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Chapters 2 to end

THE EFFECT OF CUTTING AS A FEN MANAGEMENT PRACTICE ON THE INVERTEBRATE BIODIVERSITY OF THE NORFOLK BROADS

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METHODS

2.1 Introduction

This chapter gives the general methods used in the pilot study and main study. It covers the sites, habitat types, collecting methods, invertebrates chosen and cutting and grazing managements, plus aspects of the data analysis included in this study.

Livestock in this study comprise Konik ponies, Welsh ponies, and sheep (Figures 1.4 and 1.5, pages 17 and 18). Studies using cattle were postponed. A site grazed by red deer (*Cervus elaphus*) was included in the pilot study, but not in the BA's study.

2.2 The Sites

Several representative sites with a diverse range of NVC (National Vegetation Classification) communities were chosen by the BA. Their location in Norfolk is shown in Figure 2.9 (page 41), and location in detail is shown in Figures 2.1-2.4. These were How Hill and Horning (Figure 2.1), Long Gores, Hickling and Catfield Fen (Figure 2.2), Mallow Marsh and Broad Fen (Figure 2.3), and Whitlingham Marsh (Figure 2.4). Ordinance Survey map references are: Mallow Marsh: TG 360233; Broad Fen: TG 344254; How Hill: TG 364198 ; Horning: TG 360164; Long Gores: TG 427248; Hickling: TG 429205; Catfield: TG 407216; Whitlingham: TG 281079. Catfield and Hickling are on Norfolk Wildlife Trust (NWT) land

and Long Gores is privately owned. The other sites fall under the jurisdiction of the BA.

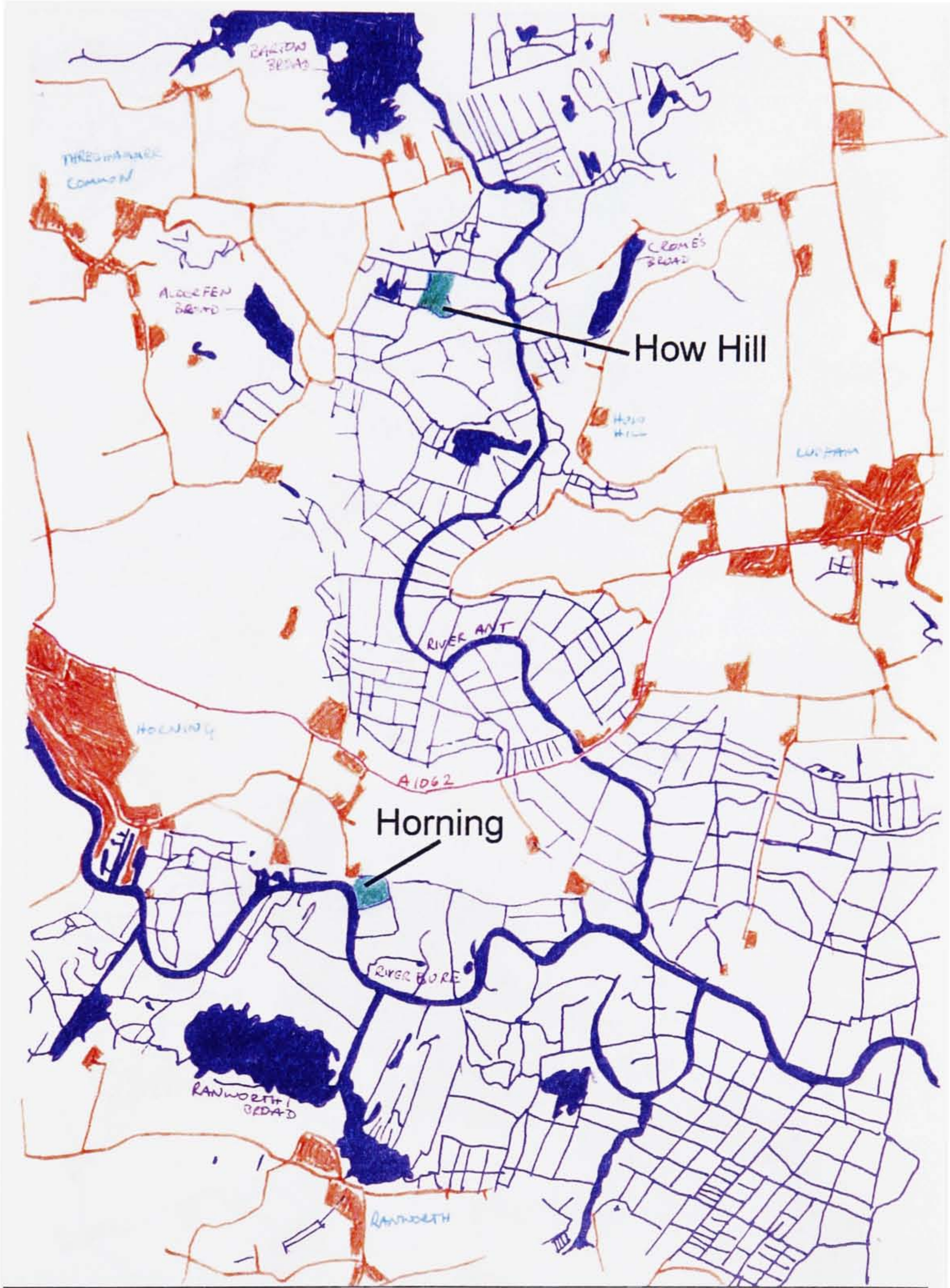


Figure 2.1 How Hill is located near the River Ant and Horning Hall is on the River Bure.

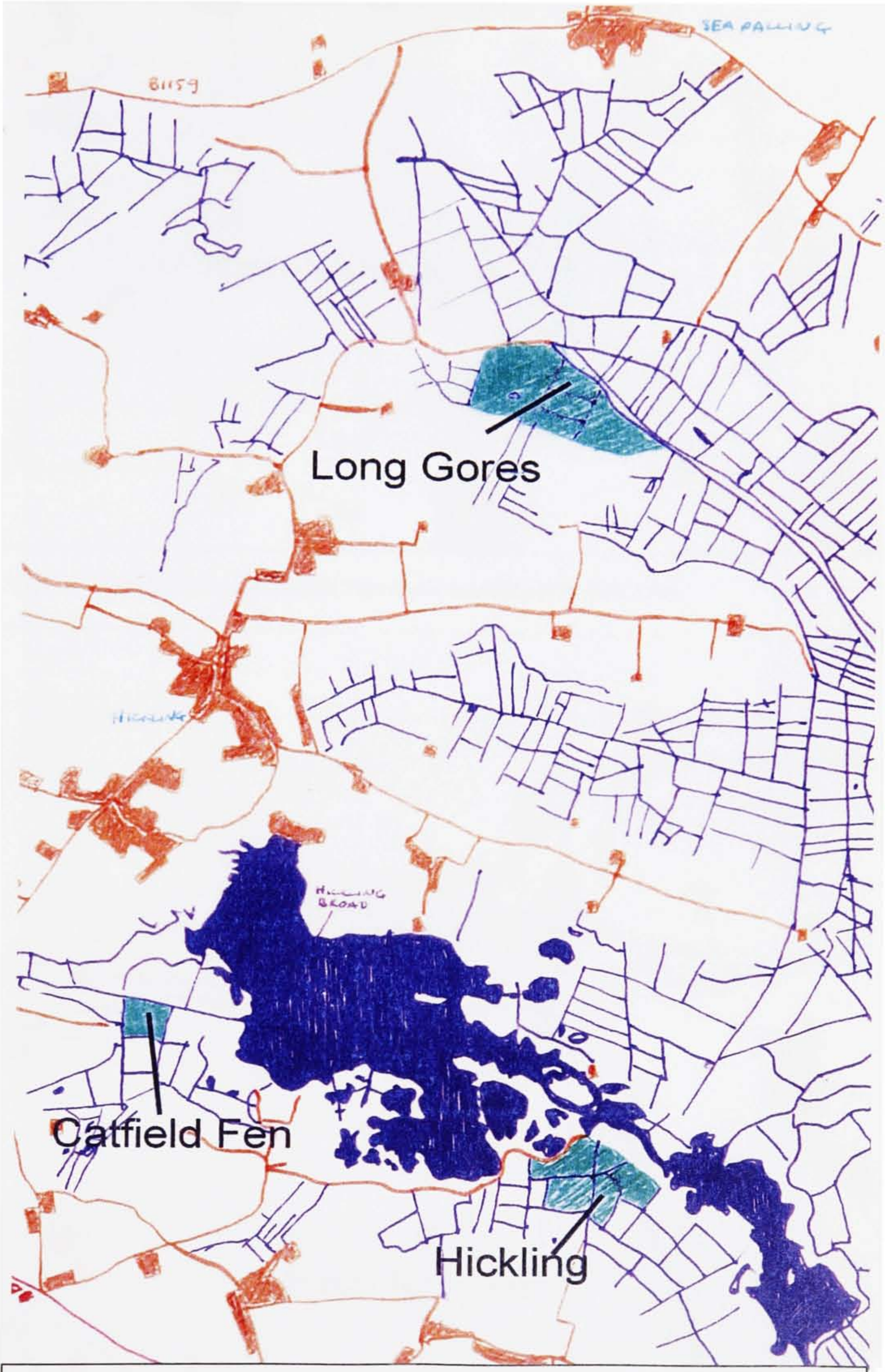


Figure 2.2 Catfield Fen and Hickling are located close to Hickling Broad. Long Gores is just to the north.

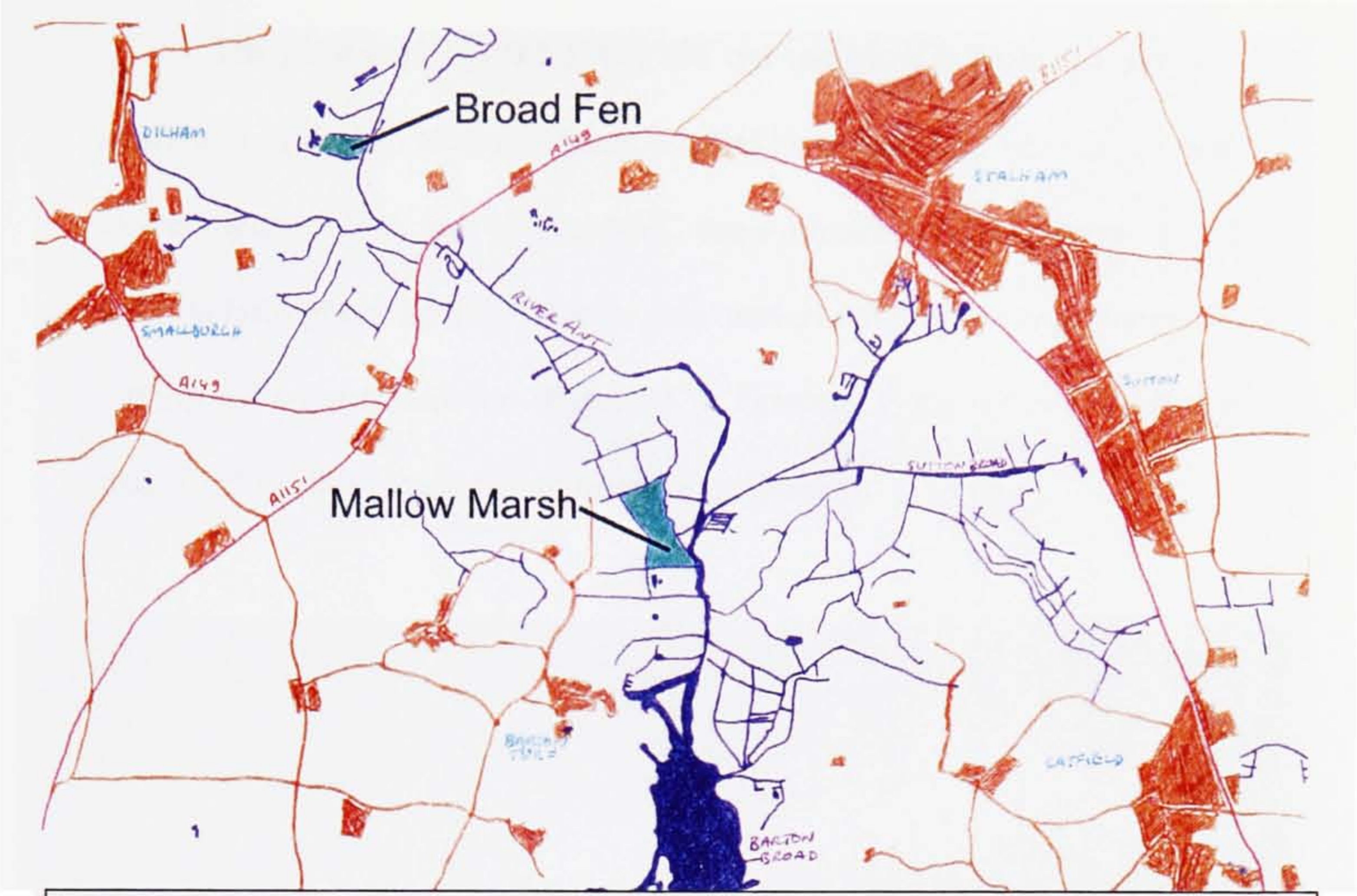


Figure 2.3 Broad Fen and Mallow Marsh are located on the River Ant.

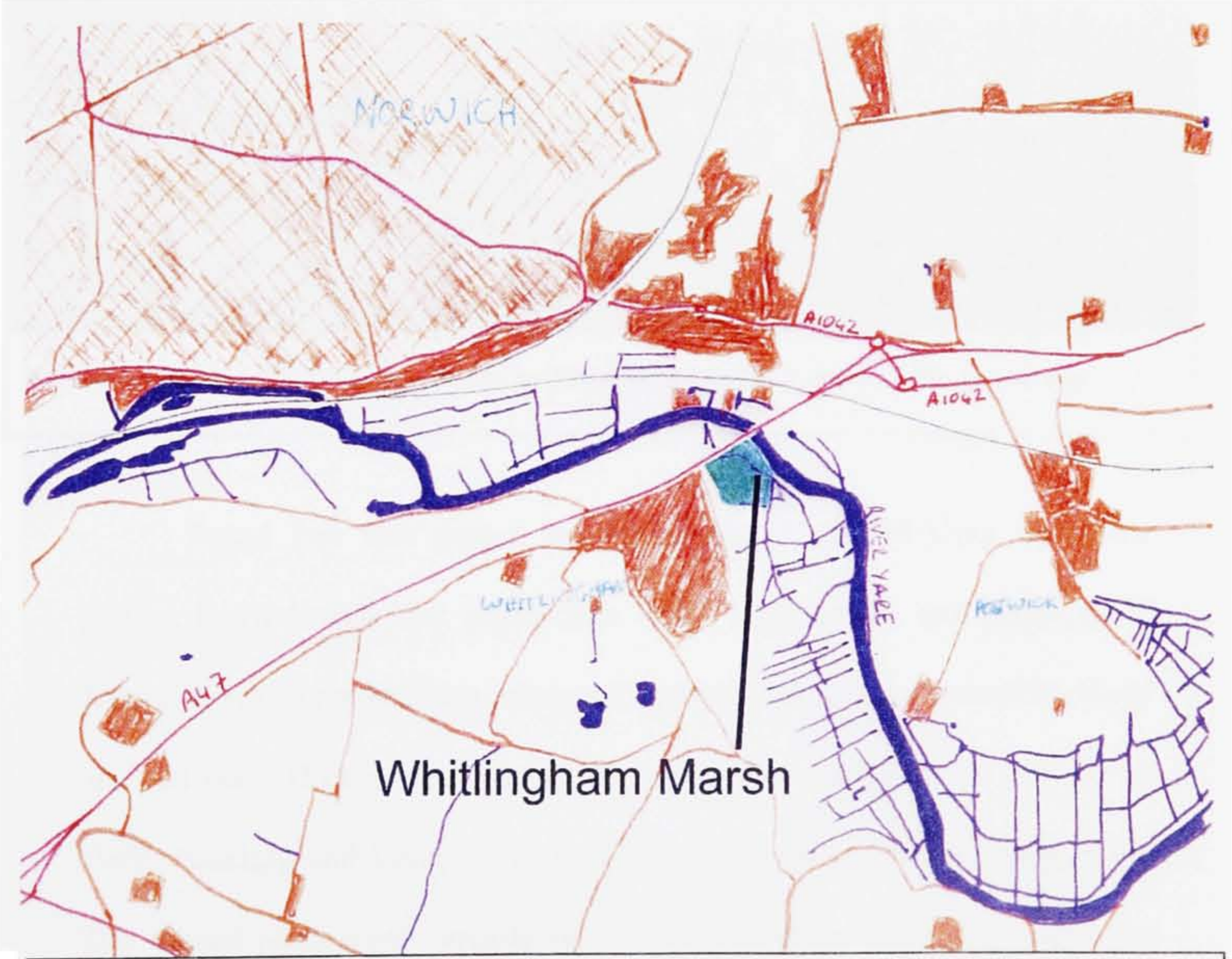


Figure 2.4 Whitlingham Marsh is south of Norwich on the River Yare.

The pilot study (1997-1998) did not include Catfield, and the main study was limited to Mallow Marsh, Catfield Fen and How Hill, which were chosen because they had similar NVC communities. Mallow Marsh (Figure 2.5), Whitlingham Marsh (Figure 2.6) and How Hill were managed by cutting, whereas Broad Fen (Figure 2.7), Horning, Long Gores (Figure 2.8) and Hickling were managed with grazing animals.

Figure 2.5 Mallow Marsh is dominated by *Phragmites australis*, mixed with *Juncus* spp.

Broad Fen was grazed by Welsh ponies and Hickling by Konik ponies, hardy breeds that could cope with boggy terrain and poor quality fodder. Long Gores had been managed against reed and was grazed by sheep and red deer. Horning had sheep for a couple of weeks in the summer of 1998. Hickling and Long Gores had no control areas, though Horning did. The grazed plots were variable in size. At Hickling, and Long Gores the grazed plots, and at Horning the grazed and control plots, were large fields, whereas at Broad Fen the ponies grazed around a fenced off area of 12x12m.

Figure 2.6 Whitlingham Marsh is eutrophic fen, being located next to a sewage treatment plant.

2.3 The Pilot Study

A wide variety of habitats were chosen for the pilot study, e.g. mixed fen, reed bed and grazing marsh, and the cutting regimes were standardised. Squares of 10 x 10 m were cut using the fen harvester or the Bücher mower and a similarly sized control plot was left uncut. A border or buffer zone was also cut around each test plot. Grazing was continuous all year round for the ponies and deer, but limited for the sheep. Grazing at Broad Fen consists of seven Welsh Mountain ponies, and at Hickling of nine Konik ponies. This constitutes low density grazing of less than 0.3 ponies per hectare. As the ponies learnt to utilise the sites over a period of months, the grazing efficiency may have increased. Long Gores Marsh, situated north of Hickling, is regularly grazed over about 35 acres by red deer and Chinese water deer (*Hydropotes ineermis*), and has been regularly cut in the past, managing against reed.

Figure 2.7 Broad Fen is very mixed, open fen, with recently dug turf ponds.

Most of the cut plots were cut in the early summer (July 1998). Cutting 'high' meant 15-20cms and cutting 'low' was 0-5cms i.e. at ground level. It is hard to be exact because of the topography of the ground. Reed litter was removed from the sites. Table 2.I provides a summary of the sites, the habitat type each site represents and grazing and cutting regimes, and Figures 2.1-2.4 show the position of the sites. Most sites were cut once only in the summer of 1998, though Whitlingham, which is eutrophic, was cut twice, once in January 1998 and again in January 1999. Thus, for the pilot study Mallow Marsh, How Hill and Whitlingham had five plots each

- fen harvester high
- fen harvester low
- hand high
- hand low
- control

The cut plots were uniform in size, being 10x10m with a border of anything from 2-200m. The cutting regime was also set up by the BA and the plots were designed for botanists in terms of size and proximity, rather than zoologists. This severely limited which invertebrates could be effectively studied. As the more mobile invertebrates such as butterflies roamed over

Figure 2.8 Long Gores is dry grazing marsh, managed against reed.

Table 2.I: The sites, habitat types and their management.

Site		How Hill	Mallow Marsh	Whitlingham Marsh	Horning Hall	Broad Fen	Hickling Broad	Long Gores Marsh
Habitat		reedbed	mixed reed fen	eutrophic fen	mixed fen	mixed fen	grazing marsh	grazing marsh
Flooding		floods annually	floods annually	flooded	floods annually	flooded	infrequent flooding	infrequent flooding
Cutting	Fen Harvester high	July 1998	July 1998	Jan 1998 and 1999	NA	NA	NA	long term cutting mgmt
	Fen Harvester low	July 1998	July 1998	Jan 1998 and 1999	NA	NA	NA	long term cutting mgmt
	Hand high	July 1998	July 1998	Jan 1998 and 1999	NA	NA	NA	long term cutting mgmt
	Hand low	July 1998	July 1998	Jan 1998 and 1999	NA	NA	NA	long term cutting mgmt
Grazing		NA	NA	NA	Sheep. Summer 1998	Welsh ponies. All year round	Konik ponies. All year round	Red deer All year round
Control		yes	yes	yes	yes	yes	no	no

an area much larger than the sample plots these were not suitable for investigation and the project therefore focussed on the less mobile invertebrates: snails, spiders and beetles. These were chosen because they were relatively easy to identify (keys for the groups exist), easy to capture and collect in high numbers, ecologically important, often habitat specific and mostly with high habitat fidelity (i.e. wetland specialists) (section 1.9,

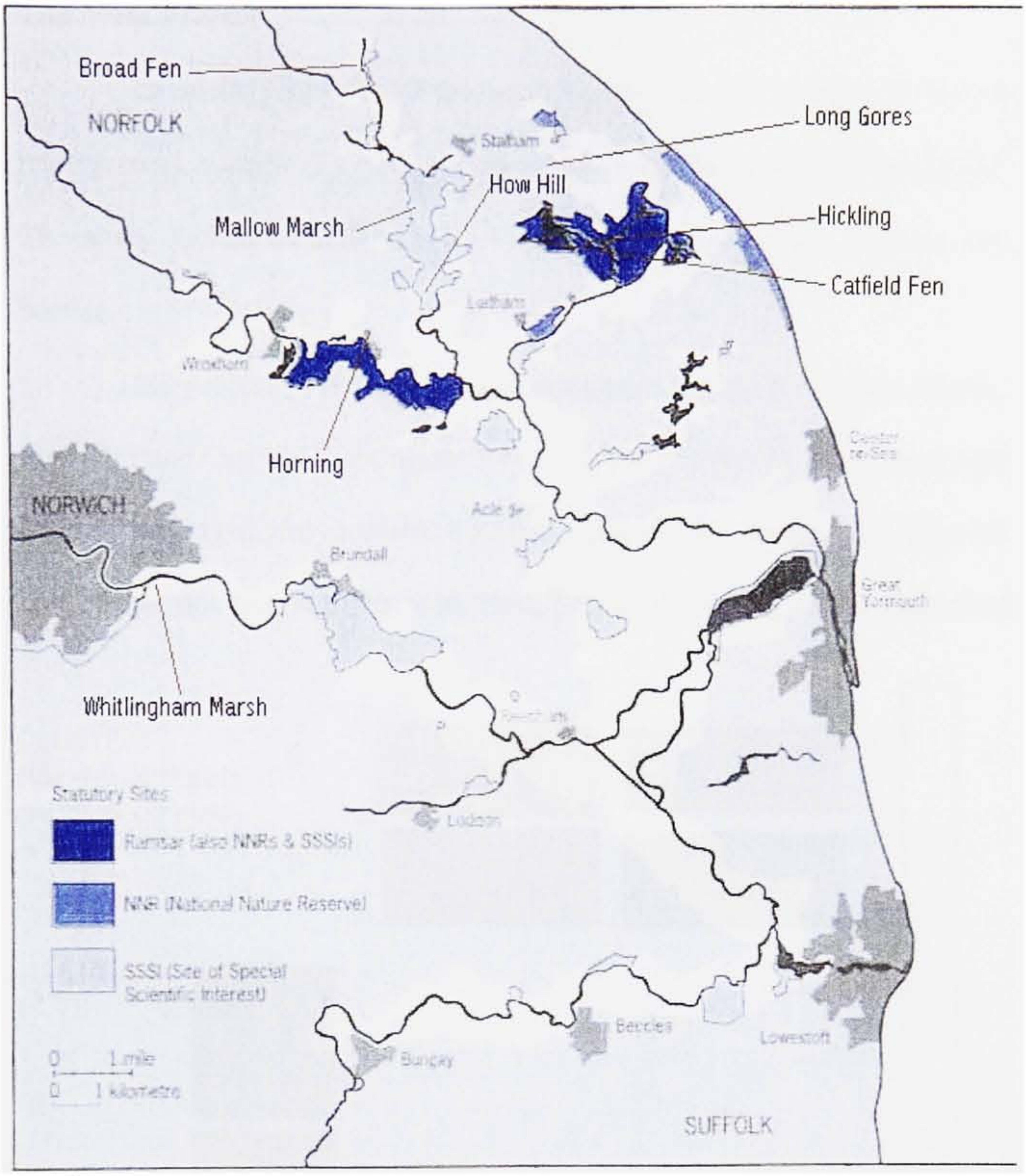


Figure 2.9 The location of the study sites within the Norfolk Broads.

page 22). Spiders and beetles were collected using pitfall traps, whereas snails were collected by hand sorting.

The Main Project

The main project was designed to discover the effect of habitat management, specifically cutting areas of reedbed compared to control areas. The study looked at differences in response between snails, spiders and beetles.

This project (1999-2000) encompassed three sites: Mallow Marsh, How Hill and Catfield Fen (Figure 2.9-2.12). These were all S4 reedbed with Catfield veering slightly towards a S24 reedbed and fen community. They all had similar flooding regimes, with How Hill being slightly wetter underfoot than Mallow Marsh, and with Catfield being the driest in places. Six plots were marked out at each site and labelled A – F. At How Hill and Catfield

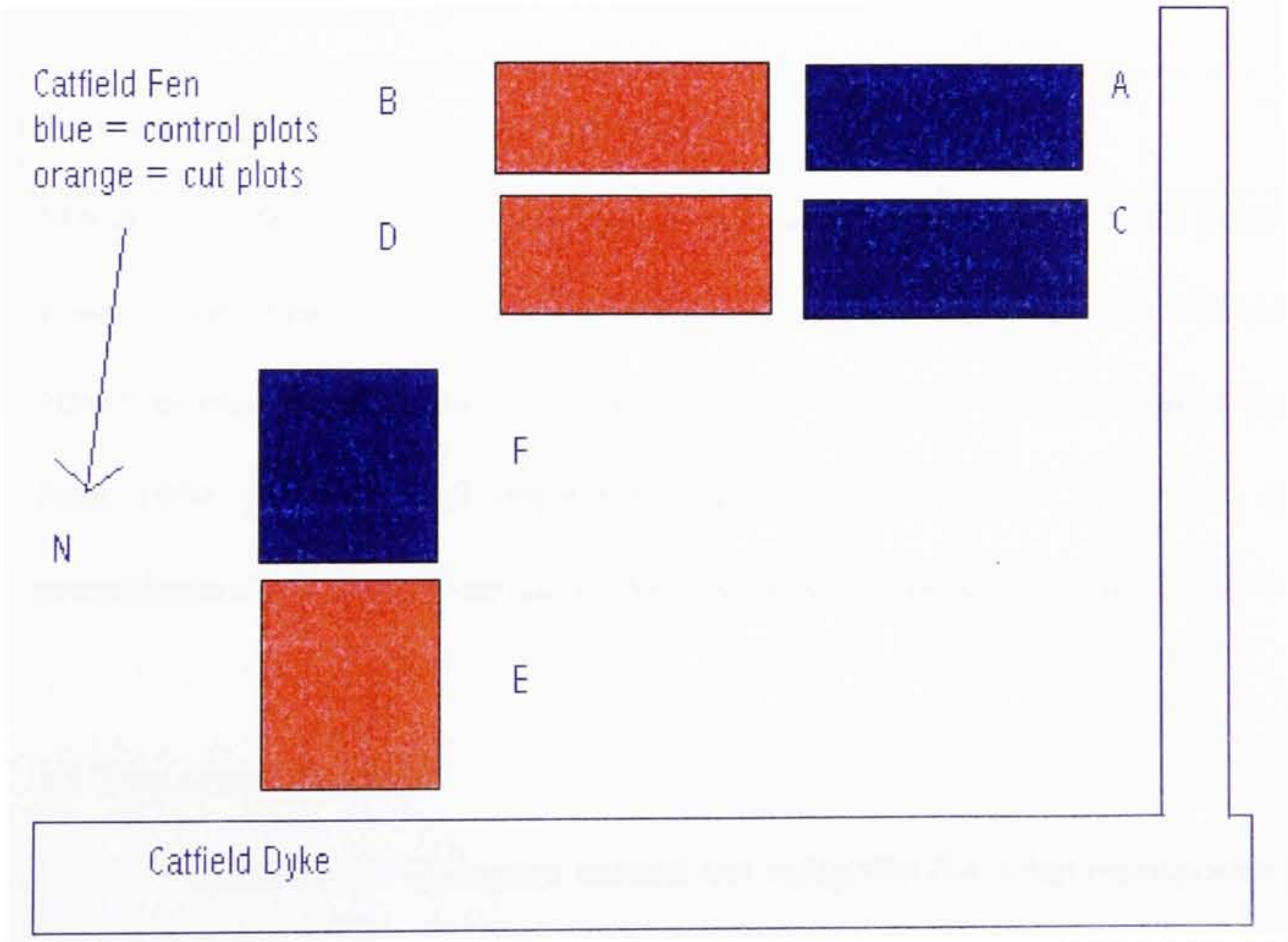


Figure 2.10 The layout of the cut and control plots at Catfield Fen.

plots A, C and E were control, uncut plots with B, D, and F cut. At Mallow Marsh it was the other way around with A, C and E being cut whilst B, D and F were control plots. (Figure 2.10-2.12 show the layout.) These plots were all 10x10 m plus a 2m+ border and they were cut in July 1999 shortly after the June 1999 sampling and vegetation surveys for that year. Sampling of invertebrates was carried out as for the pilot study (section 1.10, page 26).

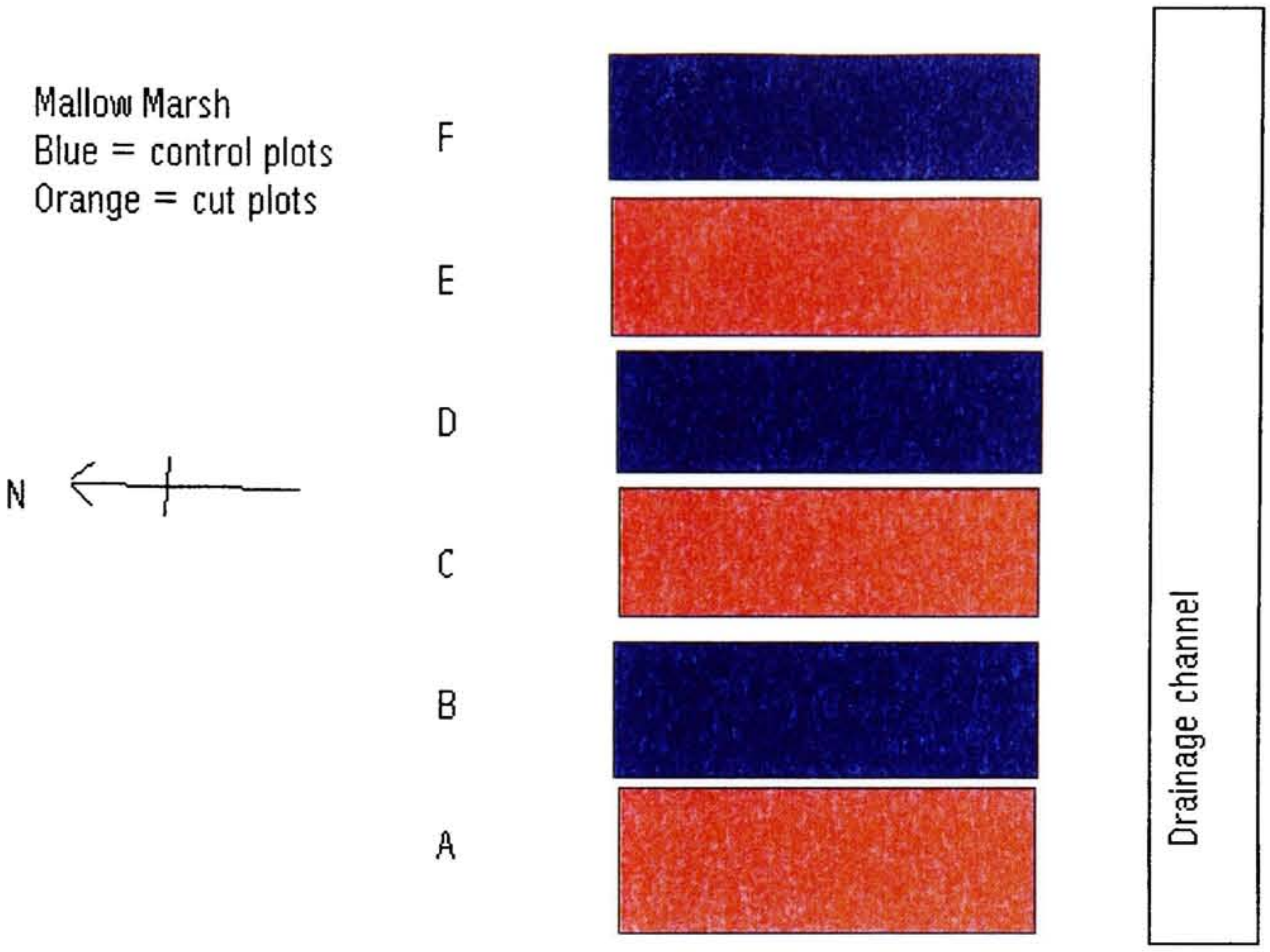


Figure 2.11 The layout of the cut and control plots at Mallow Marsh

2.5 Vegetation Surveys

Vegetation surveys were carried out using the BA's fen management monitoring programme designed by GCB Kennison. The original protocol involved creating random co-ordinates within the plot to be surveyed. At each co-ordinate four 25x25cm quadrats were scored for presence and absence of each species of vegetation. This was repeated 25 times so that the frequency scores were out of 100. Later modifications of this survey technique dispensed with the random co-ordinate method and were carried out using irregularly placed quadrats instead. The results are still comparable as quadrat size and number was not altered (Kennison 1991).

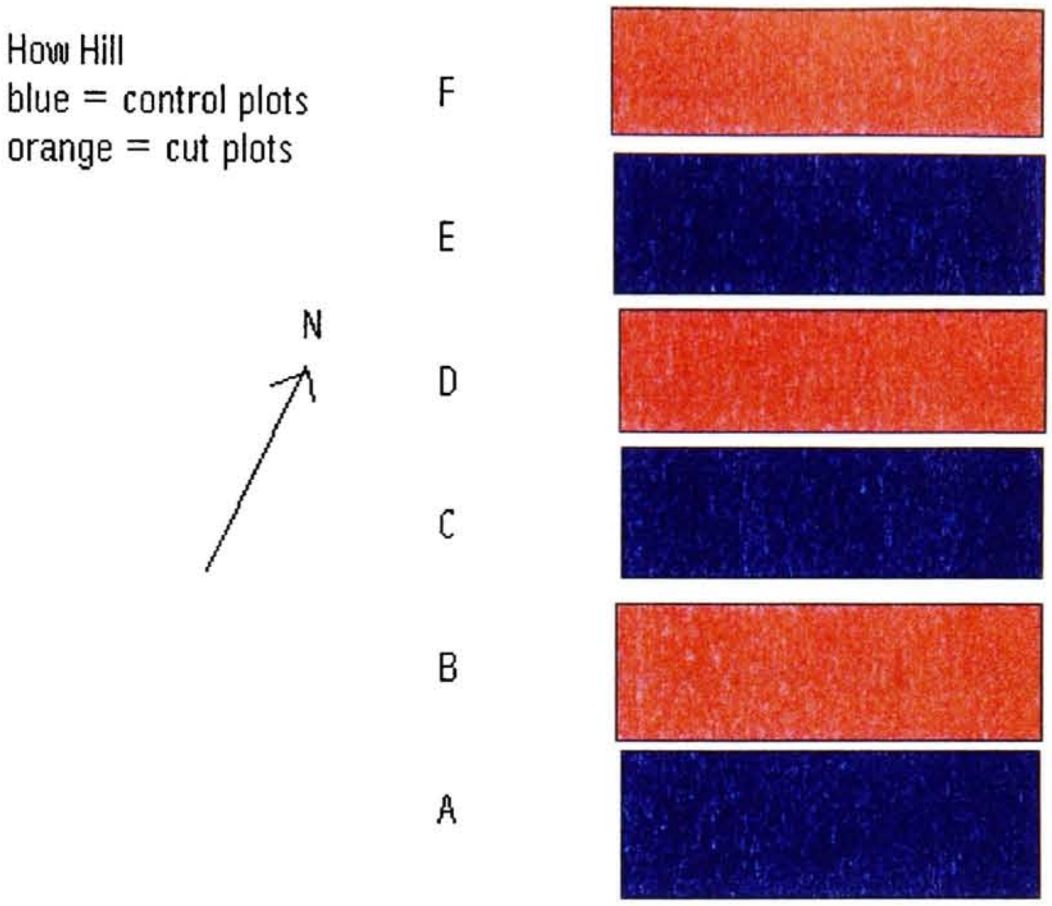


Figure 2.12 The layout of the cut and control plots at How Hill.

Frequency scores out of 100 give a percentage reflection of plant abundance, i.e. something present in 40 of the quadrats can be expected to have a 40% frequency of occurrence in the area, however clumped and regular distribution patterns can distort true abundance values. This is true for the invertebrates surveyed as well as the vegetation data. Using Raunkiaer's law of frequencies (Kennison 1991) numbers of common species may be greatly exaggerated in some communities. Results can be compared between previous surveys on the same site and between sites. Chi squared tests can be carried out on the data.

The vegetation data for the main project NVC S4 reedbed sites, Mallow Marsh, How Hill and Catfield Fen, can be found in Appendix 7.1, Table 7.IV (page 289). The three sites are similar in vegetation, being dominated by *Phragmites australis*. Several other species are present at all the sites, but in much smaller proportions. These species include the Lesser Water Parsnip *Berula erecta*, Hedge Bindweed *Calystegia sepium*, Sedge *Carex* spp, Hemp Agrimony *Eupatorium cannabinum*, Meadowsweet *Filipendula ulmaria*, Marsh Bedstraw *Galium palustre*, Marsh Pennywort *Hydrocotyle vulgaris*, Yellow Flag Iris *Iris pseudocorus*, Milk Parsley *Peucedenum palustre*, Greater Skullcap *Scutellaria galericulata* and Bittersweet *Solanum dulcamara*.

2.6 Collecting the invertebrates

Selecting the taxa to study was an important decision. Brown (1991) described criteria which should be taken into account before selecting taxa. Taxa should be taxonomically and ecologically diverse. Narrow taxonomic range would lead to an underestimation of the biodiversity, whereas a narrow ecological range could lead to a bias in either direction, depending on the nature of the survey. For wetland species an ecological range that covers all the habitats sampled is desirable.

The taxa sampled should exhibit high ecological fidelity. Differences in habitat should be reflected in the taxa found. Wetland species for example should be confined to wetland areas in order to truly assess the impact on these taxa of changes in wetland habitat. This project requires very high ecological fidelity due to the proximity of different test sites which may vary only slightly in composition or management strategy. Taxa should therefore be narrowly endemic and well differentiated between habitats, with each population specializing in a narrow habitat. Due to small plot sizes available in this project the groups sampled needed to be particularly sedentary.

The groups chosen need to be taxonomically well known and therefore easy to identify with stable nomenclature and available keys. This is particularly important as individuals in this project were identified to species level. Following from this it is an advantage if the taxa are well studied with their biology and life history understood. This enables logical, ecological conclusions to be drawn from the study, and enables easier collecting if particular rare or seasonal species are being sought.

Collecting is also aided if the populations are readily surveyed, abundant and easy to find. The populations should be always present in the habitat with dampened fluctuations rather than boom and bust cycles where one year there is a glut of the organism sought followed by a year where the population appears to have vanished. The groups should be continuously present in numbers which allow the easy collection of large random samples of species and the variation within that species.

If the taxa are functionally important in ecosystem then the effect of habitat change is often easier to see, and reflected on co-taxa. Functionality is frequently linked with the economic importance of a group and this may relate to attracting funding for a study and the public interest in the project.

Although Brown (1991) suggests also that response to disturbance should be predictable, rapid, analysable and linear, this information is not always available until after sampling, and few groups seem to fall into this box. If the group is to act as a marker for the ecosystem then it must associate closely with other species and/or species resources so that patterns observed are reflected in other related and unrelated taxa.

Figure 2.13 Pitfall traps were set one metre apart.

The animals used in this project are snails (Gastropoda), beetles (Coleoptera) and spiders (Araneae). These groups share certain features which made them suitable for this study. Firstly the number of species present in the Broads (as opposed to the tropics for example) is a tractable number, few enough species to allow accurate species level identification and diverse enough to be meaningful. They are relatively easy to identify, as keys and expert advice are both available. They are sedentary groups with high ecological fidelity. They are easy to collect and store.

The sites were sampled in June (pre-cutting) and August (post-cutting). Eight pitfall traps (12 x 6 cm) consisting 30% antifreeze to 70% water and a soupçon of washing up liquid were left in each treatment area for a week (Figure 2.13). This was not possible at Broad Fen or Whitlingham because of the standing water at the sites. Additionally the sites were sampled in August for molluscs. A riddle (36 x 10 cm) was filled with litter, shaken and the snails collected (Figure 1.6, page 28). Snails from this collecting and spiders from the pitfall traps were identified to species (Janus 1979, Kerney & Cameron 1979, Roberts 1985a & b, 1987, 1996) and the results analysed using the Decorana statistical package, Vespan (Hill 1979).

June and August were chosen as sample times as invertebrates are most active in summer and the water table is low enough to allow pitfall sampling. Preliminary sampling in April proved that the sites were far too wet at that time of the year for this to be feasible. The nature of the wetland environment meant that pitfall traps could not be left for any length of time due to the risk of flooding. A week was chosen as the minimum length necessary to collect sufficient data, yet minimise the risk of the traps flooding.

These short bursts of intensive sampling generally avoided severe flooding. The pitfall traps were designed to collect spiders and beetles. Each plot had eight pitfall traps put out at 1m intervals, starting at 2m in from the edge (Figure 2.13). The pitfall traps were 12cm tall by 6cm diameter and the mixture of antifreeze and water, also included a dash of washing up liquid to break the surface tension. The lids were propped up over the traps to protect them from rainfall, in the unlikely event that rain would flood the traps before the water table rose enough to engulf them. Additionally shrew-excluders made from wire mesh were fastened over the traps to prevent the unnecessary death of shrews, lizards, frogs and toads. These were highly successful, cutting the death rate for small mammals and other vertebrates from one every five traps to one every 60 traps (Figure 2.14).

Figure 1.14 The shrew excluder was highly effective at preventing small mammal, amphibians and lizards from drowning in the pitfall traps.

The molluscs were collected using a volumetric method. A measured amount of reed litter was collected in a garden riddle (36cm diameter x 10 cm high) from the ground layer inside the plot being sampled. The edge areas were avoided to minimize edge effects. The reed litter was shaken vigorously on to a tray (Figure 1.6, page 28). The sample on the tray was minutely searched for snails, which were then preserved in 70% Etoh (ethanol). Although this method may be biased against very small snails (this is a problem with nearly all collection methods for this group, New 1998), it does produce results which can be conveniently compared between plots and sites.

2.7 Identification and Analysis

Identification took place at the UoB laboratory, using a Leica MZ6 microscope and following identification guides: Audisio (1993), Balfour-Browne (1940), Clarke (1973) Janus (1979), Kerney (1999), Kerney and Cameron (1979), Luff (1990), Macan (1960), Pfleger (1990), Pope (1977), and Roberts (1985a, b, 1987, 1996). The pitfall trap specimens were transferred to 100% Etoh for preservation before identification.

The statistical methods used to analyse the data included Chi squared, and rank abundance (using Excel) (Fowler *et al* 1998), Mann Witney U and General Linear Model, (using MiniTab), Simpson's Diversity Index (Begon *et al* 1990) and Jaccard Similarity Index (Southwood 1978), and the multivariate technique Detrended Correspondence Analysis (Decorana) (Rohlf and Sokal 1995a, b) using the package Vespan licensed to the UoB by the late Dr Andrew Malloch of Lancaster University. A Bonferroni correction was made for repeated statistical tests. This is where the experiment – wise significance level (α) is divided by the numbers of tests (n). In most cases $\alpha = p = 0.05$. It gives the revised significance level for each individual test.

The algorithm for Simpson's Diversity Index:

$D = 1/\Sigma(\text{number of individuals of each species / total number of individuals})^2$

This was calculated for each plot. Simpson's Diversity Index is the inverse measure of the probability that two individuals picked at random would belong to the same species. The Simpson's Diversity Index is more sensitive to changes in the abundant species in the environment, and less so to any changes in the rare species. Simpson's Diversity Index was chosen for this reason, to emphasize any major changes in diversity caused by the management regime. Whilst rare species are also important, the power analysis (section 2.8, page 53) showed that the noise to data ratio is fairly high with regards to numbers of individuals, so concentrating on the abundant individuals in this instance would allow any 'signal' (patterns in the data) to be seen more easily.

The algorithm for Jaccard's Similarity Index:

$$I = j / (a+b-j) \times 100$$

where j is the number of species found jointly in both sample areas A and B

a is the number of species found in area A

b is the number of species found in area B.

The algorithm for Morisita-Horn Index:

$$C_{MH} = 2\Sigma(ani.bni) / (da+db)aN.bN$$

where, $aN = \Sigma$ no.s individuals at site a
$ani = \Sigma$ no.s individuals in sp i
$da = \Sigma(ani^2) / aN^2$

Refs (Krebs, 1989, Southwood and Henderson 2000)

The justification for using the Jaccard Similarity Index, and Morisita-Horn Index of Similarity: The power analysis (see section 2.8, pg 53) showed that presence / absence / species composition data was more robust, and liable to yield significant results in this study, and consequently the similarity index of choice is therefore the Jaccard Similarity Index. The Jaccard Similarity Index is eloquent in its simplicity, comparing the numbers of species found in both environments with the total number of species found in both environments, thereby giving a clear indication of the amount of overlap between the habitats sampled.

The Morisita-Horn index was however also included in this study, as this quantitative index is considered the least influenced by sample size (Morisita 1959, Wolda 1981), and Krebs (1989) notes that is it nearly independent of sample size, except for samples of very small size.

The default parameters for Decorana were used: downweighting 0, rescaling 4, analysis 0, segments 26, threshold 0.00, transformation 0.00. This means that rare species were not downweighted. The majority of species collected were unique, especially Coleoptera, and downweighting these species would have left the analysis based on a very small number of common species. As the study sought to look at how the habitat as a whole responds to change, it was deemed more appropriate not to downweight.

The package used meant that exact levels of percentage inertia could not be given as only the first four eigenvectors were displayed in each analysis. Inertia is the sum of the eigen values. However limits can be set on the best and worst case scenarios and the range expressed (Dixon 1992). This, for the purposes of interpretation in each chapter, can be viewed as the amount of variation in the data described by that axis i.e. between 30 and 52% of the variation in the data is described by axis 1 for the vegetation 1999 graphs (Table 2.II).

The higher the inertia calculated for an eigenvector, the more confidence that the variation expressed has a ‘real’ ecological cause, rather than being a random product of the data’s innate variation. The levels of inertia for each axis do not vary widely – the x axis is always more robust than the y axis. Interpretation specifically using inertia levels has not been included in the results section. The overall variation in the data itself is so large that any differences in inertia become negligible during interpretation.

Table 2.II The levels of inertia for each site analysis, eigenvectors 1 and 2.

sample	axis 1 eigenvector	*range to nearest 1%*	axis 2 eigenvector	*range to nearest 1%*
vegetation 1999	0.3834	30 to 52	0.2128	17 to 29
vegetation 2000	0.4454	54 to 75	0.0914	11 to 15
beetles 6/99	0.6503	24 to 43	0.5308	19 to 35
beetles 8/99	1	14 to 35	0.9432	13 to 33
beetles 6/00	0.6631	23 to 47	0.388	13 to 28
beetles 8/00	0.9453	16 to 39	0.6894	12 to 29
snails 6/99	0.8128	52 to 61	0.3605	23 to 27
snails 8/99	0.6568	67 to 77	0.1104	11 to 13
snails 6/00	0.4883	57 to 68	0.1542	18 to 22
snails 8/00	0.4648	53 to 74	0.0859	10 to 14
spiders 6/99	0.352	29 to 52	0.1915	16 to 28
spiders 8/99	0.3337	38 to 60	0.1298	15 to 24
spiders 6/00	0.3744	38 to 64	0.1278	13 to 22
spiders 8/00	0.3687	28 to 49	0.2041	16 to 27

2.8 Power Analysis

The variability of the data was tested using a power analysis. This was done on the data of the main study, pre-cutting in June 1999. The three sites were assumed to be replicates as they were all S4 reedbed. Each site had three pairs of plots, making nine replicate pairs altogether. There were two treatments – control and managed. The difference between the means of these two treatments was calculated for firstly number of species found altogether, and secondly number of individuals of those species found. The sigma level is the square root of the Mean Square Error, calculated from the Anova of the samples. The power refers to the confidence in getting a significant result, with means differing by the amount stated, and the number of replicates stated. The calculation was further computed to ascertain how many replicates would be needed for 95% confidence, given the data variability. The analysis was also carried out on the August 1999 post-cutting data.

Results:

June 1999 Number of Species

Sigma = 3.81314

Differences in means = 7.33333

With 9 replicates, power is 96.89%

With power 95%, number of replicates needs to be 9.

June 1999 Number of Individuals

Sigma = 15.5563

Differences in means = 2.33333

With 9 replicates, power is 6.03%

With power 95%, number of replicates needs to be 1157.

August 1999 Number of Species

Sigma = 1.781

Differences in means = 3.6666

With 9 replicates, power is 98.35%

With power 95%, number of replicates needs to be 8.

August 1999 Number of Individuals

Sigma = 7.6368

Differences in means = 1

With 9 replicates, power is 5.79%

With power 95%, number of replicates needs to be 1517.

From this analysis it can be seen that changes in species composition are far more significant than changes in numbers of individuals. Given the resources available it was not possible to devise a study with over 1500 sample plots. The study design is however adequate for looking at species composition.

2.9 Sampling Strategy, Main Project: Summary

Three sites of NVC S4 *Phragmites australis* dominated reedbed, Catfield Fen, Mallow Marsh and How Hill, had three pairs of plots each. These were deemed to be replicates due to the NVC classification. Initial sampling in the pilot project had not show any major differences between Mallow Marsh and How Hill. The pilot study did not include any other S4 reedbed sites, and so Catfield Fen was chosen as the third site. Nine replicates were shown to be enough, given the variability of the data, to analyse changes in species composition.

Sampling took place in June and August 1999 and 2000. The treated plots were cut in July 1999. Sampling consisted of eight pitfall traps in each plot, left down for one week. The short length of time for the pitfall traps was to minimize the chances of the traps flooding, given the wetland nature of the habitat, and surface level water table. The trap dimensions were 12cm high, by 6cm diameter, containing diluted antifreeze and water. The reedlitter was further searched for snails using a riddle, dimensions 10cm high, by 36cm diameter. The riddle was filled once per plot with around 10 litres of reedlitter. It is not possible to be exact, though efforts were made to fill the riddle by the same amount each time. The spatial arrangements of the samples within the plots are shown in Figures 2.10-2.12 (pages 42-44).

The invertebrates collected were identified to species. Identification of Mollusca was carried out by the author, with troublesome species identified by Prof. R. Cameron, and D. Howlett. The identification of the Araneae was carried out by the author, with troublesome species identified by D. Henshaw. The identification of the Coleoptera was carried out by R. Marsh, with troublesome species sent on to experts in the particular Coleopteran families involved. The full species lists are available in the Appendices at the end of Chapter 7, and checklists can be found at the end of each relevant chapter.

PILOT STUDY

3.1 Abstract

- Mollusca, Araneae and Coleoptera are shown to be habitat specific.
- Different types of habitat have different dominant species.
- Sites could be grouped broadly as 'reedy', 'dry grazing' and 'flooded' but controls situated on one site within a habitat group could not be used as controls for another site within the same habitat group.
- Spiders and beetles are strongly seasonal and have different species dominance in June and August.
- All groups tested respond subtly to management but robust statistical analysis was not possible.

3.2 Introduction

Quantifying habitats and their response to management is more complex than just using their NVC codes. Habitats are more than just their vegetation, soils or hydrology. Vegetation structure for example affects invertebrate populations (Zulka *et al* (1997) and Wheater *et al* (2000), Bell *et al* (2001) and small disturbances allow pioneer species to get a hold in an area. Biodiversity cannot be easily measured as it comprises a vast array of non-combinable features. These include everything from soil-type to food chain length (Gaston 1996), but the most commonly used criteria are species number and species abundance - how much and how many. These are the parameters measured in this study. In an ideal world all the species in a system would be accurately catalogued (Hammond 1994). However, time and practical constraints restrict the amount of information which can be collected and so judgements must be made regarding what can reasonably be achieved. Indicator taxa, snails, spiders and beetles, were chosen, based on their ability to reflect the effects in each habitat of the management regime imposed.

