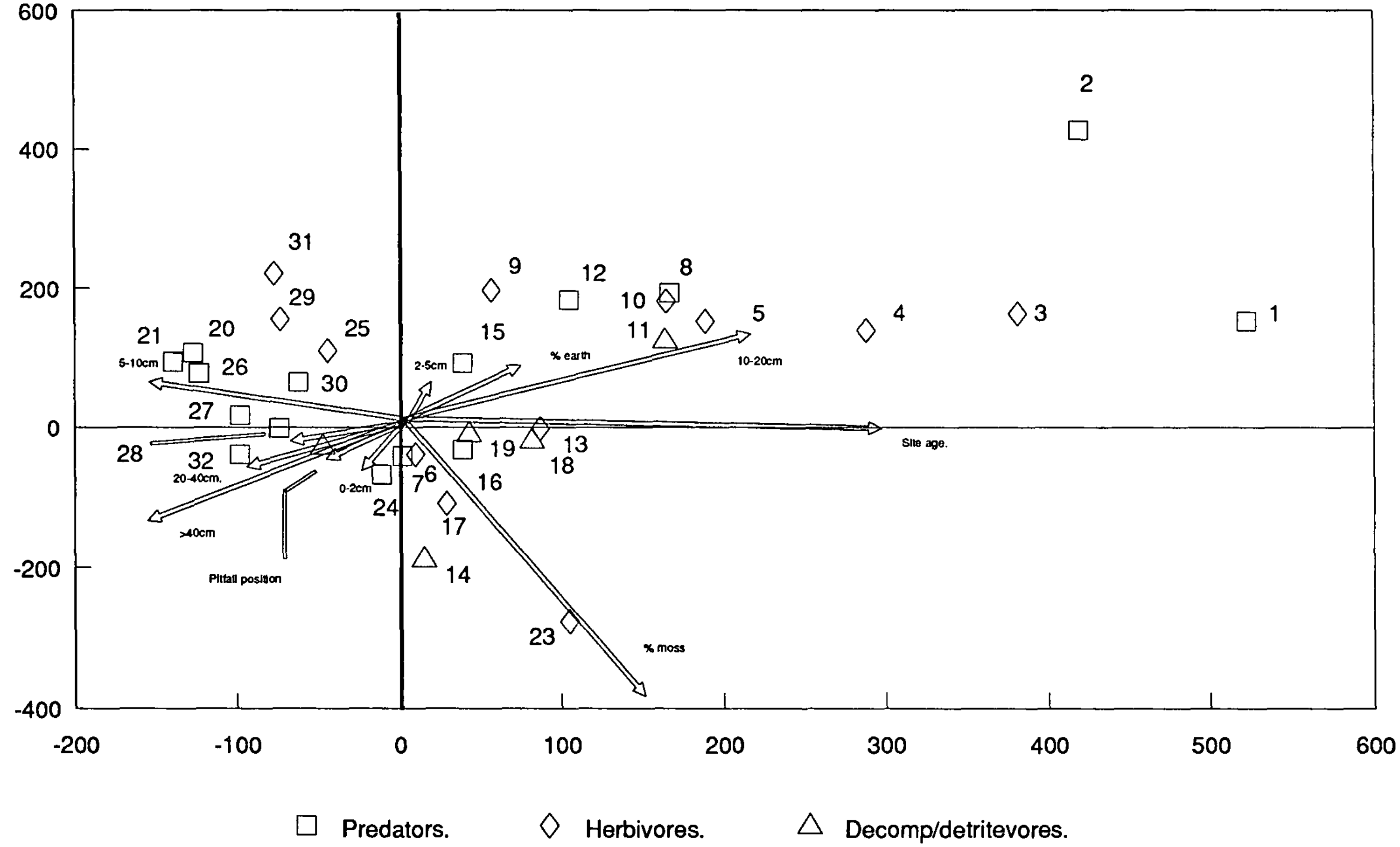


Figure.19.
CCA. Invertebrate legend.

Herbivores

4 P.undulata
5 Pollen beetles
6 Auch. nymphs
9 Rhagonycha fulva
10 Auch. imagos
13 Curculionidae
17 Elateridae
23 C.nemoralis (HS)
25 Cercopidae counts
29 *Crep. ferruginea*
3 C.nemoralis (PF)
31 Crep. transversa

Decomp/detritovours

11 T.niger
14 P.muscorum
18 Orchellia sp
19 P.angustus

Othes:-
21 Diptera
22 Acari

(PF) Pitfall catchs
(HS) Hand searchs

Predators.

1 L.forficatus
2 N.bimaculatum
7 Araneae
8 Beetle x
12 Staphylinidae >10
15 Opilione imagos
16 Staphylinidae <5
24 Opilione juv.
26 Formicidae
27 Carabidae
28 Staphs - 5-10mm
30 Parasitic wasps
32 Lamprus noctiluca
20 Staph larvae.

3.3.2. DCA invertebrate analysis.

The majority of the invertebrate groups are clustered around the origins of the 1st and 2nd axes. There are four outliers to the right of the main cluster, two predators, the centipede, *Lithobius forficatus*(*34), and harvestman, *Nemastoma bimaculatum* (*35), a detritevore, *C.nemoralis*(*27) and the herbivore, a Chrysomelid beetle.

The decomposers and detritivores are positioned in a band running beneath the first axis.

Herbivores are positioned around the origins of the 1st and 2nd axes and with five outliers - the soldier beetle, *Rhagonycha fulva*, pollen beetles and the flea beetle, Phyllotreta undulata(*42). The three outliers are associated with flowers, *R.fulva* with Umbellifers (see photograph on p27A) and the other two species on a wide range of plants, commonly observed on *H.nummularium* (Harde 1981).

The predators occur as a broad band along the 2nd axis with two outliers *N.bimaculatum* and *L.forficatus* to the right of the 2nd axis. The four Staphylinidae(*) show a wide dispersal throughout the general group predators. The Staphylinidae are not strictly predators and may also feed on vegetable matter and the 994 British species (Harde 1981) are found in a wide range of habitats and microhabitats (Fowler 1888) so would be expected to be widely dispersed throughout the ordination.

3.3.3. CCA invertebrate analysis.

The CCA analysis produced a wide spread of groups throughout the biplot with 66% of the groups occurring above the first axis. The 1st axis is one of site age. The 2nd axis is most closely associated with 0-2cm and 2-5cm i.e. ground and lower vegetation zones. The two most important axes based on length and direction are site age and % moss cover.

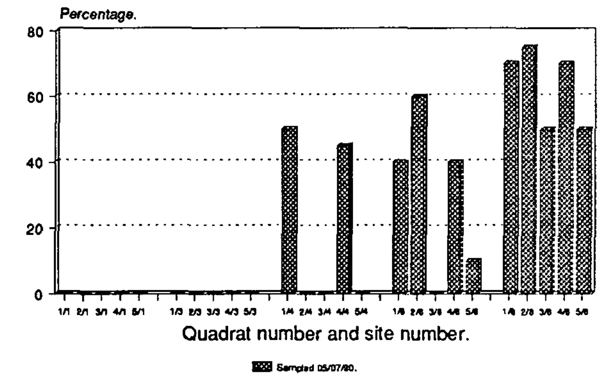
In the analysis there is a degree of separation of the three trophic groups from each other. Herbivores lie mainly above the 1st axis with detritivores below it - perhaps in response to moss cover. While predators lie mostly to the left of the 2nd axis perhaps in response to site age and reflecting their ability to disperse readily. The same four outliers are found as in the DCA analysis.

The axes will be discussed in order of importance and the species or families which are most closely associated with them. See Figures 8 and 9.

Figure.20.

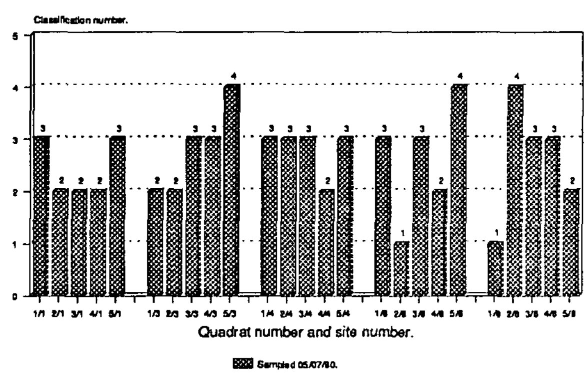
Environmental variables used in invertibrate, weevils, spiders, and Carabid CCA's.

% bare soil.
% bare soil from each of the 25 quadrats

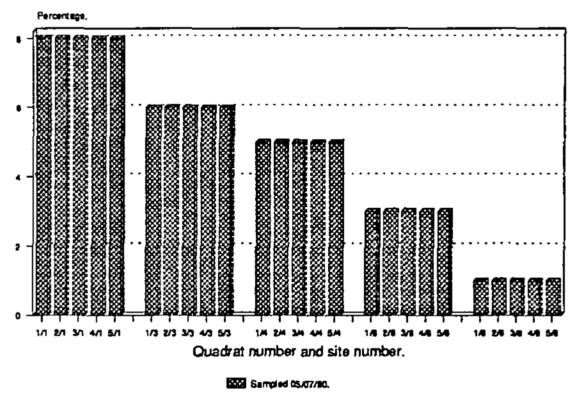


1/1 = Quadrat 1 - site 1, etc.

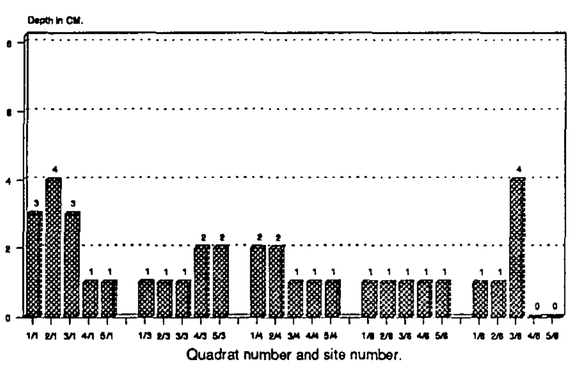
Pitfall position classification
for each of the 25 quadrats.
(See invert CCA intro for explaination).



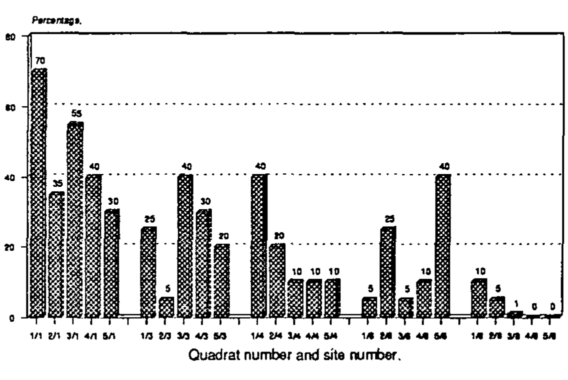
Site age.
Site age for each of the 25 quadrats.



Average moss depth for
each of the 25 quadrats.



Percentage moss for
each of the 25 quadrats.



3.3.3.1. Site age.

Curculionidae(*48,49) and the millipede, *Polydesmus angustum* (*41) occur directly on the positive arm of this axis but near to the origin. It would appear from the graphs of pitfall catches per quadrat in the appendix that there is no relationship with site age in terms of % catch per site for either. Two predators *L.forficatus* and *N.bimaculatus* are shown far to the right along the main axes.

Staphilinidae larvae, ants, carabids and *L.nocturna* are associated with younger sites in either very low or tall vegetation.

3.3.3.2. Percentage moss cover.

In a dry calcareous grassland such as this, moss is likely to be an important refuge. There are five species/groups associated with the positive axis for % moss cover - *C.nemoralis* (hand searches, see molluscs results for a detailed account of the importance of moss to this species), the woodlouse *P.muscorum*(*40), click beetles Elateridae(*31), Auchenorrynchla nymphs(*3) and imagos(*2) and all Araneae(*4 and 5) - spiders. A further three species/familys lie on the negative axis for % moss cover - Cercopidiae nymphs and the two Chrysomelid beetles, *Crepipodora ferruginea*(*28) and *Crepipidora transversa*(*29).

The CCA analysis positions *C.nemoralis* directly on the % moss axis and it's position from the origin shows it's strong association with moss cover. The molluscs feed widely in the vegetation but shelter during the day in moist mossy places.

P.muscorum occurs midpoint between the % moss cover and 0-2cm axes on the biplot. Characteristically a species of ungrazed calcareous grassland, *P.muscorum* may reach densities of 240 - 1040 per m (Harding and Sutton, 1985 p70-71). Harding and Sutton(1985) also record this species as occurring on the ground surface in 57% of records during the British Isopod survey and within litter in 27% of records. As with all members of the Isopoda, *P.muscorum* requires a dark and humid microclimate to shelter in as they are prone to desiccation and this is provided by the humid atmosphere of the moss and lower vegetation zones.

The negative end of the % moss axis is difficult to interpret as this could mean either a lot of bare earth or dense vegetation.

18/.Soldier beetles (*Rhagonchya fulva*) on hogweed (*Heracleum spondylium*) site 8.

19/.Meadow brown (*Maniola jurtina*) on knapweed (*Centurea nigra*)

3.3.3.3. The 10-20cm axis.

Three species are strongly associated with the positive 10-20cm axis - *Phyllotreta undulata*(*42) (Chrysomelidae), *C.nemoralis* (*27) (pitfalls) and *L.forficatus*(*34) and *Tachypodoiulus niger*(*47). *P.undulata* is associated with crucifers, the two commonest species at Thrislington being Ladies bedstraw, i.e. *Gallium verum* and crosswort *Gallium laevipes* which are grow at 15-100cm and 15-60cm respectively, (Clapham, Tutin and Moore,1987 3rd ed) supporting this species close association with this particular vegetation height.

As described earlier in the DCA analysis and mollusc results *C.nemoralis* is most closely associated with % moss cover with and may feed in the 10-20cm zone.

The millipede *T.niger* is strongly associated with the 1-20cm axis. Blower (1958 p54) describes this species as commonly feeding on epiphytic organisms on tree trunks, etc and has been observed feeding on blackberries. He describes this species as using the soil/litter layer as a resting place. *T.niger* is extremely active and migrating at certain life history stages but it is difficult to see why it is especially associated with this height class.

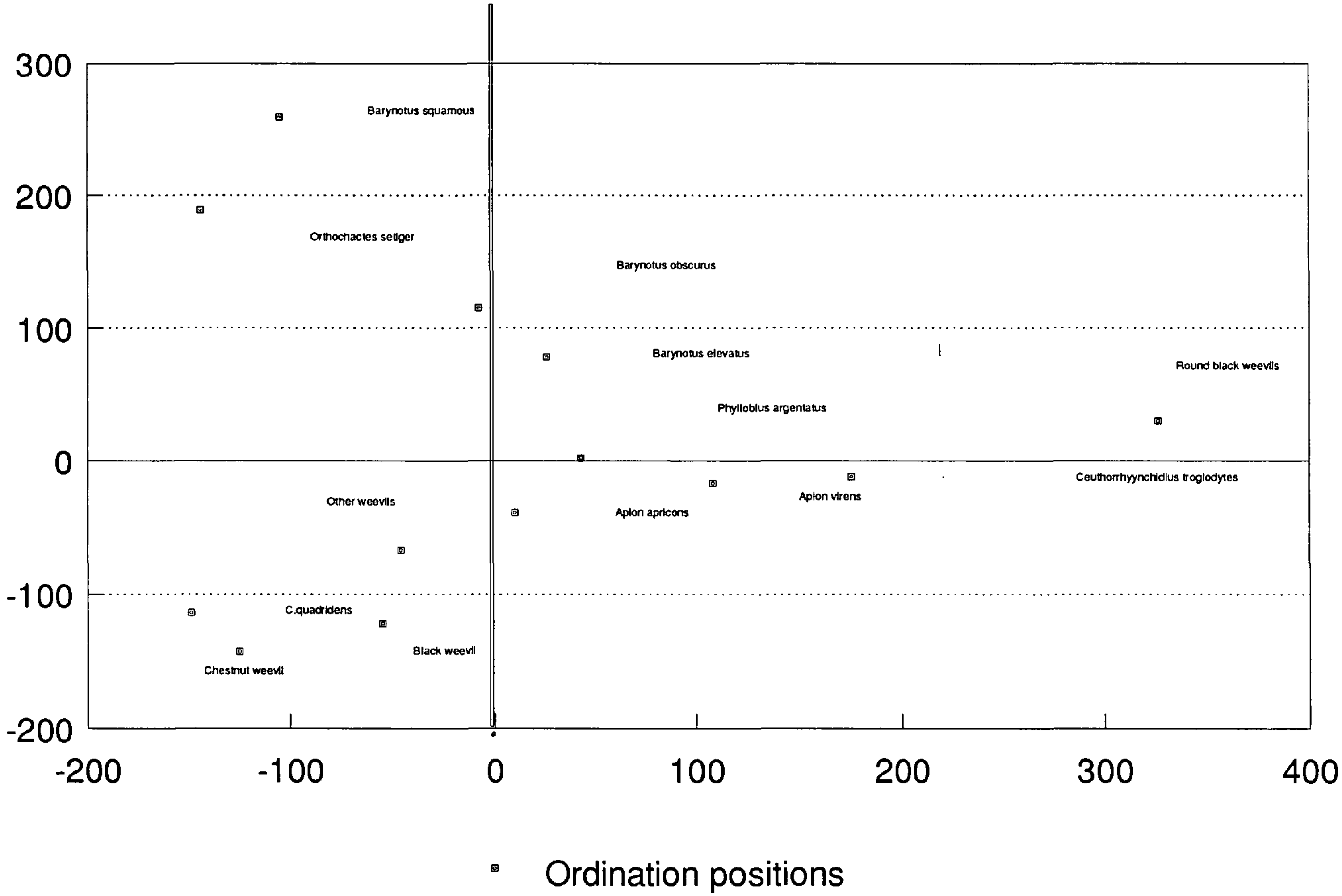
3.3.3.4. 5-10cm axis.

Formicidae (*32), in particular the *Myrmica ruginodis* probably forage in this vegetation zone. Collingwood (1979) describes this as occurring in two dimorphic races, the race *M.ruginodis macrogyna* occurring in transitory habits. This race probably occurs at Thrislington.

Cercopidae nymphs, *C.ferruginea* and *C.transversa* position cannot be explained with respect to the 5-10cm and 2-5cm axes. Fowler (1890) describes *C.ferruginea* and *C.transversa* as both occurring on dry grass, maybe at the bases i.e. 2-10cm. Cercopidae nymphs have their greatest distribution on site 6 (see Fig.32. in Auchennorhyncha results) which has a range of vegetation heights. The two beetle and Cercopidae nymphs have the greatest abundance on site 6. These three species also lie on the negative axis for % moss cover, of which site 6 has the second lowest % moss cover (Fig.20.).

Fig.21.

Ordination of Weevil species.
Based on data from pitfall trapping.

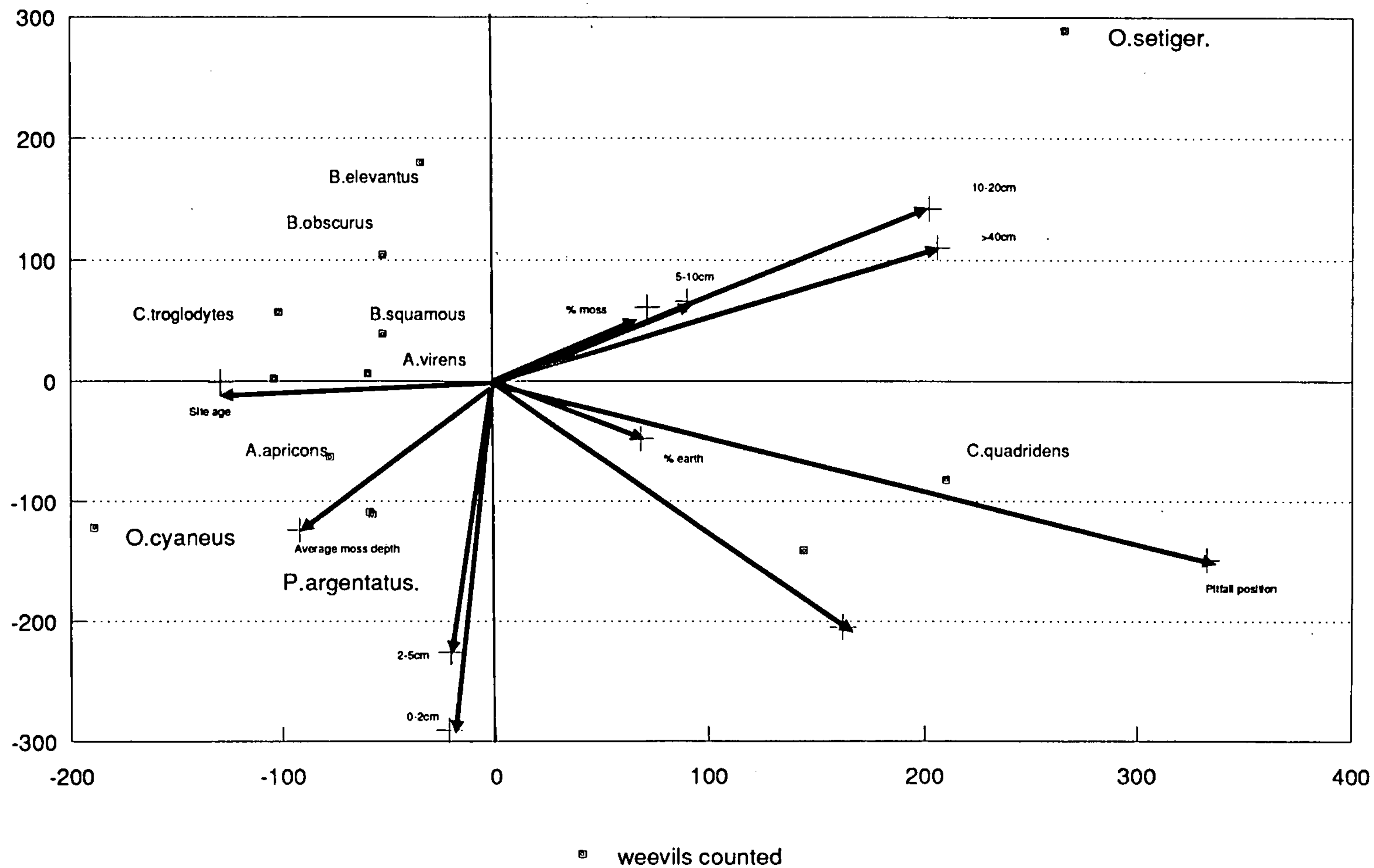


Pitfalls totals from 22/05/90-17/07/90

28A

Fig.22.

C.C.A. of weevils and plant architecture site age, % moss, % bare earth, average moss depth and pitfall position.



3.3.3.5. The 20-40cm, pitfall position, 0-2cm and average moss depth axis.

The 20-40cm and pitfall position axes have no species directly associated with them.

The 0-2cm axis has only 1 strong association - Opiliona juveniles, their positioning between the 0-2cm and % moss axes indicating they probably shelter or hunt in the moss or seek prey within it.

The snail predator, the glow worm (larvae), *L.noctiluca*(*) is positioned on the axis for average moss depth (this species showing the strongest association with this axis). *L.noctiluca* feeds solely on snails which are found in moss and may explain this association, (Boycott 1934 and Chinery 1986). The importance of average moss depth seems to be of greater importance for L.noctiluca than % moss cover and the larvae occur in the deeper moss polsters, maybe due to the abundance of juvenile snails or the protection it affords. It maybe that the larvae are prone to dessication.

3.3.3.6. Percentage bare earth (and 2-5cm axes).

Auchennorchyncha imagos(*), beetle X and the harvestman *N.bimaculatum* (*35) are strongly associated with % bare earth.

N.bimaculatum has the strongest association of any species with % bare earth lying in the top right of the biplot (Fig.18). Jones (1983) describes this species as occurring under stones and logs, it seems likely that it shelters in these microhabitats and hunts on bare ground. "Open areas" also occur under vegetation between the bases of grasses and other plants which may be utilised by this species.

The largest Staphilinidae i.e. over 10mm in length probably belong to the Genera Philonthus, Ontholestus or Othius all over 10mm in length. Many members of these genera occur in moss and litter (Fowler 1888 and Harde 1981). *Othius punculatus* was recorded by Sheppard (1989) as being new to the transplanted turfs (his 2 page report is included in the appendix).

Finally for this analysis Opilione imagos were also closely associated with the 0-2cm axis but lying between the % bare earth axis. Site 8 recorded the greatest numbers of Opliliones representing 27% of the total imagos. Site 8 also has the greatest occurrence of bare earth (Fig.20.). Jones (1983) describes Opilines as occurring in a wide variety of habitats from beneath stones to a wide range of vegetation heights, varying with species. The trend for association with bare earth is shown in the histogram for imago Opilines in the appendix. However 53% of imago opilines were collected in quadrats with no bare earth. It is possible that Opilines utilise the bare earth as "highways" between feeding areas, due to the ease of movement when compared to vegetated areas, so are more likely to fall into pitfall traps on bare earth. The greater distances travelled by imagos whilst hunting when compared to juveniles increases the chance of capture in pitfalls, hence the greater number.of imagos caught.

Opilona, staph> 10mm, Auchenorranchya imagos and *T.niger* are all dispersal stages.

3.4. Weevil DCA and CCA.

3.4.1. Weevils - Curculionoidea.

The thirteen species/groups of weevils where analysed separately using a DCA analysis run on the Canoco programme (Ter Braak 1987). These analysis represents 362 individuals caught in pitfall traps between 25/05/90 - 18/07/90. The invertebrate species list in the appendix gives further details.

The *Curculionoidea* are represented by >500 British species. All species feeding on plant material and are important grassland herbivores.

3.4.2. DCA analysis of Curculionidae.

The ordination places the species in a > shape along the length of the 1st axis, see Fig.21. The distinctive weevil *Orobitis cyaneus* is an outlier in the extreme right of axis 1. Two other species lay within the top right quarter are *Barynotus elevatus* and the metallic green weevil *Phyllobius argentatus*. The ordination places both legume feeding Apion apricans and A.virens in the bottom right quarter of the ordination. The *Plantago* feeding species *Ceuthorrhynchidius troglodytes* is also placed with the 2 *Apion* species. In the bottom left quarter of the ordination lie three species, *Ceuthorrhynchidius quadrideas*, black weevil sp, chestnut weevil sp and the group other weevils. The top left quarter contains *Barynotus obscurus*, *Barynotus squamous* and

Orthochactes setiger. All three *Barynotus* sp lie in a line in the top left of the ordination, these species are all associated with the lower stems of grass, (Fowler 1891).

3.4.3. CCA of Curculionoidae species.

The eleven environmental variables outlined in the invertebrate CCA were used with 10 weevil species and 3 weevil groups. The CCA analysis showed that pitfall position, 10-20cm, >40cm, 20-40cm and 0-2cm, etc were the most important with respect to this group (listed in order of importance), see Fig.22.

The environmental variables will be discused in order of importance (based on the relative lengths of the biplot arrows) and the species most closely associated with them.

3.4.3.1. Pitfall position.

Only one species - *C.quadridens* is positioned on the positive axis for pitfall position. This species lies between the positive >40cm and pitfall position axes. This species is associated with Crucifers on which the species live.

3.4.3.2. 10-20cm, 5-10cm and % moss cover.

O.setiger shows a strong positive association with all three axes, lying closest to the axes for % moss cover (when a line is drawn at 90° from it's position to the axes). This 2.5 - 2.75mm species is often covered in mud due to it's habit of occurring at the base of ragwort, *S.jacobaea*, dock *R.acetosa*, etc, (Fowler 1891). Fowler (1891) also describes this species as often occurring in moss which supports it's position on the biplot. It also seems to be a species of low vegetation i.e. most commonly associated with vegetation below 20cm in height.

3.4.3.3. Average moss depth.

The green weevil *P.argentatus* and the general group Curcuilionidae lay between the positive 2-5cm and average moss depth axes. *P.argentatus* is described in the literature as occurring on deciduous trees and to a lesser extent conifers. It is possible that this species shelters in moss and low vegetation when not feeding in the trees or merely the position of trees coincides with the greatest moss depth.

3.4.3.4. Average moss depth and site age.

O.cyaneus has a strong association with the axes for positive average moss depth and *A.apricons* lies midpoint between the two axes. *O.cyaneus* also lies on the negative axis for % moss cover, 5-10cm and 10-20cm supports Fowlers (1891) observations as a species of " sandy and chalky places often occurring in moss during the winter". This species also seems to be occurring in the moss to some extent during the spring and summer months as well as the winter.

A.apricons feeds on red clover, *Trifolium pratense* and other legumes, occasionally found on trees, (Fowler 1891, Harde 1981). It's position midpoint the axes cannot be explained on the presence of *T.pratense* (see CCA vegetation data file in appendix) as this plant species shows no relationship with site age. However average moss depth does increase with site age especially in site 1. See Fig.20.

3.4.3.5. Site age and % moss cover, 5-10cm and 10-20cm.

Between these four axes lie 6 weevils, round weevil sp, *C.troglodytes*, *B.elevantus*, *A.virens*, *B.obscurus* and *B.squamosus v. schonherri* closest. To further complicate the picture thee 6 species also lie between the negative axis for 20-40cm, % bare earth and pitfall position.

C.troglodytes feeds on plantain species,(Harde 1981) who's distribution is generally greater on the older sites, hence it's strong association with site age axis.

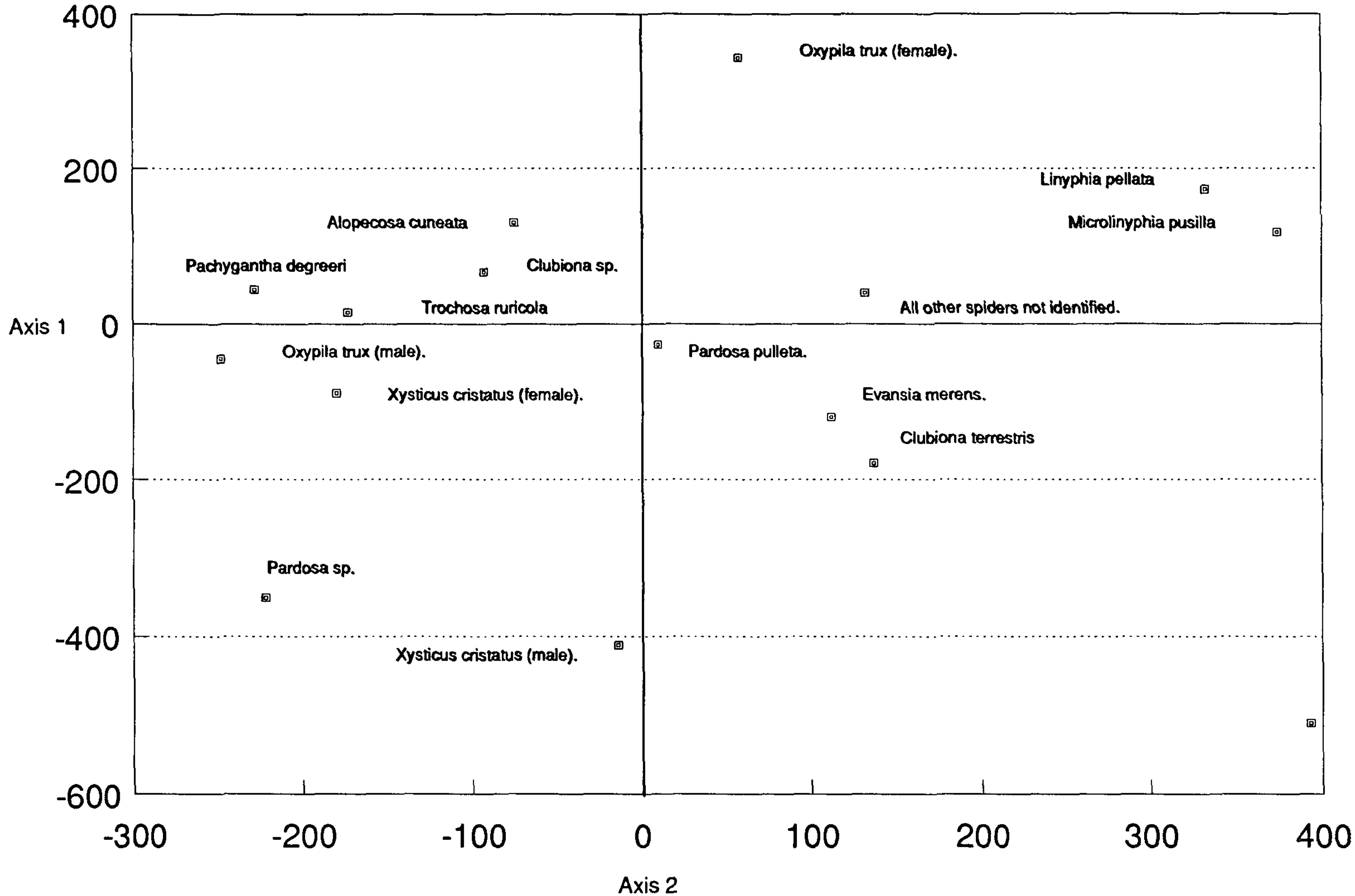
A.virens larvae are found within *T.pratense* on which the adults also feed. Given that this species feeds on *T.pratense* and this is a plant of closed swards, it's position on the negative axis for % bare earth supports it's association with these swards and areas of low % bare earth.

The three *Barynotus* species are all large robust weevils 8 - 10mm long, occurring under stones, at the bases of grasses and in moss (Fowler 1891). Lying between site age and % moss cover, 5-10cm and 10-20cm reinforces Fowlers observations that these species are associated with low to medium grassland vegetation and there position close to the negative 20-40cm axis also supports their association with low vegetation.

The importance of plant species was tested using a correlation coefficient i.e. number of plant species against number of weevil species per quadrat. No correlation was found, (r=-0.03092 at

Figure.23.

DCA of spider species on a per quadrat basis.



- 32A -

5% confidence limit). This is to be expected as many weevil species have specific host plants.

3.5. Araneae DCA and CCA.

3.5.1. Spiders - *Araneae.*

A total of 4308 individuals were collected in pitfall traps. The 13 commonest species of *Araneae* were identified and the remainder were classed in a general group as spiders. Only imagos were identified and used in these analyses. Two species *Oxypilla trux* and *Xysticus cristatus* were recorded as male or female . Casual observations suggest that at least 40 other species occur at Thrislington. The 13 species were used to run a DCA and CCA analysis within the CANOCO programme. Eleven environmental variables previously outlined in the invertebrate introduction were used in the CCA analysis. A further 6 Araneae species were represented by a few individuals which prohibited their use in both analyses (e.g. *Euophrys erratica* and *Lephyphantes leprosus*). Limited time prehibited further identifications (but see Araneae section and graphs of species distribution in the appendix).

3.5.2. Araneae and plant architecture.

The major studies on *Aran*eae and their association with plant architecture are reviewed here.

Duffey (1962) working on limestone grasslands concluded that " where the field layer is rich in numbers of individual plants, selection by the spiders for particular plant species is weak". He observed that *Araneae* species are more closely related to architecture, any plant in the height class 20-40cm will be used regardless of it's species. He notes that the number and position of horizontal stems are important for web spinning species. Robinson (1981) also showed that *Araneae* in both laboratory and experimental field trials showed a distinct preference for structure with respect to architecture. The relationship between vegetation structure and abundance of spruce living *Araneae* has been investigated by Gunnarsson (1990). He showed a significant decline in both size (by 15.6%) and abundance (16.5 - 36%) when a third of the spruce needles were removed. He suggested predation may be a consideration in population decline. Other workers have shown a strong correlation between *Araneae* and plant architecture including, Greenstone (1984), and Hatley & MacMahon, (1980).

3.5.3. Araneae DCA analysis.

The ordination of 13 species including both male and female of the two 2 species shows an even spread over the principle axes (Fig.23.). There are no clearly defined groups within the community. In the top right hand corner of the diagram are two species of the family *Linyphiidae* (moneyspiders) - *Linyphia pellata* and *Microlinyphia pusilla* (Jones 1989). There are three outliers at the bottom right of the diagram along the length of the first axis, from left to right *Pardosa* Sp, *Xysticus cristatus* (male) and *Enoplognatha ovata*. Another outlier occurs at the top right of the diagram, *Oxypilla trux* (female). The remaining species occur in a band along the 1st axis, with a loose clumping of 6 species to the left of the 2nd axis.

3.5.4. Araneae CCA analysis.

The results of the analysis are illustrated in Fig.24. Spider species are shown as points on the ordination and the environmental factors are shown as arrows. The length of the arrows reflects there relative importance with respect to each other.

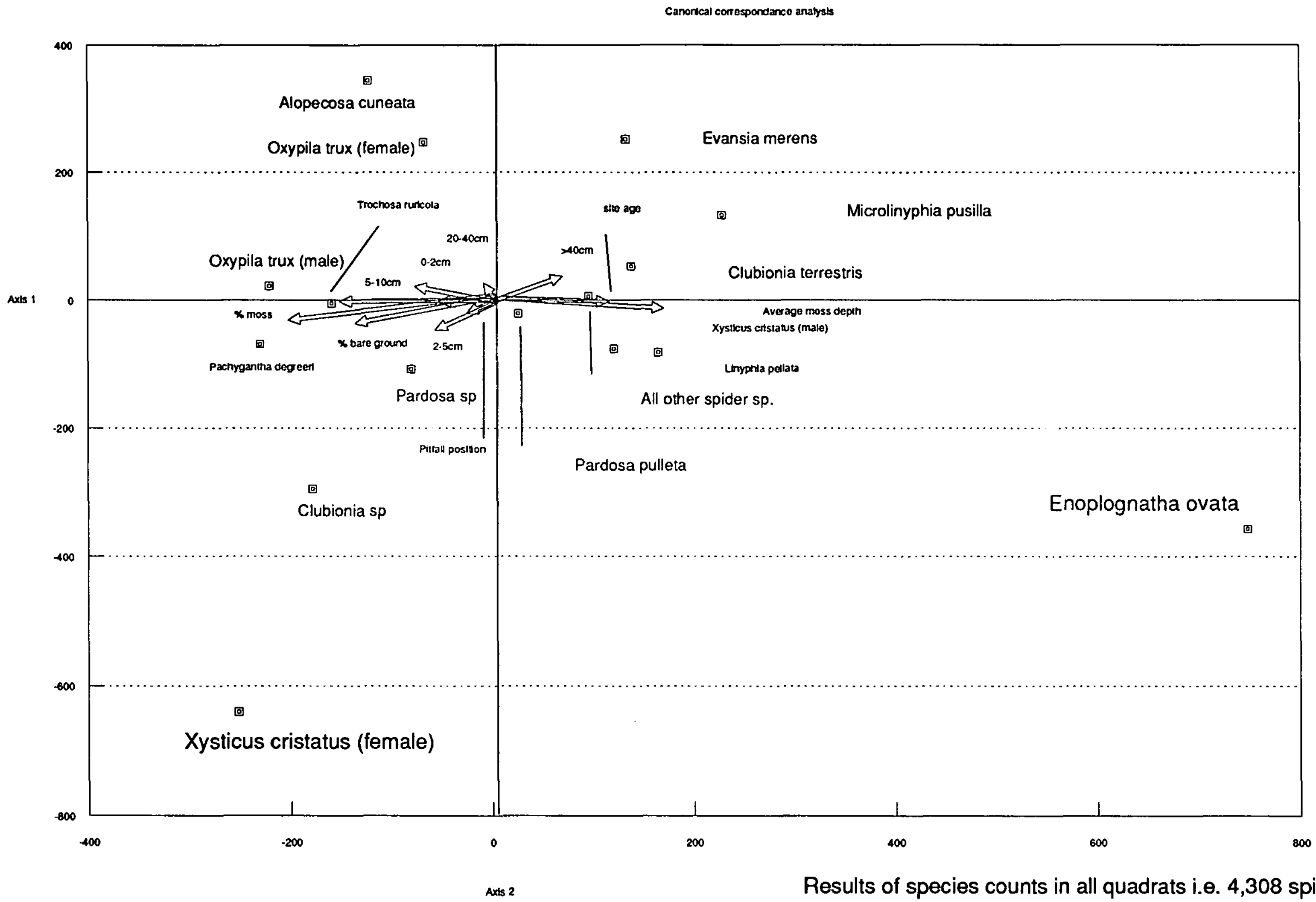
Family - Clubionidae.

Clubiona terrestris and Clubiona sp.

The genus Clubiona are associated with damp habitats and low vegetation (Jones 1983). *C.terrestris* is associated with a wide range of habitats including under stones, low vegetation, shrubs and trees (Bristowe 1958). The CCA analysis positions this species at the negative end of the axis for % bare earth and centred between positive >40cm and negative % moss, but positioned on average moss depth at negative end. Probably this species prefers the sheltered/humid conditions within the moss but hunting widely from bare earth to >40cm. This species appears to utilise the entire grassland habitat.

Figure.24.

Spider CCA with - pitfall position, plant architecture, % bare ground, site age, % moss and average moss depth.



Results of species counts in all quadrats i.e. 4,308 spiders

Family - Linyphiidae (money spiders).

This family is represented by 250 species, all web spinners. They are the commonest spiders throughout the Northern hemisphere.

Evansia merens.

The literature describes *E.merens* as occurring under stones frequented by ants, especially *Lasius niger* and *Formica fusca*,(Locket & Millidge, 1951) feeding on microdiptera and *Collembola* (Bristowe 1958). The analysis places this species positively midpoint between the axis for 20-40cm an >40cm. The presence of *E.merens* in pitfall traps shows that it is not restricted to ants nests, so it may utilise the tall vegetation although no literature supports this theory. This assumes that pitfalls are quantative with respect to each other.

However it is interesting to note that ants (*Formicidae*) are most abundant in pitfalls from sites 4,6 and 8 (Fig.32.) and that the 20-40cm and >40cm height classes are most strong associated with sites 4-8 (Fig.11-13). Since the abundance of ants was not used in this CCA analysis it is possible that the strongest association variable - tall vegetation, accounts for the distribution of *E.merens* by this CCA instead.

Linyphia pellata and *Microlinyphia pusilla.*

M.pusilla is strongly associated with the positive >40cm axis and *L.pellata* negatively with the 5-10cm axis. Lockett and Millidge (1953) describe *L.pellata* as being associated with woodland and hedges but do not asign this species to any layer in these habitats. While the literature sites the later species as associated with low vegetation. Positions of both species on the biplot appear to be reversed.

Family - Lycosidae (wolf spiders).

This family represents a large number of nomadic species which hunt by site in daylight, with the exception of the genus Trochosa which retreat to permanent hole in the ground.

Alopecosa cuneata.

This species is described by both Bristowe (1958) and Jones (1983) who refer to *Alopecosa cuneata* as *a Lycosid* (wolfspider) inhabiting downs, open ground, dunes and areas of short grass. The species is described as being locally abundant on chalk (Locket and Millidge, 1951).

Within the twenty five quadrats this species is positively associated with the height class 20-40cm.

Pardosa pullata and *Pardosa* sp.

P.pullata lies between the 5-10cm and 20-40cm axes, while *Pardosa* sp is strongly associated with the 2-5cm zone. The Genus *Pardosa* comprise hunters of open ground and low vegetation (Jones 1983)

Family - Theridiidae (comb-footed spiders).

This genus produce "scaffolding" webs of various designs. The tarsi on the fourth pair of legs is adapted to draw silk from the spinnerets and throw it over their prey (Bristowe 1958).

Enoplognatha ovata.

This species was previously known as *Theridon ovata*, (Lockett and Millidge 1951). It is associated with shrubs and low vegetation, especially bramble *R.fruticosus* leaves in which the female encloses herself and the egg sac, (Bristowe 1958). *E.ovatum* was found in low vegetation in Limestone grassland at Wytham Woods, Berkshire by Duffey (1962). This species is strongly negatively associated with both the 5-10cm and 20-40cm axes, supporting it's preferred habitat as described in the literature.

Family - Thomissidae (crab spiders).

Crab spiders are often brightly coloured , lying in ambush for their prey both on the ground or on plants (Bristowe 1958).

Oxypilla trux.

This is the commonest of the Genus *Oxypilla* , occurring throughout the year in undergrowth and grass (Locket and Millidge 1951) and in low vegetation and detritus (Jones 1983). Bristowe (1958 p145) describes the habits of the genus as follows:- "some species of *Oxypillae* climb up the low herbs at night, from which I suspect they may feed more by night than by day". From the biplot the female *O.trux* would seem to confirm this observation sheltering in the detritus, moss during the day and feeding between 20-40cm at night. The male *O.trux* lies on the axis for average moss depth and also centred between the 0-2cm and 5-10cm axes. The separation in the biplot of male and female *O.trux* maybe due to niche separation, reducing competition for prey between the predominantly terrestrial male and the arboreal female.

Duffey 1962 (p32) found a high correlation between the colour/pattern and preferred habitat within the vegetation zone. The litter/moss layer and amongst plant stems is a moist and dimly lit environment, hence the *Araneae* occurring in this habitat and combinations of black, grey, brown or dull shades of red. Male *O.trux* are brown to very dark brown with dark brown or black longitudinal lines/bars (Locket and Millidge 1951). This would support the theory that male *O.trux* hunt in the lower vegetation
and are generally dark as an adaptation to this environment, hence their position between the 0-2 and 5-10cm height classes.

The female also supports Duffels observation that *Araneae* occurring in tall vegetation are generally brightly coloured and pale in colour. The female *O.trux* having a yellow brown to brown on the carapace with a pale brown abdomen (Lockett and Millidge,
1951) suggests that the females colour/pattern is adaptation to her position in the vegetation. The lighter coloured female utilising the tall vegetation and the darker male utilising the moss and lower vegetation.

Xysticus cristatus.

The male is positioned midpoint between the negative 0-2cm and 20-40cm axes. The female is an outlier roughly centred between the positive 2-5cm and 5-10 cm and negative 20-40cm axes. Bristowe (1958) describes this species as:- "associated with grass and low herbage at ground level or on it's foliage". The analyses position both sexes in 2.5-10cm (female) and 20-40cm (male) height classes may reflect the two niches of the species. The CCA analysis shows that the male is strongly positively associated with the height class 0-2cm and the female 2-5cm. All other literature describes this species as occurring in grassland on low herbage. It is likely that this species shelters in the zone 0-10cm to avoid dessication and predators, hunting in the middle vegetation zone 2.5 - 20cm. The niche of *X.cristatus* would seem to be the 2.5 - 20cm zone, (the female between in the lower half of this zone i.e. 2.5-10cm and the male throughout this zone i.e. 2-20cm) lying between the niche for *O.trux* which utilises the ground (male utilising the 0-2 and 5-10cm) and taller vegetation (female associated with the 20-40cm axis). This would suggest niche separation is occurring between these two species thus avoiding competition.

Family - Tetragnathidae.

All three species of this genus have abandoned web spinning and are common on the ground/low vegetation (Bristowe 1958).

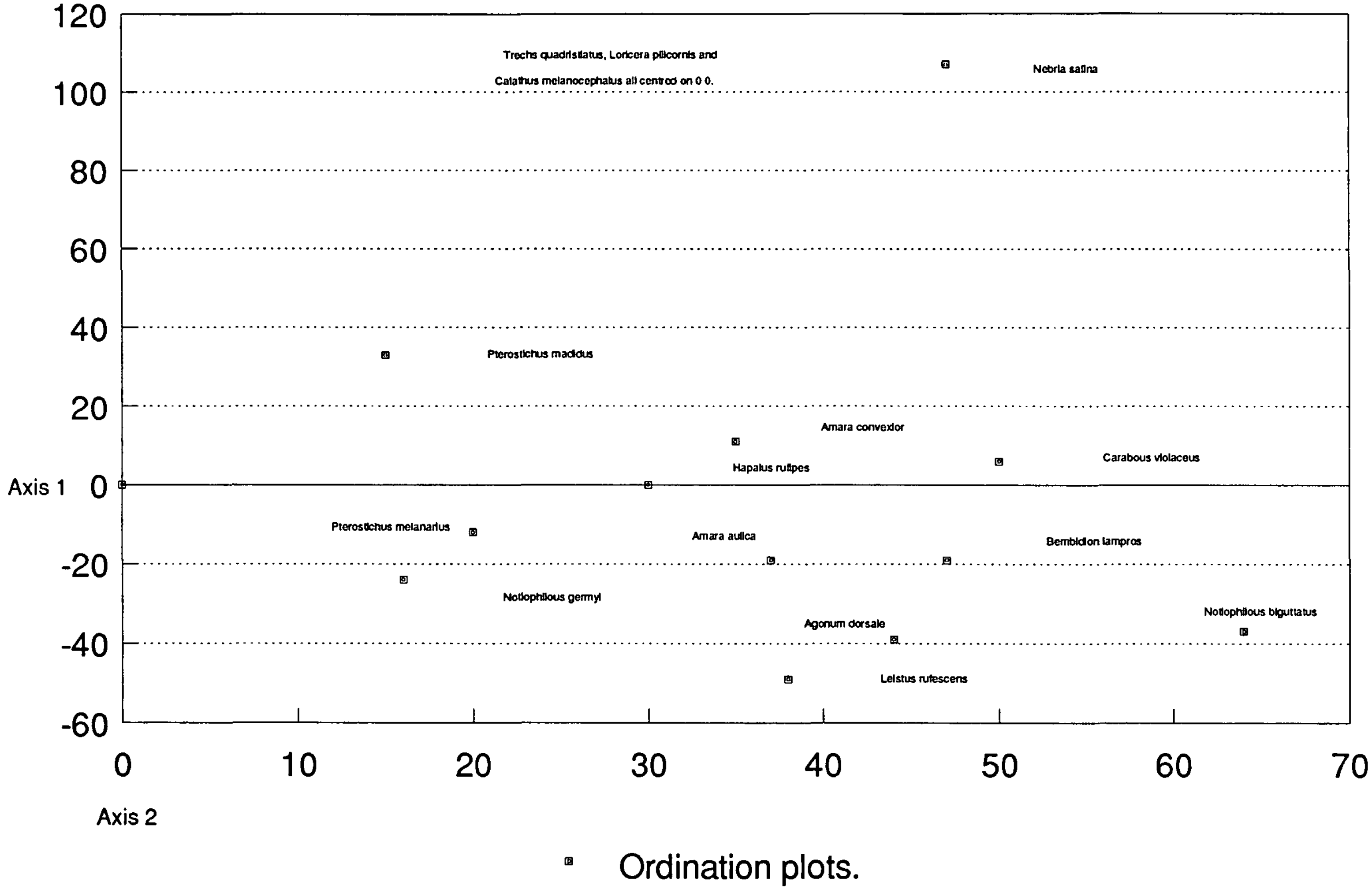
Pachygantha degreeri.

This species is described as common at ground level amoungst grass/bare ground and able to tolerate dryer conditions than other species in the Genus, (Bristowe 1958 p255).

The position of this species directly on the axis for positive % bare ground supports the later observation by Bristowe. This species also lies between the axes for % moss cover and 2-5cm, being more strongly associated with % moss cover. It seems probable that this species shelters in moss/low vegetation and hunts in low vegetation/bare ground. However a graph for % bare earth in Fig.20.) shows that bare earth occurs solely in sites 4-8. The graph of pitfall catches of *P.degreeri* (see appendix) shows the opposite tendency i.e. lower numbers of *P.degreeri* with increasing % bare ground. This anomaly could be explained by arguing that although *P.degreeri* favours bare ground for hunting it's population size would be very low in plots with high % bare

Figure.25.

DCA of Carabidae species.



earth as shown in the vegetation records.

The class - Araneae.

This general group comprising all other *Araneae* lies between the axes of average moss depth and site age. It is interesting to note that in Fig.18., the ordination of all invertabrate species also places spiders very close to the axis for % moss. It can be implied from this that in general Araneae show a strong association with presence of moss. It could be that there *Acari* and *Collembola* prey associated with moss. *Acari* are strongly associated with % moss in the ordination. However as pitfalls were the only sampling method there is a strong bias for species associated with low vegetation or ground dwelling species.

The discussion will bring together the results of these analyses with respect to invertebrate/plant architecture.

3.6. Carabidae DCA and CCA.

3.6.1. Carabidae.

Quadrat 2/6 recorded the greatest number of species (10) and individuals (76) shown in figures A16 & A17 in the appendix. These two high figures maybe due to this site having 60% bare earth and the pitfall being positioned on bare earth, see Fig.20.

A total of 664 individuals were collected in pitfalls representing 17 species of these 662 individual Carabids representing 15 species collected in pitfalls, were used in the DCA and CCA analyses. A further two species *Badister bipustulatus* and *Bembidion obtusum* represented by 1 specimen, were not used in these analyses and the remaining Carabid species were represented by 6 individuals or more.