A pilot study was carried out in order to ascertain whether similar sites could be grouped with each other. Snails (collected by riddling) and spiders and beetles (collected by pitfall traps) were identified to species (Audisio 1993, Balfour-Browne 1940, Clarke 1973, Janus 1979, Kerney 1999, Kerney & Cameron 1979, Luff 1990, Macan 1960, Pope 1977, Roberts 1985a & b, 1987, 1996). The sites were quite variable in terms of habitat and water level but fell roughly into three groups (Table 3.I) These groups were ‘reedy’, with variable water levels, ‘dry grazing’, where ‘dry’ means no standing water, and ‘flooded’, where standing water is present all year round.

3.3 Hypothesis

The hypothesis to be tested was:

Habitats with similar vegetation have similar invertebrate communities. These habitats can be grouped together for the purposes of ecological investigation.

3.4 Specific Aims

The specific aims for the pilot study were to test whether similar habitats could be grouped together for the purposes of investigation into habitat management effects on invertebrates. Additionally the pilot study sought to set limits for the necessary amount of data which needed to be collected in order to be sufficient for statistical analyses (Rohlf and Sokal 1995 a, b). It also attempted to test the feasibility of investigating the differences in cutting regimes at this scale using invertebrates.

3.5 Materials and Methods

Seven sites in the Norfolk Broads were chosen. These were: How Hill, Mallow Marsh, Whitlingham Marsh, Broad Fen, Horning Hall, Hickling and Long Gores (Table 3.I, and Figures 2.1-2.4, pages 33-35). These sites varied in habitat and vegetation composition. Each site had one or more type of management regime, and these were compared. How Hill is reedbed, Mallow Marsh is mixed reed and Whitlingham Marsh is eutrophic fen. These three sites had cutting regimes imposed on them. How Hill and Mallow Marsh were cut in July 1998 whilst Whitlingham Marsh was cut in January 1998. There were five different cutting regimes on 10 x 10 metre plots plus a buffer zone. These consisted control, fen harvester low, fen harvester high, Bücher mower low and Bücher mower high.

Table 3.I Pilot Study Sites

Site	Habitat (and group)	Regime	Plots
Mallow Marsh	reed based fen (reedy)	cutting, summer	fen harvester high and low, hand cut high and low control
Whitlingham Marsh	eutrophic fen (flooded)	cutting, summer	fen harvester high and low, hand cut high and low control
How Hill	reed fen (reedy)	cutting summer & winter	fen harvester high and low, hand cut high and low, control
Broad Fen	very mixed fen (flooded)	grazed, ponies present continuously	control plot fenced off from grazing area
Horning Hall	reedy fen (reedy)	grazed sheep present briefly	sheep and control plots separated briefly

Hickling	reedy oak wood (dry grazing)	grazed, ponies present continuously	no control plot, grazing only
Long Gores	wet grazing meadow (dry grazing)	grazed sheep and red deer, continuously	no control plot, grazing only

The Bücher mower is the original management tool, and is a light, manoeuvrable, hand-pushed and therefore labour intensive, reciprocating mower. The fen harvester is a mechanical cutting machine resembling a combine harvester with caterpillar tracks (Figure 3.1).

Figure 3.1 The fen harvester cutting reed at Mallow Marsh.

The remaining sites were all grazed. Horning Hall (a.k.a. Ebb and Flow Marshes) is drier mixed reed fen, and was grazed by sheep. There was also a control plot. Broad Fen is very open mixed fen with less reed and more saw sedge and orchids. It was grazed using Welsh ponies. There was also a control plot. Hickling and Long Gores had no control plots and were much drier than the other sites. They are reedy meadow or grazing marsh. Hickling was grazed using Konik ponies and Long Gores with red deer.

The sites grouped as 'reedy' comprised How Hill, Mallow Marsh and the control half of Horning Hall. The sites classed as 'flooded' were Whitlingham and Broad Fen. The sites classed as 'dry grazing' were Long Gores and Hickling. The grazed part of Horning also veered towards this group, but was put in the 'reedy' group. Ideally the control and grazed areas should be as close as possible the same, however the manager in charge of grazing at Horning decided the welfare of the sheep was more important and confined them to the dry half of the site.

The pitfall traps were not left down for the same length of time at each site due to sampling constraints, and some traps were lost during sampling, due to trampling by horses or deer or, most frequently due to flooding. All plots had eight traps down for seven days except for the differences listed below in Table 3.II.

Table 3.II Exceptions to the general rule that eight pitfall traps were left for seven days.

Season	Site	Treatment	Trap numbers	Days down	Trap/days
June 1998	Mallow	control	7	7	49
	Hickling	grazed	8	5	40
	Horning	control	8	3	24
August 1998	How Hill	FH high	7	7	49
	How Hill	FH low	6	7	42
	How Hill	hand low	4	7	28
	Horning	both	8	8	64
	Mallow	hand high	7	7	49
	Mallow	control	7	7	49
	Long Gores	grazed	8	8	64

3.6 Results

How complete is the sampling?

The species accumulation curve is a graph of species numbers found over time. In this case the number of novel species identified per plot is added to the graph. It indicates the level of sampling of species at that site. The sequence of plots within a site are compiled onto the species accumulation curve graph in no particular order. However June 1998 samples are added before August 1998 ones. This is shown in Figures 3.2 and 3.7 where June and August have been combined. The groups of species are treated separately.

Altogether there were 23 species of spider identified in June 1998 (Figure 3.3), and 19 identified in August (Figure 3.4), making a total of 33 species (Figure 3.2). There were 56 species of beetles for June (Figure 3.5), and 72 identified in August (Figure 3.6), making 100 species altogether (Figure 3.7). Snails were only collected in August and 17 species were identified (Figure 3.8). The data allowed more conclusions to be drawn when sampling was more complete. This is in cases where the graphs start to asymptote. This can be seen most clearly on Figures 3.4 and 3.8 for August sampling.

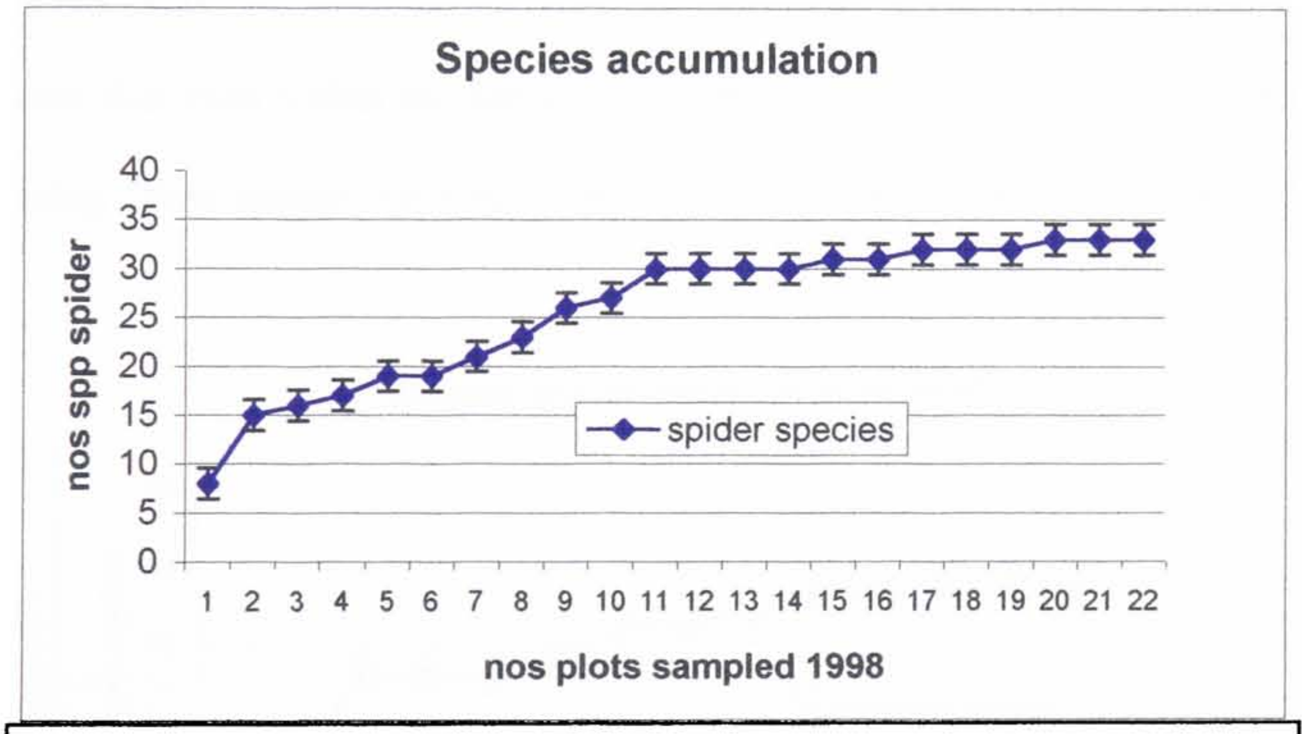


Figure 3.2 Species accumulation curve for spiders, June and August 1998, with standard error bars shown.

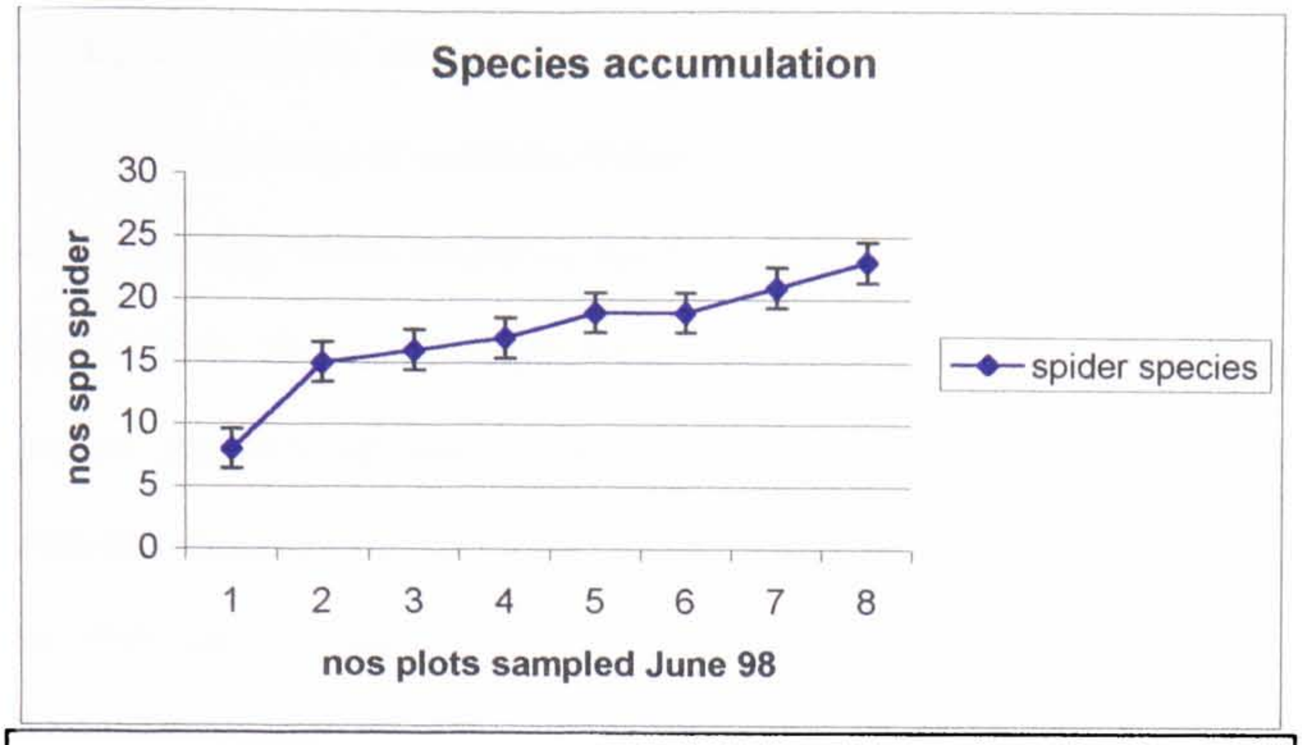


Figure 3.3 Species accumulation curve for spiders, June 1998, with standard error bars shown.

How different are the sites?

Initial analysis shows that the sites are far from similar. The Chi squared analysis shows that even within the habitat types the results are not closely correlated. 'Dry grazing' sites appear variable in terms of individuals collected, with beetles, for example ranging between 19 and 77 in August 1998 over just three sites. The numbers for the other groups are similarly different. The sites grouped as 'flooded'

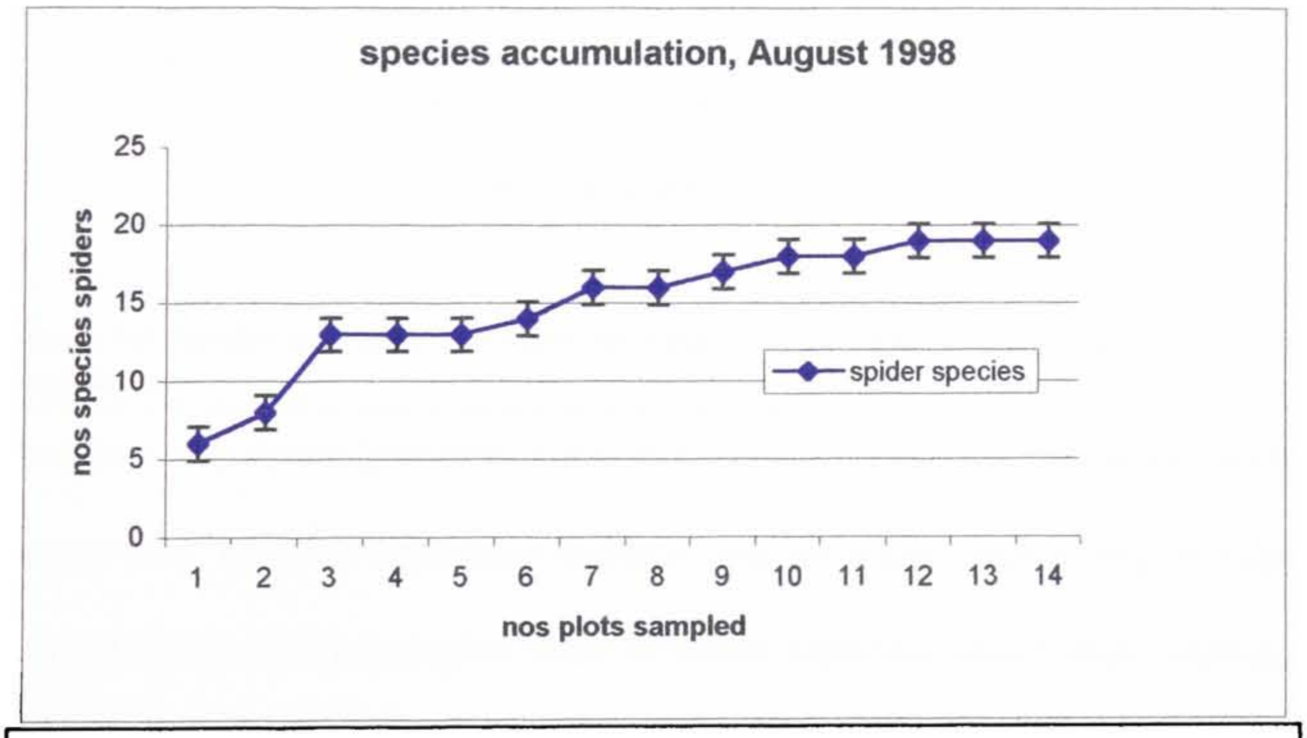


Figure 3.4 Species accumulation curve for spiders, August 1998, with standard error bars shown.

had snails collected. Broad Fen was comparatively depauperate compared to Whitlingham in terms of numbers (Table 3.V). The 'reedy' sites were less variable at least for beetles, which ranged in numbers from 6 to 37 (June 1998) and 4 to 12 (August 1998). The snails ranged from 4 to 195 due to large numbers of immature *Lymnaea palustris* present in the environment in August. These are patchily distributed. Spiders exhibited fairly variable numbers of individuals from 19 to 77 in June 1998 (over 10 plots q.v. 'dry grazing' site beetle numbers, previous page) and 22 to 132 in August, again due to patchily distributed immature individuals.

The Chi^2 analysis of number of species on managed versus control sites was difficult to carry out on this data. Control areas and effective replication would have made this task easier. Particularly difficult was deciding upon a way of expressing the expected values for each plot. Four different expected values were compared and their worth assessed in terms of their likely accuracy. These are shown in Tables 3.III – 3.VII (pages 67-71) (statistical values from Rohlf and Sokal 1995a and b).

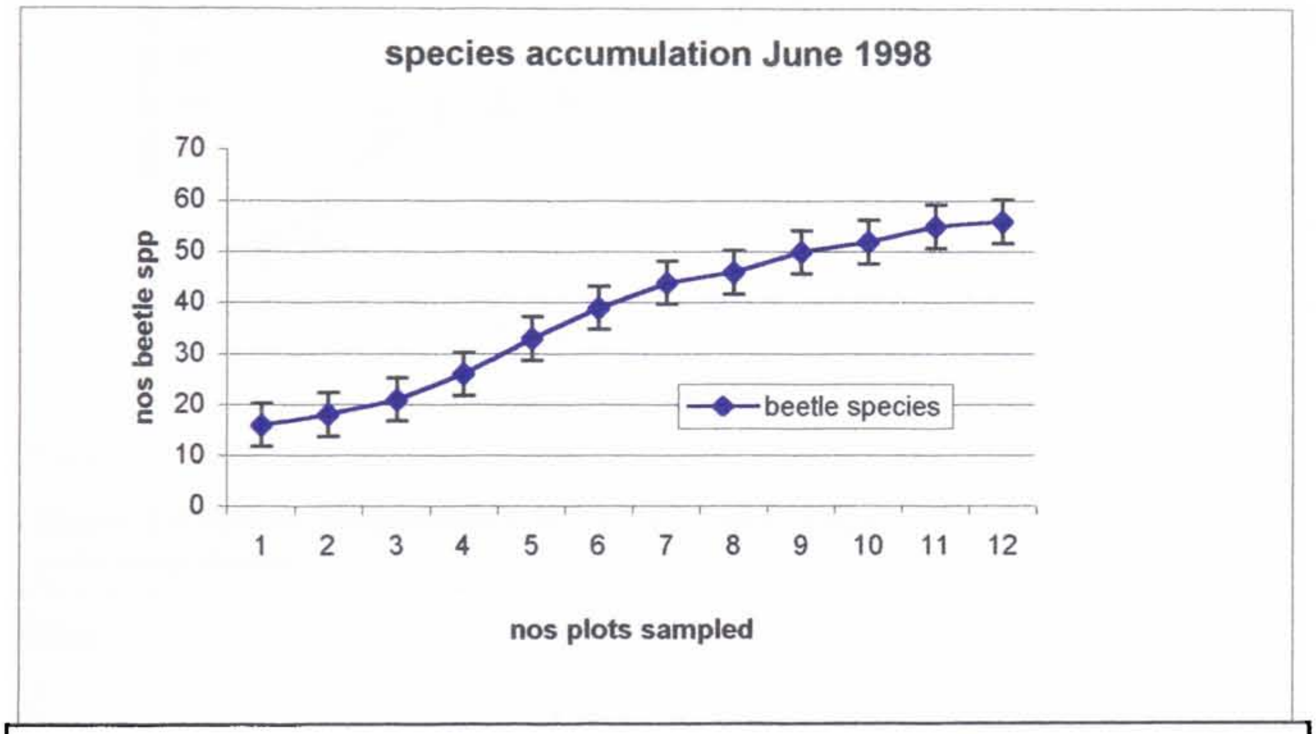


Figure 3.5 Species accumulation curve for beetles, June 1998, with standard error bars shown.

'Expected' was defined as the sum of the control plots divided by the number of control plots. This means where control plots for How Hill, Mallow Marsh and

Horning were available these three were summed and the total divided by 3. Where only How Hill and Mallow Marsh were available these were summed and divided by 2. The advantage of this method is that only control plots were used, and their differences averaged across habitats. The disadvantage is that the grazed plots with no controls and much drier habitats often appeared significant, not because of management differences, merely because the expected value did not reflect that habitat.

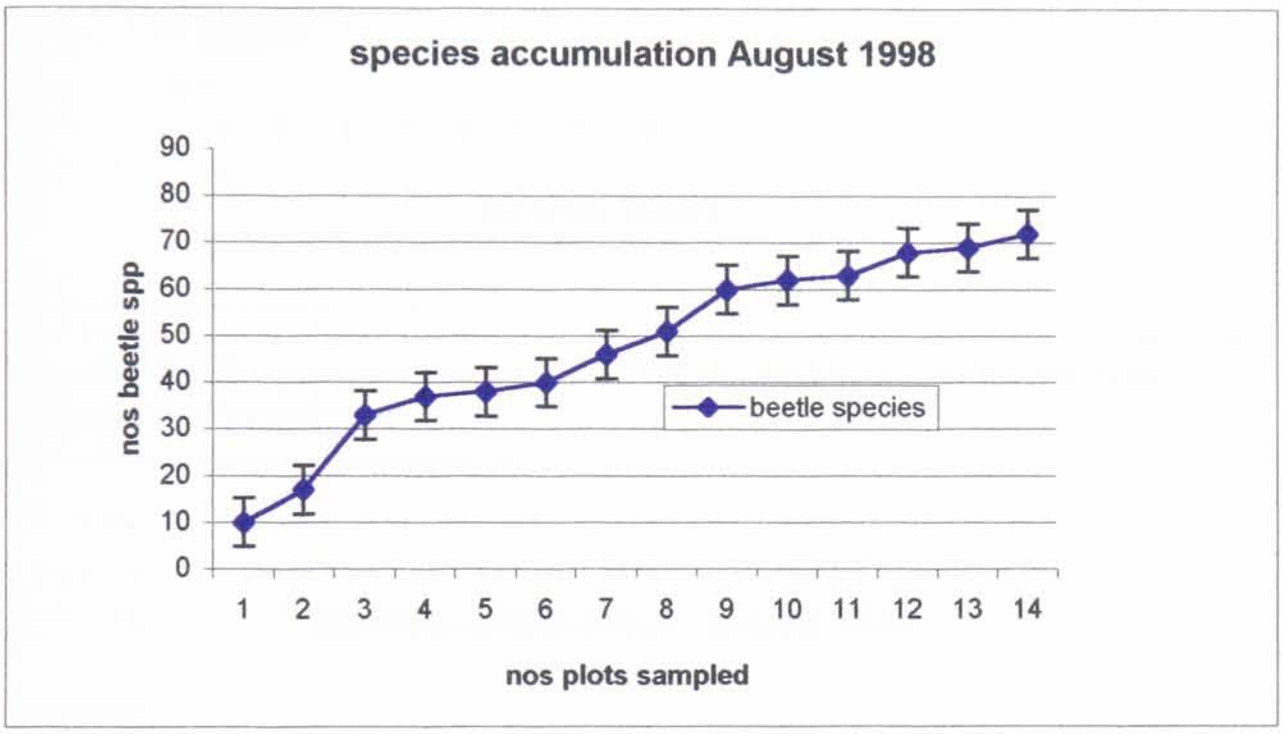


Figure 3.6 Species accumulation curve for beetles, August 1998, with standard error bars shown.

'Expected alternative' was defined as the sum of all individuals divided by the number of treatments. Whilst this version went some way towards redressing the differences in habitats it still lumped grazed plots in with cut plots and hence made many cut plots erroneously significant.

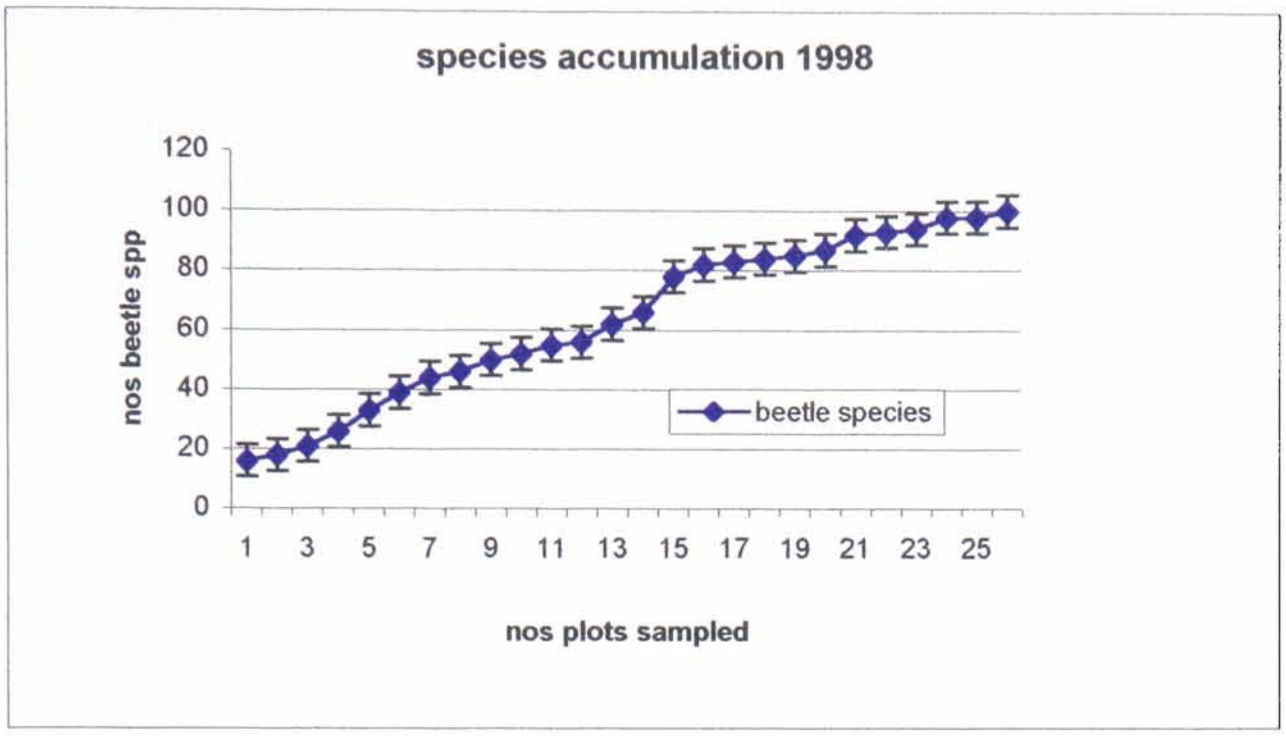


Figure 3.7 Species accumulation curve for beetles, June and August 1998 with standard error bars shown.

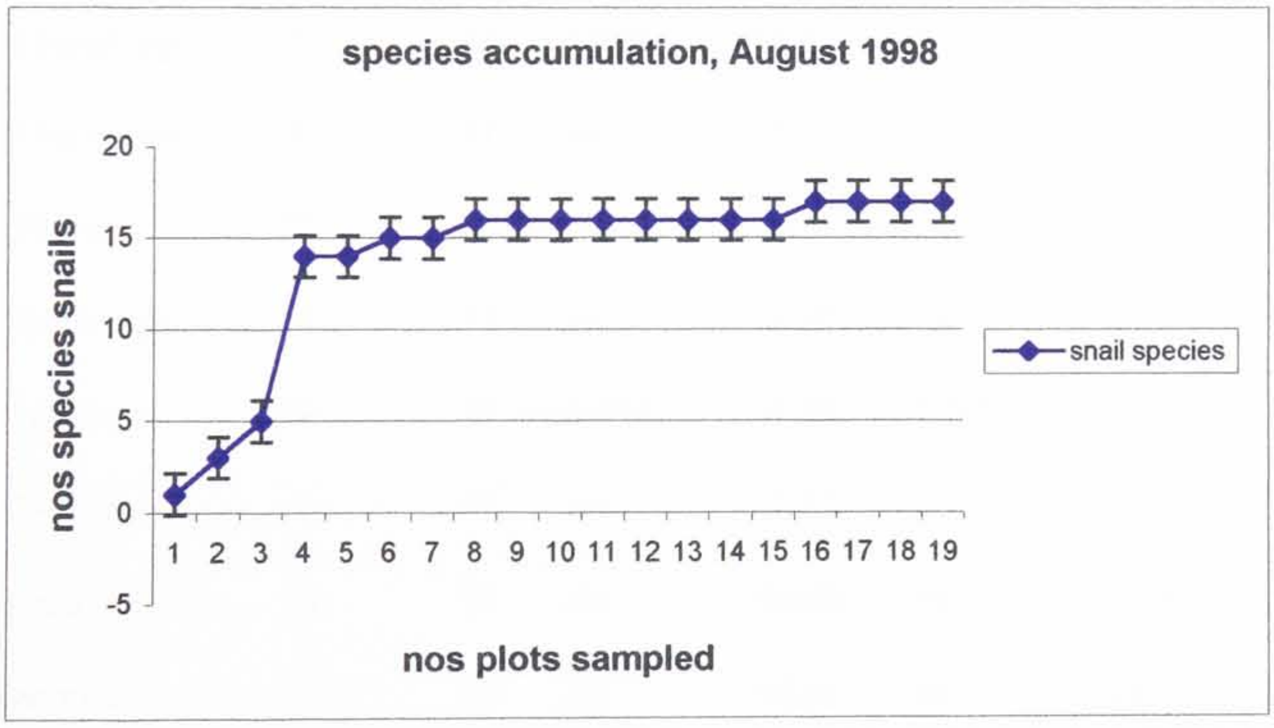


Figure 3.8 Species accumulation curve for snails, August 1998 with standard error bars shown.

'Expected HH/MM alone' sought to define expected for each plot, and hence without repeats for the grazed plots no expected value could be defined. For the remaining plots the expected value was the sum of all individuals on that site divided by the number of treatments. For example for How Hill this would be the sum of all How Hill individuals divided by five treatments, or for Broad Fen this would be the sum of all individuals on that site divided by two treatments. This has the slight disadvantage that there are on average four cut plots to one control plot, hence the expected value is biased 4:1 in favour of the managed values.

Table 3.III Beetle individuals collected June 1998 (pre-cutting)

3.III	observed	**exp**	**sig for exp**	expected value for exp alt	sig for exp alt	*expected value for HH/MM alone*	*sig for HH/MM*
Long Gores	18	**17**	**ns**	16.83	ns		
Hickling	11	**17**	**ns**	16.83	ns		
How Hill FH low	20	**17**	**ns**	16.83	ns	*12.4*	*p=0.05*
How Hill FH high	6	**17**	**p=0.01**	16.83	p=0.01	*12.4*	*ns*
How Hill hand high	8	**17**	**p=0.025**	16.83	p=0.025	*12.4*	*ns*
How Hill hand low	9	**17**	**ns**	16.83	ns	*12.4*	*ns*
Mallow FH high	37	**17**	**p=0.001**	16.83	p=0.001	*22.2*	*p=0.005*
Mallow hand high	15	**17**	**ns**	16.83	ns	*22.2*	*ns*
Mallow hand low	29	**17**	**p=0.005**	16.83	p=0.005	*22.2*	*ns*
Mallow FH low	15	**17**	**ns**	16.83	ns	*22.2*	*ns*
How Hill control	19	**17**	**ns**	16.83	ns	*12.4*	*ns*
Mallow control	15	**17**	**ns**	16.83	ns	*22.2*	*ns*

exp = [HH control + MM control] / 2
exp alt = sum all individuals / 12 treatments
HH/MM alone = sum HH individuals / 5 treatments
and sum MM / 5 treatments

Table 3.IV Beetle individuals collected August 1998 (post-cutting)

3.IV	observed	**exp**	**sig for exp**	exp alt	sig for exp alt	*HH/MM/Ho alone*	sig for HH/MM/Ho
Long Gores	19	**11**	**p=0.025**	16.79	ns		
Horning grazed	77	**11**	**p=0.001**	16.79	p=0.001	*43*	*p=0.001*
Hickling	36	**11**	**p=0.001**	16.79	p=0.001		
How Hill FH low	6	**11**	**ns**	16.79	p=0.01	*9.2*	*ns*
How Hill FH high	4	**11**	**p=0.05**	16.79	p=0.005	*9.2*	*ns*
How Hill hand high	12	**11**	**ns**	16.79	ns	*9.2*	*ns*
How Hill hand low	11	**11**	**ns**	16.79	ns	*9.2*	*ns*
Mallow FH high	5	**11**	**ns**	16.79	p=0.005	*9.6*	*ns*
Mallow hand high	9	**11**	**ns**	16.79	ns	*9.6*	*ns*
Mallow hand low	12	**11**	**ns**	16.79	ns	*9.6*	*ns*
Mallow FH low	11	**11**	**ns**	16.79	ns	*9.6*	*ns*
How Hill control	13	**11**	**ns**	16.79	ns	*9.2*	*ns*
Mallow control	11	**11**	**ns**	16.79	ns	*9.6*	*ns*
Horning control	9	**11**	**ns**	16.79	ns	*43*	*p=0.001*

exp = [HH control + MM control + Horning control] / 3
exp alt = sum all individuals / 14 treatments
HH/MM/Ho alone = sum HH individuals / 5 treatments and sum MM / 5 treatments and sum Horning / 2 treatments

Table 3.V Snail individuals collected August 1998 (post-cutting)

3.V	observed	**exp**	**sig for exp**	expected value for exp alt	sig for exp alt	*expected value for HH/MM/Whit/BF*	*sig for HH/MM/Whit/BF*	expected value for control exp	sig for control exp
Long Gores	1	**22.5**	**p=0.001**	32.1	p=0.001				
Hickling	11	**22.5**	**p=0.025**	32.1	p=0.001				
Broad Fen	6	**22.5**	**p=0.001**	32.1	p=0.001	*4*	*$*	2	$
How Hill FH low	87	**22.5**	**p=0.001**	32.1	p=0.001	*87*	*ns*	71	ns
How Hill FH high	195	**22.5**	**p=0.001**	32.1	p=0.001	*87*	*p=0.001*	71	p=0.001
How Hill hand high	53	**22.5**	**p=0.001**	32.1	p=0.001	*87*	*p=0.001*	71	p=0.05
How Hill hand low	30	**22.5**	**ns**	32.1	ns	*87*	*p=0.001*	71	p=0.001
Mallow FH high	14	**22.5**	**ns**	32.1	p=0.005	*11*	*ns*	7	p=0.01
Mallow hand high	8	**22.5**	**p=0.005**	32.1	p=0.001	*11*	*ns*	7	ns
Mallow hand low	4	**22.5**	**p=0.001**	32.1	p=0.001	*11*	*p=0.05*	7	ns
Mallow FH low	24	**22.5**	**ns**	32.1	ns	*11*	*p=0.001*	7	p=0.001
Whit FH high	26	**22.5**	**ns**	32.1	ns	*19*	*ns*	10	p=0.001
Whit FH low	16	**22.5**	**ns**	32.1	p=0.005	*19*	*ns*	10	ns
Whit hand high	28	**22.5**	**ns**	32.1	ns	*19*	*p=0.05*	10	p=0.001
Whit hand low	16	**22.5**	**ns**	32.1	p=0.005	*19*	*ns*	10	ns
How Hill control	71	**22.5**	**p=0.001**	32.1	p=0.001	*87*	*ns*	71	ns
Mallow control	7	**22.5**	**p=0.005**	32.1	p=0.001	*11*	*ns*	7	ns
Whit control	10	**22.5**	**p=0.01**	32.1	p=0.001	*19*	*p=0.05*	10	ns
Broad Fen control	2	**22.5**	**p=0.001**	32.1	p=0.001	4	*$*	2	$

exp=[HH control + MM control + Whit control + BF control]/4

exp alt = sum all individuals / 19 treatments

HH/MM/Whit/BF = sum HH individuals / 5 treatments
and sum MM individuals / 5 treatments
and sum Whit individuals over 5 treatments
and sum BF individuals / 2 treatments

control exp = where the control plot value is the expected value

Table 3.VI Spider individuals collected June 1998 (pre-cutting).

3.VI	observed	**expected value for exp**	**sig for exp**	expected value for exp alt	sig for exp alt	*expected value for HH/MM alone*	*sig for HH/MM*	**expected value for control exp**	**sig for control exp**
Long Gores	4	**42**	**p=0.001**	38.31	p=0.001				
Horning grazed	8	**42**	**p=0.001**	38.31	p=0.001				
Hickling	20	**42**	**p=0.001**	38.31	p=0.005				
How Hill FH low	63	**42**	**p=0.005**	38.31	p=0.001	*64.4*	*ns*	**57**	**ns**
How Hill FH high	63	**42**	**p=0.005**	38.31	p=0.001	*64.4*	*ns*	**57**	**ns**
How Hill hand high	77	**42**	**p=0.001**	38.31	p=0.001	*64.4*	*ns*	**57**	**p=0.01**
How Hill hand low	62	**42**	**p=0.005**	38.31	p=0.001	*64.4*	*ns*	**57**	**ns**
Mallow FH high	42	**42**	**ns**	38.31	ns	*28.8*	*p=0.025*	**27**	**p=0.005**
Mallow hand high	19	**42**	**p=0.001**	38.31	p=0.005	*28.8*	*ns*	**27**	**ns**
Mallow hand low	26	**42**	**p=0.025**	38.31	p=0.05	*28.8*	*ns*	**27**	**ns**
Mallow FH low	30	**42**	**ns**	38.31	ns	*28.8*	*ns*	**27**	**ns**
How Hill control	57	**42**	**p=0.025**	38.31	p=0.005	*64.4*	*ns*	**57**	**ns**
Mallow control	27	**42**	**p=0.025**	38.31	ns	*28.8*	*ns*	**27**	**ns**

exp = [HH control + MM control] / 2

exp alt = sum all individuals / 13 treatments
control exp is where the control plot value is the expected value
HH/MM alone = sum HH individuals / 5 treatments and sum MM individuals / 5 treatments

Table 3.VII Spiders individuals collected August 1998 (post-cutting).

3.VII	observed	**expected value for exp**	**sig for exp**	expected value for exp alt	sig for exp alt	*expected value for HH/MM/Horning*	*sig for HH/MM/Horning*	**expected value for control exp**	**sig for control exp**
Long Gores	37	**30**	**ns**	41.79	ns				
Horning grazed	26	**30**	**ns**	41.79	p=0.025	*23*	*ns*	**20**	**ns**
Hickling	31	**30**	**ns**	41.79	ns				
How Hill FH low	22	**30**	**ns**	41.79	p=0.005	*25.2*	*ns*	**25**	**ns**
How Hill FH high	23	**30**	**ns**	41.79	p=0.005	*25.2*	*ns*	**25**	**ns**
How Hill hand high	30	**30**	**ns**	41.79	ns	*25.2*	*ns*	**25**	**ns**
How Hill hand low	26	**30**	**ns**	41.79	p=0.025	*25.2*	*ns*	**25**	**ns**
Mallow FH high	132	**30**	**p=0.001**	41.79	p=0.001	*69*	*p=0.001*	**45**	**p=0.001**
Mallow hand high	55	**30**	**p=0.001**	41.79	p=0.05	*69*	*ns*	**45**	**ns**
Mallow hand low	68	**30**	**p=0.001**	41.79	p=0.001	*69*	*ns*	**45**	**p=0.001**
Mallow FH low	45	**30**	**p=0.01**	41.79	ns	*69*	*p=0.005*	**45**	**ns**
How Hill control	25	**30**	**ns**	41.79	p=0.01	*25.2*	*ns*	**25**	**ns**
Mallow control	45	**30**	**p=0.01**	41.79	ns	*69*	*p=0.005*	**45**	**ns**
Horning control	20	**30**	**ns**	41.79	p=0.001	*23*	*ns*	**20**	**ns**

exp=[HH control + MM control + Horning control] / 3

exp alt = sum all individuals / 14 treatments

HH/MM/Horning = sum HH individuals / 5 treatments and sum MM individuals / 5 treatments and sum Horning individuals / 2 treatments

control exp is where the control plot value is the expected value

'Control expected' is the last attempt and is defined as the number of individuals found on the control plot of that site. That means the number of individuals found at the control plot for Whitlingham Marsh is the expected value for the other plots at Whitlingham.

What is the community structure, with respect to dominance of any one species?

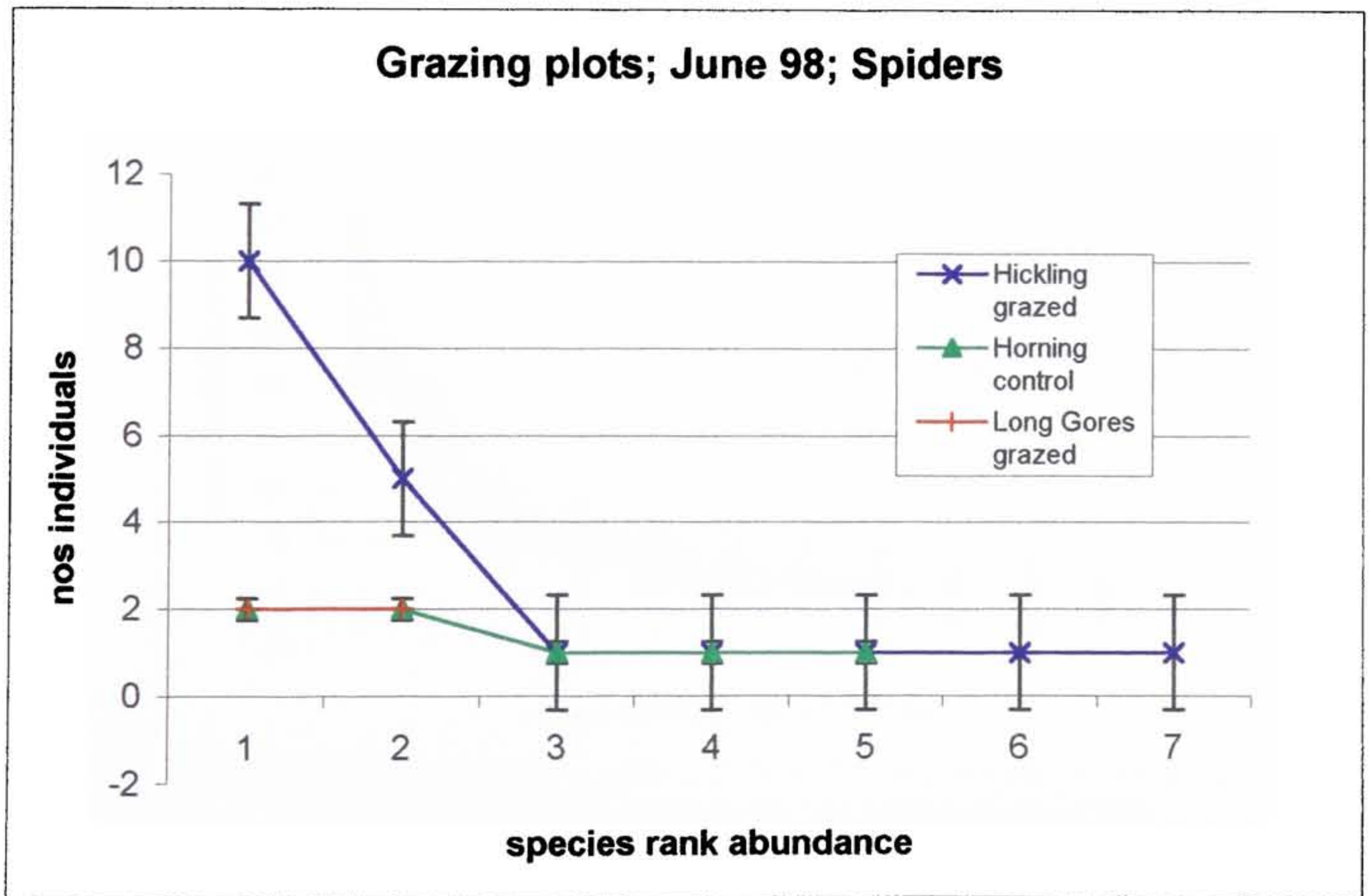


Figure 3.9 Rank abundance curve for spiders on grazed sites, June 1998. Standard error bars are shown.

These graphs (Figures 3.9 - 3.24) show the community structure by plotting the numbers of each species against the rank of that species with in the community – i.e.

the most numerous species is plotted first, followed by the second most numerous. The graphs give a characteristic curve with the steepness of the initial curve indicating the extent of the dominance of the most numerous species. Small sample sizes and differences in habitat and faunal type make these graphs hard to compare. The dominant species is not the same for each group. Dominant in this sense means most numerous – i.e. the species ranked as '1' in the graph.

Harper and Hawksworth (1994) consider a system to be more diverse if the species in it are equitable i.e. if there are equal abundances of species, or even more commonly if the species closely follow a Poisson distribution (Hammond 1994), rather than a system where there is one dominant species, and many, relatively rare, non-dominant species.

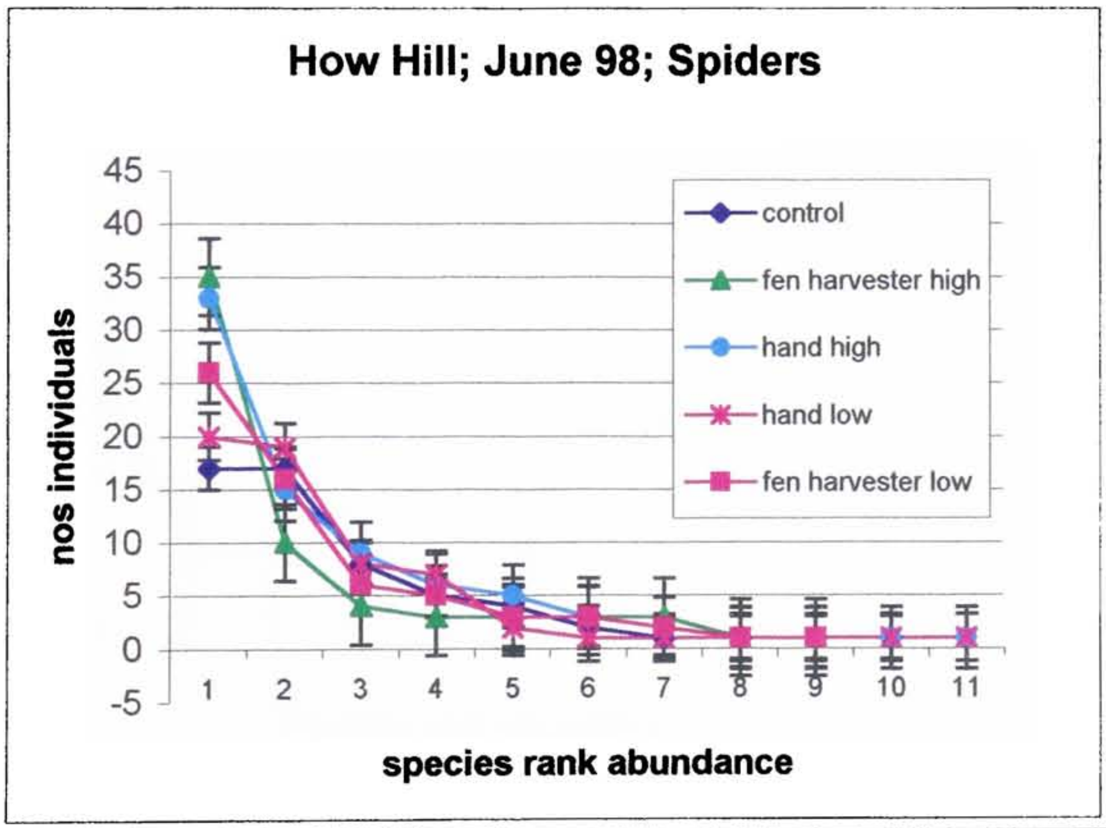


Figure 3.10 Rank abundance curve for spiders at How Hill, June 1998 with standard error bars shown.

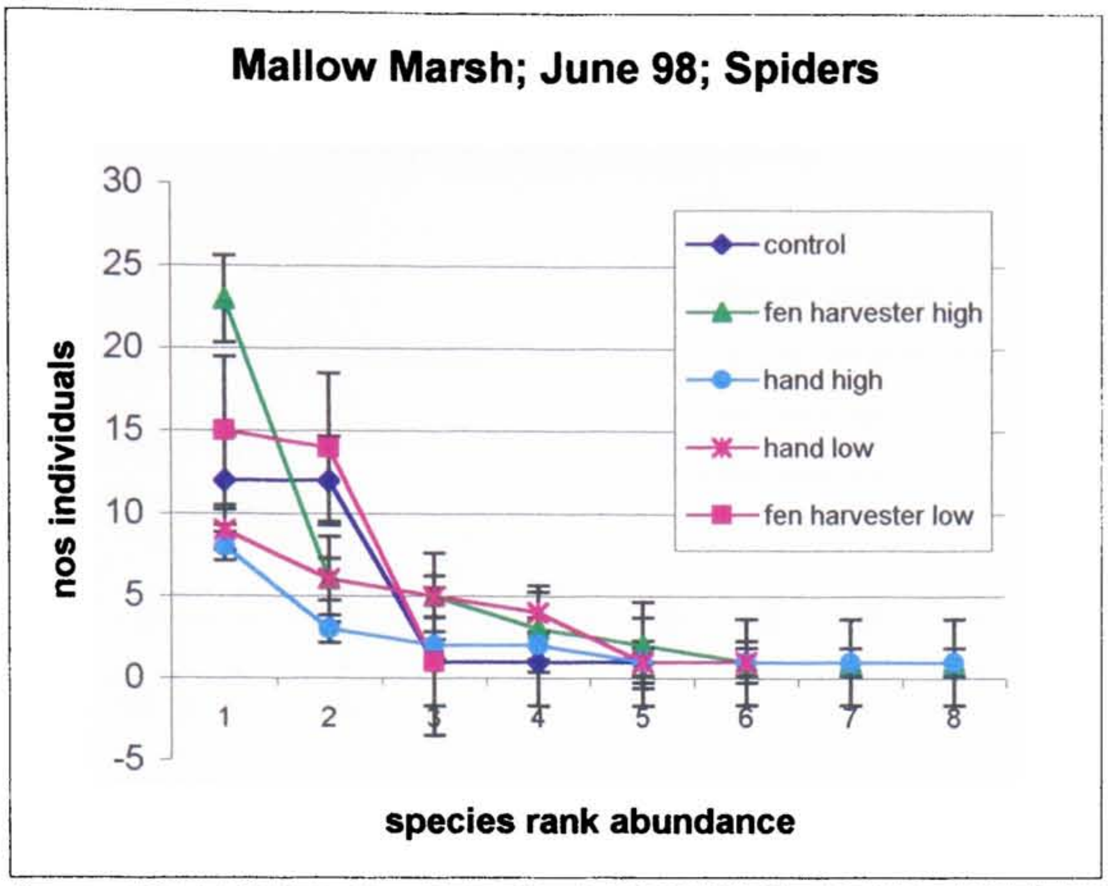


Figure 3.11 Rank abundance curve for spiders at Mallow Marsh, June 1998 with standard error bars shown.

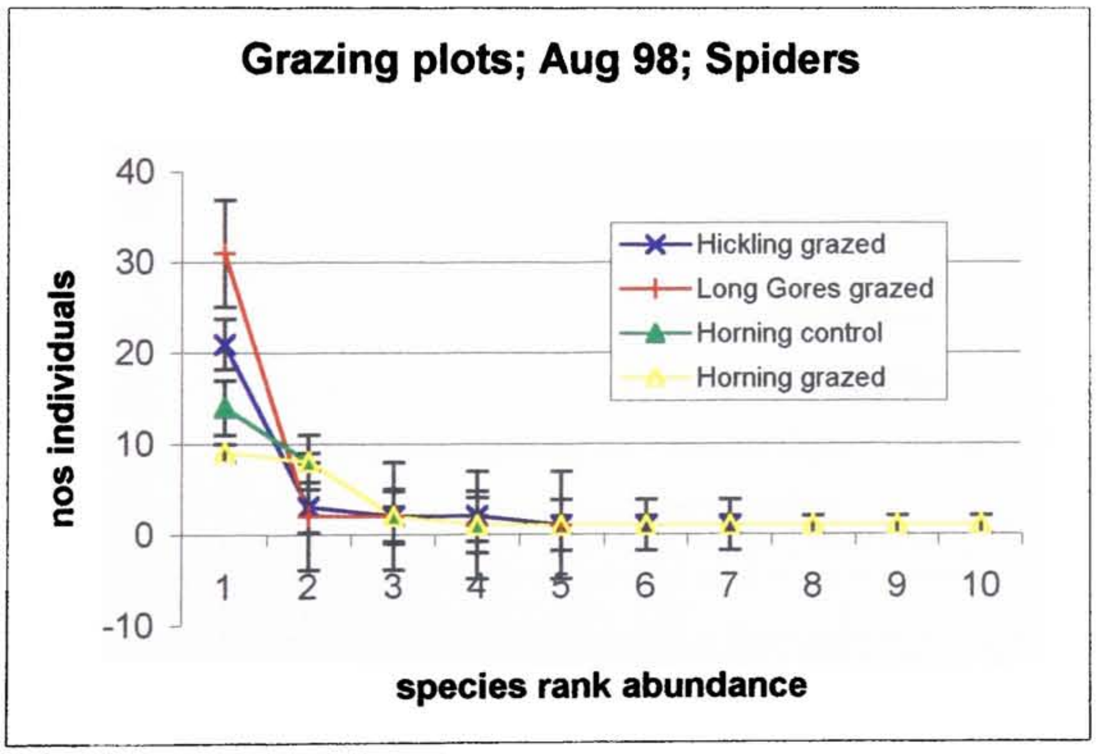


Figure 3.12 Rank abundance curve for spiders grazed sites only, August 1998 with standard error bars shown.