The general opinion is that Carabids are carnivores but recent autecological studies suggest that many species are omnivorous (Lindroth 1985). The Genus *Amara* and *Harpalus* contain omnivorous species. Carabids are predominantly ground dwellers in temperate latitudes becoming mainly aboreal in the tropics, (Lindroth 1985 and personal observation).

3.6.2. Carabidae DCA analysis.

The carabid DCA analysis (Fig 25) shows that the species lie in abroad band along the first axis. *Nebria salina* is an outlier in the top right of the ordination. Seven species lie beneath the first axis, four above the first axis and four on it. Both Pterostichus and Amara species are positioned together, to the right and in the centre of the biplot respectively. The two Notiophilous species are both positioned beneath the first axis. In general the species lying closest to the first axis are those most strongly associated with vegetation.

3.6.3. CCA analysis.

The CCA analysis (Fig.26) shows that the 2-5cm and % moss axes are the most important environmental variables. Species will be discussed in clockwise order from the 2nd axis through the biplot starting with the main outlier *Notiophilous biguttatus*. Each species or species assemblage will be discussed with respect to the axes of strongest association.

Notiophilous biguttatus.

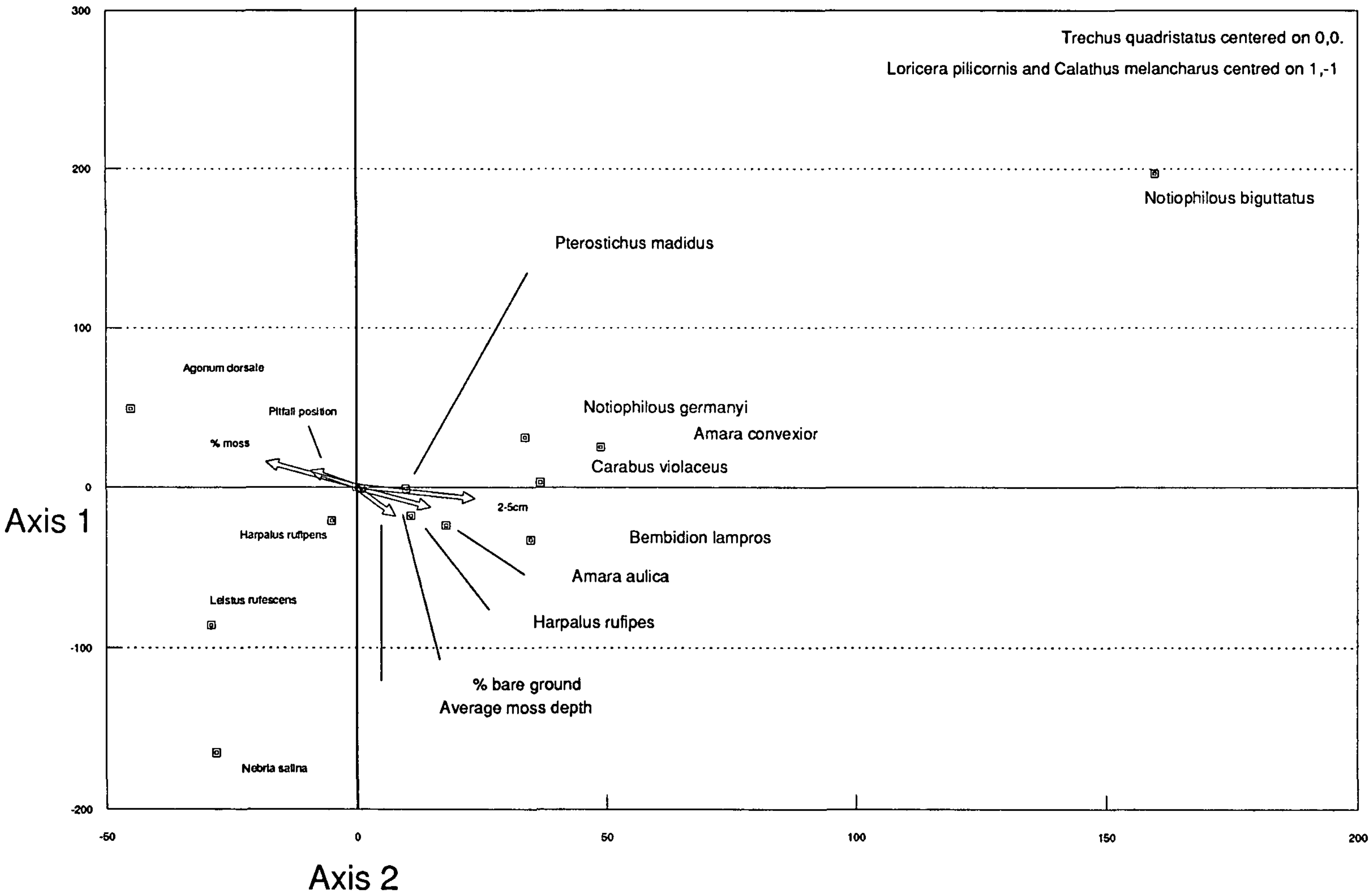
The most noticeable outlier is *N.biguttatus* in the top right hand corner of the biplot. This species is described as a woodland species, occurring in dry open areas amongst litter or sun-exposed ground with sparse vegetation, (Lindroth 1985). In this analysis the species occurs between the 5-10cm and the site age axes on the biplot. As site age increases there is a decrease in % bare ground as the sward colonizes. The % bare earth is greatest on sites 4-8 (youngest transplanted turfs) (see Fig.20.) reaching 75% on the most recent transplant - site 8. The pitfall catches of this species reflect this with *N.biguttatus* only being caught on sites 6 and 8 only (7 catches in each site). This species is likely to disappear from the transplant as the sward colonizes the remaining bare earth.

Amara convexior, Carabus violaceous, Notiophilous germanyi and *Pterostichus madidus.*

These four species are clustered between the 5-10cm and site age axes, all showing a stronger association with the 5-10cm axis. *A.convexior* and *N.germanyi* both occur in dry habitats, (Lindroth 1974). *P.madidus* and *C.violaceus* which are large ground dwelling species occur vertually on the 5-10cm axes. (An explanation for this maybe that both are ground dwelling

Figure.26.

Carabidae CCA. Species and % bare earth, plant architecture, pitfall position, av moss depth, % moss and age of site.



species). A possible reason for the strong association with axes 5-10cm is that <5cm the density of vegetation is too great and these species are excluded from the lower zones, *(P.madidas* typically 13-17mm and C.violaceøus 20-30mm), because they are too large. The highest number of catches for *P.madidas* was 1/3 with 37 captures. The plant architecture profile for 1/3 in Fig.10. shows a decline of 64% in the number of touches between 5-6cm to 6-7cm, this trend is also present in profiles for 4/1 (27 captures), 6/3 (24 captures), etc. The CCA programme has associated this species with the 5-10cm due to the strong relationship with number of *P.madidas* caught and this sudden change in the profile diagrams. It is possible that in quadrats with high numbers of touches between 0-5cm this species hunts in the 5-10cm zone and in the bare earth/open areas as their physical size excludes them from the lower zones.

Amara aulica, Bembidion lampros and Harpalus rufipes.

These three species lie between the >40cm and positive average moss axes. *B.lampros* inhabits open sparsely vegetated ground, (Lindroth 1985). It's position on the >40cm axis would suggest that this species has a strong association with this zone, which it may, the literature does not support this however. A probable explanation is that the height class >40cm is most strongly associated with site 6 and 8, which also have the greatest % bare earth. Since open ground is the habitat of *B.lampros* is possible that the CANOCO programme places the species with respect to the greatest association i.e >40cm not the actual habitat bare earth. Caution should be used when interpreting the biplot merely on the position allocated to each species, autecological studies and habitat requirements should be also used to interpret species distributions.

Both *A.aulica* and *H.rufipes* also lie between the >40cm and % moss axes. As previously mentioned *Amara* and *Harpalus* species are omnivores feeding on a wide range of plant material. Both species being associated with meadows with tall vegetation component. They feed on seeds of Compositae (*Cardius*, *Circium*, etc) in the case of *A.aulica* and a wider range of plants are utilised by H.rufipes, (Lindroth 1986). Both species are nocturnal climbing vegetation to feed (in the >40cm zone?) and remaining in the moss/leaf litter zone during the day. The autecology of both species as described by Lindroth, explains their positioning equidistant between the >40cm and % moss axes.

Leistus rufescens, Nebria salina and Pterostichus melanarius.

All three species lay between the positive site age and positive % moss axes. Lindroth (1974) describes *L.rufescens* as a hydrophilous species occurring in moist, shady places often occurring under alders (*Alnus* glutinous). The presence of two areas of *A.glutinosa* within 20m of 1/6 where this species occurs, supports this. The two other species occur on dryer habitats associated with sparsely vegetated open country, (Lindroth 1974). The greatest occurrence of open ground/bare earth is associated with sites 4-8 i.e. the most recently transplanted sites. This may explain their positioning of these species on the biplot. These three species only occur on sites 4-8.

Agonum dorsale.

Positioned on the axis for pitfall position this species is also strongly associated with the axis for % moss. Being a species of open meadows and grassland (Lindroth 1986), it often shelters under stones (Fowler 1887) and maybe occurring in the moss due to the scarcity of stones on the transplant.

Calathus quadristatus, Loricera pilicorns and *Trechus quadristatus.*

These three species are centered on 0,0. CCA analysis places ubiquitous species at this position as they show no correlation with any environmental variables. They occur equally in every quadrat (Ter Braak 1987).

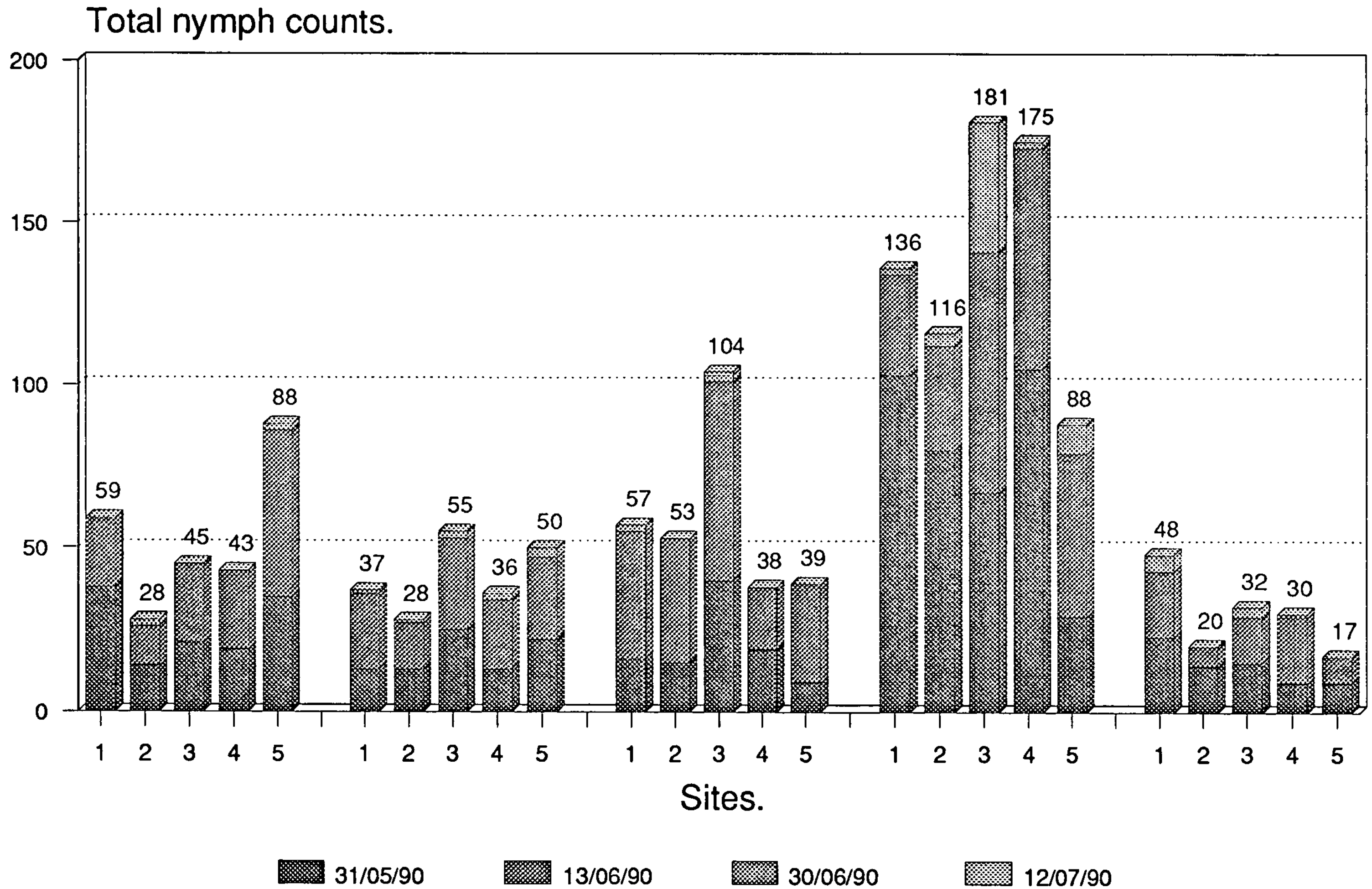
3.7. Auchenorrhyncha results.

3.7.1. Auchenorrhyncha - background.

It has been shown that both the numbers of individuals and species of leafhopppers and froghoppers (Auchennorhyncha - Homoptera) comprise an important component of the phytophagous fauna of temperate grasslands (Andrzejewska 1962, 1965, Morris 1971 and Whittaker 1979). The diversity of the fauna is reflected by the structural/architectoral diversity of

Figure.27.

Cercopidae nymph densities.
Density counts per 2x2m quadrats.



1-5= site 1, 6-10= site 3, etc.

Figure.28.

The percentage of Cercopidae nymphs (froghoppers) on 44 plant species at Thrislington plantation transplant site.

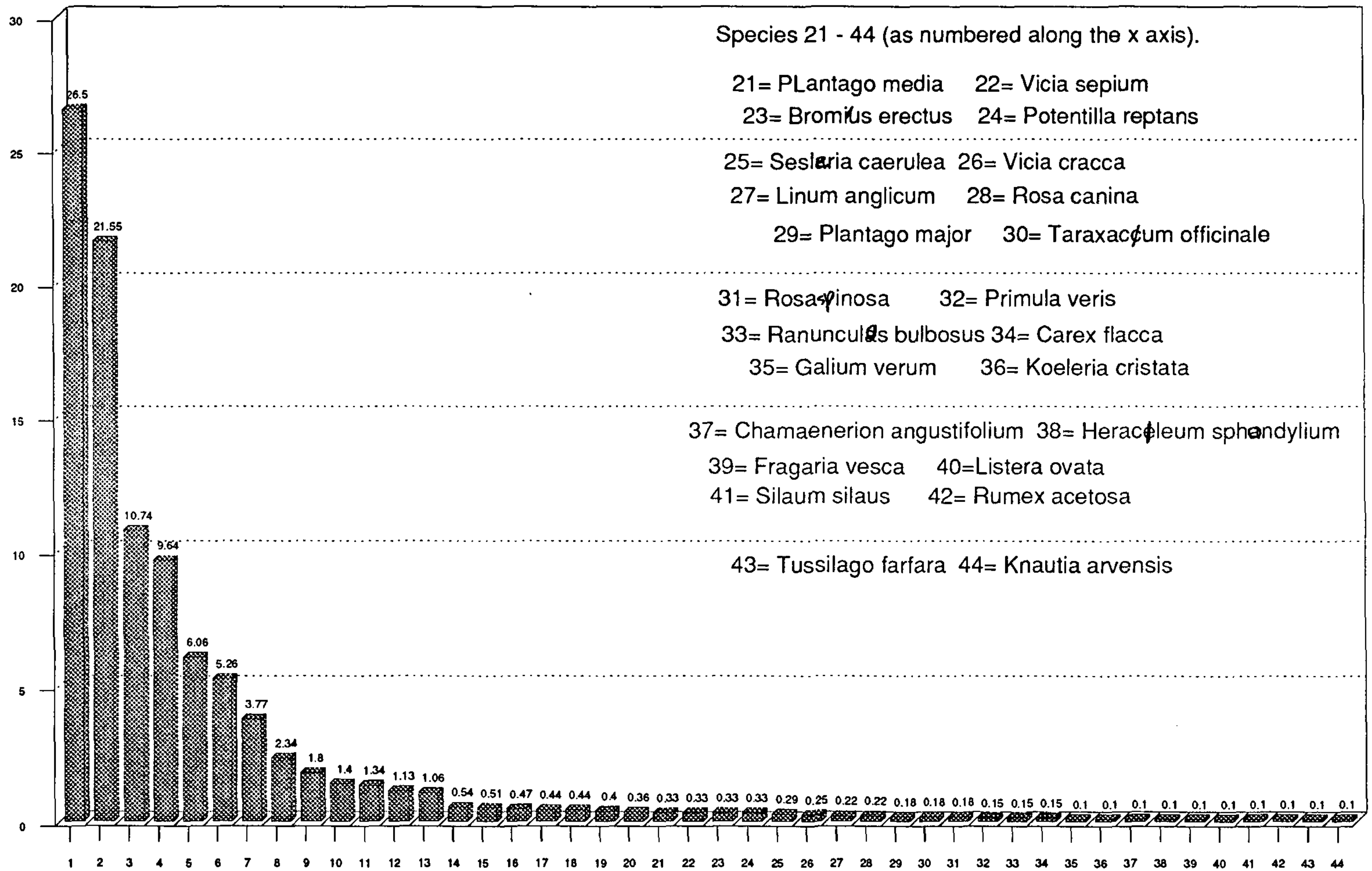
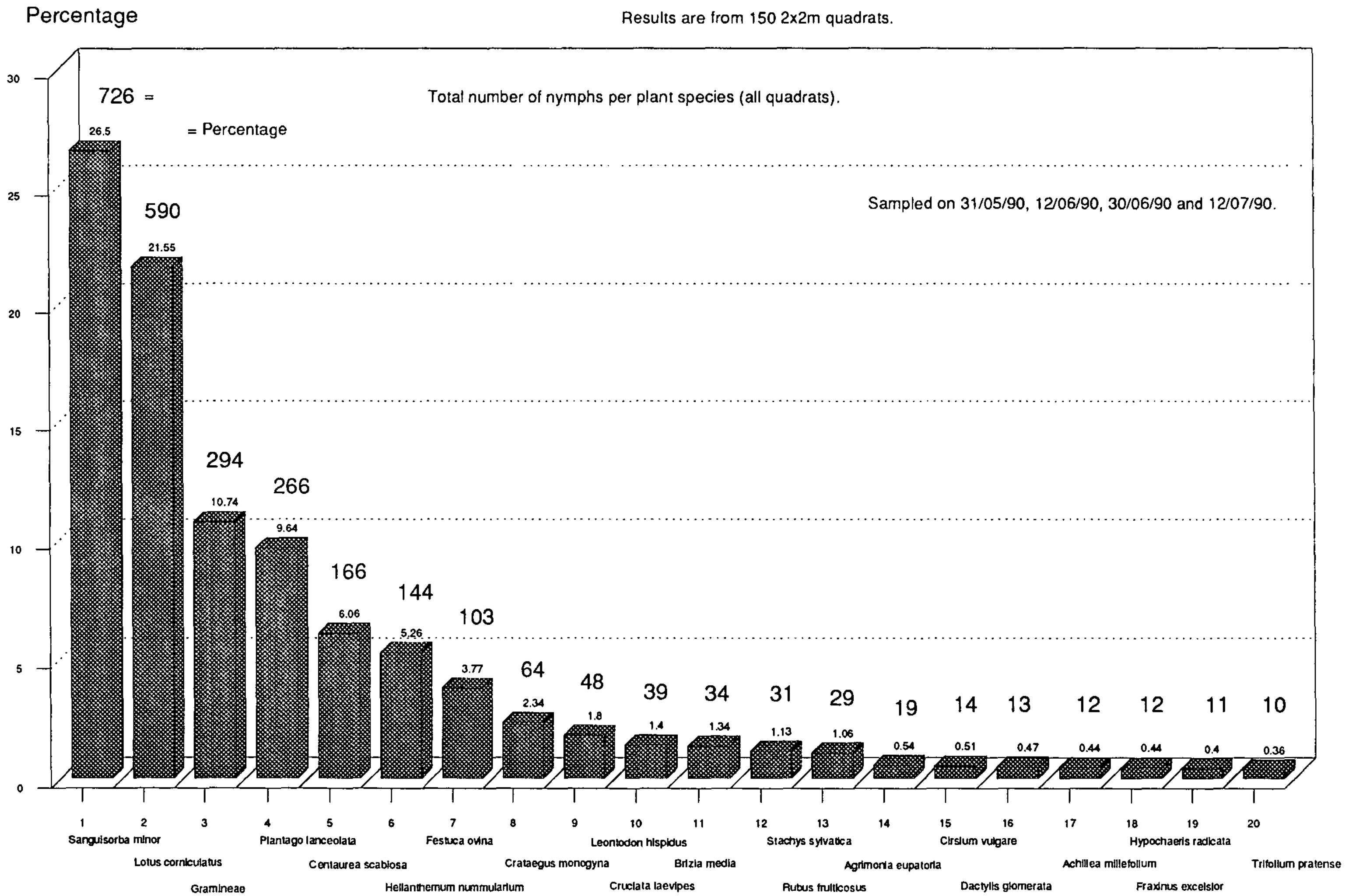


Figure.29.

The percentage of Cercopidae nymphs. (froghoppers) on 20 plant species at Thrislington plantation transplant site.



the habitat as well as diversity of microclimate conditions. The shorter the sward the lower the species diversity as short sward is unable to support species assemblages associated with tall vegetation, (Morris 1981). The niches of particular species maybe very narrow. Ross (1957) argued that here were no difference in 6 species of Auchenorrhyncha. As a result of this he proposed that Gauses competive exclusion principle was no longer valid.

The *Auchenorrhyncha* are a suborder of the order Homoptera, divided into two series, the *Cicadomorpha* (240 British sp) and the *Fulgomorpha* (84 species), Quesne 1960. Both nymphs and imagos of all species feed on plant juices extracted from plant cells and phloems through there proboscis. Many species are specialized to certain plant genera or single plant species. The plant ragged robin (*Lychnis flos-cuculi*) owes it's latin name to investations of spume, especially by the froghopper *Philaenus spumarius*. The term "host plant" follows the definition in Ossiannilsson (1978) as "plants which insects species reproduce during at least one generation". Most species are diurnal, hence commonly encounted on most vegetation. They all pose the ability to jump, with many species taking flight if disturbed.

Little is known about the biology of many species of *Auchenorrhyncha*. With few exceptions, morphology and taxonomy of larval Auchenorrhyncha have seldom been studied, exceptions to this include Vilbaste (1968) keys for the Fulgomorpha (in Ossiannilsson 1978). Ossiannilsson (1950b) constructed keys for 6 species of Cercopidae nymphs in Sweden. Morris (1971, 1973, 1981a, 1981b, 1983, 1990a, 1990b and 1990c) as produced a series of papers which has greatly increased our knowledge of their response to management of grasslands.

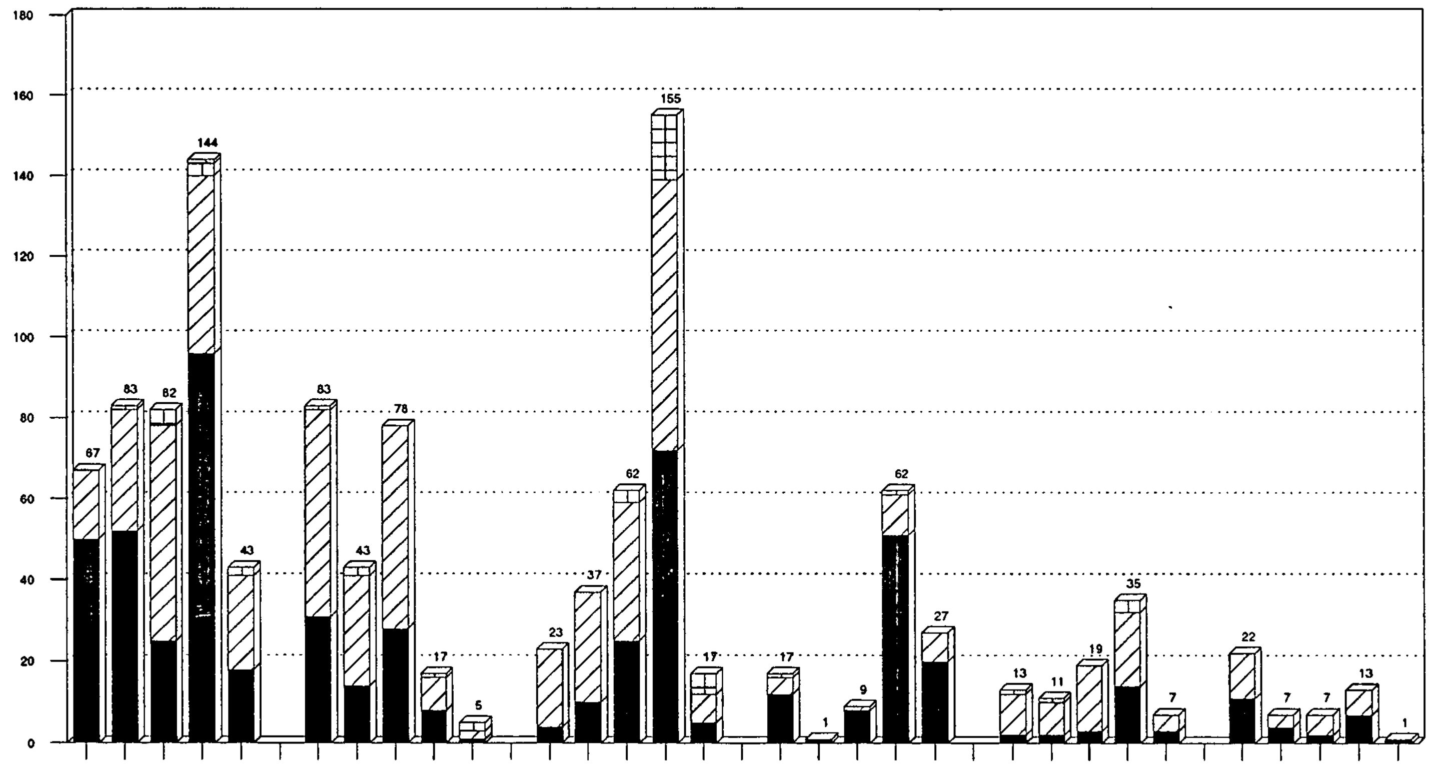
3.7.2. Auchenorrhyncha results.

Due to the cohesiveness of the froth or spittle produced by *Cercopidae* nymphs (froghoppers), Morris was not able to sample the nymphs of this family, which are not taken up by D-vac sampling. This was the main collecting method employed by Morris.

The studies by Morris excluded the nymphs of the *Cercopidae* and this study emphasises the nymphs of this family for this reason, with particular reference to plant "host species". Larvae of *Auchenorrhyncha* especially the first and second instars generally cannot be determined accurately to species level at present (Morris p141 1981a). This combined with the limited time available meant that only total nymph counts per plant species were made. No nymphs were

Figure.30.

Cercopidae nymph counts on the six commonest host plant species from 31/05/90 - 12/07/90.



	Sangulsorba minor					Lotus comiculatus					Graminae				
12/07/90	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
30/06/90	0	1	4	3	2	1	2	0	1	2	0	0	3	16	5
12/06/90	17	30	53	44	23	51	27	50	8	2	19	27	34	67	7
31/05/90	50	52	25	96	18	31	14	28	8	1	4	10	25	72	5

	Plantago lanceolata					Centaurea scablosa					Hellanthemum nummularium				
12/07/90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30/06/90	1	0	0	1	0	1	1	0	3	0	0	0	0	0	0
12/06/90	4	0	1	10	7	10	8	16	18	4	11	3	5	6	0
31/05/90	12	1	8	51	20	2	2	3	14	3	11	4	2	7	1

31/05/90 12/06/90 30/06/90 12/07/90

Column 1 = site 1, C2= site 3,etc.

identified during this study.

A total of 3391 *Auchenorhyncha* were counted. Sampling was carried out between 31/05/90 - 18/07/90 by 1/.Cercopidae nymph counts within 2x2m quadrats (2738), 2/.199 sweep netting and 3/. pitfalls (313 nymphs and 141 imagos). This group represented 2.75% of the total invertebrates collected/counted (excluding *Acari* and *Collembola*).

3.7.3. The Cercopidae (froghoppers).

Members of the *Cercopidae* have nymphal stages which exude a froth, spittle or spume. Air is forced into liquid excluded from the anus to form the spittle, (Chinery 1976). Spume is mixed with secretions from the 7th and 8th abdominal segments to enable it to maintain it's coherence even during rain, (Imms 1947). This gives rise to the common names of spittle bugs or cuckoo spit insects. This spittle is conspicuous on many plants during the summer and was used to identify the plant species on which the nymphs feed.

A total of 100 2x2m/2 quadrats were studied with respect to their Cercopidae nymphs and the plant species on which they were feeding. The 25 fixed quadrats were counted on 4 occasions fortnightly between 31/05/90 - 12/07/90. Five additional quadrats were counted on each site on 31/05/90 and 12/06/90 (five quadrats from each site) giving a total of 50. After the fourth count the study was abandoned as the total number in all quadrats dropped sharply to 0 by 12/07/90 were it remained (150 quadrats).

3.7.4. Cercopidae nymph counts.

A total of 2738 nymphs were counted on 44 plant species (54% of the total plant species recorded in the quadrats). No additional plant species with spittle were counted in the extra 50 quadrats that did not occur in the fixed quadrats, Fig's 28 and 29.

The six commonest host plant species were salad burnett - *Sanguisorba minor* (accounting for 26.5% of nymphs counted), birds foot trefoil -*Lotus corniculatus* (21.55%), grasses -Gramineae (10.47%), ribwort plantain -*Plantago lanceolata* (9.64%), greater knapweed - *Centaurea scabiosa* (6.66%) and common rockrose -*Helianthemum nummmularium* (5.26%). These five species and the *Gramineae* account for 80% of the nymphs counted. The remaining 20% of counts are distributed between the other 38 plant species (Fig). If the three other grass species are added to the general class *Gramineae* the total is 16.09%.

The commonest 6 plants were used to study in greater detail nymph plant interactions. The total number of nymphs on *S.minor*, etc were graphed with totals per site. This is given in Fig.30. Site 6 (first bar represents site 1, etc) had the highest nymph counts in 4 out of 6 commonest species i.e. *S.minor*, *Gramaneae*, *P.lanceolata* and *C.scabiousa*. This trend is present in the majority of the species recorded. This trend also occurs within the fixed quadrats. The total counts of nymphs in the fixed quadrats is shown in Fig.27.

It can be seen that all fixed quadrats within site 6 have a higher than average counts. Only fixed quadrat 3/3 having a higher nymph count. Site 6 representing 25.4% of the nymphs counted. Many plant species in site 6 occur on the other sites plus a number of ruderal species including *Rumex acetosa, Traxacum officinale* and *Tussilago farfara*. As site 6 was transplanted in 1987/88 there has been rapid colonisation especially on the overburden filler between the transplanted turfs.

Fig.28. of the relative % of nymphs on 44 plant species shows a typical sigmoidal curve. The curve shows a few plant species dominating a large number of rare species with 30 species represented by <1 % of the total nymphs counted. No nymphs were identified.

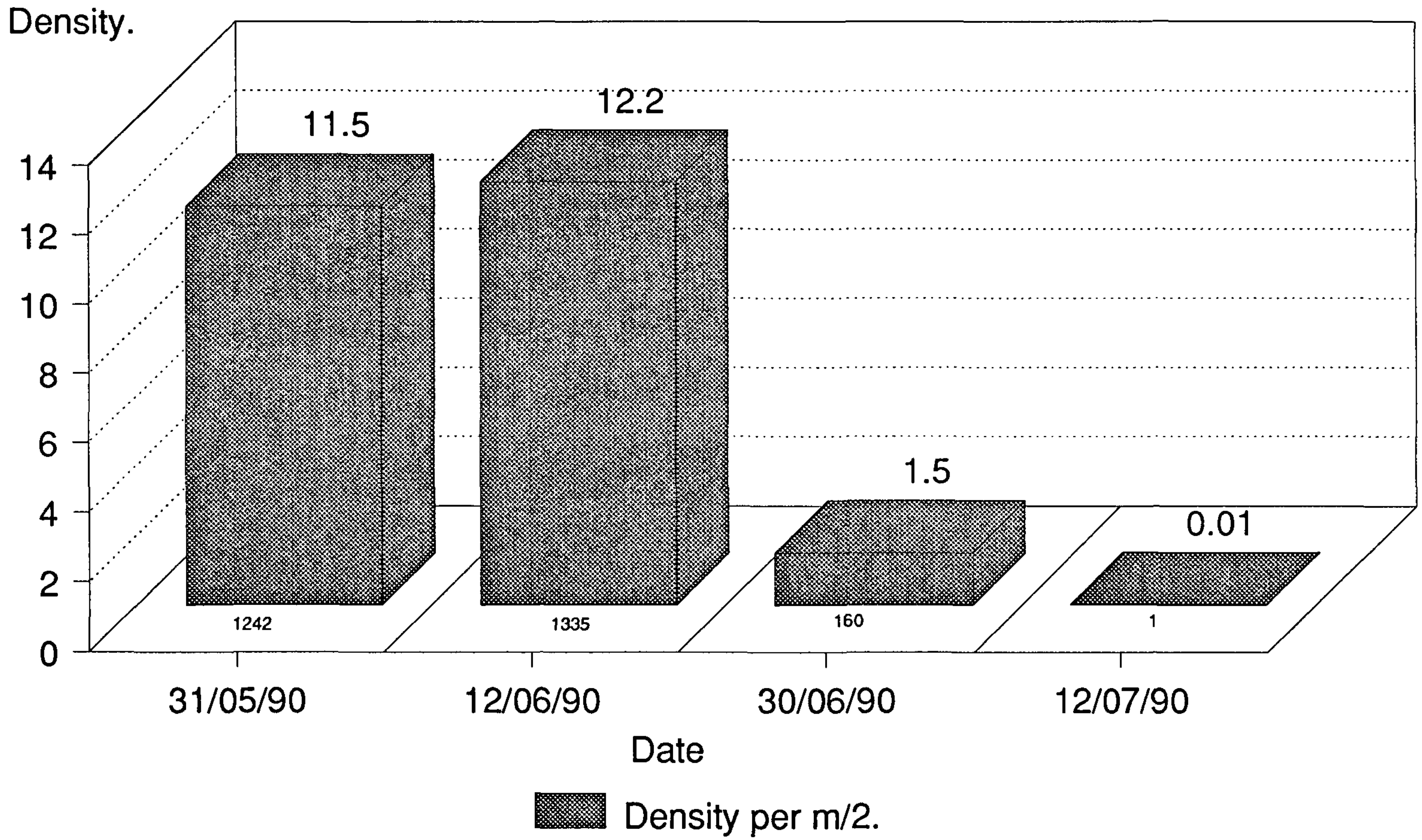
3.7.5. An estimate of Cercopidae nymph densities from spume counts.

An estimate of *Cercopidae* density per m/2 was calculated in Fig.31. No specific imformation was found on *Cercopidae* nymph densities in the literature. The data suggests that *Cercopidae* nymphs reach their highest density in Spring - early summer and decline rapidly to 0 in mid July. The excessive temperatures during the summer of 1990 could have led to a decline in spume formation or its evaporation in temperature in excess of 30 C.

The total transplant area is roughly 48,000 m2 (5,000 turfs of 4.75 x 1.75m plus the surrounding overburden infill of 0.1m width). This would give densities for the entire transplant:-

Figure.31.

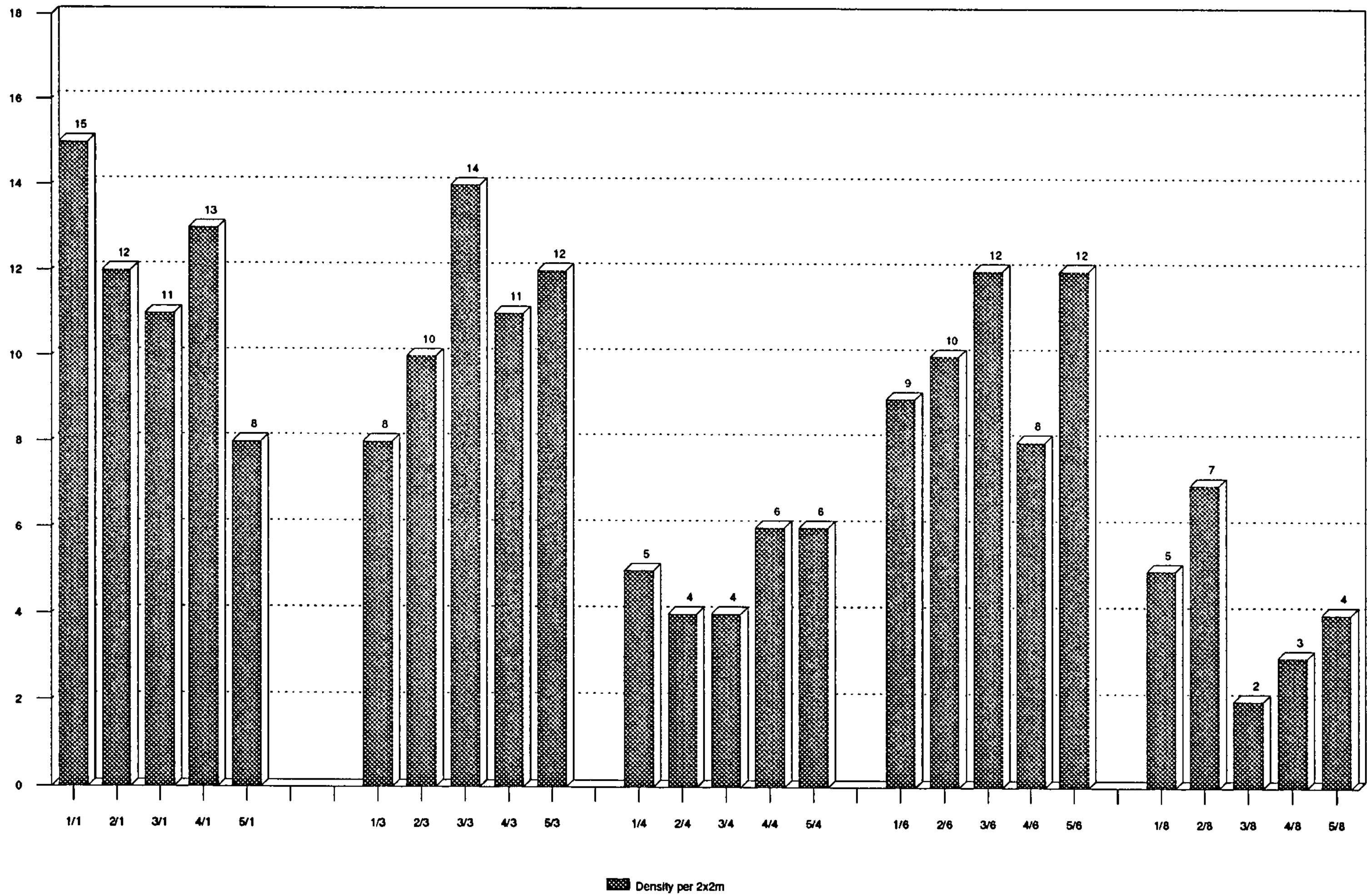
The average density of Cercopidae nymphs (froghoppers) counted in all 2x2m/2 quadrats on all sites.



Number at base of bars indicates total counts per date.

Figure. 32.

Froghopper densities per fixed quadrat.
Sweep net sample on 14/07/90.



- 45B -

31/05/90	542,000 nymphs	25
12/06/90	585,000 nymphs	25
30/06/90	72,000 nymphs	25
12/07/90	480 nymphs	25

(The third column indicates number of quadrats the calculation is based on).

These figures are crude, but show that the *Cercopidae* are important herbivores of the magnesian grassland.

3.7.6. Results of sweep netting for all species of Auchenorhycha nymphs and imagos.

The use of sweep netting for collection of grassland insects is a well established method of collecting, surpassed only by D-Vac in efficiency (Southwood 1976 2nd ed). Sweep netting was employed on the 18/07/90 and 24/07/90 within the 25 fixed quadrats, after pitfall and vegetation surveys had been completed. The results provide a rough estimate of relative abundance as shown in Fig.32. The results are given as numbers per m/2 vary between 15 per m/2 in 1/1 to 3 per m/2 in 5/8. The lowest densities where recorded in site 8 with two quadrats (2/8 and 4/8) yielded no specimens. But see Fig.32.

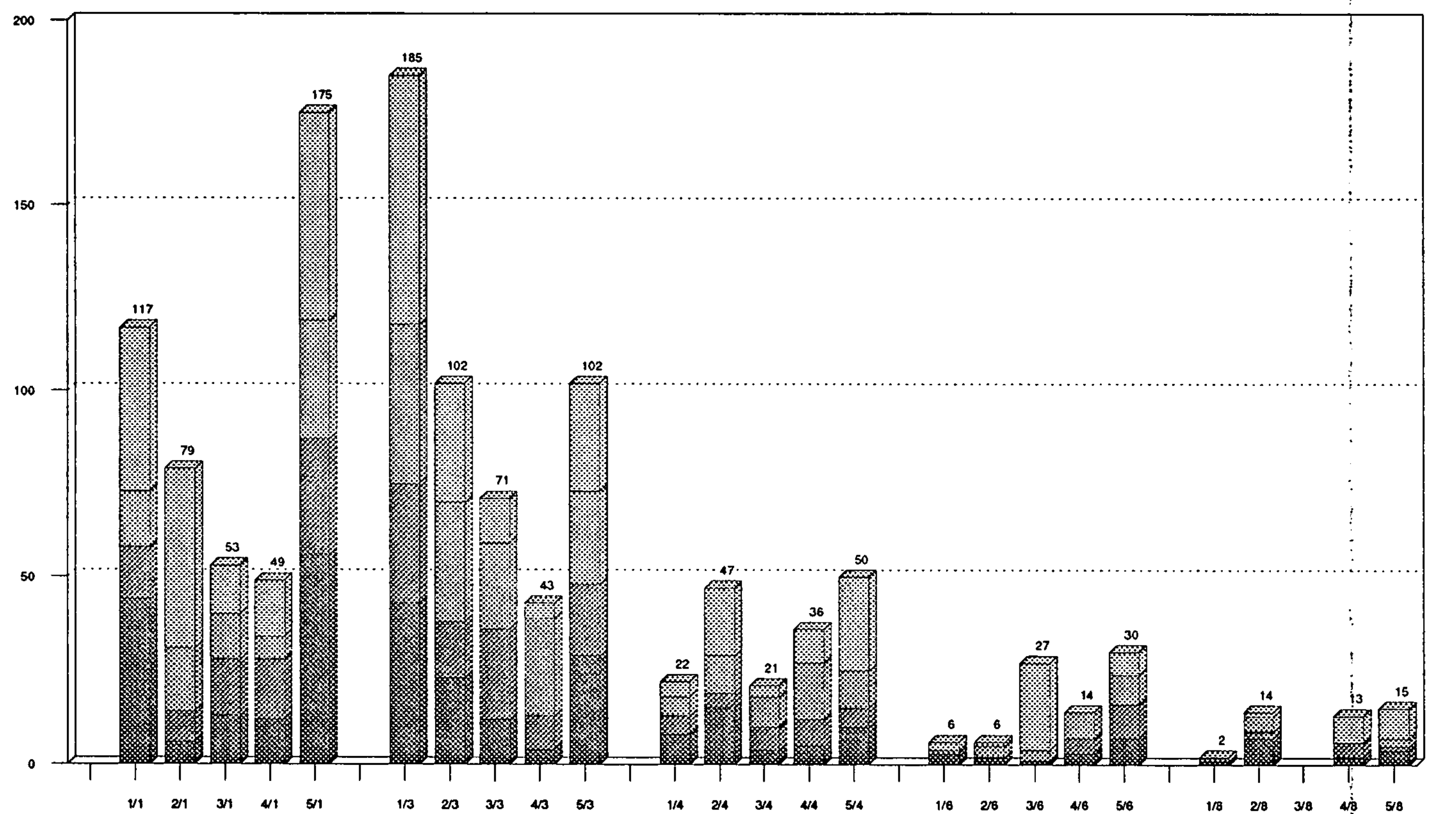
3.7.7. Results of Pitfall catches of *Auchenorhyncha.*

All *Auchenorhyncha* were separated from the pitfalls and the number from each fixed quadrat were recorded on a fortnightly basis (see bar charts A2 & A3). Pitfall traps were used by Morris, (1990a) to study colonisation of a newly sown calcareous grassland in Hertfordshire. He showed that colonisation by a few species of *Auchenorhyncha* slowed after an initial rapid colonisation. Initial colonising species such as *Macrostales laevis* and *M.sexnotatus* then many species require a mature sward to become established before their colonization can occur. Species of grass were considered by Waloff and Soloman (1973) to be a primary factor in leafhopper distribution. Andrzejewska in Waloff and Soloman (1973) showed that different species tended to occupy different levels in the vegetation. Species associated with tall grassland include *Aphrodes flavostriatus*, *Streptanus aemulans* and *Stenocranus minutus* (Whittaker 1969).

On every sampling occasion more nymphs were collected than imagos, see graphs A and A in

C.nemoralis densities per fixed quadrat. from 13/06/90 - 07/07/90.

Figure.33.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4
07/07/90	44	48	13	15	56	67	32	12	4	29	4	18	3
30/06/90	15	17	12	6	32	43	32	23	26	25	5	10	8
19/06/90	14	8	15	16	31	32	15	24	9	19	5	4	6
13/06/90	44	6	13	12	56	43	23	12	4	29	8	15	4

	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
07/07/90	9	25	2	1	23	0	6	0	1	0	7	8
30/06/90	15	10	1	3	3	7	8	1	4	0	0	2
19/06/90	7	5	0	0	0	4	9	0	2	0	4	1
13/06/90	5	10	3	2	1	3	7	1	7	0	2	4

the appendix. The percentage total catches for sites 1-8 are 17%, 23%, 18%, 21% and 21% for imagos and 24%, 17%, 23%, 21% and 15% for nymphs (respectively). The lowest totals for nymphs from pitfalls and counts of *Cecropidae* nymphs occur in site 8. The low numbers of nymphs in both estimates could be due to the colonising *Auchenorhyncha* having a low initial breeding population, affected by the recent disturbance and the lag time before plants colonised. The *Auchenorhycha* population is probably still increasing on site 8 as it was only transplanted during the winter of 1989/90. The imagos have already colonised but have not yet established a large breeding population.

This trend is repeated in the results from sweep netting shown on page which also show low densities of both *Auchenorhyncha* nymphs and imagos on site 8.

Of the remaining sites, 1 and 3 had roughly equal counts for nymphs and imagos. Sites 3 and 6 having lower numbers of individuals. No clear conclusions can be made from pitfall sampling, as it gives only relative abundance or qualitative data on distribution. However the pattern obtained from pitfalls are comparable with other methods especially sweep netting. Temporal changes in abundance are shown in the appendix.

3.8. Mollusc surveys.

3.8.1. Mollusc survey results.

The mollusc survey recorded 8 species- 5 snails and 3 slugs.

For the majority of British land molluscs the predominant food consists of decayed remains of the higher plants, fungi, lichens and algae. Dead leaves are favoured as much for their epiphytic algae and moulds, as their nutrition content, (Boycott 1934). If decaying plant material is abundant then living plant material is rarely taken (Stahl 1888 in Boycott 1934). Some species of mollusc are active carnivores however, especially *Testacella* slug species (Kerney and Cameron, 1979).

3.8.2. Pitfall catches of C.nemoralis.

The percentage of the total 110 caught in pitfalls for site 1 was 48%, site 3 was 19%, site 4 was 23%, site 6 was 9% and site 8 was 1%, shown in Fig.A27.

The general trend is very similar to that recorded for hand searches with a increase in numbers with respect to site age. Since the distribution of *C.nemoralis* is similar in both pitfalls and hand searches and hand searches are more accurate, the distribution from site 1-8 will be discussed in the hand search results below.

3.8.3. Hand searches of *C.nemoralis*.

Molluscs are very susceptible to dessication and hence are most active during wet weather or at night, the hand searches were conducted during such conditions. Four hand searches of 10 minutes duration were carried out per quadrat on 13/06/90, 19/06/90, 30/06/90 and 07/07/90, see Fig.33. This yielded a total of 1279 individuals. With densities ranging from 0-185 per quadrat sites 1 and 3 accounted for 37% and 39% of the total counts respectively, the remaining 24% were divided between site 4 (14%), site 6 (6.5%) and site 8 (3.5%).

Fig.34. shows the relationship between numbers found in pitfalls and found by hand searches and shows that pitfalls produced 16% of the number found by hand searches. Since data from both pitfalls and hand searches are available a regression analysis was carried out, to determine the effectiveness of pitfalls for collecting this species. This gave an r value of 0.21836 which was not significant at the 5% confidence level. Nevertheless pitfalls do produce only 16% of numbers found by hand searching.

Two environmental variables showed a high correlation with *C.nemoralis* distributing. 1/./. Percentage moss cover and 2/ percentage soil carbonate content.

3.8.4. *C.nemoralis* and % moss cover.

Despite the limitations of the hand search method the major trend in *C.nemoralis* distribution appears to be correlated with % moss cover, see Fig.18. Since mosses are seldom eaten by molluscs (Cheetham 1920 in Boycott 1934), it is assumed the % moss cover is predominantly used for shelter. Boycott (1934) defines shelter with respect to molluscs as:- " by shelter I mean such conditions as secure damp air and provide nooks and crannies into which mollusca can retire to escape dessication and cold and lay their eggs". The degree of dampness provided by moss is important as it determines the foraging time available. Damp and sheltered calcareous ground produces greatest numbers of species and individuals (Boycott 1934).

Low numbers were counted on the two dryer sampling occasions i.e. 19/06/90 and 30/06/90. When the conditions are dry molluscs retire to the ground surface (or below it) and where dessication is minimised, this probably explains the low counts on these dates.

3.8.5. Percentage soil carbonate content and *C.nemoralis* distribution.

Sites 1/1 to 1/3 show a high correlation, see Fig.6. and Fig.33. The other 19 quadrats however show no apparent relationship between % carbonate content and number of *C.nemoralis*. The significance of % soil carbonate content and *C.nemoralis* density was tested using a correlation coefficient. No significant result was found, (r=0.39472 at 5% confidence level). When the amount of calcium carbonate in soil reaches the threshold of 0.5% then this seems to mark the level at which earth begins to be "calcareous" from a snail's point of view, (Boycott 1934 p10). They require a threshold level of calcium carbonate simply to produce their shells.

3.8.6. Colonisation by molluscs with reference to *C.nemoralis*.

Boycott (1934) describes many molluscs as being poorly adapted to colonisation due to their slow movement and reliance on moist conditions. This may be a reason for the low numbers of *C.nemoralis* on sites 4-8 as shown in Fig. p . It seems likely that such environmental conditions as quantity of decayed plant material, moss for shelter or other cover needs to be well established before colonisation can be successful.