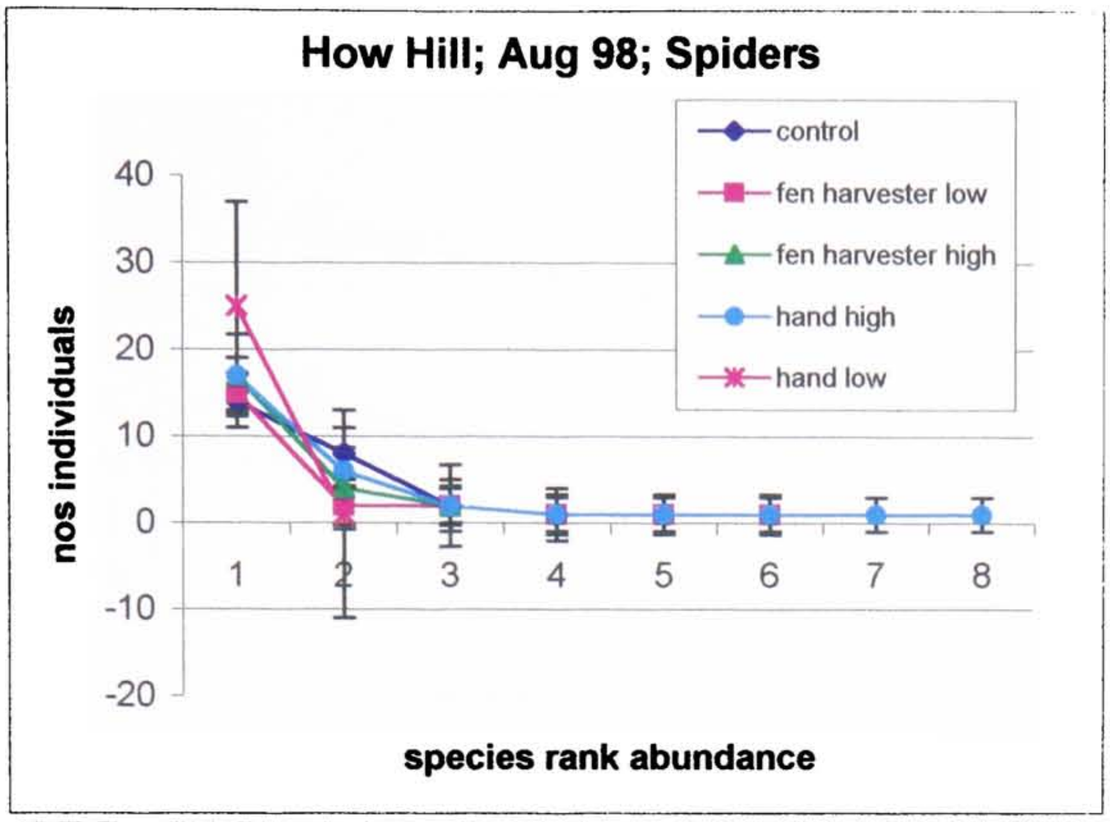


Figure 3.13 Rank abundance curve for spiders at How Hill, August 1998 with standard error bars shown.

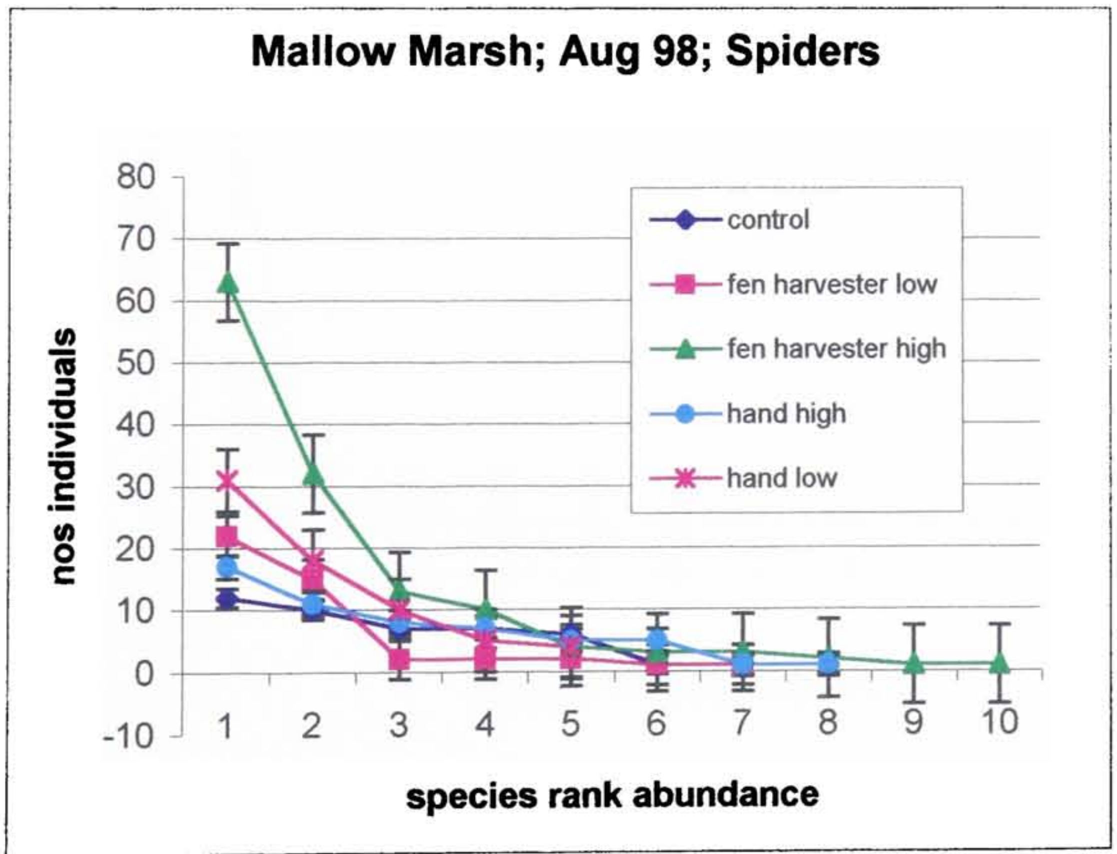


Figure 3.14 Rank abundance curve for spiders at Mallow Marsh, August 1998 with standard error bars shown.

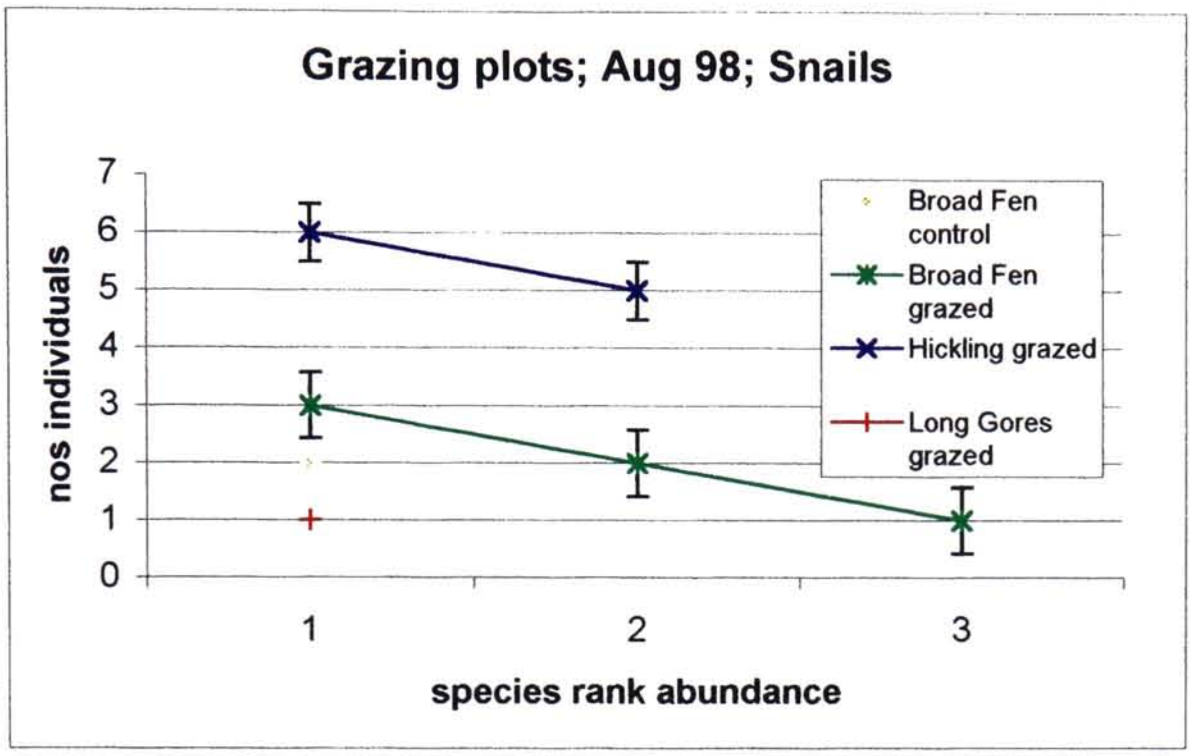


Figure 3.15 Rank abundance curve for snails, grazing sites only, August 1998 with standard error bars shown.

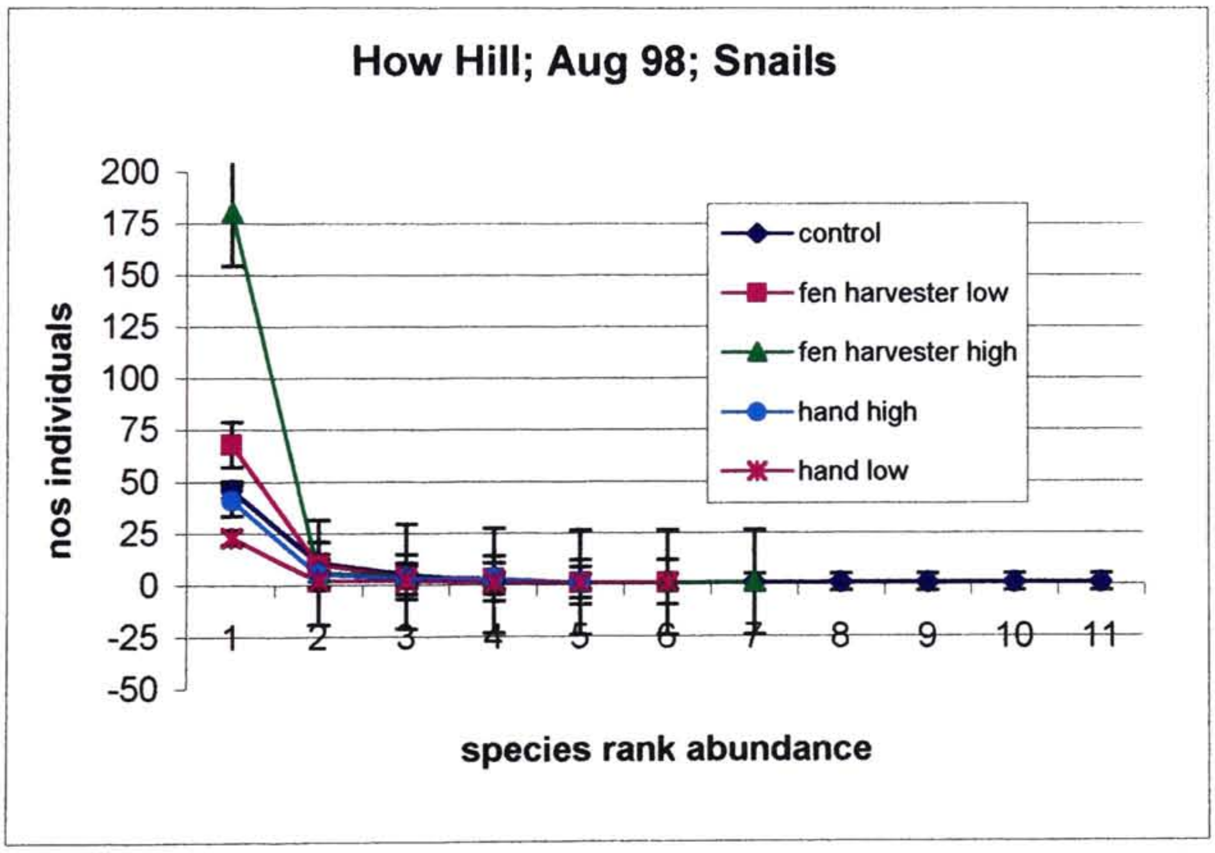


Figure 3.16 Rank abundance curve for snails at How Hill, August 1998 with standard error bars shown.

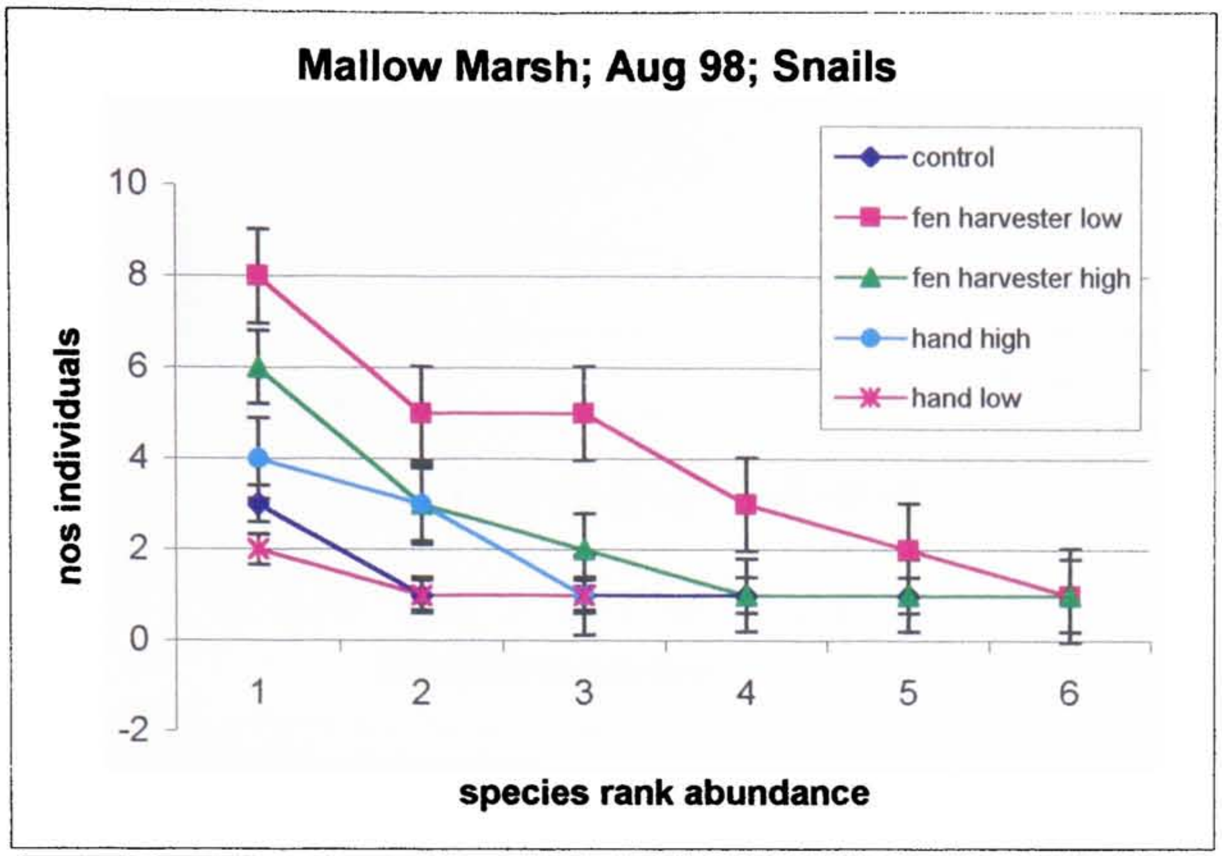


Figure 3.17 Rank abundance curve for snails at Mallow Marsh, August 1998 with standard error bars shown.

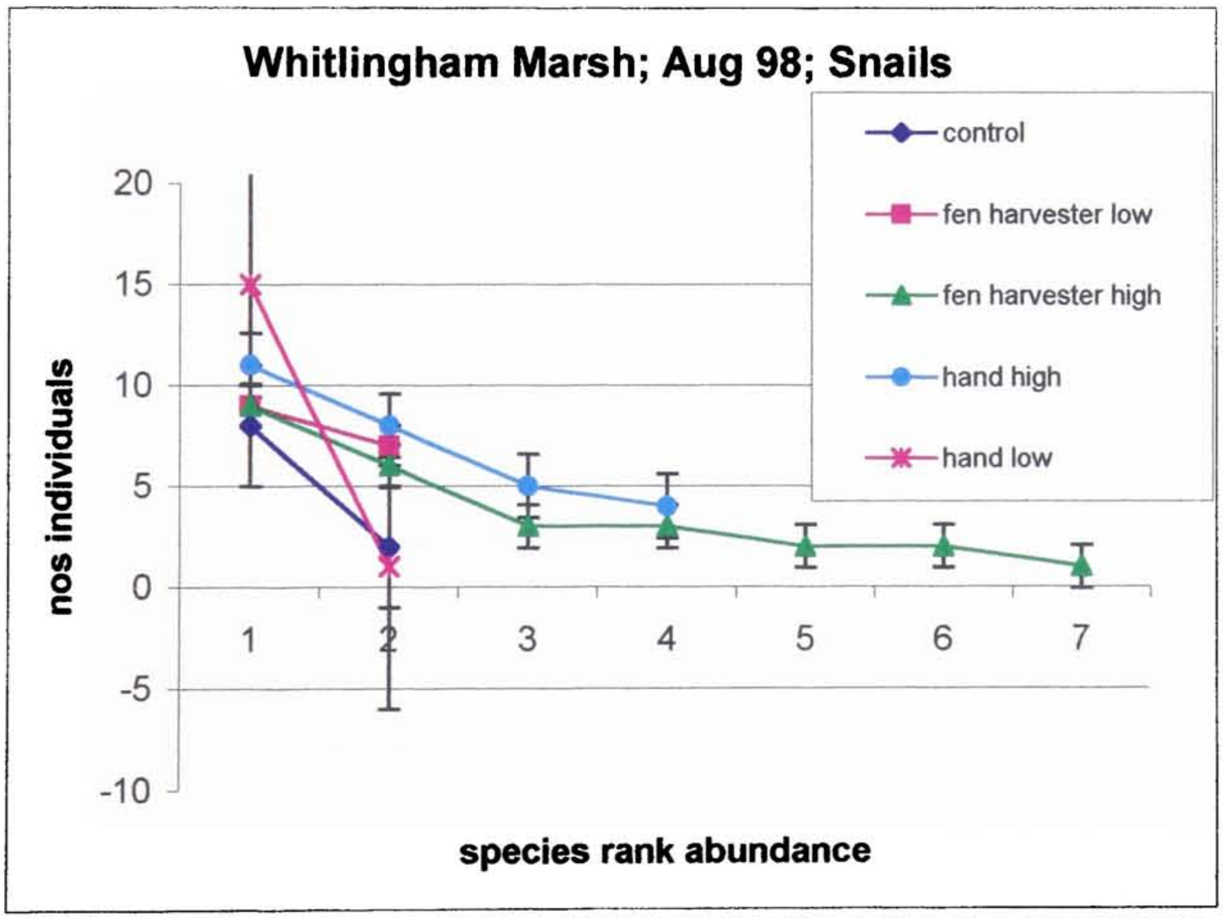


Figure 3.18 Rank abundance curve for snails at Whitlingham Marsh, August 1998 with standard error bars shown.

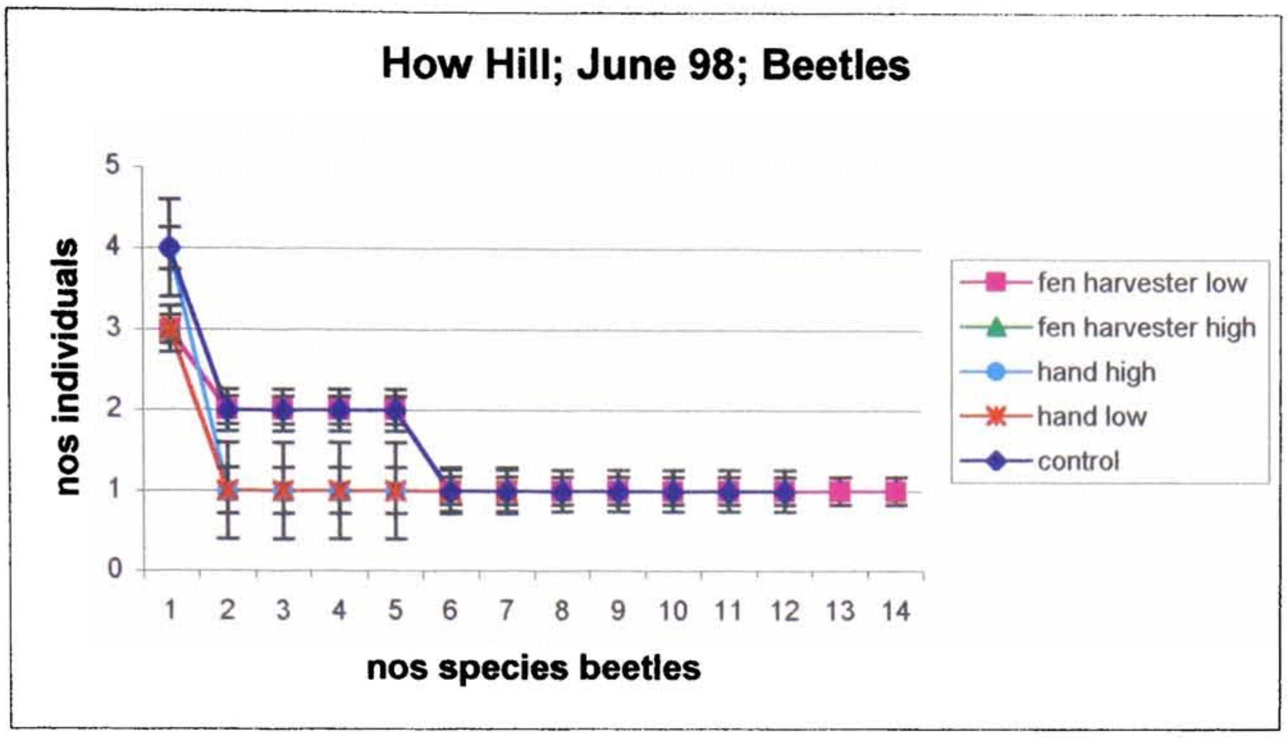


Figure 3.19 Rank abundance curve for beetles at How Hill June 1998 with standard error bars shown.

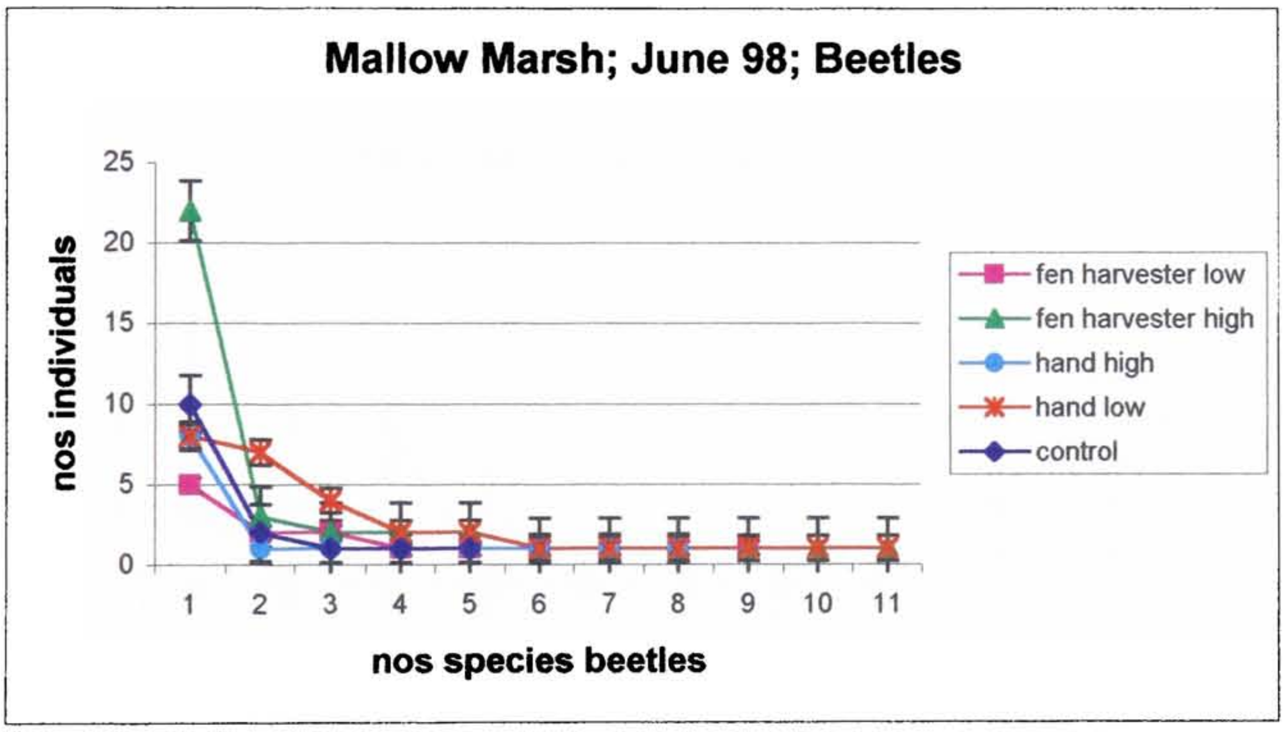


Figure 3.20 Rank abundance curve for beetles at Mallow Marsh June 1998 with standard error bars shown.

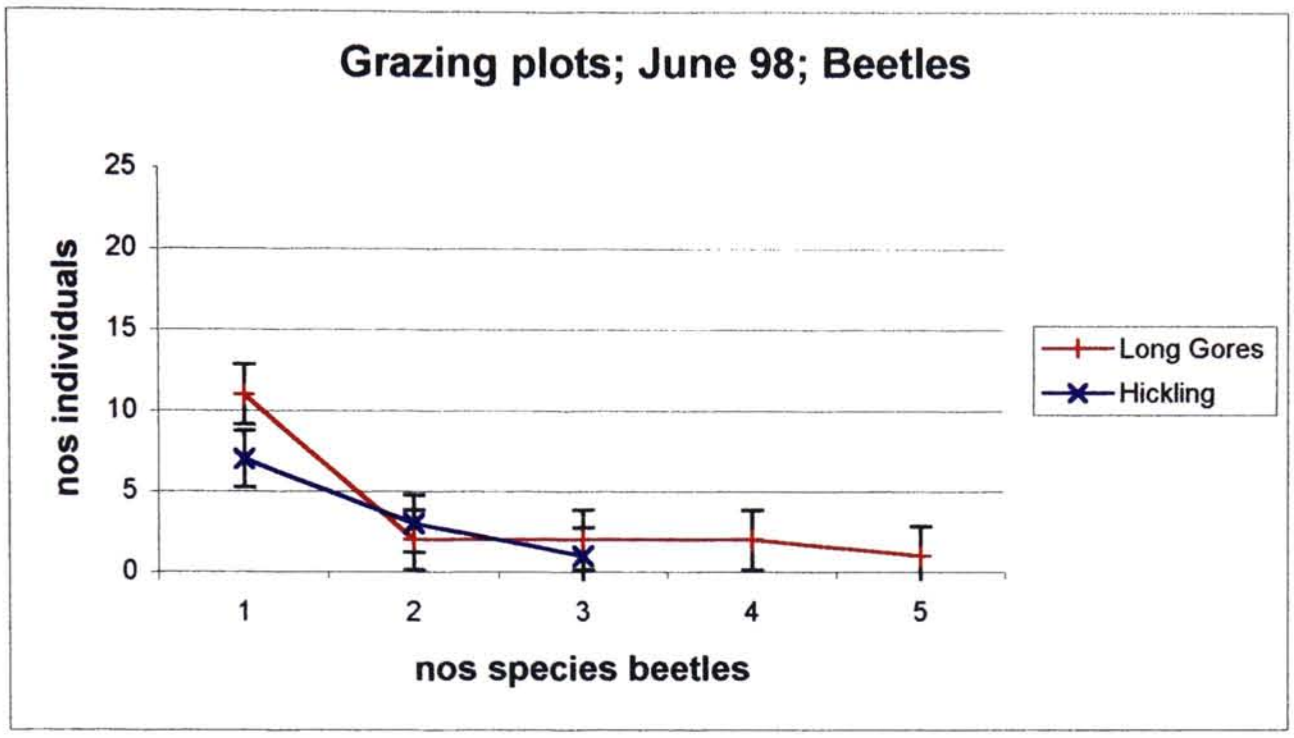


Figure 3.21 Rank abundance curve for beetles on grazing sites June 1998 with standard error bars shown.

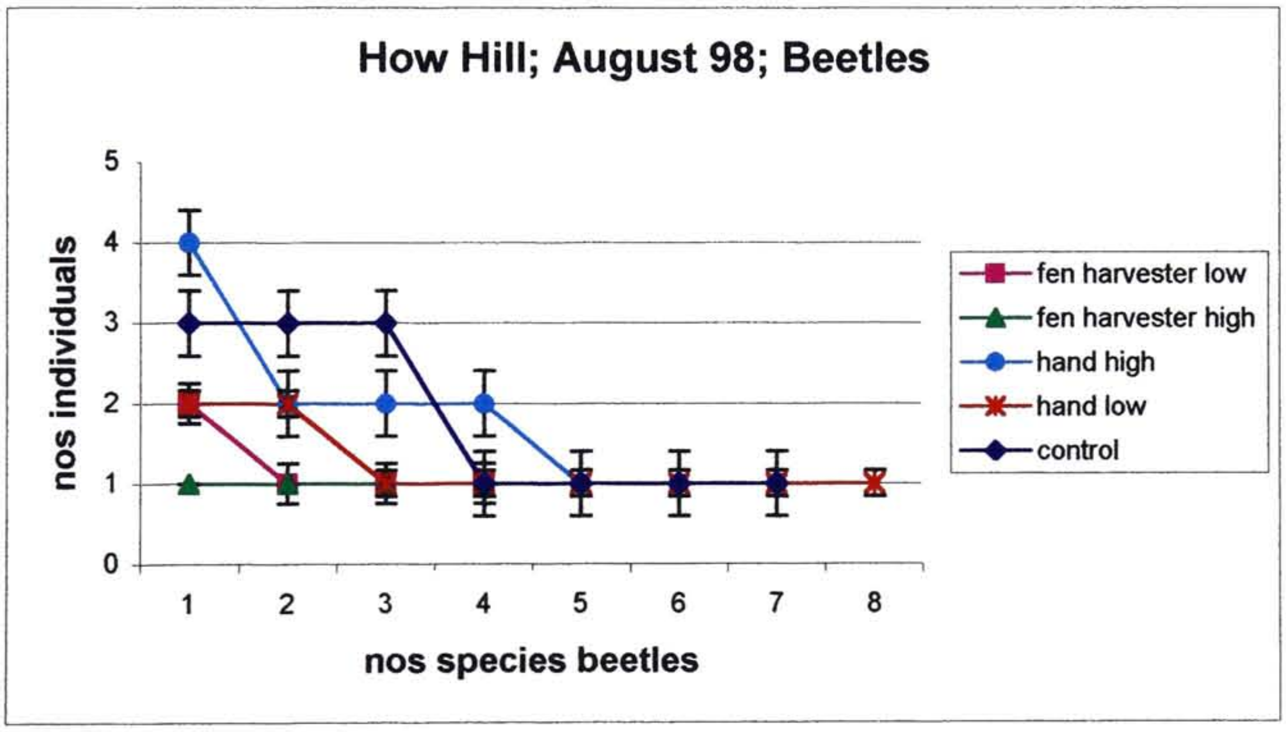


Figure 3.22 Rank abundance curve for beetles at How Hill August 1998 with standard error bars shown.

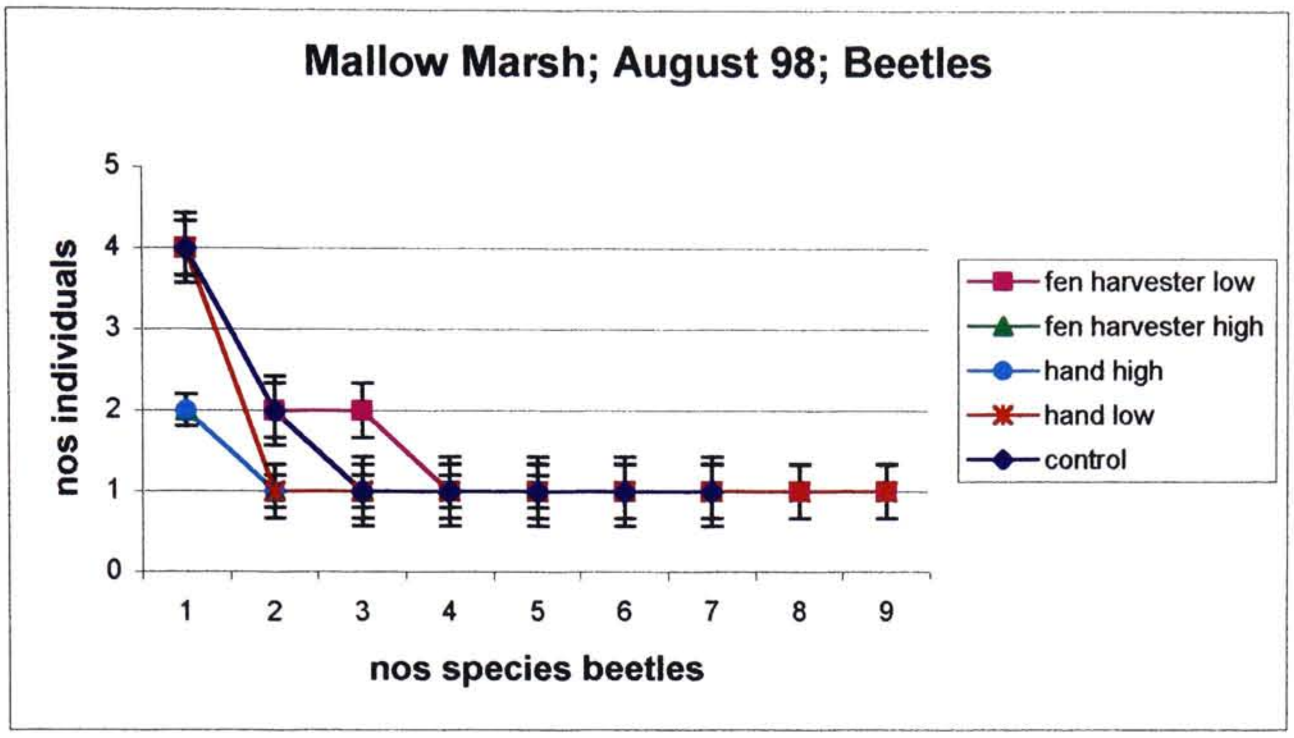


Figure 3.23 Rank abundance curve for beetles at Mallow Marsh August 1998 with standard error bars shown.

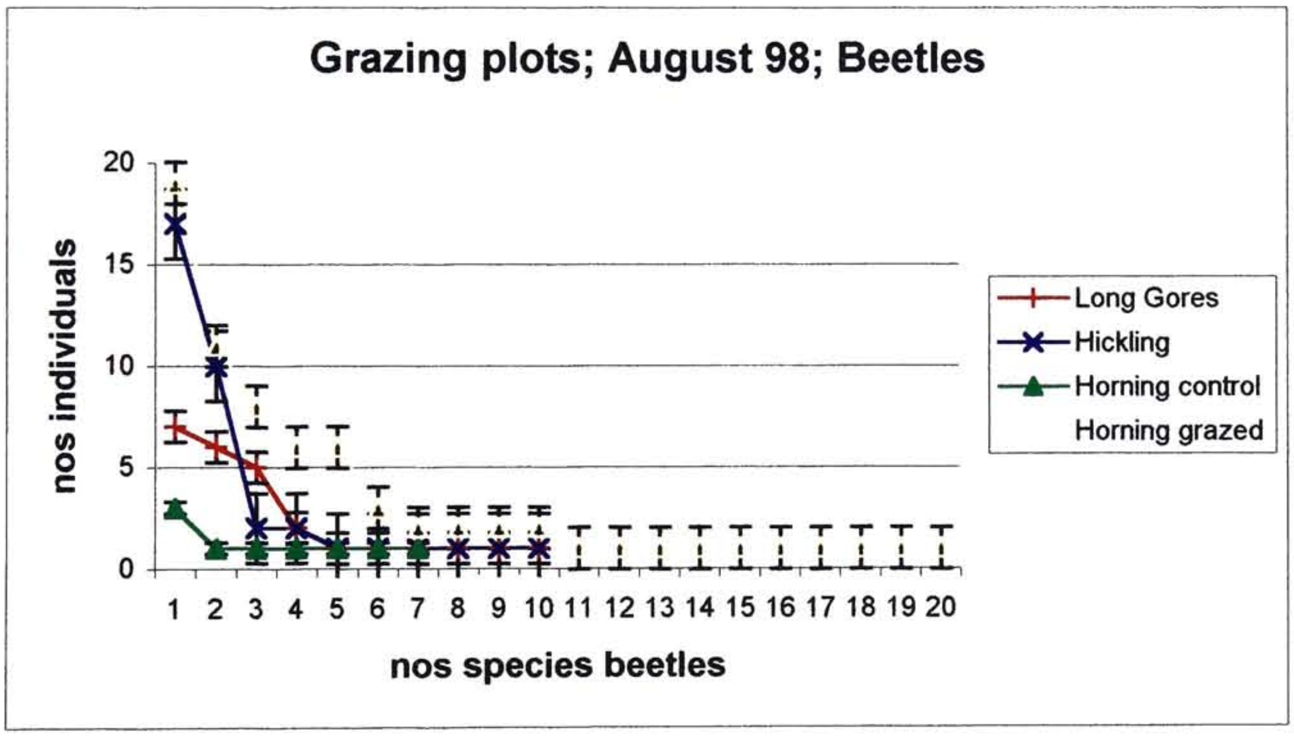


Figure 23 Rank abundance curve for beetles on grazing sites August 1998 with standard error bars shown.

Listed below (Tables 3.VIII-3.X, pages 81-82) are the most numerous categories (species, with a few exceptions) for each group. The numbers of individuals is shown in brackets. The second most numerous group is shown where relevant, and immature individuals are included for spiders to emphasize the changing demography of this group between seasons. The snail category 'Succinid' refers to the group of snails including *Succinea putris*, *Oxyloma sarsi* and *Oxyloma pfeifferi*. An exploratory number of these individuals were dissected and all of these were *Succinea putris*.

Table 3.VIII: The dominant species of snails found on each plot, August 1998. Numbers of individuals are shown in brackets.

Site	Plot	August 98
Mallow	control	Punctum pygmaeum (3)
	FH high	Lymnaea palustris (6)
	FH low	Lymnaea palustris (8)
	hand high	Punctum pygmaeum (4)
	hand low	Succinid (2)
How Hill	control	Lymnaea palustris (46)
	FH high	Lymnaea palustris (180)
	FH low	Lymnaea palustris (68)
	hand high	Lymnaea palustris (41)
	hand low	Lymnaea palustris (23)
Whitlingham	control	Succinid (8)
	FH high	Punctum pygmaeum (9)
	FH low	Lymnaea palustris (9)
	hand high	Succinid (11)
	hand low	Succinid (15)
Broad Fen	grazed	Succinid (3)
	control	Succinid (2)
Long Gores	grazed	unidentified Helicidae (1)
Hickling	grazed	Collumella edentula (6)

Table 3.IX: The dominant species of spider found on each plot with immature individuals shown for reference to the changing demography. Numbers of individuals are shown in brackets.

Site	Plot	June 98	August 98
Mallow	control	Pirata piraticus (12) Pardosa prativaga (12)	Immature (12) Allomengea vidua (10)
	FH high	Pirata piraticus (23)	Immature (63) Allomengea vidua (32)
	FH low	Pirata piraticus (23)	Immature (22) Allomengea vidua (15)

	hand high	Pirata piraticus (8)	Allomengea vidua (17) Immature (11)
	hand low	Pirata piraticus (9)	Immature (31) Bathyphantes gracilis (18)
How Hill	control	Pardosa prativaga (17)	Immature (14) Antistea elegans (8)
	FH high	Pirata piraticus (35)	Immature (17) Antistea elegans (4)
	FH low	Pirata piraticus (26)	Allomengea vidua (15) Antistea elegans (2)
	hand high	Pirata piraticus (33)	Immature (17) Allomengea vidua (6)
	hand low	Immature (20) Pirata piraticus (19)	Immature (25) Pachygnatha clercki (1)
Horning	grazed	-	Bathyphantes parvulus (9) Immature (8)
	control	Erigone atra (2)	Immature (13) Antistea elegans (4)
Long Gores	grazed	Alopecosa pulverulenta (2) Immature (2)	Immature (31) Bathyphantes gracilis (2)
Hickling	grazed	Bathyphantes parvulus (10)	Immature (21) Pirata hygrophilus (3)

Table 3.X: The dominant species of beetle found on each plot. Numbers of individuals are shown in brackets.

Site	**Plot**	**June 98**	**August 98**
Mallow	control	Paederus riparius (10)	Paederus riparius (4)
	FH high	Paederus riparius (22)	Atheta fungi (2)
	FH low	Lythraria salicariae (5)	Paederus riparius (2) Philonthus varians (2)
	hand high	Paederus riparius (8)	Pterostichus rhaetious (4)
	hand low	Paederus riparius (8)	Acrotrichis fascicularis (4)
How Hill	control	Paederus riparius (4)	Acrotrichis sitkaensis (3)
	FH high	Paederus riparius (3)	Atheta fungi (1) Agonum thoreyi (1) Philonthus quisquiliorus (1)
	FH low	Pachnida nigella (3)	Lathrobium brunnipes (2) Acrotrichis fascicularis (2)
	hand high	Paederus riparius (4)	Euaesthetus ruficapillus (4)
	hand low	Pachnida nigella (3)	Lathrobium brunnipes (2) Agabus bipustulastus (2) Euaesthetus laeviuseulus (2)
Horning	grazed	-	Acrotrichis sitkaensis (19)
	control	Carabus granulatus (1)	Acrotrichis cognata (3)
Long Gores	grazed	Carabus granulatus (11)	Pterostichus niger (6)

Hickling	grazed	Rugilus rufipes (7)	Pterostichus niger (17)

What does multivariate analysis of the data show? Where is the strongest variation?

Spiders and Vegetation

Figure 3.25 shows the how the spider species group before management. There is a clear boundary between the 'dry grazing' sites and the 'reedy' sites of How Hill and Mallow Marsh. When the data is reanalysed omitting the 'dry grazing' sites (Figure 3.26) How Hill and Mallow Marsh are separated with the arachnids of How Hill forming a much tighter group surrounded by the Mallow Marsh sites. Note this is the variation before cutting, so this is just due to habitat. If the sites are plotted against the vegetation plots (Figure 3.27) then the sites again group together by habitat. When the vegetation is analysed alone the sites show up very clearly (Figure 3.28 and 3.29), and this is unchanged after management.

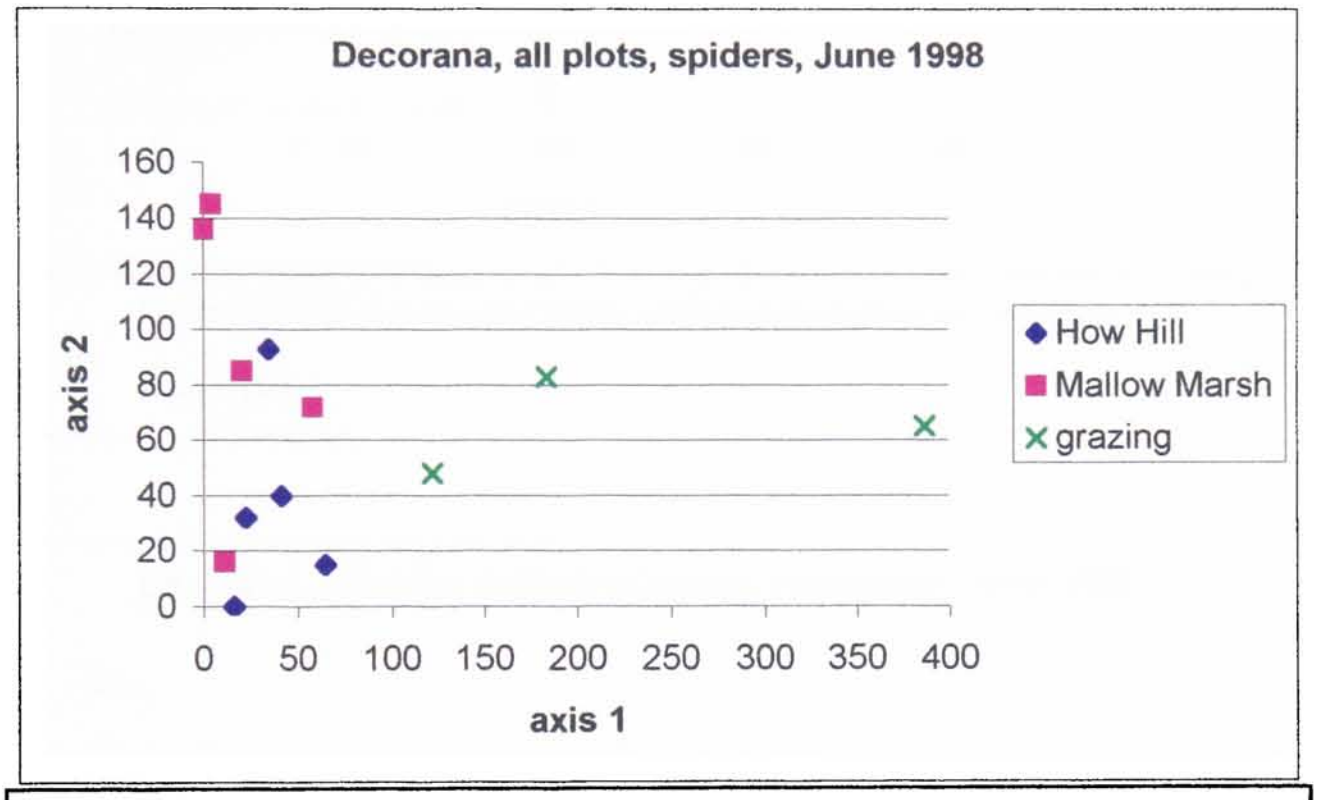


Figure 3.25 Decorana plot of the spiders distribution for all plots in June 1998

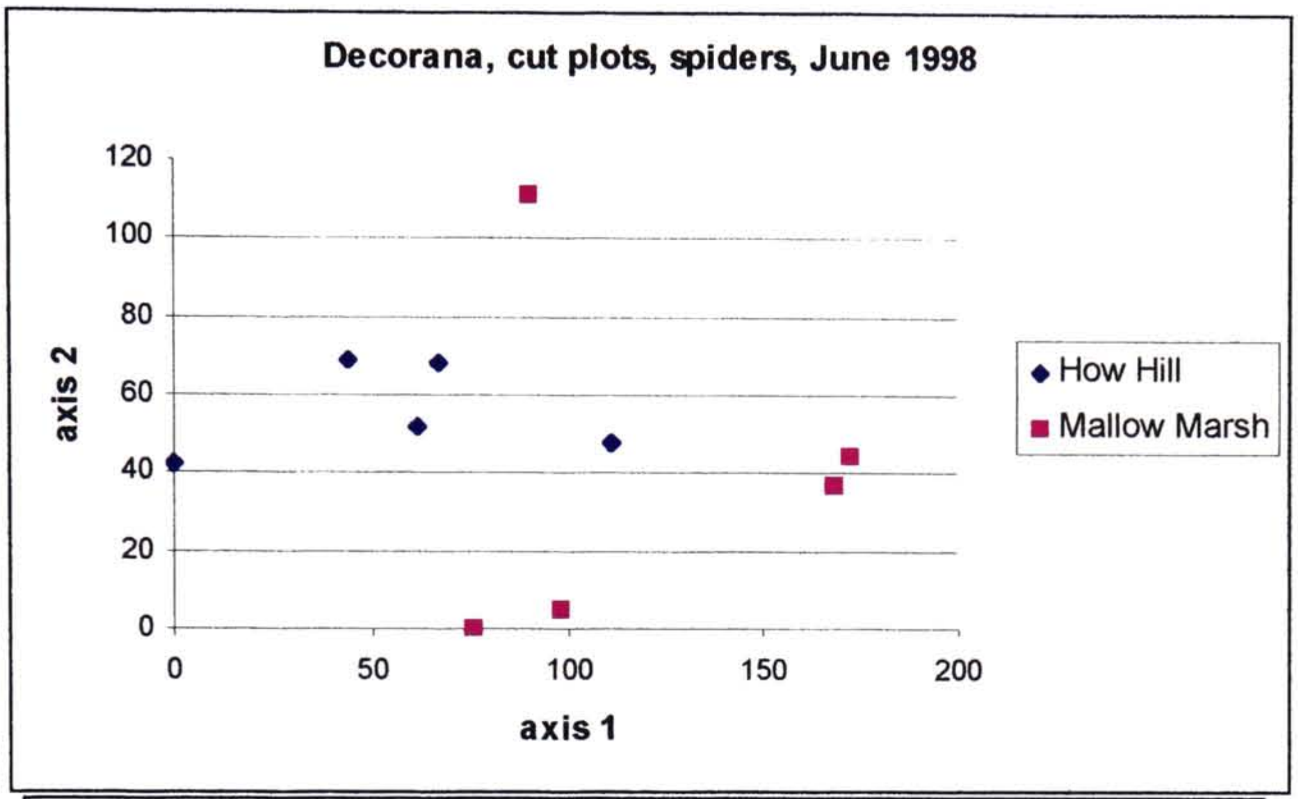


Figure 3.26 Decorana plot of the spiders distribution for cut plots in June 1998

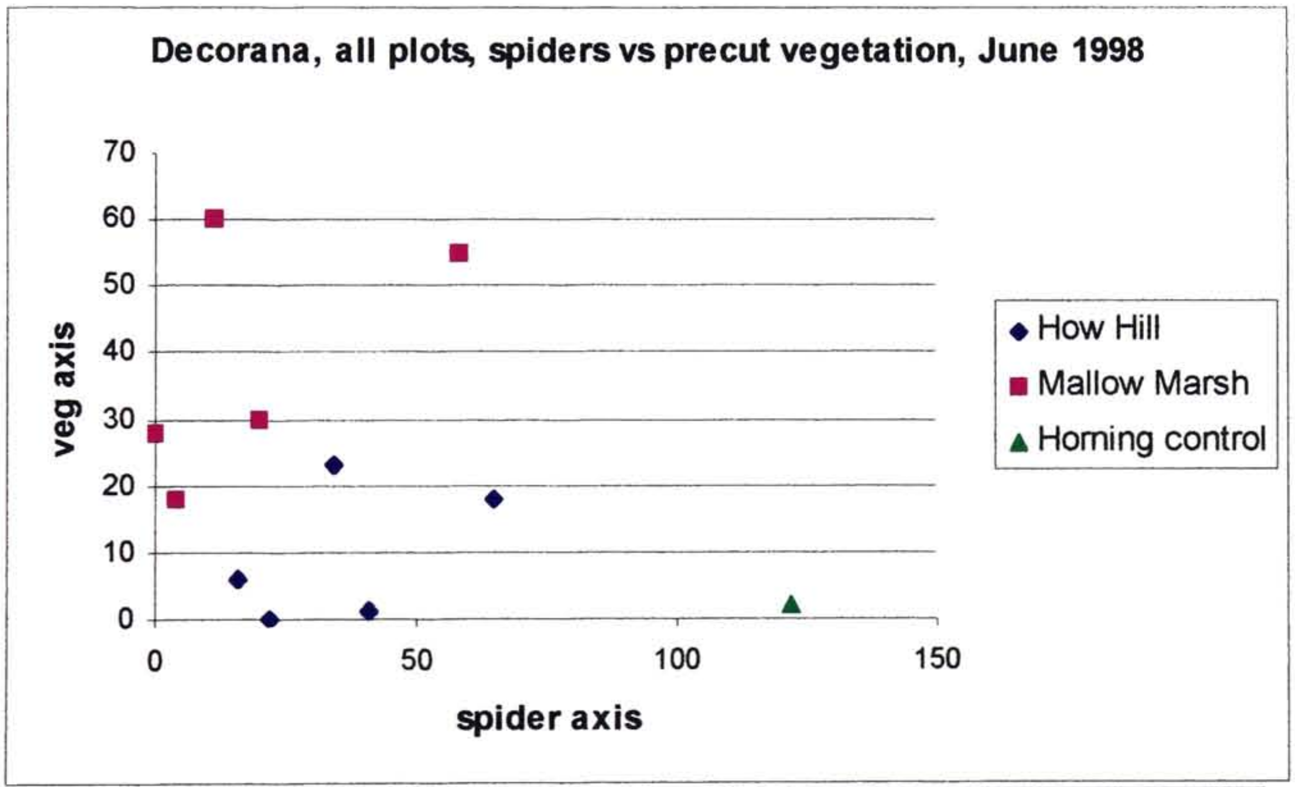


Figure 3.27 Decorana biplot of spiders versus vegetation distribution, before cutting in June 1998

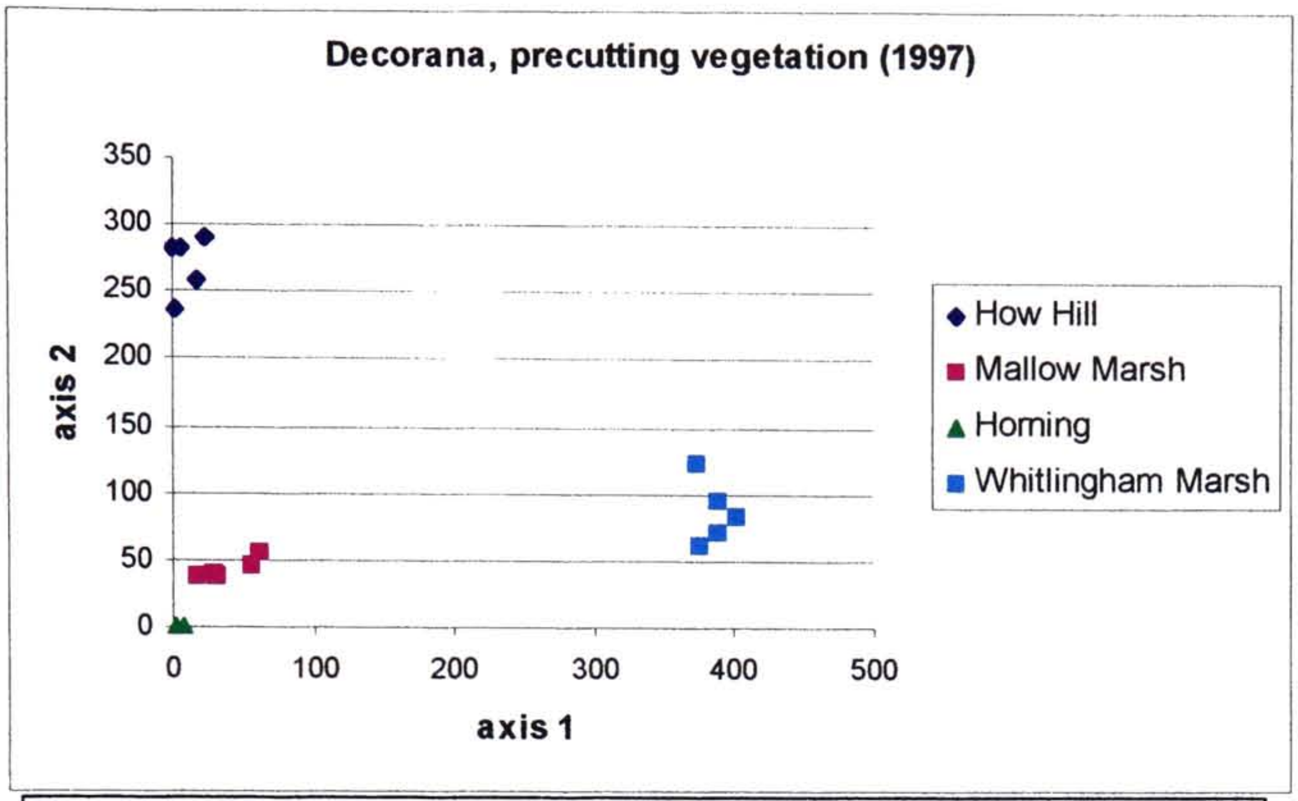


Figure 3.28 Decorana plot of the vegetation distribution in 1997, before management.