3.8.7. Other molluscs recorded.

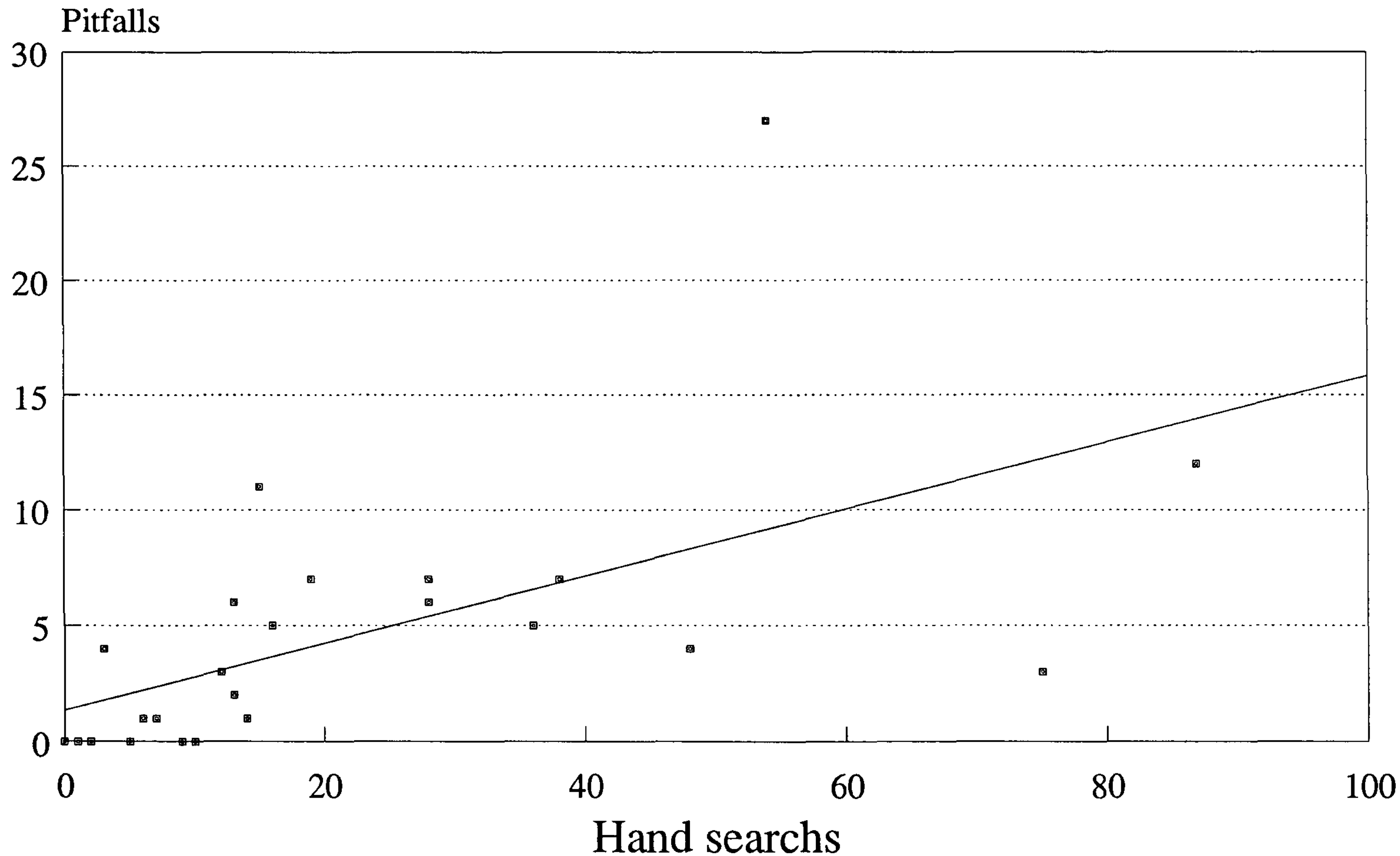
In addition to *C.nemoralis* four other snail species were recorded- *Cepaea hortensis*, *Candidula intersecta*, *Carychium*
tridentatum and Alpine hairy snail *Hygromia* (*Trichia*) *liberta*, all from odd specimens in pitfall traps.

The slugs were only presented by three species - the great black slug, *Arion ater*, *Arion subfuscus* and *Dececerus reticulatum*.

A.ater was recorded in all sites with an average of 0.01 per m/2 i.e. four individuals in the 400m/2 surveyed. The commonest slug was *D.reticulatum* with an average density of 0.0175 m/2. *A.subfuscus* was only represented by one individual.

Figure.34.

Graph showing relationship of number of pitfall counts and hand searchs of Cepaea sp.



Many slug species can burrow to depths of up to 1 metre into the soil to avoid dry weather, (Boycott 1934). The lower than average rainfall of only 63% of the average for the study period combined with the high temperatures, reaching 32.5°C on the 3rd August (Meteorological summary of Durham University Observatory, 1990) may have caused the slug species to burrow thus leading to low population counts.

Little is known of the relative tendency for slugs and snails to be caught by pitfalls.

3.9. Lepidotera survey results.

3.9.1. Lepidotera transect results

Number of species recorded on transects = 10
Additional species from pitfalls = 1
Additional species observed = 2
Total number of species = 13.

The results of the 40 transects (8 replicates of the 5 sites) are given as total species counts per site in Fig.35. In addition to this the total species counts were summed to determine the species abundance over the entire transplant. See Fig.36.

Four of the five sites recorded a total of six species with site three with five species.

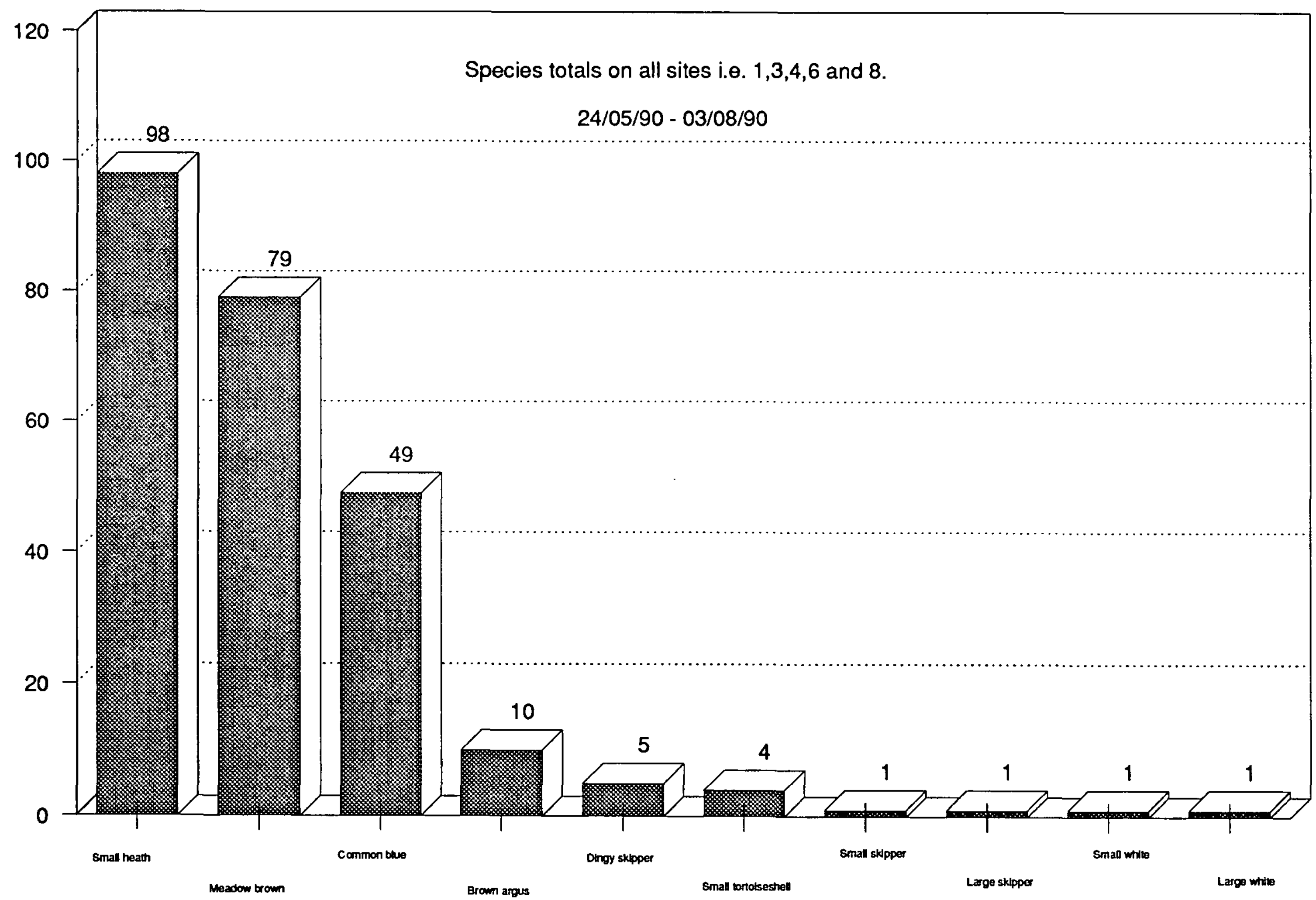
Table.5. Butterfly transect results per site.

Site.	Total counts.	Percentage of total.
Site 1	56	19.7
Site 3	77	27.1
Site 4	59	20.8
Site 6	38	13.4
Site 8	54	19.0

The two commonest species - the small heath (*Coenomympha pamphilus*) and the meadow

Figure.35.

Results of butterfly transects.
Species totals 24/05/90 - 03/08/90.



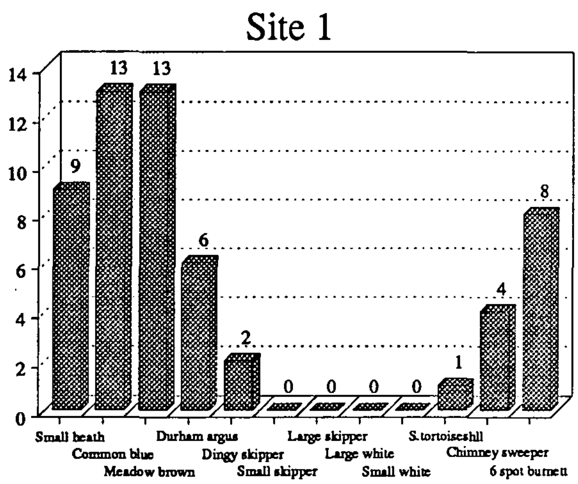
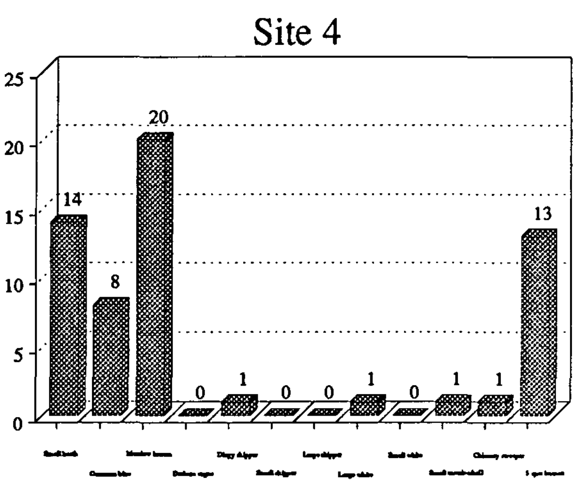
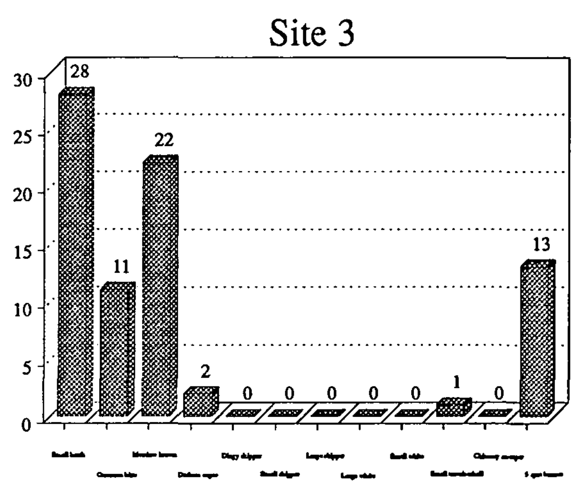
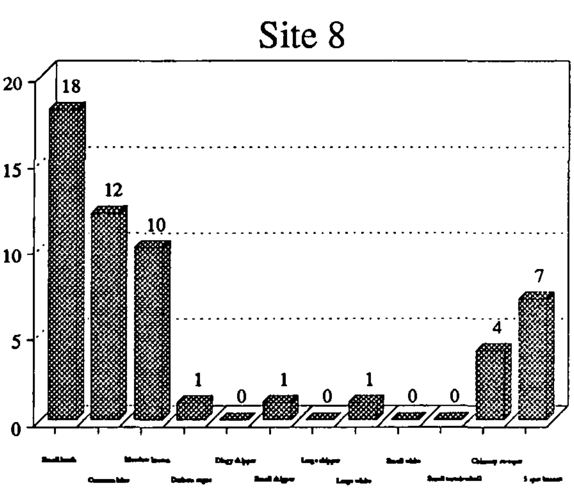
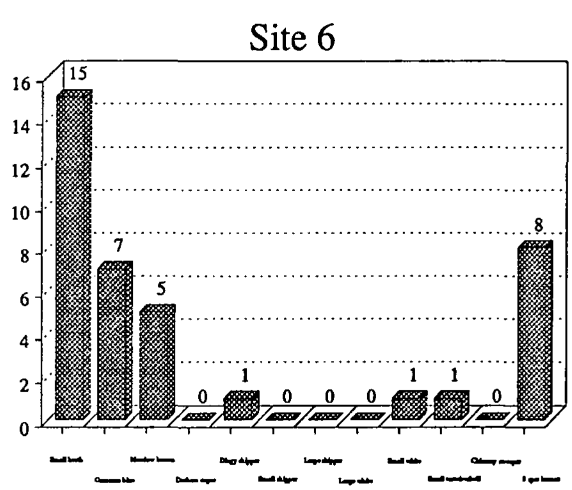


Figure.36.
Butterfly transect
results, total
species counts
per site.
24/05/90 - 03/08/90.









brown (*Maniola jurtina*) (photograph 19) are both members of the Family *Satyridae* or browns and representing 34.5% and 27.8% respectively of the total counts. The caterpillars of both species feed on a variety of grass species including *Festuca ovina* and *Dactylis glomerata*, (Carter and Hargreaves 1986). Both species are common throughout Britain in grasslands and heaths, (Novak, 1980). *C.pamphilus* was the commonest species on sites 3,6 and 8 and *M.jurtina* was co-dominant with the common blue (*Polyommatus icarus*) on site 1. Site 4 being the only site were *M.jurtina* was dominant, with 20 records. Caterpillars of both species occurred in pitfall traps along with two caterpillars of the common blue *P. icarus* the later from site one.

Polyommatus icarus caterpillars feed on *Lotus corniculatus, Trifolium sps.*,etc. which are common throughout the transplant.. *L.corniculatus* has the highest average Domin scale value of 4.5 within all quadrats on site one. Thus it is reasonable to assume that these high Domin values explain the occurrence of *P.icarus* on

site one, representing 17.3% of the total counts. As previously stated *P.icarus* was co-dominant with *M.jurtina* on site 1. This species was common on sites 3 and 8 with 11 and 12 records respectively. Sites 4 and 6 having 8 and 7 records respectively.

Thrislington plantation has the largest inland population of the Durham argus *Aricia artexerxes salmaeis*, (represented by 3.5% of the total counts) in the North of England, (Shephard 1987). The caterpillar of this species feeds exclusively on common rockrose *Helianthemum nummularium*. Again this species is commonest on site one which has the greatest Domin values for *H.nummularium* i.e. 8 (50 to 75%) for 1/1. Again the food plant abundance is the most likely cause of the high records of *A. artexerxes salmaeis* on site 1. Sites 3 and 8 had only 2 records each for this species. Figure.36. shows an apparent absence of this species from sites 4 and 6. However this is misleading as it has been observed on all sites. This indicates caution should be employed when using this technique to describe butterfly populations.

The six spot burnet (*Zygaena filipendulae*) caterpillars feed on *L.corniculatus*, from which caterpillars search for suitable

cover or a tall grass stem prior to the formation of the cocoon (photograph 1). This species is shown emerging in the photograph on the frontispiece of this dissertation. This species attains its maximum abundance on sites 3 and 4, being commonly observed feeding on the flowers of *Centaurea scabiosa* and *C.nigra*. Its larval foodplant is however, commonest on site one but as many species of *Lepidoptera* range widely in search of flowers and *Z.filipendulae* imagos are equally distributed throughout the 3 other sites as seen in Fig.36.

The chimney sweeper (*Odezia atrata*) caterpillars feeds on pignut (*Conopodium denudatum*), Chervil (*Chaerophyllum sylvestre*) and small Umbellifers, Chinery 1986. Equally common on sites 4 and 8 and a single occurrence on site 4.

3.9.3. Additional species recorded on the transplant.

Three additional species were not recorded during transects but observed on during fieldwork. These are the orange tip (*Anthocharis cardamines*), wall brown (*Lasiommata megera*) and small copper (*Lycaena phlaeas*). *L.phlaeas* was common in pitfalls especially on site one (7 individuals), but species was only seen three times on the wing during the twenty week study. It is therefore likely that the 2% formalin used in the pitfalls has a high attrction for this species hence the 7 specimens caught by this method.

3.9.4. General comments on butterflies during 1990.

It has been the best year for butterflies since 1976, especially for *P.icarus*, *E.tages* and *A.cardaminees*, (Oates, 1990). Exceptional early emergences were recorded for *E.tages* and *A.cardamines* which were 2-3 weeks early throughout Britain. High summer species such as *A.artexerxes salmaesis*, may have suffered from excessively hot weather in July, (Oates, 1990).

Chapter.4.

Discussion

4.0. General discussion.

4.1. Validity of sampling techniques.

4.1.1. Vegetation fixed quadrats.

A total of 25 2m square quadrats were used (5 per site giving a area covered of 20 square metres per site and 100 square metres in total) in the vegetation survey. As table.1. in vegetation results section shows these quadrats represented between 70.3% for site 8 to 93% in site 1 of all the on the entire site. The quadrat method of vegetation sampling proved to be very accurate method even with the low sample size i.e. less than 1% of the total sites. This was not entirely unexpected as calcicolous grassland has a high species diversity. Number of species per square metre are the highest for any vegetation in Britain.

Davis et al (1981 p7) gives a figure of number of species per metre squared of 18.9 (typical) and 20.6 (ancient grassland). The figures obtained in this survey were based on 2m square so are not comparable with figures per m2.There is a clear pattern of total species per site increasing from the oldest site 1 - (59) to the youngest - site 8 (81). However there is a distinct pattern of species recorded per quadrat decreasing from an average of 27.4 in site 1 to 20.2 in site 8. Also site 1 has 93% of the species recorded on that site recorded within the quadrats compared to 73% of species recorded in site 8 also recorded within the quadrats, see Table.1. Both these two previous observations suggest that the flora is more homogeneous in the older sites when compared to the younger sites. The older sites have lower numbers of ruderals and a closed sward of predominately calcicolous grassland species when compared to the younger sites. (but presumably more of the 'competitive' species).

The degree to which each site is homogeneous with respect to their plant communities is also shown by the presence of 93% of species within the fixed quadrats on site 1 compared to 73% in site 8. The lower figure for site 8 suggests that it is more heterogeneous. Although clear associations between the age of the site and site diversity and quadrat homogenenity were established it cannot be concluded that age since transplantation is the main factor. This is because the site age from which the transplants were taken was not homogenous and no records exist for the exact species composition of each of five sites studied. Nevertheless the implication is that the process of transplantation allowed ruderal species to become established and this increased site diversity but not with time. The ruderals were outcompeted leading to lower site diversity. At the same time the predominant grassland species became fully established as a homogenious sword leading to increased diversity per quadrat. Species spread randomly on patches of bare earth. Grime (1979, p169) observed that "Close scrutiny of small samples of vegetation often reveals situations in which species of contrasting ecology are growing in intimate association and in which it is difficult to explain their coexistence in terms of spatial heterogeneity in environment. In many of these cases, it is apparent that the species concerned have different seasonal patterns of shoot expansion and flowering and are adapted to different parts of the annual climatic cycle". This was also found in the vegetation CCA e.g. *R.repens* and the axis for % bare earth.

4.1.2. Pitfalls.

Pitfalls have formed the basis of invertebrate collection for this study. Pitfall trapping is widely used for collecting surface active arthropods and is most successful in collecting corsorial species, those that walk or run, (Luff 1975). No other method could economically provide information (both in time and cost wise) on the large numbers of species and individuals required for this project.

Pitfall method has a number of drawbacks: 1/. they tend to trap and so do not reflect the comparative abundance of the more sedentary species and 2/. they do not give the density of individuals in the population. The amount of vegetation cover influences the catch probably by influencing the mobility of certain species. Overall it is possible that pitfalls that were overhung by vegetation caught less individuals than those in open areas. Nevertheless pitfalls have been used extensively for investigating the life history of species including - Carabids (Greenslade 1974) and Auchenorhyncha (Morris 1990a). This may introduce bias when comparing open and vegetated sites.

Uetz and Unzicker (1976) compared quadrat sampling and pitfalls for efficiency in collecting wandering spiders. Pitfalls of curcorial species were found to be comparable to quadrat sampling. My own investigations into the efficiency of pitfalls in catching *C.nemoralis* when compared to pitfall catch produced a figure of 16% for pitfall catches (Fig.34.) compared to hand searches, showing that pitfalls under sample by 84% for this species, a very rough estimate.

In this study it is considered that the catches of invertebrates reflect the relative sizes of populations on different sites.

4.1.3. Hand searches.

Hand searches provide the best method of surveying large invertebrates without killing them or resorting to destructive methods such as removing vegetation for tulgren funnel analysis or sieving, (Kerney and Cameron 1979). Hand searches were successfully employed for *C.nemoralis* and slug species. This seems to be an appropriate technique for producing a quantitive estimate of snail populations over a wide range of sites. The hand search method revealed that *C.nemoralis* achieves a high density on sites with correspondingly high % moss cover. Litter depth was not measured, but this probably has a equal importance to *C.nemoralis* distribution. Since dead leaves and other plant fragments fall onto the grassland floor there is a constant food resource that can be utilised by *C.nemoralis* and other detritovours on or near ground level. Many detritovours only require leaves, generally irrespective of plant species, (Wikkamp and Ausums, in Anderson and Macfadyen, 1976).

4.2. Plant architecture.

4.2.1. General.

The 25 profile diagrams included in the architecture results (Fig's 9-13) illustrate a large amount of information in a concise manner. Profiles are useful for portraying features of grassland structure not easily appreciated by photographs or quantitative data. When Richards (1983) plotted number of trees against height classes, which showed some very obvious strata and this is seen in the profile diagrams for number of touches recorded in the grassland sward, (Figs. 9-13). The architecture profile diagrams for Thrislington show a layered architecture i.e. micro layering with respect to plant species. It may be possible to assign each "plateau" to a species or group of species if a detailed study is conducted of number of touches per plant species. The large plateau or peak in number of touches at 21-25cm is distinctive throughout all the sites and the majority of quadrats. The profiles reveal a dominance of touches within the first 5cm and a second peak at 21-25cm, which may be due to resource partitioning with respect to plants avoiding competition for light.

The classification of quadrats by their architecture, increased in accuracy with age since transplantation i.e. there is an decrease in homogeneity with increased site age, (see section 4.1).

4.2.2. Why should plant architecture be important for invertebrates ?

Vegetation provides "home and table for invertebrates" (Jacobs 1981 in Richards 1983), but they also require shelter and perhaps other less easily defined attributes. The more diverse the plant architecture of a plant community the more numerous are it's niches, (Richards 1983). A niche was defined by Elton (1927 in Krebs 1985) as: "The niche of an animal means it's place in the biotic environment, it's relations to food and enemies".

Thrislington plantation has a mosiac of vegetation types from magnesian grassland and scrub to deciduous woodland, hence a more diverse architecture and richer fauna than magnesian grassland alone. A successional mosiac occurs throughout the 5000 turfs, consisting of a patchwork of ruderal species on the overburden infill and magnesian grassland flora, which increases in homogeneity with age giving a diverse herbaceous architecture.

The architecture determines the avaidable niches for organisms, changing with seasonal growth, so niches appear and disappear throughout the season. Niches are real spaces with real life spans within the grassland community and the majority of the herbaceous flora is ephemeral compared to the moss and litter layer (Richards 1983). Herbivore niches have rapid dynamics, related to leaf phenology, etc. "Freak" niches contain ubiquitous species or remain empty, (Oldeman 1983). An invertebrate requires a feeding niche and also a shelter niche within the same habitat. This may be provided predominantly by the moss and litter layer at Thrislington due to the lack of temporary niches when compared to deciduous woodland i.e. the large herbaceous element at Thrislington. This may explain why the 2nd axis on the invertebrate CCA was % moss cover (eigenvalue of 0.11204 or 11%). The finely branching and close proximity of moss stems produces a large number of available microclimates i.e. niches. Invertebrates can move vertically through the moss through a vertical moisture gradient from the damper lower layers to the dryer upper layers. For example a 2mm spider can find a wide range of microclimates in 5cm of moss. The vertical structure and density of the sward determines the internal microclimate of that sward. Microhabitats are short living niche volumes which are derived from the overall architecture. Magnesian grassland supports a species rich invertebrate community. This suggests that there are a high proportion of specialists with narrow niches. They depend on a particular specialised niche to be sufficiently frequent within the grassland environment or within it's architecture to sustain a viable population. When disturbance occurs, such as transplantation these niches are destroyed or reduced in frequency to such an extent that they can no longer sustain a viable population. Recolonisation can only occur when these niches are created. This may explain the loss of the 66 species reported after transplantation (Sheppard 1985 and 1989). At least 8 species have successfully colonised post-transplant including, *A.virens*, *O.setiger* and *E.ovata*. Other species may be "pseudo-extinctions" (Strong 1979 p110) i.e. thought to be extinct due to lack of collection post transplant. Many more species may in time colonise as their specialised niches are created as a product of architecture or stability of the grassland environment. Successful recolonisation depends on there being a "source pool" of particular species close enough to recolonise this niches, (Strong, 1979).

4.2.3 Importance of vegetation size and surface area to invertebrates, as function of plant architecture.

4.2.3.1 Vegetation size.

A direct relationship between the size of a plant and the number of invertebrates occurs throughout all vegetation types, (Lawton 1973, Southwood *et al* 1979, etc). The species richness of herbivorous insects declines thus: woody shrubs > perennial grasses > weed and other annuals > monocots (excluding grasses, for which many records are unreliable), (Lawton 1986). On average North European trees support a 1.5-3.0 times richer insect fauna (herbivores) than shrubs, and shrubs 1.5 - 3.0 greater than perennial herbs (Lawton 1983).

This is explained purely as a function of a trees height and surface area, tall vegetation is more likely to be found and colonised by insects than a low growing vegetation in both ecological time and evolutionary time (Lawton 1986). A tree has a constant position in the landscape for hundreds of years, whereas a herbaceous plant may only be present in any one locality, for one or two seasons before successional pressures via competition remove it from that habitat).

The larger a plant the greater the number of feeding, overwintering and sheltering places/niches avaidable. These manifest themselves in terms of a greater variety of microclimates, such as under bark, shade, temperature within trees when compared to architecturally simple grasses (Lawton 1986). It may be simply that a large plant has a wider range of niches so can be colonised by a wider range of species than a smaller plant.

Fowler (1985) investigated the importance of plant size i.e. birch - *B.pendula* seedlings, saplings and trees to invertebrate diversity. Of the 112 species of herbivores recorded only one aphid (*Kallistaphis betulicola*) was confined to seedlings. He found that no insects were confined to any one height. The most likely explanation for the diversity of *B.pendula* (second only to oak - *Quercus* sp in number of species) is it's wide geographical distribution and the number of overwintering sites and hiding places on buds, bark, etc rather than vertical structure. The importance of hiding places was investigated by Gardener and Dixon (1985) who studied the aphid- *Aphidius rhopulosiphi* and concluded that aphids that shelter between the ears of wheat had a lower rate of parasitism i.e. ichneumonid wasps, etc as they were sheltered between the grains.

4.2.3.2. Surface area and niche.

The height of a plant may be of only secondary importance when compared to plant surface area. This is not easy to define, however. How much surface area is there ?. Mandelbrot (1967) introduced the idea of fractals by posing the question how long is the coastline of Britain. If a long ruler is used which is too long to fit into the bays you get one answer but if a 1mm ruler is used then every boulder can be measured and the coast becomes immensely long. The same approach can be applied to plant surfaces. With increasingly finer resolution more and more niches become apparent.

Many workers (Erwin 1983, May 1973, etc) have investigated why there are many more small species than large ones. This may be due to the greater number of small niches available (as a function of plant architecture, etc), too small species. Small invertebrates require proportionally less resources than big invertebrates so are able to utilise narrower niches. There should be more small species than larger to utilise the greater number of small niches within plant architecture, etc.

Small species tend to have higher population dynamics and hence higher populations than large species (Peters 1983 in Lawton 1983) and can utilise the larger number of small niches. There are many more niches at the ground surface than within the higher grassland habitat. This may explain the multitude of species at this level. Erwin (1983) in the rainforests of the mixed water inundation forest of Manaus, Brazil used chemical fogging to collect canopy invertebrates. He collected a total of 1078 species of Coloeoptera, of which 97% were less than 8mm in length. This seems to support the general theory that small animals are more numerous than large ones because of the greater abundance of small niches. Plant architecture supplies some but not all theses small niches.

It is relevant to mention something about plant geographical range and it's importance to invertebrate faunas. Basically the greater the geographical range of a plant the greater it's invertebrate fauna compared to plants with a restricted range, (Strong, 1979).

4.3. Vegetation survey.

The first axis of the vegetation CCA was % bare earth (eigenvalue of 0.14057 or 14%) which is a direct result of disturbance, a function of time since transplantation. This main influence on vegetation, the amount of disturbance or % bare earth is to be expected in a nature reserve that has been physically moved 800 metres. Thrislington shows retrogressive succession were a succession is diverted (by disturbance, an arresting factor) and then continues towards it's original succession.

Table.1. in the vegetation survey results shows that site 6 and site 8 have the most diverse flora with 84 and 81 species respectively (species totals per site, see Table.1.). The relationship of plant and insect diversities in succession was investigated by Southwood et al (1979) and they recorded a peak diversity for plant and insect species after 16 months since disturbance. After 16 months both the floral and insect diversity declined, the flora more so than the insects. They concluded that the increasingly diverse plant architecture compensated for the reduction in floral diversity, thus maintaining a high insect diversity. Grime (1979, p155) observed that in highly productive environments there is often a rapid turnover of populations and species during initial colonisation and vegetation development.

The same conclusions can be drawn from this study as site 6 has the highest floral diversity (84 species) and was transplanted in the winter of 1987/88. It is probable that the unsampled site 7 would have the highest floral diversity if Southwood (*et al* 1979) observations hold true. The number of species then declined (Table.1.) with increasing site age to 59 species in site 1, a 30% decline in species in just 5 years.

Site 6 represented 60% of the total flora of the whole transplant compared to 49% in site 1. As Richlers (1973 in Southwood et al 1979) observed - "Many structural and functional attributes of the community change during it's successional development" and this seems to be of importance with respect to invertebrates, to be discussed later. Since the complexity of community organization along a successional gradient has never been monitored, the likely outcome of the transplantation cannot be fully predicted (Southwood et al 1979). It is clear however that even in the oldest sites there still remains a persistent ruderal and late successional species element evident by the presence of such species as *T.officinalis* and *T.farfara*.

4.4. Weevils.

The Currculionidae represented 12.5% (362 individuals) of the Coleoptera and 2.19% of the total invertebrates collected in pitfalls. The first axis of the weevil CCA (Fig.22.) was one of pitfall position (eigenvalue of 0.257 or 26%) and the 2nd axis was one of % moss cover (eigenvalue of 0.235 or 24%). The Currculionidae are important grassland herbivores often associated with specific plant families e.g. *C.quadridens* with Crucifers, *A.apricons* on legumes and *C.troglodytes* on Plantago species.

4.5. The Cercopidae.

The Cercopidae utilise a wide variety of host plant species (39% of the total species on the transplant and 54% of the total species occurring within the quadrats) as revealed by the counts of spume or cuckoo spit within the quadrats. No conclusions can be made about particular species as none were identified. The majority of plants (30 species) were represented by counts of 1% or less (see Fig.28.).

The results of the Cercopidae survey show that their nymphs are likely to be important grassland herbivores as are all Auchennorchyncha (Morris, 1971 - ongoing, Stinton and Brown, 1983 and Walloff and Soloman, 1973.

The family Cercopidae is successful by utilising a wide range of plant species at Thrislington. The abundance of a plant maybe the limiting factor in herbivore distribution especially of monophagous species or species restricted to one host family. The number of froghopper counts (on the 44 host plant species recorded within the 25 quadrats) and the average domin value of the 44 host plants were used to perform a correlation coefficient analysis. No correlation was found, (r=0.00104 at the 5% confidence limit), showing that the abundance of host plants does not directly determine the abundance of Cercopidae. This lack of correlation indicates a deggree of selectivity by the Cercopidae. Two possible reasons for the selectiveness maybe due to plant defence chemicals within the leaves or competition from other herbivores.

4.6. Araneae and plant architecture.

The total of thirteen species of spider and the group containing all unidentified individuals, showed that 9 species were positively associated within a height axis in the spider CCA (Fig.24.) i.e. 5-10cm, >40cm, 0-2cm, 2-5cm, 10-20cm and 20-40cm (given in order of importance). The highest association representing axis 1 was average moss depth (eigenvalue of 0.04% or 4%) with the second axis representing the height i.e. 2-5cm (eigenvalue of 0.02 or 2%) from the origin to the bottom of the biplot and >40cm from the origin to the top of the biplot.

The majority of the spiders identified were hunting spiders, which do not rely on webs (exception being Clubiona sp and *Enoplognatha ovata*) or burrows (exception being *Trochosa ruricola*). The wandering habit would suggest these spiders require alternative shelter other than webs or tunnels. The association with moss on both the DCA and CCA analyses seems to support the importance of moss for shelter and/or foraging for these wandering spiders. The importance of shelter within sitka spruce needles was demonstrated by Gunnerson (1990). Who found increased predation occurring with a decrease in shelter.

As pitfalling was the main sampling method then the presence of so many wandering hunting spiders is not unexpected. A correlation coefficent was carried out to test the significance between the number of plant species per quadrat and number of spiders per quadrat. A positive correlation was found both at the 1% and 5% significance levels (r=0.6717), showing a significant relationship between spider diversity and plant species diversity. This rather unexpected result may be simply explained by postulating that with increasing plant species diversity there is an increased diversity of plant architecture and niches which can support a diverse spider fauna. Alternatively it may be the diverse flora supports a generally diverse fauna which increase the number of prey species for spiders. A significant correlation between number of beetle species and plant species has been found by Buce (1988), even though only 15% were herbivores.

Lawton (1983) found a correlation with vegetation size and invertebrate diversity throughout all vegetation types, since the younger sites contain a greater scrub element which provides the necessary diversity of plant architecture to support the diverse spider fauna on the younger sites.

The total of spiders collected in pitfalls per site was 20.7% for site 1, 22.7% for site 3, 20.7% for site 4, 19.1% for site 6 and 16.8% for site 8. No clear conclusions can be made from these figures with regards to colonisation, but it seems that stable sites i.e. older sites contain slightly more individuals of spiders than the younger more disturbed sites. (This maybe due to plant diversity as described previously. Southwood *et al* (1979 p33) observed that - "Although the smaller numbers of individuals in the season early in the season may give a high diversity with respect to species"). The biplot arrow (spider CCA) for site age lies directly on the first axis, although shorter than the arrow for average moss depth, indicating that site age or some factor associated with this may influence the spider fauna.

As the spider CCA showed, this group utilise the entire grassland habitat from ground level to >40cm. Spiders use widely different niches ranging from the predominantly ground species Pardosa sp, to Clubiona terrestris which uses the whole vegetation structure from ground to >40cm. The two Thomissidiae sp (crab spiders) O.trux and X.cristatus were identified as male and female. These two species, especially O.trux showed what seemed to be niche separation between the sexes and the species. The male O.trux associated with the 0-2cm and 5-10cm axes and the female associated with the 20-40cm axis in the Spider CCA. *O.trux* species as with many other species of spider exhibits sexual dimorphism. This may be an adaptation to avoid competition, as size differences may allow utilisation of different prey items by the sexes (Bristowe 1941).

The Araneae represented 26.1% of the number of individuals collected in pitfalls (Acari less than 2mm in length and all Collembola species except Orchella sp were not counted however). This is probably due to their large numbers and the wandering habit of many species which increases the tendency to be caught in pitfalls. Araneae by there utilisation of the entire grassland habitat are a very successful Order represented by a large number of species and individuals at Thrislington. There seems to be no shortage of prey items, with woodlice, ants and collembola very abundant, one pitfall containing 361 Collembola.

4.7. Carabidae.

The Carabid CCA (Fig.26.) was less clear cut in it's positioning species with known habitats than the Araneae CCA (Fig.24.). The high association with the height class >40cm for *N.biguttatus* and *N.germanyi* cannot be explained by the life histories described in the literature. It is possible that since these two species are found predominantly on sites 6 and 8 and the grass, *Festuca arundinacea* is abundant on these sites (60-200cm in height, Clapham, et al 1962) they maybe sheltering within the dense tussock these species produce.

Butterfield and Coulson (1983) and Luff (1975) have suggested that plant architecture is more important for Carabids which are almost entirely carnivorous than plant species. The relationship between the number of plant species and number of carabid species per quadrat was tested using a correlation coefficient. No correlation was found (r=0.15063 at the 5% confidence level). Certain omnivorous species of carabids probably show a greater relationship with plant species including both Harpalus and Amara species.

The average number of carabid species per site was 3.8 for site 1; 4.6 for site 3; 6.2 for site 4; 7.2 for site 6 and 6.2 for site 8 (also see appendix for bar chart of number of Carabids per quadrat), showing that carabid diversity is greatest in the younger sites. An explanation for this may be the amount of bare earth on the younger sites, allowing easy hunting for these active predatory beetles. The combination of open ground and plentiful refuges i.e. moss, grass tussocks on the younger sites seems to favour a diverse carabid fauna. An association between carabids and bare earth (at Bishop middleham, magnesian limestone quarry) has also been found by Mathieson (1985 p39) - "There is a general trend of a drop in diversity with increase in density of vegetation. One can therefore conclude that the important feature as far as hunting carabids is concerned is the amount of bare earth".

The seventeen carabid species at Thrislington and the 21 species at Middleham quarry (Mathieson 1986 and Woodford and Bruce 1983, also see table of carabid records for limestone sites in County Durham in the appendix) show the diversity of limestone grasslands/quarrys for carabids. Other magnesian grasslands (Hawthorn Dene) and quarries (Raisby, Trimdon) in County Durham are likely to harbour similiar numbers of species. As yet they have not been fully surveyed for the carabid and the majority of their invertebrate fauna (see list of Carabids in the appendix). The Durham County invertebrate survey (Woodford and Bruce, 1983) has helped bridge some of the gaps in our knowledge, however.

4.8. Butterfly transect.

The butterfly population at Thrislington is dominated by three species - *C.pamphilus* (small heath), *M.jurtina* (meadow brown) and *P.icarus* (common blue). These three species represented 79% of the butterflies counted (see Fig.35.).

The early spring species such as *E.tages* (dingy skipper) did well during 1990 due to the warm weather but the midsummer species such as *A.artexerxes salmaeis* were adversley affected by the very dry conditions. In general however it was a very good year for butterflies, only surpassed by 1976 (Oates 1990).

Butterfly populations at Thrislington should remain high and are likely to increase as the magnesian grassland flora recolonises the overburden infill and increases foodplants and flower availability and the site becomes increasingly stable with regards to plant species (see vegetation quadrat sampling disscussion). The Durham Argus butterfly should increase as it's foodplant, rockrose, achieves it's greatest abundance on the older sites i.e. site 1 with average domin value of 7.8. If this figure becomes an average for the whole transplant rather than site 1, when all the sites have "stabilised", then this should premote a large increase in this species, probably by the mid 1990's.

Plant architecture is probably of limited importance to butterflies in general. Their larvae are often dependent on a limited range of foodplants and butterflies, adults require plant species with high necter sources, while shelter is found within any vegetation, (Ford 1975 2nd ed).

4.8.1. The CANOCO programme.

Any DCA or CCA that is run on the CANOCO programme is reliant on the initial data set accurately reflecting the environmental conditions present in the study site. It is also impossible to know whether the environmental variables recorded were those that have the greatest influence on the species being studied or weither other important variables not recorded, (such as wind speed for butterflies) also affect the results obtained and conclusions drawn from the DCA and CCA analyses. Caution must always be used therefore when analysing any CANOCO programme for this reason. Table 4. gives the eigenvalues obtained for the first 4 axes in the 5 CCA's.

4.9. Summary of discussion.

This study shows two major factors that are important for invertebrates at Thrislington - site age and shelter in the form of % moss cover. As pitfall trapping was the main method used for collecting invertebrates the diverse ground living species and the high association with the lower vegetation classes and bare earth was to be expected.

The vegetation CCA analysis revealed that site age and % carbonate explained the the greatest variation within the plant species (eigenvalues of 0.14053 and 0.11204 respectively). It seems likely that transplantation has altered the origional mosaic of the magnesian grassland species, with an increase in the ruderal element and competitive species.

The uniqeness of Thrislington both in terms of it's diverse flora and fauna and it's transplantation 800m to a new site make it an important site for research. It's associations of rare flora and fauna made this site important in it's own right but it's subsequent transplantation also allows the affects of disturbance, extinction, colonisation and recolonisation to be investigated. It is hoped that this study has contributed in some way to this greater understanding. Ongoing research by Sheppard and Parks should yield more imformation in the coming years.

Appendix contents.

Pitfall catches.

A1 Acari (2mm+).
A2 Auchenorhyncha imagos.
A3 Auchenorhyncha nymphs
Araneae.
A4 Araneae - totals number of individuals per quadrat.
A5 Araneae - total number of species per quadrat.
A7 *Alopecosa cuneata.*
A8 *Clubionia terrestris.*
A9 *Evensia merens.*
A10 *Oxypilla trux* (female).
A11 *Oxypilla trux* (male).
A12 *Pachygantha degreeri.*
A13 *Trochosa ruricola.*
A14 *Xysticus cristatus* (female).
A15 *Xysticus cristatus* (male).
Carabidae - (Coleoptera).
A16 Carabidae - number of individuals per quadrat.
A17 Carabidae - number of species per fixed quadrat.
A18 *Amara aulica.*
A19 *Amara convexior.*
A20 *Bembidion lampros.*
A21 *Carabus violaceus.*
A22 *Harpalus rufipes.*
A23 *Notiophilous biguttatus and Notiophilous germanyi.*
A24 *Pterostichus madidus.*
A25 *Pterostichus melanarius.*
A26 *Trechus quadristatus.*
Mollusca.
A27 *Capaea nemoralis.*
General invertebrates.
A28 *Crepidodera ferrugina.*
A29 *Crepidodera transversa.*
A30 Diptera.
A31 Elatridae.
A32 Formicidae.
A33 *Lampyris noctiluca.*
A34 *Lithobis forficatus.*
A35 *Nemastoma bimaculatum.*
A36 Opiliona spp (imagos).
A37 Opiliona spp (juvieniles).
A38 Orchellia spp.
A39 Parasitic wasps.
A40 *Philoscia muscorum.*
A41 *Phyllobius angustum.*
A42 *Phyllotreta undulata.*
A43 Staphilinidae - number of individuals per site.
A44 Staphilinidae <5mm.
A45 Staphilinidae 5-10mm.
A46 Staphilinidae >10mm.
A47 *Tachypodoilus niger.*
Curculioidae (weevils).
A48 Curculionidae - number of individuals per quadrat.
A49 Curculionidae - number of species per quadrat.
A50 *Apion apricons* and *Apion virens.*
A51 *Barynotes elevatus.*
A52 *Barynotus obscurus.*
A53 *Barynotus squamous.*

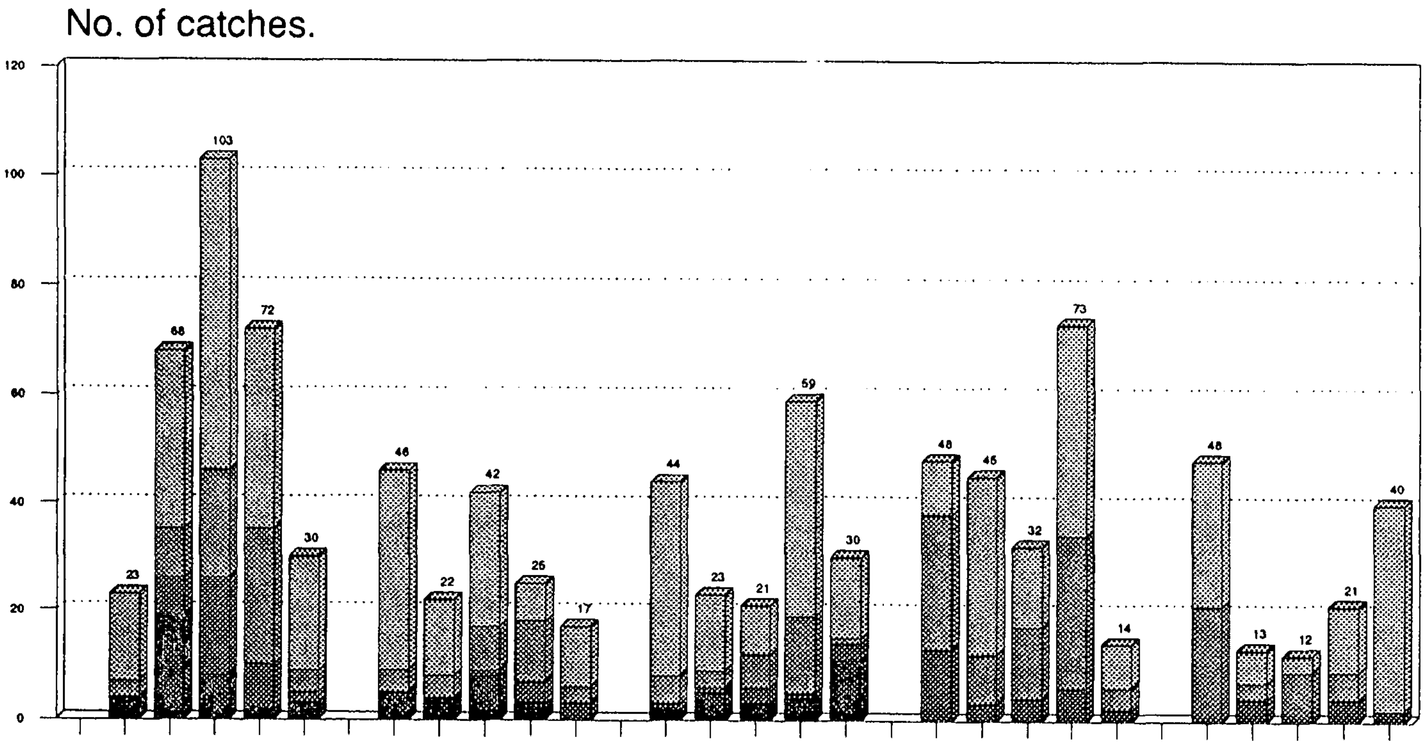
A54 *Ceuthorrhychidius troglodytes.*
A55 *Orthocheates setiger.*
Mammals.
A56 *Sorex minutous.*

Vegetation species lists (on a site basis).

A57 Part 1 species recorded within the quadrats.
A58 Part 1 species recorded within the quadrats.
A59 Part 1 species recorded within the quadrats.
A60 Part 1 species recorded within the quadrats.
A61 Part 2 species recorded outside the quadrats.
A62 Bibliography.
A63 Bibliography.
A64 Bibliography.
A65 Bibliography.
A66 Bibliography.
A67 Bibliography.
A68 Domin values obtained in the vegetation survey on 17/07/90 within the 25 fixed quadrats.
A69 Domin values obtained in the vegetation survey on 17/07/90 within the 25 fixed quadrats.
A70 Page 1 of Sheppard (1989) invertebrate survey.
A71 Page 2 of Sheppard (1989) invertebrate survey.
A72 Invertebrate species list.
A73 Invertebrate species list.
A74 Invertebrate species list.
A75 Invertebrate species list.
A76 Invertebrate species list.
A77 Invertebrate species list.
A78 Carabidae distribution in quarries, etc within Co.Durham.

Pitfall catches of Acari (red).

Number per quadrat from 22/05-18/07/90.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	16	33	57	37	21	37	14	25	7	11	36	14	9	40	15	10	33	15	39	8	27	6	3	12	38
05/07/90	3	9	20	25	4	4	4	8	11	3	5	3	6	14	1	25	9	13	28	4	21	3	9	5	0
21/06/90	0	7	18	8	2	0	0	1	4	3	1	1	3	1	3	13	3	4	6	2	0	4	0	4	2
06/06/90	4	19	8	2	3	5	4	8	3	0	2	5	3	4	11	0	0	0	0	0	0	0	0	0	0

Table of catches per quadrat over time.

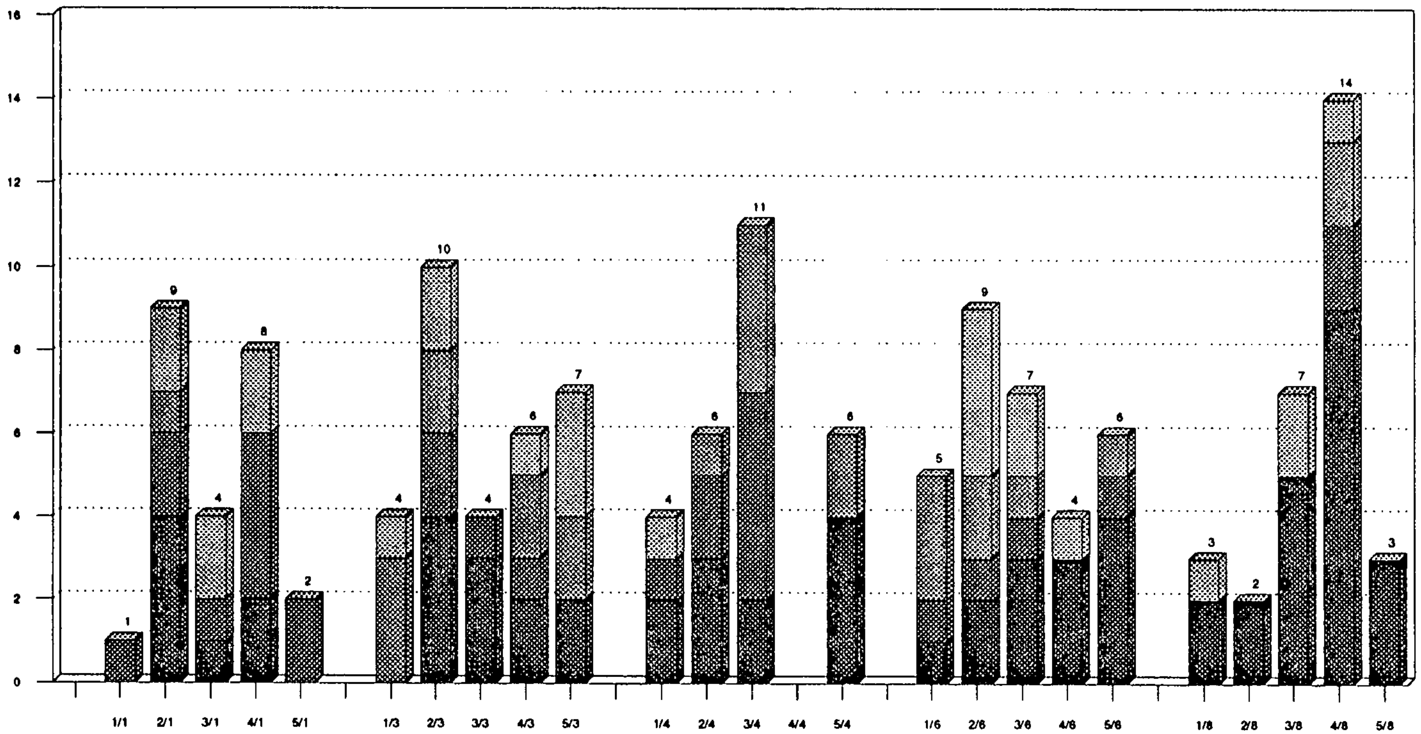
06/06/90 21/06/90 05/07/90 18/07/90

- A1 -

Pitfall catches of Auchenorhyncha imagos

Number per quadrat from 22/05-18/07/90.

No. of catches.



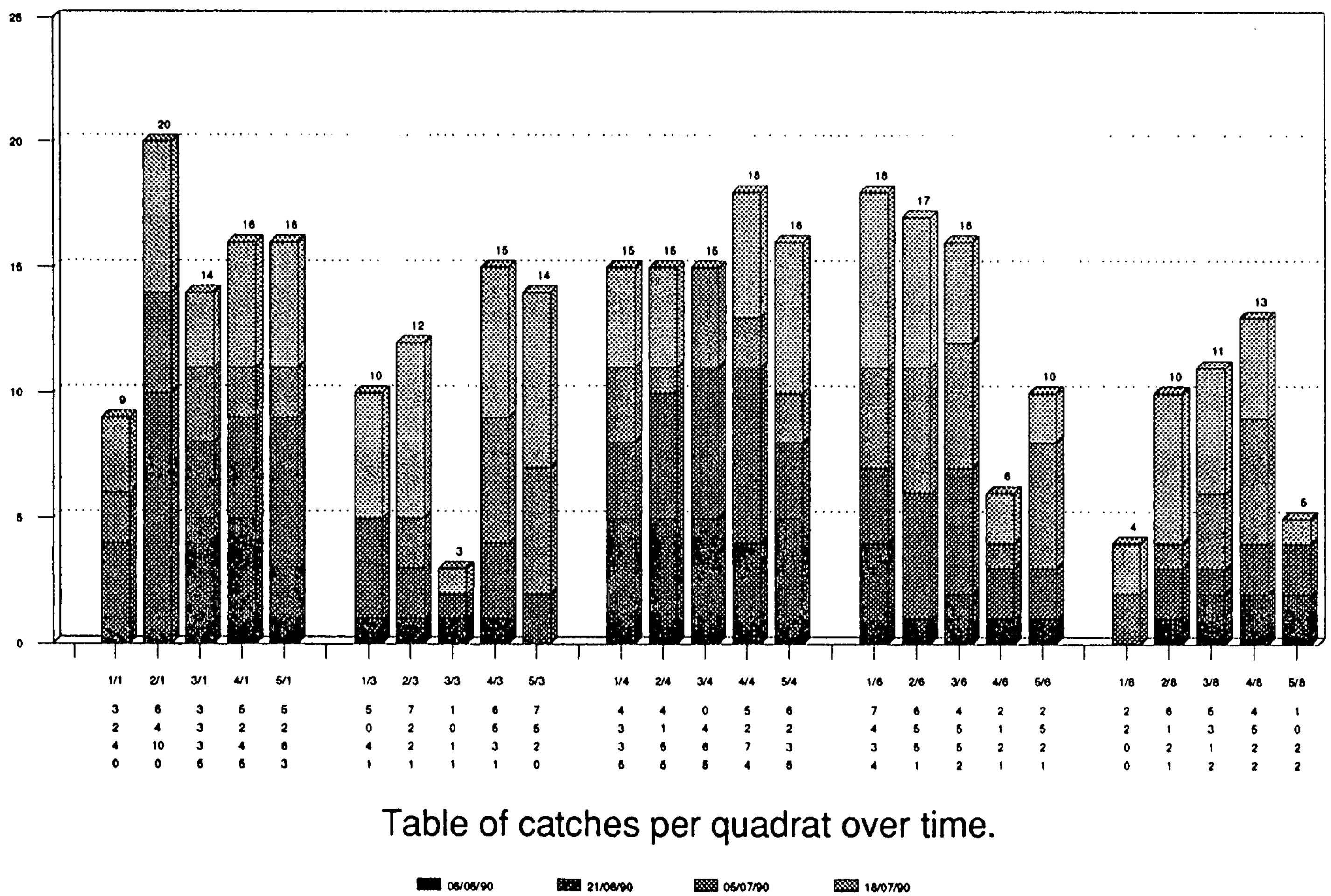
	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	0	2	2	2	0	1	2	0	1	3	1	0	0	0	0	0	4	2	1	0	1	0	2	1	0
05/07/90	0	1	0	0	0	3	2	0	2	2	0	1	4	0	2	3	2	1	0	1	0	0	0	2	0
21/06/90	1	2	1	4	2	0	2	1	1	0	1	2	5	0	0	1	1	1	0	1	0	0	0	2	0
06/06/90	0	4	1	2	0	0	4	3	2	2	2	3	2	0	4	1	2	3	3	4	2	2	5	9	3

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of Auchenorhyncha nymphs

Number per quadrat from 22/05-18/07/90.

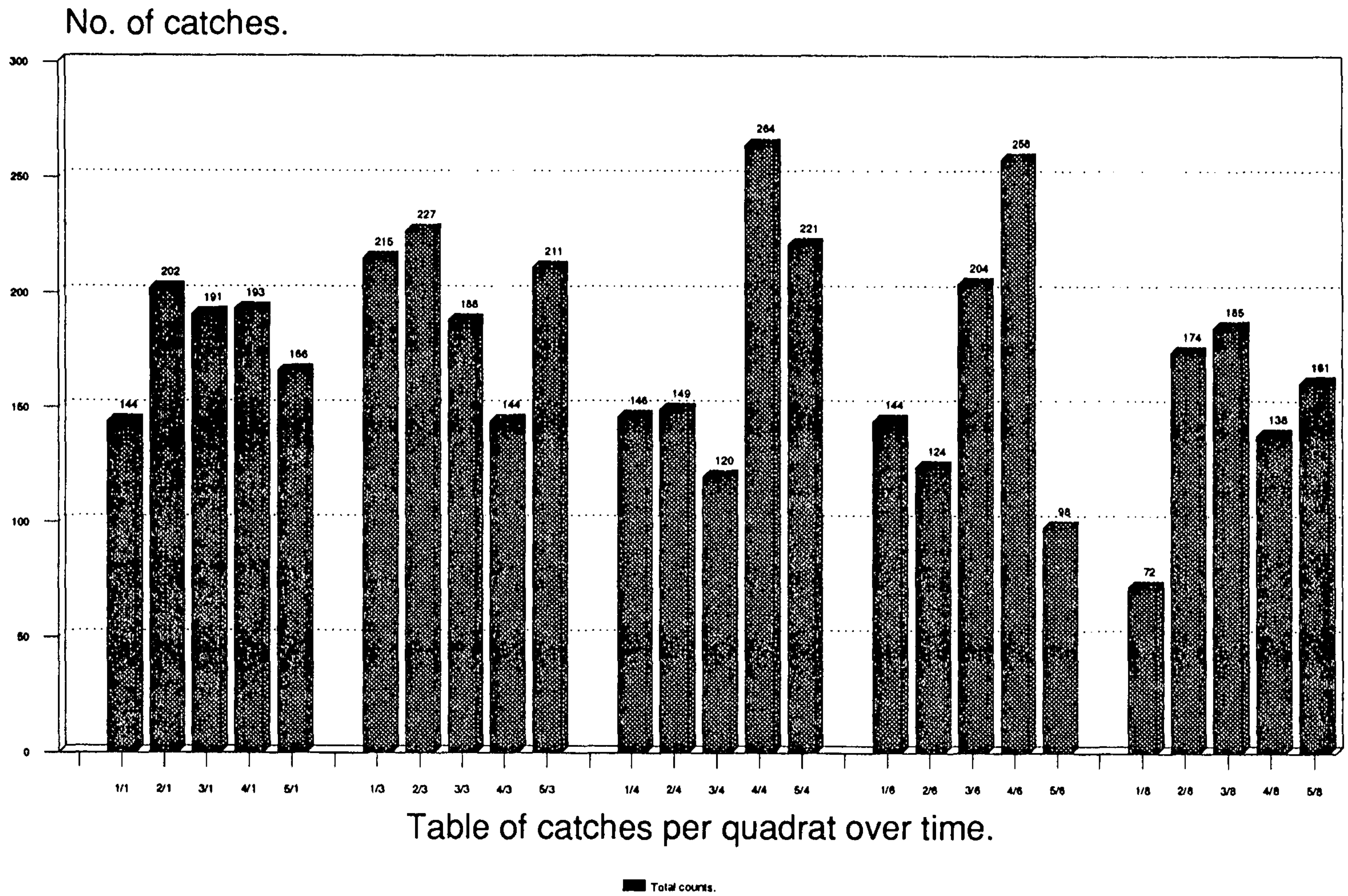


	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	3	6	3	5	5	5	7	1	6	7	4	4	0	5	6	7	6	4	2	2	2	6	5	4	1
05/07/90	2	4	3	2	2	0	2	0	5	5	3	1	4	2	2	4	5	5	1	5	2	1	3	5	0
21/06/90	4	10	3	4	6	4	2	1	3	2	3	5	6	7	3	3	5	5	2	2	0	2	1	2	2
08/06/90	0	0	5	5	3	1	1	1	1	0	5	5	5	4	5	4	1	2	1	1	0	1	2	2	2

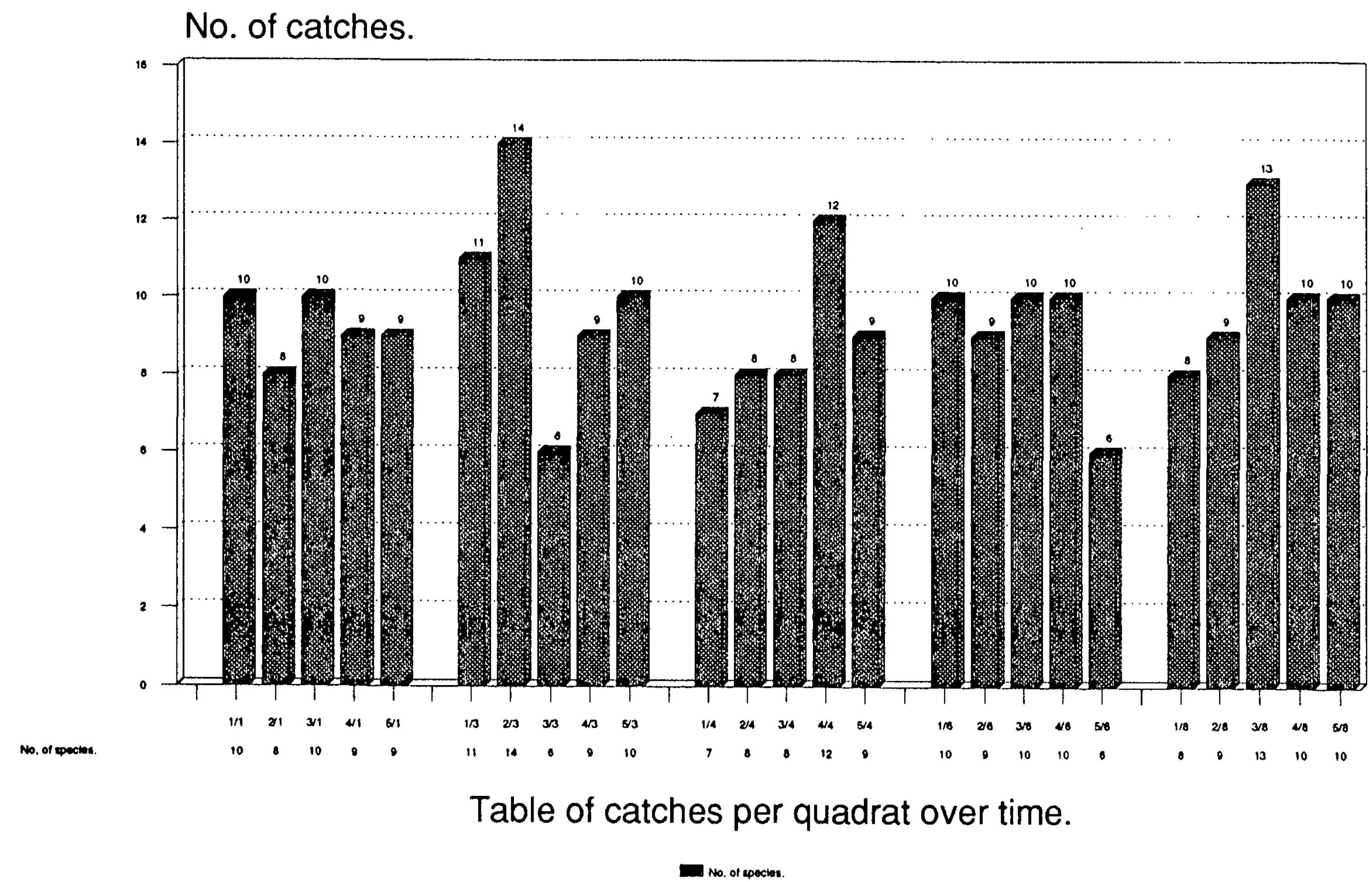
Table of catches per quadrat over time.

Number of Araneae per quadrat.

Number per quadrat from 22/05-18/07/90.

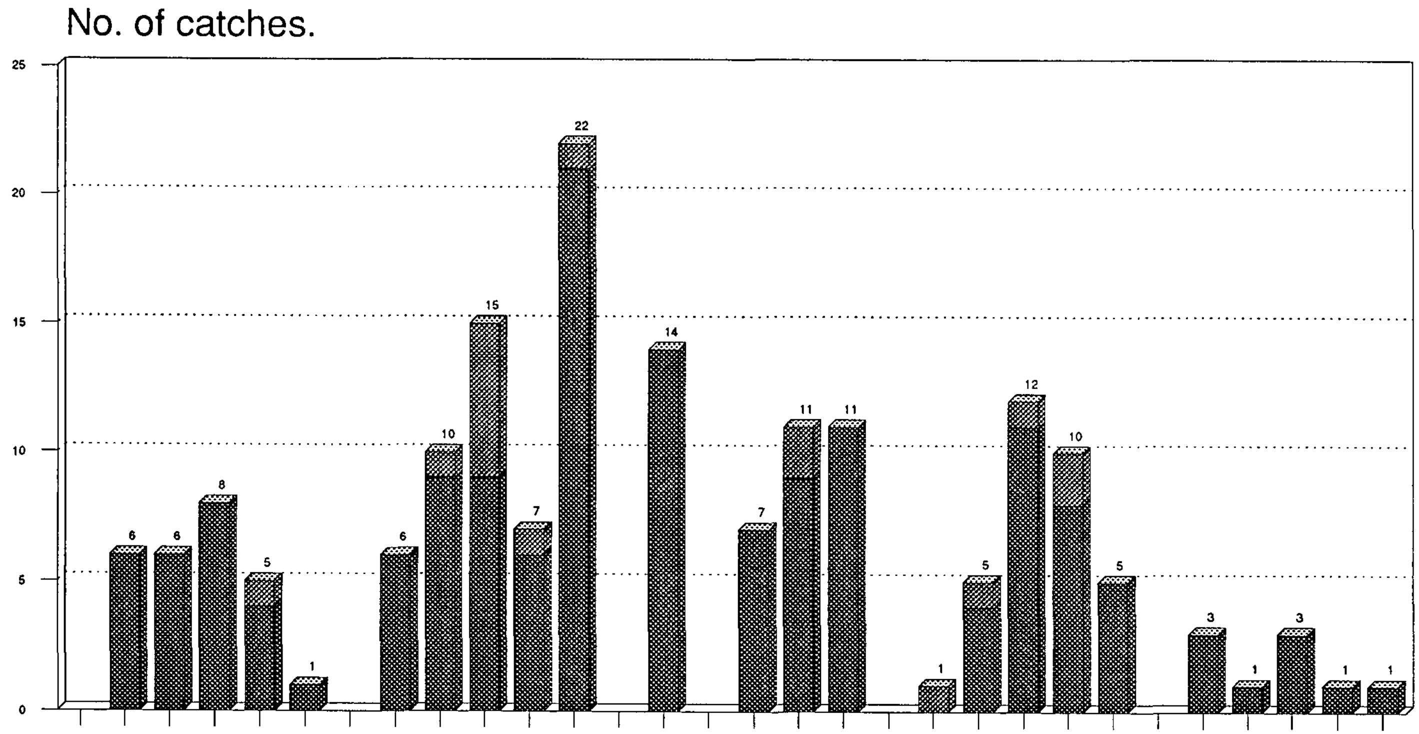


Number of species of spider per quadrat from 22/05 -18/07/90. Pitfall catchs.



Pitfall catches of Alopecosa cuneata.

Number per quadrat from 22/05-18/07/90.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3
18/07/90	0	0	0	0	0	0	0	0	0	0
05/07/90	0	0	0	0	0	0	0	0	0	0
21/06/90	0	0	0	1	0	0	1	6	1	1
06/06/90	6	6	8	4	1	6	9	9	6	21

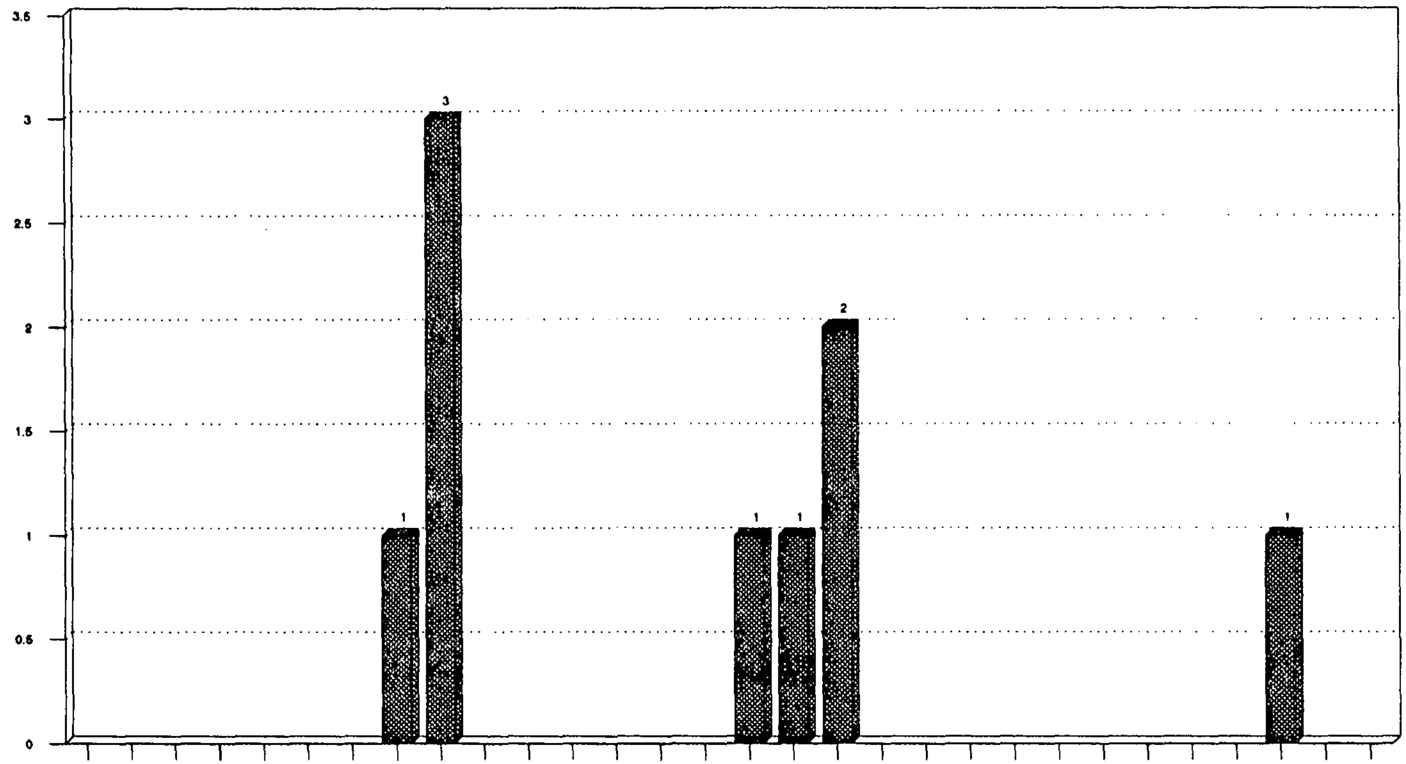
	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05/07/90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21/06/90	0	0	0	2	0	1	1	1	2	0	0	0	0	0	0
06/06/90	14	0	7	9	11	0	4	11	8	5	3	1	3	1	1

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of Clubionia terrestris.

Number per quadrat from 22/05-18/07/90.

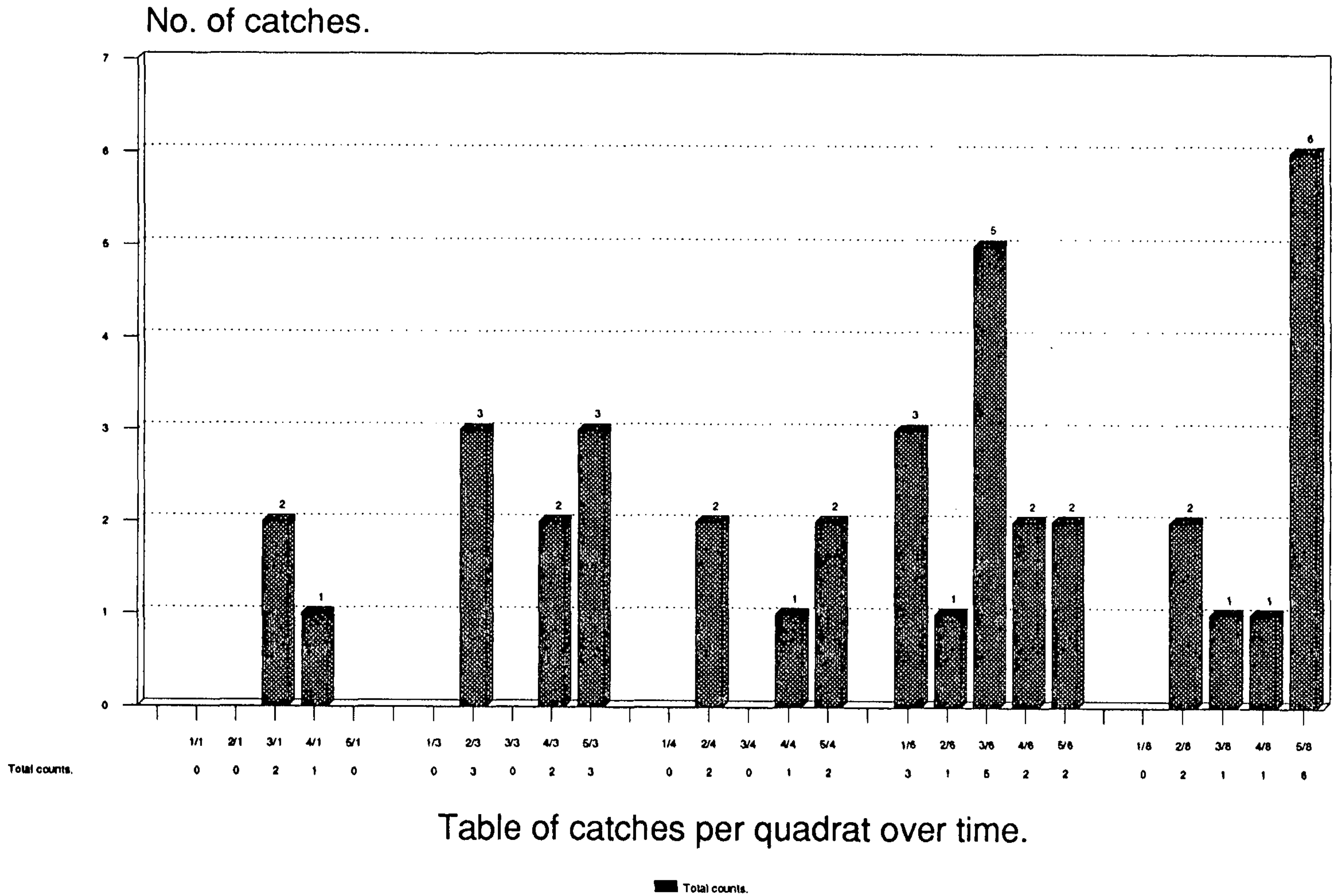


	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
Total counts.	0	0	0	0	0	1	3	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	1	0	0

Table of catches per quadrat over time.

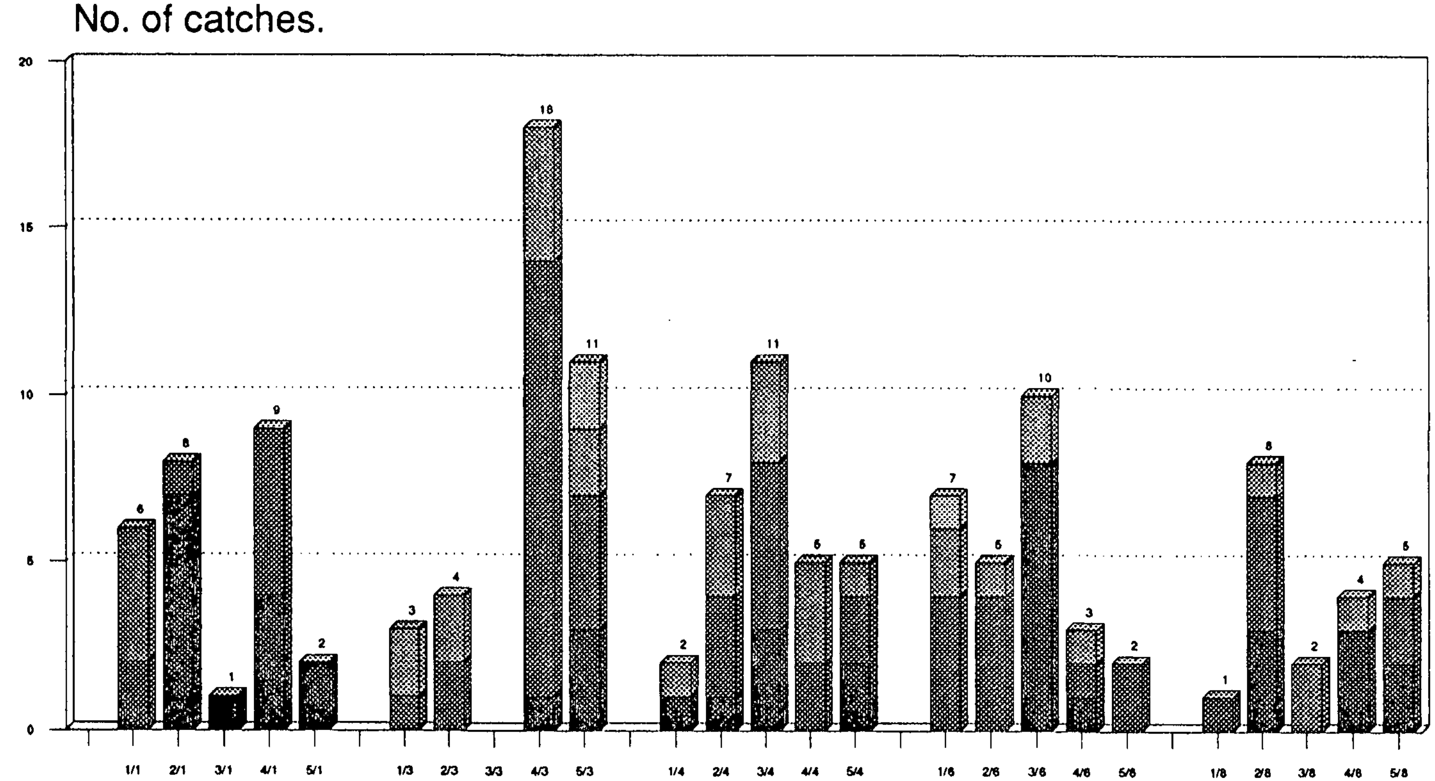
■ Total counts.

Pitfall catches of Evensia merens.
Number per quadrat from 22/05-18/07/90.



Pitfall catches Oxypilla trux (female).

Number per quadrat from 22/05-18/07/90.

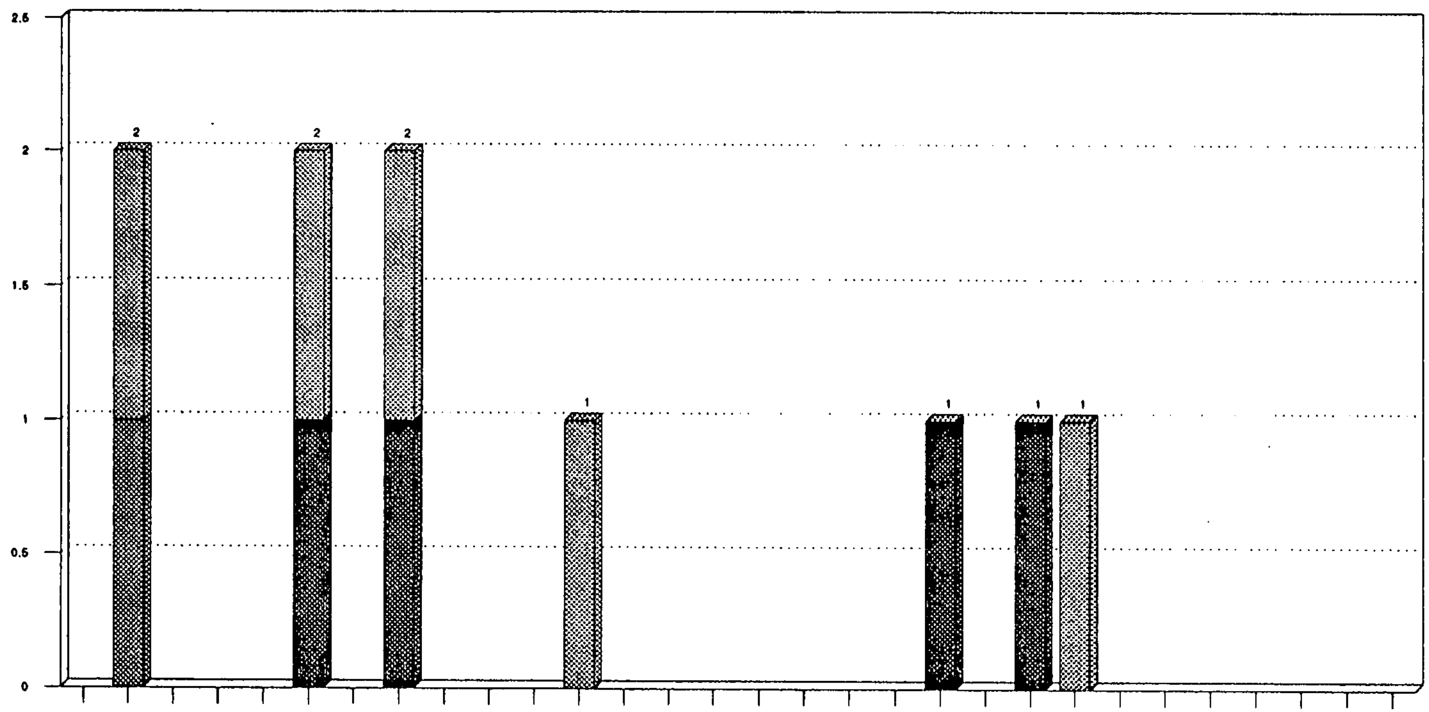


	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/5	2/5	3/5	4/5	5/5	1/8	2/8	3/8	4/8	5/8
18/07/90	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
05/07/90	4	0	0	0	0	1	2	0	4	2	1	3	3	3	1	2	1	2	1	0	0	1	2	1	1
21/06/90	2	1	0	5	0	0	2	0	13	4	0	3	5	2	2	4	4	0	1	2	1	4	0	0	2
05/06/90	0	7	1	4	2	0	0	0	1	3	1	1	3	0	2	0	0	8	1	0	0	3	0	3	2

Table of catches per quadrat over time.

Pitfall catches-Oxypila trux (male).

Number per quadrat from 22/05-18/07/90.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4
18/07/90	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0
05/07/90	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21/06/90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06/06/90	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0

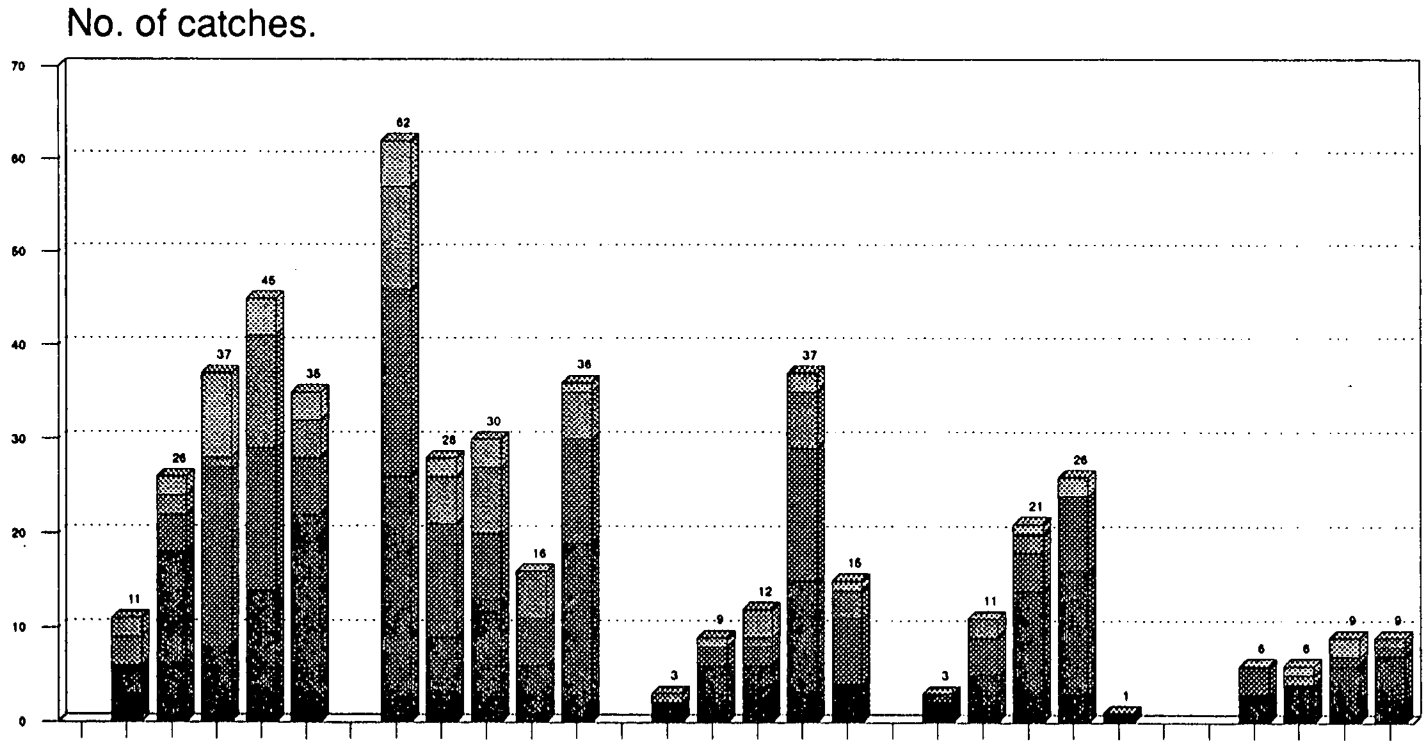
	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	0	0	0	1	0	0	0	0	0	0
05/07/90	0	0	0	0	0	0	0	0	0	0
21/06/90	0	0	0	0	0	0	0	0	0	0
06/06/90	1	0	1	0	0	0	0	0	0	0

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of Pachygantha degeeri.

Number per quadrat from 22/05-18/07/90.



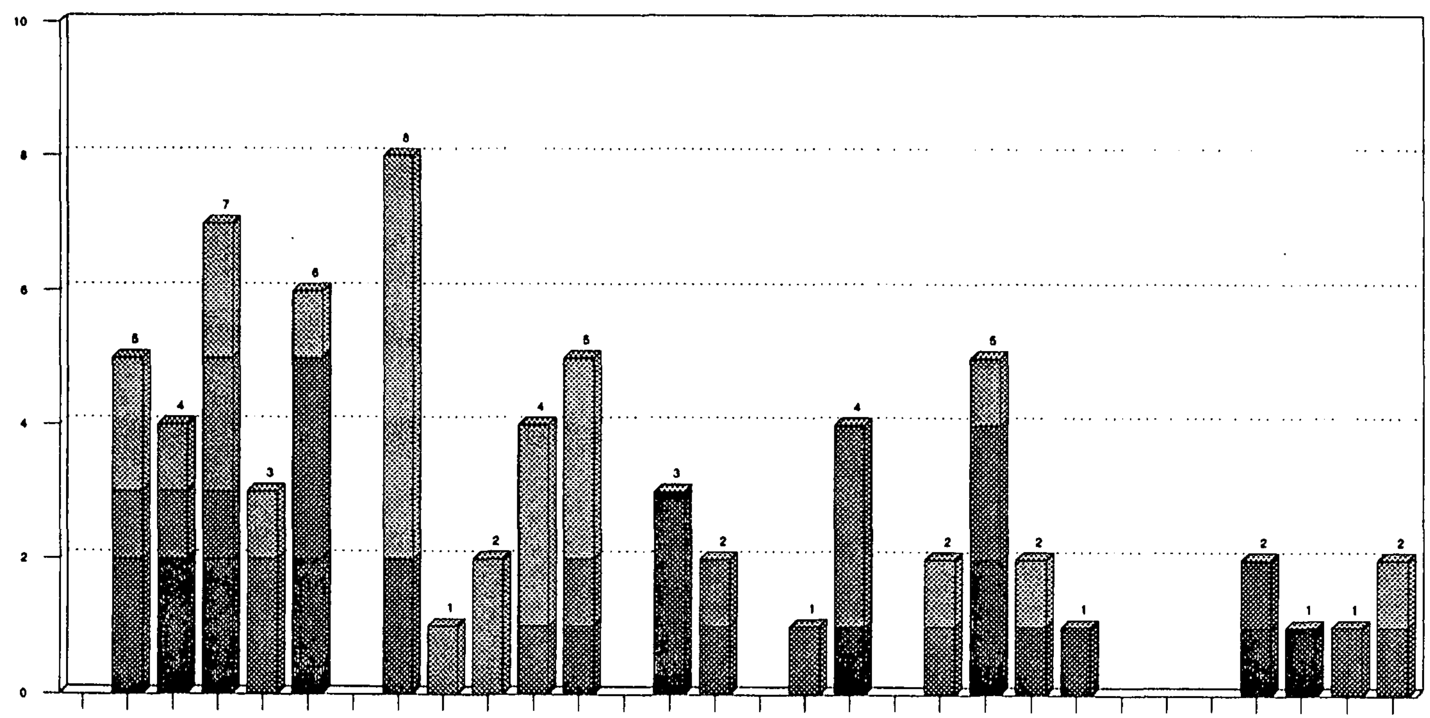
	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	2	2	9	4	3	5	2	3	0	1	0	1	3	2	1	0	0	1	2	0	0	0	1	2	0
05/07/90	3	2	1	12	4	11	5	7	5	5	1	0	1	6	3	0	2	2	0	0	0	0	1	0	1
21/06/90	0	4	19	15	6	20	12	7	5	11	0	2	2	14	7	1	4	4	8	0	0	3	0	1	1
06/06/90	6	18	8	14	22	26	9	13	6	19	2	6	6	15	4	2	5	14	16	1	0	3	4	6	7

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of Trochosa ruricola.

Number per quadrat from 22/05-18/07/90.

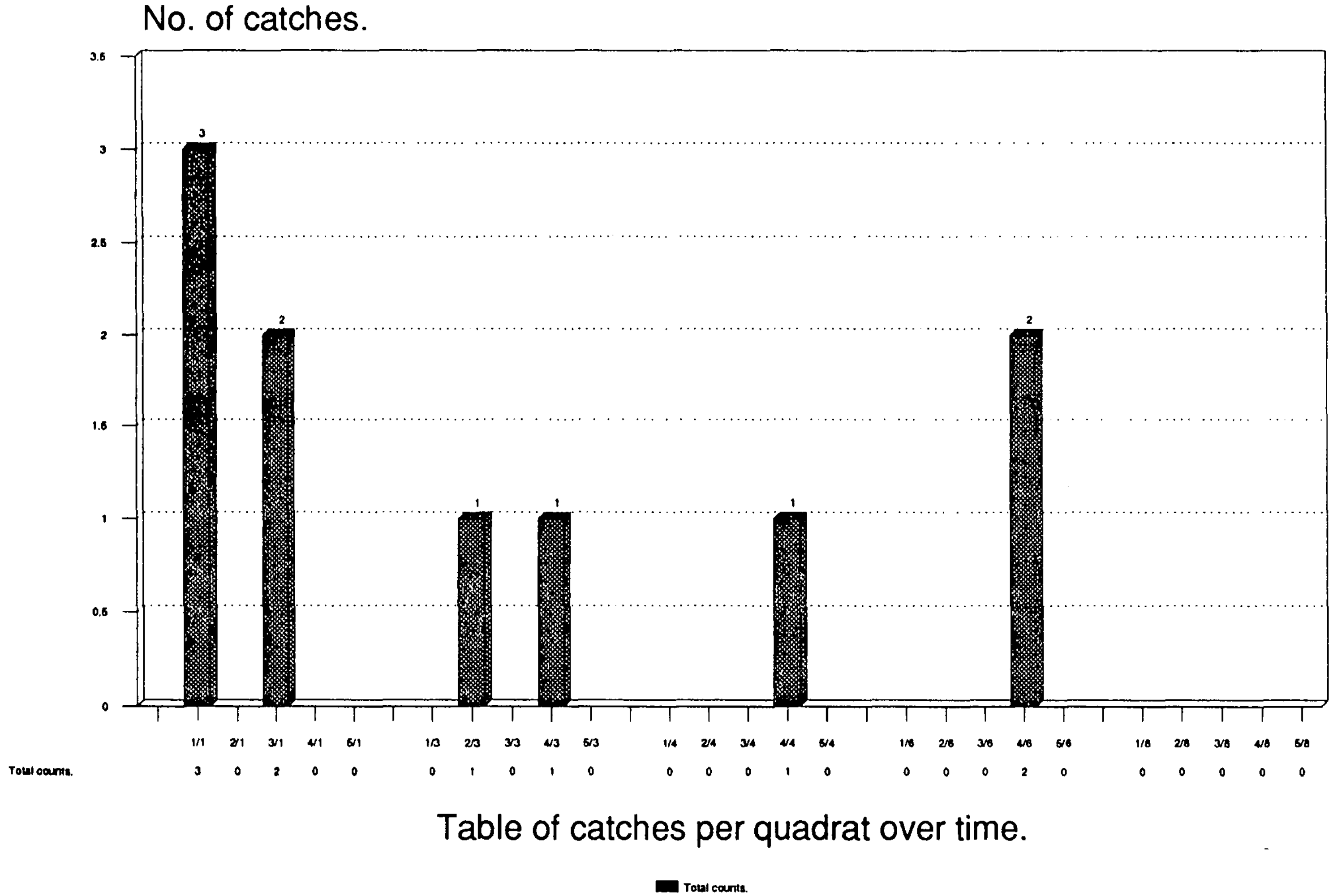


	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	2	1	2	1	1	6	1	2	3	3	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1
05/07/90	1	1	2	2	0	0	0	0	1	1	0	1	0	1	3	1	1	0	0	0	0	0	0	1	1
21/06/90	2	0	1	0	3	2	0	0	0	1	0	1	0	0	0	0	2	1	1	0	0	1	0	0	0
06/06/90	0	2	2	0	2	0	0	0	0	0	3	0	0	0	1	0	2	0	0	0	0	1	1	0	0

Table of catches per quadrat over time.

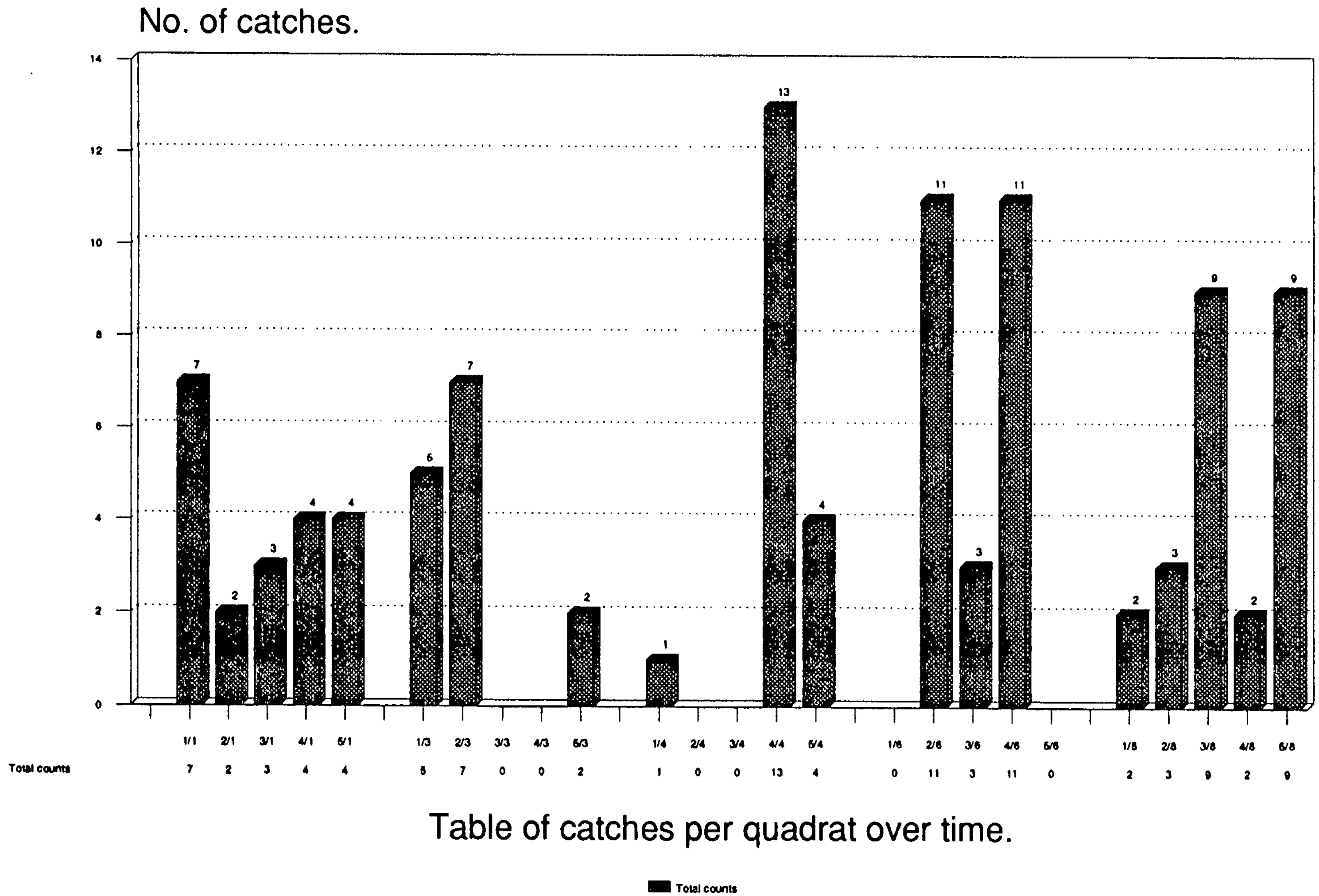
06/06/90 21/06/90 05/07/90 18/07/90

PitfallS - Xysticus cristatus (female).
Number per quadrat from 22/05-18/07/90.



Pitfall-Xysticus cristatus (male).

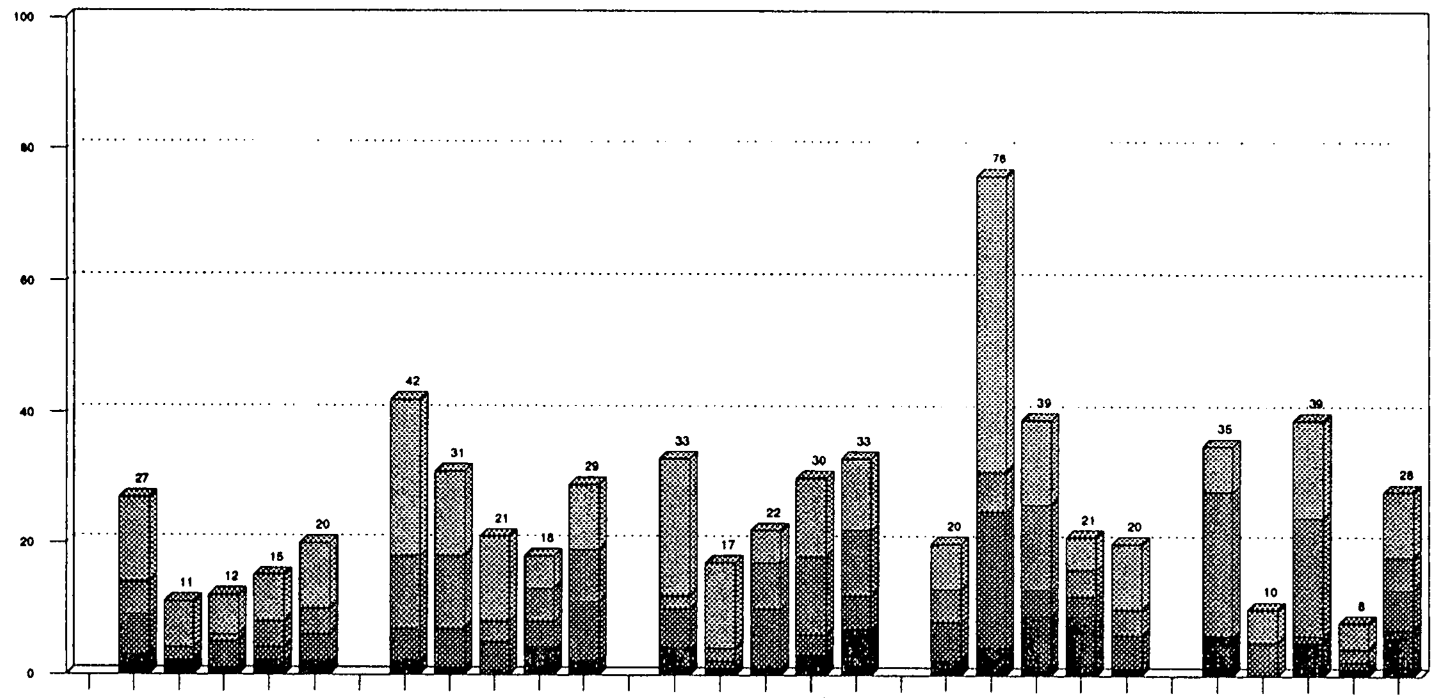
Number per quadrat from 22/05-18/07/90.



Pitfall catches of Carabidae.

Number per quadrat from 22/05-18/07/90.

No. of catches.

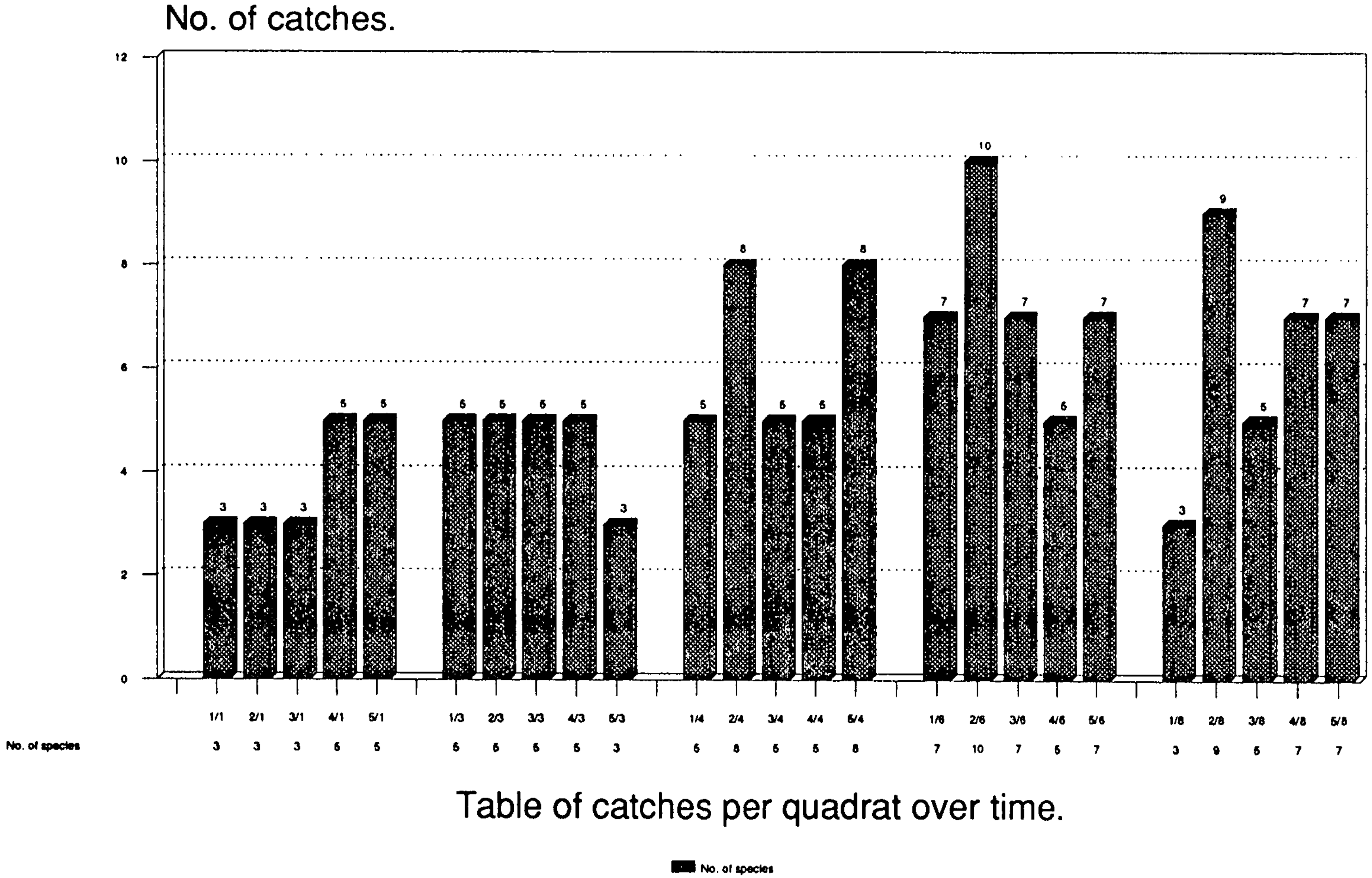


	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	13	7	6	7	10	24	13	13	5	10	21	13	5	12	11	7	45	13	5	10	7	5	15	4	10
05/07/90	5	2	1	4	4	11	11	3	5	8	2	2	7	12	10	5	6	13	4	4	22	5	18	2	5
21/06/90	6	0	4	2	4	5	6	5	4	9	6	1	9	3	5	6	21	4	3	5	0	0	1	1	6
06/06/90	3	2	1	2	2	2	1	0	4	2	4	1	1	3	7	2	4	9	9	1	6	0	5	1	7

Table of catches per quadrat over time.