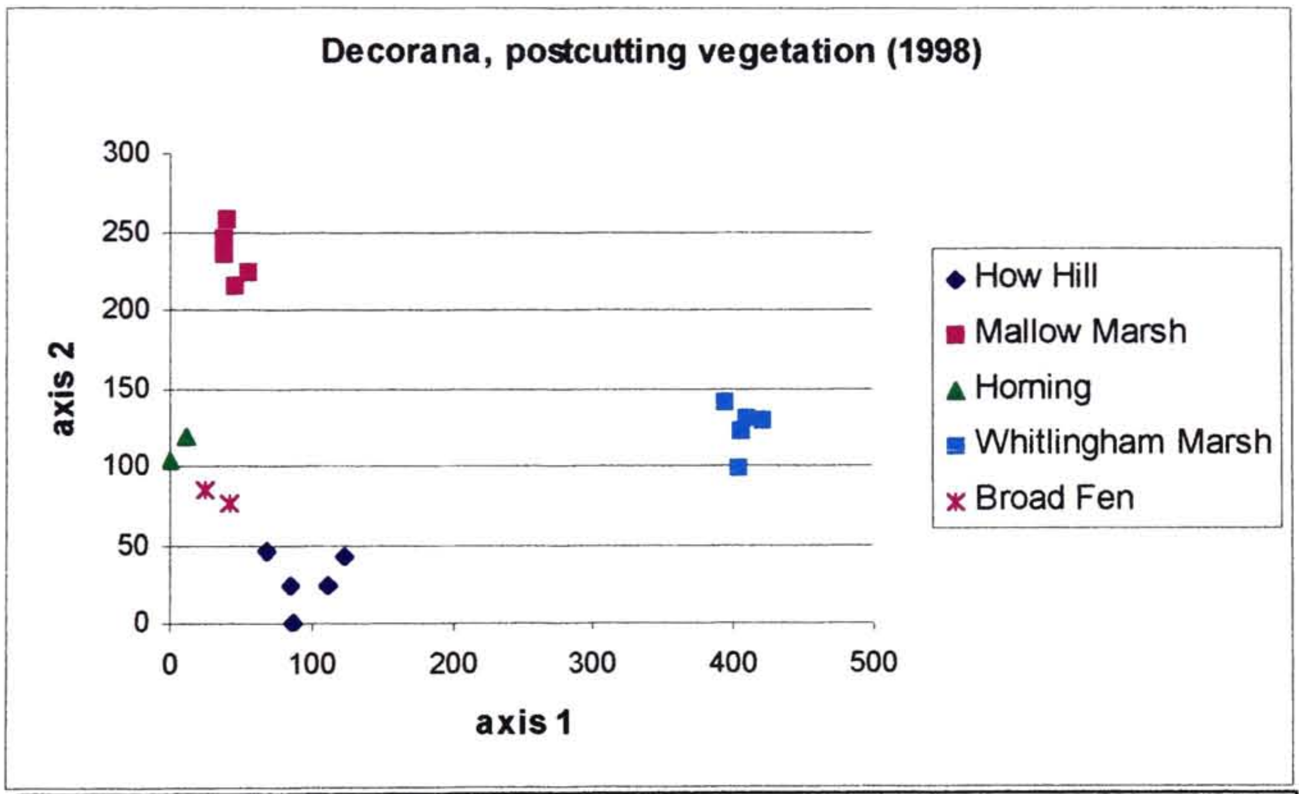


Figure 3.29 Decorana plot of the vegetation distribution in 1998, after management.

The August sampling, post cutting, for spiders (Figure 3.30) shows the sites still group together, but less closely. The Mallow Marsh group is quite clear, as is most of the How Hill group and the 'dry grazing' sties. However there are a few anomalies that don't show up on the vegetation analyses (Figure 3.29). One plot at How Hill groups with Mallow Marsh, and this is the hand high plot. The Horning control plot groups with How Hill, rather than with the other dry grazed plots. This is probably because this plot had more standing water than the grazed Horning plot, and was therefore more similar to How Hill. The grazed Horning plot was dryer underfoot and therefore more similar to Hickling and Long Gores. Removing the grazed plots from the analysis, and just looking at How Hill and Mallow Marsh gives a Decorana plot (Figure 3.31) where the sites no longer group clearly together. However there does not appear to be any coherent management trends. The control plots occur together at around 100 on axis 1, though vary on axis 2; and FH low plots come out close together around 50 on axis 1 and 80 on axis 2. It is hard to believe that this is anything other than co-incidence. When the spiders are plotted against post-management vegetation (Figure 3.32) there is a similar jumble, with the habitat boundaries being disrupted, but no obvious groupings due to cutting treatment. It is

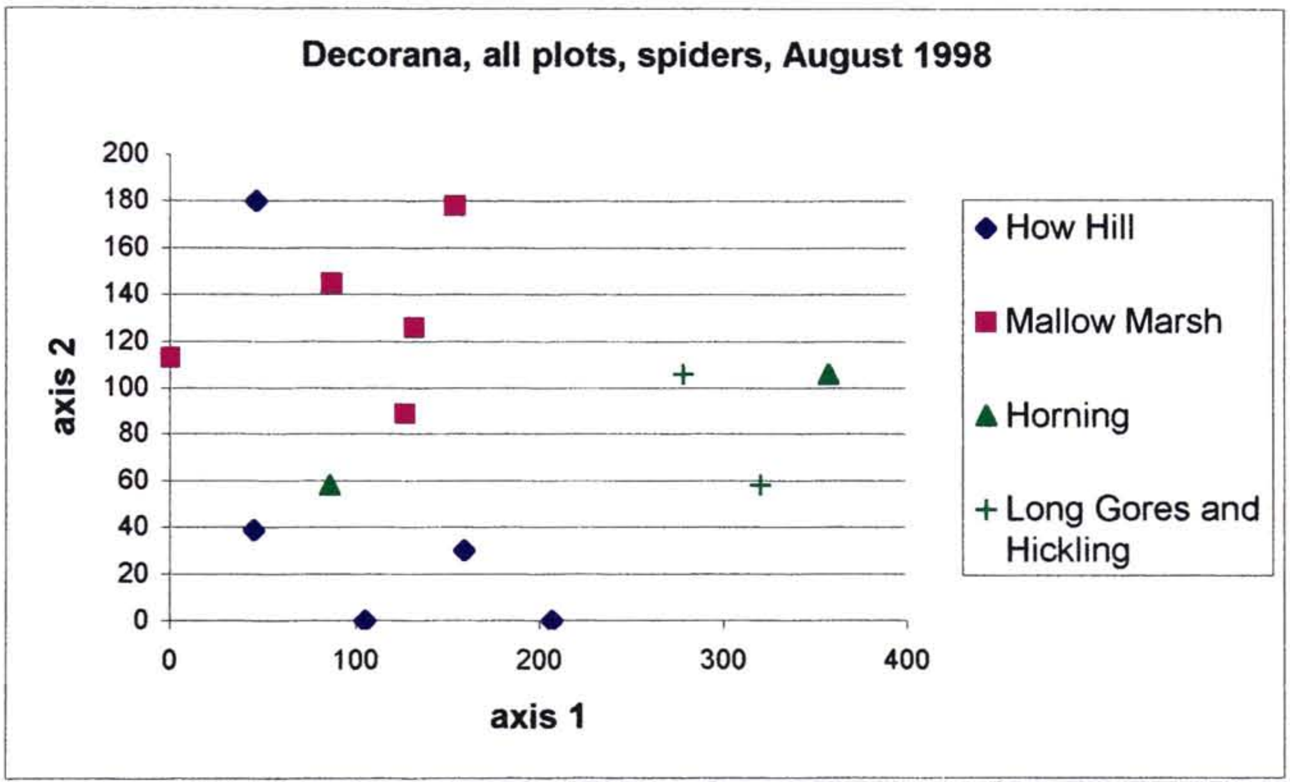


Figure 3.30 Decorana plot of spider distribution in all plots in August 1998, after management. Control plots: How Hill (105, 0) Mallow (87, 145)

clear cutting is having an effect, though of course seasonal variations should be noted too.

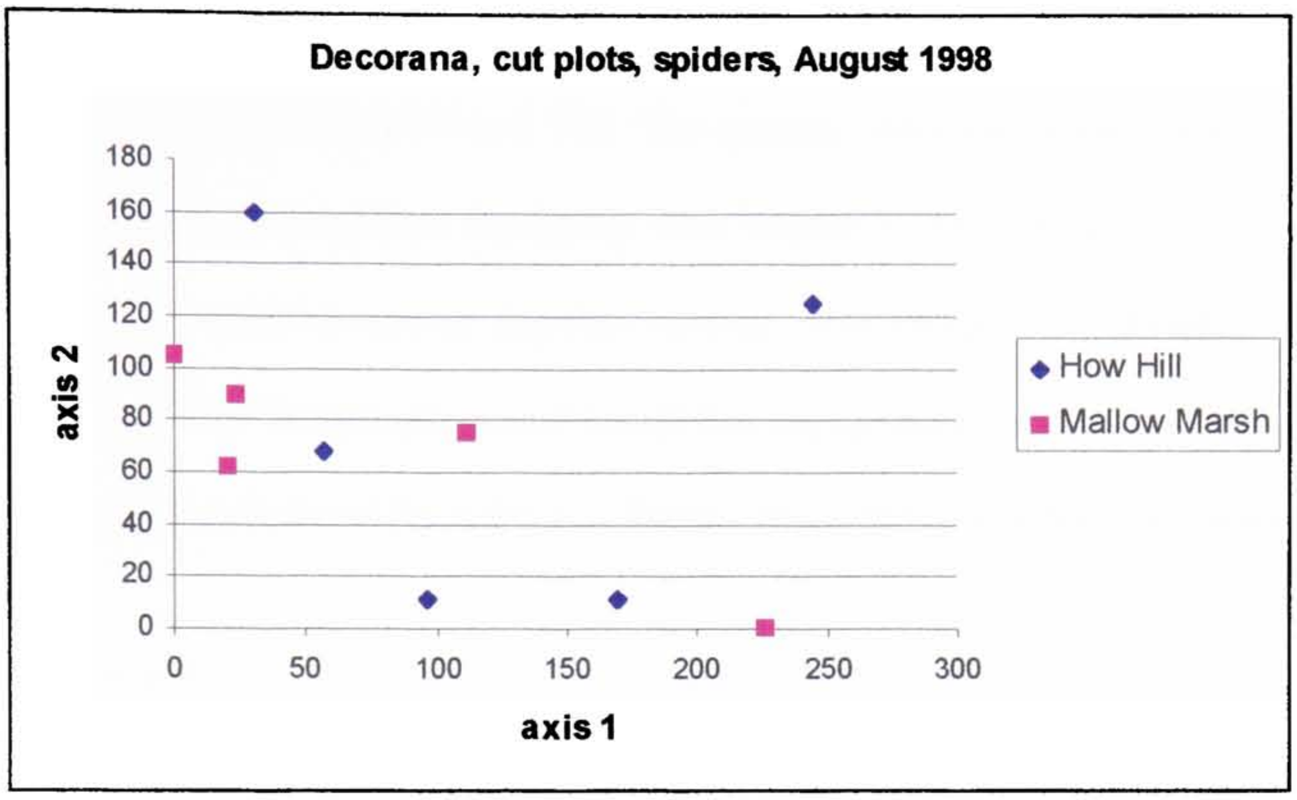


Figure 3.31 Decorana plot of spider distribution in cut plots in August 1998, after management. Control plots: How Hill (96, 11) Mallow (111,

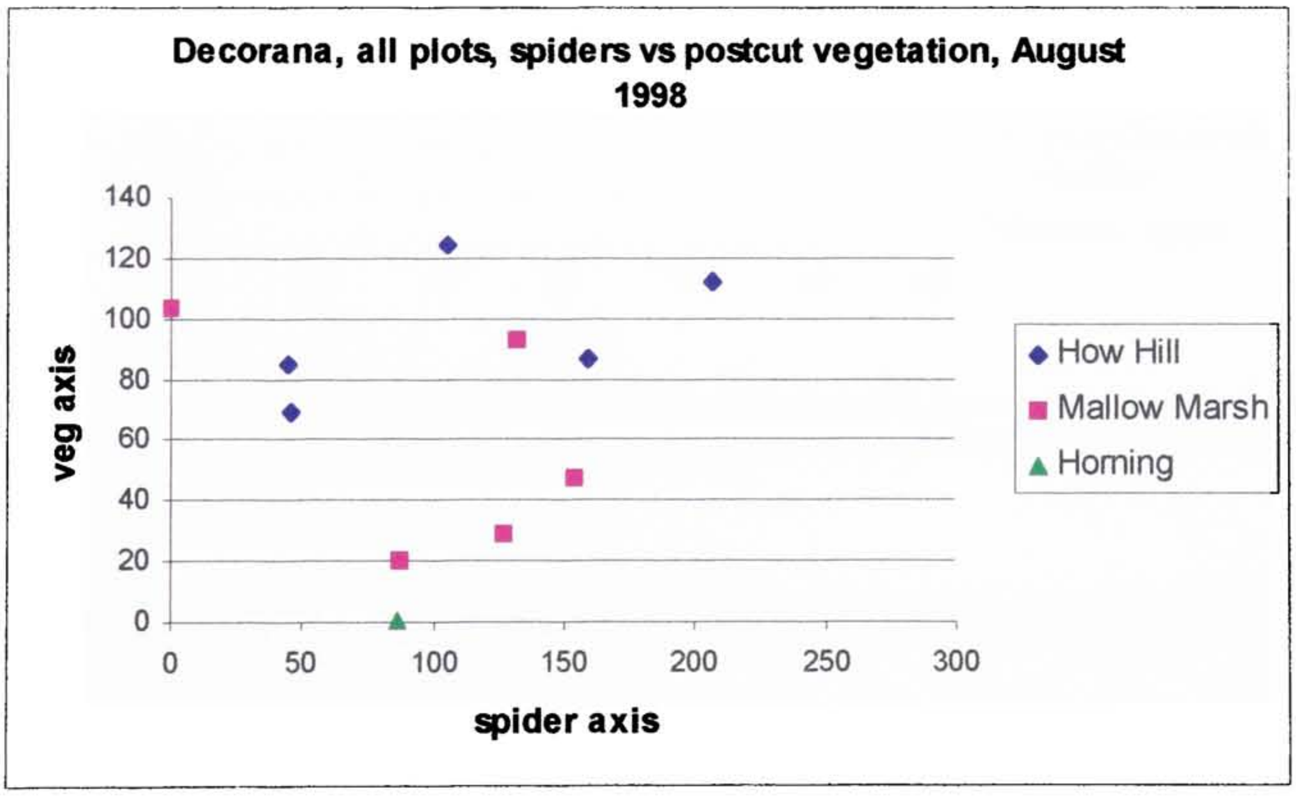


Figure 3.32 Decorana biplot of spiders versus vegetation distribution, after cutting in 1998

Snails

Snails (all sampled post-cutting) appear to have very strict habitat affinities. Looking at all the sites (Figure 3.33) the wetland sites group so tightly together that it is impossible to discern them. The 'dry grazing' sites are outliers and the analysis was redone omitting these dry grassy sites (Figure 3.34). In this analysis the habitats within the wetlands group together broadly. Interestingly the 'flooded' sites with standing water Whitlingham and Broad Fen group together. It seems the snail fauna is strongly influenced by habitat – firstly 'dry grazing and then by standing water.

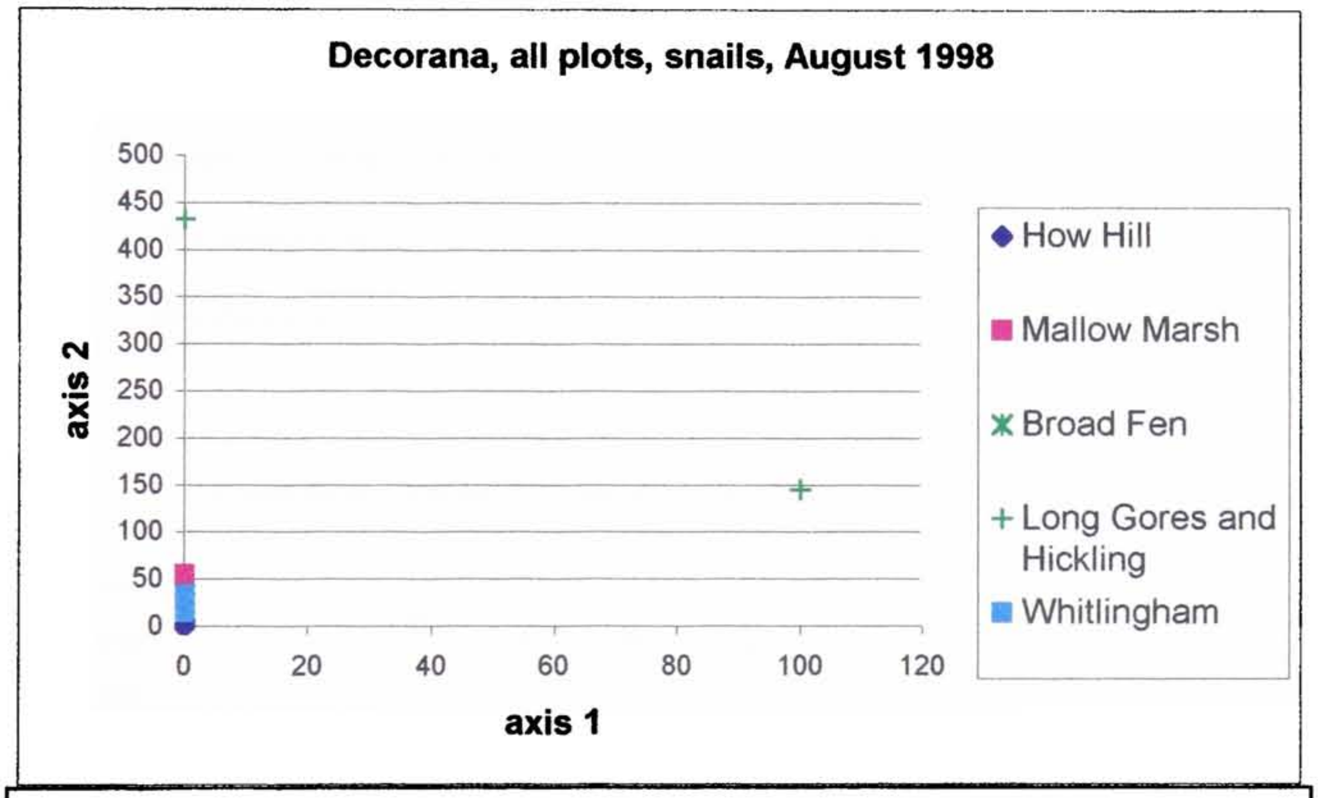


Figure 3.33 Decorana plot of snail distribution all plots in August 1998, after management.

When the snails are plotted against the vegetation (Figure 3.35) then the 'flooded' sites separate out, showing that the vegetation, though important, is not the main factor in determining the snail fauna at these sites. There is no clear management trend between sites, though without a pre-cutting June sampling it is difficult to make comparisons.

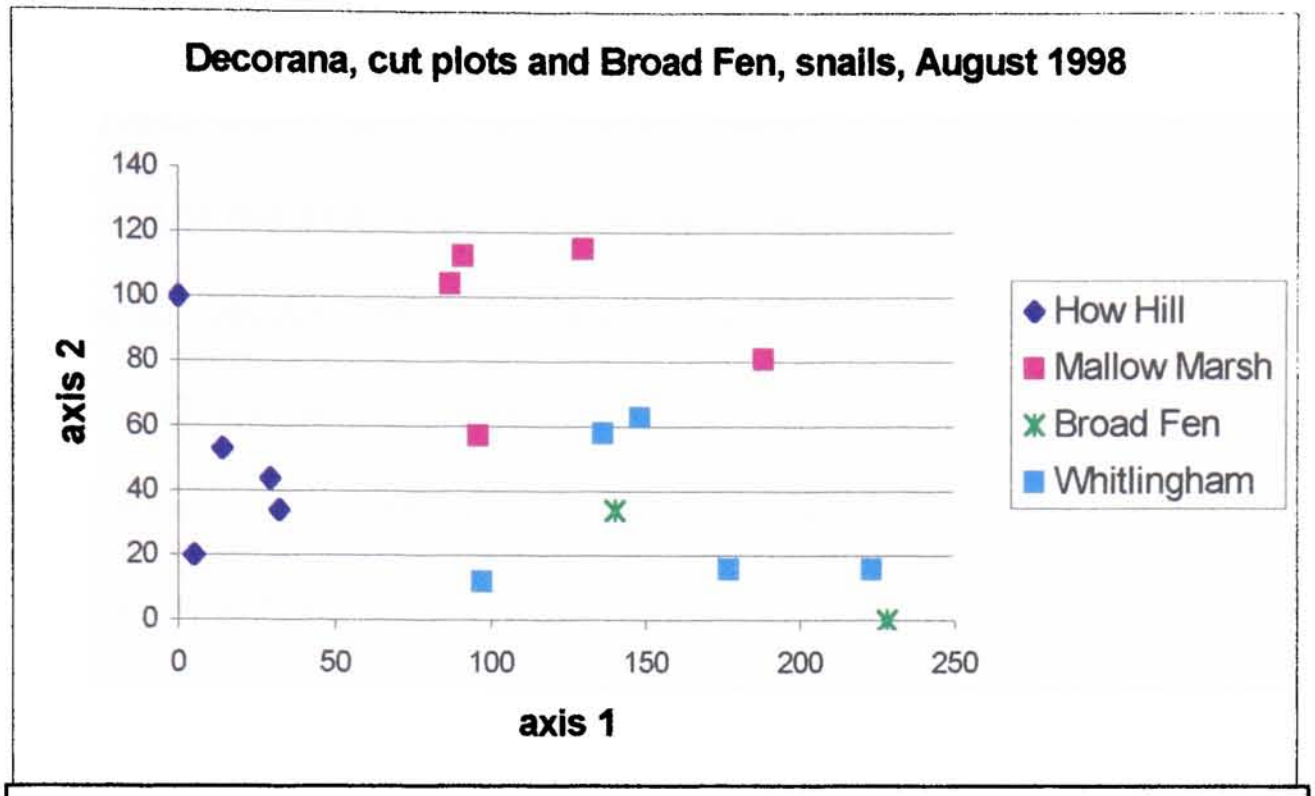


Figure 3.34 Decorana plot of snail distribution for cut plots in August 1998, after management. Control plots: How Hill (0, 100) Mallow (130, 115) Whitlingham (177, 16) Broad Fen (228, 0)

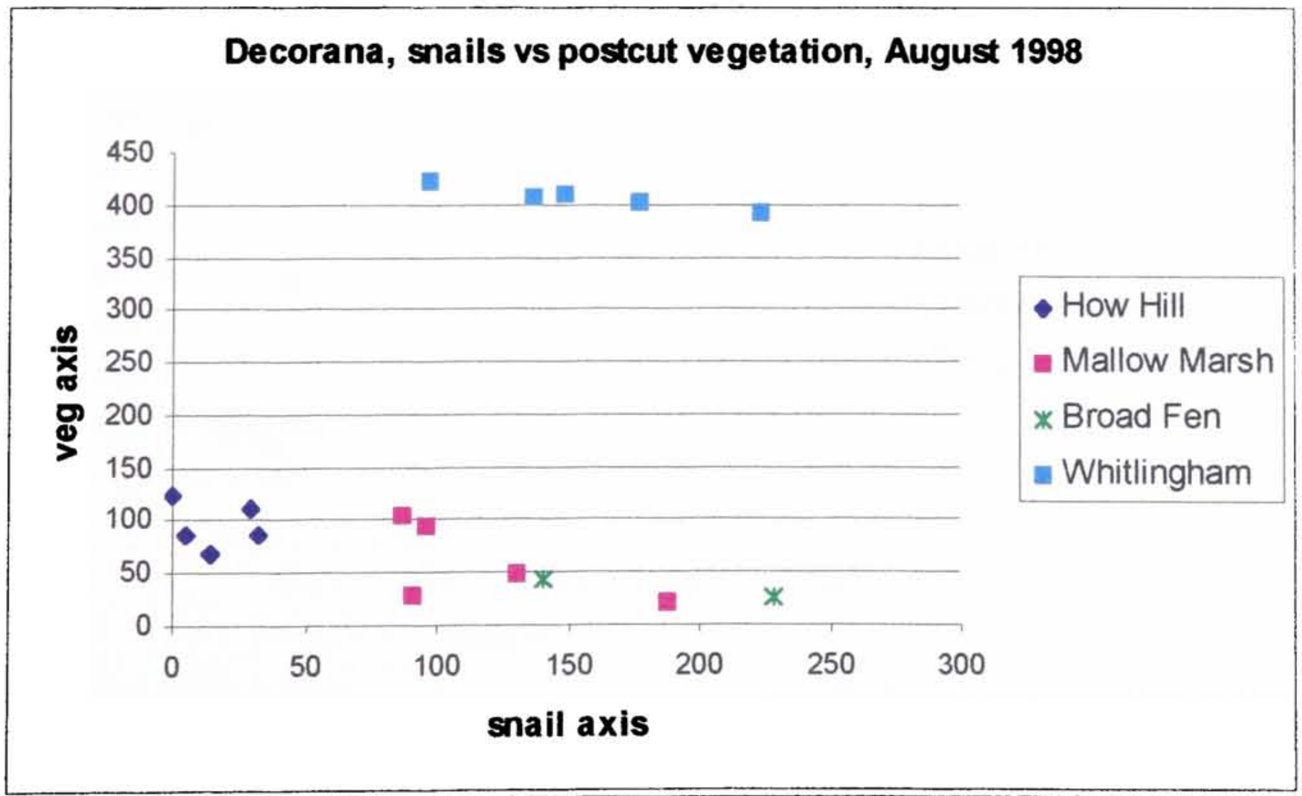


Figure 3.35 Decorana biplot of snail versus vegetation distribution in 1998, after management.

Beetles

The beetles sampled before the sites were cut form habitat groups (Figure 3.36). The 'reedy' sites fall together, with the damper, more densely packed reedy How Hill to the lower end of axis 1 than Mallow Marsh. The 'dry grazing' sites fall to the higher end of this axis, indicating that waterlogging and/or reediness is an important variable for beetles. When the data in reanalysed omitting the 'dry grazing' sites (Figure 3.40) the two remaining sites form separate groups. This is reinforced by the plot (Figure 3.38) of pre-cut vegetation against beetles, where the sites are nicely separated on both axes.

After treatment the beetles still form habitat groups, but, like the spiders these groups are more spread out, with the 'dry grazing' plots, Long Gores and Hickling falling to the top end of axis 1 as before (Figure 3.37). Mallow Marsh plots fall higher up axis 2 than the How Hill plots, with the Horning plots interspersed between them. Removing Horning, Long Gores and Hickling (Figure 3.41) leaves a group of

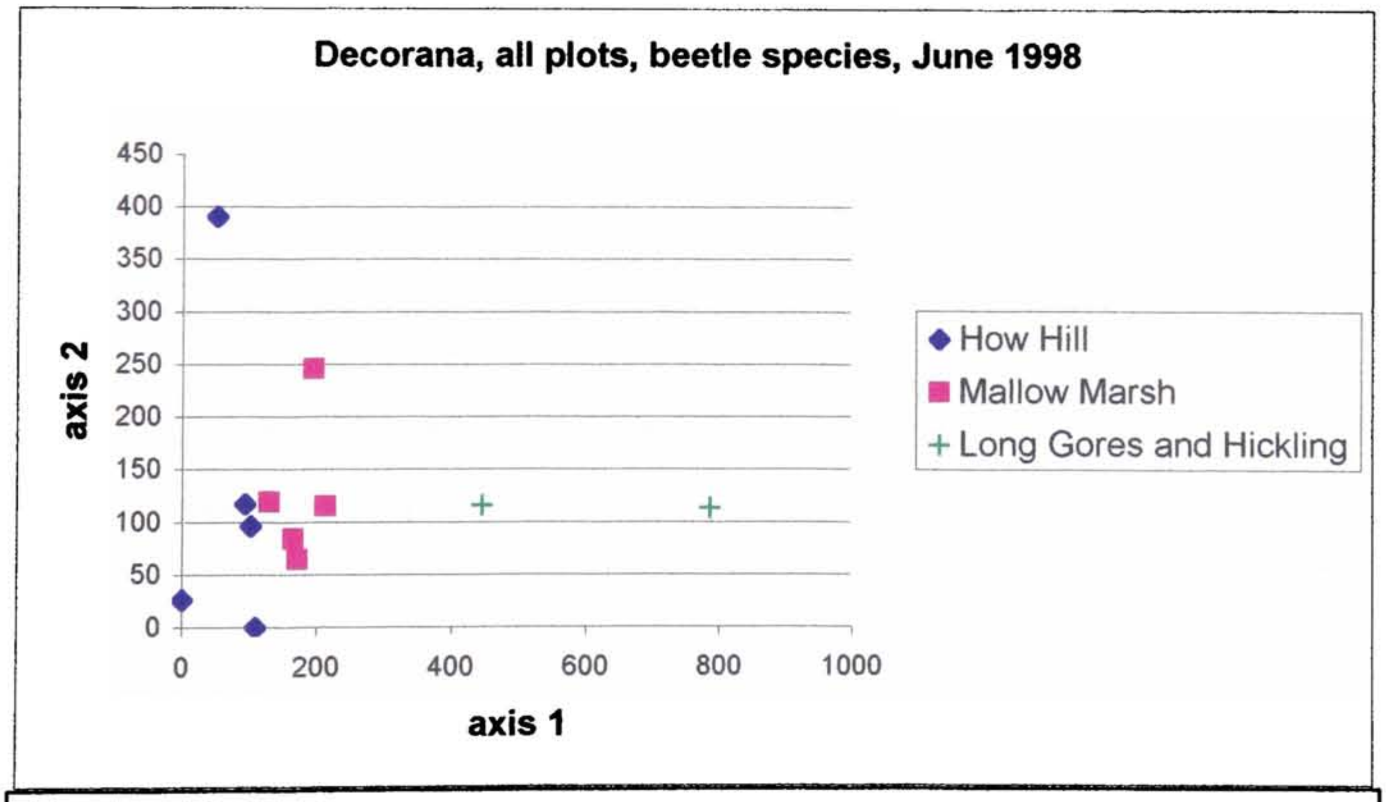


Figure 3.36 Decorana plot of beetle distribution for all plots in June 1998, before management.

Mallow Marsh plots surrounded by How Hill plots, very different from the June 1998 data. Interestingly the How Hill control plot falls most closely to the Mallow Marsh plots and so it could be suggested that the treatment affects How Hill more strongly than Mallow Marsh in terms of disrupting the beetle diversity. Certainly it does not appear to be exclusively related to vegetation changes (Figure 3.39) as the sites group more closely when beetles are plotted against vegetation. Again it appears cutting has a disruptive effect, but that the effect is not in any one direction.

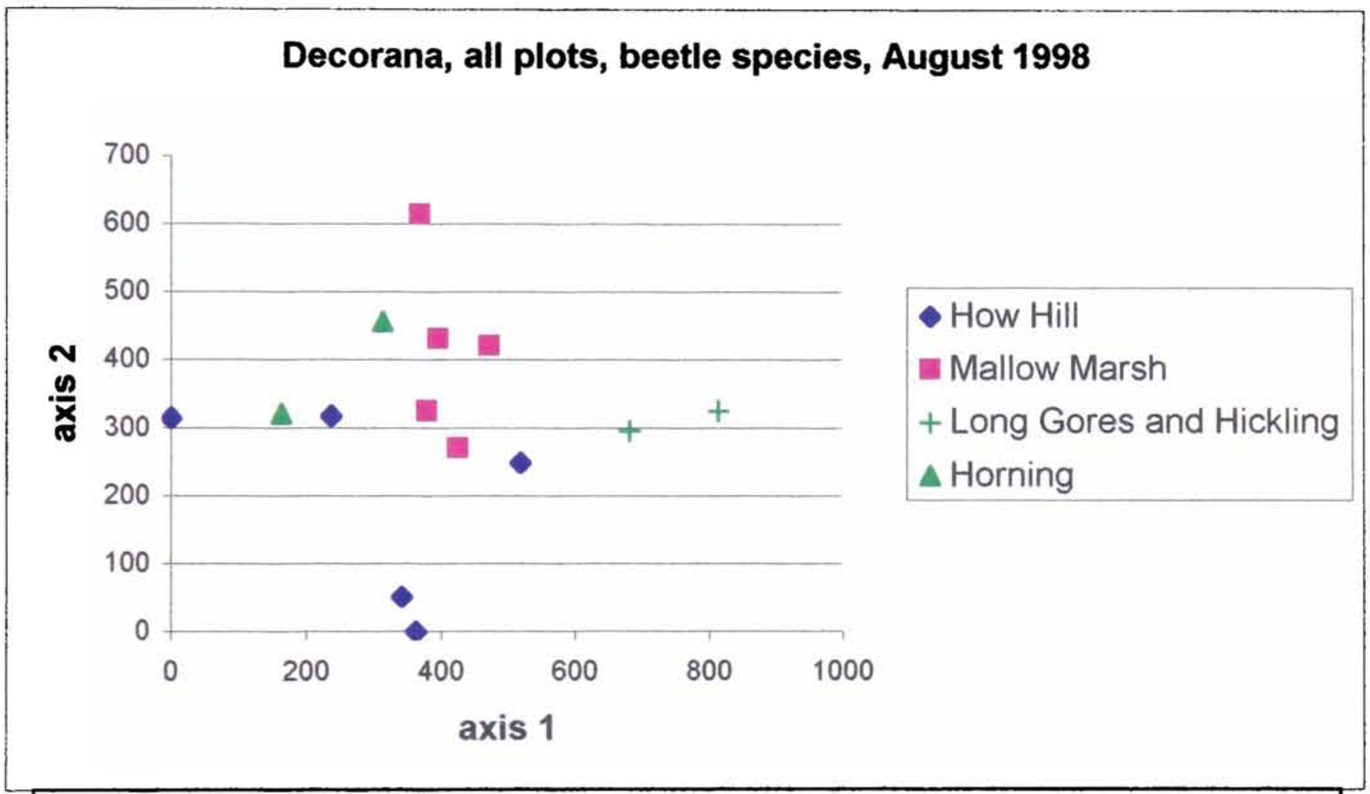


Figure 3.37 Decorana plot of beetle distribution for all plots in August 1998, after management. Control plots: How Hill (236, 318) Mallow (471, 421) Horning (312, 456)

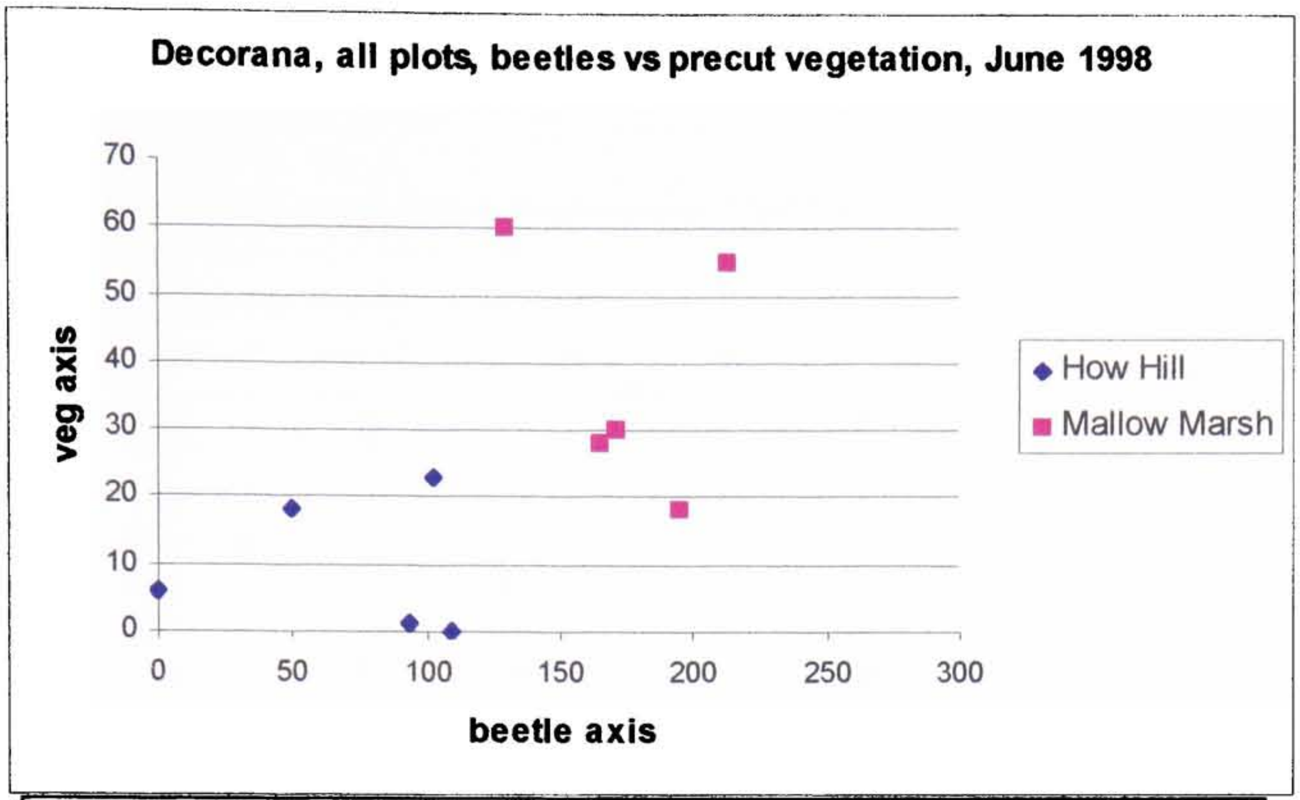


Figure 3.38 Decorana biplot of beetles versus vegetation distribution in June 1997, before management.

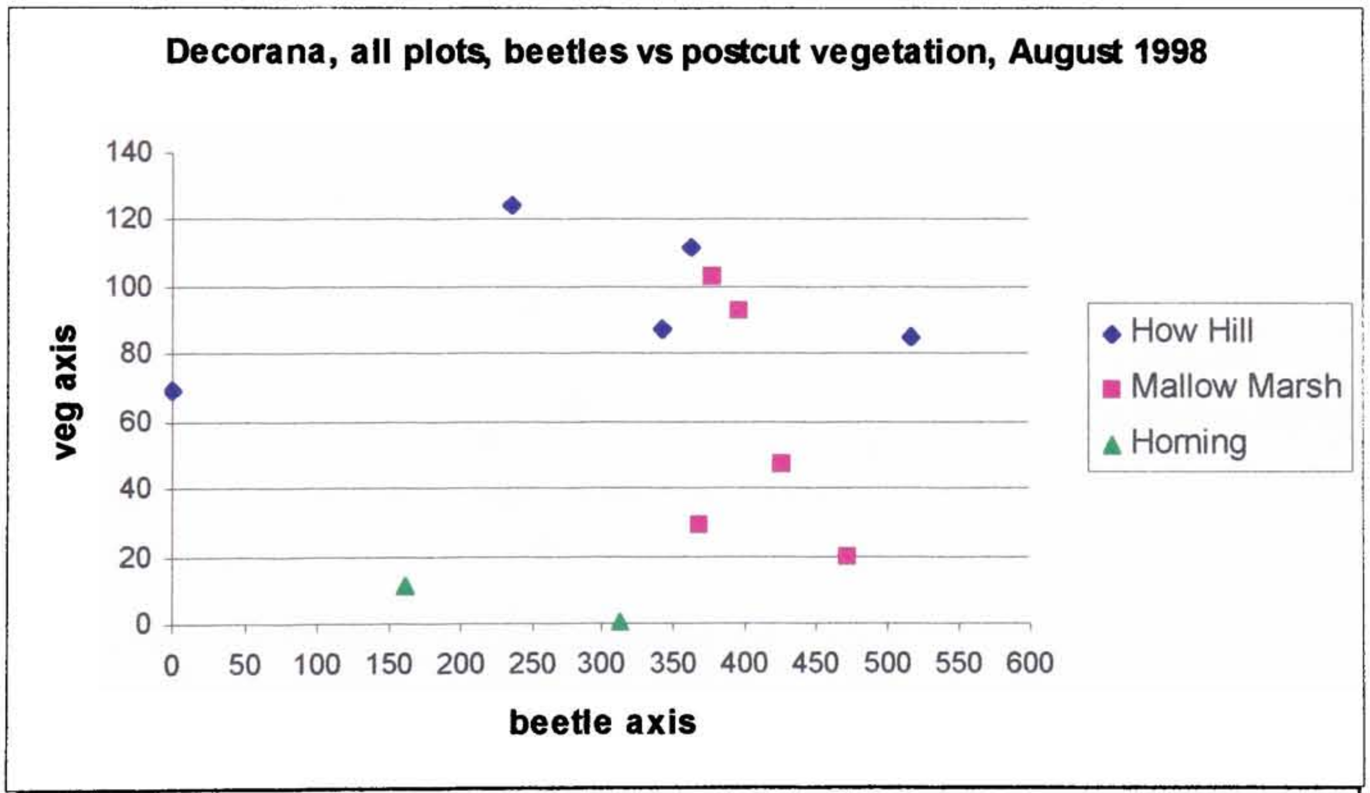


Figure 3.39 Decorana biplot of beetles versus vegetation distribution in August 1998 after management.

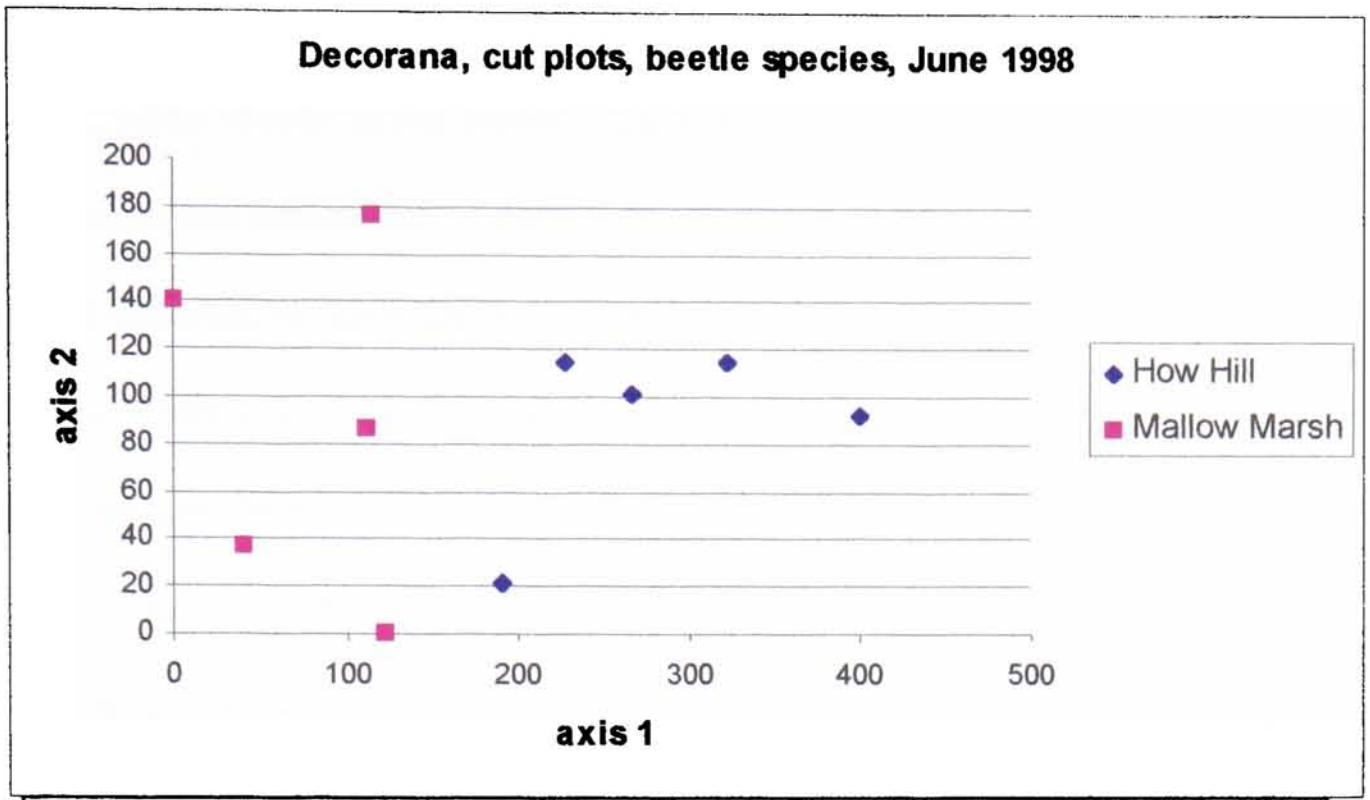


Figure 3.40 Decorana plot of beetles distribution for cut plots in June 1998, before management.

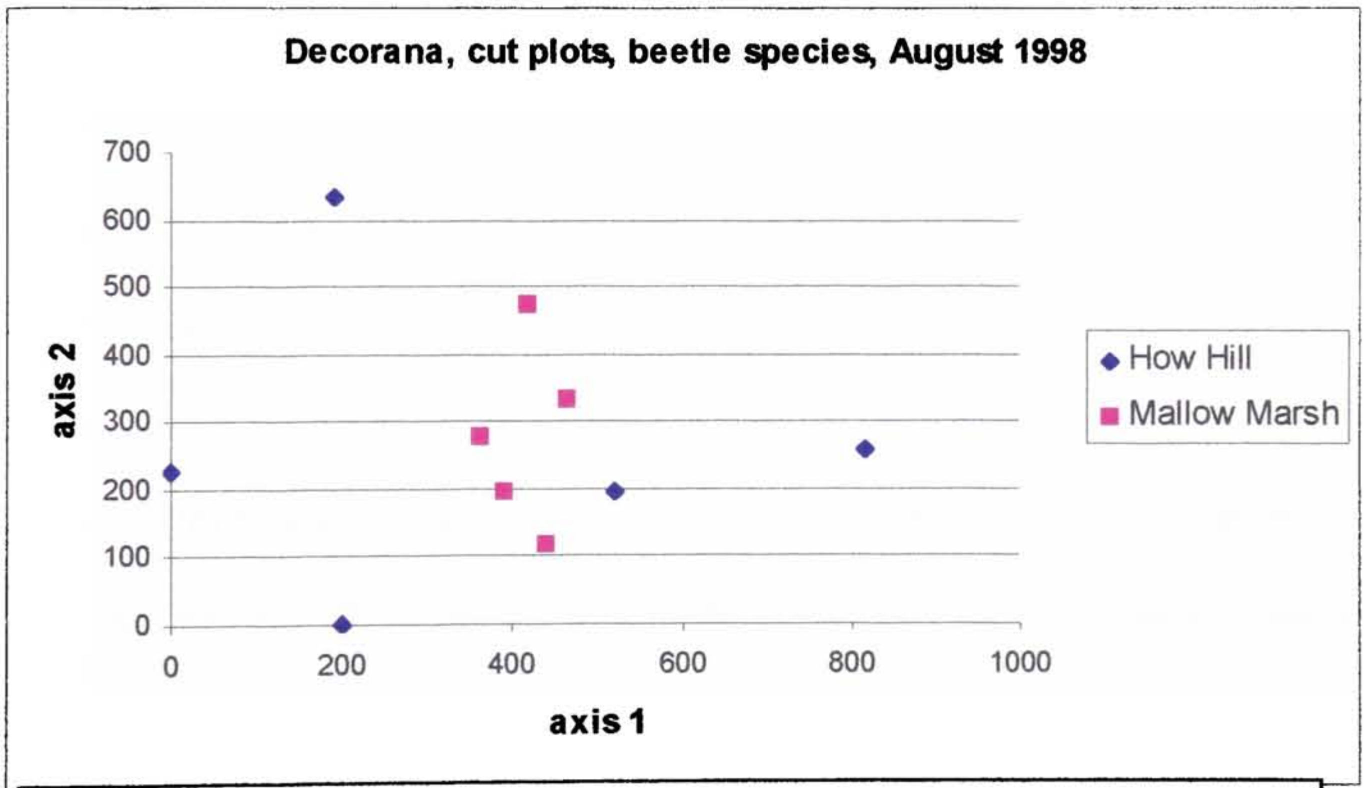


Figure 3.41 Decorana plot of beetles distribution for cut plots in August 1998, after management. Control plots: How Hill (520, 196) Mallow (362, 277)

3.7 Discussion

The results of the samples taken before the sites were cut show that the most important influences on all the groups (spiders, snails and beetles) are the habitat differences. Each habitat contains a different yet predictable selection of species. There is a pervasive historical basis to the fauna and flora and this has strong repercussions throughout the study. It also implies that management and habitat creation schemes intending to alter, influence or change an existing habitat have an uphill task against the ecosystem that is already there. Whilst it is good news to know that fen habitats are robust in terms of their underlying structure it makes restoration of degraded habitats much more complex. Large enough disturbances allow pioneer species to obtain a toe hold in an area (Uzarski, pers. comm., Doshi *et al* in press) and this can potentially alter a habitat. However it seems that pioneers tend to be quickly out competed by later succession fauna.

Some plots that are similar in terms of vegetation e.g. How Hill and Mallow Marsh have differences in fauna – for example *Anisus leucostoma*, a common snail at How Hill is virtually absent from Mallow Marsh. The reason for this is unknown. Similarly Whitlingham Marsh and Broad Fen have very different vegetation (Figure 3.35), but are both flooded and this leads these sites to have similar snail fauna (Figure 3.34) in terms of a dominance of *Succinea putris*, where other more reedy sites are dominated by *Lymnaea palustris*.