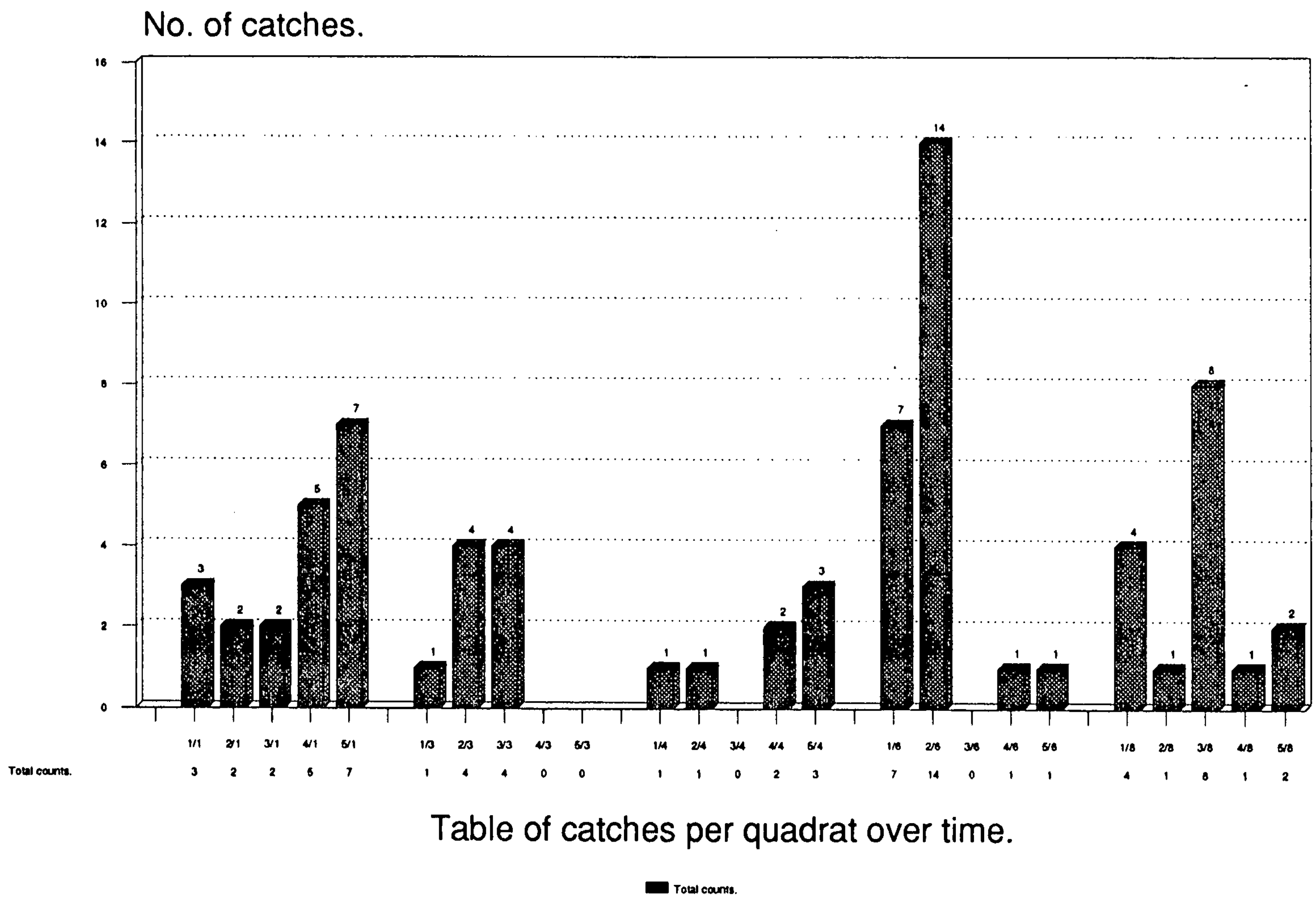
06/06/90 21/06/90 05/07/90 18/07/90

Number of Carabid species per quadrat from 22/05-18/07/90. Pitfall catchs.



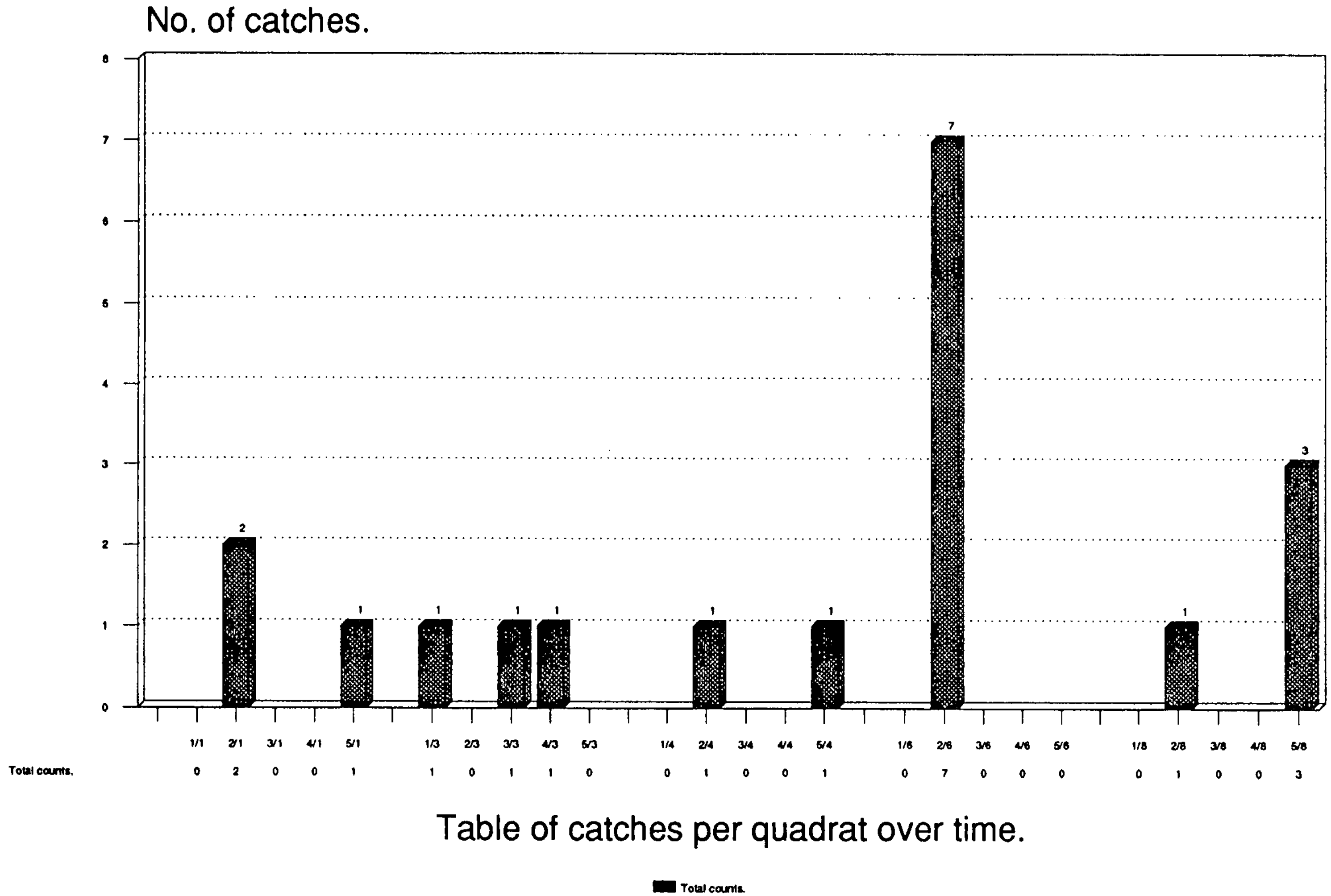
Pitfall catches of Amara aulica.

Number per quadrat from 22/05-18/07/90.



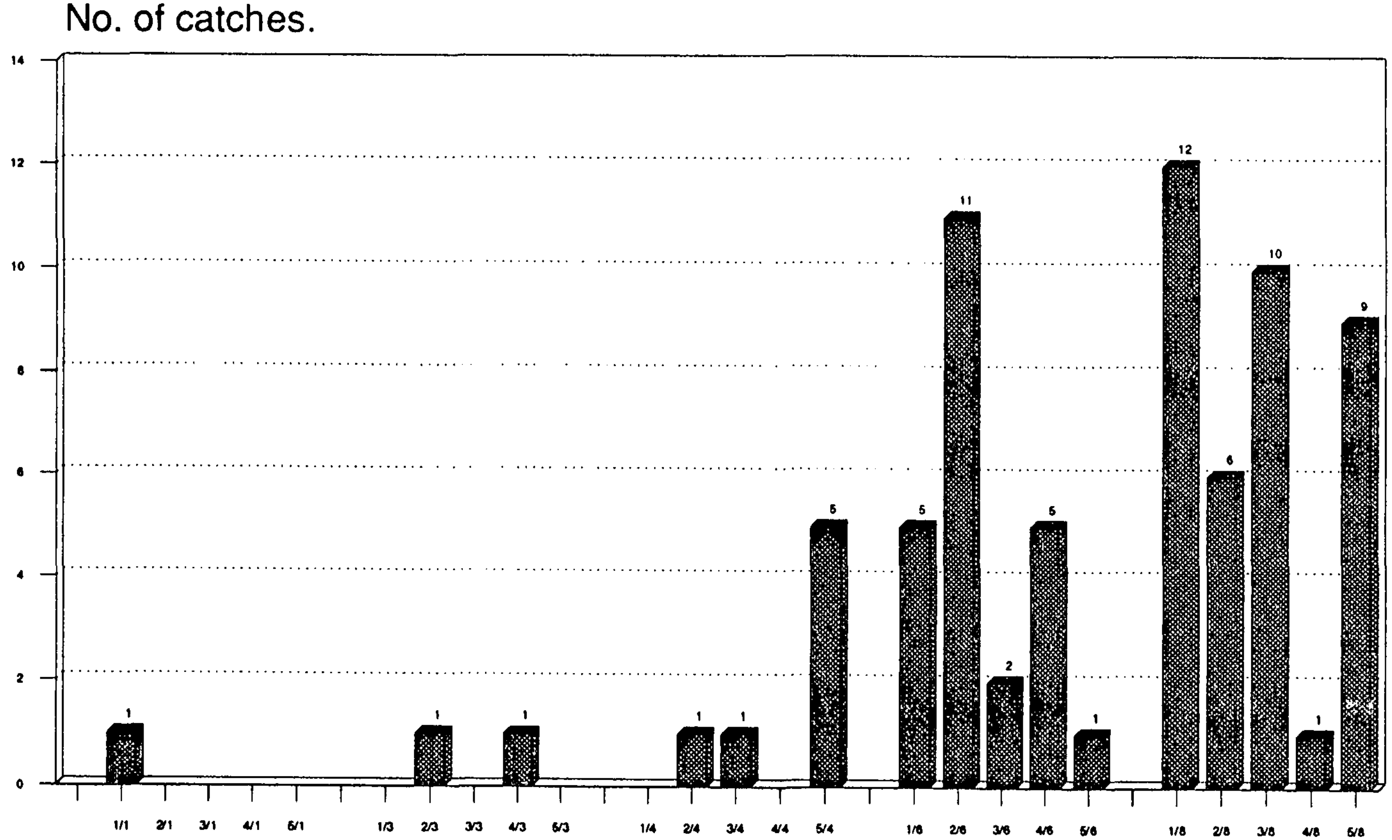
Pitfall catches of Amara convexior.

Number per quadrat from 22/05-18/07/90.



Pitfall catches of Bembidion lampros.

Number per quadrat from 22/05-18/07/90.



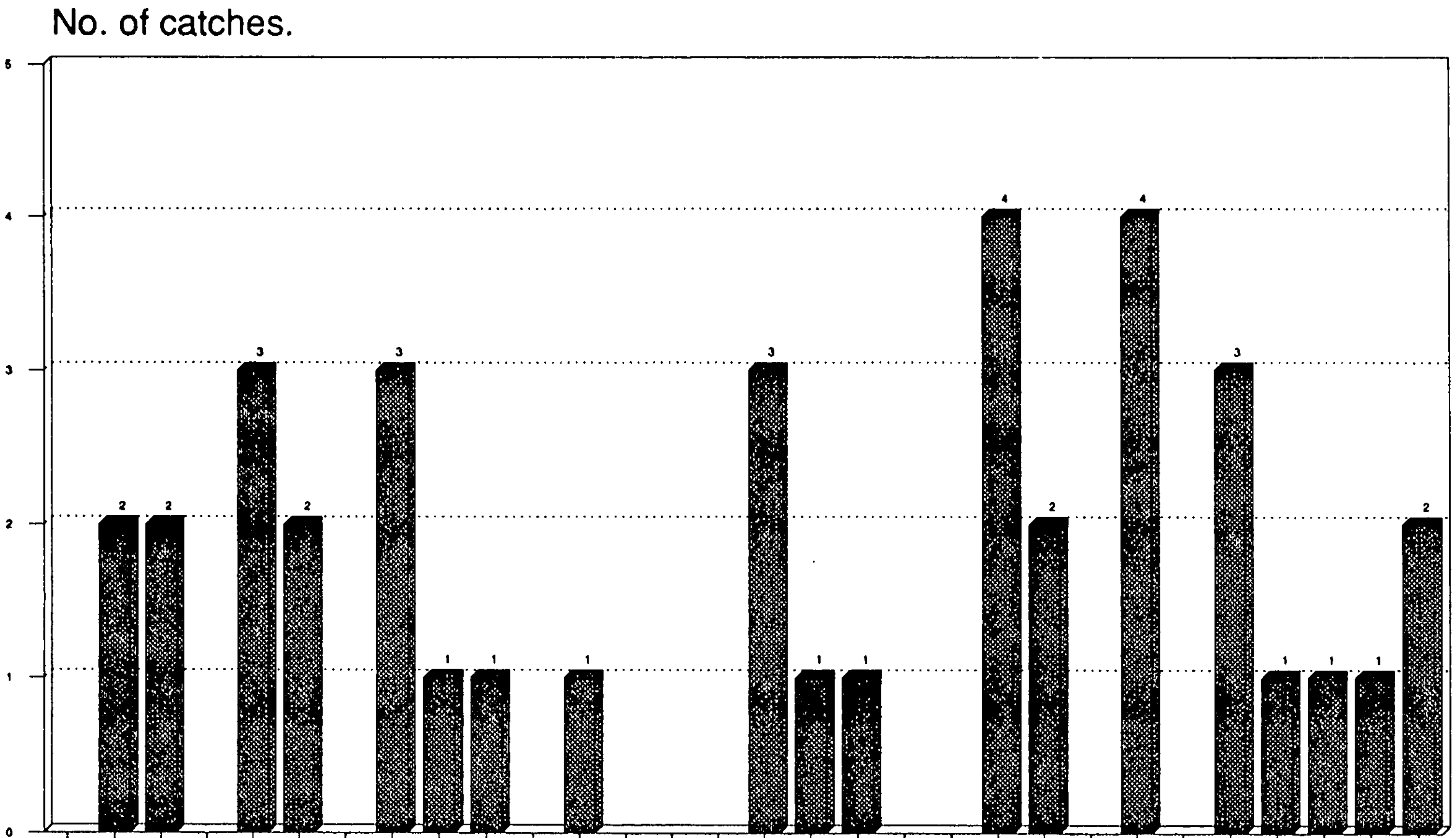
	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4
Total counts.	1	0	0	0	0	0	1	0	1	0	0	1	1	0	5

	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
Total counts.	5	11	2	5	1	12	6	10	1	9

Table of catches per quadrat over time.

Pitfall catches of Carabus violaceus.

Number per quadrat from 22/05-18/07/90.

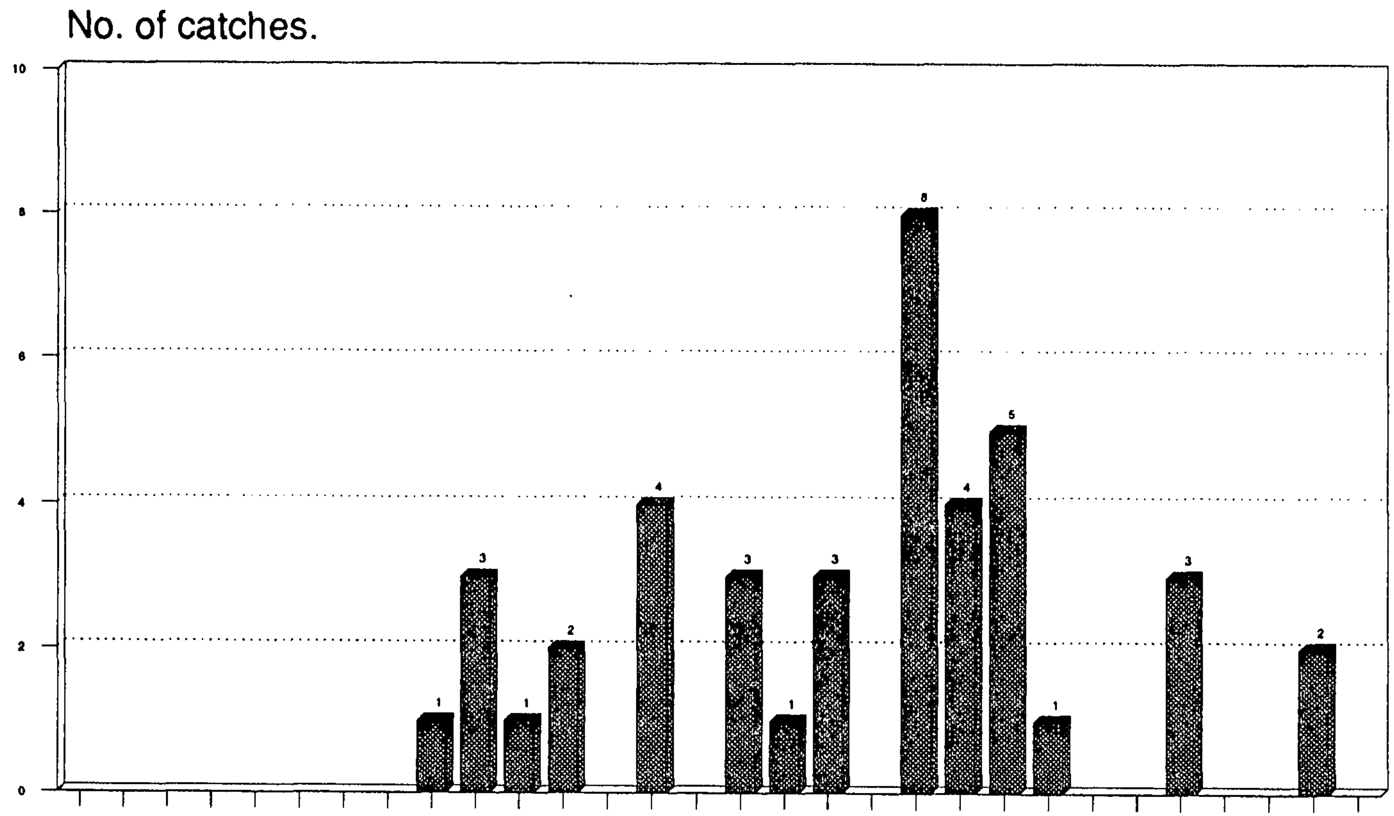


1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/5	2/5	3/5	4/5	5/5	1/6	2/6	3/6	4/6	5/6
2	2	0	3	2	3	1	1	0	1	0	0	3	1	1	0	4	2	0	4	3	1	1	1	2

Table of catches per quadrat.

1/1 = quadrat 1 site 1, etc

Pitfall catches of Harpalus rufipes.
Number per quadrat from 22/05-18/07/90.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
Total counts.	0	0	0	0	0	0	1	3	1	2	4	0	3	1	3	8	4	5	1	0	3	0	0	2	0

Table of catches per quadrat over time.

Total counts.

Pitfalls -Notiophilous biguttatus and Notiophilous germanyi.

Number per quadrat from 22/05-18/07/90.

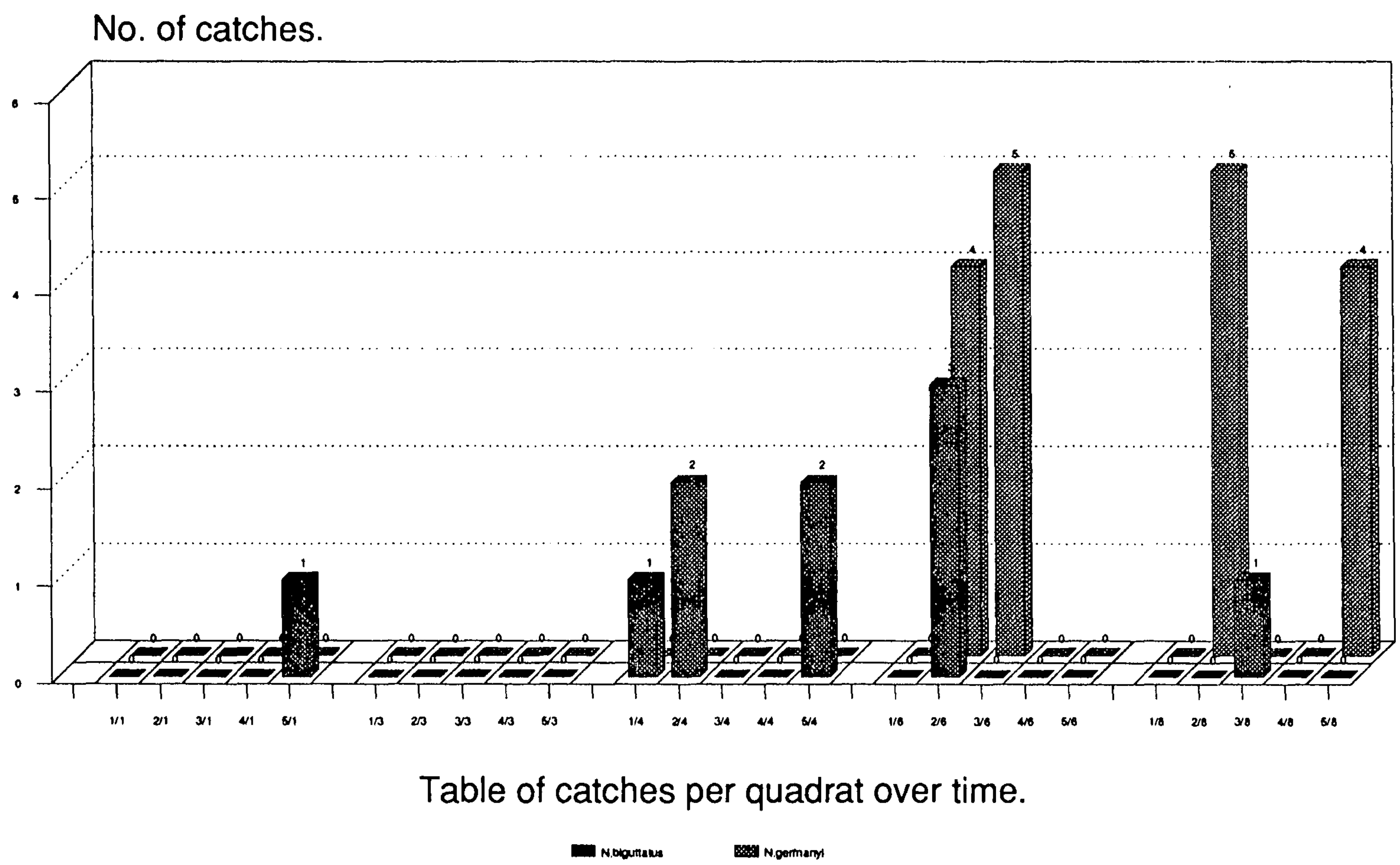


Table of catches per quadrat over time.

Pitfall catches-Pterostichus madidus.

Number per quadrat from 22/05-18/07/90.

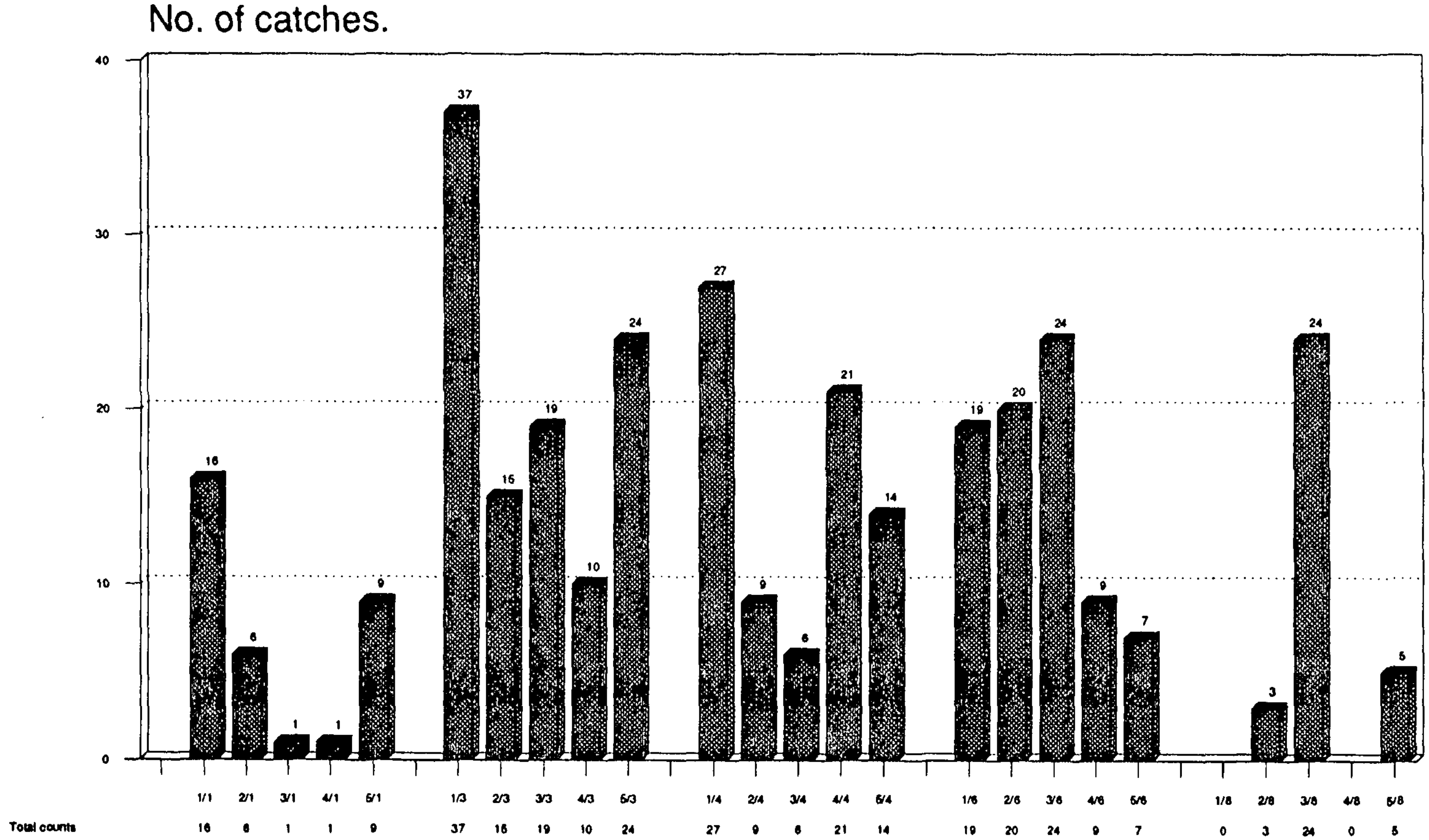
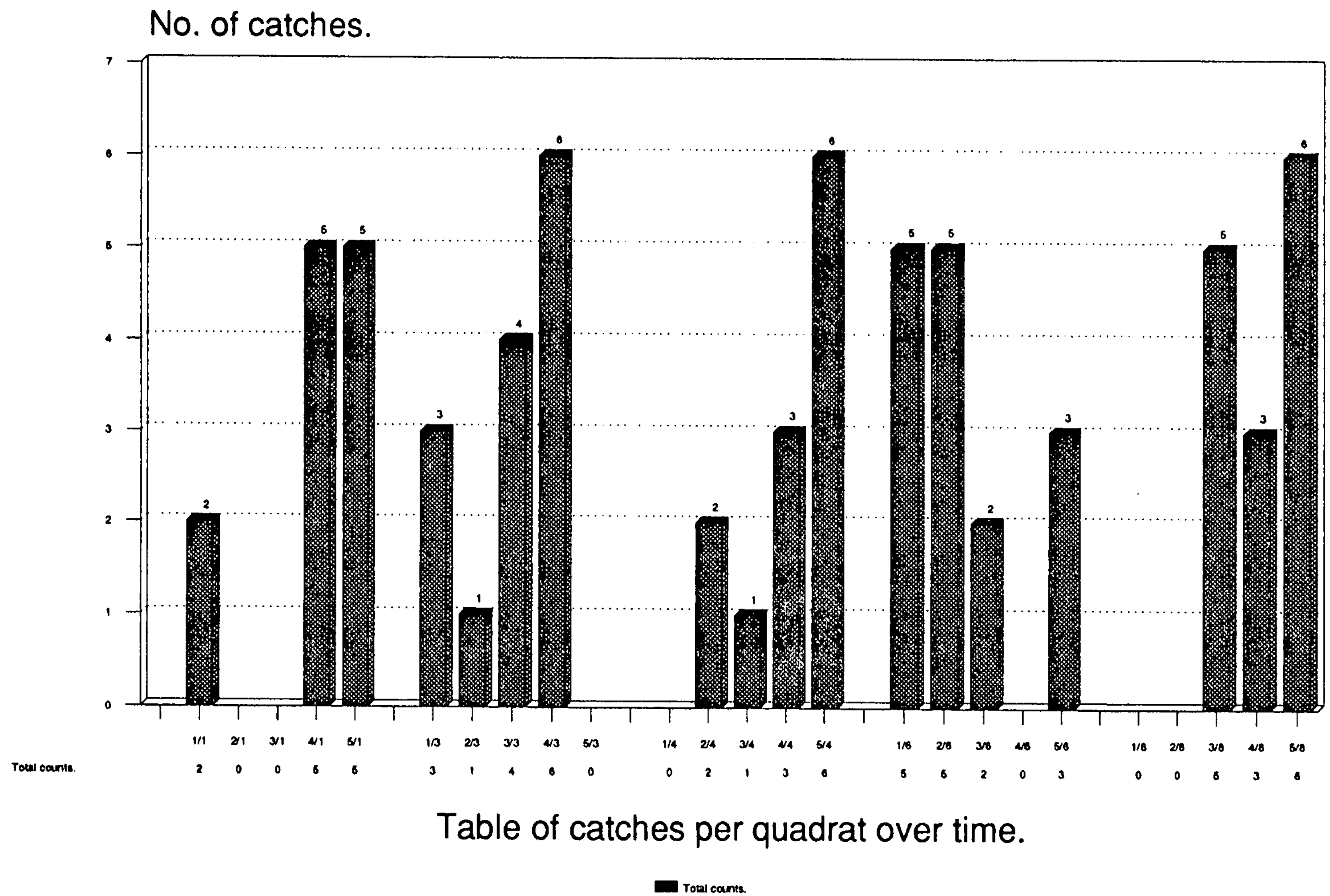


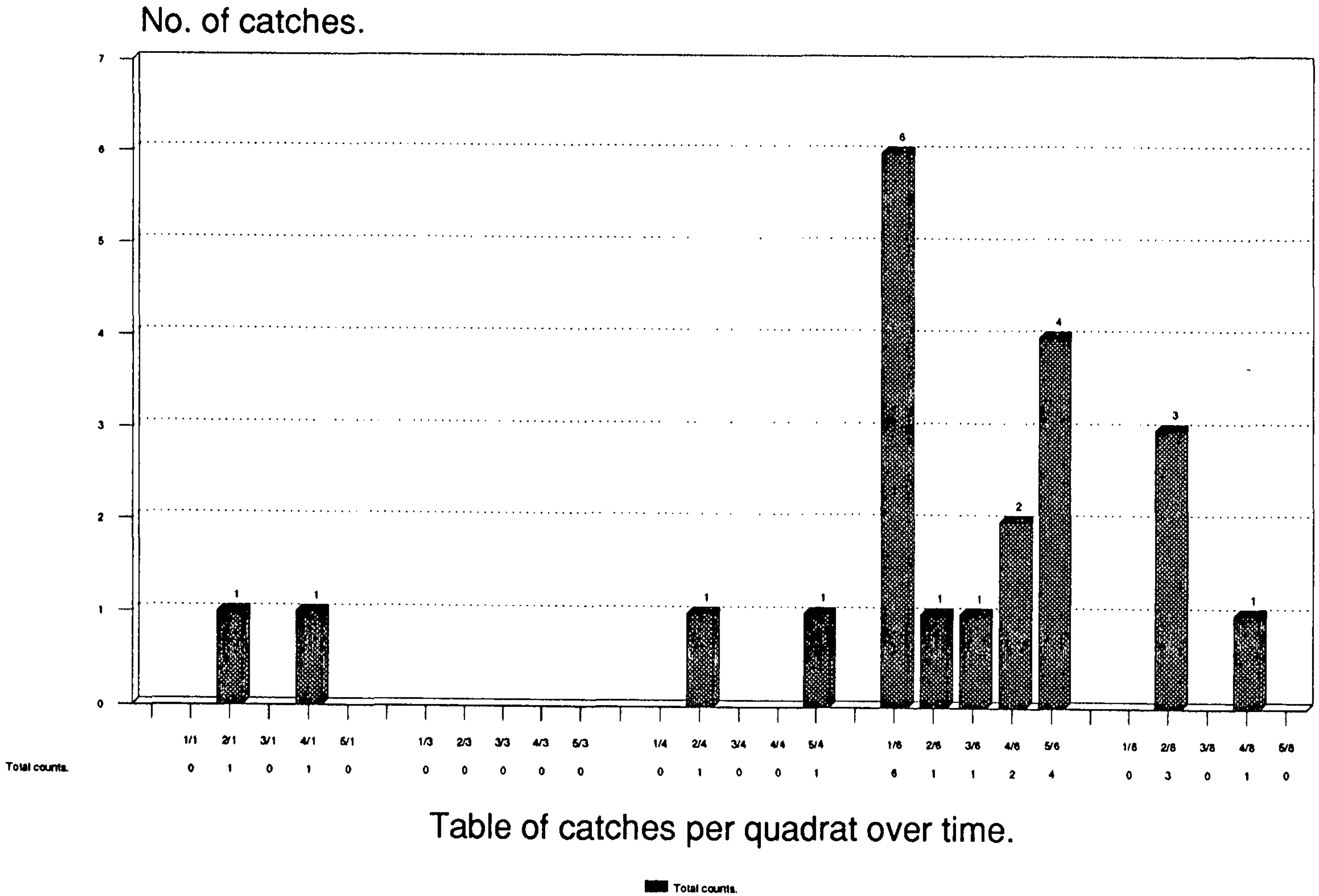
Table of catches per quadrat over time.

Pitfall catches-Pterostichus melanarius.
Number per quadrat from 22/05-18/07/90.



Pitfall catches of Trechus quadristiatus

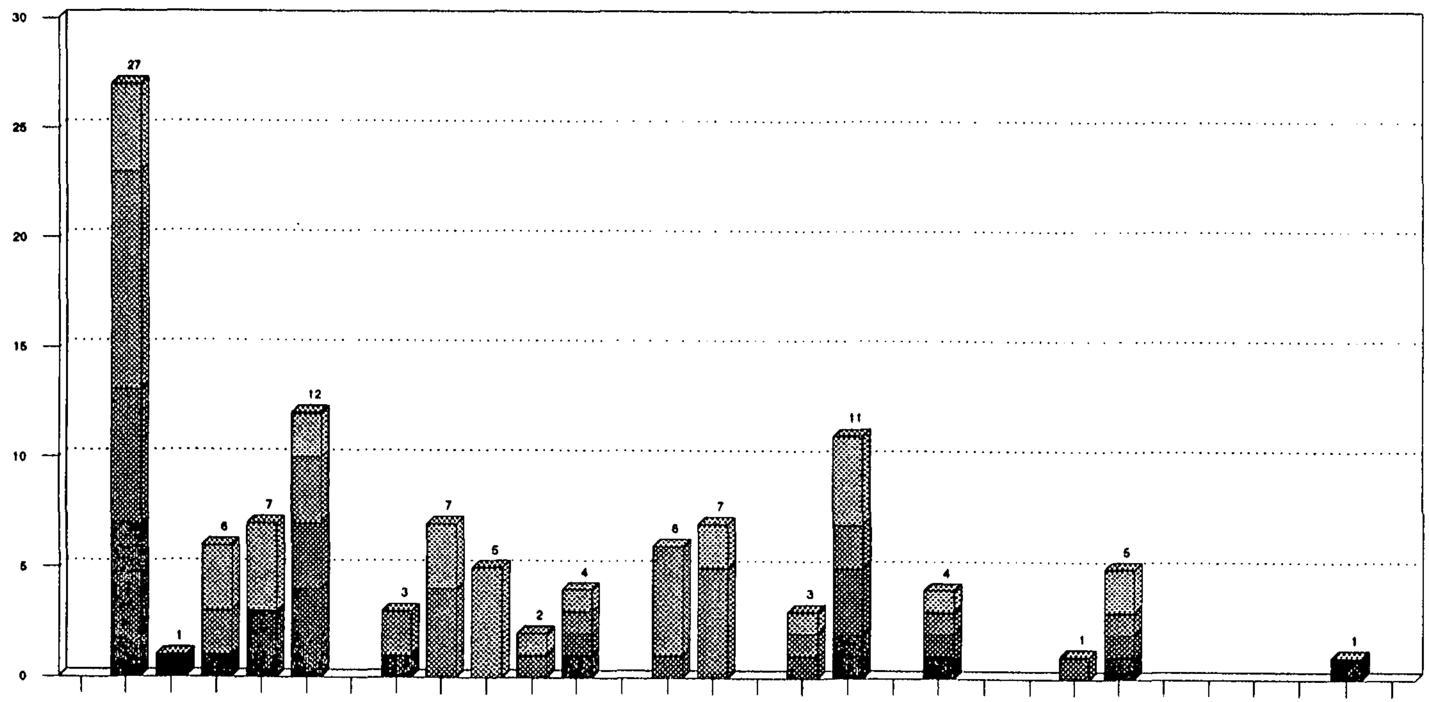
Number per quadrat from 22/05-18/07/90.



Pitfall catches of C.nemoralis

Number per quadrat from 22/05-18/07/90.

No. of catches.



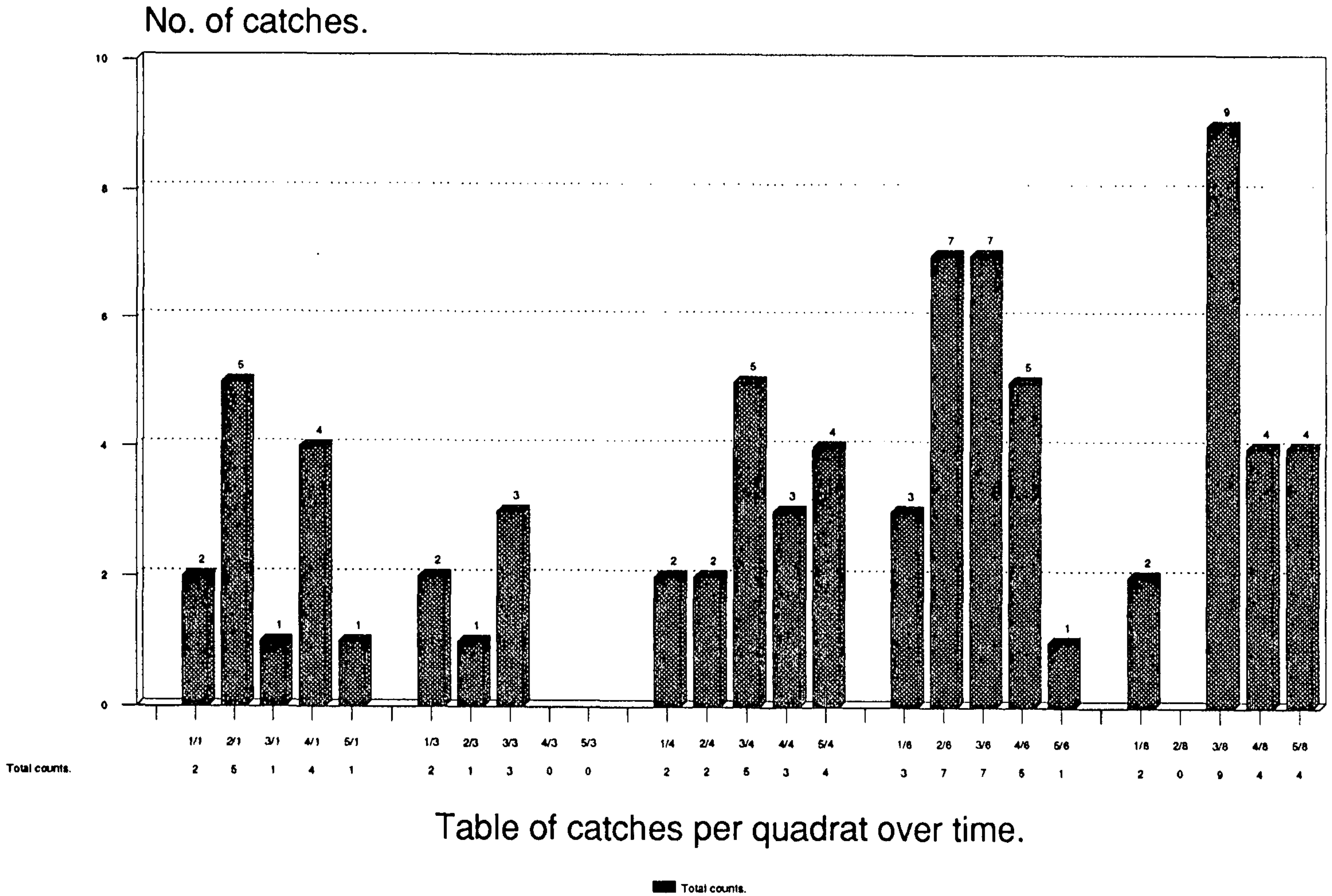
	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	4	0	3	4	2	0	3	5	1	1	0	2	0	1	4	1	0	0	0	2	0	0	0	0	0
05/07/90	10	0	2	0	3	2	4	0	1	1	5	5	0	1	2	1	0	0	1	1	0	0	0	0	0
21/06/90	6	0	0	0	3	0	0	0	0	1	1	0	0	1	3	1	0	0	0	1	0	0	0	0	0
06/06/90	7	1	1	3	4	1	0	0	0	1	0	0	0	0	2	1	0	0	0	1	0	0	0	1	0

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches - Crepidodera ferruginea

Number per quadrat from 22/05-18/07/90.



Pitfall catches - Crepidodera transvera.

Number per quadrat from 22/05-18/07/90.

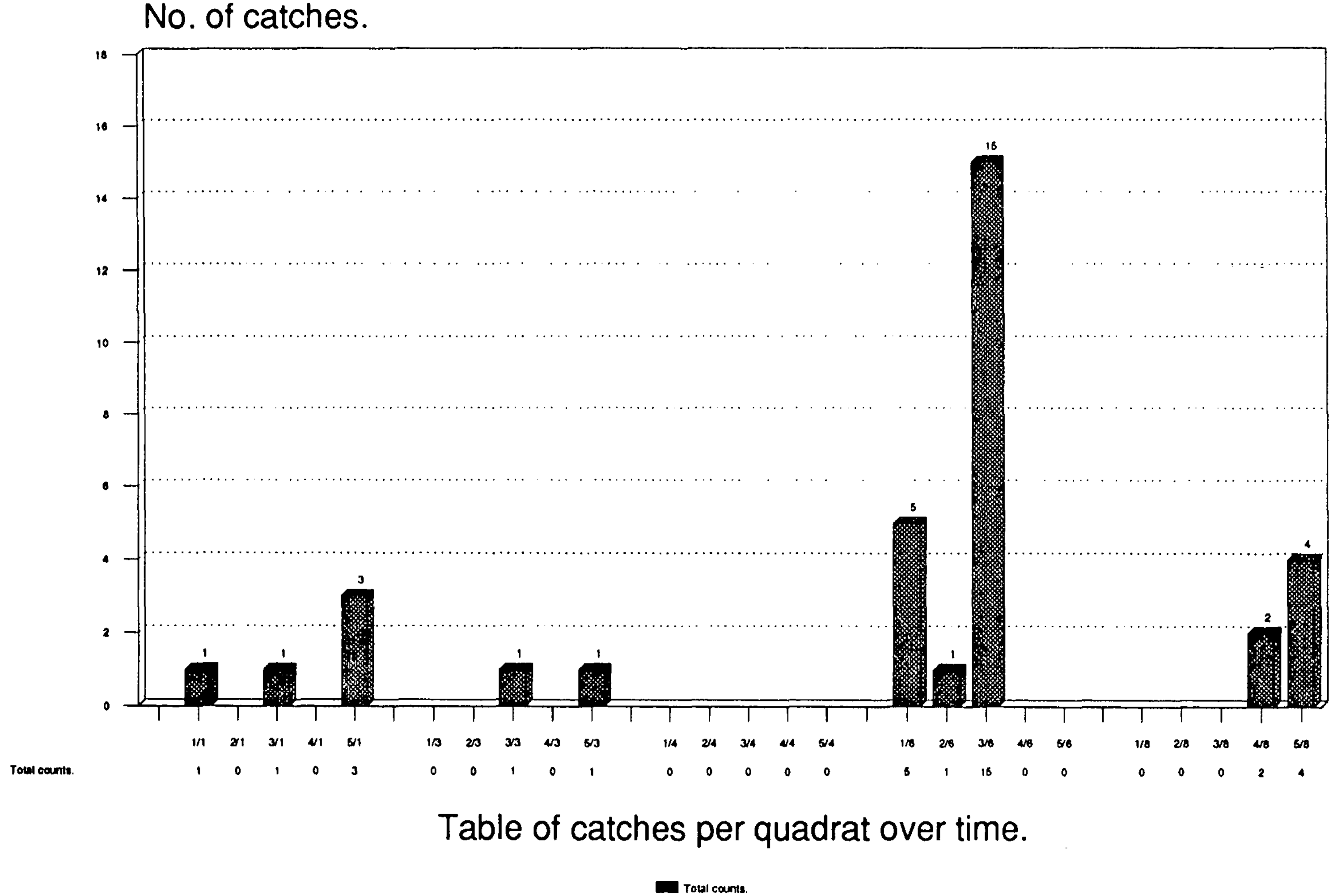
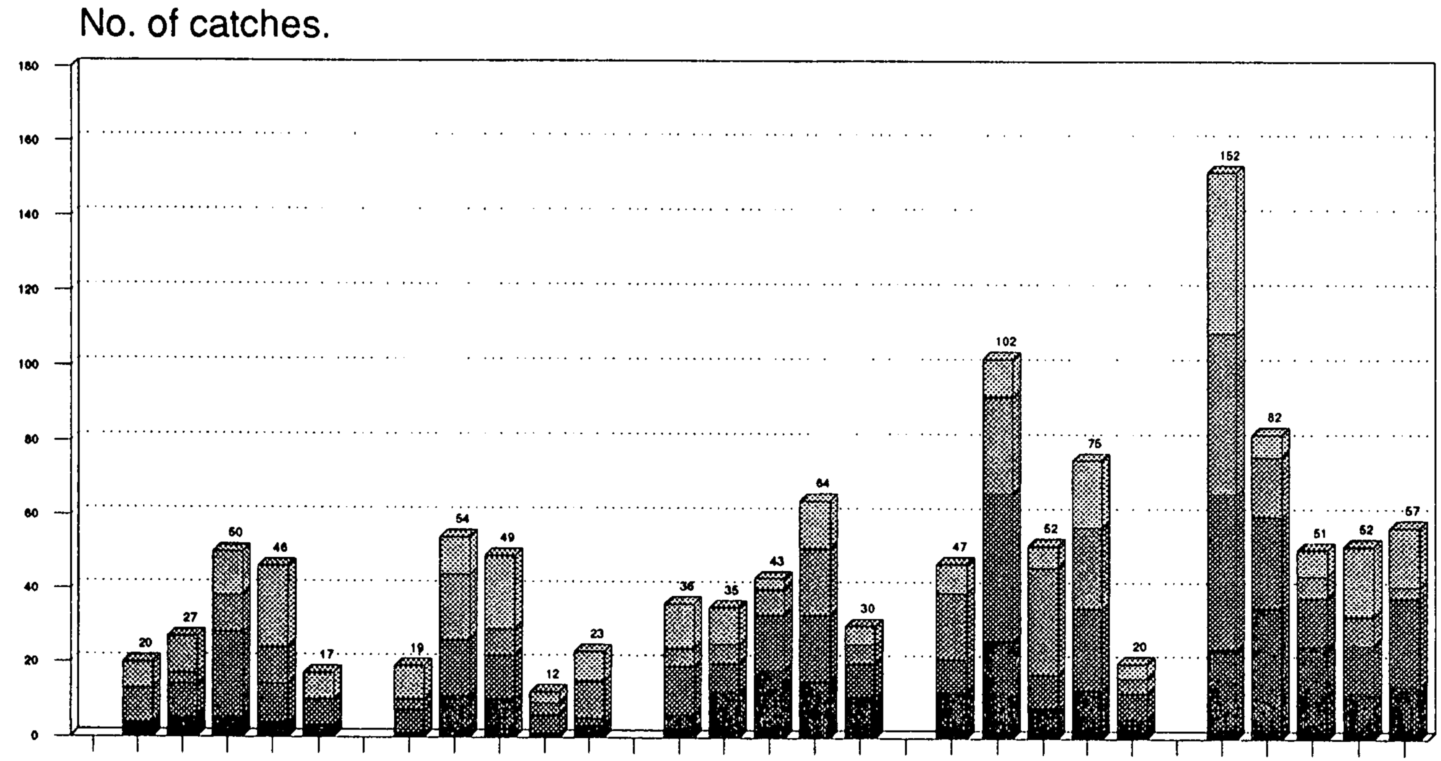


Table of catches per quadrat over time.

Pitfall catches of Diptera.