Snails are affected by the management, however, despite the strongest influence in the data being habitat, especially the dampness of the sites (Figure 3.33). Once the two dry grazing sites – Hickling and Long Gores – had been removed from the Decorana analysis the effect of management showed up much more clearly. Cutting the vegetation changes the habitat and causes mechanical damage. The removal of this vegetation removes a food supply either directly or indirectly from the fauna. It also removes refuges allowing the invertebrates to become vulnerable to predators such as birds and hazards such as flooding. Snails are very habitat specific and Decorana analyses shows precise groups of snails relating to site.

After cutting in August 1998 the control plots for How Hill and Mallow Marsh appear to fall above the rest of the points for those sites. This indicated management is having an effect on the snails at those sites. This does not appear to be the case at Whitlingham and Broad Fen, but as mentioned above these two sites have a different dominant species which appears unaffected by cutting management. Additionally when plotted against the vegetation the control plots do not stand out from the site groups, which is again a sign, when compared with the snail only plots, that management is affecting the snails. This is because vegetation is a slow responder to change compared with the molluscs, and differences in the two analyses show subtle, unequal differences in effect, given management is the same.

The spider and beetle fauna was only sampled on the ‘reedy’ and ‘grazing’ sites as pitfall traps could not be used on ‘flooded’ sites. Spiders showed different faunal compositions on ‘reedy’ as opposed to ‘grazing’ sites. Before cutting (Figure 3.27) the habitat groups are apparent, with different sites having different communities. After cutting the habitat differences are still there and just looking at the control plots in these analyses they do not appear to be at the extremes of the ranges. In other words spider communities are not noticeably affected by this sort of management as far as this type of analysis can show.

A very similar pattern emerges for the beetles. The habitat groups are very clear before cutting (Figure 3.40), even without plotting the results against the vegetation analysis (Figure 3.38). After cutting, the sites are still separate, and analysis with and without the grazing sites leaves the control plots for each site central to the group of points relating to that site. Basically cutting is not changing the community composition of Coleoptera to any noticeable degree.

How did irregularities in sampling affect the results?

Variability in the length of time the pitfall traps were left down and the occasional missing pot may have influenced the results in several analyses. The most striking is the difference between the Horning results. In June the traps were left out for three days and had far fewer numbers of beetles (Tables 3.III and 3.VI, pages 67-68) whereas in August the traps were left for eight days and gave higher numbers of beetles. The sampling difference is between 24 and 64 trap-days, a factor of three. Difference in beetle numbers is unlikely to be due to the influence of sheep, though may be influenced by seasonal variations in beetle numbers.

Similarly the traps at Hickling were left out for just five days in June and seven days in August, but the numbers of beetles were not significantly different. At How Hill the situation is yet more puzzling. Of the five treatments fen harvester low lost two pots, fen harvester high lost one pot and hand low lost four pots due to flooding in August. Yet only the fen harvester high had significantly fewer beetles than expected, and the hand low plot, (which had half the pots flooded) had significantly higher numbers of beetles. This may be due to an increase in the number of water beetles found (Dytiscidae and Ptiliidae), and patchiness in the Staphylinid distributions. (There were large differences in beetle abundance between seasons – this is expanded in Chapter 6 (page 216).

For the other group collected by pitfall trapping, spiders, it does not appear that the missing trap at Mallow in June 1998 would have affected the results. Fen Harvester high plot at Mallow would most likely still have significantly more individuals (Tables 3.VI and 3.VII, pages 70-71).

The grazed sites are depauperate in terms of spider species numbers with a slight increase in August. Hickling and Horning had significantly fewer spiders than expected in June. This is most likely due to inappropriate application of expected values in the Chi squared analysis, rather than a pitfall trap effect. Having said that the number of spiders found in August 1998 was far more than in June 1998 and this bucks the trend (Chapter 5, section 5.8, page 197) of this study which generally collected more spiders in June, than later in the season.

The very high numbers of spiders collected in August 1998 on the Mallow Marsh Fen Harvester high plot was due to a large number of immature individuals. These are patchy in distribution. It is more likely that the anomaly in numbers is due to one pitfall trap being placed close to a spider nest than to any management effect, especially as this result is not repeated in the other groups or at the same management plot at How Hill. Additionally the significant increase in numbers found on the hand low plot at the same time may not have shown a significant result had the control plot at Mallow not lost a pitfall trap.

The How Hill plots which lost quite a few pots did not show as significantly low in numbers of individuals collected, and it is difficult to speculate if they would have shown as significantly high had the pitfall traps not been flooded. This is similar to the results with the beetle species on these plots.

The sheep at Horning were unexpectedly removed halfway through the first year's sampling. Hickling and Long Gores had no control areas, though Horning did, but both the sheep and the control fence were removed after a few weeks, making any differences between the control and the grazed plot very difficult to interpret.

How complete is the sampling?

When numbers of species for June and August 1998 are combined in the form of species accumulation curves there is a 'step' as new season species are discovered, and the graphs level off at a higher number. Although the second season adds a lot of species the curves are starting to level off within each season for snails and partly for spiders indicating that only a small amount of extra sampling is needed to accurately sample the biodiversity. The species accumulation curve for beetles on the other hand look in no danger of slowing down in the near sampling future. The numbers of species identified in each group (17, 33 and 100 for snails, spiders and beetles respectively) tally closely, inversely with the fullness of the sampling, reflecting the speciosity of the groups. This further suggests that the more fully sampled snails may reflect environmental variance more accurately, with less data noise.

Beetles appear little influenced by management, but that trend could be partly due to the less complete sampling of the highly speciose beetles. Snails appear to be more habitat sensitive than spiders or beetles and consequently may reflect long term changes in habitat more effectively. Again this may be due to the more complete sampling the snails received compared to the other groups. Spiders appear to be slightly management sensitive but they are mobile and can be expected to quickly recolonise areas that are not too frequently or destructively managed or disturbed.

Additionally, as there range of sites included was so varied it is no surprise that the fauna was not fully sampled. The eight different sites were shown by the pilot study to be widely differing in vegetation and faunal composition, and consequently a much larger effort would have been needed to fully sample each of the habitats.

How different are the sites?

The sites appear to be very different. It is beyond doubt that the three categories of habitats – 'dry grazing', 'reedy' and 'flooded' cannot be grouped together for the purposes of analysis. The invertebrate fauna is different with both different communities, different dominant species and different numbers of individuals. Within the habitat groups the species are more similar, but the numbers of individuals and species still variable. Within site analysis is the most robust, as plots within a site are the most similar.

The Chi^2 analysis of number of species on managed versus control sites was difficult to carry out on this data as the experimental treatments were not repeated and several of the grazing plots had no controls once it was established that one site could not be used as a control for another similar site. The attempts to define an expected values for each plot was somewhat complicated. Four different expected values were compared and their worth assessed in terms of their likely accuracy. These are shown in Tables 3.III – 3.VII, pages 67-71.

'Expected' was defined as the sum of the control plots divided by the number of control plots. The advantage of this method is that only control plots were used, and their differences averaged across habitats. The disadvantage is that the grazed plots with no controls and much drier habitats often appeared significant, not because of management differences, merely because the expected value did not reflect that habitat, and because no control plot values from those habitats had contributed to the expected value.

'Expected alternative' was defined as the sum of all individuals divided by the number of treatments. Whilst this version went some way towards redressing the differences in habitats it still lumped grazed plots in with cut plots and hence made many cut plots erroneously significant. Effectively the grazed plots were so different in environment, that any attempt to formulate a combined measure of expected value was doomed to failure.

'Expected HH/MM alone' sought to define expected for each plot, and hence without repeats for the grazed plots no expected value could be defined. For the remaining plots the expected value was the sum of all individuals on that site divided by the number of treatments. This has the disadvantage that there are on average four cut plots to one control plot, hence the expected value is biased 4:1 in favour of the managed values, and is therefore not a true estimation of the expected value for that habitat.

'Control expected' is the last attempt and is defined as the number of individuals found on the control plot of that site. That means the number of individuals found at the control plot is the expected value for the other plots at the same site. This has the advantage that any significant differences between managed and control plots should be due to management. However analysis of data collected pre-cutting shows that the control plot was not always an impartial marker for the experiment. Without a repeat measure it is impossible to tell how typical the control plot is for that habitat. This is a type of pseudoreplication, and though not scientific, appears intuitively more accurate than the other attempts at defining an expected value.

What is the community structure, with respect to dominance of any one species?

Comparison of pre- and post-cutting needs to take into account the different season – which adds a confounding variable and makes interpretation hard. There are some trends but it is impossible to tell if the trends are a response to management, a natural effect resulting from seasonal changes, group or habitat driven. The lack of replication is felt most strongly here. Snails have even fewer comparisons as they have no June sampling so there is no pre-cut baseline to give an idea of numbers, although the base line from spiders and beetles in equally unhelpful as there is considerable variation in numbers of species and individuals between seasons (Chapters 5 and 6).

For snails (Tables 3.VIII – 3.X, pages 81-82) the August dominant is *Lymnaea palustris* for the 'reedy' sites and *Succinea putris* for the' flooded' sites (Chapter 4). The dominant species changes with season in the groups where more than one season was sampled. For spiders the June dominant is *Pirata piraticus* on 'reedy' sites and a mixture of other spiders on 'grazed' sites and the August dominant is *Allomengea vidua*. Beetles are more varied. The 'reedy' sites in June had *Paederus riparius* whereas the 'grazed' sites had *Carabus granulatus*. The August dominant on the grazed sites was *Pterostichus niger* and the 'reedy' sites were very mixed.

Hammond (1994) and Harper and Hawksworth (1994) have suggested that more diverse communities do not have one strongly dominant species, but instead have a spread of species which are equally dominant, or following a Poisson distribution. From this, looking at spiders first, the low diversity plots include the grazing plots in June 1998 (Figure 3.9) and the higher diversity plots include those at How Hill for the same sampling period (Figure 3.10). Looking at the curves for the control plots in August 1998 (Figures 3.12- 3.14) it appears that the control plots are not more diverse than the managed plots at that time. The same trend appears to be true for snails (Figures 3.15-3.18).

Beetles however show the control plot for August 1998 at How Hill to be slightly more diverse than any of the experimental plots (Figure 3.22). This trend does not appear at Mallow Marsh and may be merely a random fluctuation. Additionally at Horning the control plot is much less diverse than its grazed counterpart.

In August 1998 after cutting the results show some influence of management on the spider communities. Spiders are affected by habitat structure, as are snails. The removal of vegetation may preclude web building spiders by removing the mechanical support for the webs.

3.8 Conclusions

The hypothesis that habitats with similar vegetation have similar invertebrate communities was only partially borne out. The more similar the habitat, the more similar the invertebrate communities. Snails were more habitat specific that spiders or beetles. The range of sites chosen varied significantly in vegetation type and subsequently fauna.

The hypothesis that the most similar habitats could be grouped together for the purposes of ecological investigation was found to be true. Unalike habitats, however, could not, and where to draw the line is not obvious, and indeed is likely to change, dependant on the ecological investigation.

The range of habitats looked at in this study were found to be so different it was inappropriate to group them for the purposes of analysis and consequently the sites without controls became unusable. The differences between the cutting regimes showed that the sampling strategy was unable to accurately discern differences between the high and low, fen harvester and hand cut plots.

The grazing studies were particularly difficult to draw conclusions from, as there was a lack of replication and the different studies could not be readily compared due to habitat differences and the lack of controls. The initial assumption that sites could be grouped as 'reedy', dry grazing' and 'flooded' was partially borne out, and sites did not resemble each other closely enough to permit the control on one site to be valid as a marker for another site. The three habitats do broadly correlate in terms of species however.

All three groups did exhibit different communities in the different habitat groups. Snails had a different dominant species in the 'reedy' as opposed to 'flooded' sites. Spiders and beetles, not sampled in the 'flooded' sites had different dominant species in 'reedy' and 'dry grazing' sites. The dominant species is also different between seasons for these two groups. This was not tested in snails.

The groups are all habitat specific. Snails were most thoroughly sampled, and beetles least, which correlates inversely with the numbers of species present in these groups.

Management has a subtle effect possibly, but this is hard to discern given the habitat differences. Further work focussing on one habitat and one management technique in more detail is needed. This would also make statistical analysis much easier.

3.9 Criticisms

The plot size is 10 x 10 metres plus a border, which may not be large enough to avoid edge effects. The project was originally designed by botanists, for botanists, and works well for vegetation surveys. However for invertebrates it is somewhat inadequate as the organisms that were collected are fairly mobile, and can easily cross the areas investigated. The borders also vary in size from a less than a metre to more than ten metres. Any edge effects were minimized by avoiding sampling close to the edge of the study area. Adjacent plots did not appear to influence each other;

for example How Hill control plot is directly next to the How Hill fen harvester high plot and yet the species collected on these two plots were quite distinct. It might however be useful to repeat the experiment on a larger scale to confirm the trends and results, and to attempt to increase the recordable influence of management on each plot as mobility of organisms, recolonisation ability and any edge effects, will affect the statistical analysis.

The statistical analysis would be significantly more robust with replication of habitat types. The pseudoreplication, where there is only one control plot for four treated plots, is very difficult to analyse statistically. This shows up most clearly with the Chi^2 analysis where no satisfactory expected values could be calculated. Grazing plot controls and repeats of areas with the same grazing animals would make interpretation of the results much easier in a further study.

Similarly the grazing project suffered from a lack of repeats. Only one example of each type of grazer was tested, and these were all on different habitats, and the sheep project was further confounded when the sheep were unexpectedly removed half way through the sampling. Indeed the grazed part of the site at Horning was noticeably drier than the control part. These communication problems were particularly problematic in the first year before stable links had been formed with Broads Authority staff. Problems with the management of the grazing project coupled with the difficulties in obtaining control data, the differences in size of the sampling areas and problems with replication amongst different habitats, management treatments and types of grazing animal, all led to the decision to abandon the grazing project entirely and concentrate on more controllable projects in the following years.

3.10 Further Work – The Main Study

The continuation of the study focussed on the differences between cut and uncut reedbed. Just one habitat S4 / S24 reedbed was chosen in order to concentrate on the management effects, rather than habitat differences. The strongest variable found in the Pilot Study (i.e. habitat differences) was therefore omitted. The three sites chosen for the main study were therefore intended to be directly comparable, as the habitats on the three sites were as similar as possible. The effect of cutting on the different invertebrates chosen were studied in detail over a two year period to ascertain whether cutting has an immediate effect, within a season, or a delayed effect through to the following season. (Chapters 4, 5 and 6). Any signs of recovery in the timescale studied were also observed. Different groups were studied to see if the effects of management were similar or different between these groups.

THE SHORT TERM EFFECT OF CUTTING AS A FEN MANAGEMENT PRACTICE ON THE SNAIL (MOLLUSCA) BIODIVERSITY OF THE NORFOLK BROADS

4.1 Abstract

- The study sought to discover whether summer cutting of reedbeds changed the biodiversity of snails in managed areas compared to control areas.
- Species level changes were also investigated in order to identify any specific level responses to management.
- Snails were collected from 18 plots at three sites with the same habitat, half of which had been managed by cutting. Snails were identified to species level.
- Mollusca are shown to be habitat specific, and sensitive to management.
- Different species are shown to respond in different ways to cutting management.
- Snails positively affected by cutting management include *Lymnaea palustris* and *Anisus leucostoma. Nesovitrea hammonis* was negatively affected by cutting. Statistically, only *L. palustris* showed an effect due to the interaction of management and season.
- Overall biodiversity and similarity was not affected by management, but there is a change in diversity between August 1999 and August 2000.
- There is limited evidence of recovery in numbers of individuals 14 months post-cutting.

4.2 Introduction

Fenland and reedbed are not climax communities in this country. Without management, over time, fen habitats turn to woodland, and fen specialist species become rarer as habitat is lost. The Norfolk Broads has been suffering from progressive site abandonment for the past 150 years, particularly in the latter half of the 20th Century. More and more land has been left to fend for itself. Consequently the scrub cover increased dramatically in the 50 years from 1945 to 1995. The Broads Authority (BA) has the unenviable task of attempting to redress the balance and recreate the fenland of yesteryear with little resources and labour.

Their Habitat Action Plan (Bartlett 1993) has been to clear large areas of scrub-encroached fen using a rotational cutting method, cutting every few years. The lack of research into the effects of such cutting, the speed of recovery of the fen and the impact of such disturbance on the communities that make up the flora and fauna has been a limitation in assessing the suitability of this method of fen management.

Wetlands Harvests (1997) (also Andrews 2000) was a preliminary study, but lacked the rigour of a scientific investigation and concentrated on the marketing strategies for the marsh hay rather than the ecological impact of the technique. This study was not really suitable for assessing whether the cutting method should be used.

This investigation looked at the Molluscan biodiversity of three sites in the Norfolk Broads, two managed by the BA (Mallow Marsh, Figure 4.1, and How

Hill) and the third by the Norfolk Wildlife Trust (NWT) (Catfield Fen). The aims of this investigation were to ascertain whether cutting management affects the biodiversity of snail species in the first year following management of reedbeds. Both biodiversity and the individual responses of species were investigated. Snails are sensitive indicator species and have been used in several studies as such (Bush 1988, Davies *et al* 1996, Ditlhogo *et al* 1992, Doshi *et al* in press). They respond to disturbance (e.g. Meyer *et al* 1995) and are therefore useful tools in assessing habitat quality and monitoring environmental change.

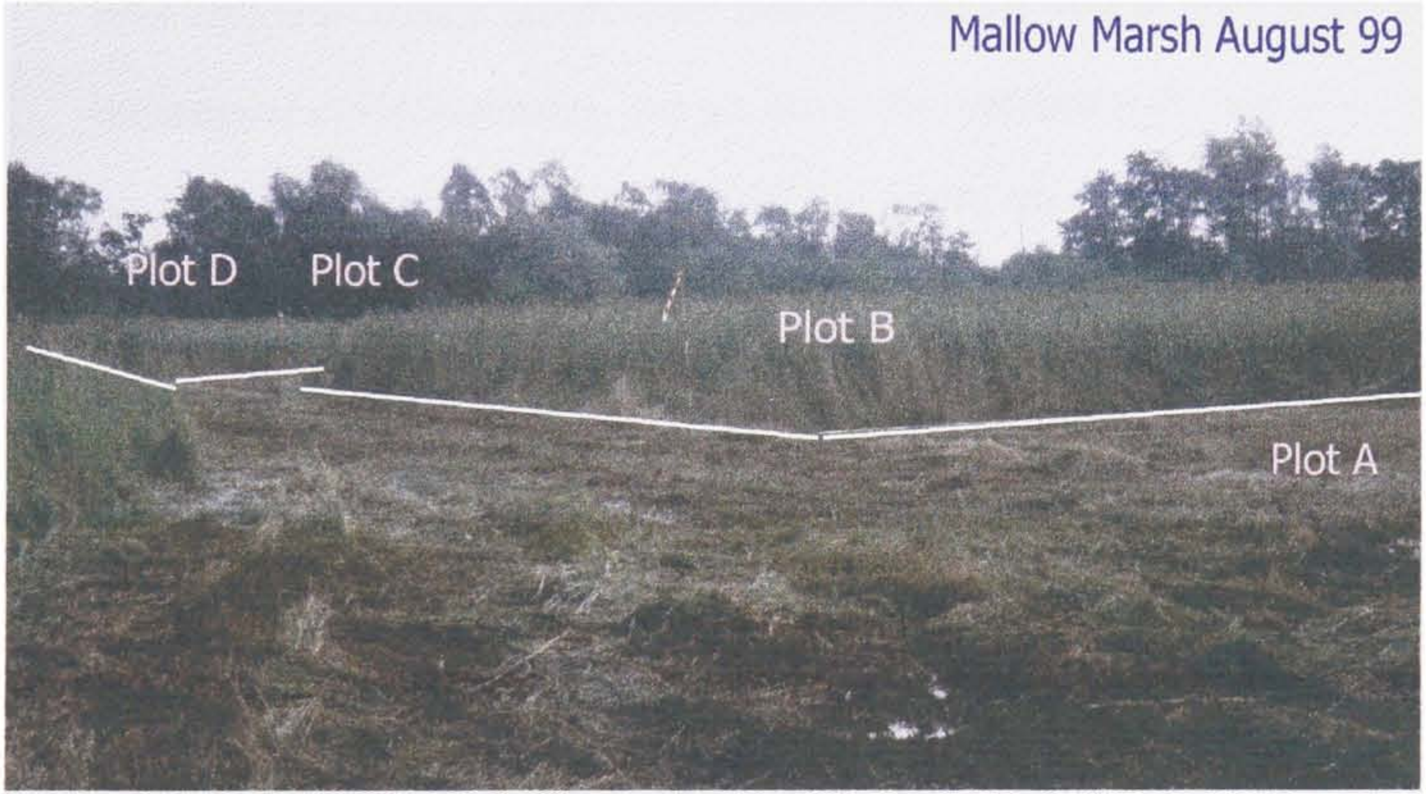


Figure 4.1 The experimental and control plots at Mallow Marsh, August 1999

Bush (1988) showed that multivariate analysis (Decorana) separated snail communities in grasslands, wetlands and woodland, but had difficulty separating different types of fenland such as fen and fen carr. This certainly agrees with the results found in the Pilot Study (Figure 3.33, page 88). Bishop (1981) had similar problems (using PCA). Davies *et al* (1996) state that it appears "from a molluscan point of view fen and carr afford similar opportunity". However they go on to say that "consideration of the dominant species may help to differentiate between assemblages", as was shown in the Pilot Study between 'flooded' and 'reedy' sites.

Ditlhogo *et al* (1992) found water depth affected the response of invertebrates to management, and found that unmanaged plots were different from both cut and burnt plots. They point out that "Loss of old reed by cutting or burning probably affects invertebrates through loss of food, habitat or refuges, or by changes in microclimate". Further, they conclude that the majority of the short-lived effects on certain invertebrates are due to the creation of open spaces and the removal of old vegetation, and not due to the mechanical damage of cutting or burning. They found recovery to be swift, showing little effect of management after one year. They did however pool the groups to family level and this may mask individual species responses.

4.3 Hypothesis

From the results of the pilot study the following hypothesis was formed:

- Gastropods are management sensitive.

From this it can be predicted that the numbers of individual snails will decline in the short-term after habitat cutting and the composition of the Molluscan assemblage will be less diverse in the short term after cutting management.

4.4 Aims

This project set out to quantify the effects of cutting management on the Molluscan diversity of the fen. The aim of this investigation were to ascertain whether cutting management affects the biodiversity of snail species in the first year following management of reedbeds. To this end the following questions were asked:

- Is there a significant difference between the numbers of individual snails found on cut and control plots at each site?
- Is there a significant difference between the numbers of individuals of each species of snail found in cut and control plots at each site?
- Is there a difference between the composition of snails at each site, or between the different management treatments?
- How diverse are the plots in terms of snail species composition, taking both number of species and relative abundance into account?
- How does snail diversity change over the sampling time?
- How similar are the plots to each other in terms of species composition?
- How similar are the plots to themselves one year on?
- What are the responses of individual species to management?

4.5 Autecology

Details of autecology for this group is sketchy with few reliable references on ecological data for the land snails. There is an assumption that most small species are "annual", but no good studies of actual life history for the species mentioned in this study.

Some species of Vertigo (not *V. antivertigo* though) do have some information, which indicates that they are capable of more than one generation a year, but that the precise pattern varies a lot from site to site, and from year to year within the same site (Prof. R. Cameron, pers. comm.). The same is likely to be true for *O. alliarius* and *N. hammonis*. Both those species are extremely broad in habitat range, and can be found in places where most other snails are missing. A mixture of adults and juveniles can virtually always be found, regardless of time of year, so although breeding and growth surely benefit from warmer weather, there is no narrow "breeding season". This may not be so true much further east in Europe, where the winters are much colder. Autecology of the more numerous snails collected in this study is listed below (Janus 1979, Kerney 1999, Kerney & Cameron 1979, Pfleger 1990).

Anisus leucostoma (Millet, 1813) Button or white lipped ram's-horn

Status – Common, though declining. Distribution – Native, declining in farmed areas due to drainage. Widespread in SE Britain, sparser elsewhere, found in Europe. Recorded from Norfolk. Habitat – Aquatic habitats, rivers, canals, lakes, ponds, typical of swampy pools and ditches, especially those drying up in summer, marshes, drought / desiccation resistant in mud. Associates with *Aplexa hypnorum* the moss bladder snail, *Lymnaea truncatula* the dwarf pond snail, *L. palustris* the marsh snail, *Pisidium personatum* the red-crusted pea mussel. Mainly lowland with preference for hard water.

Aplexa hypnorum (Linnaeus, 1758) Moss bladder snail

Status – Local, declining. Distribution – Declining due to infilling of ditches and ponds. Local in Britain, absent from much of Wales and Scotland, Holarctic. Native, declining. Found in Europe. Occasionally recorded from Norfolk. Habitat – Shallow ponds, swampy pools, ditches, stagnant water and grassy pools, in lowland areas found in weed-choked roadside ditches or small ponds, often among floating sweet-grass *Glyceria fluitans*. Drought / desiccation resistant. Associated with *Lymnaea truncatula* the dwarf pond snail, *Anisus leucostoma* the button or white lipped ram's-horn, *Pisidium personatum* the red-crusted pea mussel. Rare in 'good' diverse freshwater habitats.

Lymnaea palustris (Müller, 1774) Marsh pond snail

Status – Common. Distribution – Widespread in Britain except NW Scotland. Showing decline due to agricultural drainage. Native. Holarctic. Recorded from Norfolk. Habitat – Ubiquitous in shallow, well-aerated waters, amphibious, lowland species, hard or soft water. Typical of swamps, shallow drains and choked ditches. Drought / desiccation resistant. More rarely found in lakes, rivers and canals. Some European authors consider 'palustris' to be a complex of 2+ species in the genus / subgenus *Stagnicola*.

Lymnaea peregra (Müller, 1774) Common or Wandering pond snail

Status – Common. Distribution – Ubiquitous in Britain, Europe. Native. Recorded from Norfolk. Habitat – Ubiquitous in slow and standing waters, aquatic habitats of all kinds, hard and soft water, can live on almost bare muddy or stony bottoms with little obvious plant life, ephemeral ditches, rich canals and rivers. Drought / desiccation resistant, tolerant of brackish water. Colonist in new habitats and tolerant of mild pollution.

Nesovitrea hammonis (Ström, 1765) Rayed glass snail

Status – Common. Distribution – Widespread, native, Palaearctic, throughout Europe. Recorded from Norfolk. Habitat – Catholic, damp to moderately dry places, marshes, fens, coniferous and deciduous woodland, grassland, roadside verges, poor acidic places, vegetation, ground litter, some high altitudes, scarce in base-rich lowland habitats such as beech woods on chalk.

Oxychilus alliarius (Miller, 1822) Garlic snail

Status – Common. Distribution – Relatively frequent in Scottish mountains, but scarce in rich lowland habitats. Ubiquitous in Britain, native, W and N European. Recorded from Norfolk. Habitat – Catholic, fields, woods, hedge banks, cliffs, waste ground, rocks, occasionally gardens and greenhouses, tolerant of poor acidic places such as conifer plantations, and upland country where other shelled molluscs are hard to find. Found in moist sheltered places, and ground litter. Although the snail is described as avoiding marshes, it was found abundantly during this study. Specimen identification was confirmed by Prof R. Cameron.

4.6 Methods

Snails were collected by shaking a measured amount of reed-litter (Chapter 2, section 2.6, page 43) through a garden riddle and hand-sorting the residue (Emberton 1996, Quinn *et al* 1996, D. Howlett pers. comm.). Ditlhogo *et al* (1992) found significantly more snails by hand sorting than by heat extraction. The small snails were sieved out into a tray, killed in 80% ethanol, preserved and later identified to species level (Janus 1979, Kerney 1999, Kerney and Cameron 1979, Macan 1960, Pfleger 1990). Identification of snails was carried out by the author, with help from Prof. R. Cameron and D. Howlett. Snails requiring dissection for positive identification were identified to morphospecies level. These were of the *Succinid* group which comprised three snails – *Oxyloma sarsi, Oxyloma pfeifferi* or *Succinea putris*. Some token snails were dissected by D. Howlett and all were found to be *Succinea putris*, however for the purposes of this study they have been grouped under the heading 'Succinid'.

Three sites were used Catfield Fen, Mallow Marsh and How Hill. These were all *Phragmites australis* dominated (NVC) S4 reedbed, though Catfield had more S24 tendencies. Vegetation surveys were taken in 1999 before cutting and one year later in the summer of 2000. One hundred 25x25 cm quadrats were taken randomly in each plot. Presence and absence of each species was noted, and this gave frequency data for each plot at each site.

The sites each had six 10x10m plots A-F, half of which were cut in July 1999. At Catfield and How Hill the plots A, C and E were control plots (uncut) and B, D and F were cut plots. At Mallow Marsh A,C and E were cut and B, D and F were control. Samples were taken from each plot in mid-June 1999 before management, and post-management at the end of August 1999, mid-June 2000 and end August 2000.

Snails (Figure 4.2) were identified to species and the data combined with the vegetation survey data. Chi^2 tests were used to discern whether there is a significant difference between the numbers of individual snails found on cut and control plots at each site and also to test whether there is a significant difference between the numbers of individuals of each species of snail found in cut and control plots at each site.

DECORANA (Hill 1979) from the Vespan III (licensed by A. Malloch 1990) program, was used to ascertain whether there is a difference between the composition of snails at each site, and between the different management treatments. Vegetation and snail multivariate analyses were combined using a two-way biplot. Plotting the two against one another enabled a visual representation of the different influences of the vegetation and snail composition on the biodiversity to be differentiated. Further analyses of the Indices and multivariate data was carried out using the Mann Witney U test and the General Linear Model (Dixon 1992, Fowler *et al* 1998, Rohlf and Sokal a, b, 1995).

Figure 4.2 ***Anisus leucostoma*** **snails collected from How Hill August 2000**

The Simpson Diversity Index (e.g. Begon *et al* 1990) was used to estimate how diverse the plots are in terms of snail species composition, taking both number of species and relative abundance into account. Changes over the sampling time could be seen.

The Jaccard Similarity Index (Southwood 1978), and Morisita-Horn Index (Krebs 1989) were used to quantify how similar the plots are to each other in terms of species composition, and how similar they are to themselves one year on.

4.7 Results

Nearly 2000 individuals were collected (1987). The number of species and individuals collected is shown in Table 4.I.

Table 4.I The number of snail species and individuals collected.

Collected	June 1999	August 1999	June 2000	August 2000
no.s species	10	11	11	14
no.s individuals	110	270	806	801

Is there a difference between the numbers of individual snails found on cut and control plots at each site?

The distribution of snails before cutting in June 1999, shows that at Catfield and How Hill there is no significant difference between numbers of individuals (all gastropod species together) on experimental compared to control plots (Table 4.II). At Mallow Marsh, however there is a difference, apparently due to an unexpectedly high number of *Lymnaea palustris* in one (due to be cut) plot (Table 4.II). *Anisus leucostoma,* the only other species present in sufficient numbers to be analysed, shows no significant difference in distribution between experimental and control plots.

Table 4.II Chi squared analysis of snail distribution before cutting in June 1999. The top part of the table show the differences between the numbers of individuals found on each treatment at each site. The second half of the table

shows the differences in the numbers of individuals of each species found on plots of different treatments.

Jun-99					
Sites	cut	uncut	expected	Chi^2	sig
Catfield	21	26	23.5	0.53	ns
Mallow	22	3	12.5	14.44	p=0.001
How Hill	18	28	23	2.17	ns
Species					
Anisus leucostoma	18	18	18	0	ns
Lymnaea palustris	35	13	24	10.08	p=0.001

Using a Bonferroni correction on the significant values, the sites are significant at p<0.0167. The species are significant at p<0.025, so both Mallow and *L. palustris* have significant differences between the numbers of individuals found in plots to be cut compared to those found in the control areas.

Is there a difference between the numbers of individuals of each species of snail found in cut and control plots at each site?

Chi^2 analysis of the August 1999 snail distribution, one month post cutting (Table 4.III), shows Catfield as the only site with a significant difference (p=0.025) in numbers of individuals with more individuals in cut than control plots. *Anisus leucostoma* and *Nesovitrea hammonis* are the only species to show a significant difference in numbers between cut and control plots, with more individuals of *A. leucostoma* in cut plots compared to control plots, and more individuals of *N. hammonis* in control plots compared to cut plots.

Table 4.III Chi squared analysis of snail distribution in August 1999. The top part of the table show the differences between the numbers of individuals found

on each treatment at each site. The second half of the table shows the differences in the numbers of individuals of each species found on plots of different treatments.

Aug-99

Sites	cut	uncut	expected	Chi^2	sig
Catfield	54	31	42.5	6.22	p=0.025
How Hill	68	50	59	2.75	ns
Mallow	33	34	33.5	0.01	ns

Species	cut	uncut	expected	Chi^2	sig
Anisus leucostoma	50	13	31.5	21.73	p=0.001
Lymnaea palustris	79	65	72	1.36	ns
Nesovitrea hammonis	1	11	6	8.33	p=0.005
Oxychilus alliarius	17	13	15	0.53	ns

Using a Bonferroni correction on the significant values, the sites are significant at $p<0.0167$. The species are significant at $p<0.0125$, so Catfield, *A. leucostoma* and *N. hammonis* have significant differences between the numbers of individuals found in cut plots compared to those found in the control areas.

By June (2000) all the sites show a $p=0.001$ significance, with more individuals in cut plots than control plots, and all the species present in sufficient numbers to analyse (i.e. with expected values >5) also show significance in the same direction (Table 4.IV) before applying the Bonferroni correction.

Table 4.IV Chi squared analysis of snail distribution in June 2000. The top part of the table show the differences between the numbers of individuals found on each treatment at each site. The second half of the table shows the differences in

the numbers of individuals of each species found on plots of different treatments.

Jun-00					
Sites	cut	uncut	expected	Chi^2	sig
Catfield	204	60	132	78.55	p=0.001
Mallow	216	33	124.5	134.49	p=0.001
How Hill	189	104	146.5	24.66	p=0.001
Species					
Anisus leucostoma	162	77	92.5	104.44	p=0.001
Aplexa hypnorum	18	7	12.5	4.84	p=0.05
Lymnaea palustris	408	96	252	193.143	p=0.001
Lymnaea peregra	11	3	7	4.57	p=0.05

Using a Bonferroni correction on the significant values, the sites are significant at p<0.0167. The species are significant at p<0.0125, so all three sites, *A. leucostoma* and *L. palustris* have significant differences between the numbers of individuals found in cut plots compared to those found in the control areas. *A. hypnorum* and *L. peregra* show significant differences as an artefact of repeating the statistical test many times.

In August 2000 there is a significant difference in distribution of snails between cut and control plots at Mallow and Catfield, but not How Hill. More individuals are found in the control plots at Catfield than in the cut plots, whereas at Mallow Marsh it is the other way around. The only species to show significance is *Nesovitrea hammonis* (Table 4.V), and this showed more individuals in the control plots than in the cut plots.

Table 4.V Chi squared analysis of snail distribution in August 2000. The top part of the table show the differences between the numbers of individuals found

on each treatment at each site. The second half of the table shows the differences in the numbers of individuals of each species found on plots of different treatments.

Aug-00

Sites	cut	uncut	expected	Chi^2	sig
Catfield	61	93	77	6.65	sig p=0.01
Mallow	96	42	69	21.13	sig p=0.001
How Hill	246	263	254.5	0.57	ns

Species	cut	uncut	expected	Chi^2	sig
Anisus leucostoma	148	152	150	0.05	ns
Aplexa hypnorum	33	23	28	1.79	ns
Lymnaea palustris	188	158	173	2.6	ns
Lymnaea peregra	5	7	6	0.05	ns
Nesovitrea hammonis	5	25	15	13.33	sig p=0.001
Oxychilus alliarius	19	20	19.5	0.03	ns

Using a Bonferroni correction on the significant values, the sites are significant at $p<0.0167$. The species are significant at $p<0.0083$, so Catfield, Mallow and *N. hammonis* have significant differences between the numbers of individuals found in cut plots compared to those found in the control areas.

The effect of cutting vs not cutting, and effects of sampling time i.e. June vs August and 1999 vs 2000, plus any interaction between treatment and sampling time are tested using the General Linear Model (GLM). A significance score of $p<0.05$ for sampling time indicates seasonal or year to year fluctuations. A significance score of $p<0.05$ for treatment indicates either an increase or decrease in numbers of individuals of that species following treatment. A significance score of $p<0.05$ for an interaction between treatment and sampling time indicates the reaction of the species in question is influenced by both processes. This is shown in Table 4.VI.

Table 4.VI The effect of sampling date, treatment and an interaction between the two, tested using a General Linear Model. Species showing a significance level <0.05 are shown.

Species	effect of sample date		effect of treatment		sample*treatment	
	F value at d.f. 3	sig level	F value at d.f. 1	sig level	F value at d.f. 3	sig level
Anisus leucostoma	5.52	<0.005	0.55	ns	0.56	ns
Aplexa hypnorum	4.87	<0.005	0.31	ns	0.34	ns
Lymnaea palustris	11.9	<0.001	5.49	<0.05	6.01	<0.001
Nesovitrea hammonis	3.26	<0.05	2.37	ns	2.18	ns
Oxychilus alliarius	4.81	<0.005	0.3	ns	0.25	ns
Vertigo antivertigo	3.82	<0.05	1.57	ns	0.98	ns

Using a Bonferroni correction on the significant values, the species are significant at $p<0.0083$. This means no snails are significantly affected by treatment, and that *N. hammonis* and *V. antivertigo* do not have significant seasonal variations. These anomalous significance results could be due to repeated use of the GLM statistical test.

Is there difference between the composition of snails at each site, or between the different management treatments?

Multivariate analysis of vegetation distribution before management, using Decorana, shows a group consisting of Mallow Marsh and How Hill and a separate, more widely dispersed group of Catfield Fen points (Figure 4.3). Inertia figures on each plot relate to the amount of variation described by that axis i.e. for Figure 4.3 Axis 1 describes between 30 and 52% of the variation found within the data, whereas axis 2 explains between 17 and 29% of the variation found within the dataset. This is notable particularly where axis 1 is dominant and describes a much larger proportion of the dataset than axis 2.

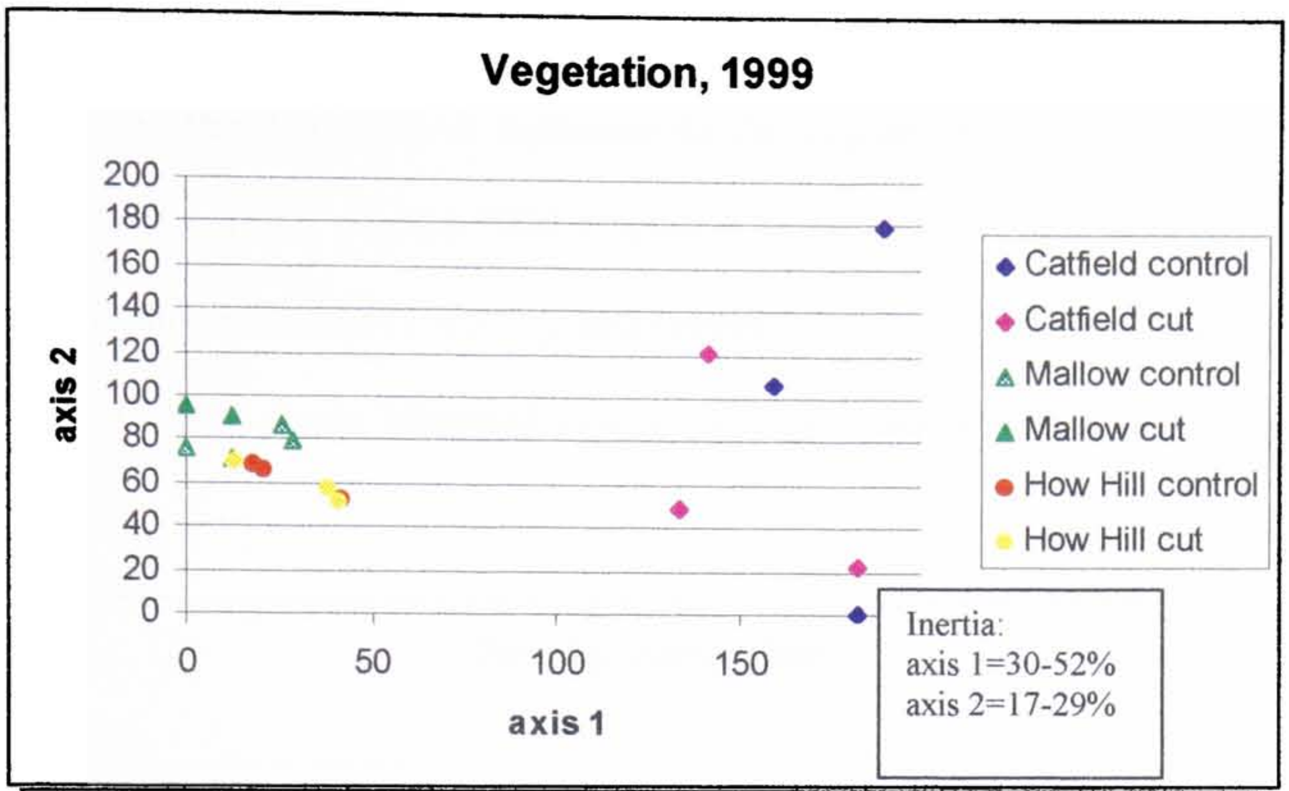


Figure 4.3 Decorana plot of the vegetation distribution in 1999, before management.

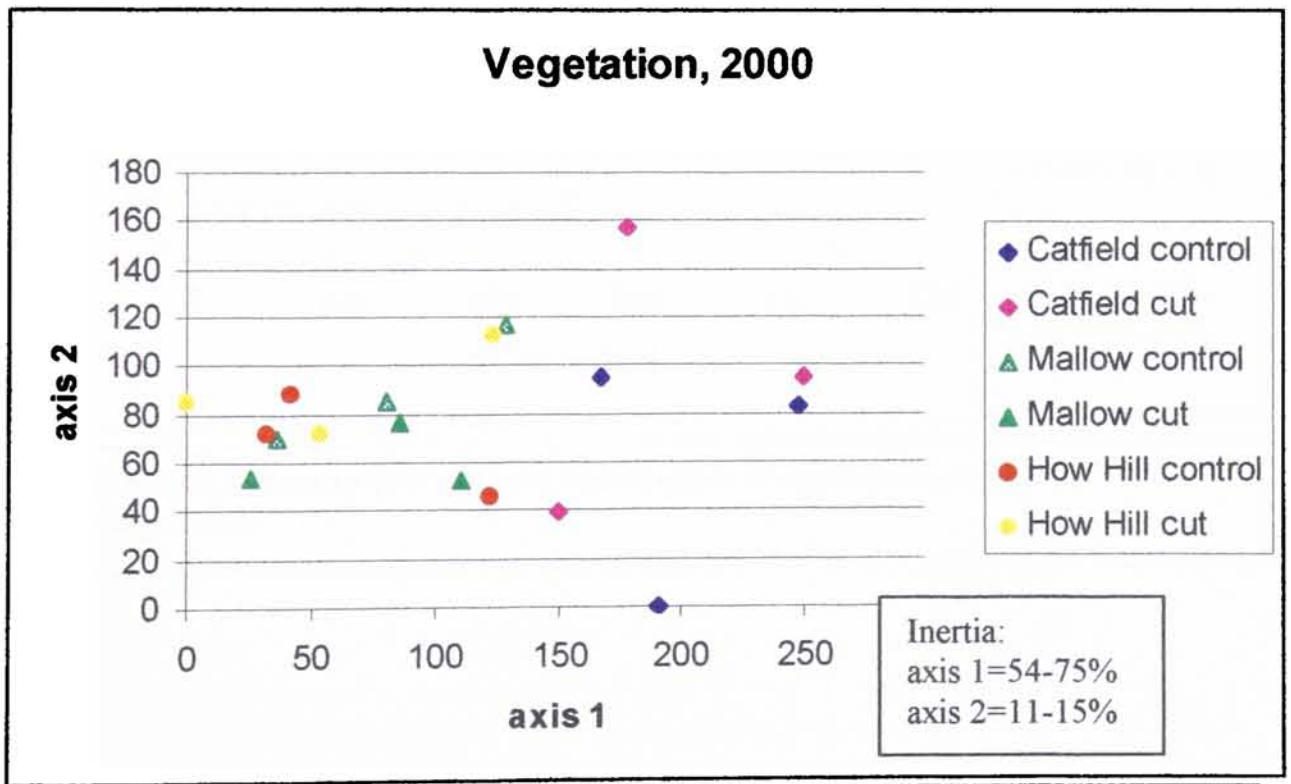


Figure 4.4 Decorana plot of the vegetation distribution in 2000, after management.

After cutting, August 1999 (Figure 4.4), the Catfield sites still fall to the right end of axis 1, however the Mallow Marsh and How Hill groups are now more spread out. Looking at the multivariate distribution of snails before management, (Figure 4.5), it appears the sites all have similar assemblages of snails, there being a main group around (50,50). The few outlying points are from all three sites, and both cutting and not cutting. Plotting snails (pre-management) against vegetation (Figure 4.6) show the Catfield sites as separate from the other two. This is separated on the vegetation axis, not on the snail axis. Post cutting, August 1999 (Figure 4.7) the Mallow Marsh snails group most tightly at around (150,110), surrounded by the How Hill snails and flanked by the Catfield snails. Managed sites do not group together compared to control plots.

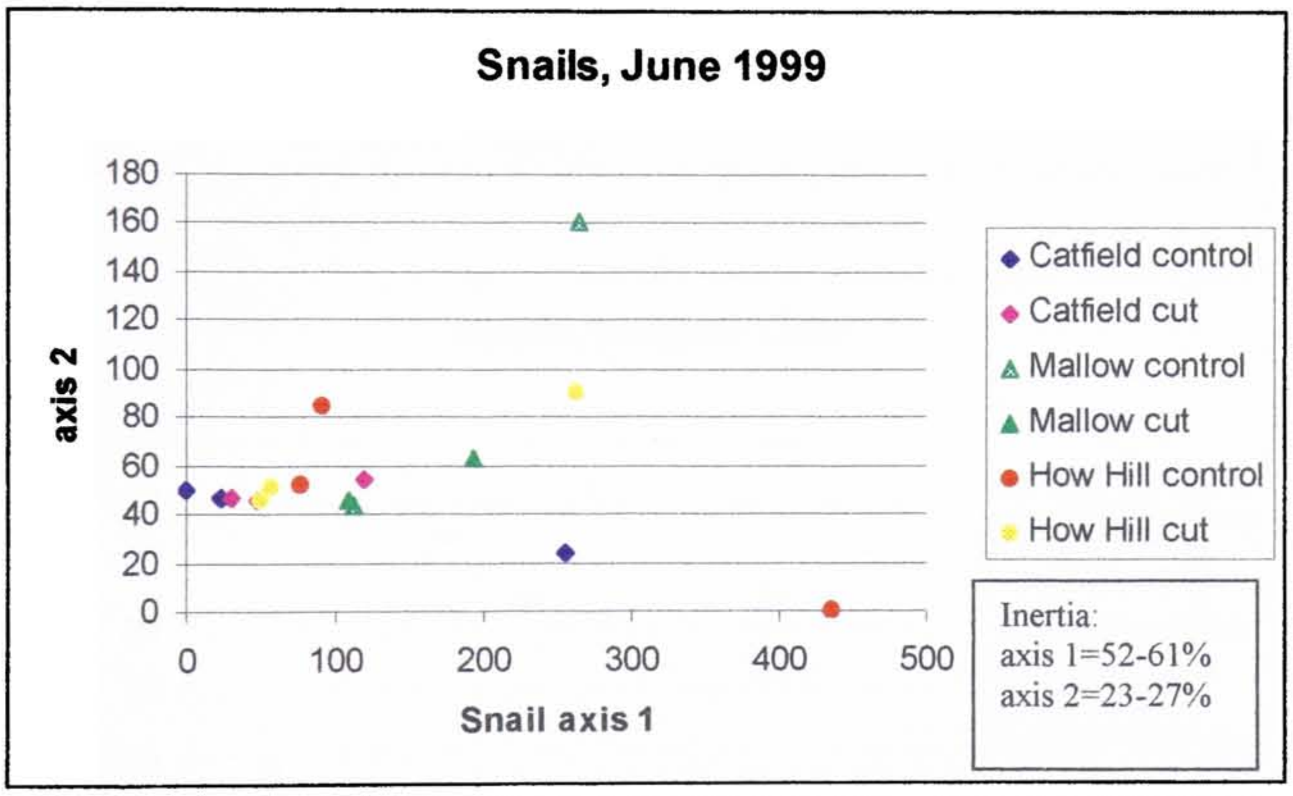


Figure 4.5 Decorana plot of snail distribution in June 1999, before management.

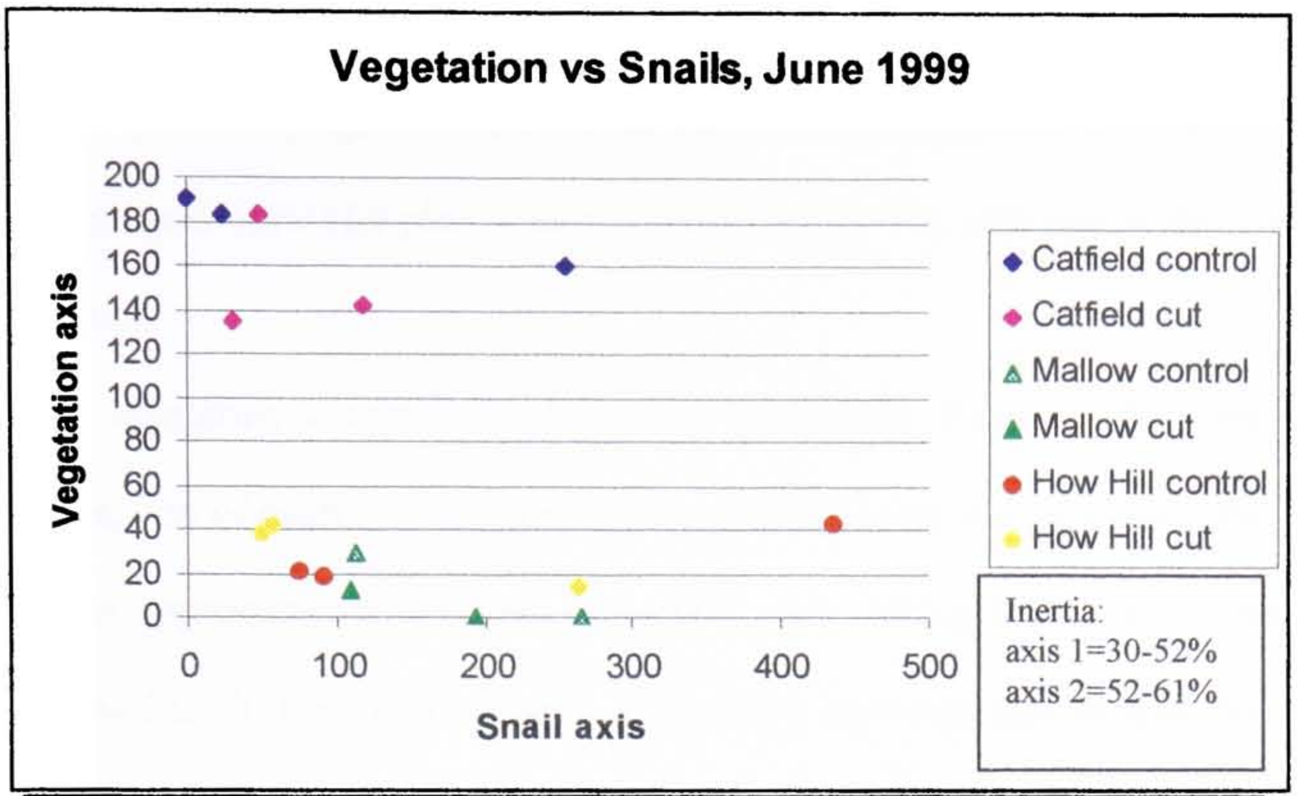


Figure 4.6 Decorana biplot of snail versus vegetation distribution in June 1999, before management.

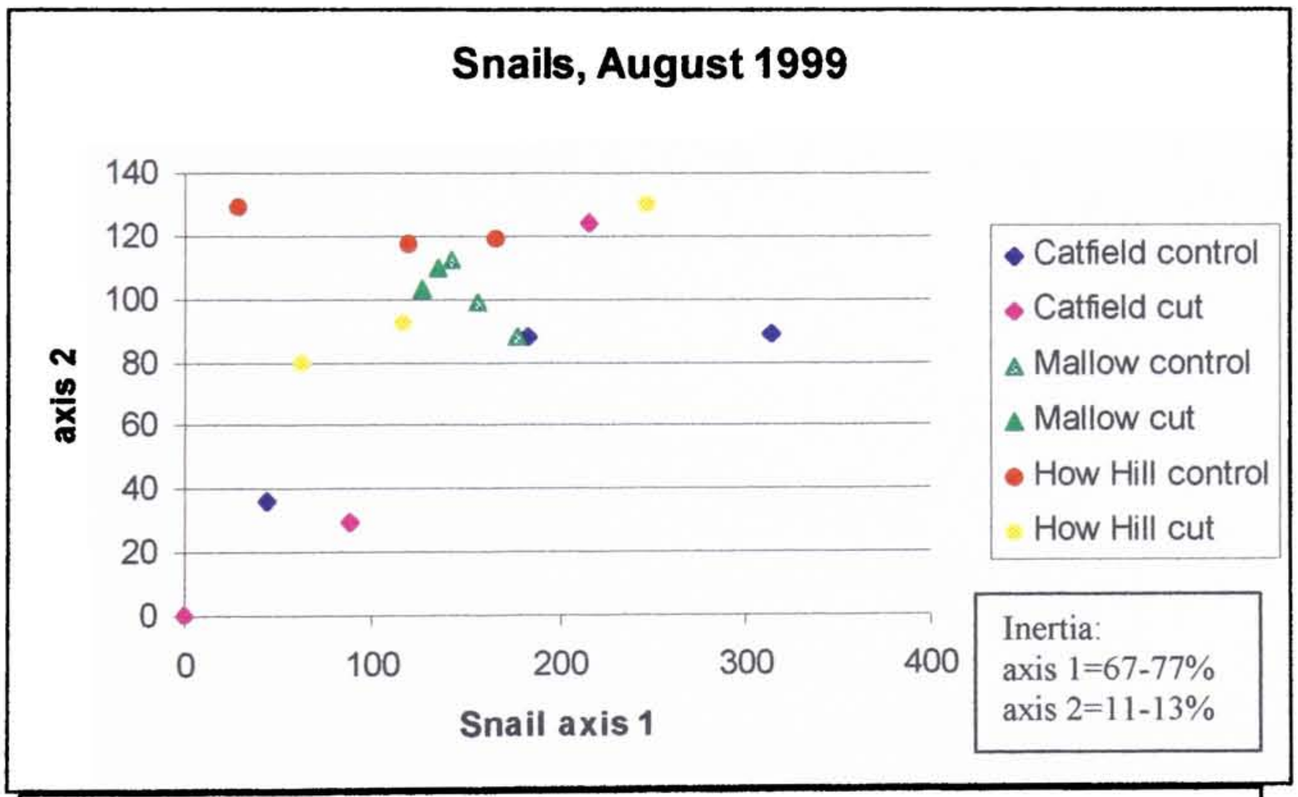


Figure 4.7 Decorana plot of snail distribution in August 1999, after management.

August 1999 snails against vegetation (Figure 4.8), shows Mallow grouping most closely at around (150, 10), and How Hill and Catfield being most spread out along the snail axis. Again Catfield is separated by vegetation, not snails.

The June 2000 snail analysis shows the Mallow Marsh snails group tightly at around (30,130) (Figure 4.9), with the cut plots grouped, and the control plots, less grouped. How Hill plots also group tightly (20, 60), with two of the Catfield cut plots.

The vegetation versus snails biplot for June 2000 (Figure 4.10) gives three groups, one of each site. Mallow Marsh and How Hill are split along the snail axis at approximately 25, with How Hill plots falling below this point and Mallow Marsh plots falling above it. Catfield, however, can be split from the other sites by drawing a line on the vegetation axis at 150. Catfield plots fall above this marker. There is no consistent management trend.

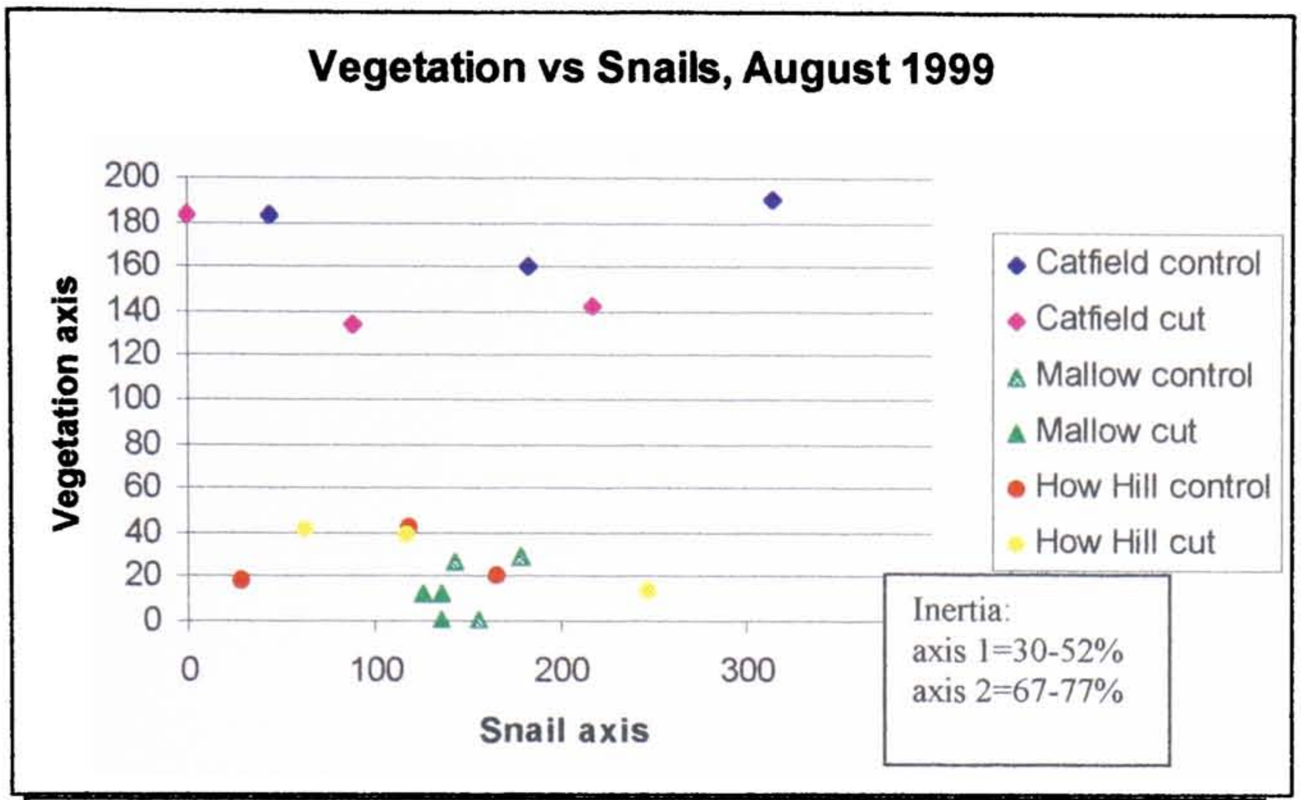


Figure 4.8 Decorana plot of snail versus vegetation distribution in August 1999, after management.

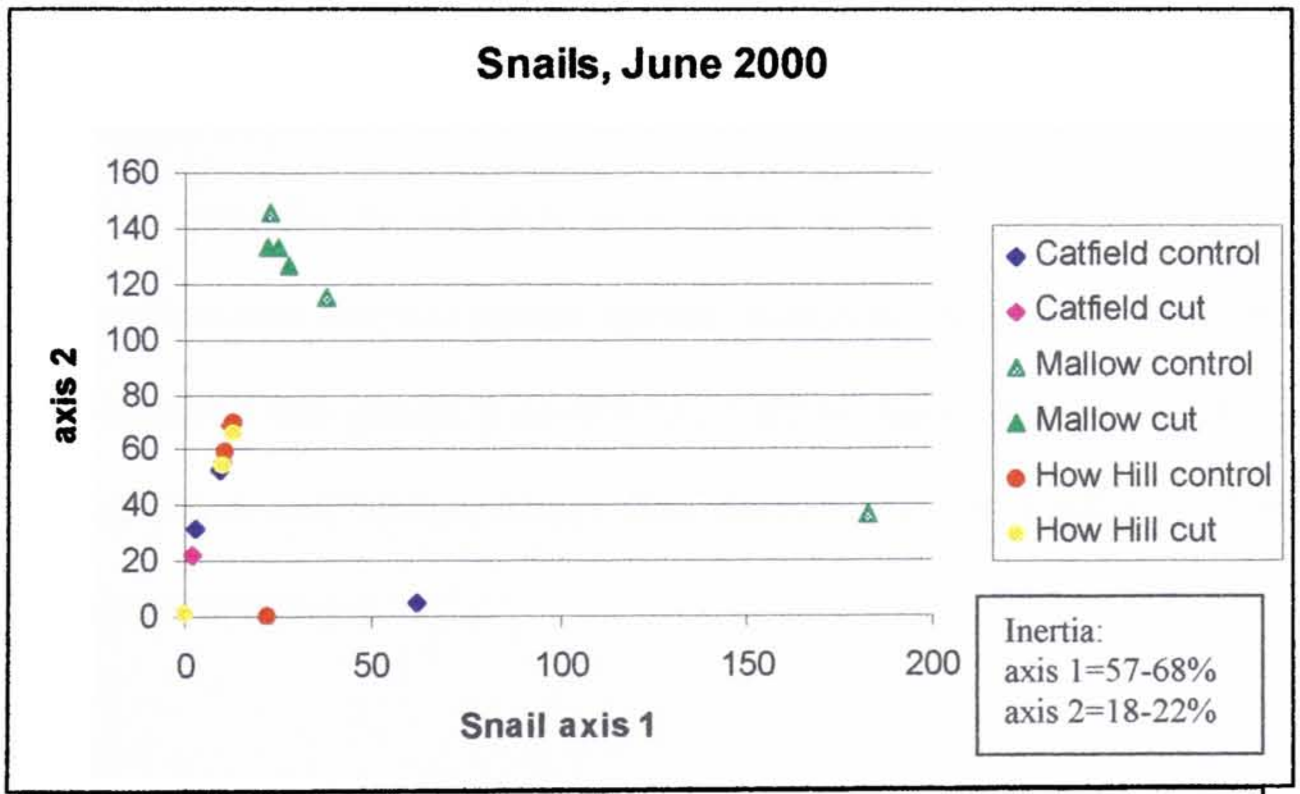


Figure 4.9 Decorana plot of snail distribution in June 2000, after management.

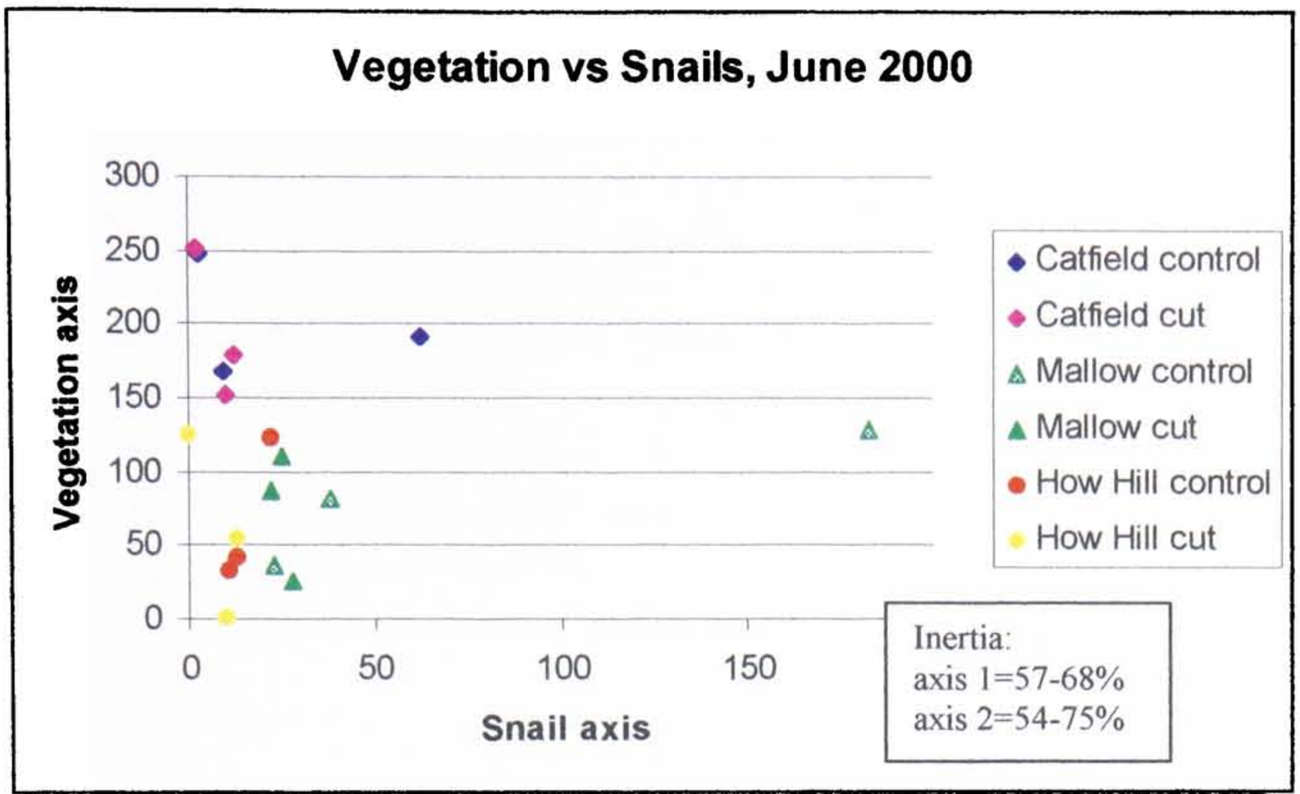


Figure 4.10 Decorana biplot of snail versus vegetation distribution in June 2000, after management.

The August 2000 results (Figure 4.11) showed the Mallow Marsh cut plots grouped together away from the control plots. Similarly two of the How Hill cut plots are at the bottom of axis 2, and even the less well defined Catfield plots showed a trend for the cut plots to be lower on axis 2 than the control plots. Snail multivariate analysis plotted against vegetation (August 2000) showed the sites separated into groups (Figure 4.12). Catfield again falls above 150 on the vegetation axis and Mallow Marsh falls above 100 on the snail axis. How Hill falls below both these markers.

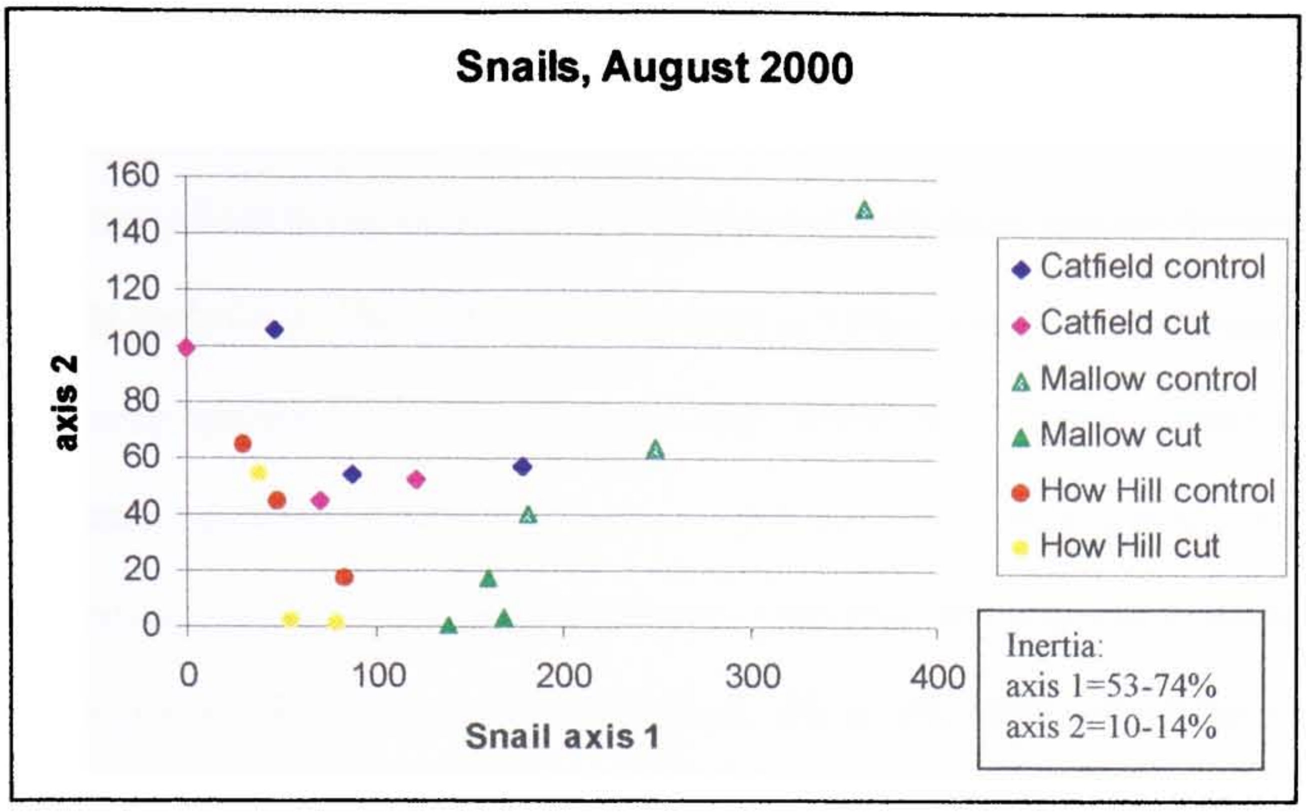


Figure 4.11 Decorana plot of snail distribution in August 2000, after management.

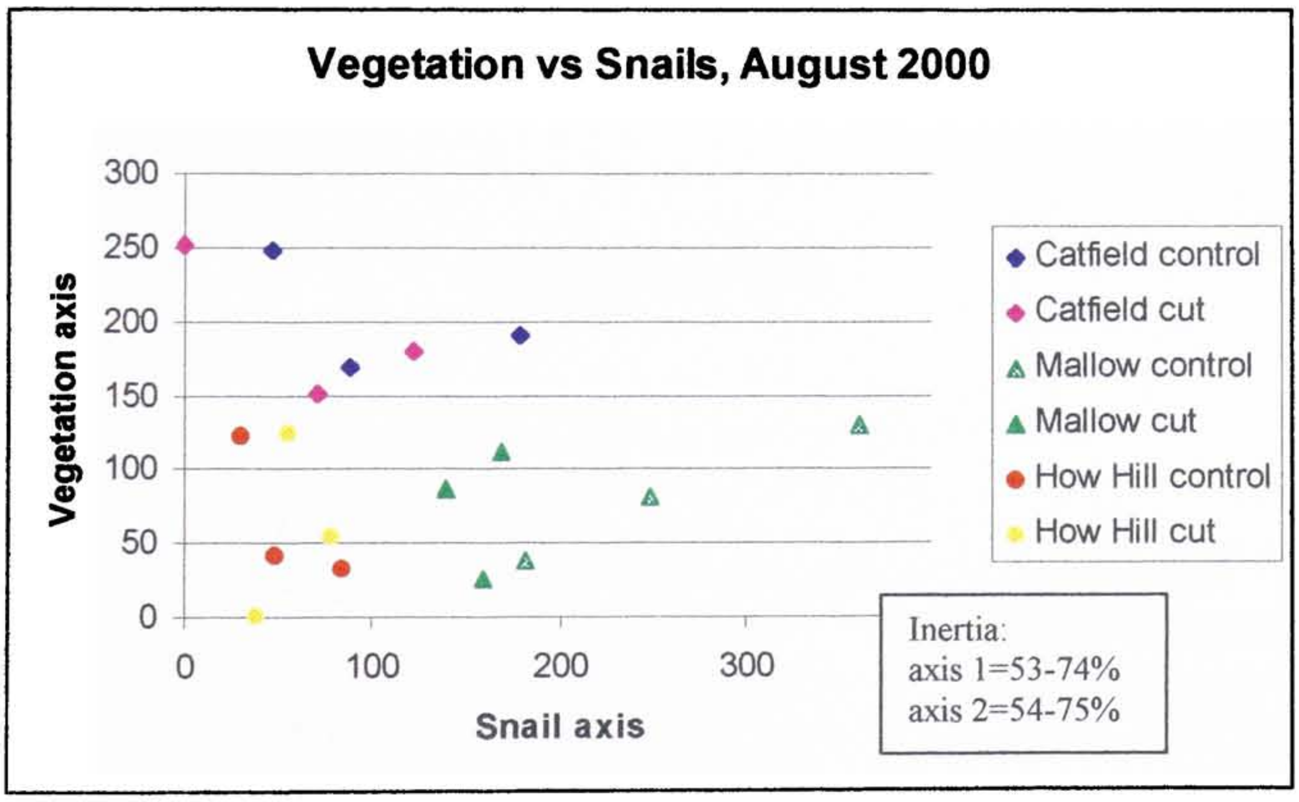


Figure 4.12 Decorana biplot of snail versus vegetation distribution in August 2000, after management.

Looking at the species ordinations of the same samplings gives a similar picture. Initially, pre-management (Figure 4.13), the one control preferring species, *Nesovitrea hammonis*, falls to the extreme end of axis 2. The management preferring species are, however, widely scattered through out the rest of the data points. Post-cutting, August 1999, the snails showing a preference for management plots appear in Figure 4.14, at the lower end of axis 1, separate from the *N. hammonis*, but concurrent with those species showing no overall preference. The following June there is a clear divide. The management preferring species centre around the *y* axis (Figure 4.15) These comprise the Lymnaids *Lymnaea palustris* and *L. peregra*, *Succinea putris*, *Aplexa hypnorum*, *Anisus leucostoma*, *Viviparus viviparus* and *Valvata cristata*. *N. hammonis* which prefers undisturbed plots, fall at the other end of the *x* axis together with several other species, including *Oxychilus alliarius* which showed no overall preference, and *Euconulus alderi* and *Zonitoides nitidus*, which occurred in numbers too small to analyse using Chi^2. Notably, the data points pertaining to all the members of the family Zonitidae that were collected fall together in this analysis.

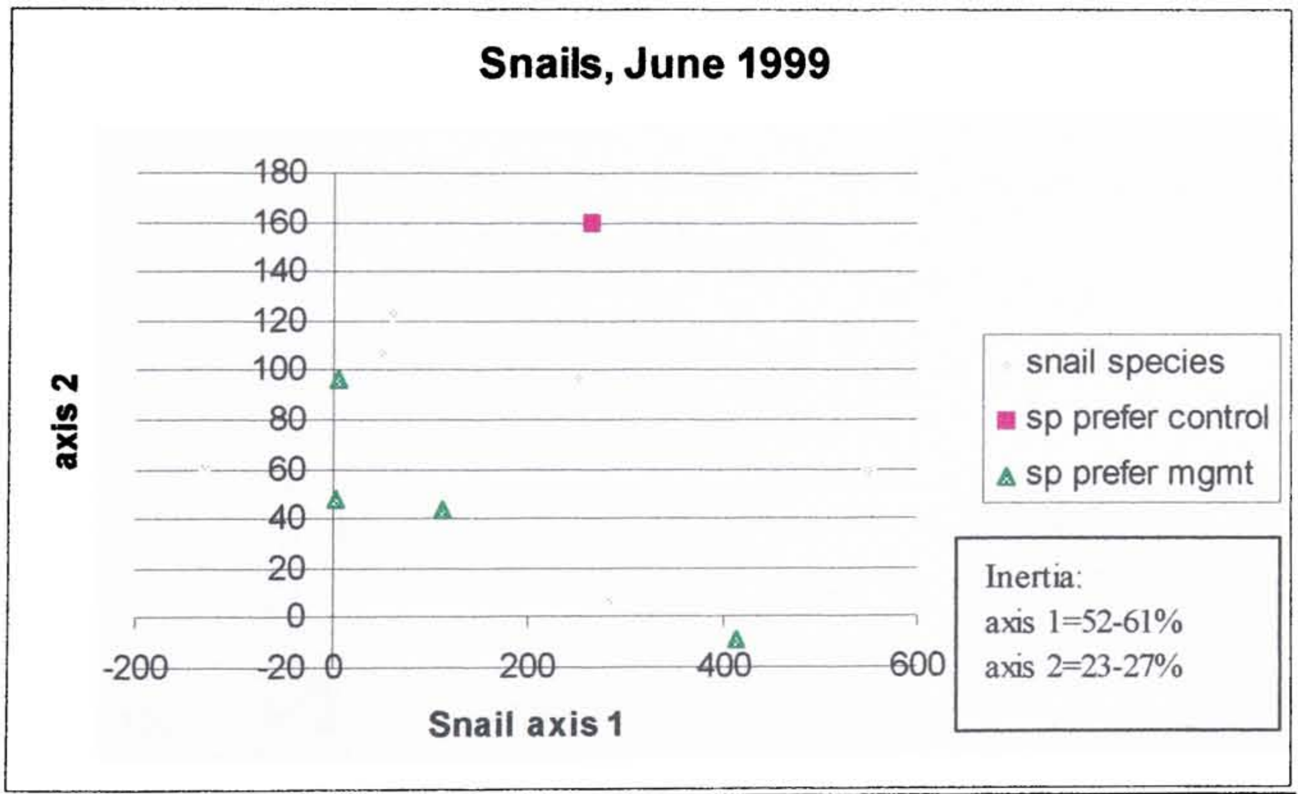


Figure 4.13 Decorana plot showing species ordinations for snails, in June 1999, before management. Species showing a preference for managed or control plots are shown separately.

Groupings are again more difficult to discern by August 2000 (Figure 4.16), but the data point range of the species showing an analysable preference still do not overlap.

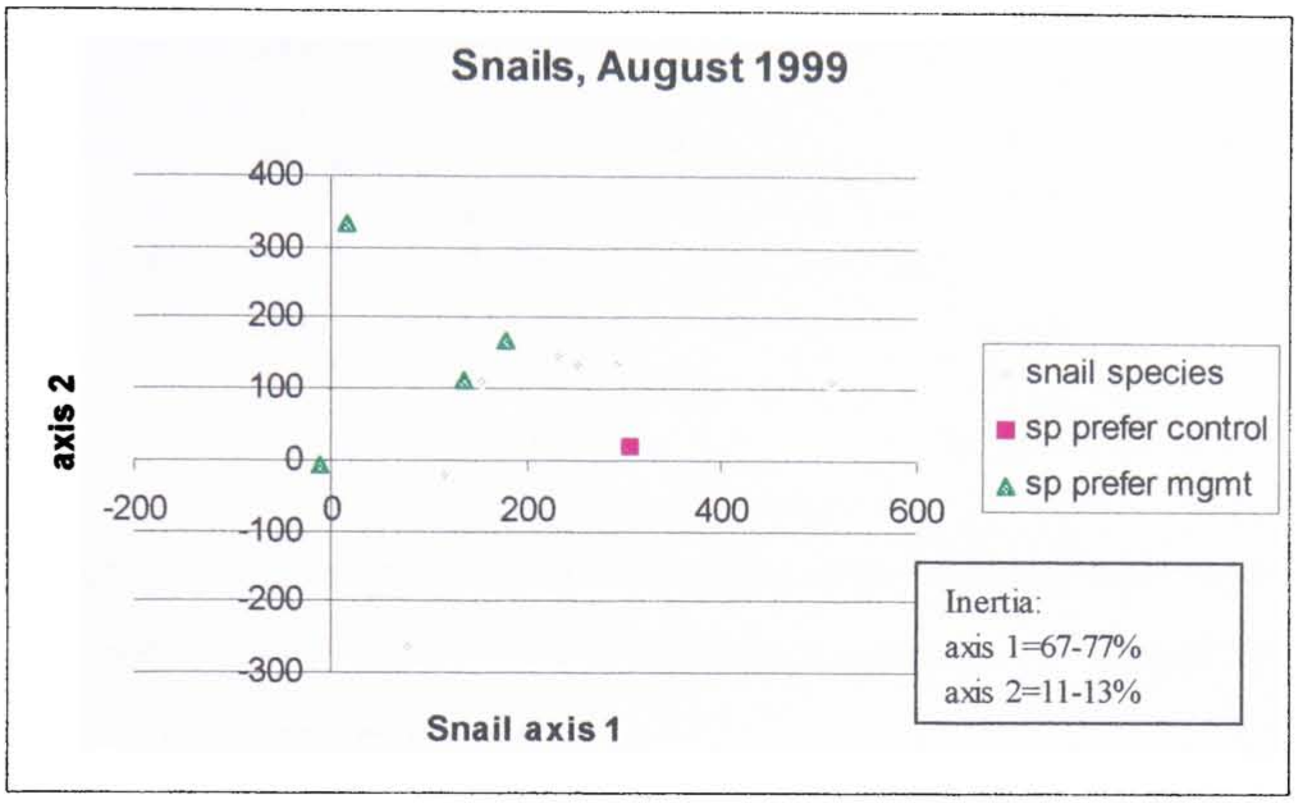


Figure 4.14 Decorana plot showing species ordinations for snails after management in August 1999. Species showing a preference for managed or control plots are shown separately.

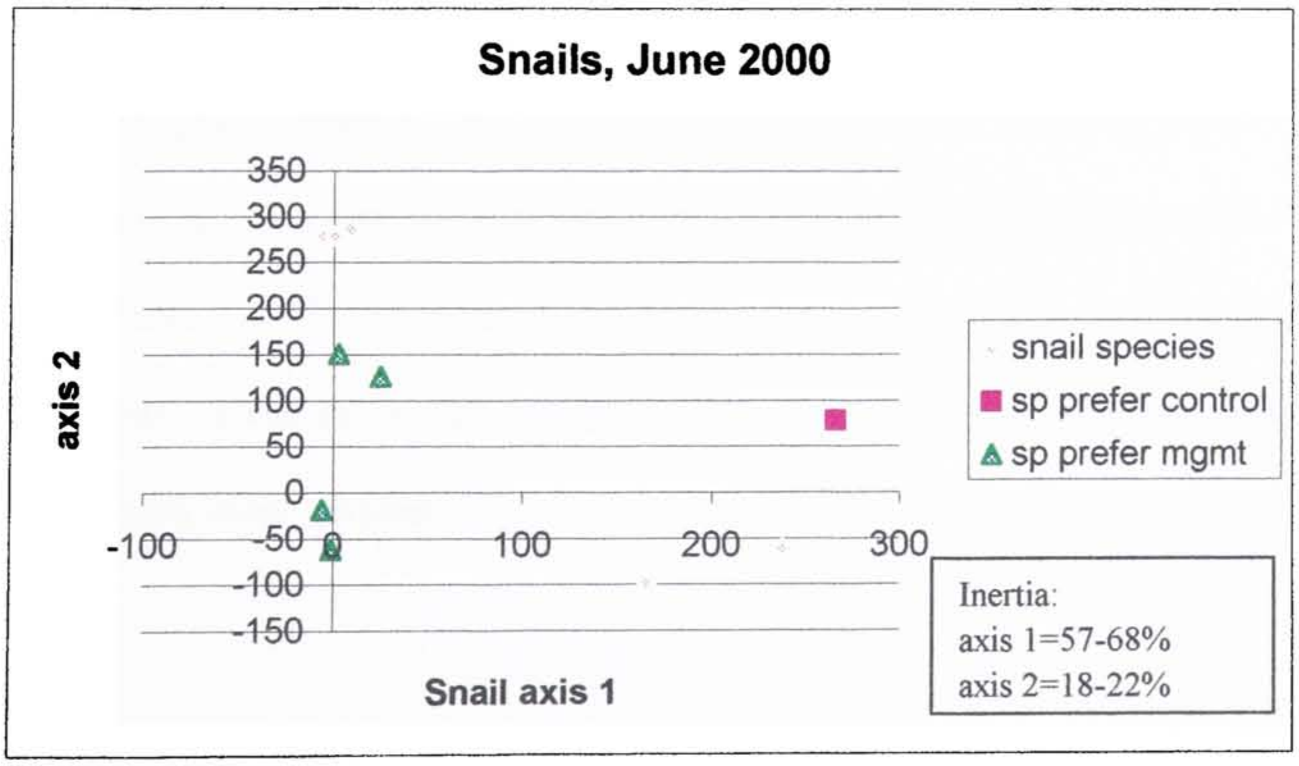


Figure 4.15 Decorana plot showing species ordinations for snails after management in June 2000. Species showing a preference for managed or control plots are shown separately.

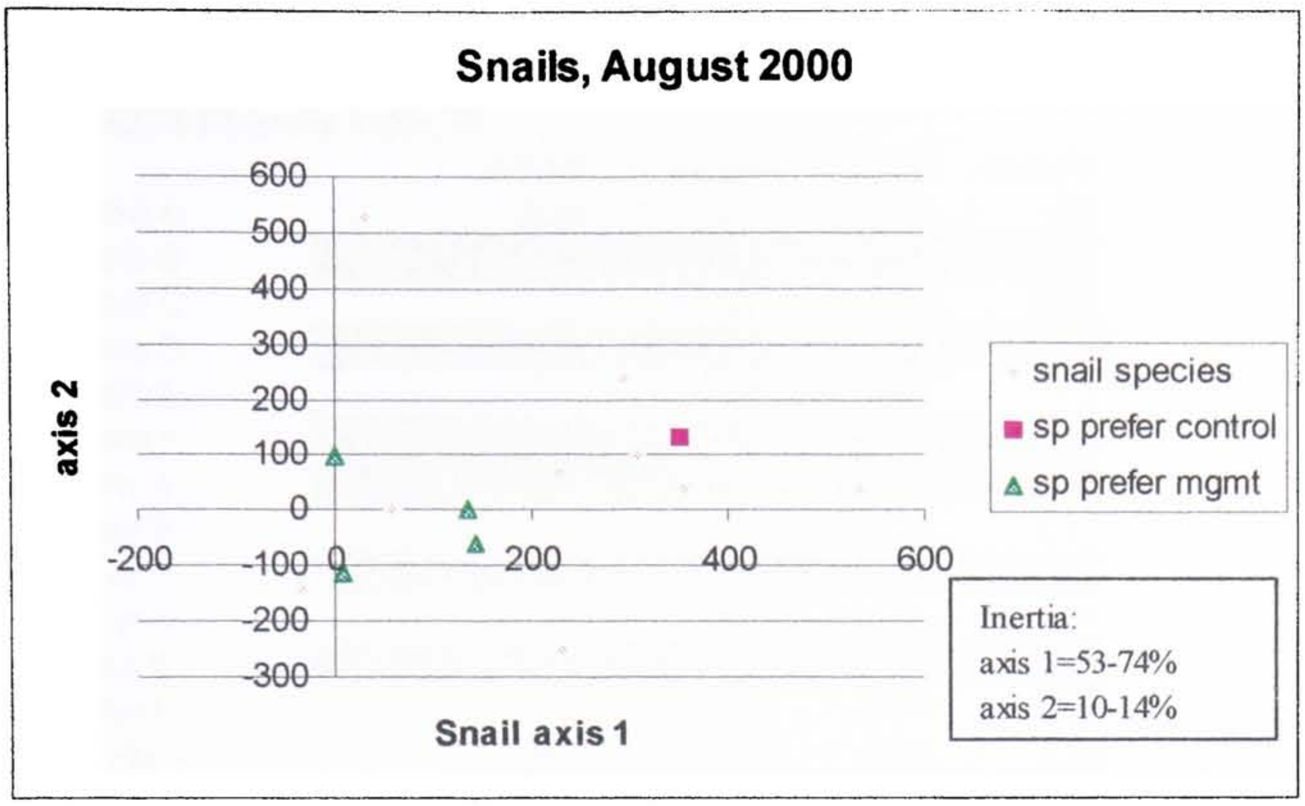
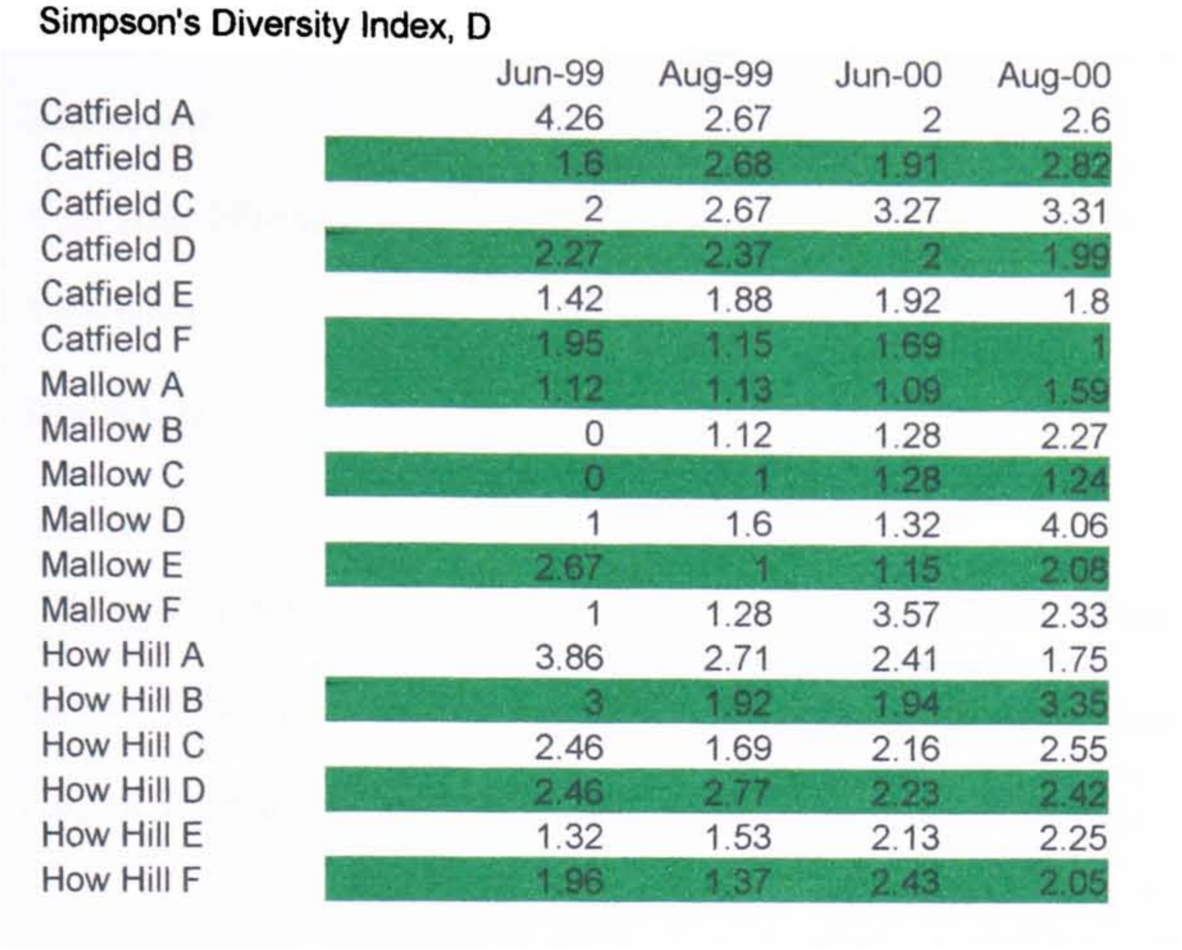


Figure 4.16 Decorana plot showing species ordinations for snails after management in August 2000. Species showing a preference for managed or control plots are shown separately.

How diverse are the plots in terms of snail species composition, taking both number of species and relative abundance into account? How does this change over the sampling time?

The Simpson Diversity Indices for each plot for each sampling time (Table 4.VII) are all very similar, and quite low, with the data ranging between 0 and 4.26 (Table 4.VIII) Fluctuations in the diversity values appear just as likely in the control plots as in the cut plots, and neither control, nor cut plots are consistently more diverse.

Table 4.VII The Simpson Diversity Index, D. Shaded plots were cut in July 1999.



Simpson's Diversity Index, D

	Jun-99	Aug-99	Jun-00	Aug-00
Catfield A	4.26	2.67	2	2.6
Catfield B	1.6	2.68	1.91	2.82
Catfield C	2	2.67	3.27	3.31
Catfield D	2.27	2.37	2	1.99
Catfield E	1.42	1.88	1.92	1.8
Catfield F	1.95	1.15	1.69	1
Mallow A	1.12	1.13	1.09	1.59
Mallow B	0	1.12	1.28	2.27
Mallow C	0	1	1.28	1.24
Mallow D	1	1.6	1.32	4.06
Mallow E	2.67	1	1.15	2.08
Mallow F	1	1.28	3.57	2.33
How Hill A	3.86	2.71	2.41	1.75
How Hill B	3	1.92	1.94	3.35
How Hill C	2.46	1.69	2.16	2.55
How Hill D	2.46	2.77	2.23	2.42
How Hill E	1.32	1.53	2.13	2.25
How Hill F	1.96	1.37	2.43	2.05

Table 4.VIII The range of Simpson Index values for each treatment at each sampling time.

range	June 1999	August 1999	June 2000	August 2000
control	0-4.26	1.12-2.71	1.28-3.57	1.8-4.06
cut	0-3	1-2.77	1.09-2.43	1-3.35

Using a General Linear Model to compare the Simpson Diversity Indices of the cut and control plots between June 1999 and June 2000 and between August 1999 and August 2000 (Table 4.IX) showed a significant difference between diversity in August 1999 and August 2000.

Table 4.IX General Linear Model analysis of the Simpson Diversity Index results for cut and control plots between June 1999 and June 2000 and between August 1999 and August 2000

Effect of :

Year June 1999 to June 2000	F= 0.08	p=0.781	ns
Treatment	F=0.55	p=0.470	ns
Interaction	F=0.64	p=0.435	ns
Year Aug 1999 to Aug 2000	F=6.72	p=0.020	sig*
Treatment	F=1.55	p=0.232	ns
Interaction	F=0.58	p=0.458	ns

Using a Bonferroni correction $p<0.05$ divided by 3 = 0.0167. This invalidates the claim that Simpson's Diversity Index shows a significant change between August 1999 and 2000.

How similar are the plots to each other in terms of species composition? How similar are they to themselves one year on?

The plots are compared June 1999 to June 2000 and August 1999 to August 2000 in Table 4.X. Note the first column compares pre-cut plots with managed plots one year on whereas the second column compares like with like one year on. The results are again very variable. For the June-June results on control plots the similarities range between 0 where no snails were found, 20 where snails were found to 66.67. Where the plots had been cut in July 1999 the data ranged between 0 (where snails were found) and 100.

Comparing like with like over a year between August 1999 and August 2000 the control plots varied between 20 and 75 whereas the cut plots varied between 14.29 and 60.

Table 4.X The Jaccard Similarity Index values for each plot, comparing June 1999 with June 2000 and August 1999 with August 2000. Shaded plots were cut in July 1999.

Jaccard Similarity Index, I

		Jun 99-00	Aug 99-00
Catfield A		50	20
Catfield B	🟩	100	60
Catfield C		40	28.57
Catfield D	🟩	100	25
Catfield E		66.67	50
Catfield F	🟩	100	33.33
Mallow A	🟩	50	25
Mallow B		0	50
Mallow C	🟩	0	33.33
Mallow D		33.33	33.33
Mallow E	🟩	33.33	14.29
Mallow F		25	25
How Hill A		50	75
How Hill B	🟩	0	16.67
How Hill C		66.67	25
How Hill D	🟩	75	60
How Hill E		20	75
How Hill F	🟩	50	16.67

A Mann Witney U Test to compare the Jaccard results from cut and control plots for the June to June and August to August results gave no significant results (Table 4.XI).

Table 4.XI The Jaccard Similarity Index results analysed over each year, using a Mann Witney U test.

June-June: W=73.5 p=0.310 ns

Aug-Aug: W=99.0 p=0.251 ns

The change in similarity in species composition between plots was analysed using the Jaccard Similarity Index. The full results for each plot at each site at each sampling time are shown in Appendix 4.1. The Jaccard Similarity Index showed a rise in similarity between cut and control plots over the four sampling times for How Hill and Catfield Fen, but a drop, followed by a return to pre-management levels for Mallow Marsh (Figure 4.17). The between site similarity for the control plots only showed Catfield becoming more similar to How Hill and Mallow Marsh following management, followed by a drop in similarity. How Hill and Mallow Marsh become slightly more similar over the first three sampling times, followed by a decline (Figure 4.18).

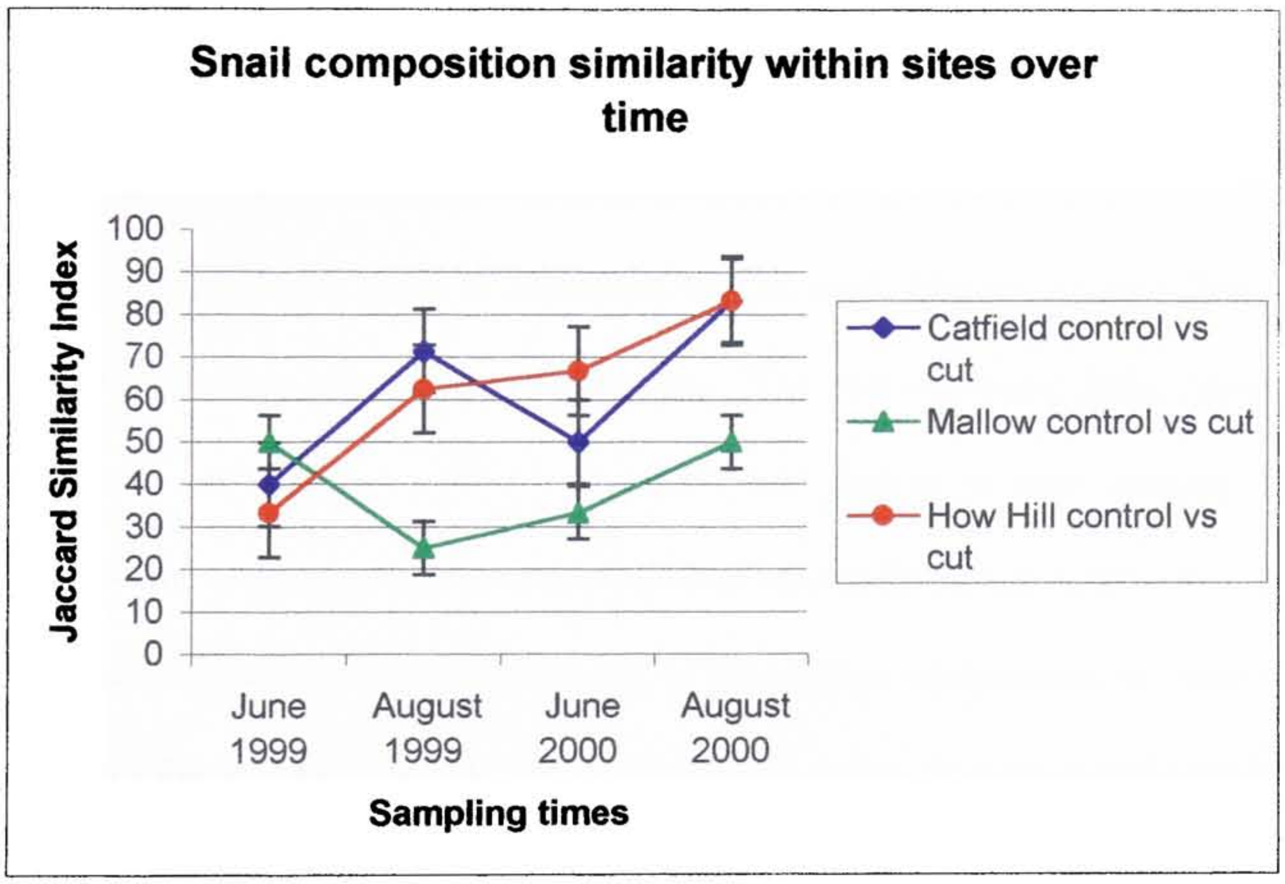


Figure 4.17 The change in the Jaccard Similarity Index within each site, over the four sampling times. Standard error bars are shown.

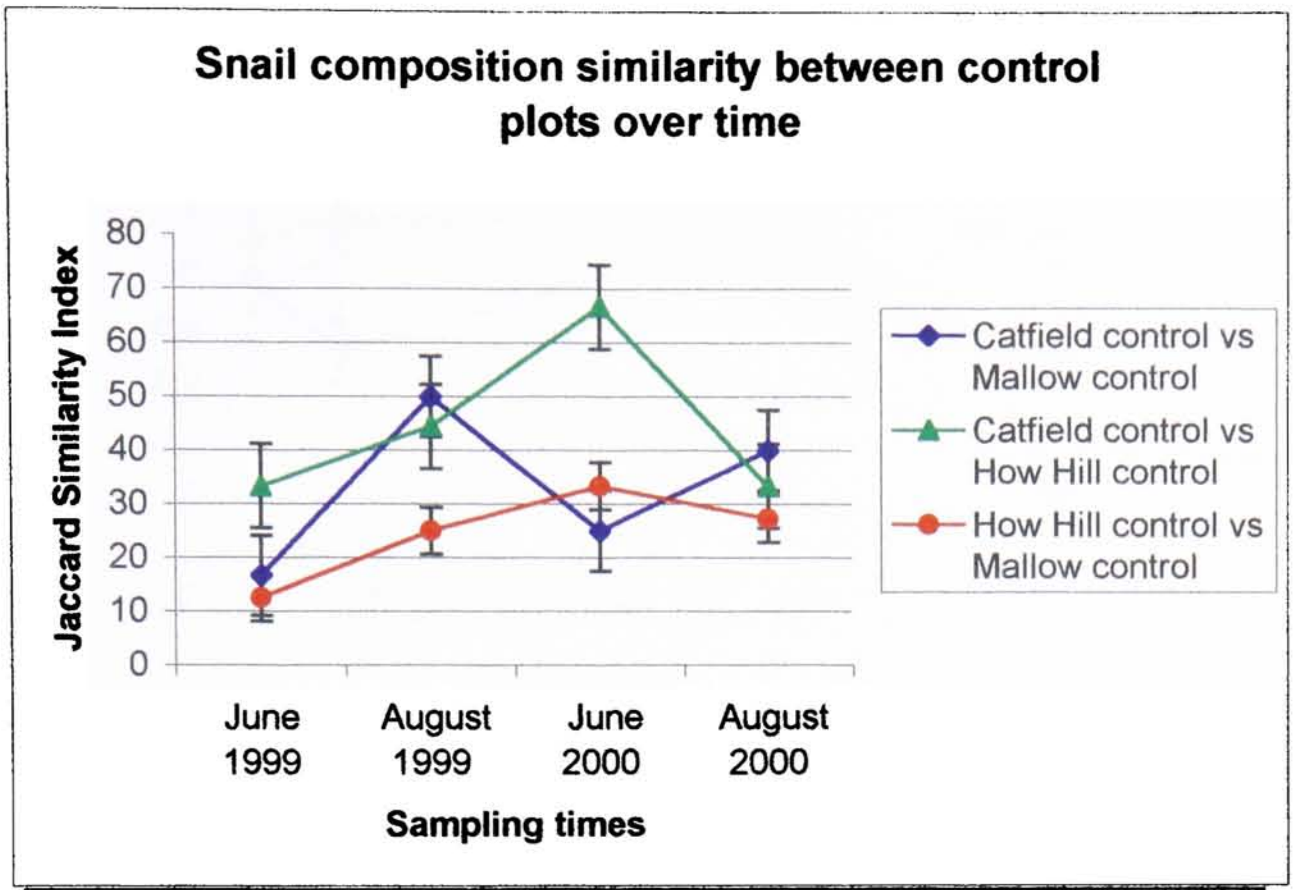


Figure 4.19 The change in the Jaccard Similarity Index between each site's control plots, over the four sampling times. Standard error bars are shown.

The Morisita-Horn Index of similarity can be used, like the Jaccard Similarity Index to compare sites in a binary manner. The Morisita-Horn Index, however, takes into account the numbers of individuals present in each species, rather than just the presence/absence data that the Jaccard Similarity Index uses. Table 4.XII shows the Morisita-Horn Index of Similarity comparison of sites at all four samplings. These results are not the same as the Jaccard Similarity Index, but the conclusions are.

Table 4.XII Morisita-Horn Index of similarity; comparison of sites.

site	vs site - snails	Jun-99	Aug-99	Jun-00	Aug-00
cat control	cat cut	0.777	0.519	0.958	0.494
mallow control	mallow cut	0.904	0.99	0.945	0.594
how control	how cut	0.58	0.956	0.996	0.63
cat control	mallow control	0.286	0.348	0.577	0.577
cat control	how control	0.621	0.459	0.97	0.592
mallow control	how control	0.453	0.891	0.721	0.505

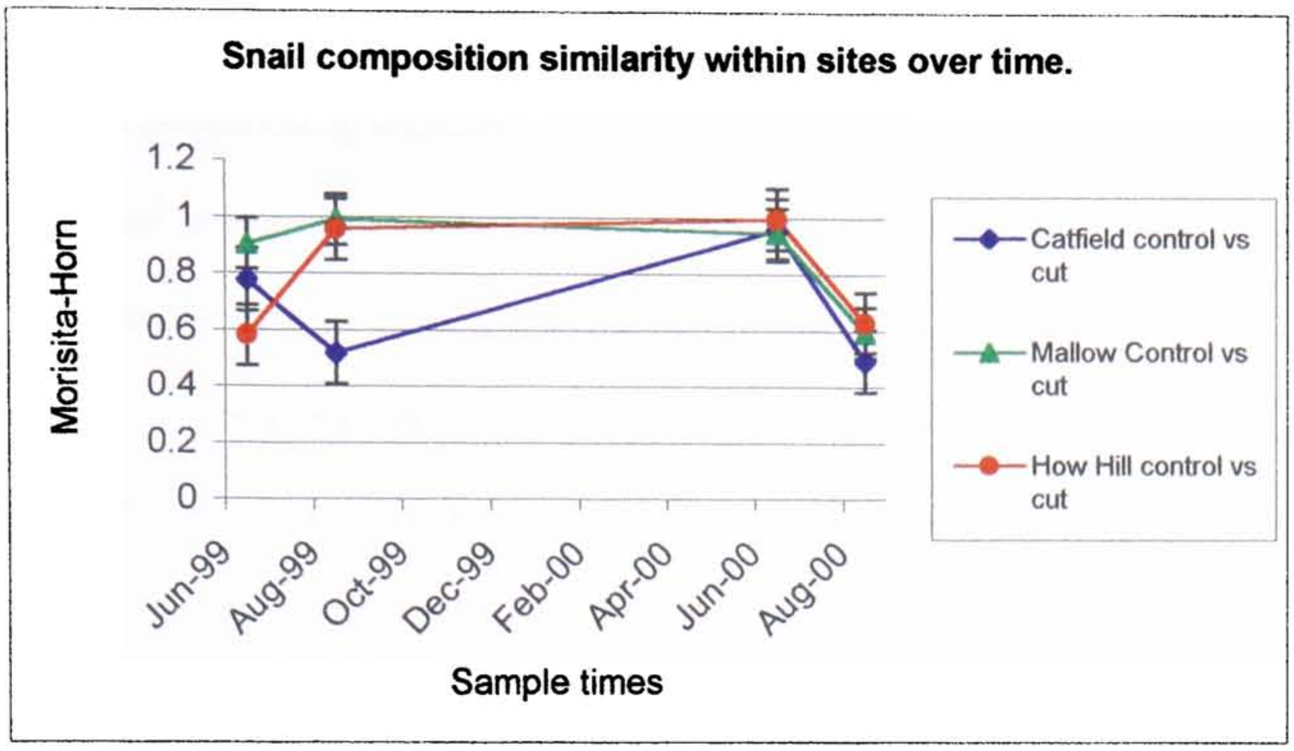


Figure 4.19 Snail composition similarity changes between the control and cut plots, over the sampling period, using the Morisita-Horn Index. Standard error bars are shown.