Number per quadrat from 22/05-18/07/90.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4
18/07/90	7	10	12	22	7	9	10	20	3	8	12	10	3	13	5
05/07/90	9	3	10	10	0	3	18	7	3	10	5	5	7	18	5
21/06/90	1	9	23	10	7	6	15	12	5	2	13	8	15	18	9
06/06/90	3	5	5	4	3	1	11	10	1	3	6	12	18	15	11

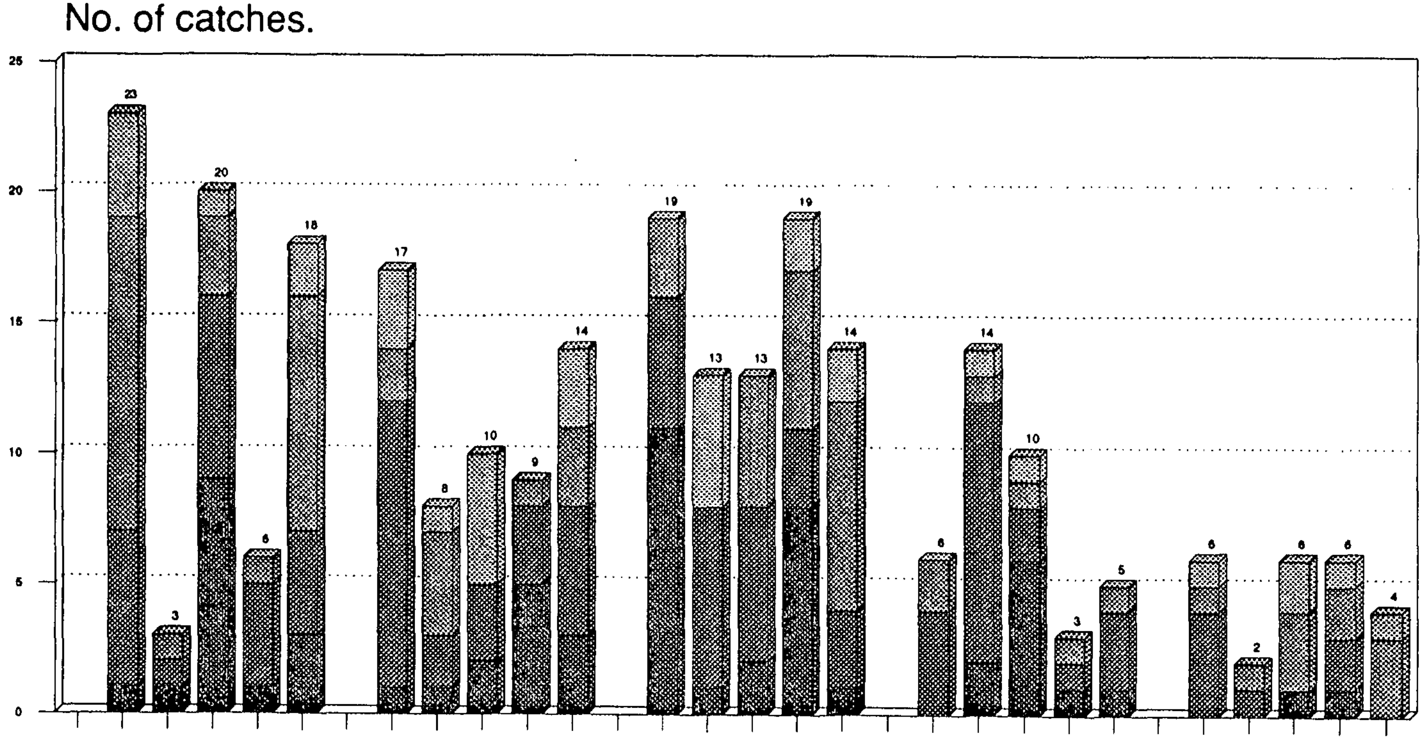
	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	8	10	6	18	4	43	6	7	19	16
05/07/90	18	26	29	22	4	43	16	6	8	3
21/06/90	9	40	9	22	7	42	25	13	13	24
06/06/90	12	26	8	13	5	24	35	25	12	14

Table of catches per quadrat over time.

06/06/90   21/06/90   05/07/90   18/07/90

Pitfall catches of Elateridae.

Number per quadrat from 22/05-18/07/90.



	1/1	2/1	3/1	4/1	5/1
18/07/90	4	0	1	0	2
05/07/90	12	1	3	1	9
21/06/90	6	1	7	4	4
06/06/90	1	1	9	1	3

	1/3	2/3	3/3	4/3	5/3
18/07/90	3	1	5	0	3
05/07/90	2	4	0	1	3
21/06/90	11	2	3	3	5
06/06/90	1	1	2	6	3

	1/4	2/4	3/4	4/4	5/4
18/07/90	0	5	0	2	2
05/07/90	3	0	5	6	8
21/06/90	5	7	6	3	3
06/06/90	11	1	2	8	1

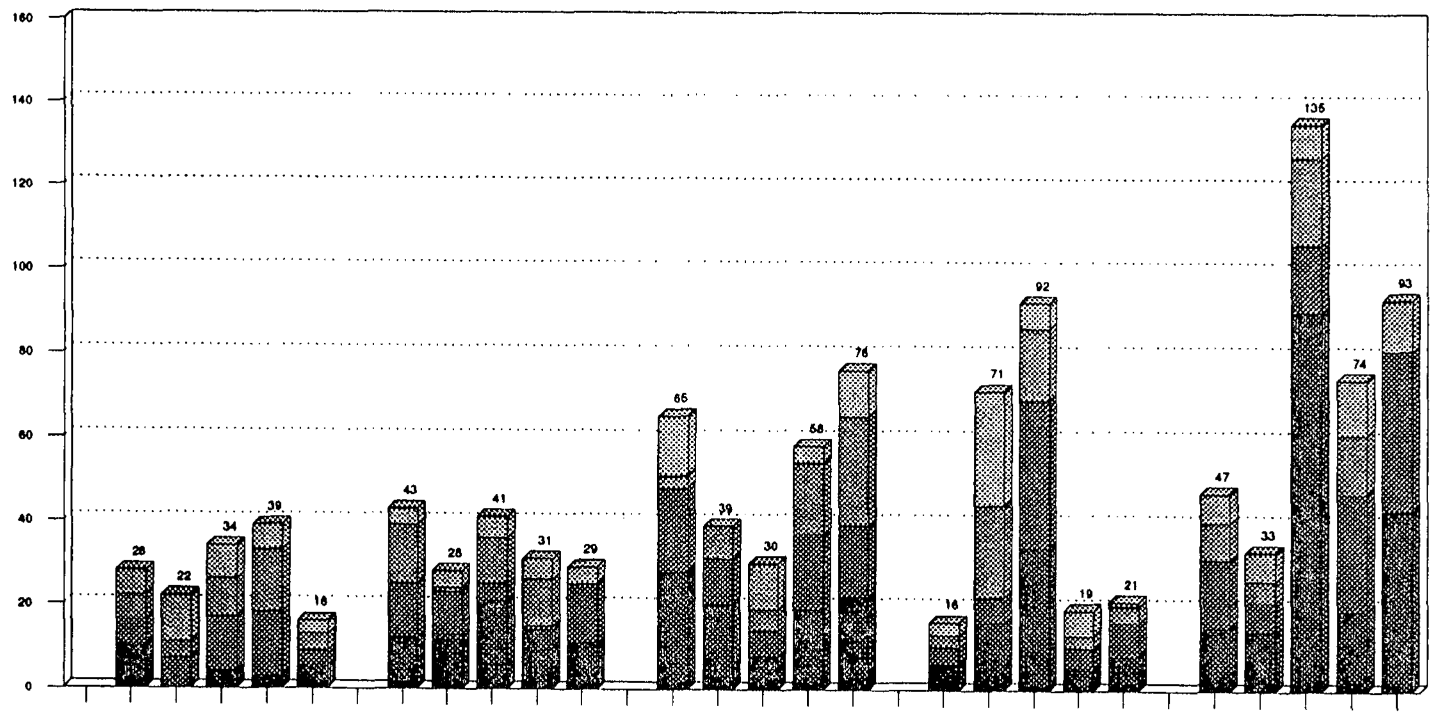
	1/6	2/6	3/6	4/6	5/6
18/07/90	0	1	1	0	0
05/07/90	2	1	1	1	1
21/06/90	4	10	2	1	3
06/06/90	0	2	6	1	1

	1/8	2/8	3/8	4/8	5/8
18/07/90	1	0	2	1	1
05/07/90	1	1	3	2	3
21/06/90	4	1	0	2	0
06/06/90	0	0	1	1	0

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of Formicidae.
Number per quadrat from 22/05-18/07/90.



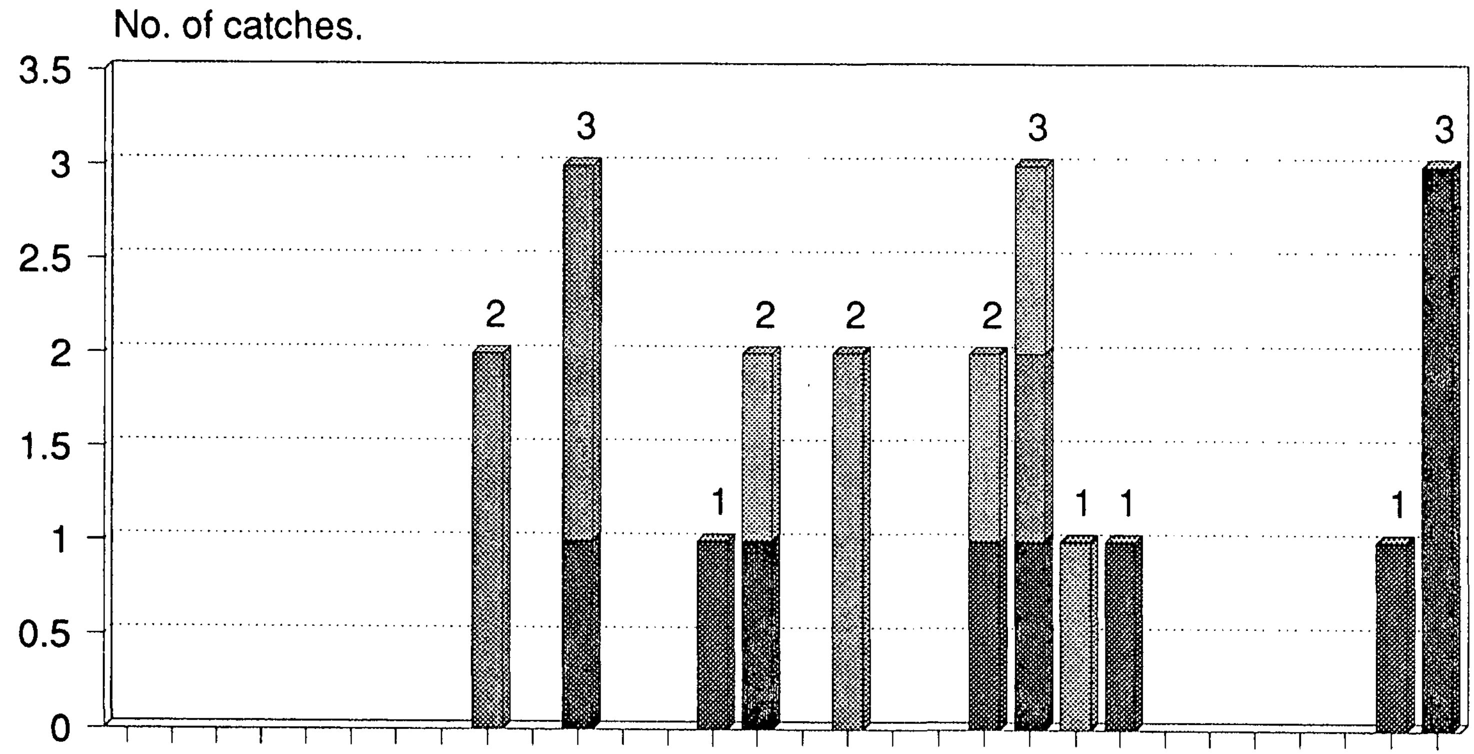
	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	6	11	8	6	3	4	4	5	5	4	14	0	11	4	11	3	27	6	6	1	7	7	8	13	12
05/07/90	6	4	9	15	4	14	1	11	11	0	3	8	5	17	26	3	22	17	3	4	9	5	21	14	0
21/06/90	6	7	13	15	4	13	10	4	1	14	20	11	6	18	17	4	6	35	5	8	16	7	16	28	38
06/06/90	10	0	4	3	5	12	13	21	14	11	28	20	8	19	22	6	16	34	5	8	15	14	90	19	43

Table of catches per quadrat over time.

- A32 -

Pitfall catches of Lampyris noctiluca.

Number per quadrat from 22/05-18/07/90.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3
18/07/90						0	0	0	0	0
05/07/90	0	0	0	0	0	0	2	0	2	0
21/06/90	0	0	0	0	0	0	0	0	0	0
06/06/90	0	0	0	0	0	0	0	0	1	0

	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	0	1	0	2	0	1	1	1	0	0	0	0	0	0	0
05/07/90	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
21/06/90	1	0	0	0	0	1	0	0	1	0	0	0	0	1	0
06/06/90	0	1	0	0	0	0	1	0	0	0	0	0	0	0	3

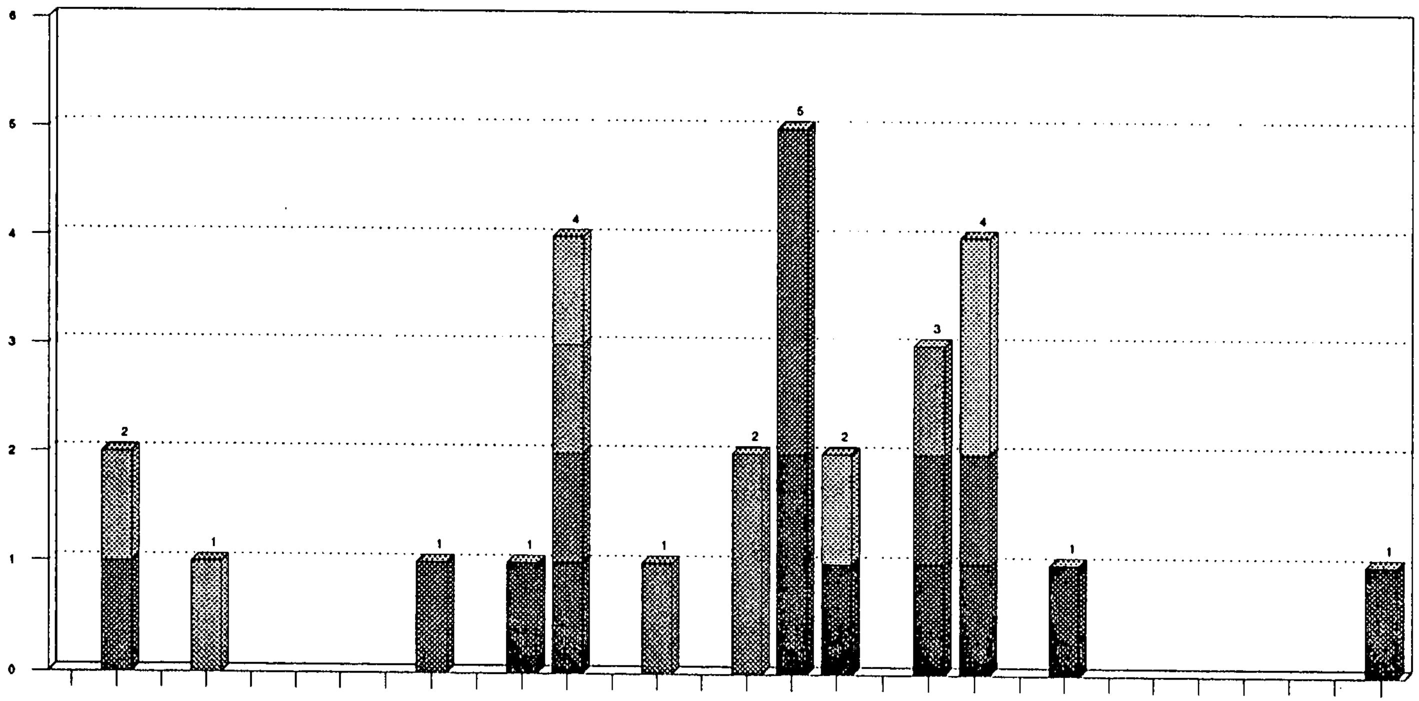
Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of Lithobis forticatus.

Number per quadrat from 22/05-18/07/90.

No. of catches.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4
18/07/90	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1
06/07/90	0	0	0	0	0	0	0	0	0	1	1	0	2	0	0
21/06/90	1	0	0	0	0	0	1	0	0	1	0	0	0	3	0
06/06/90	0	0	0	0	0	0	0	0	1	1	0	0	0	2	1

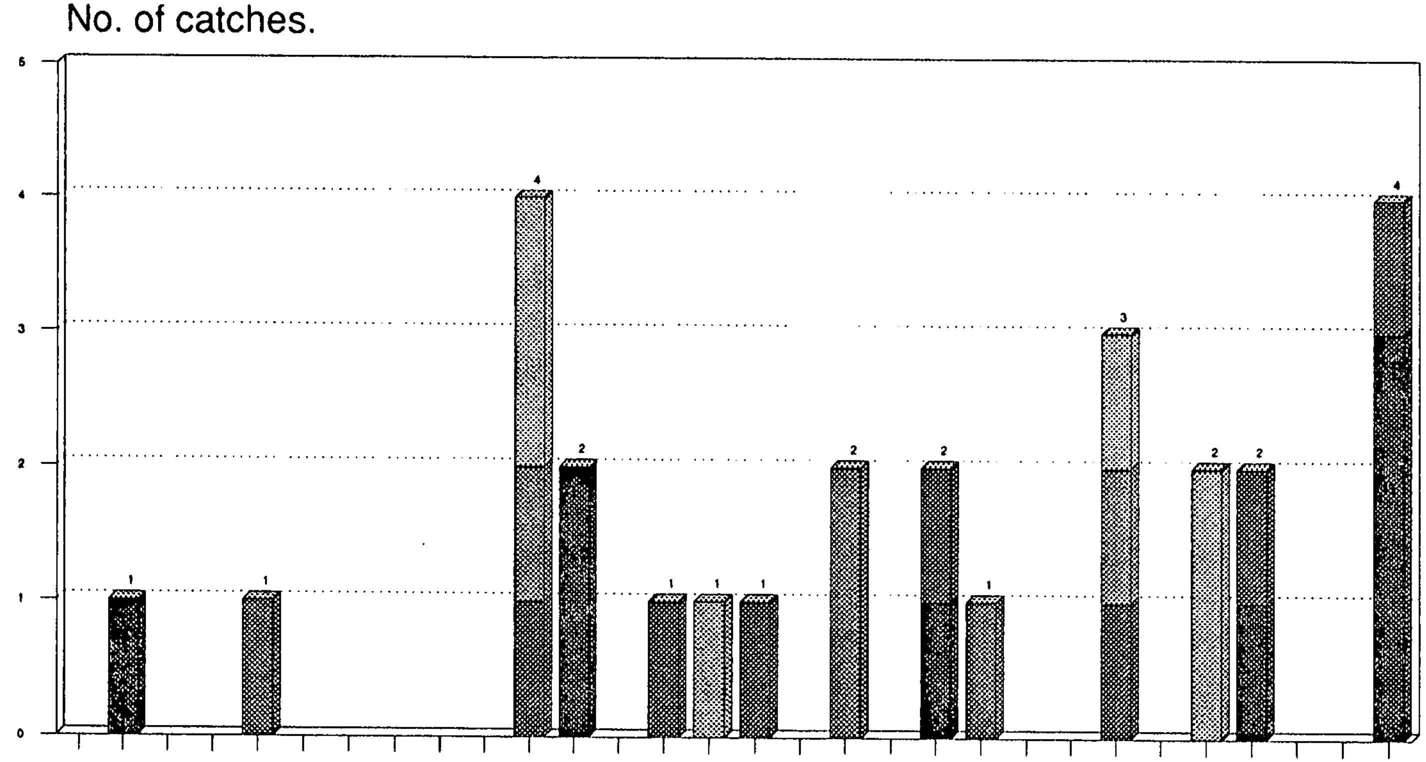
	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	0	2	0	0	0	0	0	0	0	0
06/07/90	1	0	0	0	0	0	0	0	0	0
21/06/90	1	1	0	0	0	0	0	0	0	0
06/06/90	1	1	0	1	0	0	0	0	0	1

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of Nemastoma bimaculatum

Number per quadrat from 22/05-18/07/90.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	1	2	0	0	0	0
05/07/90	0	0	0	1	0	0	0	0	1	0	0	0	0	0	2	0	1	0	0	1	0	0	0	0	0
21/06/90	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	1
06/06/90	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	1	0	0	3

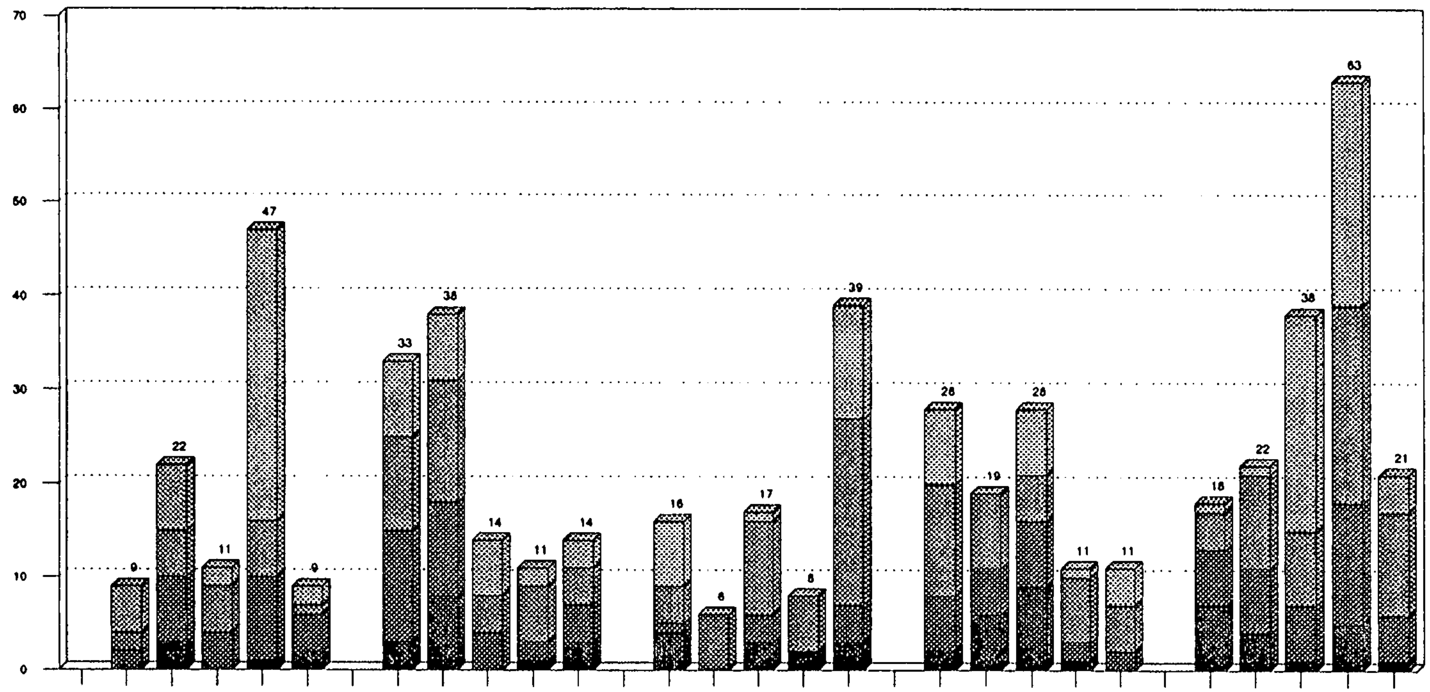
Table of catches per quadrat over time.

06/06/90   21/06/90   05/07/90   18/07/90

Pitfall catches of imago Opiliona sp.

Number per quadrat from 22/05-18/07/90.

No. of catches.



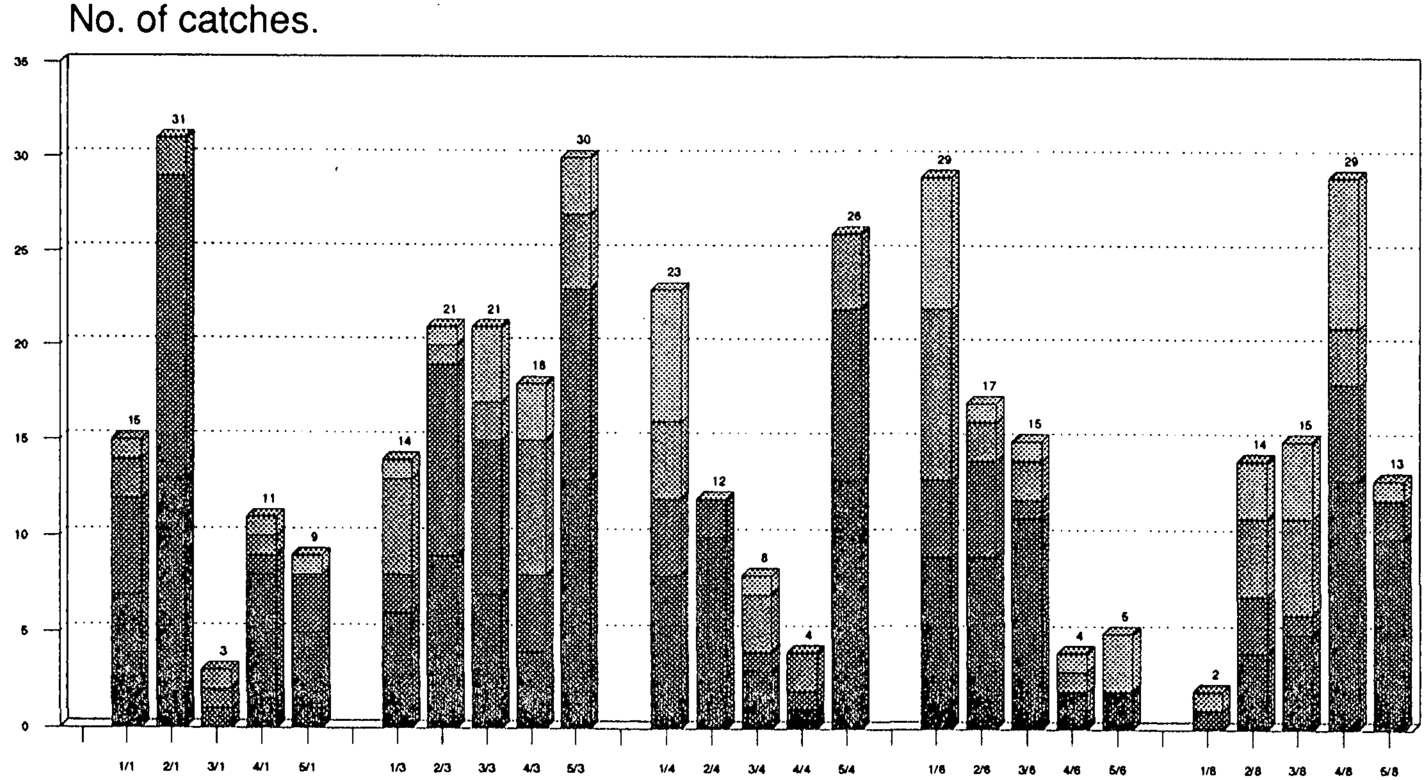
	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	5	7	2	31	2	8	7	6	2	3	7	0	1	0	12	8	0	7	1	4	1	1	23	24	4
05/07/90	2	5	5	6	1	10	13	4	6	4	4	6	10	6	20	12	8	5	7	5	4	10	8	21	11
21/06/90	2	7	4	9	4	12	10	4	2	4	1	0	3	0	4	6	5	7	2	2	6	7	6	13	5
06/06/90	0	3	0	1	2	3	5	0	1	3	4	0	3	2	3	2	6	9	1	0	7	4	1	5	1

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of juv. Opiliona sp.

Number per quadrat from 22/05-18/07/90.

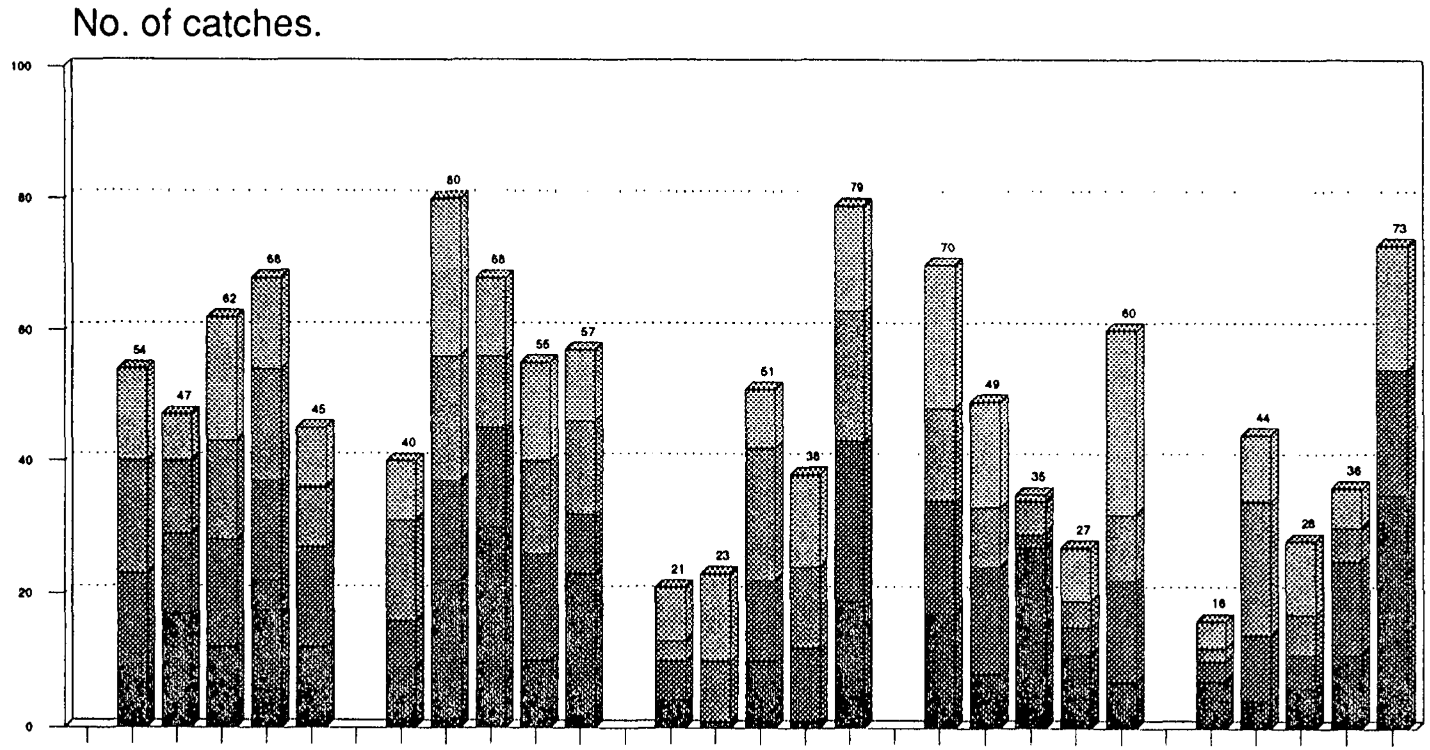


	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	1	0	1	1	1	1	1	4	3	3	7	0	1	0	0	7	1	1	1	3	1	3	4	8	1
05/07/90	2	2	1	1	0	5	1	2	7	4	4	0	3	2	4	9	2	2	1	0	0	4	5	3	0
21/06/90	5	16	1	1	3	2	10	8	4	10	4	2	1	1	9	4	5	1	0	0	1	3	1	5	2
06/06/90	7	13	0	8	5	6	9	7	4	13	8	10	3	1	13	9	9	11	2	2	0	4	5	13	10

Table of catches per quadrat over time.

Pitfall catches of Orchellia sp.

Number per quadrat from 22/05-18/07/90.

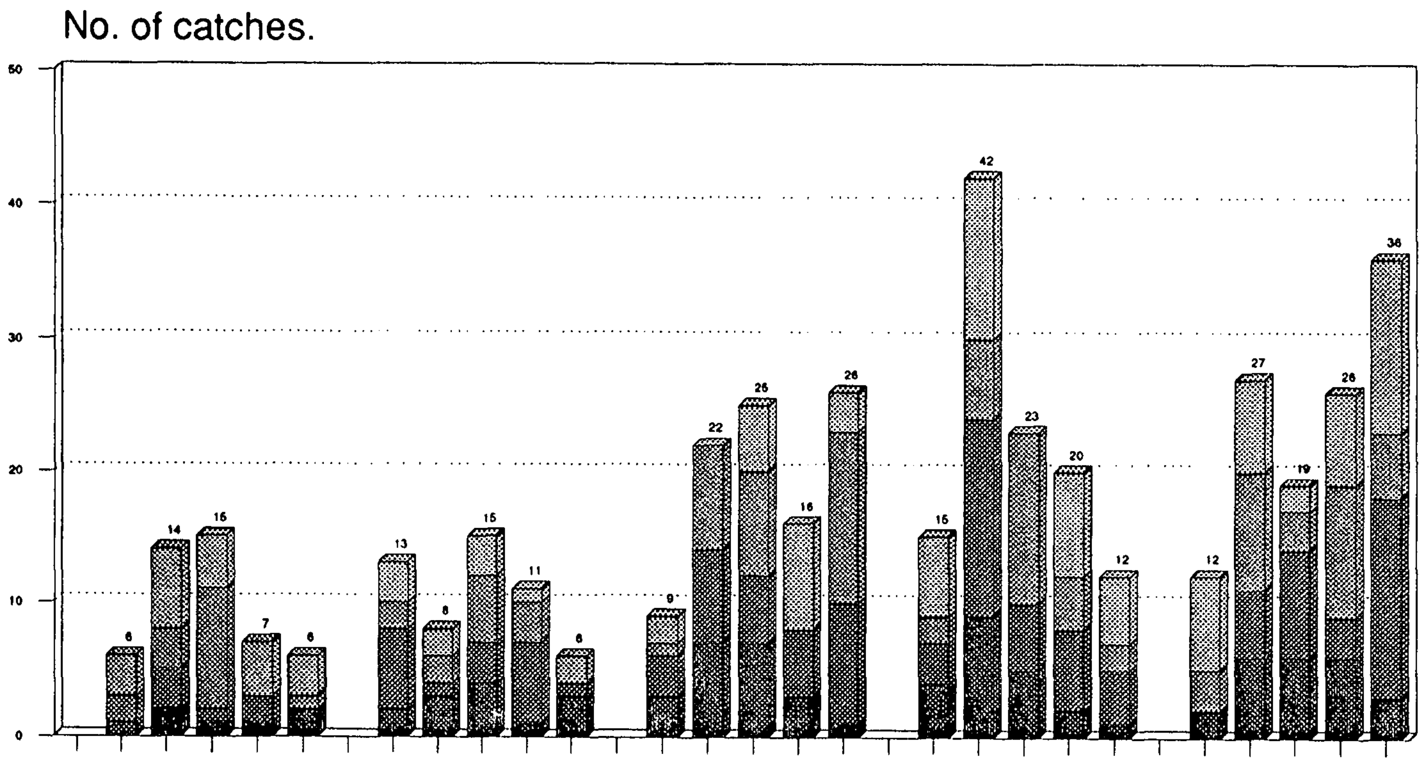


	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	14	7	19	14	9	9	24	12	16	11	8	13	9	14	16	22	16	1	8	28	4	10	11	6	19
05/07/90	17	11	15	17	9	15	19	11	14	14	3	9	20	12	20	14	9	5	4	10	2	20	6	5	0
21/06/90	12	12	16	15	15	7	15	15	16	9	6	1	12	11	24	17	16	2	4	15	3	10	5	14	19
06/06/90	11	17	12	22	12	9	22	30	10	23	4	0	10	1	19	17	8	27	11	7	7	4	6	11	35

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of parasitic wasps.
Number per quadrat from 22/05-18/07/90.



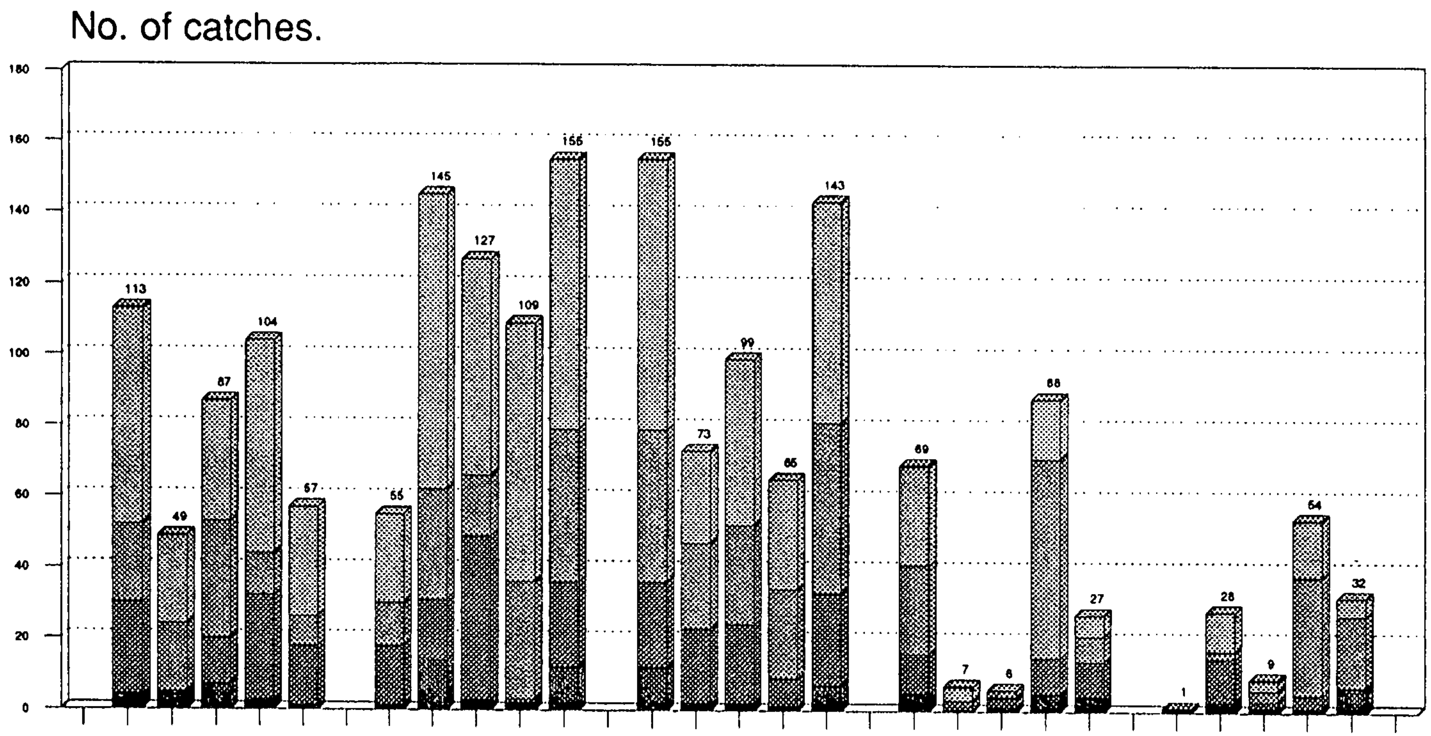
	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	3	6	4	4	3	3	2	3	1	2	2	0	5	8	3	6	12	0	8	5	7	7	2	7	13
05/07/90	2	3	9	0	1	2	2	5	3	0	1	8	8	0	13	2	6	13	4	2	3	9	3	10	5
21/06/90	1	3	1	2	0	6	1	3	6	1	3	7	5	5	9	3	15	5	6	4	0	5	8	3	15
06/06/90	0	2	1	1	2	2	3	4	1	3	3	7	7	3	1	4	9	6	2	1	2	6	6	6	3

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of Philoscia muscorum.

Number per quadrat from 06/06-18/07/90.

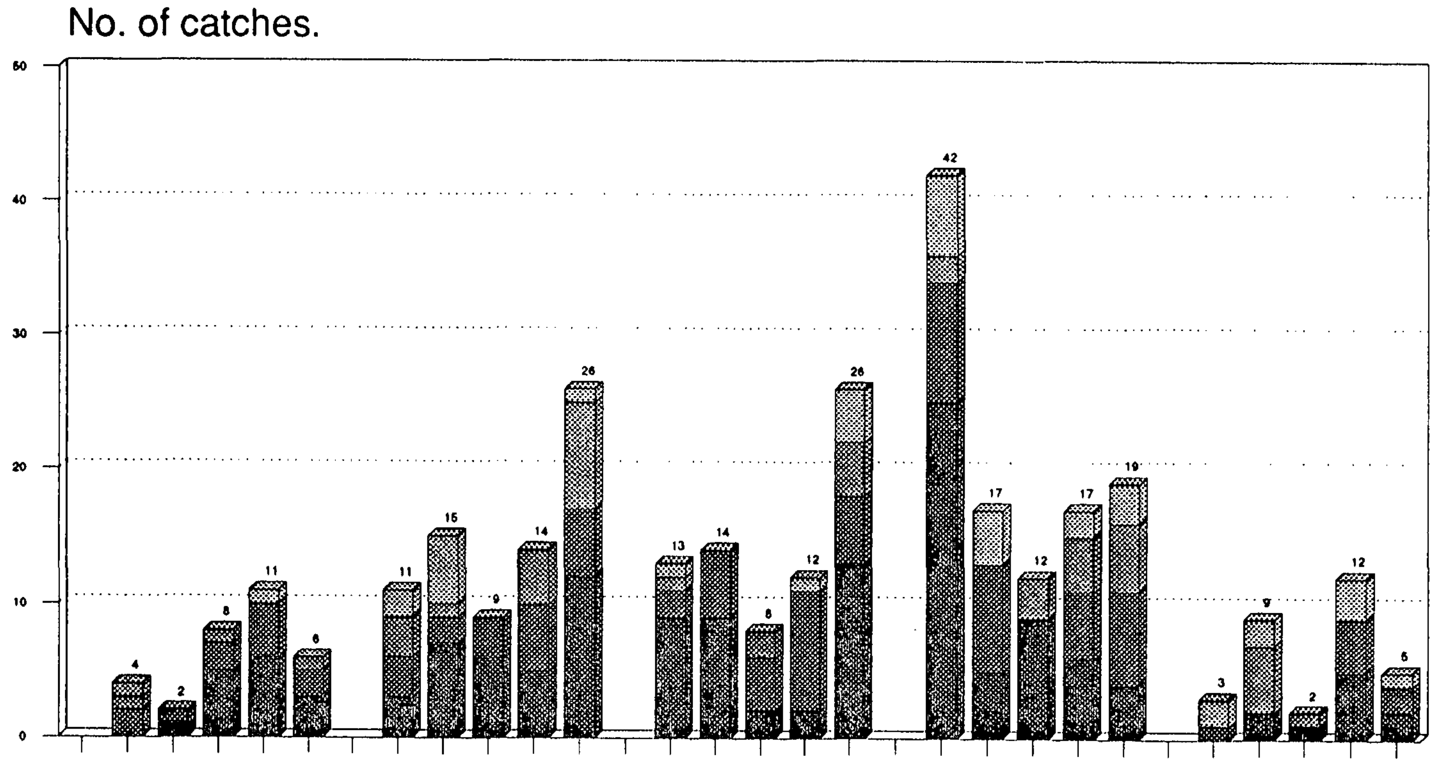


	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8	
18/07/90	61	25	34	60	31	25	83	61	73	76	76	26	47	31	62	28	4	0	17	6	0	11	3	16	6	0
06/07/90	22	19	33	12	8	12	31	17	33	43	43	24	28	25	48	25	3	2	56	7	0	2	3	33	20	0
21/06/90	26	1	13	29	17	17	17	46	1	24	24	21	22	8	26	11	0	3	10	10	0	12	2	4	1	0
06/06/90	4	4	7	3	1	1	14	3	2	12	12	2	2	1	7	6	0	1	5	4	1	3	1	1	6	0

Table of catches per quadrat from time.

Pitfall catches of Phyllobius angustum.

Number per quadrat from 22/05-18/07/90.

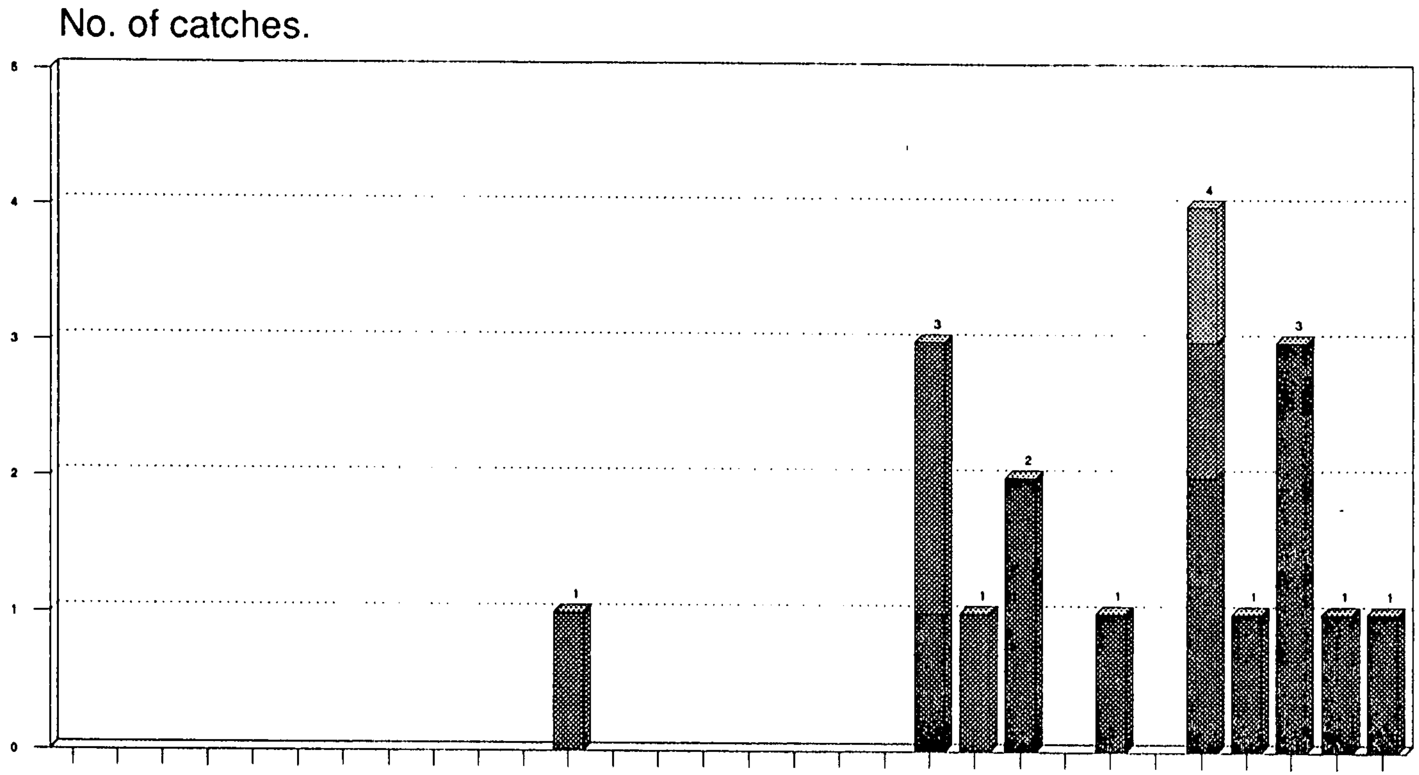


	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	1	0	0	1	0	2	5	0	0	1	1	0	0	1	4	6	4	0	2	3	2	2	0	3	1
05/07/90	1	0	1	0	1	3	1	0	4	8	1	0	2	0	4	2	0	3	4	5	0	5	1	0	0
21/06/90	2	1	2	4	2	3	2	3	5	5	2	5	4	9	5	9	8	0	5	7	1	0	0	4	2
06/06/90	0	1	5	6	3	3	7	6	5	12	9	9	2	2	13	25	5	9	6	4	0	2	1	5	2

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of Phyllotreta undulata.
Number per quadrat from 22/05-18/07/90.



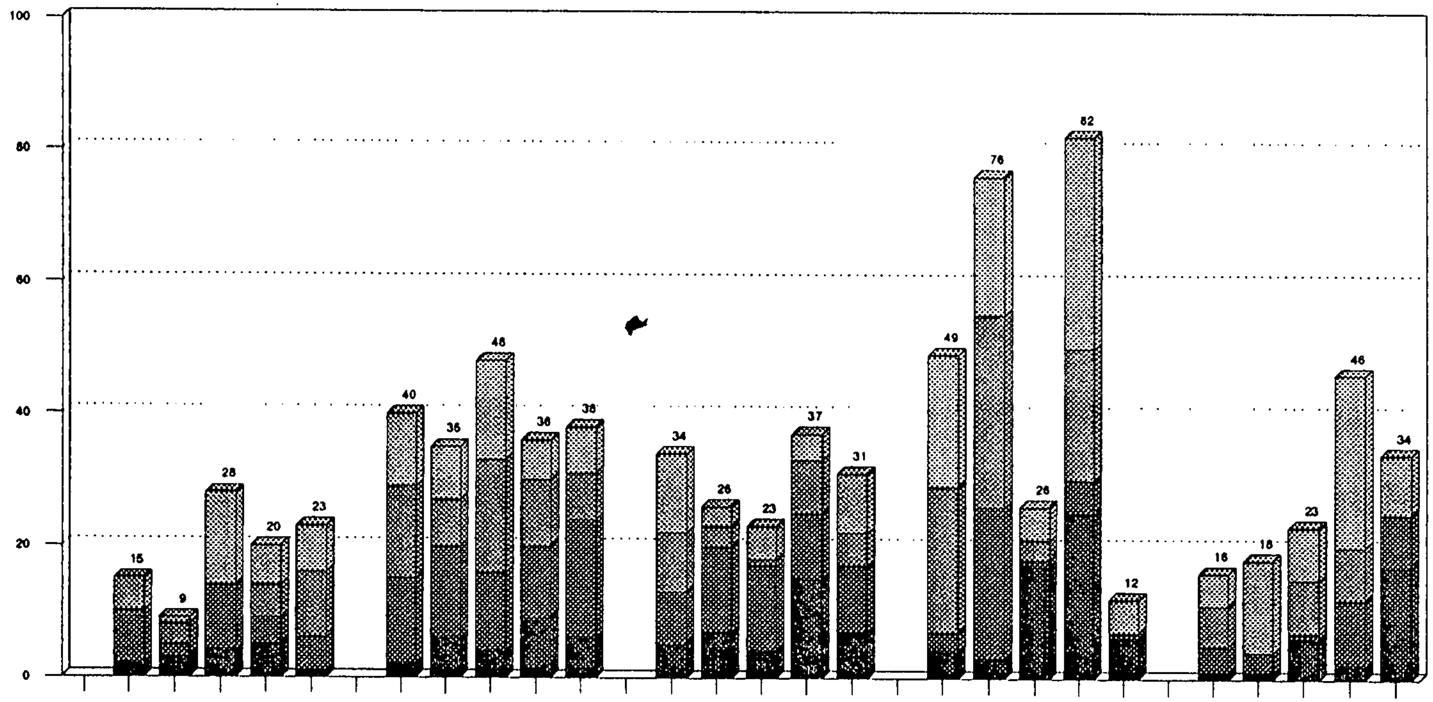
	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06/07/90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
21/06/90	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	1	0	0	0	1	0	0	0	0
06/06/90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	2	1	3	1	1

Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

Pitfall catches of Staphylinidae.

Number per quadrat from 22/05-18/07/90.



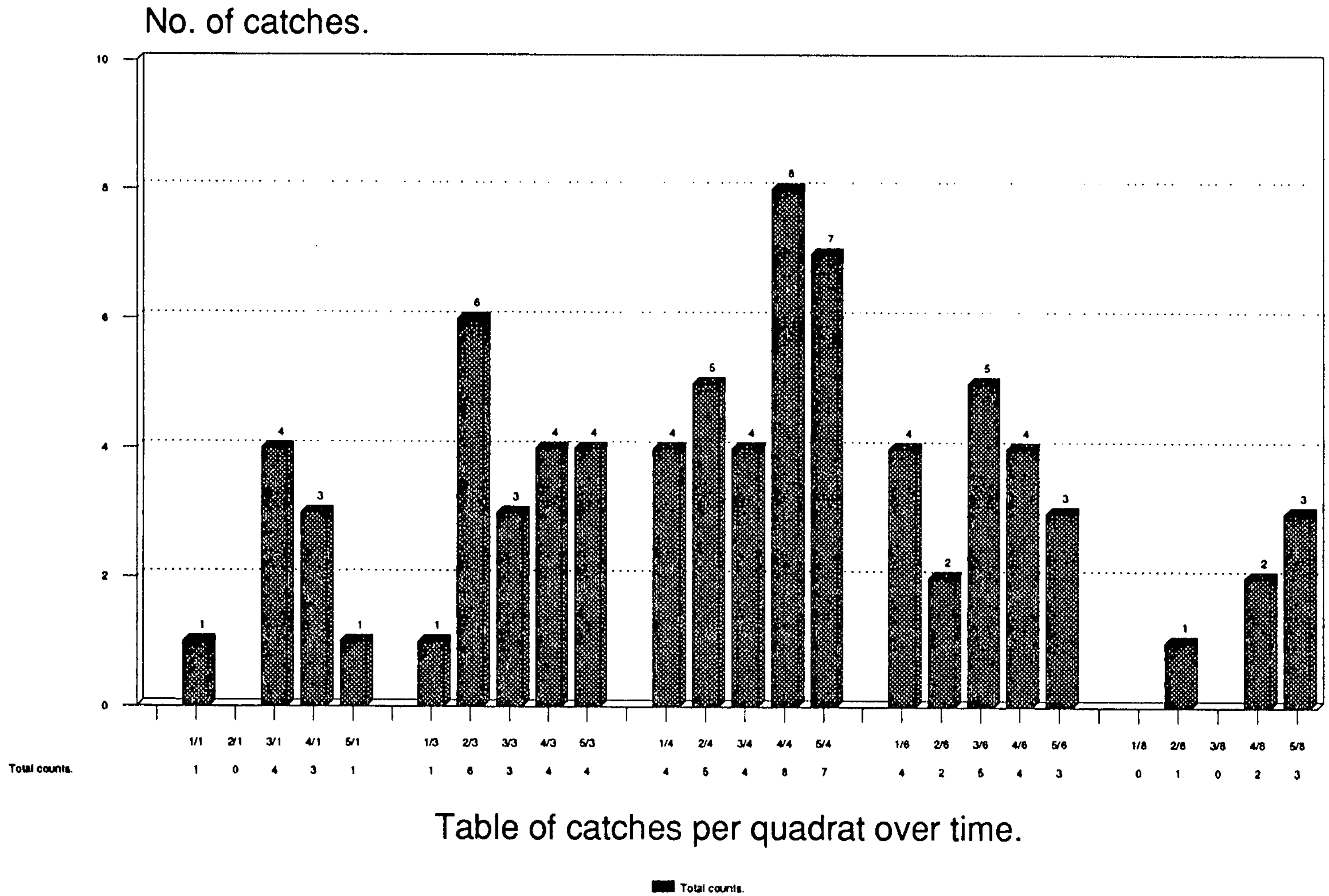
	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	5	1	14	6	7	11	8	15	6	7	12	3	5	4	9	20	21	5	32	5	5	14	8	28	9
05/07/90	1	3	0	5	10	14	7	17	10	7	9	3	1	8	5	22	29	3	20	0	6	0	8	6	0
21/06/90	7	2	10	4	5	13	14	12	11	18	8	13	13	10	10	3	23	1	5	1	4	3	1	10	8
06/06/90	2	3	4	5	1	2	6	4	9	6	5	7	4	15	7	4	3	17	25	6	1	1	6	2	17

Table of catches per quadrat over time.