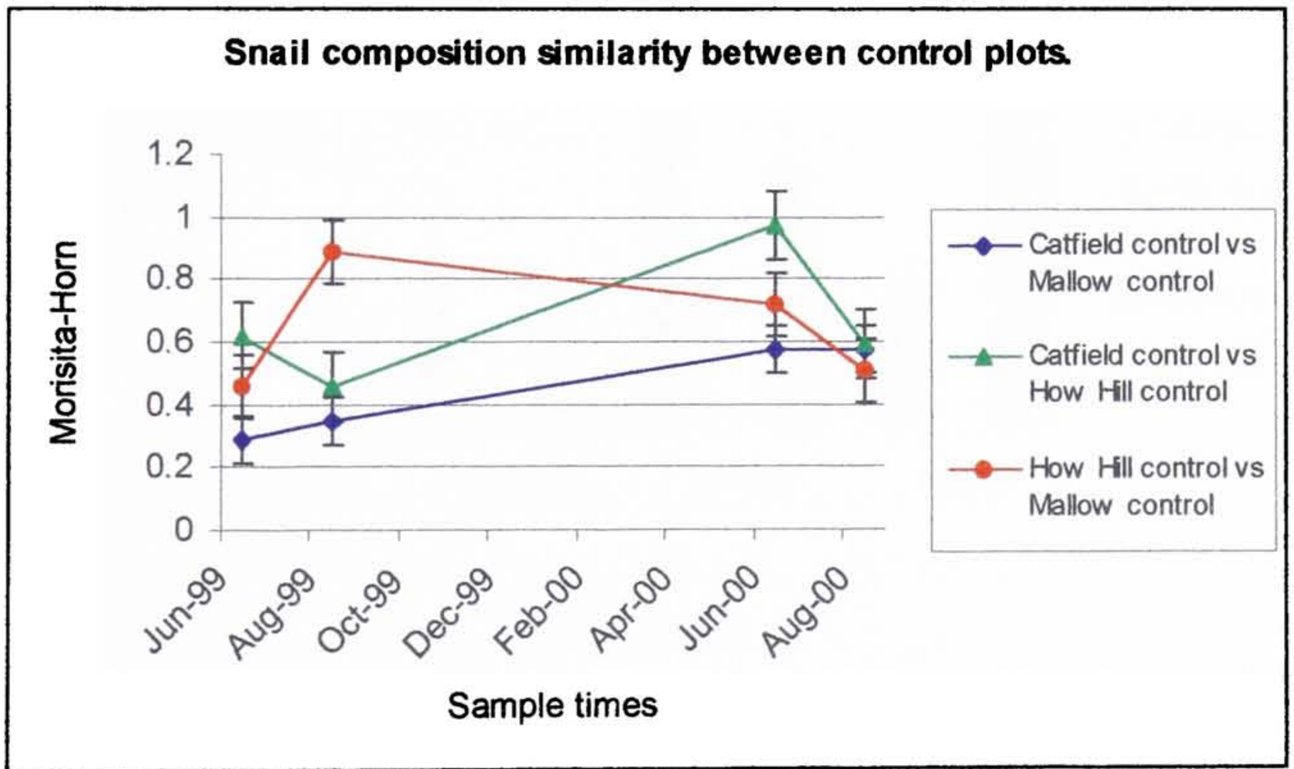


Figure 4.20 Snail composition similarity changes in the control plots, over the sampling period, using the Morisita-Horn Index. Standard error bars are shown.

Figures 4.19 and 4.20 show that the within site similarity is greater than the between site similarity, despite management. This correlates with the Jaccard Similarity Index.

What are the responses of individual species to management?

These graphs bring together the results of the Chi^2 analysis and show that for individual species the effect of cutting is not uniform. All the species that had large enough sample sizes to analyse have been plotted. Figure 4.21 show how *Anisus leucostoma* responds to management. Note that this snail is virtually absent from Mallow Marsh. One year after cutting this snail is more numerous on cut plots than on control plots.

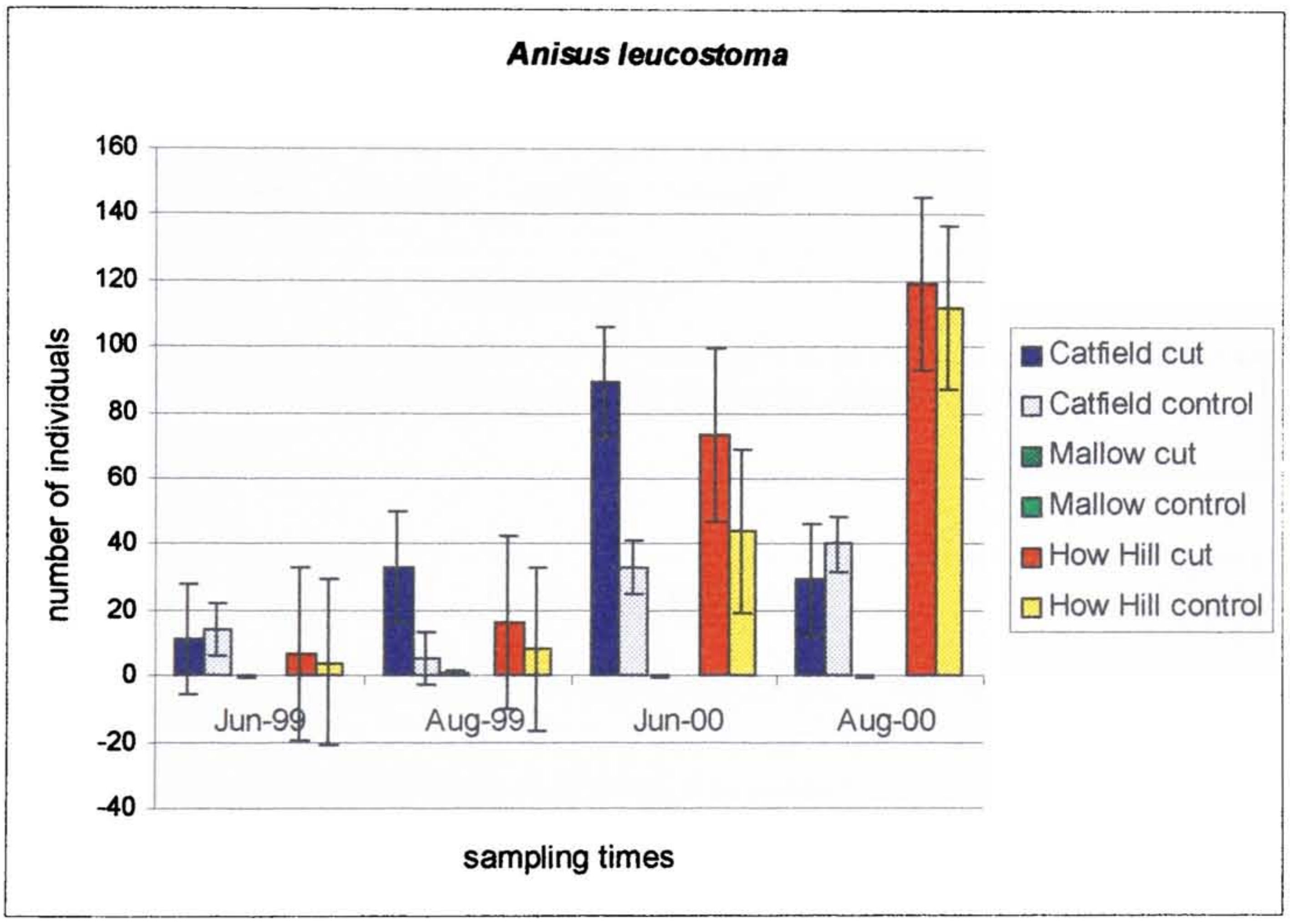


Figure 4.21 Numbers of individuals of *Anisus leucostoma*. Standard error bars are shown.

Similarly for *Aplexa hypnorum*, a snail found only at How Hill. The trend (Figure 4.22) is for cut plots to have more individuals than control plots. The two *Lymnaea* species *palustris* (Figure 4.23) and *L. peregra* (Figure 4.24) also respond well to cutting, whilst their numbers remain low on control plots. *L. palustris* is the only snail to show a significant effect between management and season. No species show an effect solely due to management, though several are seasonal.

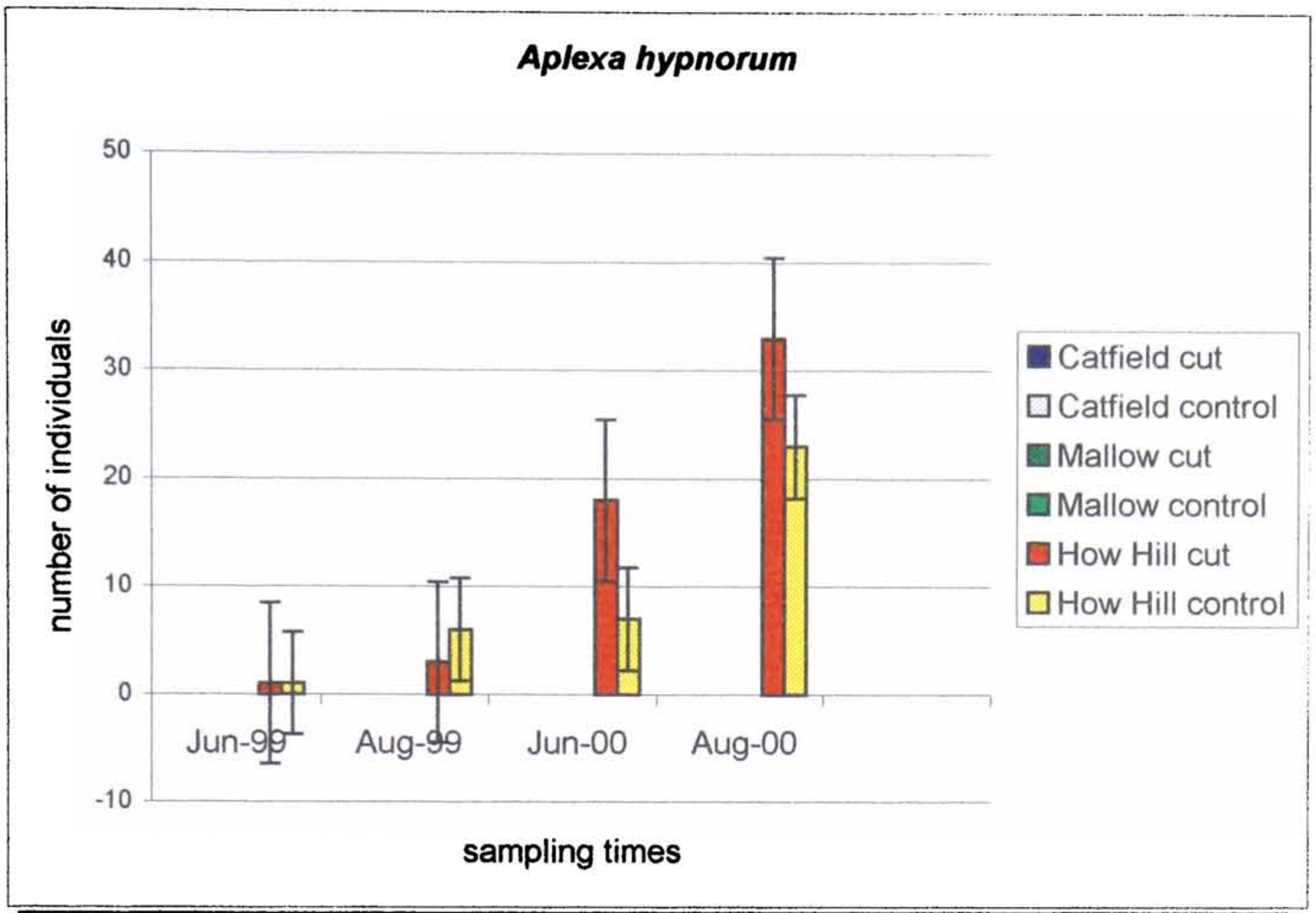


Figure 4.22 Numbers of individuals of *Aplexa hypnorum*. Standard error bars are shown.

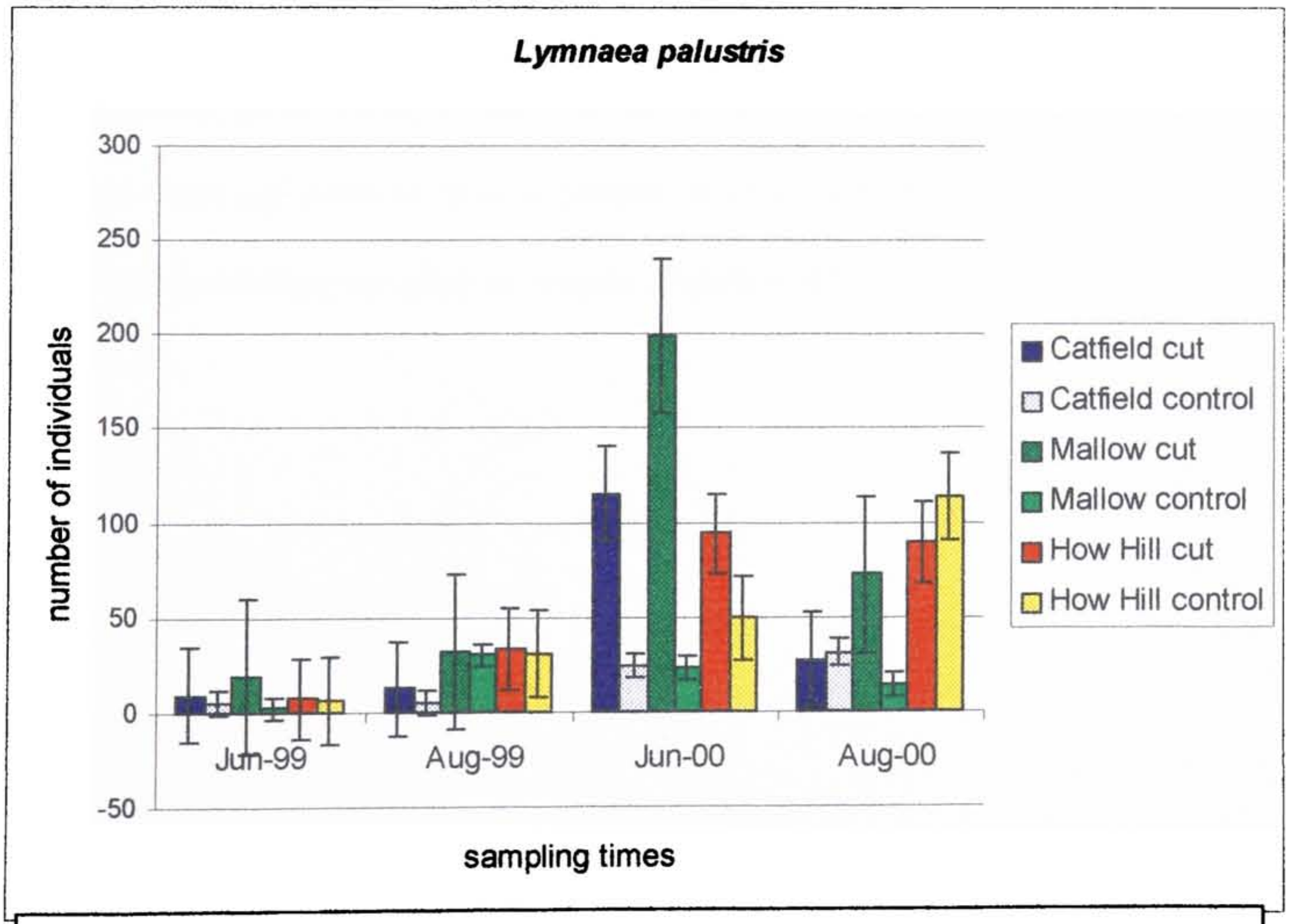


Figure 4.23 Numbers of individuals of *Lymnaea palustris*. Standard error bars are shown.

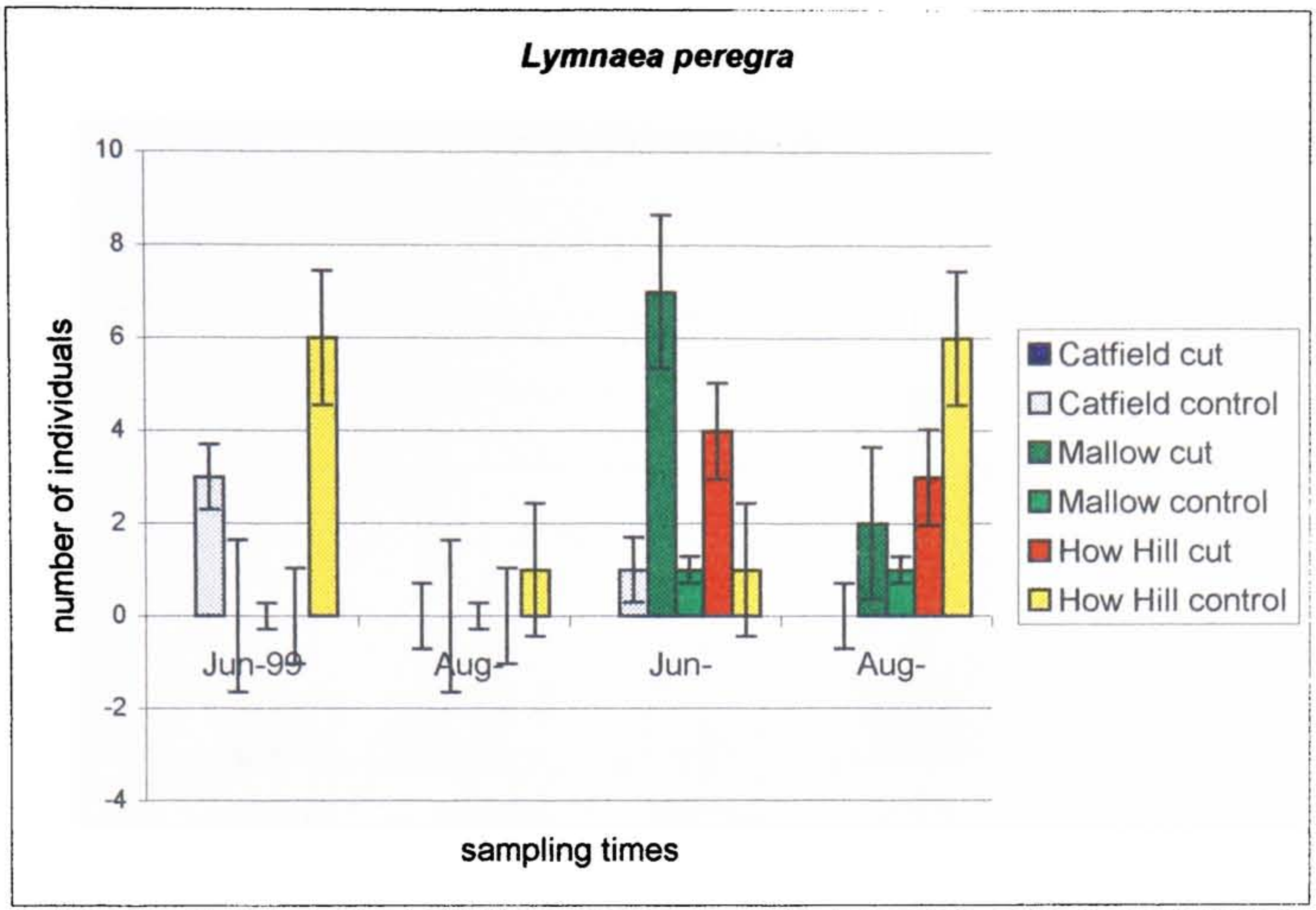


Figure 4.24 Numbers of individuals of *Lymnaea peregra*. Standard error bars are shown.

Nesovitrea hammonis bucks the trend (Figure 4.25) and survives much better on untouched plots, being virtually absent in some cut plots. Lastly *Oxychilus alliarius* does not seem to have a pattern. It does well on the Catfield control plots and the Mallow cut plots in August (Figure 4.26).

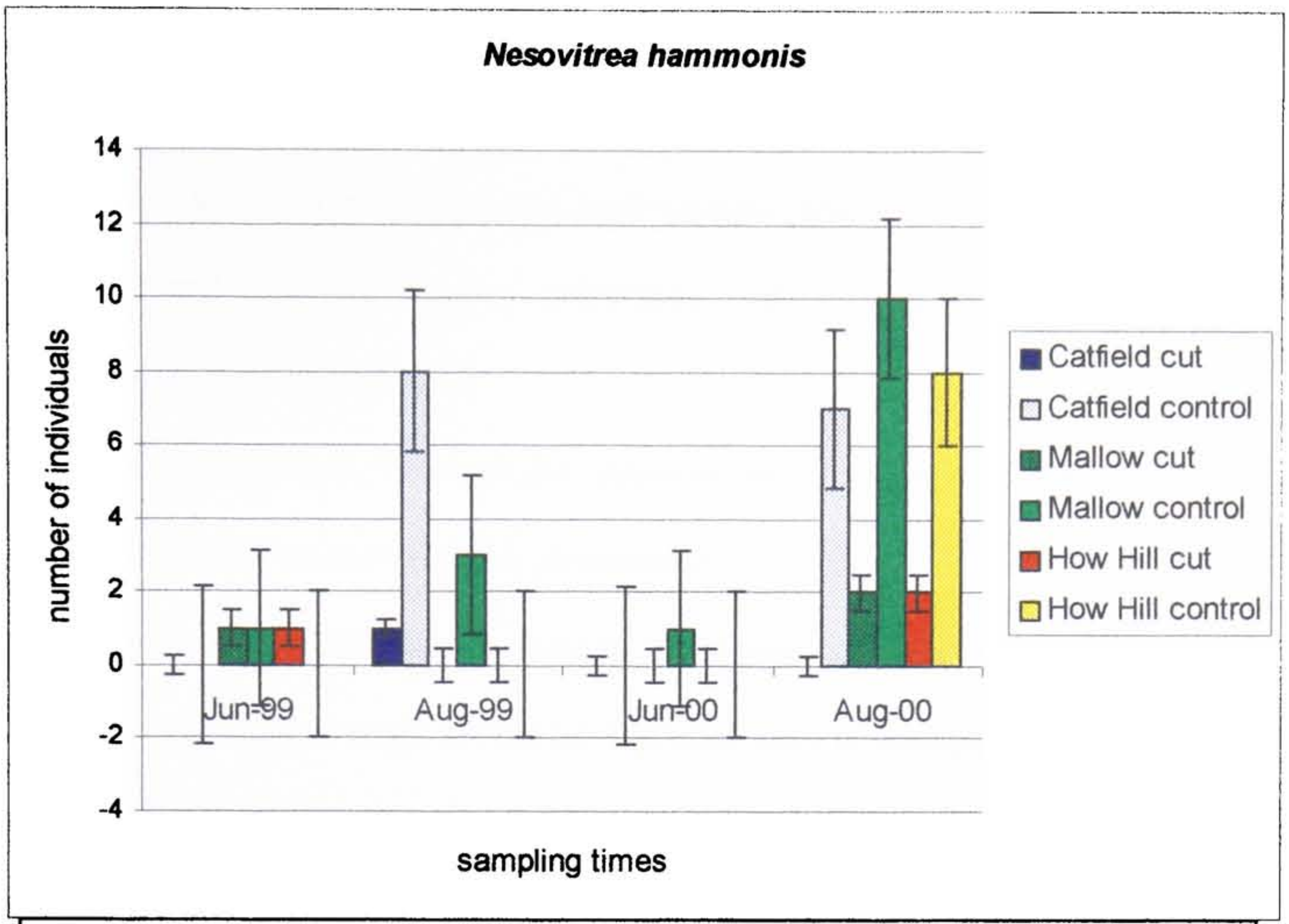


Figure 4.25 Numbers of individuals of *Nesovitrea hammonis*. Standard error bars are shown

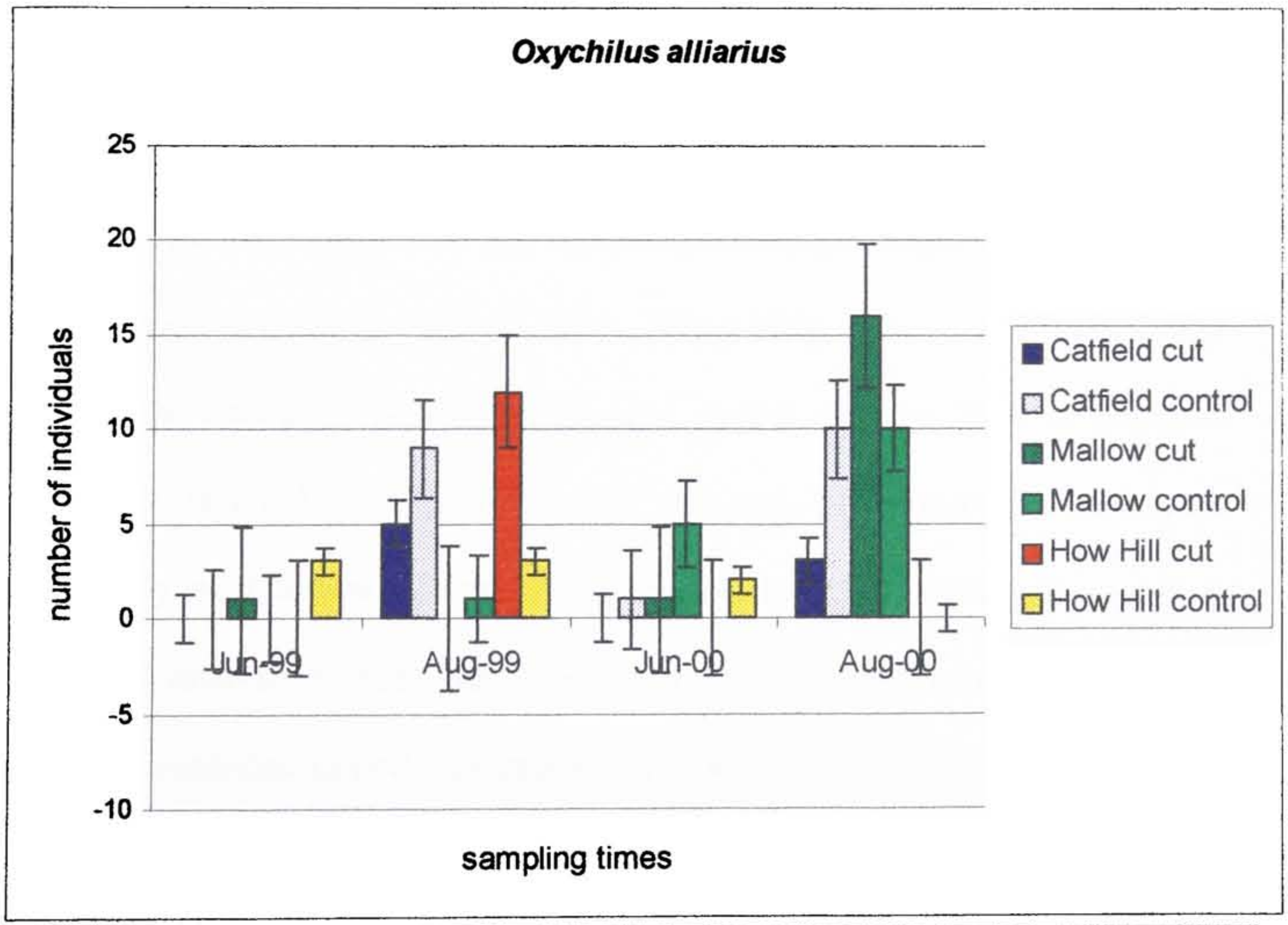


Figure 4.26 Numbers of individuals of *Oxychilus alliarius*. Standard error bars are shown.

4.8 Discussion

The hypothesis was that snails are affected by habitat management, and that from this it could be predicted that snail composition will change in terms of diversity, and that numbers of individuals will decline in the short-term following habitat management.

Is there a difference between the composition of snails at each site, and between the different management treatments?

Chi^2 pre-cutting results should show no significant difference between cut and control plots, which is what should be expected prior to management. However Mallow Marsh shows a highly significant result, which could be due to natural variability of the *Lymnaea palustris* population. Whilst this is not ideal prior to cutting, the result is due to just one plot, and removing the results from this plot leads to insufficient numbers of *L. palustris* for Chi^2 analysis. As this plot does not show any further anomalous results it may be hard to ascertain the cause beyond patchiness in the distribution of the *L. palustris* population. The offending species, *L. palustris,* has significant readings in June 1999 and again, with much greater numbers in June 2000. This is likely to be a 'real' response to management because it is not significant in August 1999 or 2000. *L. palustris* appears to respond very positively to this sort of disturbance and does exceedingly well following fen cutting relative to other gastropods sampled. The GLM analysis singles out *L. palustris* as the only species showing a significant response to both treatment and to an interaction between treatment and season. The other species showing a response in numbers as analysed using

Chi^2, showed no response to management using the more sensitive GLM analysis. Many did however show seasonal fluctuations.

Using Chi^2, the first sampling post-cutting in August 1999, shows a slow initial response to management. Catfield has a significant result in numbers of individuals in cut compared to control plots, and close examination show that this is likely to be mostly due to *Anisus leucostoma*, as *Nesovitrea hammonis* is pushing the results in the opposite direction, being more populous on uncut plots compared to cut plots. *A. leucostoma* appears to react positively to management, although this is not picked up using the GLM analysis, whereas *N. hammonis* does not. This is continued throughout the study, with *A. leucostoma* showing signs of recovery in the final sampling and *N. hammonis* still being strongly biased in favour of control plots.

Brown *et al* (1997) found that some snail taxa which were initially abundant in newly restored wetlands decreased in numbers by the following year. Danell and Sjöberg (1982) looked at the invertebrate succession in a newly formed lake and found that molluscs took six years to colonise. Ditlhogo *et al* (1992) looked at family level relationships and these showed virtually no effect one year following burning, but that there was an initial short lived effect of management. The pooled data for each site treatment in this study is comparable to Ditlhogo *et al*'s study. It shows a significant effect at all three sites one year on and four of the six species measured show an increase in numbers on cut sites. At species level this effect is continued through into the August 2000 sampling for most species. There is only partial return to the original ecosystem state by August 2000, 14 months after cutting.

Indeed the August 2000 results are still significant at Mallow and Catfield, which both show significant differences between cut and control plots, due to numbers of *Nesovitrea hammonis*. How Hill does not, however as the numbers of *Aplexa hypnorum* are high where the *Nesovitrea hammonis* numbers are low, and *vice versa*, thus giving the impression of no change between the cut and control sites when in fact there has been a shift in species composition. Ditlhogo *et al* (1992) would have missed the fine detail shown here with the How Hill results as they did not look at species level changes, but instead pooled the data to family level.

This type of analysis shows how important it is to look at the results in detail, at the species level. Analysis at higher taxonomic levels can miss responses at lower levels. It is clear that not all species respond in the same way to disturbance and consequently blanket statements about 'Mollusca' or 'Gastropoda' can be an inaccurate over-generalisation.

At this level of sampling most species of snail seem to respond positively to disturbance. The exception to this is *Nesovitrea hammonis*, though rarer species may also react negatively and may not show up on this type of analysis (Appendix 4.2). Additionally *Oxychilus alliarius* seemed unaffected by management, neither consistently decreasing, nor increasing in abundance. Uzarski (pers. comm.) and Doshi *et al* (in press) also found an increase in planorbids and lymnaids after disturbance. The GLM analysis supports the findings of a strong positive response by lymnaids to disturbance.

Management decisions based on family level data could be disastrous for certain species, such as *N. hammonis*, which appears to require undisturbed fen. Family level data suggests the fen recovers quickly following disturbance, and that management has little effect, when in fact the equilibrium has been disrupted and species level changes show little sign of recovery in the short term.

What autecology is available sheds little light on the nature of the response to management. Certainly drought and desiccation resistant species appear to cope with management better that damp-dependent species. However *N. hammonis* and *O. alliarius* are found in some moderately dry areas, so this is unlikely to be the sole cause of the differences in response to management. Detailed life history and life-cycle information is not available for the species in this study. Differences in response could be due to differences in breeding times, breeding patterns, numbers of cycles per year, overwintering requirements, microhabitat requirements for either adults or juveniles or food sources. Further study looking at the detailed autecology of fen specialist snails would go some way towards answering these questions, and explaining the response to cutting management.

Looking at the species ordinations of the samples shows little grouping initially, indicating that species do not associate in particular groups of species, or rather, as is more likely to be the case, that all the snail species sampled are part of one assemblage of wetland snails. *Nesovitrea hammonis*, is not found centrally with any of the management preferring species, which could indicate that *N. hammonis* has slightly different micro-habitat requirements apparent in the sites before management. The gross scale management in August 1999, seriously changes both the micro and macro habitat in the short term, and this is most apparent in June 2000. Groups can be discerned comprising management preferring species such as the Lymnaids *Lymnaea palustris* and *L. peregra*. *N.*

hammonis which prefers undisturbed plots, falls together with several other Zonitidae species, including *Oxychilus alliarius* which showed no overall preference, and *Zonitoides nitidus*, which occurred in numbers too small to analyse using Chi^2. Notably, the data points for all the members of the family Zonitidae that were collected fall together in this analysis, indicating that members of the family Zonitidae appear to prefer undisturbed habitat. Further studies would clarify if this is a general or specific trend.

It is clear that the two S4 reedbed sites Mallow Marsh and How Hill are more closely related in terms of vegetation than the third site, the S4/S24 site, Catfield Fen. Also the vegetation at Catfield seems more varied between plots than that at the other two sites put together. This can also be seen in the field, as the first two sites are dense reed whereas Catfield, particularly plots E and F, are mixed with *Juncus* and more open. It would be expected that vegetation differences would be reflected in the snail populations, however snails before management do not reflect the vegetational groups, and the sites all appear to have similar assemblages of snails. Consequently the nine replicates over the three sites can be combined and compared.

Immediately post-cutting, August 1999, the Mallow Marsh snails show very little variation, as shown in the Decorana analysis. How Hill appears to have slightly more and Catfield snails the most. The Mallow Marsh snails appear to have lower variability, probably due to the exceptionally low numbers of individuals found at this site.

Managed plots do not seem more similar to each other than to unmanaged plots at the same site. In other words there is a typical site community, within the overall habitat community, but not a typical management snail community.

This shows a strong historical element to environmental management. It does not seem to be easy to change a habitat or to stop succession. What went before leaves a mark on the habitat and even moderate disturbance is not likely to easily change the snail diversity (Wheater *et al* 2000). Wheater found the same results when he looked at reconstructed quarries compared to reseeded sites.

The Jaccard Similarity Index, Morisita-Horn Index and the Decorana plots all show that in June 2000 the How Hill and Catfield plots have converged in terms of snail composition, but not in terms of vegetation. All three sites are similar at this time, and form one large group, however the sites do occupy different multivariate space and consequently have subtly different assemblages of snails (Mallow and How Hill) and vegetation (Catfield). The management trend one year on is inconsistent and not clearly discernable. The Morisita-Horn Index shows that in June and August 2000 all three sites sported very similar compositions of snails, but that the within site variation was still less than the between site variation.

Despite the Morisita-Horn and Jaccard Indices showing no management trend for August 2000, the results from the Decorana analysis show the Mallow Marsh cut plots grouped together away from the control plots, and there is a similar trend with the other sites, though less obvious. It seems disturbing the fen in this way does have an effect, but in terms of snail composition it is difficult to detect using these similarity indices. The low numbers of individuals collected may have something to do with the inconclusive results, though both indices were chosen for their robustness even at small sample size. Further study may clarify the overall changes to the sites following disturbance.

Looking at family level data, rather than the individual species, the effect of management is further diluted. It seems possible that over a longer study management trends would have a prominent and lasting effect, but during this short study it is difficult to say whether management of this type is irreversibly changing the biodiversity of the fen. It is however clear that changes do take place, but not clear on what scale these changes are in terms of the natural changes that occur seasonally. Seasonal changes appear greater than management changes, and this is shown by the Simpson's Diversity Index.

How diverse are the plots in terms of snail species composition, taking both number of species and relative abundance into account? How does this change over the sampling time?

The lowest diversity is found pre-cutting, where two plots yielded no snails. The highest diversity is also found pre-cutting in a control plot. After management managed plots always exhibit a lower limit to diversity than control plots during the same sampling. Greatest diversity is found in control plots throughout 2000, though in a managed plot in August 1999. The highs and lows exhibit a huge overlap in scores.

This is of course disappointing, as it would be expected that the Simpson Index would pick up the diversity changes shown in the Chi^2 analyses. However a shift in species composition doesn't necessarily change the composite diversity for a plot. This shows a failing in the usefulness of the Simpson Index to pick up changes in diversity, and indeed shows how different species assemblages can give the same biodiversity measure when analysed this way. In other words biodiversity is more complex than the Simpson Index can measure.

How similar are the plots to each other in terms of species composition? How similar are they to themselves one year on?

Like the Simpson Index, the Jaccard Similarity Index, and Morisita-Horn Index attempt to reduce something complex down to a single number. With small sample sizes and low numbers of species this is a tall order, and the Jaccard Index becomes very variable. Indeed comparing cut plots from August 1999 to August 2000 this Index varies over its entire range from 0 to 100. It is hard to draw any meaningful conclusions from such results.

How Hill and Catfield control plots appear similar in terms of species composition, especially in June 2000. Mallow Marsh controls are less similar to either other sites' control plots, or to the cut plots at Mallow Marsh. The Decorana plots of the vegetation show the sites group with How Hill and Mallow Marsh more similar to each other than Catfield. It appears the vegetation and faunal analyses give different results. The habitats are however the same, despite slight vegetational differences, so it would be expected that the snail faunal composition would overlap.

By June 2000 the cut plots at How Hill and Catfield are showing increased similarity with each other. However this is unlikely to be because of management, as the control plots at these sites are also becoming closer, and Mallow Marsh is not joining in the trend. It seems unlikely that it is more than natural random fluctuations in the species composition. Indeed two months later no management trend at all is discernable and within site similarity is still much higher than any between site similarity. This fits in well with the Decorana analysis.

4.9 Conclusions

The hypothesis that Mollusca are management sensitive is only true for some species. Many snail species persist in the environment at a low level, before, during and after management, seemingly unperturbed. Management does however leads to an increase in some snail species. Of the species numerous enough to be analysed, most snail species do well. This goes against the prediction that numbers of individuals would decline following management.

Some species do not increase, however, and it is maybe the rare ones that are more under threat. Snails such as *Euconulus alderi*, *Valvata cristata*, *Vertigo antivertigo* and *Zonitoides nitidus* (Appendix 4.2) are present in such low numbers it is impossible to say what cutting the fen does to their populations. It could be the final straw that precipitates local extinctions. The planorbids such as *Anisus leucostoma* and lymnaids such as *Lymnaea palustris* do do well, but, of the Zonitidae, *Nesovitrea hammonis* appears to prefer unmanaged habitat, whereas *Oxychilus alliarius* doesn't seem unduly affected by management.

The prediction from the hypothesis, that species composition should become more depauperate following management is not found to be valid. Overall biodiversity of the snail assemblage not affected, though the detail of species numbers and abundance change. Managed plots remain most similar to unmanaged plots on the same sites, rather than converging in terms of diversity to be like other managed plots. There is no significant difference between the sites.

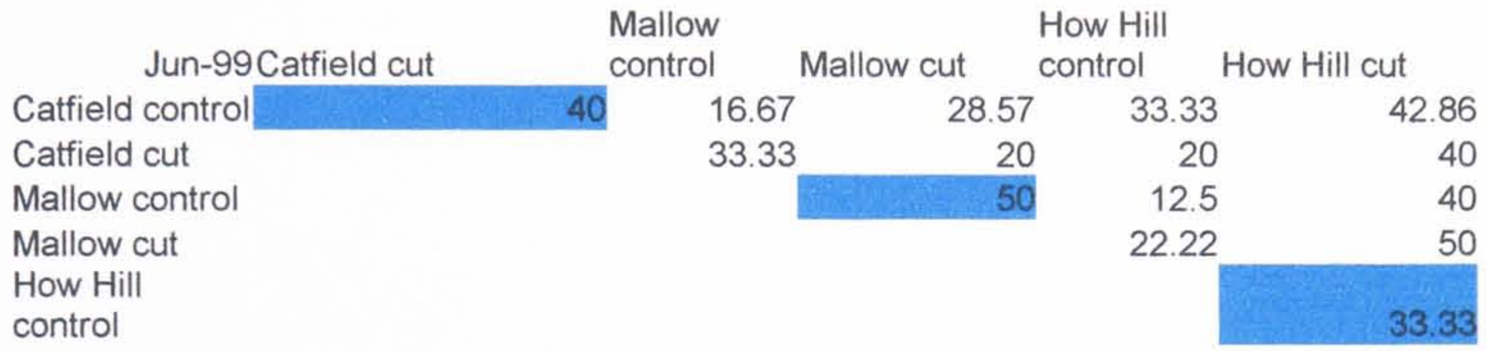
After 14 months there is a little evidence of recovery and the start of a return to pre-management levels for most species. However for *Nesovitrea hammonis* this is not the case, and numbers remain low on managed plots.

Overall the majority of common Mollusca are found to respond positively to management. Species composition and number of individuals does not in general suffer from habitat management in the short-term. Some species e.g. *L. palustris* do very well following management, some do not appear affected and still others appear to decline. The general biodiversity of fen Molluscs is not reduced by cutting fens and reed-beds.

4.10 APPENDIX 4.1

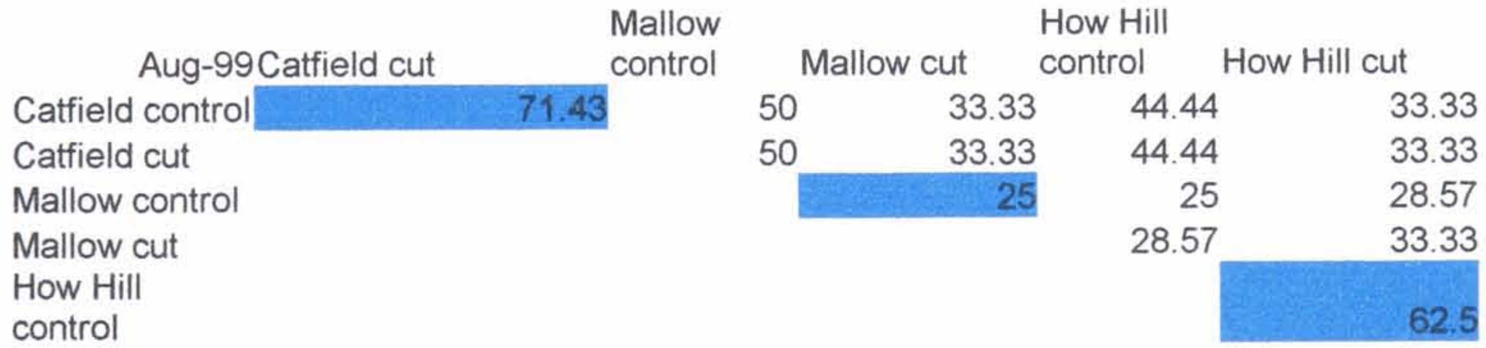
The Jaccard Similarity Index data for each site (accumulated cut and control values) for each sampling time.

Table 4.XIII Jaccard Similarity Index for each site (accumulated cut and control values) for June 1999



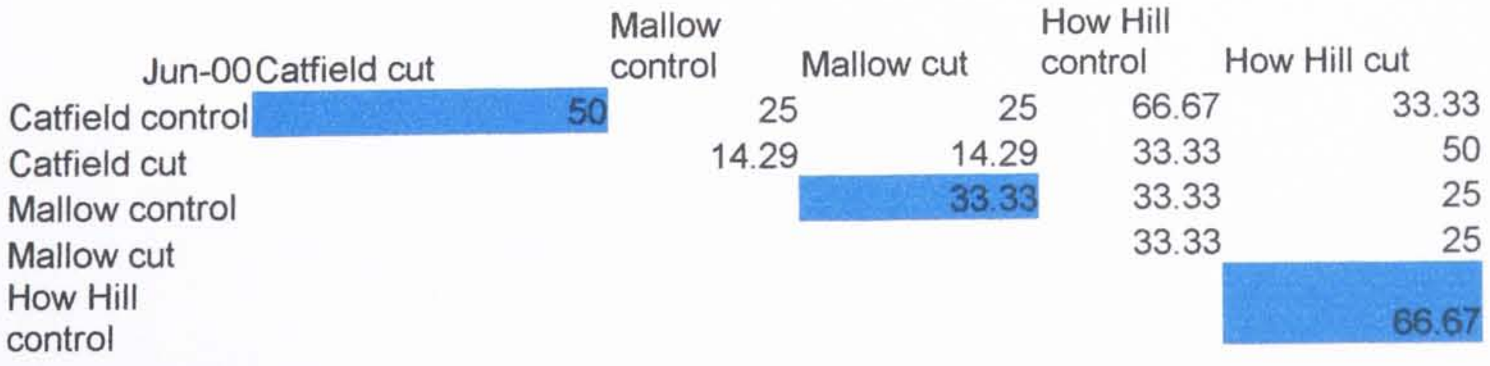
Jun-99	Catfield cut	Mallow control	Mallow cut	How Hill control	How Hill cut
Catfield control	40	16.67	28.57	33.33	42.86
Catfield cut		33.33	20	20	40
Mallow control			50	12.5	40
Mallow cut				22.22	50
How Hill control					33.33

Table 4.XIV Jaccard Similarity Index for each site (accumulated cut and control values) for August 1999.



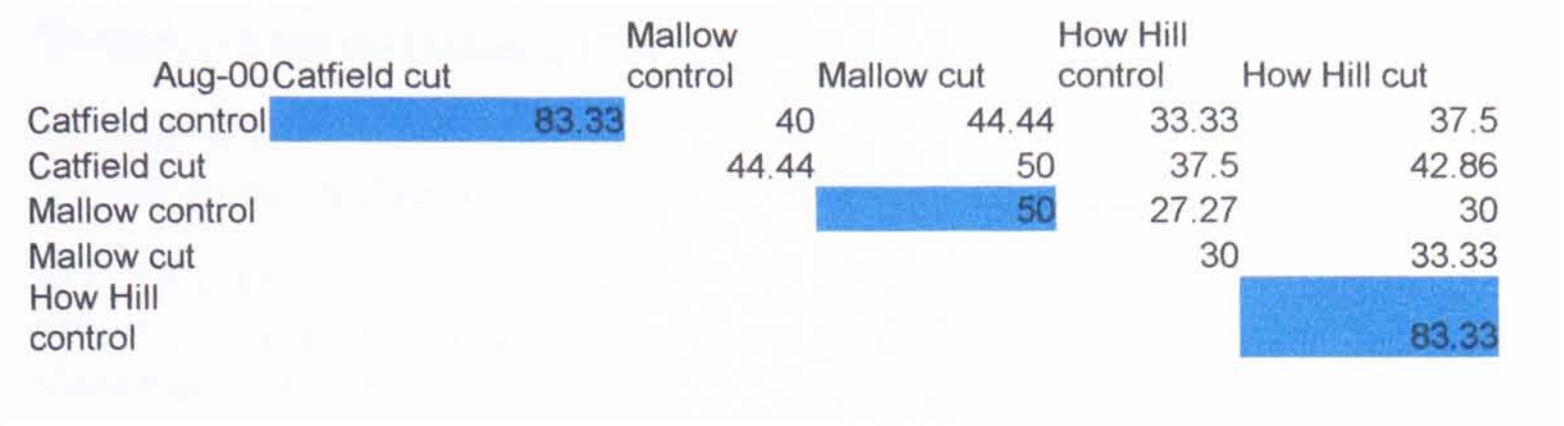
Aug-99	Catfield cut	Mallow control	Mallow cut	How Hill control	How Hill cut
Catfield control	71.43	50	33.33	44.44	33.33
Catfield cut		50	33.33	44.44	33.33
Mallow control			25	25	28.57
Mallow cut				28.57	33.33
How Hill control					62.5

Table 4.XV Jaccard Similarity Index for each site (accumulated cut and control values) for June 2000.



Jun-00	Catfield cut	Mallow control	Mallow cut	How Hill control	How Hill cut
Catfield control	50	25	25	66.67	33.33
Catfield cut		14.29	14.29	33.33	50
Mallow control			33.33	33.33	25
Mallow cut				33.33	25
How Hill control					66.67

Table 4.XVI Jaccard Similarity Index for each site (accumulated cut and control values) for August 2000.



Aug-00	Catfield cut	Mallow control	Mallow cut	How Hill control	How Hill cut
Catfield control	83.33	40	44.44	33.33	37.5
Catfield cut		44.44	50	37.5	42.86
Mallow control			50	27.27	30
Mallow cut				30	33.33
How Hill control					83.33

4.11 APPENDIX 4.2 Mollusc Checklist

Checklist follows Kerney (1999)

VIVIPARIDAE
Viviparus viviparus (Linnaeus, 1758)

VALVATIDAE
Valvata cristata Müller, 1774 Local

ELLOBIIDAE
Carychium minimum Müller, 1774
Carychium tridentatum (Risso, 1826)

PHYSIDAE
Aplexa hypnorum (Linnaeus, 1758)

LYMNAEIDAE
Lymnaea truncatula (Müller, 1774)
Lymnaea palustris (Müller, 1774)
Lymnaea peregra (Müller, 1774)

PLANORBIDAE
Anisus leucostoma (Millet, 1813)

SUCCINEIDAE
Succinea putris (Linnaeus, 1758)

COCHLICOPIDAE
Cochlicopa lubrica (Müller, 1774)

VERTIGINIDAE
Columella edentula (Draparnaud, 1805)
Vertigo antivertigo (Draparnaud, 1801) Local
Vertigo pygmaea (Draparnaud, 1801)

PUNCTIDAE
Punctum pygmaeum (Draparnaud, 1801)

ZONITIDAE
Nesovitrea hammonis (Ström, 1765)
Oxychilus alliarius (Miller, 1822)
Zonitoides nitidus (Müller, 1774) Local

EUCONULIDAE
Euconulus alderi (Gray, 1840) Local

THE SHORT TERM EFFECT OF CUTTING AS A FEN MANAGEMENT PRACTICE ON THE SPIDER (ARANEAE) BIODIVERSITY OF THE NORFOLK BROADS

5.1 Abstract

- The study sought to discover whether summer cutting of reedbeds changed the biodiversity of spiders in managed areas compared to control areas.
- Species level changes were also investigated in order to identify any specific level responses to management.
- Spiders were collected from 18 plots at three similar sites, half of which had been managed by cutting. Spiders were identified to species level.
- Spiders are habitat sensitive.
- Spiders are management sensitive. The number of *Erigone atra, Pirata piscatorius* and *Pirata piraticus* increase after cutting, whereas *Pirata hygrophilus* and *Allomengea vidua* numbers decrease after cutting management.
- *Erigone atra* is the only species to show a response to treatment/season interaction. So species shows a response to treatment alone using the GLM statistic.
- Spiders have a strongly seasonal distribution, with very different communities in June compared to August.
- Diversity did not change significantly with management, yearly variation or an interaction of the two.
- Each plot was as similar to itself in terms of species presence and absence one year on, irrespective of the management or lack of it received.

5.2 Introduction

Spiders are a useful tool in diversity studies. They are sensitive to environmental change and have been used in a variety of habitats and situations. Their response to disturbance has been well documented (Abensperg-Traun *et al* 1996, Downie *et al* 1999, Menéndez 2000, York 1999), as have the effects of grazing on many types of invertebrate (Batzer and Wissinger 1996, Fock and Reinke 1994, Gibson *et al* 1992, McFerran *et al* 1994, Meyer *et al* 1995, Mishra and Rawat 1998) though with mixed results. Fock and Reinke (1994) found more spiders in ungrazed fields, whereas Mishra and Rawat (1998) suggest that grazing enhances biodiversity rather than degrades it, and Zulka *et al* (1997) found slightly higher species numbers on grazed rather than ungrazed plots. Gibson *et al* (1992) found reduced spider species richness and density in more heavily grazed plots but found that light grazing had little effect whereas Meyer *et al* (1995) found results which led them to suggest a policy of zero grazing management to prevent the loss of grazing-sensitive species. Thomas and Jepson (1997) added weight to these findings when their studies showed heavy grazing led to the local extinction of many linyphiid species.