06/06/90   21/06/90   05/07/90   18/07/90

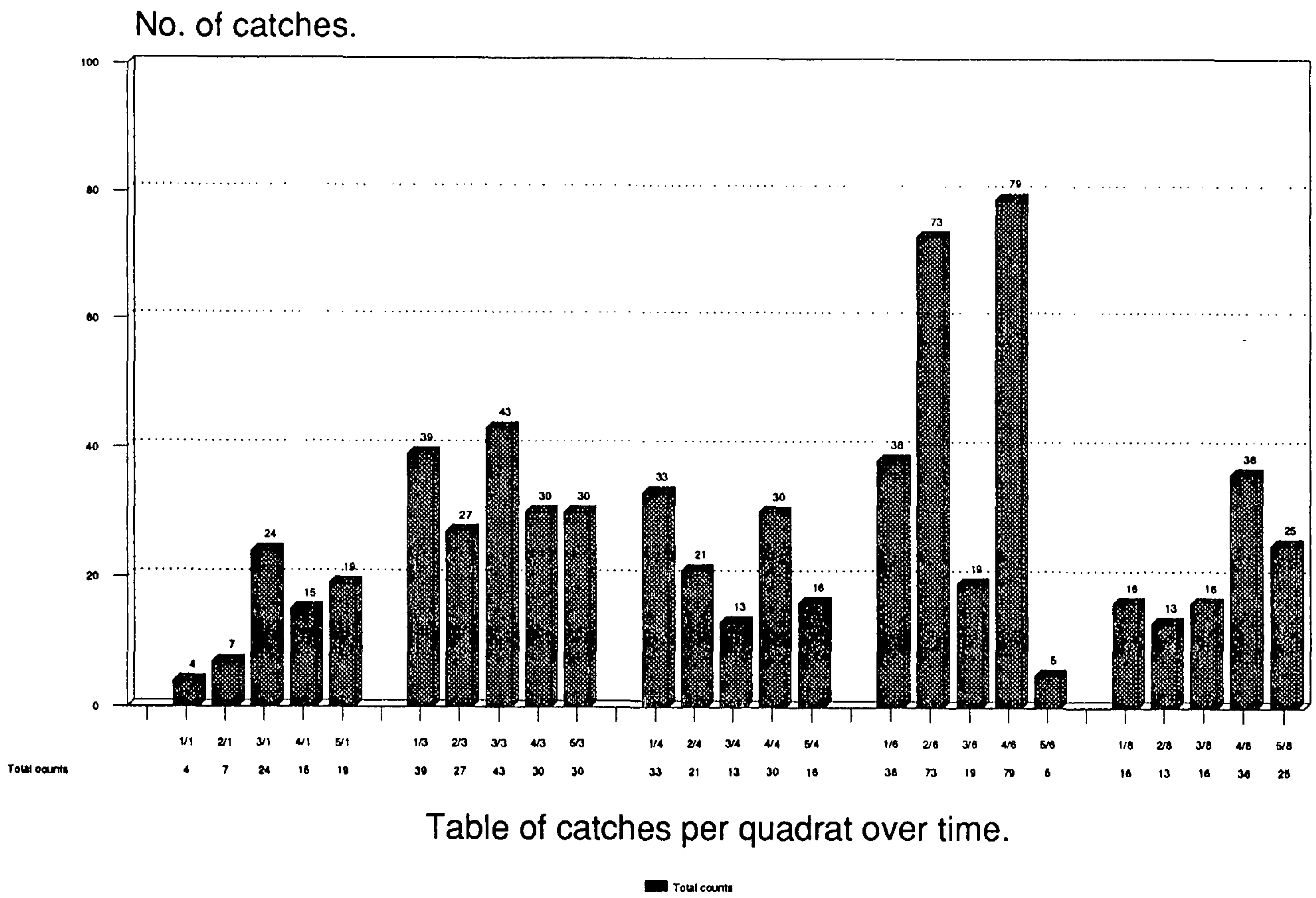
Pitfall catches of Staphilinidae <5mm.

Number per quadrat from 22/05-18/07/90.

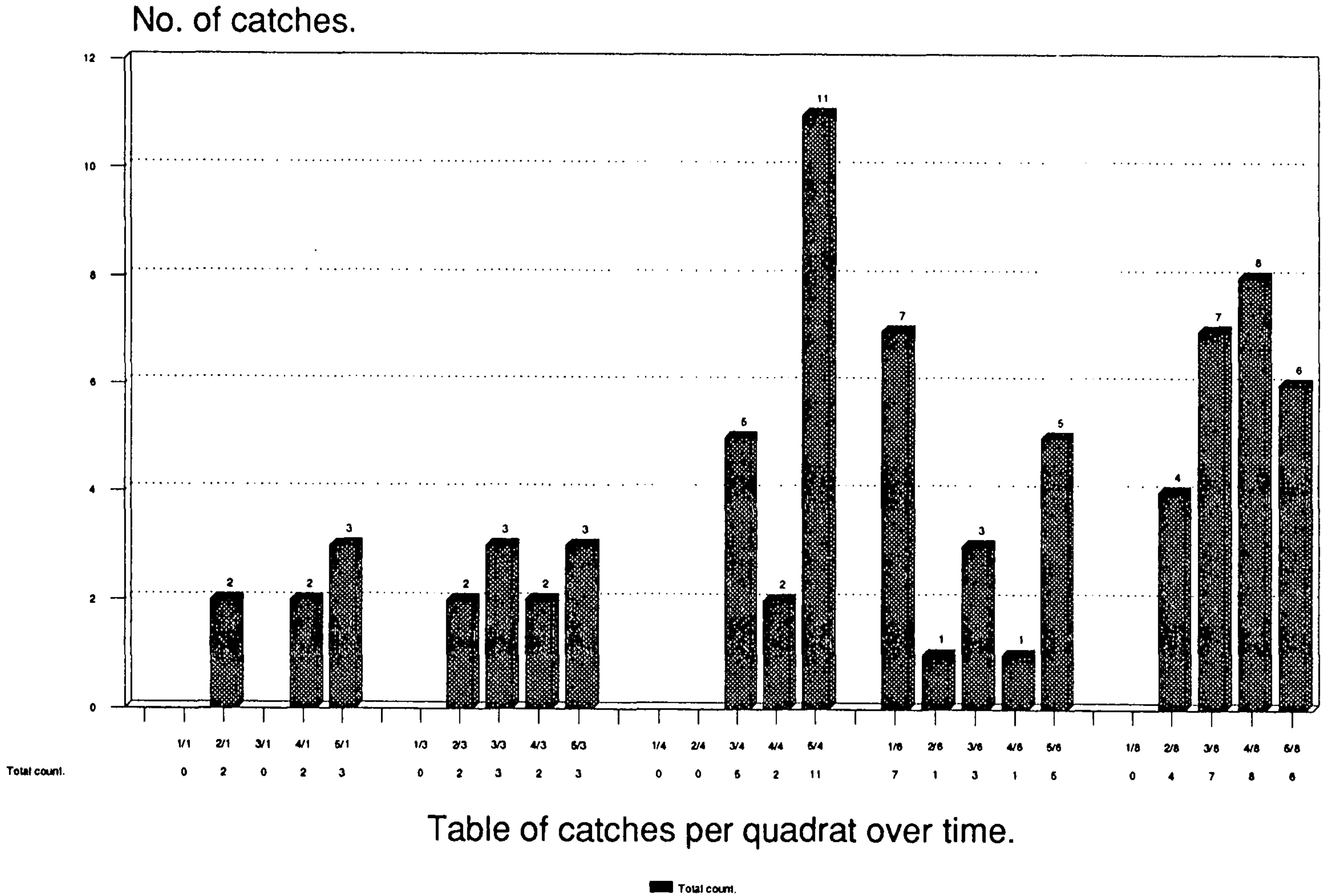


Pitfall catches of Staphilinidae 5-10mm.

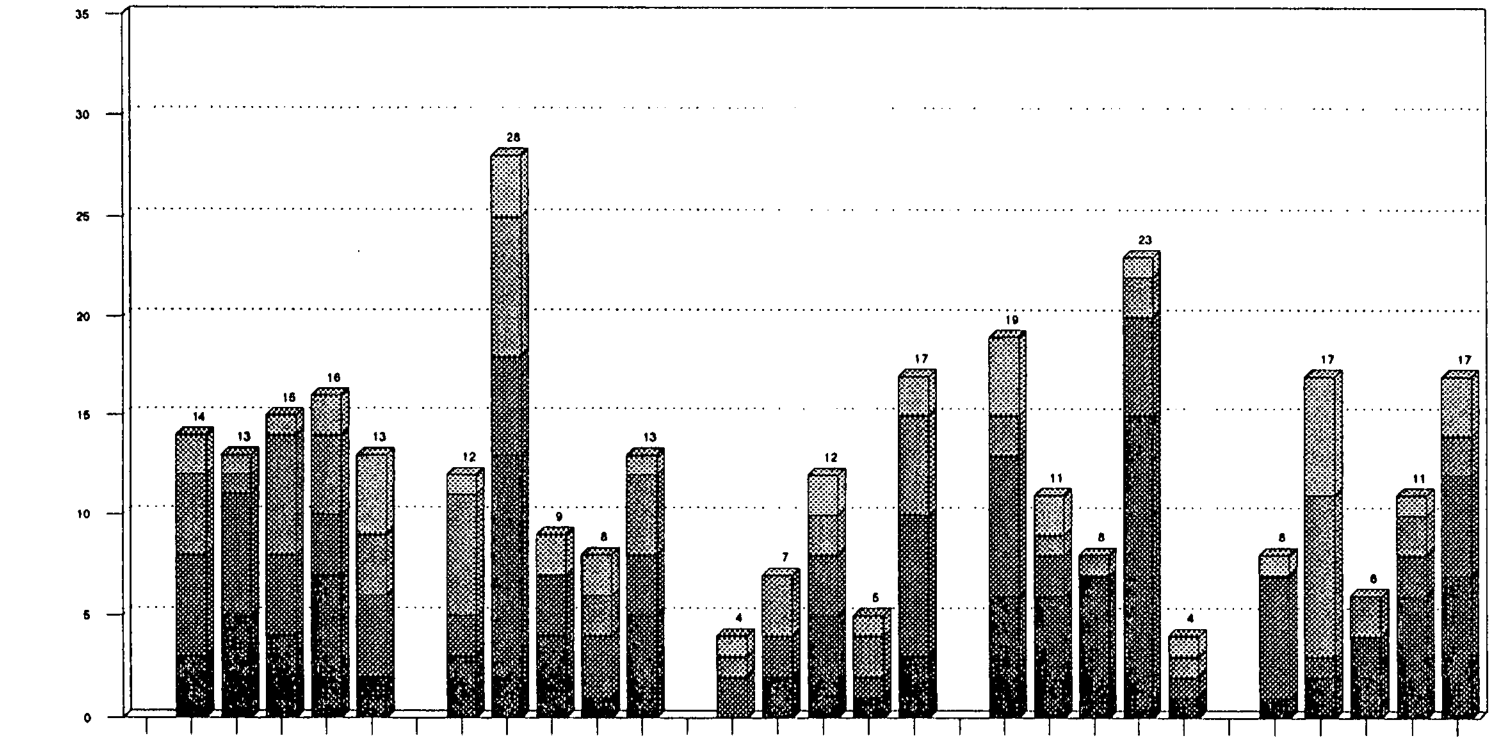
Number per quadrat from 22/05-18/07/90.



Pitfall catches of Staphalinidae >10mm.
Number per quadrat from 22/05-18/07/90.



Pitfall catches of Tachypodoiulus niger.
Number per quadrat from 22/05-18/07/90.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	2	1	1	2	4	1	3	2	2	1	1	0	2	1	2	4	2	0	1	1	1	6	0	1	3
05/07/90	4	1	6	4	3	6	7	0	2	4	1	3	2	2	5	2	1	1	2	1	0	8	2	2	2
21/06/90	5	6	4	3	4	2	5	3	3	3	2	2	3	1	7	7	2	0	5	1	6	1	0	2	5
06/06/90	3	5	4	7	2	3	13	4	1	5	0	2	5	1	3	6	6	7	15	1	1	2	4	6	7

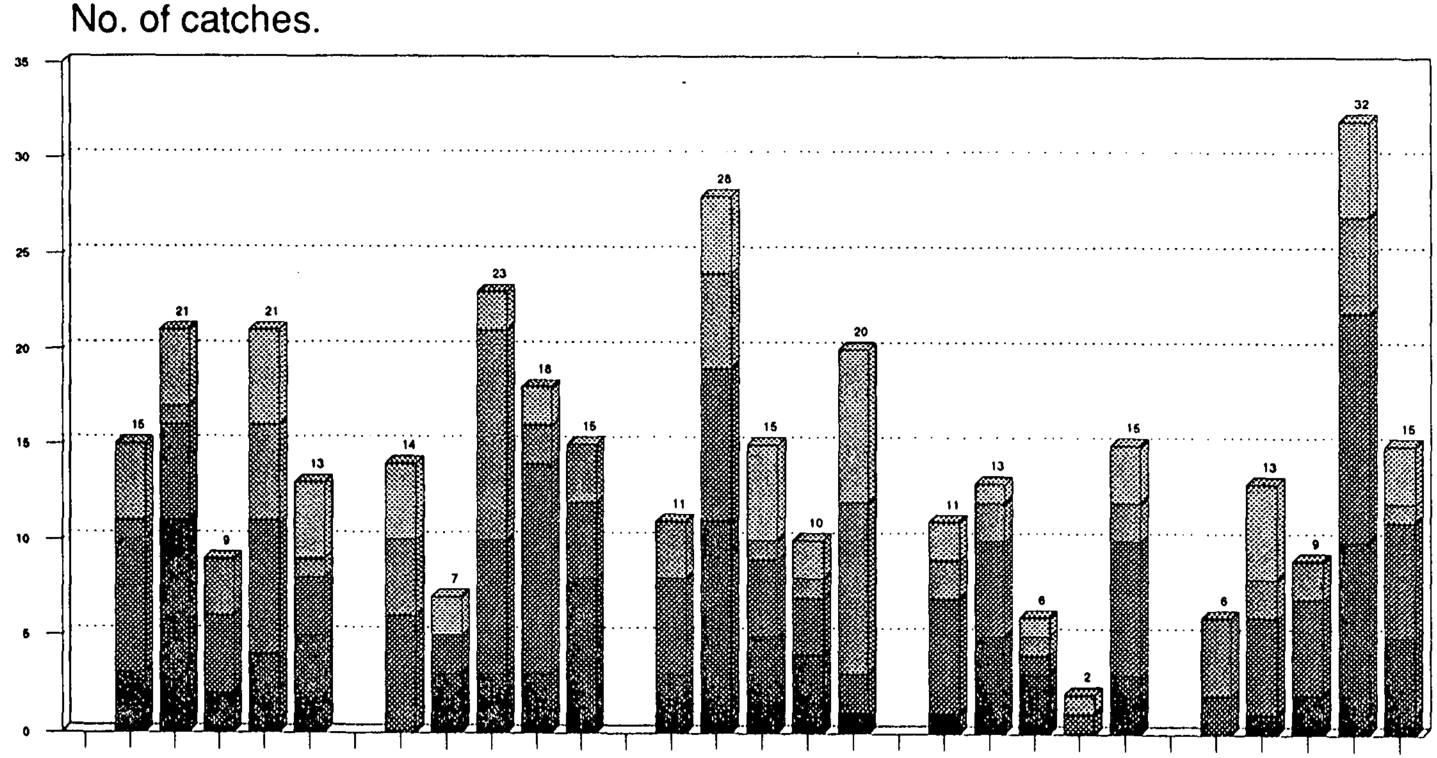
Table of catches per quadrat over time.

06/06/90 21/06/90 05/07/90 18/07/90

- A47 -

Pitfall catches of Curculionidae.

Number per quadrat from 22/05-18/07/90.

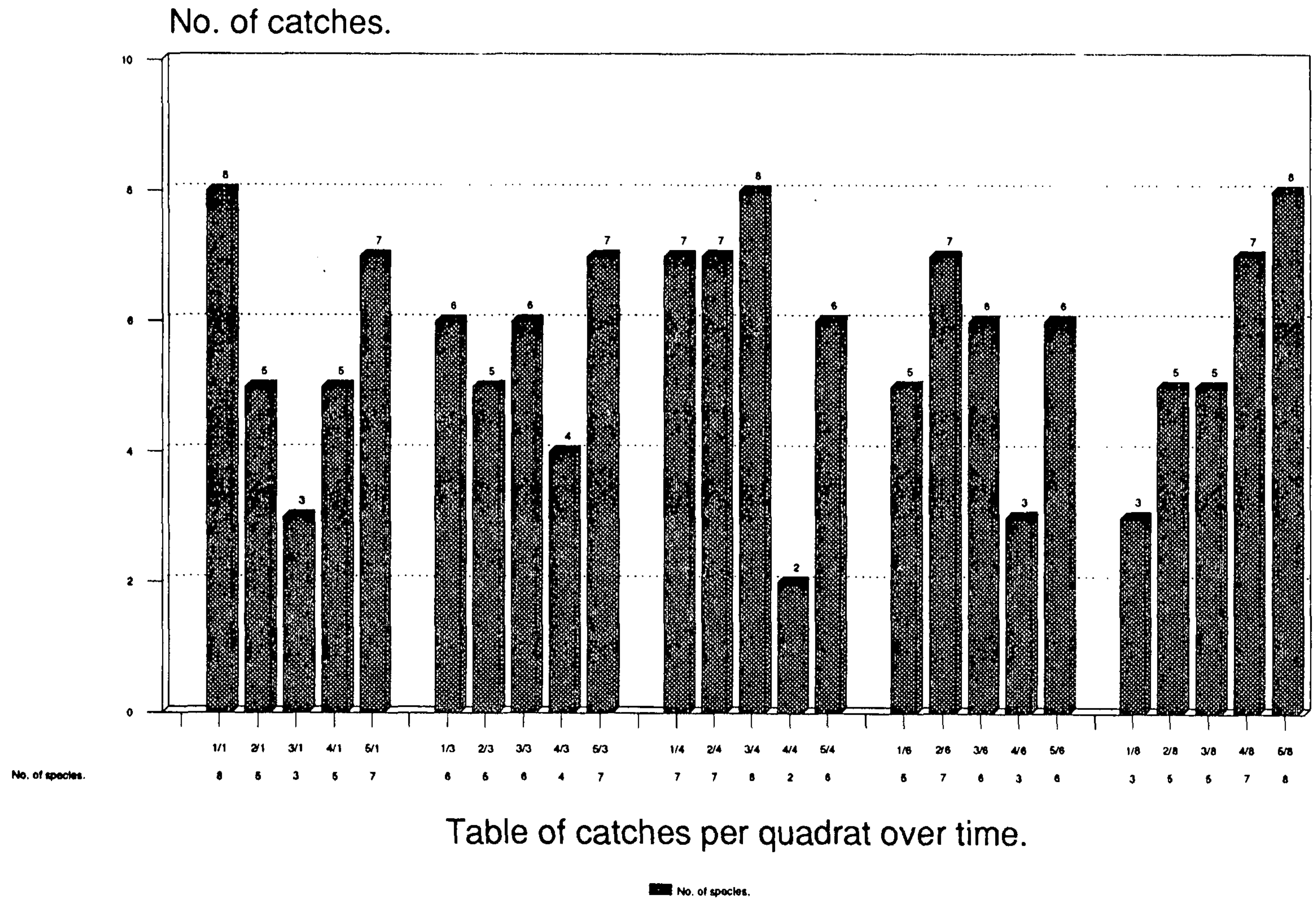


	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
18/07/90	4	4	0	5	4	4	2	2	2	0	0	4	5	2	8	2	1	1	1	3	0	5	0	5	3
05/07/90	1	1	3	5	1	4	0	11	2	3	3	5	1	1	9	2	2	1	1	2	4	2	2	5	1
21/06/90	7	5	4	7	3	6	2	7	11	4	5	8	4	3	2	6	5	1	0	7	2	5	5	12	6
08/06/90	3	11	2	4	5	0	3	3	3	8	3	11	5	4	1	1	5	3	0	3	0	1	2	10	5

Table of catches per quadrat over time.

08/06/90 21/06/90 05/07/90 18/07/90

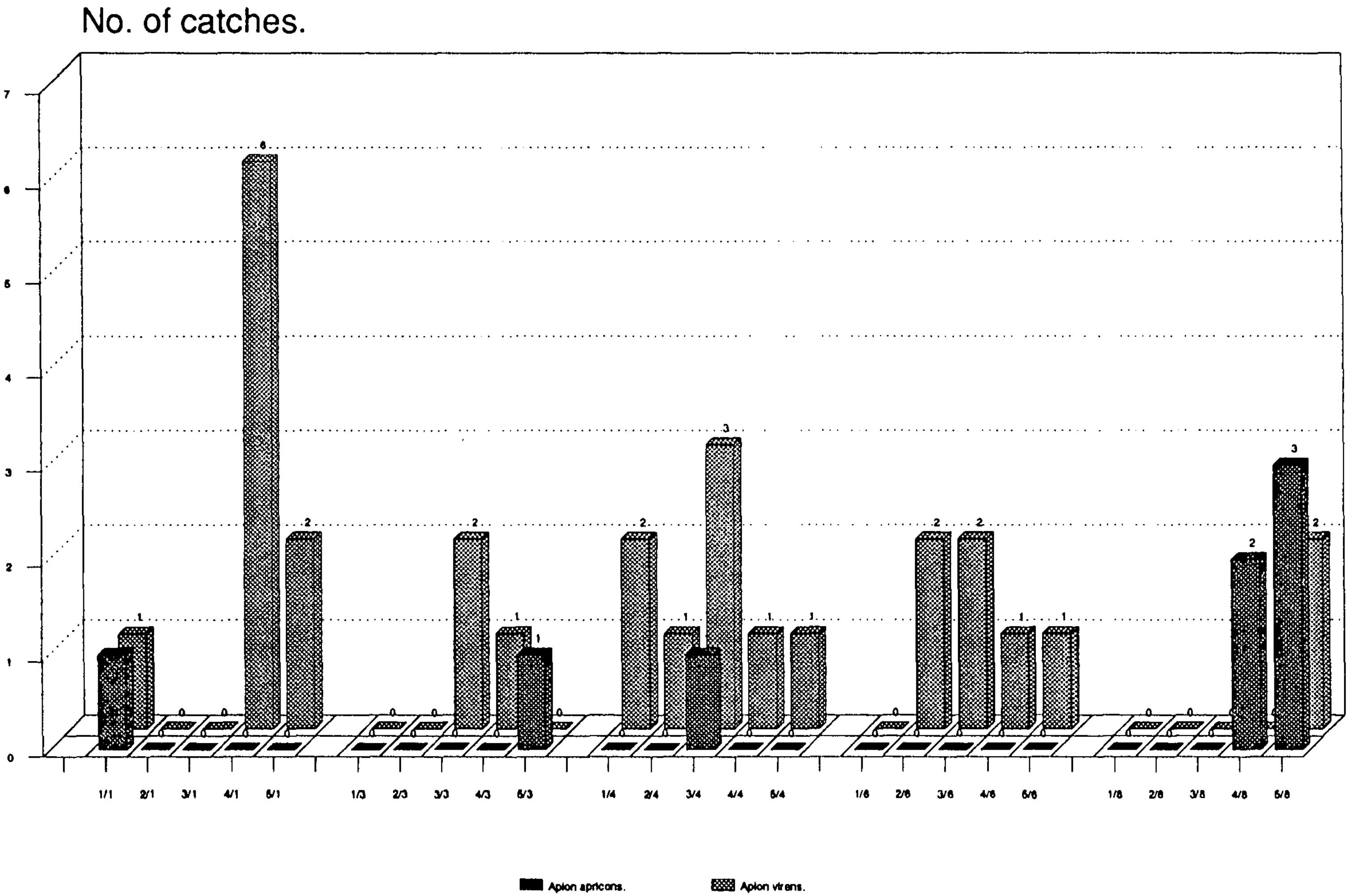
Number of weevil species per quadrat from 22/05-18/07/90.



Pitfall catchs.

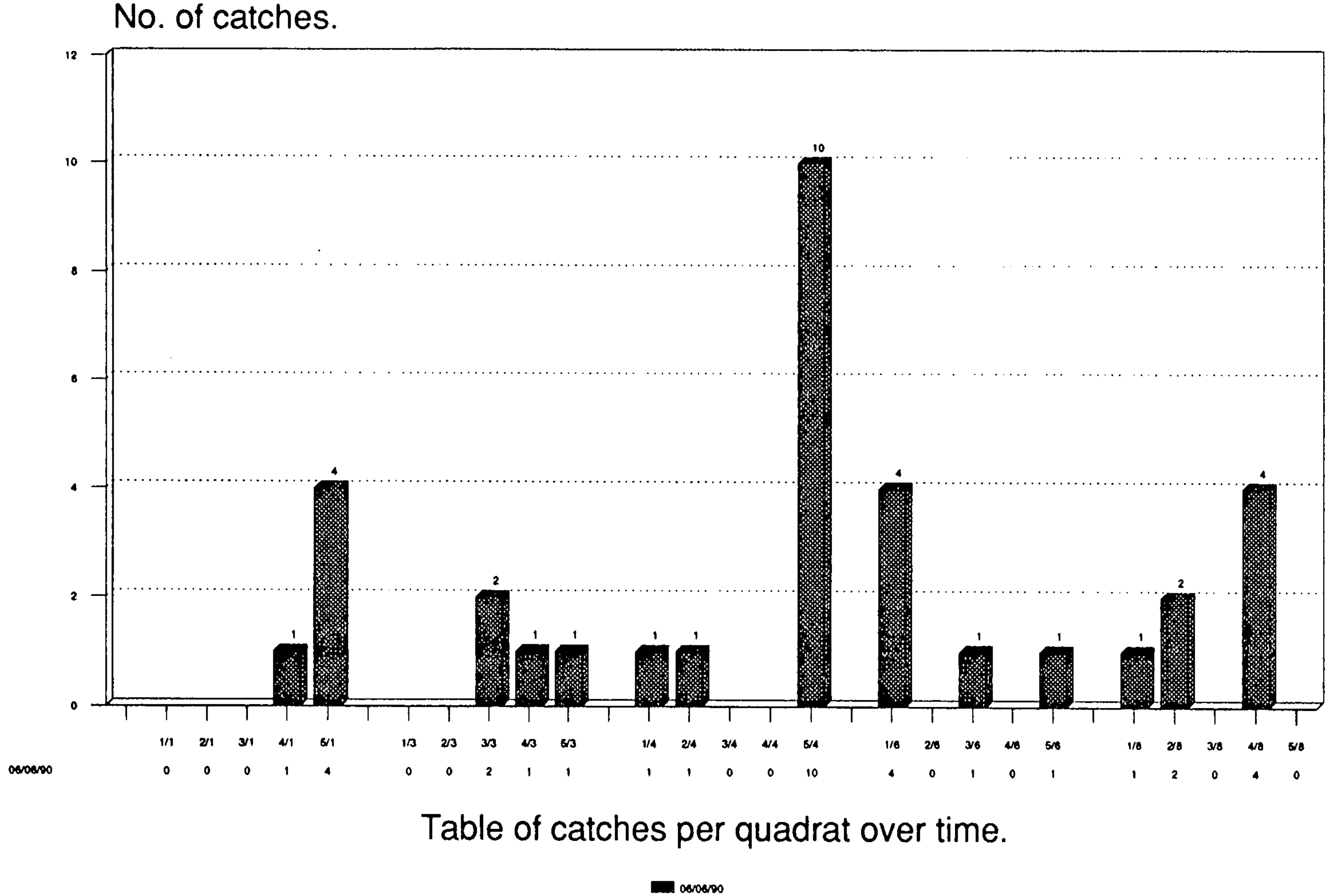
Pitfall catches of two Apion species.

Number per quadrat from 22/05-18/07/90.



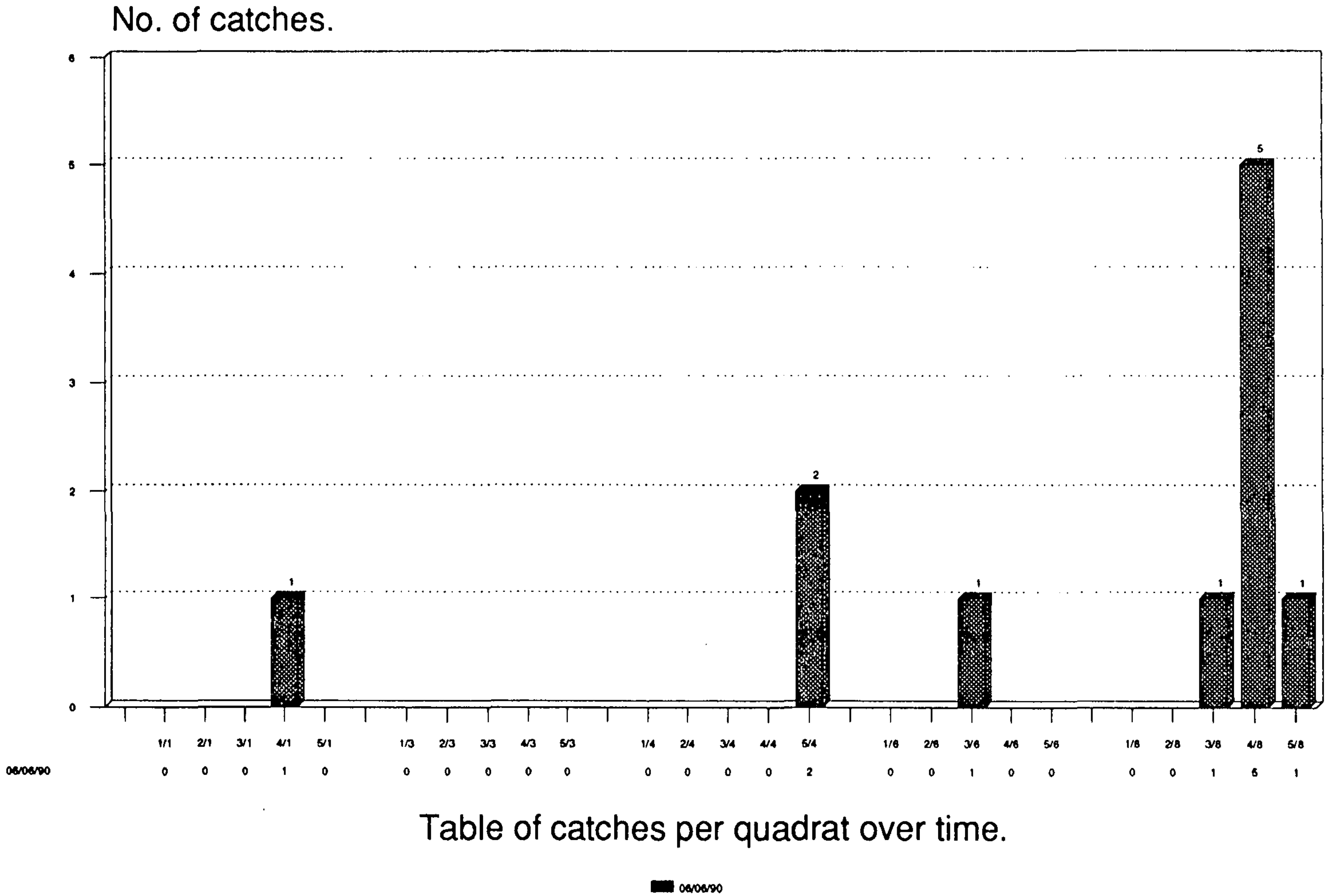
Pitfall catches of Barynotes elevatus.

Number per quadrat from 22/05-18/07/90.



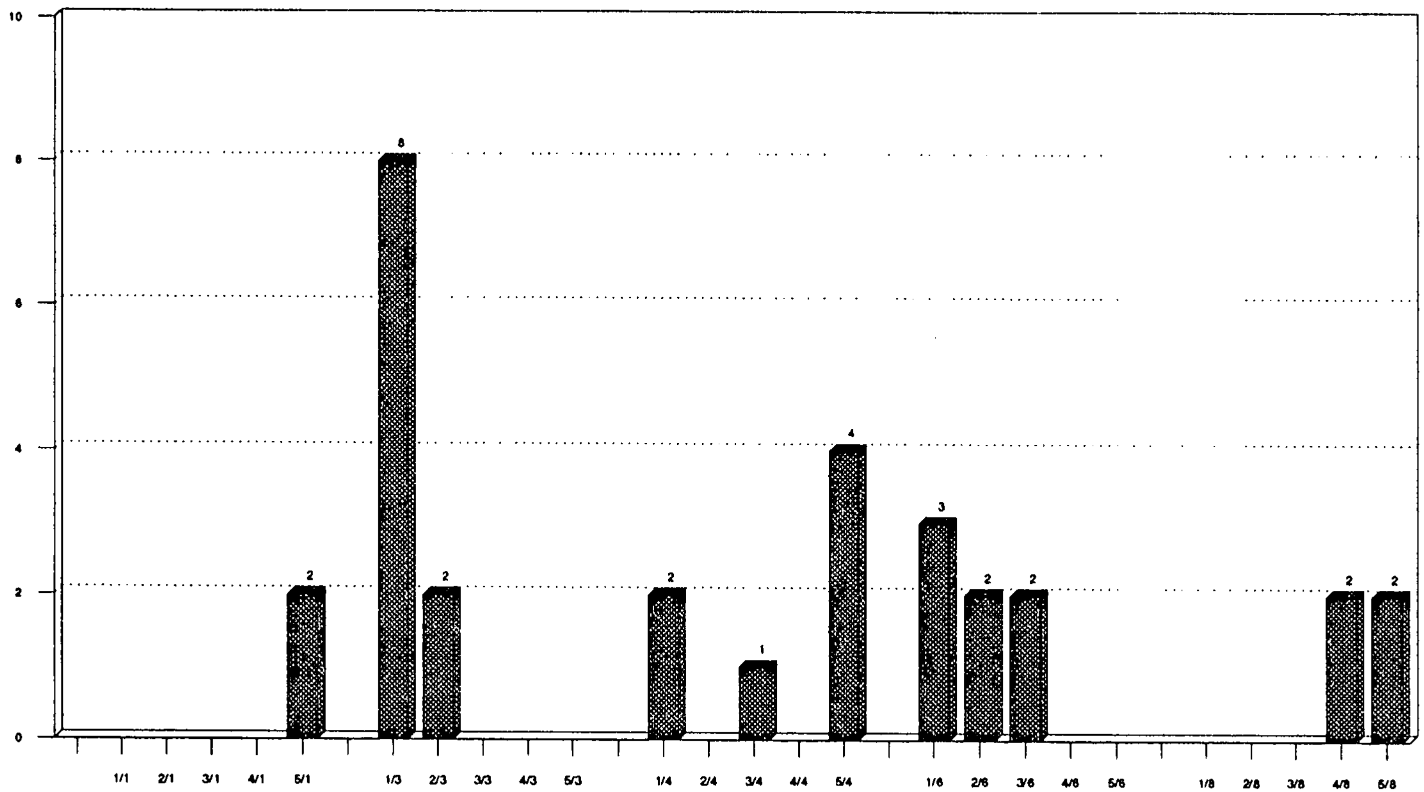
Pitfall catches of Barynotus obscurus.

Number per quadrat from 22/05-18/07/90.



Pitfall catches of Barynotus squamosus.

Number per quadrat from 22/05-18/07/90.



	1/1	2/1	3/1	4/1	5/1	1/3	2/3	3/3	4/3	5/3	1/4	2/4	3/4	4/4	5/4	1/6	2/6	3/6	4/6	5/6	1/8	2/8	3/8	4/8	5/8
06/06/90	0	0	0	0	2	8	2	0	0	0	2	0	1	0	4	3	2	2	0	0	0	0	0	2	2

Table of catches per quadrat over time.

06/06/90

Ceuthorrhynchidius troglodytes.

Number per quadrat from 22/05-18/07/90.

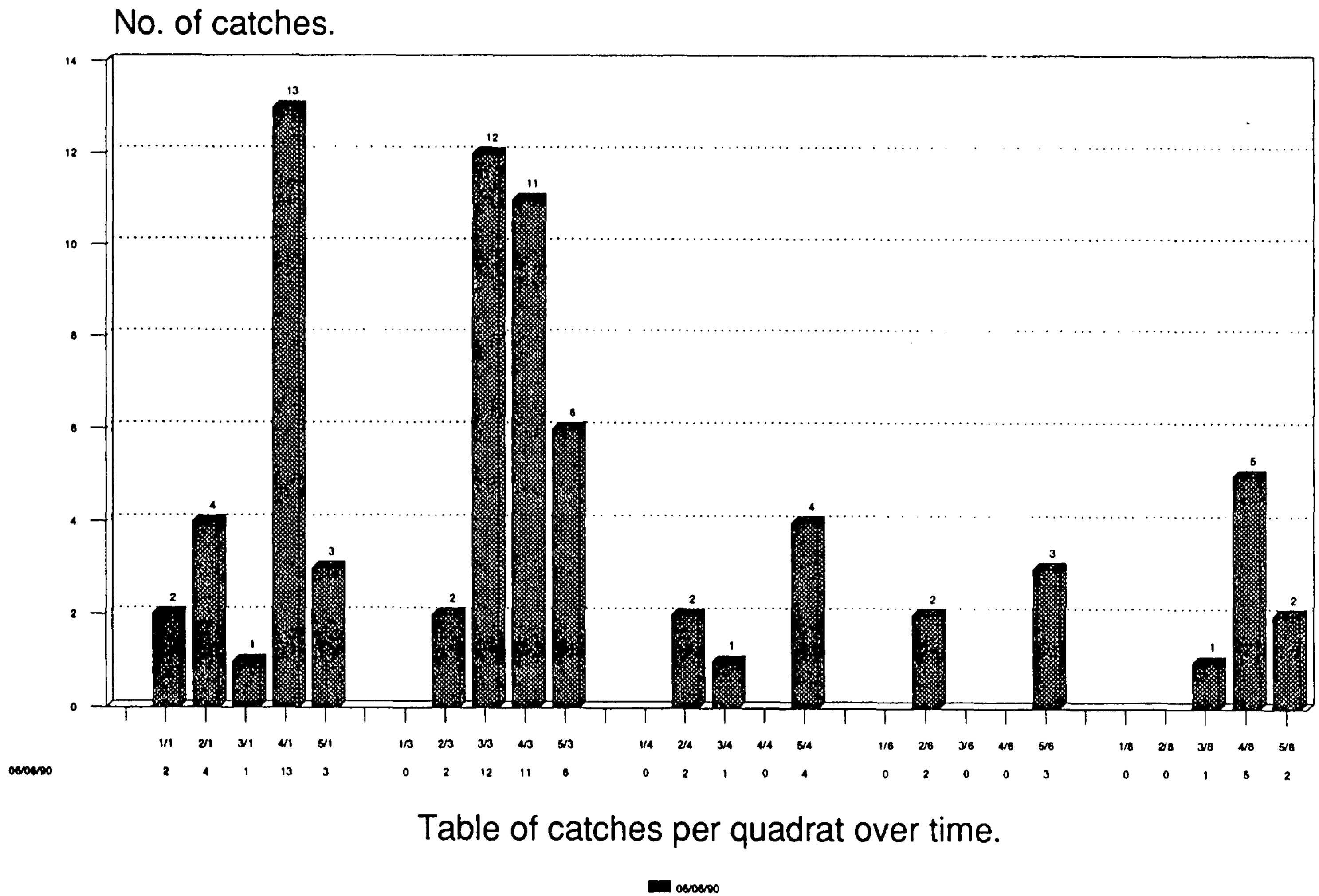
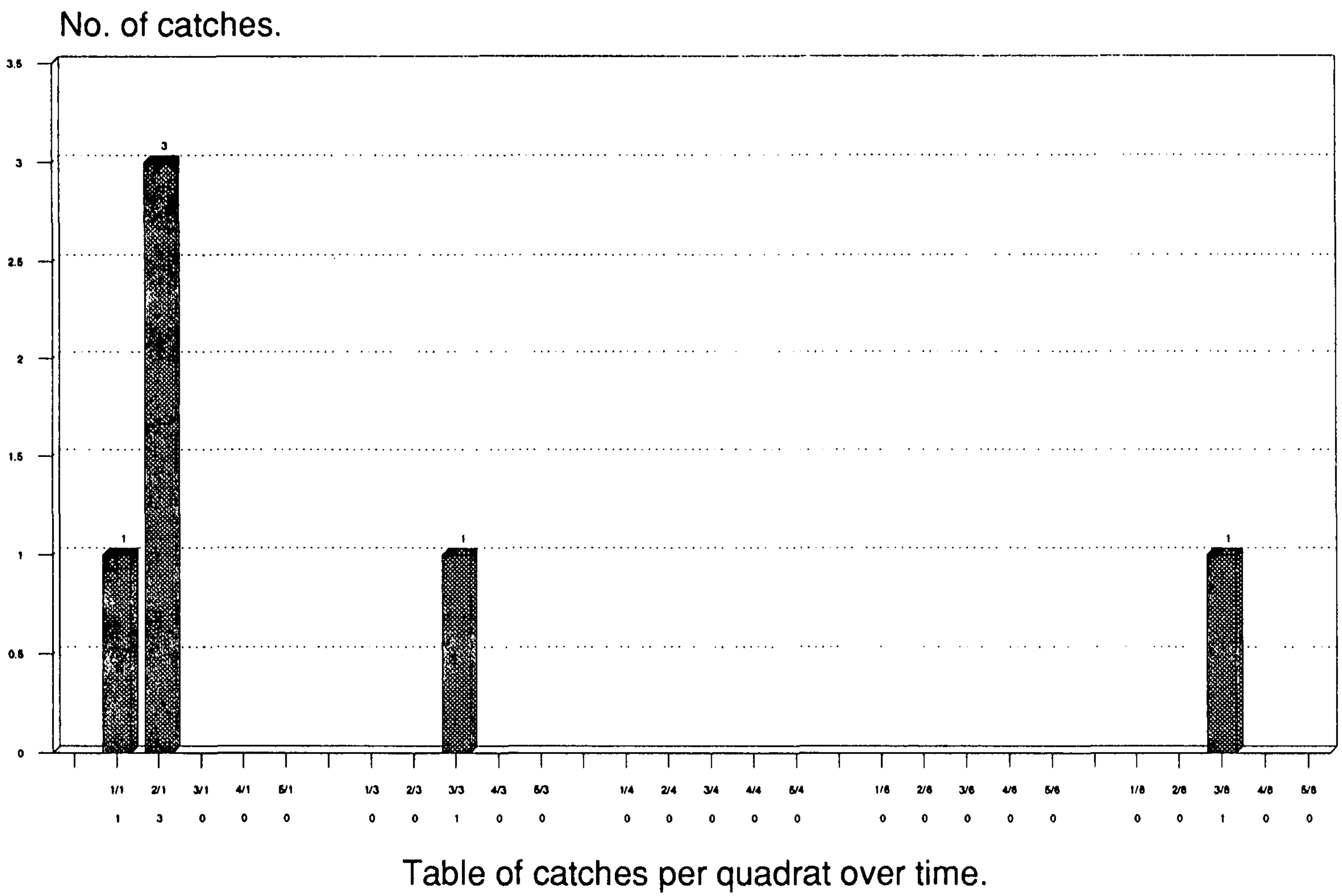


Table of catches per quadrat over time.

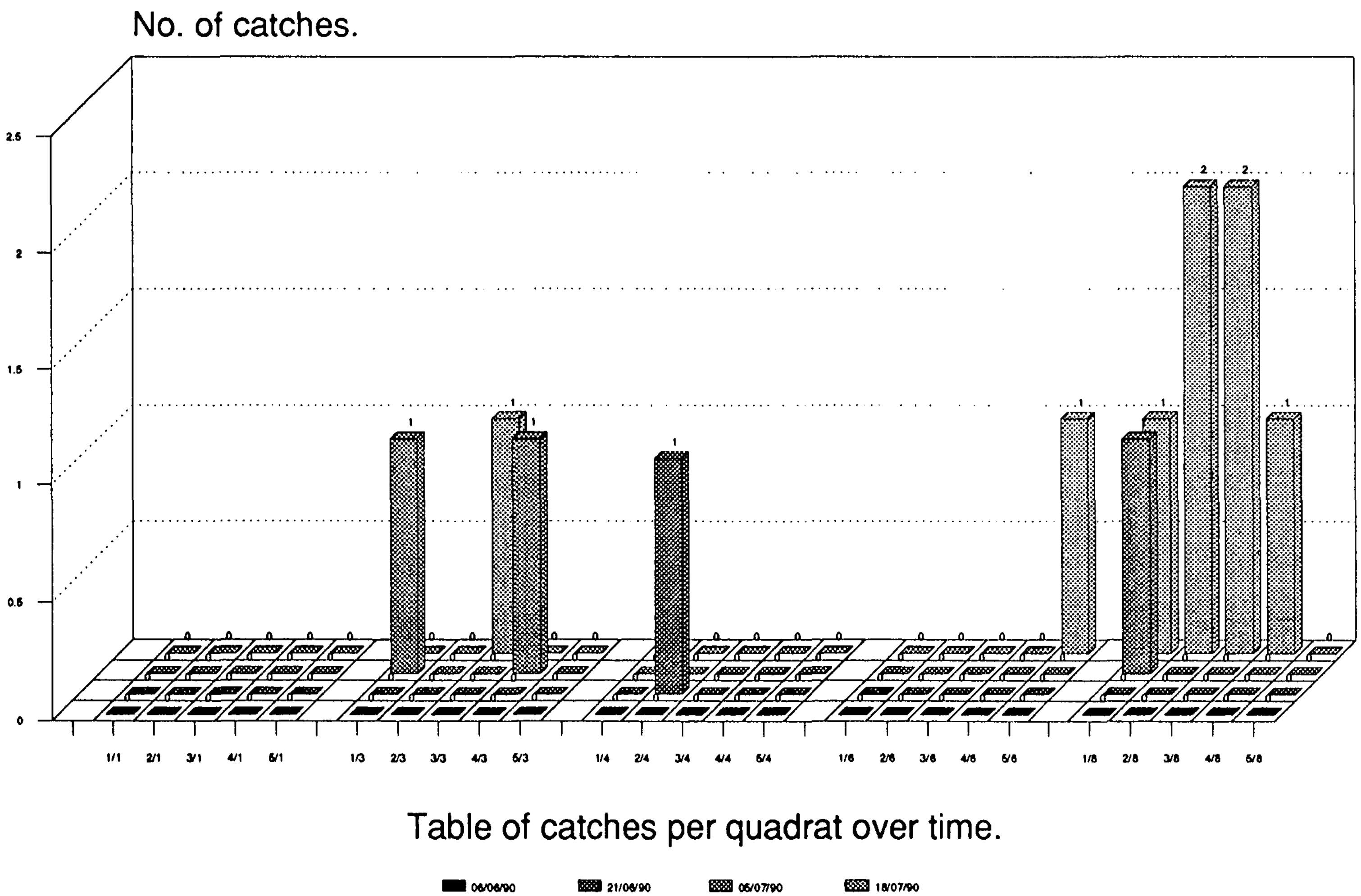
Pitfall catches of Orthocheates setiger.

Number per quadrat from 22/05-18/07/90.



Pitfall catches of Sorex minutous.

Number per quadrat from 22/05-18/07/90.



Thrislington transplant vegetation list.

Part 1 - Table of the 82 plant species occuring within the 25 2x2m/2 quadrats.

Species. Sites=	1	3	4	6	8
Acer pseudplantanus				x	
Achillea millifolium	x	x		x	x
Agrimonia eupatoria	x	x	x	x	x
Agrostis stolonifera		x			
Agrostis tenuis	x				
Anthyllis vulneraria		x		x	x
Arenaria serphyllifolia		x	x	x	
Arrhenatherum elatius	x	x	x	x	x
Brachypodium sylvaticum	x	x	x	x	x
Briza media	x	x	x		x
Bromus erectus	x	x	x	x	x
Campanula rotundifolia				x	
Carex flacca	x	x	x	x	
Centaurea nigra	x	x	x	x	x
Centaurea scabiosa	x	x	x	x	x
Chamaenerion angustifolium				x	
Chenopodium polyspermum			x	x	x
Chrysanthemum lucanthemum			x		
Crataegus monogyna	x		x	x	x
Cynosurus cristata	x	x	x	x	x
Dactylis glomerata	x	x	x	x	x
Dactylorchis fuschii	x	x	x	x	x
Dactylorchis purpurella	x	x	x	x	x
Daucus carota				x	x

Species. Site:-	1	3	4	6	8
Festuca arundinacea			x	x	x
Festuca ovina	x	x	x	x	x
Festuca rubra	x	x	x	x	
Fraxinus excelsior				x	x
Fragaria vesca		x	x	x	x
Galium cruciata	x		x	x	x
Galium verum		x			x
Gymnadenia conopsea	x	x			
Helianthemum chamaecistus	x	x	x	x	x
Hypochaeris radicata	x	x	x	x	
Knautia arvensis		x		x	x
Koelaria cristata	x	x	x		x
Lathyrus pratensis	x	x	x	x	x
Leontodon hispidus	x	x	x	x	x
Linum anglicum			x		
Listera ovata	x	x	x	x	x
Lotus corniculatus	x	x	x	x	x
Medicago lupulina				x	
Pimpinella saxifraga	x	x	x	x	x
Plantago lanceolata	x	x	x	x	x
Plantago major	x	x	x	x	x
Plantago media	x	x	x	x	x
Poa annua		x	x	x	x
Poa trivialis		x	x	x	x
Polygala vulgaris	x				

Species. Site:-	1	3	4	6	8
Potentilla reptens	x	x	x	x	x
Poterium sanguisorba	x	x	x	x	x
Prunella vulgaris	x				
Ranunculus auricomus				X	
Ranunculus bulbosus		x		x	
Ranunculus repens	x			x	x
Rhiananthus minor	x	x	x	x	x
Rosa canina	x	x			x
Rosa dumalis					x
Rosa villosa	x	x	x	x	x
Rubus fruticosa	x	x	x	x	x
Rumex acetosa				x	x
Sanicula europaea	x	x	x		
Senecio jacobaea	x			x	x
Sesleria caerulea	x	x	x		x
Silaum silaus	x	x			
Stachys sylvatica		x			
Taraxacum officinale	x	x	x	x	x
Tragopgon pratensis	x	x	x	x	x
Trifolium pratense	x	x	x	x	x
Trifolium repens	x	x	x	x	x
Trisetum flavescens	x	x	x	x	x
Tussilago farfafa	x	x	x	x	x
Veronica chamaedrys		x		x	x
Veronica officinalis	x	x			
Vicia cracca	x	x	x	x	x

Species. Site:-	1	3	4	6	8
Vicia sepium				x	
Viola hirta	x		x	x	
Viola rivinana	x	x	x	x	x
Moss 1	x	x	x	x	x
Moss 2	x	x	x	x	x

Thrislington transplant vegetation list. Part.2.
Additional species not recorded within the fixed quadrats

Species Site:-	1	3	4	6	8
Alnus glutinosa					x
Alopecurus pratensis				x	x
Angallis arvensis					x
Anthyllis vulneraria	x	x		x	
Betula pendula		x	x		x
Conopodium majus			x	x	x
Circium eriophorum			x	x	x
Corylus avellana					x
Dryopteris filis-mas (M.fern)				x	
Euphorbia exigua					x
Filipendula ulmaria			x	x	
Fumaria offinalis					x
Geranium robertianum					x
Gymnadenia conopsea			x		
Ilex aquifolium				x	
Knautia arvensis		x	x		
Leucanthemum vulgare	x	x	x	x	x
Lonicera pericylmenum			x		
Populas tremula				x	
Prunus spinosa					x
Orchis mascula	x	x	x	x	x
Quercus robur				x	x
Reseda luteola		x		x	
Rubus idaeus			x		
Salix caprea			x	x	x
Senecio asper					x
Sonchus oleraceus					x
Sonchus vulgaris				x	x
Thymus drucei					x
Urtica dioica					x

Bibliography:-

Alan.S.E.,Grimshaw.H.M., Parkinson.J.A. and Quarmby.C. (1974). Chemical analysis of ecological materials. (Blackwell Scientific Publications).

Anderson.J.M. and Macfadgen.A. (1975). The role of terrestrial and aquatic organisms in decomposition processes. The 17th symposium of the British Ecological Society. (Blackwell Scientific Publications).

Andrewartha.M.G. and Birch.L.C. (1954). The distribution and abundance of animals. (The university of Chicargo Press).

Armstrong.S.F. (1937). British grasses. (Cambridge University Press).-

Blower.G. (1958). No.11.-British Millipedes. The Linnean Society of London - synopses of the British fauna. (Linnean Society).

Bellman.H. (1985). A field guide to the grasshoppers and crickets of Britain and Northern Europe. (Collins).

Boving.A.G. and Craighead.F.C. (1930). An illustrated synopsis of the principal larval forms of the order Coleoptera. In Entomologica Americana. Volume 11. June 1930. No.1. (Brooklyn Entomological Society).

Boycott.A.E.(1934). The habits of land mollusca in Britain. Journal of Ecology. Volume XXII. 1-38.

Buce.A.C.(1988). Habitat selection and grouping of beetles (Coleoptera). Holarctic Ecology. 11: 241-247.

Butterfield.J. and Coulson.J.C.(1983). The carabid communities of peat and upland grasslands in Northern England. Holeoarctic Ecology. 6:163 - 174.

Bristowe.W.S. (1941). The comity of spiders. Volume.2. (Ray Society).

*

Cameron.R.A.D., Kerney.M.P. (1979). A field guide to the Land snails of Britain and North-West Europe. (Collins).

Cameron.R.A.D., Jackson.N and Eversham.B. (1983). A field key to the slugs of the British Isles. (Field studies council).

Causton.D.R.(1988). Introduction to vegetation analysis. (Unwin Hyman).

Carter.D.J. and Hargreaves.B. (1986). A field guide to the caterpillars of Britain and Northern Europe. (Collins).

Chapman.S.B. (1976). Methods in plant ecology. (Blackwell Scientific Publications).

Chinery.M. (1972). A field guide to the insects of Britain and Northern Europe. (Collins).

Chinery.M. (1986). Collins guide to the insects of Britain and Western Europe. (Collins).

Collingwood.C.A. (1979). Fauna Entomologica Scandinavia - Volume 8. The Formicidae (Hymenoptera) of Fennoscandia and Denmark. (Scandanavian Science Press Ltd).

Clapham.J.E., Tutin.T.G. and Moore.D.M. (1987). Flora of the British Isles. Cambridge University Press.

Crowson.R.A. (1956). Handbooks for the identification of British insects - Vol 5. Part 1. Coleoptera. Introduction and Keys to the Families. (Royal Entomological Society of London).

* Bristowe (1958). Spiders. New Naturalist guide. (Collins).

Davis.B.N.K. (1981). Ecology of quarries. The importance of natural vegetation. (Institute of Terrestrial Ecology).

Dibb.J.R. (1948). Field book of Beetles. (A.Brown and Sons).

Duffey.E. (1962). A population study of spiders in Limestone Grassland. The field layer fauna. Oikes. 13, 15-34.

Dunn.T.C. (Editor). (1980). The Magnesian Limestone of Durham County. (Durham Wildlife Trust).

Eason.E.H. (1964). Centipedes of the British Isles. (Warne).

Edney.E.B. (1954). British woodlice, with keys to the species. (Linnean Society of London).

Erhardt.A. (1985). Diurnal Lepidoptera: Sensitive indicators of cultivated and abandoned grassland. Journal of Applied Ecology. Vol.22. pp849-861.

Erwin.T.L.(1983). Beetles and other insects of tropical forest canopies at Manaus, Brazil, sampled by insecticidal fogging. p 59 -77. In - Tropical rainforest: Ecology and management special publications series of the British Ecological Society, Number 2. Edited by Sutton.S.L, Whitmore.T.C. and Chadwick.A.D. (Blackwell Scientific Publications).

Fitter.A. (1987). Wildflowers of Britain and Northern Europe. Collins New generation guide. (Collins).

Fitter.A. and Fitter.R. (1978). The wild flowers of Britain and Northern Europe. (Collins).

Fitter.A. and Fitter.R. (1989). Guide to the grasses, sedges, rushes and ferns of Britain and Northern Europe. (Collins).

Ford.E.B.(1971). Butterflies. The Fontana new naturalists. (Collins).

Forsythe.T.G. (1987). Common ground beetles. Naturalists handbooks 8. (Richmond Publishing Co. Ltd).

Fowler.S.V. (1985). Differences in insect species richness and faunal composition of birch seedlings, saplings and trees: the importance of plant architecture. Ecological Entomology. 10, 159-169.

Fowler.W.W. (1887). The Coleoptera of the British Islands. Vol.1. Adephaga-Hydrophilidae. (L.Reeve and Co).

Fowler.W.W. (1888). The Coleoptera of the British Islands. Vol.2. Staphylinidae. (L.Reeve and Co).

Fowler.W.W. (1889). The Coleoptera of the British Islands. Vol.3. Leptinidae-Heteroceridae. (L.Reeve and Co).

Fowler.W.W. (1890). The Coleoptera of the British Islands. Vol.4.Lamellicornia-Serricornia-Longicornia-Phytophaga. (L.Reeve and Co).

Fowler.W.W. (1891). The Coleoptera of the British Islands. Vol.5. Heteromera-Rhynchophora-Abnormal Coleoptera. (L.Reeve and Co).

Gardener.S.M. and Dixon.A.F.G. (1985). Plant structure and the foraging success of Aphidius rhopalosiphi (Hymenoptera: Aphidiidae). Ecological Entomology. **10**, 171-179.

Golley.F.B. (1983). Tropical rainforest ecosystems structure and function. Ecosystems of the World 14A. (Elsevier Scientific Publishing Company).

Gunnarsson.B. (1990). Vegetation structure and the abudance and size distribution of spruce-living spiders. 743-752. Journal of Animal Ecology.

Graham.G.G. (1988). The flora and vegetation of county Durham. (The Durham Flora committee and the Durham county conservation trust).

Greenslade.P.J.M. (1963). Pitfall trapping as a method of method for studying populations of Carabidae (Coleoptera).
Journal of Animal Ecology. 33, 301-310.

Grime.J.P.(1979). Plant statergies and vegetation processes. (Wiley).

Grime.J.P., Hodgson.J.G. and Hunt.R. (1988). Comparative plant ecology. A functional approach to common British species. (Unwin Hyman).

Hall.M.L. (1981). Butterfly research in Institute of Terrestrial. Ecology. (.H.M.S.O.).

Harde.K.W. (1983). A field guide in colour to beetles (Octopus).

Harding.P.T. and Sutton.S.L. (1985). Woodlice in Britain and Ireland: Distribution and Habitat. (Institute of Terrestrial Ecology.

Hendrix.S.D., Brown.V.K. and Dingle.H. (1988). Arthropod guild structure during early and old field succession in a new and old world site. Journal of Animal ecology. Vol.57. pp1053-1065.

Hermann.G. (1960). Collembolenfauna Europas. (Museum D'Historie Naturelle).

Heslop.I.R.P. (1947). Indexed check-list of the British Lepidoptera with the English Name of each of the 2313 species. (Watkins and Doncaster).

Hesse.P.R.(1971). A textbook of soil chemical analysis. (John Murray, London).

Hubbard.C.E.(1954). Grasses. (Pelican).

Imms.A.D. (1947). Insect Natural History. Collins New Naturalist. (Collins).

Jahns.H.M. (1965). Molluscs. (Burke).

Jahns.H.M. (1980). A field guide to the ferns, mosses and lichens of Britain and Northern and Central Europe. (Collins).

Jones.D. (1989). A guide to the spiders of Britain and Northern Europe. (Hamlyn).

Joy.N.H. (1932). A practical handbook of British beetles. Volumes 1 and 2. (E.W. Classey).

Krebs.C.J. (1985). Ecology: The experimental analysis of distribution and abundance. 3rd edition. (Harper and Row, Publishers, Inc).

Lawton.J.H. (1983). Plant architecture and the diversity of phytophagous insects. Annual review of Entomology. 28, 23-39.

Lawton.J.H. (1986). Surface avaidability and insect community structure: the effects of architecture and fractal dimension of plant surface. pp 317-332. (Edward Arnold).

Le Quesne.W.J. (1960). Handbooks for the identification of British insects Vol.2. Part 3. Hemiptera - Fulgoromorpha. (Royal Entomological Society of London).

Le Quesne.W.J. (1965). Handbooks for the identification of British insects Vol. 2. Part 2(b).- Hemiptera - Cicadomorpha, Deltocephalinae. (Royal Entomological Society of London).

Le Quesne.W.J. (1969). Handbooks for the identification of British insects Vol. 2. Part 2(a).- Hemiptera (excluding Deltocephalinae and Typhlocybinae) (Royal Entomological Society of London).

Lindroth.C.H. (1974). Handbooks for the identification of British insects Coleoptera - Carabidae. Vol. IV. Part 2. (Royal Entomological Society of London).

Lindroth.C.H. (1). Fauna Entomologica Scandinavia - Volume 15, part 1. The Carabidae (Coleoptera) of Fennoscandia and Denmark. (E.J.Brill/Scandinavian Science Press Ltd).

Lindroth.C.H. (1986). Fauna Entomologica Scandinavia - Volume 15, part 2. The Carabidae (Coleoptera) of Fennoscandia and Denmark. (E.J.Brill/Scandinavian Science Press Ltd).

Lockett.G.H. and Millidge.A.F. (1951-53). British Spiders. Volumes 1,2 and 3. (Ray Society. London).

Lousley.J.E. (1950). Wildflowers of chalk and limestone. Collins new naturalist series. (Collins).

Lowe.E.J. (1915). Natural history of British Grasses. (Groombridge and Sons).

Luff.M.L. (1975). Some features influencing the efficency of pitfall traps. (Oceologia.) Vol.19: 342-357.

Lyneborg.L. (1977). Beetles in colour. (Blandford Press).

Manglebrot. (1967). In Lawton 1986.

Mathieson.F.B. (1985). Carabid beetles as indicators of sucessional stages of vegetation. (M.Sc dissertation, University of Durham. Unpublished).

Mooney.H.A. and Gordon.M. (Editors). (1983). Disturbance and Ecosystems -Components of response. Ecological studies analysis and synthesis - Volume 44. (Springer-Verlag).

Morris.M.G. (1971). Differences between the invertibrate faunas of grazed and ungrazed chalk grassland. IV. Abundance and diversity of Homoptera - Auchenorhyncha. J. appl. Ecol., 8, pp37-52.

Morris.M.G. (1973). The affects of seasonal grazing on the Heteroptera and Auchenorhyncha (Hemiptera) of chalk grassland. J.appl.Ecol., 10, 761-780.

Morris.M.G. (1981a). Responses of grassland invertibrates to management by cutting.III. Adverse affects on Auchenorhyncha. J.appl.Ecol.,18, 107-123.

Morris.M.G. (1981b). Responses of grassland to management by cutting.IV. Positive responses of Auchenorhyncha. J.appl.Ecol, 18, 763-771.

Morris.M.G. (1983). Colonisation of sown calcareous grassland by leafhoppers (Hemiptera, Auchenorhyncha). In I.T.E. annual report 1983. (I.T.E.).

Morris.M.G. (1990). The Hemiptera of two sown calcareous grasslands.I. Colonisation and early succession. The Journal of Applied Ecology. 367-378.

Morris.M.G. (1990). The Hemiptera of two sown calcareous grasslands.II. Differences between treatments. 379-393. Journal of Applied Ecology.

Morris.M.G. (1990). The Hemiptera of two sown calcareous grasslands. III. Comparisons with the Auchenorhyncha faunas of other grasslands. 394-409. Journal of Applied Ecology.

Murdoch.W.W., Evans.F.C. and Peterson.C.H. (1972). Diversity and pattern in plants and insects. Ecology. 53, 819-829.

Nilsson.S.G., Bengtsson.J. and As.S. (1988). Habitat diversity or area per se ? Species richness of woody plants , carabid beetles and land snails on islands. Journal of Animal Ecology. Vol. 57. pp685-704.

Oates.M.(1990). Trends in butterfly populations. Radio.4. Natural history programme, (13/09/90). (BBC Radio 4).

Oldeman.R.A.A.(1983). Tropical rainforest, architecture, silvigenesis and diversity. p 139-151. In - Tropical rainforest: Ecology and management special publications series of the British Ecological Society, Number 2. Edited by Sutton.S.L, Whitmore.T.C. and Chadwick.A.D. (Blackwell Scientific Publications).

Ossiannilsson.F. (1978). The Auchenorrhyncha (Homopteria) of Fennoscandia and Denmark. Part 1. Introduction, infraorder Fulgomorpha. Fauna Scandinavica. Vol 7. (part 1) (Scandinavian Science Press Ltd)..

Ossiannilsson.F. (1978). The Auchenorrhyncha (Homopteria) of Fennoscandia and Denmark. Part 2 .The Families Cicadidae, Cercopidae, Membracidae and Cicadellidae (excluding Deltocephalinae). Fauna Scandinavica. Vol 7. (part 2) (Scandinavian Science Press Ltd).

Park.D.G. (1989). Limestone grassland relocation -technique and practice. pp 18-23. In Mining and quarrying environment. The environmental managers journal. Vol 2. No.4. (Ashire Publishing).

Poissonet.P.S., Daget.P.M., Poissonet.A. and Long.G.A. (1973). Rapid point survey by bayonet blade. 1072 Vol.25. pp 313. Journal of Range Management.

Press.J.R. et al (1988). Field guide to the wild flowers of Britain. (Readers digest).

Pyrs-Jones.O.E. and Corbett.S.A. (1986). Bumblebees. Naturalists. Handbooks No.6. (Cambridge University Press).

Richards.P.W.(1983). The three dimensional structure of tropical rain forest. p 3-11. In - Tropical rainforest: Ecology and management special publications series of the British Ecological Society, Number 2. Edited by Sutton.S.L, Whitmore.T.C. and Chadwick.A.D. (Blackwell Scientific Publications).

Richardson.J.A. and Evans.M.E.(1986). Restoration of grassland after Magnesian Limestone Quarrying. Journal of Applied Ecoloogy. Vol.23. pp317-332.

Robinson.J.V. (1981). The affect of architectural variation in habitat selection on a spider community: An experimental field study. Ecology. 62(1), 73-80.

Romney.V. (1945). The affect of physical factors upon the catch of the beet leafhopper (*Eutettix tenellus*) by a cylinder and two sweep-net methods. Ecology. Vol.26. 135-147.

Saunders.E. (1896). The Hymenoptera Aculeata of the British Isles. (L.Reeve and Co).

Sheppard.D.A. (1987). Changes in the invertebrate fauna of Magnesian Limestone grassland after transplantation. (Nature Conservancy Council).Unpublished.

Sheppard.D.A. (1989). Changes in the fauna of magnesian limestone grassland after transplantation. In Wells.D.E. (ed) Calcareous grasslands - Ecology and management, British ecological society and Nature Conservancy Council joint symposium.

Southwood.TR.E. (1978). Ecological methods with particular reference to the study of populations. (2nd ed). (Chapman and Hall).

Southwood.T.R.E., Brown.V.K. and Reader.P.M. (1979). The relationships of plants and insect diversies in succession. Biological journal of the Linnean Society. 12: 337-348. (Linnean Society).

Shimwell.D.W. (1968). The phytosociology of calcareous grasslands in the British Isles. PhD thesis. (University of Durham).

Smith.I.R.,Wells.D.A. and Welsh.P. (1985). Botanical survey and monitering methods for grasslands. (NCC).

Sutton.S.L.(1968). The population dynamics of *Trichoniscus pusillus* and *Philoscia muscorum* in Limestone grassland. Journal of Animal Ecology. 37: 425-444.

Stinton.C.S.A. and Brown.V.K. (1983). Seasonal changes in the Architecture of Natural plant communities and it's relevance to insect herbivores. Ocelogia. 56: 67-69.

Strong.O.R.(1979). Biogeographic dynamics of insect-host plant communities. Annual review of entomology. 24: 89-119. (Annual review's Inc).

Ter Braak.C.J.F. (1987). The analysis of vegetation-environment relationships by canonical correspondance analysis. Vegetatio. 69: 69-77.

Ter Braak.C.J.F. (1987). Unimodal models to relate species to environment. (Agricultural mathematics group).

Ter Braak.C.J.F. (1988). CANOCO - a FORTRAN program for canonical community ordination by (partial) (detrended) (canonical) correspondance analysis, principal components analysis and redundancy analysis (version 2.1). (Agricultural mathetatics group ministery of agriculture and fisheries).

Thompson.C. and Sankey.J. (1961). Land invertibrates. (Methuen).

Tilling.S.M. (1987). A key to the groups of British terrestrial invertibrates. (Field Studies Council).

Tottenham.C.E. (1954). Handbooks for the identification of British insects - Vol.5. Part 8(a). Coleoptera - Staphylinidae Section (a) Piestinae to Euaesthetinae. (Royal Entomological Society of London).

Uetz.G.W. and Unzicker.J.D. (1976). Pitfall trapping in ecological studies of wandering spiders. Journal of Arachnicology. 3: 101-111.

Unwin.D.M. (1984). A key to the families of British Beetles. (Field studies council).

Watt.A.S. (1947). Pattern and process in the plant community. Journal of Ecology. 35: 1-22.

Woodford.W.J. and Bruce.C. (1983). A survey of the insects of County Durham. (Durham Wildlife Trust).

Bishop Middleham Nature Reserve: Five year management plan. (1984). Durham Wildlife Trust.

Canoco condensed format. Vegetation survey domin values in 25 fixed 2x2m quadrats at Thrislington SSSI, Durham. 17/07/90.
Quadrats are number vertically with the species code number i.e. 1 = Achilla millifolia, then the domin scale is given i.e 2.0. The code number for next species - 2 is then given. Only the species that were recorded are listed, for each of the 25 quadrats - 1 =1/1 2=2/1 to 25 = 5/8.

```
(I3,X,8(I3,F4.0)) = Fortran code.
 8                = Number of couplets per line.
  1   1 2.0  2 1.0  4 1.0  5 4.0 10 1.0 13 1.0 14 3.0 20 1.0
  1  21 1.0 22 2.0 25 2.0 26 7.0 27 5.0 31 1.0 32 7.0 37 2.0
  1  38 1.0 39 4.0 42 5.0 43 1.0 44 5.0 45 2.0 50 2.0 51 3.0
  1  63 4.0 77 1.0 78 1.0 79 1.0 80 2.0 81 6.0 82 5.0
  2   2 1.0  6 1.0  9 1.0 10 5.0 11 1.0 13 1.0 15 3.0 21 1.0
  2  23 1.0 26 5.0 27 1.0 33 7.0 38 1.0 41 2.0 42 4.0 44 4.0
  2  45 2.0 49 1.0 50 3.0 63 4.0 70 1.0 73 2.0 80 1.0 81 5.0
  2  82 4.0
  3   2 1.0  6 1.0 10 3.0 13 2.0 15 2.0 21 3.0 27 7.0 28 5.0
  3  30 2.0 33 7.0 39 1.0 41 1.0 42 5.0 44 4.0 45 2.0 49 2.0
  3  50 5.0 51 3.0 58 1.0 59 1.0 61 1.0 63 2.0 66 1.0 73 1.0
  3  75 1.0 77 1.0 81 5.0 82 4.0
  4   2 1.0  5 2.0  9 1.0 10 1.0 13 1.0 14 2.0 21 1.0 26 7.0
  4  33 5.0 35 4.0 38 1.0 39 2.0 42 5.0 44 4.0 45 4.0 50 4.0
  4  51 2.0 54 1.0 63 3.0 67 1.0 68 2.0 73 1.0 79 1.0 80 1.0
  4  81 4.0 82 4.0
  5   2 1.0  6 1.0  9 1.0 10 6.0 11 2.0 13 1.0 14 1.0 15 2.0
  5  21 1.0 26 7.0 30 4.9 33 5.0 35 4.0 39 2.0 42 1.0 44 4.0
  5  45 1.0 47 1.0 50 3.0 51 1.0 55 1.0 58 1.0 59 3.0 64 1.0
  5  77 2.0 79 1.0
  6   1 1.0  2 2.0  8 1.0 10 4.0 11 3.0 13 1.0 21 1.0 26 7.0
  6  27 1.0 31 1.0 33 5.0 36 1.0 38 1.0 39 4.0 42 4.0 44 4.0
  6  49 1.0 50 4.0 51 2.0 55 1.0 59 1.0 66 1.0 67 1.0 72 1.0
  6  76 6.0 77 2.0 79 1.0
  7   5 2.0  9 1.0 10 7.0 11 2.0 13 1.0 14 2.0 21 4.0 22 3.0
  7  26 6.0 27 4.0 29 1.0 32 1.0 39 2.0 41 2.0 42 5.0 44 1.0
  7  49 1.0 50 5.0 58 1.0 61 7.0 73 1.0 77 1.0 79 1.0 81 3.0
  7  82 4.0
  8   3 1.0  5 4.0  8 1.0  9 1.0 10 4.0 11 2.0 14 3.0 15 1.0
  8  18 1.0 20 1.0 22 4.0 26 7.0 27 4.0 33 8.0 42 5.0 44 1.0
  8  48 1.0 50 5.0 67 4.0 70 1.0 73 1.0 77 2.0 81 4.0 82 7.0
  9   2 1.0  8 1.0  9 1.0 10 4.0 11 1.0 13 5.0 15 1.0 21 1.0
  9  23 3.0 26 7.0 35 2.0 38 1.0 40 1.0 43 3.0 44 1.0 50 2.0
  9  59 2.0 61 4.0 65 2.0 66 3.0 68 1.0 73 1.0 81 4.0
 10   5 4.0  7 1.0  8 1.0  9 4.0 11 2.0 13 2.0 14 3.0 21 6.0
 10  26 5.0 27 5.0 33 4.0 35 1.0 39 2.0 41 3.0 42 1.0 44 3.0
 10  45 1.0 49 4.0 50 1.0 52 1.0 55 1.0 56 2.0 59 1.0 61 1.0
 10  67 1.0 68 1.0 73 1.0 76 1.0 77 2.0 78 1.0 79 1.0
 11   5 4.0  7 1.0  8 1.0  9 1.0 10 2.0 11 3.0 13 1.0 21 6.0
 11  27 4.0 29 1.0 34 4.0 37 3.0 42 5.0 44 4.0 45 4.0 50 3.0
 11  51 2.0 59 1.0 68 4.0 68 3.0 78 1.0 79 1.0 81 4.0
 12   2 2.0  5 3.0  9 1.0 10 7.0 13 1.0 14 2.0 21 3.0 26 5.0
 12  26 4.0 30 1.0 34 2.0 35 4.0 37 2.0 38 1.0 39 1.0 41 4.0
 12  42 5.0 43 4.0 50 3.0 51 2.0 59 4.0 61 1.0 73 2.0 75 1.0
 12  79 1.0 82 7.0
 13   2 2.0  5 3.0  9 1.0 10 7.0 13 1.0 14 2.0 21 1.0 22 2.0
 13  23 1.0 26 8.0 35 2.0 38 1.0 39 4.0 41 3.0 42 6.0 43 1.0
 13  44 4.0 45 2.0 47 4.0 49 2.0 50 7.0 51 1.0 59 2.0 66 2.0
 13  70 1.0 81 5.0 82 6.0
 14   2 1.0  5 2.0  8 1.0 10 1.0 11 4.0 13 1.0 15 1.0 19 1.0
 14  23 4.0 27 5.0 33 7.0 35 2.0 38 2.0 39 1.0 41 1.0 42 4.0
 14  44 3.0 45 4.0 50 4.0 51 1.0 53 2.0 44 1.0 62 1.0 67 1.0
 14  70 1.0 73 1.0 77 1.0 81 6.0
```

Thrislington plant species - domin values page 2.

```
 15    5 4.0  8 1.0  9 1.0 10 5.0 13 3.0 15 4.0 21 3.0 22 2.0
 15   26 5.0 27 1.0 29 4.0 33 4.0 38 3.0 42 2.0 44 4.0 50 5.0
 15   51 1.0 58 1.0 59 4.0 66 2.0 75 1.0 79 1.0 81 4.0 82 2.0
 16    2 1.0  5 1.0 10 7.0 13 1.0 20 1.0 22 4.0 26 7.0 28 4.0
 16   29 1.0 49 2.0 50 1.0 52 3.0 55 2.0 58 1.0 59 1.0 66 1.0
 16   70 1.0 73 1.0 74 4.0 76 1.0 79 1.0 81 5.0
 17    8 2.0 10 4.0 15 2.0 16 1.0 22 4.0 23 1.0 25 6.0 26 7.0
 17   43 1.0 44 3.0 45 4.0 50 2.0 51 1.0 58 1.0 59 2.0 62 1.0
 17   76 1.0 79 1.0
 18   10 5.0 13 1.0 14 1.0 20 2.0 22 1.0 24 1.0 26 4.0 29 1.0
 18   34 1.0 38 1.0 43 1.0 45 1.0 46 1.0 47 4.0 48 1.0 51 1.0
 18   58 1.0 59 1.0 66 1.0 70 2.0 74 1.0 75 1.0
 19    1 4.0  9 1.0 10 4.0 12 1.0 13 1.0 15 4.0 17 1.0 23 1.0
 19   26 7.0 28 1.0 41 1.0 42 4.0 44 3.0 47 1.0 50 5.0 51 1.0
 19   53 1.0 58 1.0 59 1.0 66 1.0 67 1.0 71 4.0 73 2.0 76 1.0
 19   81 5.0 82 4.0
 24   42 3.0  6 1.0  7 1.0  8 1.0  9 1.0 10 4.0 13 2.0 14 2.0
 40   16 1.0 20 1.0 21 1.0 22 1.0 26 6.0 27 3.0 30 1.0 35 1.0
 20   36 1.0 42 4.0 43 1.0 44 3.0 45 1.0 48 1.0 49 2.0 50 4.0
 20   53 1.0 55 1.0 56 1.0 59 1.0 62 1.0 66 1.0 67 3.0 73 2.0
 20   76 1.0 81 4.0
 21    1 1.0  9 5.0 10 4.0 15 1.0 20 3.0 25 4.0 26 3.0 29 1.0
 21   31 1.0 37 1.0 38 2.0 39 1.0 43 1.0 45 2.0 46 3.0 49 1.0
 21   50 2.0 51 1.0 59 1.0 62 1.0 66 1.0 70 1.0 13 1.0 76 1.0
 21   81 4.0
 22    9 1.0 10 1.0 11 1.0 15 1.0 21 1.0 22 1.0 26 8.0 33 4.0
 22   36 1.0 38 2.0 41 1.0 42 1.0 43 1.0 44 1.0 45 1.0 51 1.0
 22   59 1.0 61 7.0 66 1.0 67 1.0 73 1.0 76 1.0 79 1.0 81 5.0
 23    8 1.0  9 1.0 10 1.0 15 4.0 21 1.0 22 1.0 26 8.0 33 4.0
 23   50 4.0 51 2.0 55 1.0 67 4.0 78 2.0 81 3.0
 24    2 4.0 10 5.0 16 7.0 22 4.0 23 1.0 25 2.0 30 1.0 33 1.0
 24   41 1.0 43 3.0 46 2.0 50 5.0 51 2.0 59 3.0 68 2.0 73 4.0
 25    1 1.0  2 1.0  5 1.0  6 1.0 10 4.0 14 1.0 18 1.0 20 3.0
 25   21 1.0 22 4.0 29 1.0 38 1.0 43 1.0 44 3.0 48 4.0 54 1.0
 25   55 1.0 56 4.0 53 1.0 59 1.0 60 2.0 71 1.0
  0
ACHI MILAGRI EUPAGRO STOAGRO TENCYNO CRISENA JACANTH VULARRH SERAREN ELABRAC SYL
BRIZ MEDCAMP ROTCARE FLACENT NIGCENT SCABAUS CARACER SEUCHEN POLCHRY LEUCRIS LEU
CRAT MONDACT GLODACT FUSDACT PURFEST ARUFEST OVIFEST RUBFRAX EXCFRAG VESGALI CRU
GALI VERGYMN CONHELI CHAMEDI LUPHYPO RADKNAU ARVKOEL CRILATH PRALEON HISLINU ANG
LIST OVALOTU CORPIMP SAXPLAN LANPLAN MAJPLAN MEDPOA  ANNPOA  TRIPOTE REPPOTE SAN
GRIM VULRANI AURRANU BULRANU REPRHIA MINROSA CANROSA DUMROSA VILRUBU FRURUME ACE
SANT EURCHAM ANGSESL CAESILA SILSTAC SYLTARA OFFTRAG PRATRIF PRATRIS REPTRIS FLA
VERO CHAVERO OFFVICI CRAVICA SEPVIOL HIRVIOL VIVTUSS FARPOLY VULPRUN VULBROM ERE
..MOSS.1..MOSS.2
.....1/1.....2/1.....3/1.....4/1.....5/1.....1/3.....2/3.....3/3.....4/3.....5/3
.....1/4.....2/4.....3/4.....4/4.....5/4.....1/6.....2/6.....3/6.....4/6.....5/6
                                         .....1/8.....2/8.....3/8.....4/8.....5/8
```

CHANGES IN THE FAUNA OF MAGNESIAN LIMESTONE GRASSLAND AFTER TRANSPLANTATION: PRELIMINARY OBSERVATIONS AT THRISLINGTON PLANTATIONS

D.A. Sheppard

England Field Unit, Nature Conservancy Council, Northminster House, Peterborough, PE1 1UA, UK

Background

Thrislington Plantations, a 36 ha area of grassland on the western edge of the Magnesian Limestone plateau of eastern County Durham, was designated as a Site of Special Scientific Interest in 1962. The area is well known for a number of rare plants and insects, including the largest inland colony of the northern brown argus butterfly *(Aricia artaxerxes salmacis)* and the largest known colony of the glow-worm *(Lampyris noctiluca)* in the north-east of England. A proposed extension of quarrying activities into the SSSI resulted, after a public enquiry, in an agreement that some 10.5 ha of ungrazed grassland would be transplanted, during the winter months, over a period of about ten years as the quarry face advanced, the remaining undisturbed land to be managed as a nature reserve. After scrub removal, turves 1.7 m wide, 4.75 m long and 40 cm-55 cm deep were moved 400 m to an area nearby already stripped of topsoil. After-care involved attention to gaps appearing between turves and mowing once a year in September.

Changes in the invertebrate fauna

Analysis of the effects of transplantation on the invertebrate fauna is so far based on samples (pitfall trap, D-vac and sweep-net) taken prior to and two years after transplantation (1982 and 1985 respectively) and control samples from a part of Thrislington Plantations which was not moved. At present, only six groups — Heteroptera (plant bugs), Homoptera Auchenorrhyncha (leaf hoppers), Coleoptera (part) (beetles), Aranea (spiders), Opiliones (harvestmen) and Peudoscorpiones (false scorpions) — have been examined in detail and the following assessment of the effects of the transplant must therefore be considered as very preliminary.

On the control site, a total of 156 species were recorded of which seventy-two were found in both 1982 and 1985, thirty-five were only recorded in 1982 and forty-nine in 1985. Out of a total of 194 species so far identified from the transplant areas, only seventy-seven were recorded both from the pre-transplant area and also, three years later, from the transplanted turves. Sixty-six species were apparently lost during the transplant (Table 1) but an additional fifty-one species were recorded from the turves only after transplantation (Table 2) and thirty-eight of these were apparently new colonists to Thrislington Plantations since they were not recorded during either the 1982 or the 1985 surveys of the control site. However, many species were found only once or twice in the 400 samples taken from Thrislington. Care is needed, therefore, in interpreting the absence, or indeed the presence, of species occurring at such low densities (or at least so poorly sampled).

Comparisons between the two sampling dates revealed that:

(i) Of the taxa (includes specimens, usually juveniles, which could not be identified beyond family or genus, as well as those identified to species) sampled fairly consistently (occurring in at least 80% of the samples from at least one sampling method during at least one sampling period), *Stenus ochropus* (Coleoptera: Staphylinidae) had disappeared totally from both sites by 1985;

(ii) *Cicadella viridis* (Homoptera: Cicadellidae) and *Meioneta saxatilis* (Araneae: Liniphiidae) disappeared from the transplanted turves. Both prefer tall grassland in damp areas or with a deep litter layer. They persisted at the control site but in reduced abundance;

(iii) On the transplanted turves, the beetles *Ptomophagus subvillosus* (Lelodidae), a detritivore associated with nests, burrows and corpses of small mammals; and *Calathus fuscipes* (Carabidae), a predatory ground beetle associated with disturbed land, were new to the transplant. The

Table 1. Species apparently lost from Thrislington Plantations after the transplant.

(• unique to transplant)

Araneae

• *Robertus lividus*
• *Micrargus rufus*
• *Monocephalus fuscipes*
Clubiona reclusa
• *Allomenges scopigera*
• *Tapinocyba longidens*
• *T. pygmaea*
Diplocephalus latifrons
Linyphia clathrata
• *L. montana*
Walckenaera acuminata
Meioneta beata
M. saxatilis
• *Enoplognatha ovata*
Centromerita bicolor
Bathyphantes pullata

Opiliones

• *Phalangium opilio*
• *Mitopus morio*
Nemastoma bimaculatus
Mitostoma chrysomelas
Mitopus ericaeus
Megabunus diadema
• *Odiellus spinosus*
Paroligolophus agrestis
Oligolophus tridens

Heteroptera

• *Myrmus miriformis*
• *Anthocoris nemorum*
• *Pithanus maerkeli*
• *Mecomma ambulans*
• *Calocoris norvegicus*

Homoptera

Aphrophora alni
Cicadella viridis
Evacanthus interruptus
• *Agallia consobrina*
Aphrodes bicinctus
Thamnotettix confinis
Adarrus multinotatus
• *Streptanus marginatus*
• *Cicadula aurantipes*
• *C. persimilis*
• *Javesella discolor*

Coleoptera

• *Cychrus caraboides*
• *Leistus rufescens*
Bembidion lampros
Dromius linearis
Othius myrmecophilus
Quedius molochinus
• *Oxypoda spectabilis*
Stenus nanus
S. ochropus
• *Anthrobius unicolor*
Tachinus signatus
Tachyporus obtusus
• *Aridus nodifer*
• *Enicmus histrio*
• *Colon latum*
Catops nigricans
• *Simplocaria semistriata*
• *Alophus triguttatus*
• *Ceutorhynchus quadridens*
Ceuthorhynchidius troglodytes
Brachysomus echinatus
Orthochaetes setiger
• *Polydrusus undatus*
• *Apion viciae*
• *A. virens*

Table 2. Species new to the transplanted turves.

(* unique to transplant.)

Araneae	Coleoptera
* *Walckenaera vigilax*	* *Clivinia fossor*
* *Pardosa palustris*	* *Pterostichus cristatus*
Oedothorax fuscus	* *P. strenuus*
* *O. retusus*	* *Calathus fuscipes*
* *Diplostyla concolor*	* *Amara bifrons*
Ceratinella brevis	* *A. communis*
* *Heliophanus flavipes*	* *A. ovata*
* *Tiso vagans*	* *A. similata*
* *Porhomma convexum*	* *Harpalus rufipes*
P. pallidum	* *Badister bipustulatus*
* *Theridion pallens*	* *Bradycellus verbasci*
	* *Bembidion 4-maculatum*
Pseudoscorpiones	* *Tachyporus solutus*
Neobisium muscorum	*Othius punctulatus*
	Xantholinus linearis
Heteroptera	* *Staphylinus compressus*
* *Nabis ferus*	* *Bolitobius analis*
* *Orthocephalus coriaceus*	* *Philonthus cognatus*
* *O. saltator*	* *P. laminatus*
	P. marginatus
Homoptera	*P. varius*
* *Streptanus sordidus*	*Tachinus corticinus*
Zyginidia scutellaris	* *T. lignosum*
* *Eurysa lineata*	* *Xantholinus jarrigei*
* *Muellerianella brevipennis*	* *Nicrophorus vespillo*
* *Craspedolepta sonchi*	*Ptomaphagus subvillosus*
	* *Stephostethus lardarius*
	* *Byrrhus pilula*
	Lampyris noctiluca
	* *Bruchus loti*
	Coccinella 7-punctata

weevil *Ceuthorhynchidius troglodytes* (Curculionidae), which is associated with *Plantago* spp. and may therefore favour disturbed ground and two species associated with calcareous grassland: the leaf-hoppers *Turrutus socialis* and *Eupteryx notata* (Cicadellidae), had been recorded previously from the pre-transplant area only at low density;

(iv) The sixty-six species apparently lost as a result of transplantation included the following nationally rare or notable species: the spider *Tapinocyba pygmaea* (Linyphiidae) which was known from only five sites, perhaps now only four; the leaf-hopper *Adarrus multinotatus* (Cicadellidae); the harvestmen *Odiellus spinosus* and *Mitopus ericaeus* (Phalangiidae); and three weevils, *Alophus triguttatus*, *Brachysomus echinatus* and *Orthochaetes setiger* (Curculionidae).

The present analysis of the data suggests therefore, that populations of some species, mostly either active ground-dwelling predators or herbivores associated with short turf, increased as a result of the transplant. The evidence so far indicates that the new arrivals tend to prefer either dry, fairly tall grassland with a thick litter layer or open, dry, gravelly soil with little or no vegetation. Three species were detritivores associated with small mammals and at least two species were associated with disturbed or cultivated land. In addition, several species were associated with the increase in abundance of certain flowering plants, particularly composites and crucifers. However, at least six nationally rare or notable species and two species specifically associated with calcareous grassland, as well as a number of other species, have disappeared from the transplanted turves. Unless reservoir populations occur nearby, these species may become permanent casualties of the transplant.

Discussion

Some of the changes in the invertebrate fauna noted above may be a reflection of differences in management (from ungrazed to mown grassland) before and after transplantation. Major alterations in habitat structure consequent upon the removal of scrub and its associated long grassland also occurred. The transplanted turves were prone to drying out thus reducing damp grassland and moist litter habitats and enlarging the dry grassland area. If the moist grassland fauna fails to recolonize or expand, in future it may be advisable to impede the drainage in some way in order to retain habitat characteristics suitable for moisture loving species. Some species did not survive the transplant or were present at such very low densities that they were not found during the 1985 survey. On the other hand, the transplanted turves appeared to provide suitable habitats for some species which may have been excluded by habitat requirements from the undisturbed pre-transplant area, or were present at such low densities that they were not recorded in the 1982 survey. These colonists may have imposed increased predator pressure on the populations and communities which survived the transplant, or they may have led to increased competition for some essential resource.

Preliminary analyses of the kind described here suggest that, at least temporarily, transplanted turves are poorer in species numbers, poorer in calcareous grassland specialists and poorer in rare species. However, it is likely that the fauna of the transplanted turves was still composed of unstable communities three years after relocation. It is hoped that monitoring will continue for several more years in order that a full assessment of the success or failure of this experiment can be made.

Acknowledgements

It is a pleasure to thank Dr David Park, Land Management Officer, Steetley Quarry Products Ltd and Steetley Quarry Products Ltd as a whole, for their sympathy, interest and continuing co-operation in this project. My thanks also go to those specialists who helped in the sorting and identification of several thousand specimens: Dr M L Cox, Dr C M Drake, G Forrester, Dr P Kirby, Dr M L Luff, D Procter and Dr D B Shirt.

Invertebrate species list.

The invertebrates are arranged by Order, family then species. The numbers in the brackets after the species name referre to the sites the species was observed or collected from.

Order - *Aranaea - Spiders.*

Agriopidae.
Pachygantha degreeri:- (1,3,4,6,8).

Clubionoidea.
Clubiona sp:- (1,3,4,6,8).
Clubiona terrestris:- (3,4,6,8).
Zora spinimana:- (6,8).

Gnaphosidae.
Drassodes lapidosus:- (1,4).

Linyphiidae.
Evansia merens:- (1,3,4,6,8).
Gonathium rubens:- (1).
Lephyphantes leprosus:- (6).
Linyphia pellata:- (1,3,4,6,8).
Microlinyphia pusilla:- (3,4,6,8).

Lycosidae.
Alopecosa cuneata:- (1,3,4,6,8).
Pardosa pulleta:- (1,3,4,6,8).
Pardosa sp:- (1,3,4,8).
Trochosa ruricola:- (1,3,4,6,8).

Salticidae.
Euophrys erratica:- (4).

Theridiidae.
Araneus sp:- (3).
Enoplognatha ovata:- (8).

Thomisidae.
Oxypila trux:- (1,3,4,6,8).
Xysticus cristatus:- (1,3,4,6,8).

Order - Coleoptera.

Family - Byrrhidae.

Byrrhus pilula:-(3). 1 speicemen collected in pitfall.

Family - Cantharidae (soldier beetles).

Cantharis rustica:-(1,3,4,6,8). Common on all sites especially 6 and 8.
Rhagonycha fulva:-(1,3,4,6,8). Very common on all sites.

Family - Carabidae.

(see Carabidae CCA results).
Agonum dorsale:-(6).
Amara aulica:-(1,3,4,6,8).
Amara convexior:-(1,3,4,6,8).
Badister bipustulatus:-(8).
Bembidion lampros:-(1,3,4,6,8).
Bembidion obtusum:-(8).
Calathus melanocephalus:-(8).
Carabus violaceus:-(1,3,4,6,8).
Harpalus rufipes:-(3,4,6,8).
Leistus rufescens:-(6,8).
Loricera pilicornis:-(8).
Nebria selena:-(6)
Notiophilus biguttatus:-(1,4,6,8).
Notiophilus germanyi:-(6,8).
Pterostichus madidas:-(1,3,4,6,8).
Pterosticus melanarius:-(1,3,4,6,8).
Trechus quadristiatus:-(1,4,6,8).

Family - Coccinellidae (ladybirds).

Coccinella 7 punctata:-(1,3,4,6,8). Common on all sites. (7 spot ladybird).
Thea-22- puncata:-(1). 1 speciemen collected from pitfall.

Family - Chrysomelidae (leaf beetles).

Cassida viridis:-(6). 1 speciemen collected in pitfall on 21/06/90. Also larvae in pitfall on
Crepidodera ferruginea:-(1,3,4,6,8). Common on all sites.
Crepidodera transversa:-(1,3,4,6,8). Common on all sites.
Chrysolia staphylea:-(1). 2 speciemens collected in pitfalls.
Phyllotreta undulata:-(3,6,8). Common sites 6 and 8 in pitfalls and speciemens taken whilst sweep netting.
Serica brunnea:-(8). 1 speciemen collected in pitfall.

Family - Curculionidae (weevils).

Apioninae.
Apion apricons:-(1,3,4,8).
Apion virens:-(1,3,4,6,8).

Barynotina.
Barynotus elevatus:-(1,3,4,6,8).
Barynotus obscurus:-(1,4,6,8).
Barynotus squamosus:-(1,3,4,6,8).

Ceuthorrhynchus.
Ceuthorrhynchidius quadridens:-(1,3,4,6,8).
Ceuthorrhynchidius troglodytes:-(1,3,4,6,8).

Erirrhinina.
Orthocheates setiger:-(1,3,8).

Phyllobiina.
Phyllobius argentatus:-(1,3,6,8).

Orobitus.
Orobitus cyaneus:-(1,3,4,6,8)

Family - Elateridae - (click beetles).

Althous haemorrhoidais. 22/05/90 - 5 individuals.

Family - Histeridae.

Seprinus semistriatus:-(6). Sexton beetle.

Family - Lampyridae.

Lampyris noctiluca:-(3,4,6,8). The glow worm was recorded by odd individuals per site.

Family - Serropalpidae.

Osphya bipunctata:-(4). 1 speciemen collected in pitfall on 06/06/90.

Family - Silphaidae - (burying beetles).

Nicrophorus vespillo:-(8). On dead common shrew.
Silpha atrata:-(*). One speciemen in pitfall. This species is a predator of snails, (Harde 1981).

Order - Chilipoda (centipedes).

Lithobius crassipes:-(1). Only one individual of this 20mm long grey species was collected.
Lithobius forticatus:-(1,3,4,6,8). This large reddish brown species is the commonest centipede at Thrislington

Order - Collembola (springtails).

Orcellia sp:-(1,3,4,6,8). This large 8mm springtail has a characteristic long upright hairs along the thorax and is very common in all the sites.

Order - Dermaptera (earwigs).

Forticula auricularia:-(1,3,4,6,8). In pitfalls from all sites or disturbed during hand searches.

Order - Diplopoda (millipedes).

Polydesmus angustus:-(1,3,4,6,8). This pinky/white species is very common.
Schizophyllum sabulosum:-(3). This large millipede with it's unmistakable double longtidudinal orange stripes was recorded by odd speciemens.
Tachypodoiulus niger:-(1,3,4,6,8). This species was common on all sites.

Order - Diptera (flies).

Family - Culicidae (mosquitos).

Bibio macri:-(1,3,4,6,8). Common on all sites in May. (St.Marks fly).

Family - Syrphidae (hoverflies).

Epistrophe (Epistrophe) grassulariae:-(1). 1 speciemen whilst sweep netting on 13/07/90.
Paragini pellatus:-(6). 2 speicemens whilst sweep netting on 06/06/90.
Syrphus ribesii:-(3). 1 speicemen whilst sweep netting on 16/06/90.

Family - Tipulidae (crane-fies).

Nemhrotoma appendiclata:-(4,6). Spotted crane-fly.
Tipula oleracea:-(1,3,4,6,8). Common on all sites. (daddy long legs).

Order - Hemiptera (bugs).

Family - Miridae.

Capsus ater:-(4). 1 speciemen collected in pitfall.

Order - Hymenoptera (sawflies, bees, ants and wasps).

Family - Bombus (bumblebees).

Bombus lapidarius:-(1,3,4,6,8). A common bumblebee at Thrislington.

Family - Formicidae (ants).

Formica lemani:-(6) 2 speciemen collected in pitfalls.
Myrmica ruginodius:-(1,3,4,6,8). very common.

Family - Tenthredinidae (sawflies).

Rhogogaster viridis:-(1,3,4,6,8). This vivid green species was commonly seen on flowers e.g. 06/06/90.

Family - Vespidae (social wasps).

Vespula vulgaris:-(1,3,4,6,8). In pitfalls from all sites.

Order - Isopoda (woodlice).

Philoscia muscorum:-(1,3,4,6,8). Very common, the commonest woodlouse by far.

Order - Lepidoptera (butterflies and moths).

Coleophora anatipennella:-(8). This species common name is the pistol case barrier, due to it's pistol shaped case in which it feeds on hawthorn, (Harde 1981).

Geometridae.
Camptorgramma bilineata:-(1,3,4,6,8). Commonly called the yellow shell, seen on 21/06/90, etc.
Odezia atrata:-(1,3,4,6,8).

Family - Lasiocampidae (eggar moths).

Philudaria potataria:-(4). 1 caterpillar in pitfall, drinker moth.
Malacosoma neustria:-(8). 1 caterpillar feeding on hawthorn.

Family -Noctuidae.

Agrochola litura:-(1,3,4,6,8). Caterpillar of this species recorded on all sites feeding on bramble, 2 reared on bramble hatching on 21/08/90.(Brown spot pinion).
Autographa gramma:-(8). 1 speciemen collected in pitfall. Commonly called Silver Y moth.
Callistege mi:-(1,3,4,6,8). Often seen on the wing e.g. 22/05/90. Commonly called the mother shiptern.
Noctura janthina:-(4). 1 adult disturbed. (lesser broad boarded yellow undrwing).

Family - Zygaenidae (Burnets and foresters).

Zygaena filipendulae:-(1,3,4,6,8). Common on all sites see butterfly results.

Butterflies.
(see butterfly results section).
Aglais urticae:-(1,3,4,6,8).
Artogeria rapae:-(1,3,4,6,8).
Artogeria napi:-(1,3,4,6,8).
Aricia artexerxes salmaeis:-(1,3,4,6,8).
Anthocharis cardamines:-(1,3,4,6,8).
Coenomympha pamphilous:-(1,3,4,6,8).
Erynnis tages:-(1,3,4,6,8).
Lasiommata megera:-(1,3,4,6,8).
Lycaena phlaeas:-(1,3,4,6,8).
Maniola jurtina:-(1,3,4,6,8).
Ochlodes venatus:-(1,3,4,6,8).
Pieris brassicae:-(1,3,4,6,8).
Polyommatus icarus:-(1,3,4,6,8).
Thymelicus flavus:-(1,3,4,6,8).

Order - Oligocheates (worms).

Lumbricus terrestricus:-(1,3,4,6,8).Occured in pitfalls on all sites.

Order Opilines (harvestmen).

Nemastoma bimaculatum:-(1,3,4,6,8). Shepard recorded this species as being abscent in 1985 on all transplanted sites but has

successfully recolonised all sites since then.

Orders- Pulmonata (snails and slugs).

Arion ater:-(1,3,4,6,8). This large black slug was common after rain.
Arion subfuscus:-(8). 1 speciemen recorded during hand searches. (slug).
Candidula intersecta:-(1,3,4,6,8). Odd speicemens in pitfalls and hand search on 13/06/90. (snail).
Cepaea hortensis:-(1,3,4,6,8). Rarer than C.nemoralis.
Cepaea nemoralis:-(1,3,4,6,8). The commonest large snail.
Carychium tridentatum:-(4). 1 speicemen collected in pitfall on 21/06/90. 1.7mm snail.
Decoceras reticulatum:-(1,3,4,6,8). odd speicemens collected in pitfalls and hand searches. (slug).
Hygromia (Trichia) liberta:-(1,3,4,6,8). Patchy distribution throught the sites.

Order Pseudoscorpiones (Pseudoscorpions).

Neobisium muscorum:-(1,4). 1 speicemen from each site in pitfalls.

Order - Siphonaptera (fleas).

Hystrichopsylla talpae:-(4). Odd speciemens collected in pitfalls.

Comparison of Caribidae species occuring Magnesian Limestone Grassland and Magnesian Limestone quarry floors in County Durham.

Key:- Thris = Thrislington plantation. (Past refers to all previous studies and present to this study), **B.M.** = Bishop Middleham, **F.C.** = Ferryhill cut, **T.G.** = Tudhoe Grange, **H.D.**= Hawthorn dene and **K.P.** = Kelloe plantation.

Species	Thris. Past	Thris. Present	Raisby.	B.M.	F.C.	T.G.	H.D.	K.P.
Agonom dorsale		*	*			*		
Amara aulica			*			*		
Amara bifrons						*		
Amara communis			*					
Amara convexior		*		*				
Amara ovata	*							
Amara praetensis				*				
Amara similata	*							
Amara spereta				*				
Badister bipustulatus	*	*		*				
Bembidion lampros		*		*				
Bembidon 4-maculatum	*							
Bradycellus verbasci	*							
Calathus fuscipes				*		*		
Calathus melanocephalus		*		*				
Calathus micropterus				*		*		
Calathus mollis				*				
Carabus gallicus.			*	*		*		
Carabus violaceus.	*	*		*		*		
Cicindela campestris				*				
Clivina fossor	*			*				
Cychrus caraboides				*				
Dromius quadrimaculatus								*
Harpalus rufipes	*	*		*				
Leistus ferrugines	*							
Leistus rufescens		*						
Loricera pilicornis		*				*		
Nebria brevicollis						*		
Nebria gyllenhali								
Nebria selena		*		*				
Notiophilous biguttatus		*		*				
Notiophilous germinyi		*						
Pterostichus cristatus.	*		*					
Pterostichus madidus.	*	*	*	*	*	*	*	*
Pterostichus melanarius		*		*		*		
Pterostichus niger				*		*		*
Trechus quadristiatus		*						