Different grazers have seemingly different effects (Abensperg-Traun *et al* 1996, Norris *et al* 1997) and these are often different again from the effects of burning (Aitchison-Benell 1994, Chambers and Samways 1998, Ditlhogo *et al* 1992, Johnson 1996, York 1999) or cutting. The effect of cutting on invertebrates has been studied in many environments (Chambers and Samways 1998, Downie *et al* 1999, Morris and Rispin 1988, Thomas and Jepson 1997), though rarely in wetlands - see de Szalay *et al* (1996) for their description of cutting and dredging in an aquatic environment, Andrews and Ward (1991) on fen management, and Wettstein and Schmid's (1999) study on grasshopper and butterfly responses to mowing and grazing in wetlands. Gathmann *et al* (1994) noted that cutting increased plant species richness in early set aside fields. This led to a doubling of the bee species richness, but not in the same year that the fields were mown. Mackenzie and Averill (1995) found that, for bogs, the uncultivated plots showed a larger number of native bees, so clearly cutting does not have the same effects in different environments.

Gaston (1992) points out that plant species richness is a good indicator of insect species richness, but that each group of insects has a different relationship to the levels of plant species richness. However, this makes plant species richness an imprecise surrogate to use. Viejo *et al* (1989) and Usher (1986) suggest that botanical and arthropod diversity is not always correlated. Quicke and Kruft (1995) and Janzen (1981) found Ichneumonoidea species richness to vary with latitudinal gradient, and suggested water availability may determine the global trend, as fewer species are found in the arid regions around Mexico and North Africa. This correlates intuitively with global plant species richness trends. Finnamore (1994) described how species numbers of arthropods could be estimated from the diversity of Hymenoptera parasitoids collected at a site. Downie *et al* (1999) state that spiders are good predictors of overall invertebrate biodiversity. The link between plant species richness, spider diversity and invertebrate biodiversity as a whole is likely to be habitat structural complexity. Luff and Rushton (1988) relate changes in spider fauna following pasture improvement to vegetation structure (see also McFerran *et al* 1994), and found differences in spider community assemblages between differently managed sites. Ditlhogo *et al* (1992) found management to initially increase the numbers of Araneae.

The vast majority of studies where structural complexity of the habitat was measured, show that it is a significant factor in determining species composition and diversity for invertebrates (Gibson *et al* 1992, Kurashov *et al* 1996, Norris *et al* 1997, O'Connor 1991, Rushton *et al* 1990, Webb 1989, Wettstein and Schmid 1999, Wheater *et al* 2000). Studies show an increase in community complexity and diversity with and increase in plant structural diversity (e.g. Wettstein and Schmid 1999).

Partly because of this, spiders tend to exhibit strong habitat specificity (Dondale and Redner 1994, Gunnarsson 1990, McFerran *et al* 1994, Niemelä 1997, Petterson 1996 and refs within such as Uetz 1991, Thomas 1991, Wheater *et al* 2000, Wise 1993). Different species compositions are found in bogs as opposed to fens (Dondale and Redner 1994), and between individual bogs and peatlands (Blades and Marshall 1994, Koponen 1994, Marshall and Finnamore 1994, Runtz and Peck 1994). Rushton *et al* (1990) found spider and beetle fauna in wetlands depended on hummocks or tussocks in the environment in order to overwinter. Schikora (1994) found that ground living spider fauna changes rapidly after the biotope changes (e.g. Huhta 1971). Habitat specificity and response to change is species specific. Thomas (1991) pointed out that in reference to butterflies 'Secondary forest is not an adequate substitute for primary forest, if endemics are to be conserved' and this seems to hold true for other habitats and groups. Disturbed habitats often seem to exhibit a depauperate version of the undisturbed community (Dondale and Redner 1994, Gibson *et al* 1992, Mackenzie and Averill 1995, Maelfait and de Keer 1990).

This investigation looked at the diversity and response to management of Araneae at three sites in the Norfolk Broads, two managed by the BA (Mallow Marsh and How Hill) and the third by the NWT (Catfield Fen) (Andrews 2000, Wetland Harvests 1997).

5.3 Hypothesis

The hypothesis based on the results of the pilot study is as follows:

- Araneae (spiders) are not sensitive to habitat management.

From this it can be predicted that numbers of individuals will not decline following management, and that the species composition of the spider assemblage will not alter following management.

5.4 Aims

The aims of this investigation were to ascertain whether cutting management affects the biodiversity of spider species in the first year following management of reedbeds. Both biodiversity and the individual responses of species were investigated. Spiders are sensitive indicator species and have been used in several studies as such (e.g. Coddinton *et al* 1996, Duelli and Obrist 1998, Johnson 1995b). They respond to disturbance (e.g. Downie *et al* 1999, York 1999) and are therefore useful tools in assessing habitat quality and monitoring environmental change.

This project set out to quantify the effects of cutting management on the Araneae diversity of the fen. To this aim the following questions were asked:

- Is there a significant difference between the numbers of individual spiders found on cut and control plots at each site?

- Is there a significant difference between the numbers of individuals of each species of spider found in cut and control plots at each site?
- Is there a difference between the composition of spiders at each site, or between the different management treatments?
- How diverse are the plots in terms of spider species composition, taking both number of species and relative abundance into account?
- How does spider diversity change over the sampling time?
- How similar are the plots to each other in terms of species composition?
- How similar are the plots to themselves one year on?
- What are the responses of individual species to management?

5.5 Autecology

The autecology of wetland spiders is little known. Life cycle details and life history are sketchy, though distribution and habitat requirements are generally known for the commoner species. Information on the more numerous spiders and the rarer species collected in this study, (taken from Harvey *et al* (2002a and 2002b) and Roberts (1985a and 1987)) is listed below.

Allomengea vidua (L. Koch, 1879) (Figure 5.1)

Status - Very local, commoner than *A. scopigera* in the south, but less so in the north. Found July to November, peak in September, generally more females collected than males. Distribution widespread – includes Wales, much of England, occasional records from Scotland, widespread in central and NW Europe. Recorded from Norfolk. Habitat and Ecology – usually wet habitats – swamp, fen and marsh, low altitudes.

Figure 5.1 ***Allomengea vidua***

Antistea elegans (Blackwall, 1841)

Status – Common, found all year round, peaking in September. Females found all year, males from July – November. Distribution – widespread in Britain and W and C Europe. Scattered in N and S Britain. Recorded from Norfolk. Habitat – builds small sheet web over depressions in wetland soil (Locket and Millidge 1953), typically beneath plants. Recorded from reedbeds, marshes, upland blanket bogs, lowland sphagnum bogs, seeps, woodland pool sides, wet Sphagnum on Snowdonia at 470m.

Bathyphantes gracilis (Blackwall, 1841)

Status – Common. Distribution – widespread throughout Britain, W and C Europe. Recorded from Norfolk. Found all year round, peak June - October with more females recorded than males. Habitat – grassland, undergrowth, heathland, woodland, marshes. Common aeronaut.

Clubiona iuvenis Simon, 1878

Status –Nationally vulnerable, RDB2. Distribution – Well established in the Broads. Also recorded from Dorset, Essex and Cambridgeshire. Found in 11 countries in Europe stretching from Estonia to Italy. Found in May, and again in September and October. Habitat – reed-beds and fens, *Phragmites/Cladium* fens. Decleer and Bosmans (1989) suggest two generations per year, the first generation hatching in the spring, hibernating as adults and reproducing the following spring, and the second generation in the summer hibernating as sub-adults and reproducing in the autumn (possibly two reproductively isolated sub-species). The biggest threat to this species is loss of reed-bed through eutrophication and scrub encroachment.

Clubiona phragmitis C.L. Koch, 1843

Status –Locally common. Distribution – widespread in England and lowland Wales and NW and C Europe. Recorded from Norfolk. Habitat – wetland, especially emergent vegetation. Builds a silk retreat/nest in folded *Phragmites* leaves. Found all year round, but mostly May to June and again in September.

Donocochara speciosa (Thorell, 1875)

Status –Nationally scarce, Notable A. Distribution – found in E England, Kent to Norfolk, widespread but uncommon in N and C Europe. Recorded late in the year, September – November. Habitat – wetland, especially very wet places in fens, marshes and sewage beds. It may be adult for most of the year. Threats come from scrub encroachment and drainage.

Entelecara omissa O.P.-Cambridge, 1902

Status –Nationally scarce, Notable A. Distribution – Mostly found in Norfolk, Suffolk and Cambridgeshire. Recorded in Europe. Recorded from May – November. Habitat – fens and marshes, *Carex* tussocks, reed litter, sedge. Threats come from scrub encroachment and drainage.

Erigone atra Blackwall, 1833

Status – Common, aeronaut. Distribution – widespread in Britain and W and C Europe. Recorded from Norfolk. Habitat – ubiquitous, ground level, low vegetation, under bark of fallen trees. Found all year round, peak in June. More males than females recorded.

Figure 5.2 ***Erigone atra***

Gnathonarium dentatum (Wider, 1834)

Status – Common in wet habitats. Found all year round, peaks May – July and again in October. Distribution – widespread in S Britain, W and C Europe, scattered in the N and absent from N Scotland. Recorded from Norfolk. Habitat – wetland, ground level, coloniser of disturbed ground. Flooded pools alongside grassland. Not found in upland blanket bogs, but up to 250m in Wales.

Hypomma fulvum (Bösenberg, 1902)

Status –Notable A. Distribution – Most common in East Anglia. Habitat – wetland, fens and marshes, reed-beds, also occasionally grassland, sand dunes and salt-marshes. Females construct egg cocoons in flowering heads of *Phragmites*. Found mostly in May, though females persist into September. Principal threat is from drainage and scrub encroachment.

Lepthyphantes flavipes (Blackwall, 1854)

Status – Common. Found all year round, peak June/July with more females recorded than males. Distribution – widely distributed in S Britain, scattered in N. Recorded from Norfolk. Widespread in W and C Europe, as far N as S Norway. Habitat – woodland sp, leaf litter and undergrowth, also grasslands, heaths, marshes, ground level, heather, moss, grass.

Lophomma punctatum (Blackwall, 1841)

Status – Local, frequent in wet habitats. Peaks April – June and September – October. Distribution – widespread in Britain, NW and C Europe. Recorded from Norfolk. Habitat – litter and low vegetation, wetlands from brackish *Phragmites communis* at the coast to upland blanket bogs, alder carr.

Oedothorax gibbosus (Blackwall, 1841)

Status – Common, peaks May – June, collected January – November. Distribution – widespread, patchy in places. Widespread in NW and C Europe. Recorded from Norfolk. Habitat – bogs, fens, wet meadows. Does not make webs – hunts over surface. Male variation – form *tuberosus*, does not have hairs that *gibbosus* has, which appears at last moult. Juvenile development takes less than one month.

Pachygnatha clercki Sundevall, 1823

Status – More local and less common than *P. degeeri*, but frequent in wet habitats. Found all year round, peaks in May-June and September. Distribution – widespread in Britain, W and C Europe, scattered into Scotland. Recorded from Norfolk. Habitat – bogs, marshes, edges of ponds, rivers, streams, low vegetation.

Pardosa prativaga (L. Koch, 1870)

Status – may be abundant locally, scarce in N Britain. Found May – November. Males peak in May – July. Females also peak at these times, but persist longer and fewer are collected. Distribution – widespread in S half of Britain, W and C Europe, scattered in N Britain. Recorded from Norfolk. Habitat – open ground, herbage of open habitats, including grasslands, waste grounds, fields, heathland, woodland clearings, dunes, old quarries, roadside verges, wet places incl dyke edges, fens, marshes and bogs. Occasionally interbreeds with *P. pullata* in the laboratory and this sometimes results in fertile eggs. It has only been observed in captivity but in possible in the field and this could explain mixed colouring (Locket and Millidge 1951)

Pirata hygrophilus Thorell, 1872

Status – less frequent than *P. piraticus*. May be locally abundant. Distribution – widespread in S half of Britain, NW and C Europe, scattered in N Britain.

Recorded from Norfolk. Habitat – abundant in ground layer of damp woodland and raised bogs, lowland heaths, marshy grassland, not open water. Found May – September, peak in June. Females persist later than males.

Pirata piraticus (Clerck, 1757)

Status – Local. Distribution – widespread in Britain, W and C Europe. Recorded from Norfolk. Found April – November, peak in May – July. Habitat – wetland, including pond and stream margins, marshes, fens, upland blanket bogs, Sphagnum seeps and reed-beds. Ambush predator, found in open in sunny weather, concealed in low vegetation in cooler weather. Females carry single ovoid white egg-sac attached to spinnerets.

Pirata piscatorius (Clerck, 1757)

Status – very local. Distribution – absent from large areas of England and Scotland, but widespread in Wales, parts of England, NW and C Europe. Recorded from Norfolk. Females found May-August, probably all year round, and males only in May. Habitat – very wet areas, near standing water. Bristowe (1923) observed females build a vertical tube in Sphagnum moss from which they dart out to catch passing insects. The lower end is in water and spider goes below water if disturbed.

Porrhomma pallidium Jackson, 1913

Status – local. Distribution – Widespread in Britain, but scattered, especially in S England. **Not** previously recorded from Norfolk. Found all year round with a peak in April / May, but fewer in late summer. Habitat – shade tolerant, woodland, upland, small webs close to ground either under stones or within moss layer. In C Europe also occurs in meadows, raised bogs. Complex adult period between late spring and the autumn.

5.6 Methods

Three sites were sampled Catfield Fen, Mallow Marsh and How Hill. These were all (NVC) S4 reedbed, though Catfield had more S24 tendencies. The sites each had six plots A-F, half of which were cut in July 1999. At Catfield and How Hill the plots A, C and E were control plots (uncut) and B, D and F were cut plots. At Mallow Marsh A,C and E were cut and B, D and F were control. Samples were taken from each plot before management in mid-June 1999, and post-cutting at the end of August 1999, mid-June 2000 and end August 2000.

Vegetation surveys were also taken in 1999 before cutting and one year later in the summer of 2000. One hundred 25x25 cm quadrats were taken in each plot. Presence and absence of each plant species was noted, and this gave accurate frequency of occurrence data for each plot at each site.

Spiders were collected using pitfall traps containing 50% antifreeze and water with a dash of washing up liquid to break the surface tension. Eight pitfall traps were left out for a week at each plot on each site in June and August 1999 and 2000. The spiders were preserved in 100% ethanol and identified to species (Figures 5.1 and 5.2) (Roberts 1985a, b, 1987 and 1996). The species data, combined with the vegetation survey data, were analysed using DECORANA (Hill 1979a) using the Vespan III (licensed by Dr A. Malloch 1990) program, Chi^2 tests, rank abundance, Simpson Diversity Index (e.g. Begon *et al* 1990), Morisita-Horn (Krebs, 1989) and the Jaccard Similarity Index (Southwood

1978). Vegetation and spider multivariate analyses were combined using a two-way biplot. Plotting the two against one another enabled a visual representation of the different influences of the vegetation and spider composition on the biodiversity to be differentiated. Further analyses of the Indices and Multivariate data was carried out using the Mann Witney U test and the General Linear Model, and levels of inertia were calculated for each multivariate axis (Dixon 1992).

5.7 Results

Nearly 3000 individuals were collected (2987). The data is shown in Table 5.I

Table 5.I The numbers of spider species and individuals collected.

Sample date	June 1999	August 1999	June 2000	August 2000
Numbers species	34	17	35	18
Numbers individuals	730	387	1556	314

Is there a difference between the numbers of individual spiders found on cut and control plots at each site?.

The first parts of Tables 5.II - 5.V, look at the difference in numbers of individuals collected in control and experimental plots at each sample date, regardless of species, of Araneae. The pre-cutting data from June 1999, and the one month post-cutting data from August 1999 show that the difference between control and experimental plots at all three sites was not significant. The following year shows significant differences for Catfield and Mallow Marsh in June 2000 and for Mallow Marsh in August 2000.

Table 5.II Chi squared analysis of spider distribution before cutting in June 1999. The top part of the table show the differences between the numbers of individuals found on each treatment at each site. The second half of the table shows the differences in the numbers of individuals of each species found on plots of different treatments.

Chi^2 June 1999 Spiders

Sites	uncut	cut	expected	Chi^2	sig
Catfield	152	126	139	2.43	ns
Mallow	99	94	96.5	0.13	ns
How Hill	139	125	132	0.74	ns

Species	uncut	cut	expected	Chi^2	sig
Bathyphantes gracilis	80	84	82	0.1	ns
Erigone atra	26	14	20	3.6	ns
Gnathonarium dentatum	11	28	19.5	7 41	sig p=0.01
Lepthyphantes flavipes	12	14	13	0.15	ns
Lophomma punctatum	13	14	13.5	0.04	ns
Oedothorax gibbosus	52	44	48	0.67	ns
Porrhomma pallidium	7	7	7	0	ns
Pirata piraticus	41	46	43.5	0.29	ns
Pardosa prativaga	21	6	13.5	8.33	sig p=0.005

Using a Bonferroni correction on the significant values, the species are significant at p<0.0055, so *P. prativaga* has a significant difference between the numbers of individuals found in plots to be cut compared to those found in the control areas, but *G. dentatum* does not.

Table 5.III Chi squared analysis of spider distribution after cutting in August 1999. The top part of the table show the differences between the numbers of individuals found on each treatment at each site. The second half of the table shows the differences in the numbers of individuals of each species found on plots of different treatments.

Chi^2 August 1999 Spiders

Sites	uncut	cut	expected	Chi^2	sig
Catfield	62	44	53	3.06	ns

Mallow	87	80	83.5	0.29	ns
How Hill	65	49	57	2.24	ns

Species	uncut	cut	expected	Chi^2	sig
Antistea elegans	11	9	10	0.2	ns
Allomengea vidua	55	13	34	25.94	sig p=0.001
Bathyphantes gracilis	16	13	14.5	0.31	ns
Pachygnatha clercki	6	13	9.5	2.58	ns

Using a Bonferroni correction on the significant values, the species are significant at $p<0.0125$, so *A. vidua* has a significant difference between the numbers of individuals found in cut plots compared to those found in the control areas.

Table 5.IV Chi squared analysis of spider distribution after cutting in June 2000. The top part of the table show the differences between the numbers of individuals found on each treatment at each site. The second half of the table shows the differences in the numbers of individuals of each species found on plots of different treatments.

Chi^2 June 2000 Spiders

Sites	uncut	cut	expected	Chi^2	sig
Catfield	169	659	414	289.98	sig p=0.001
How Hill	152	178	165	2.05	ns
Mallow	84	314	199	132.92	sig p=0.001

Species	uncut	cut	expected	Chi^2	for 1 df
Antistea elegans	10	5	7.5	1.67	ns
Bathyphantes gracilis	67	63	65	0.12	ns
Erigone atra	17	93	55	52.51	sig at p=0.001
Gnathonarium dentatum	11	21	16	3.13	ns
Oedothorax gibbosus	9	13	11	0.73	ns
Pirata hygrophilus	17	4	10.5	8.05	sig at p=0.005
Pirata piraticus	184	274	229	17.69	sig at p=0.001
Pirata piscatorius	6	26	16	12.5	sig at p=0.001
Pardosa prativaga	7	15	11	2.91	ns

Using a Bonferroni correction on the significant values, the sites are significant at $p<0.0167$. The species are significant at $p<0.0055$, so Mallow, Catfield, *E. atra*, *P. hygrophilus*, *P. piraticus*, and *P. piscatorius* have significant differences between the numbers of individuals found in experimental plots compared to those found in the control areas.

Table 5.V Chi squared analysis of spider distribution after cutting in August 2000. The top part of the table show the differences between the numbers of individuals found on each treatment at each site. The second half of the table shows the differences in the numbers of individuals of each species found on plots of different treatments.

Chi^2 August 2000 Spiders

Sites	uncut	cut	expected	Chi^2	sig
Catfield	30	45	37.5	3	ns
Mallow	104	48	76	20.63	sig p=0.001
How Hill	45	41	43	0.19	ns

Species	uncut	cut	expected	Chi^2	sig
Antistea elegans	5	9	7	1.14	ns
Allomengea vidua	47	9	28	25.79	sig at p=0.001
Bathyphantes gracilis	13	18	15.5	0.81	ns
Pachygnatha clercki	7	6	6.5	0.08	ns
Pirata piraticus	2	16	9	10.89	sig at p=0.001

Using a Bonferroni correction on the significant values, the sites are significant at $p<0.0167$. The species are significant at $p<0.01$, so Mallow, *A. vidua* and *P. piraticus* have significant differences between the numbers of individuals found in cut plots compared to those found in the control areas.

The effect of cutting vs not cutting, and effects of sampling time i.e. June vs August and 1999 vs 2000, plus any interaction between treatment and sampling time are tested using the General Linear Model (GLM). A significance score of $p<0.05$ for sampling time indicates seasonal or year to year fluctuations. A significance score of $p<0.05$ for treatment indicates either an increase or decrease in numbers of individuals of that species following treatment. A significance score of $p<0.05$ for an interaction between treatment and sampling time indicates the reaction of the species in question is influenced by both processes. This is shown in Table 5.VI.

Table 5.VI The effect of sampling date, treatment and an interaction between the two, tested using a General Linear Model. Species showing a significance level <0.05 are shown.

Species	effect of sample date		effect of treatment		sample*treatment	
	F value at d.f. 3	sig level	F value at d.f. 1	sig level	F value at d.f. 3	sig level
Allomengea vidua	9.18	<0.001	7.73	<0.05	3.24	<0.05
Bathyphantes gracilis	16.76	<0.001	0	ns	0.06	ns
Clubiona phragmitis	2.29	ns	5.33	<0.05	2.29	ns
Diplocephalus picinus	3.27	<0.05	0.36	ns	0.36	ns
Erigone atra	11.92	<0.001	3.83	ns	7.17	<0.001
Gnathonarium dentatum	8.14	<0.001	3.09	ns	1.56	ns
Hypomma fulvum	3.47	<0.05	0.14	ns	0.65	ns
Immature	4.05	<0.05	3.49	ns	5.86	<0.005
Lepthyphantes flavipes	5.51	<0.005	0.01	ns	0.04	ns
Lophomma puntcatum	9.37	<0.001	0.01	ns	0.73	ns
Oedothorax gibbosus	12.91	<0.001	0.02	ns	0.06	ns
Pachygnatha clercki	4.79	<0.005	1.48	ns	1.32	ns
Pardosa prativaga	4.04	<0.05	0.03	ns	1.36	ns
Pirata hygrophilus	3.71	<0.05	1.27	ns	2.52	ns
Pirata piraticus	76.67	<0.001	4.05	ns	2.6	ns
Pirata piscatorius	9.72	<0.001	4	ns	3.81	<0.05
Porrhomma pallidium	3.21	<0.05	0.06	ns	0.5	ns

Using a Bonferroni correction on the significant values, the species are significant at $p<0.002$, so only those interactions above shown as $p<0.001$ have significant differences between the numbers of individuals found in managed plots compared to those found in the control areas. The remaining interactions are not significant, and only appear so due to repetitions of the statistical test.

This means only *Erigone atra* is influenced by an interaction of sample date (seasonality) and treatment. No species are influenced by management alone, though many of the spiders are seasonal.

Is there a difference between the numbers of individuals of each species of spider found in cut and control plots at each site?

The second part of Tables 5.II – 5.V show the difference between numbers of individuals of each species (of those species where sufficient data was collected to carry out analysis i.e. with an expected value >5) collected in control and experimental plots at each sample date. June 1999, pre-cutting showed significance for *P. prativaga* only out of the nine species analysed (Table 5.II), which showed more individuals in the control plots than the cut plots. One month post-cutting, August 1999, (Table 5.III), four species were present in sufficient number to analyse. Just one, *A. vidua* showed significance between cut and control plots, with more individuals in the control plots. June 2000 yielded nine species in sufficient numbers to analyse, of which four showed significance (Table 5.IV). These are *E. atra*, *P. hygrophilus*, *P. piscatorius* and *P. piraticus*. Only *P. hygrophilus* showed more individuals in the control plots. August 2000, (Table 5.V) showed significance for two of the five species. These are *A. vidua* and *P. piraticus* again, with *A. vidua* more common in the control plots and *P. piraticus* more numerous in the cut plots.

Is there difference between the composition of spiders at each site, or between the different management treatments?

A multivariate Decorana plot of vegetation before management shows a group comprising Mallow Marsh and How Hill together and more spread out group of the Catfield points (Figure 4.3, page 122). After cutting in summer 2000 (Figure 4.4, page 122), the groups are less discernable though Catfield still falls to the right-hand end of axis 1.

Looking at the multivariate distribution of spiders before management (Figure 5.3), the three sites are clearly separated, apart from one How Hill plot, which falls with in the Catfield group. Plotting spiders (pre-management) against vegetation (Figure 5.4) shows the three sites separate well, with Catfield at the top end of the vegetation axis and the bottom end of the spider axis, where Mallow Marsh points fall at the top end of the spider axis and the bottom end of the vegetation axis. How Hill is similar to Mallow Marsh in terms of vegetation, and spread out between the two sites in terms of spider species composition.

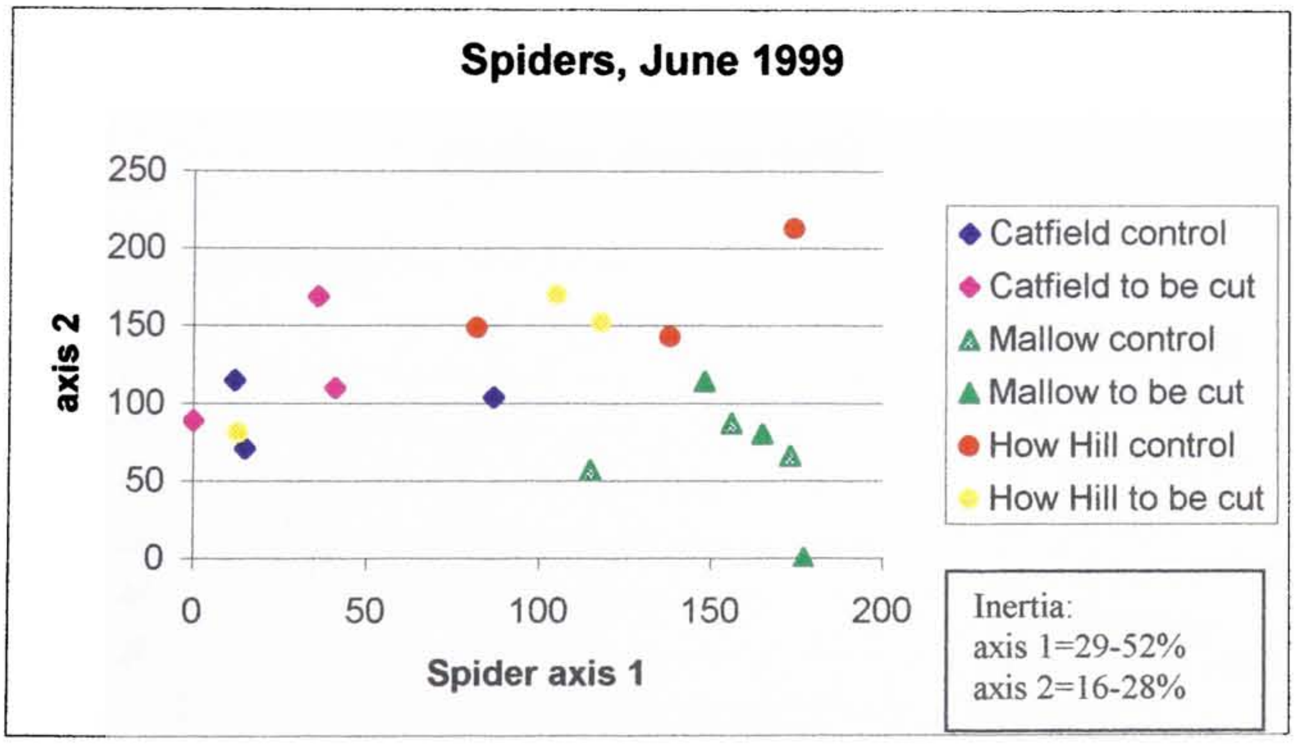


Figure 5.3 Decorana plot of spider distribution in June 1999, before management.

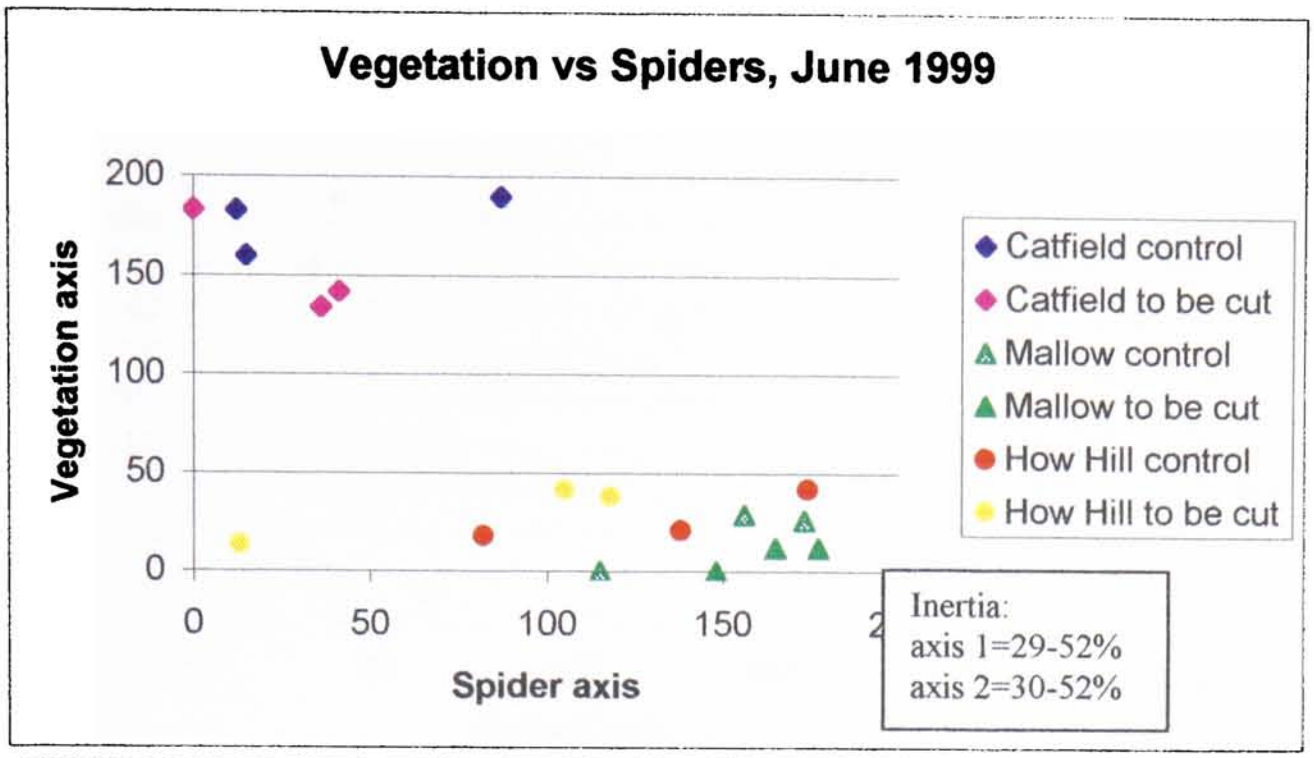


Figure 5.4 Decorana biplot of spider versus vegetation distribution in June 1999, before management.

Post-cutting, August 1999 (Figure 5.5), Mallow Marsh plots group tightly, surrounded by the Catfield plots, and flanked by the How Hill plots. August 1999 spiders against vegetation (Figure 5.6), show Catfield and Mallow Marsh forming groups, but How Hill being more spread out across the spider axis.

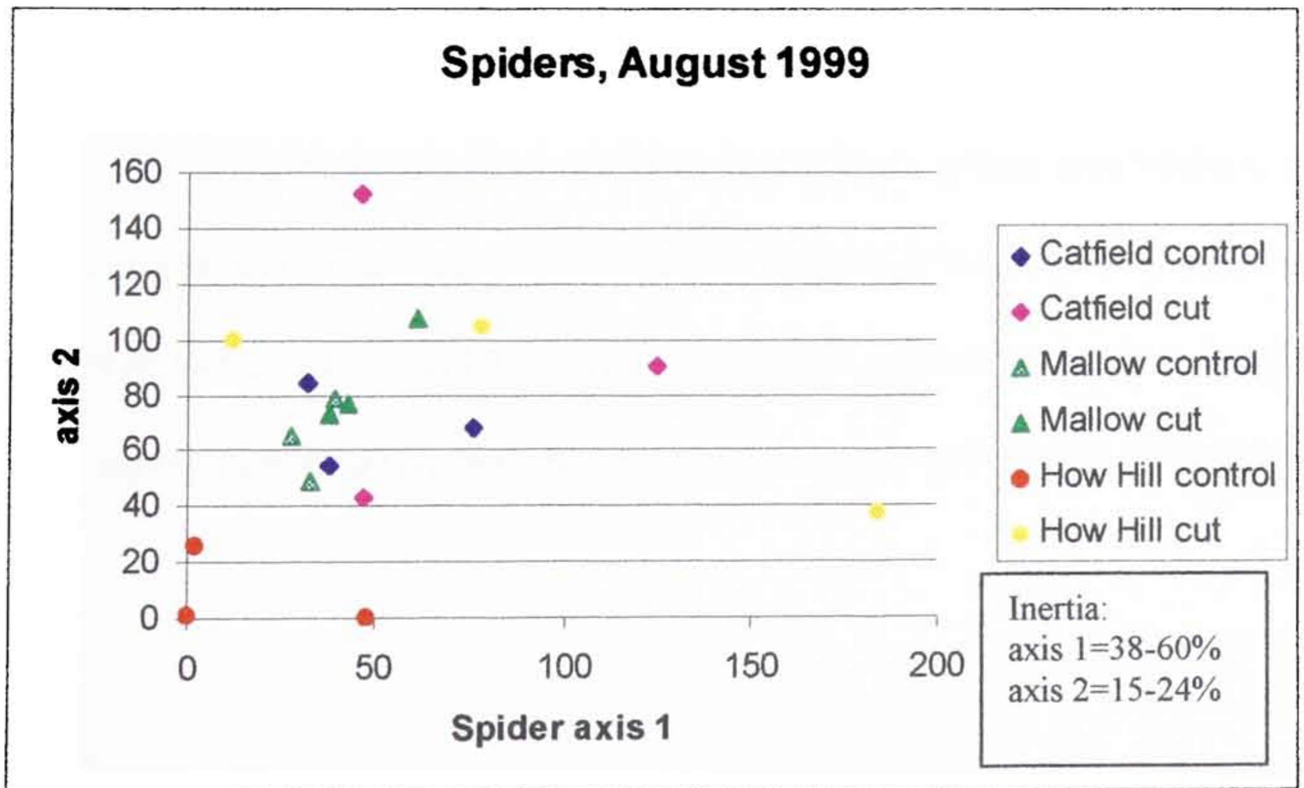


Figure 5.5 Decorana plot of spider distribution in August 1999, after management.

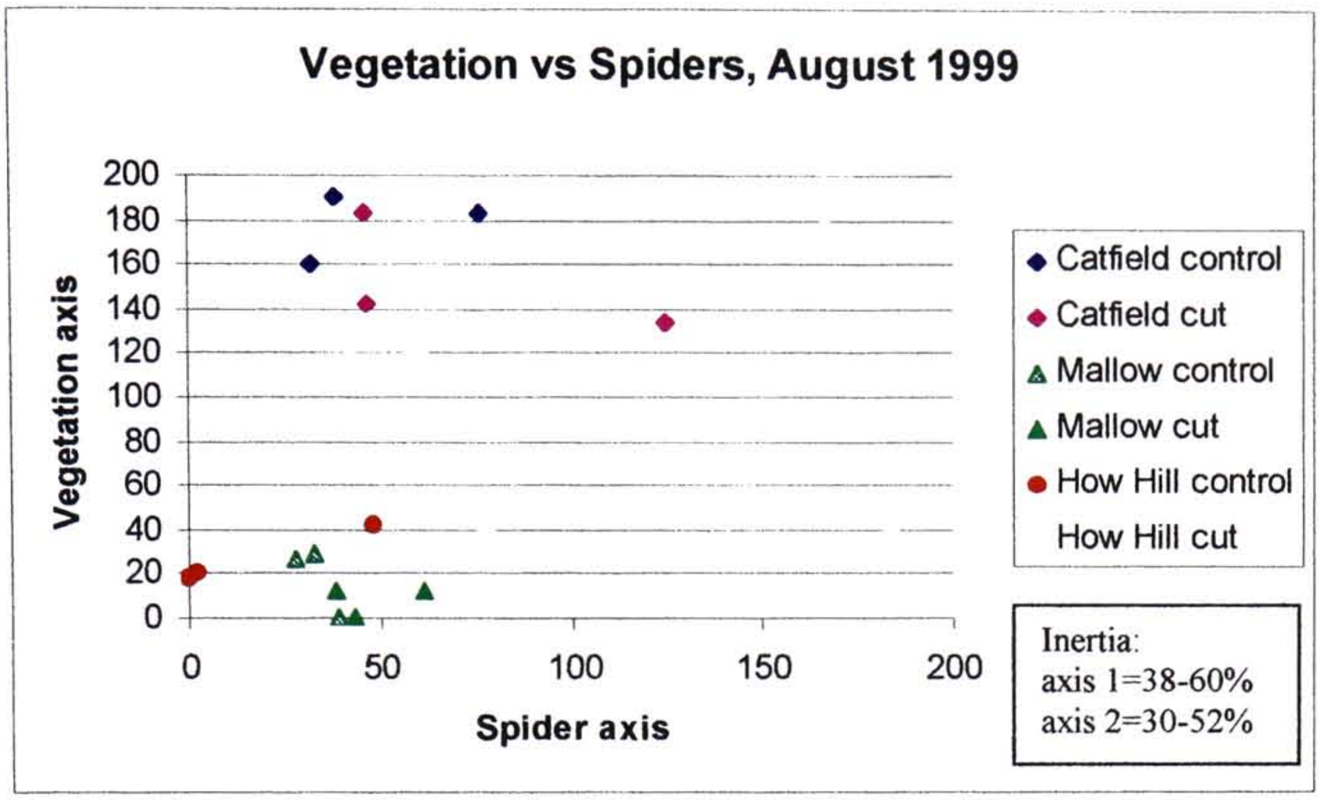


Figure 5.6 Decorana plot of spider versus vegetation distribution in August 1999, after management.

The June 2000 spider analysis (Figure 5.7) shows a much more complex picture. How Hill points group to the top end of axis 1 and the bottom end of axis 2. Catfield Fen points overlap these and the Mallow Marsh points towards the lower end of both axes. Mallow Marsh forms a dispersed group in the upper reaches of axis 2, covering the full extent of axis 1.

The vegetation versus spiders plot for June 2000 (Figure 5.8) gives a similar picture, with Catfield and How Hill forming distinct groups and Mallow being more spread out. The August 2000 results (Figure 5.9) show total overlap for the three sites. August 2000 analysis of spiders against vegetation shows the sites separated only on the vegetation axis, not on the spider axis (Figure 5.10).

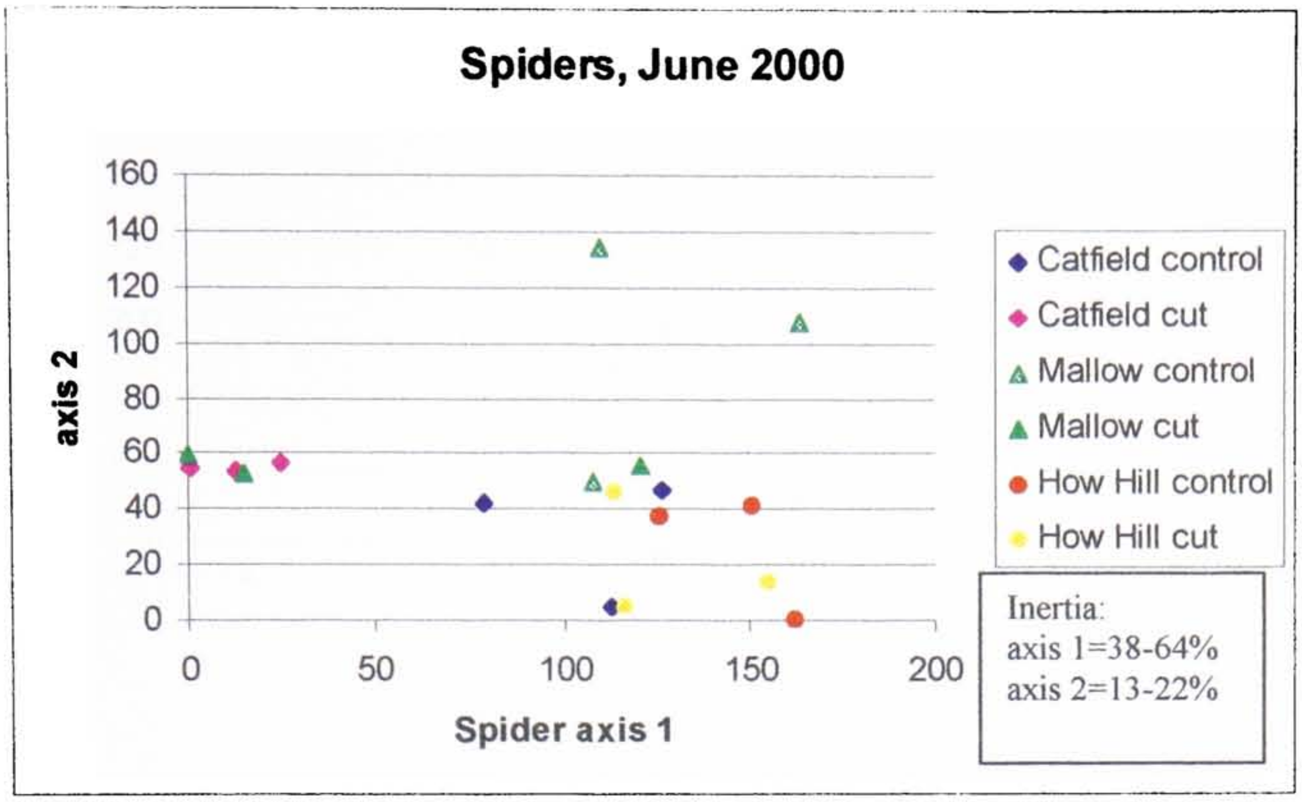
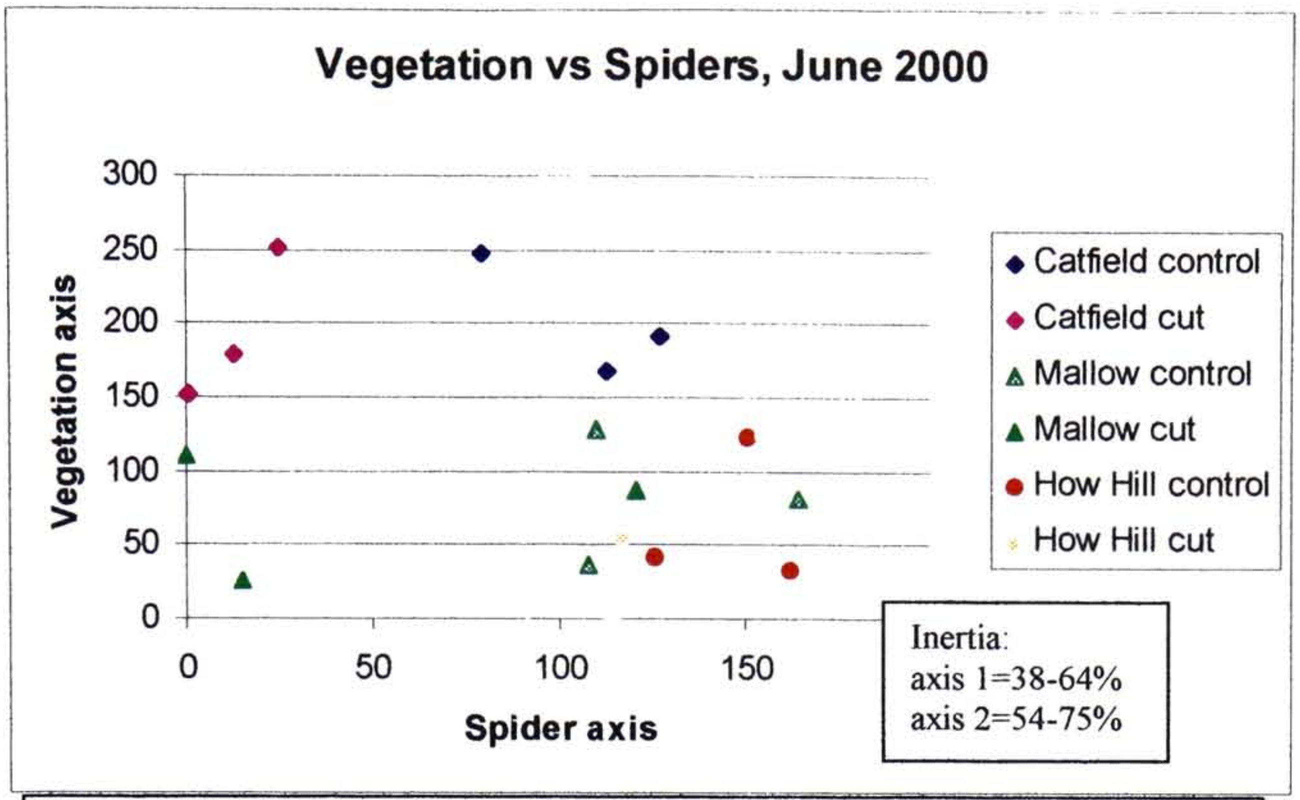


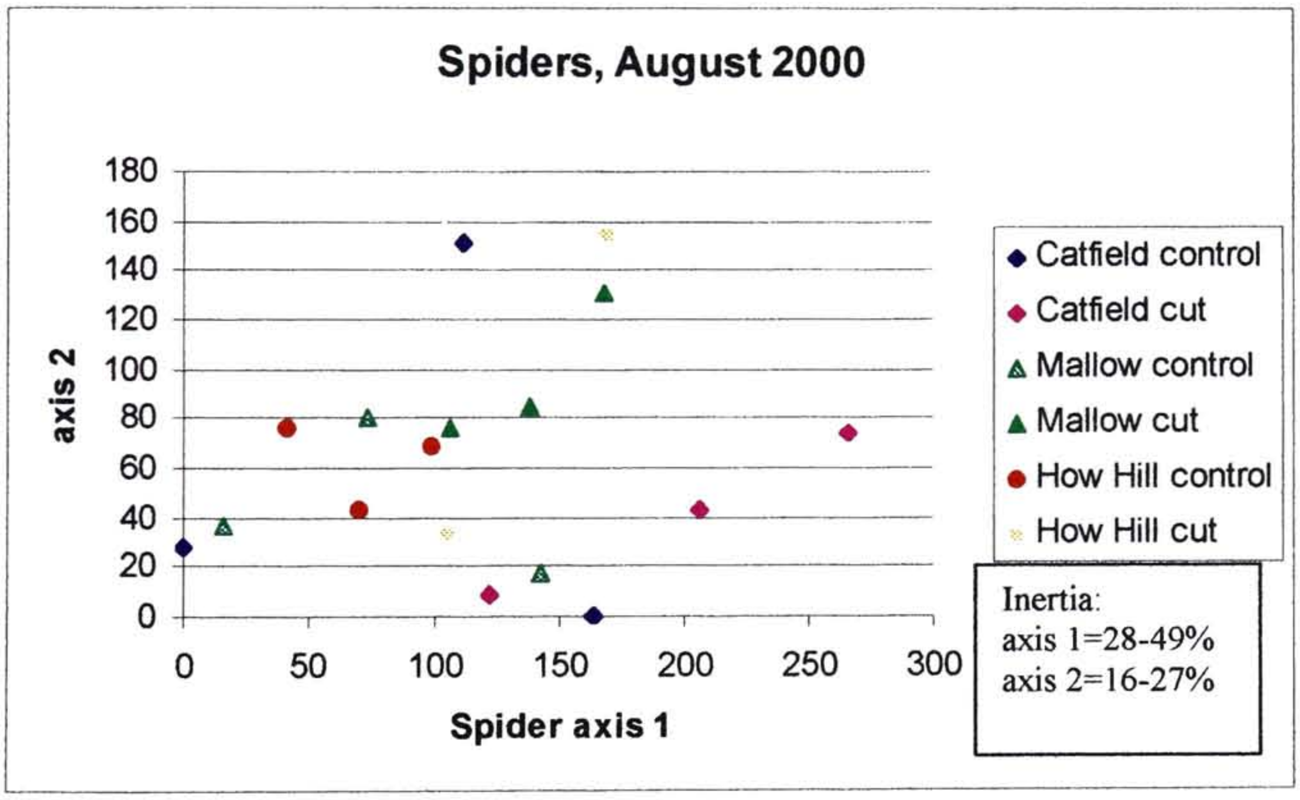
Figure 5.7 Decorana plot of spider distribution in June 2000, after management.

The species ordinations show a scattering of spider species initially, pre-management (Figure 5.11). The first sample after management shows the species which prefer control plots all falling below zero on the *x* axis, and those preferring managed plots falling above this value (Figure 5.12). By one year after management the spider species which show a preference are still clearly separated along the *x* axis (Figure 5.13). However by August 2000 (Figure 5.14), the distribution of species points is once again more scattered, with more of an overlap between species preferring one or other of the treatments.



Inertia:
axis 1=38-64%
axis 2=54-75%

Figure 5.8 Decorana biplot of spider versus vegetation distribution in June 2000, after management.



Inertia:
axis 1=28-49%
axis 2=16-27%

Figure 5.9 Decorana plot of spider distribution in August 2000, after management.

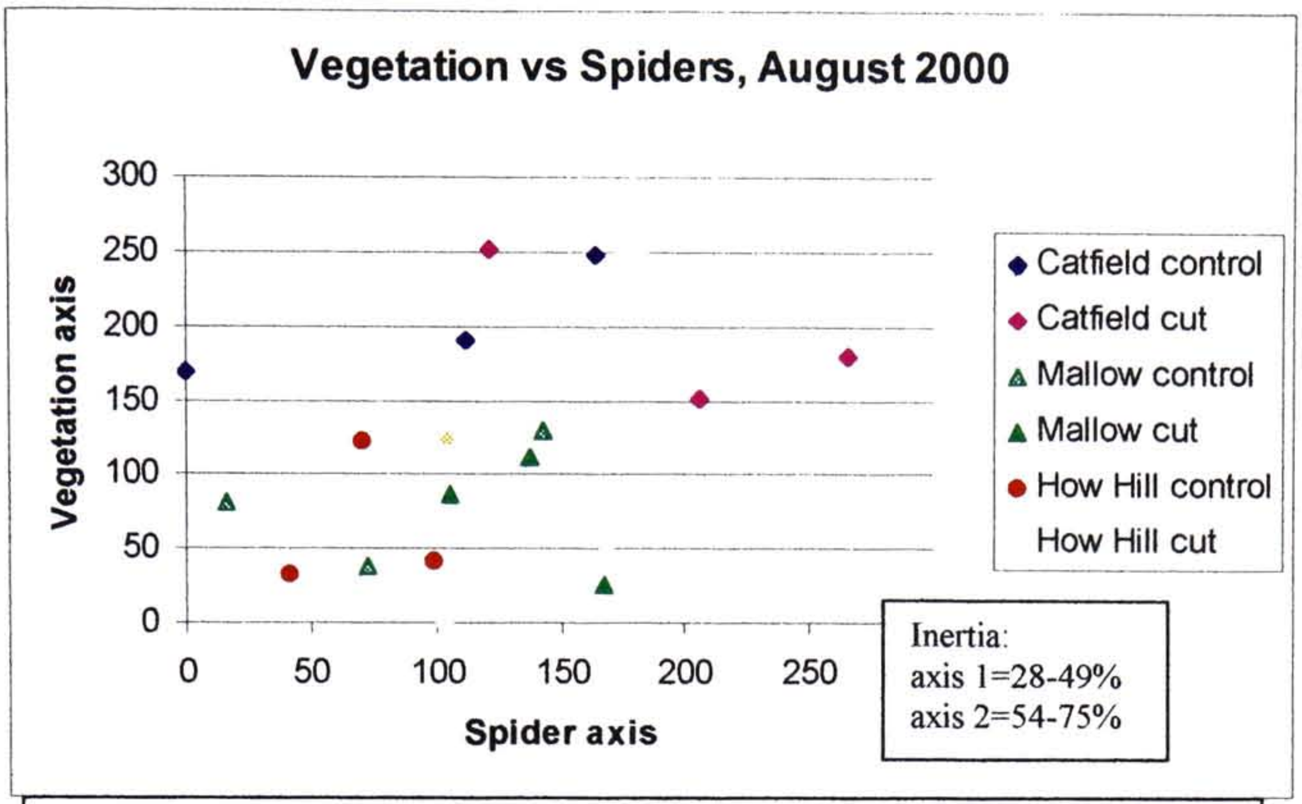


Figure 5.10 Decorana biplot of spider versus vegetation distribution in August 2000, after management.

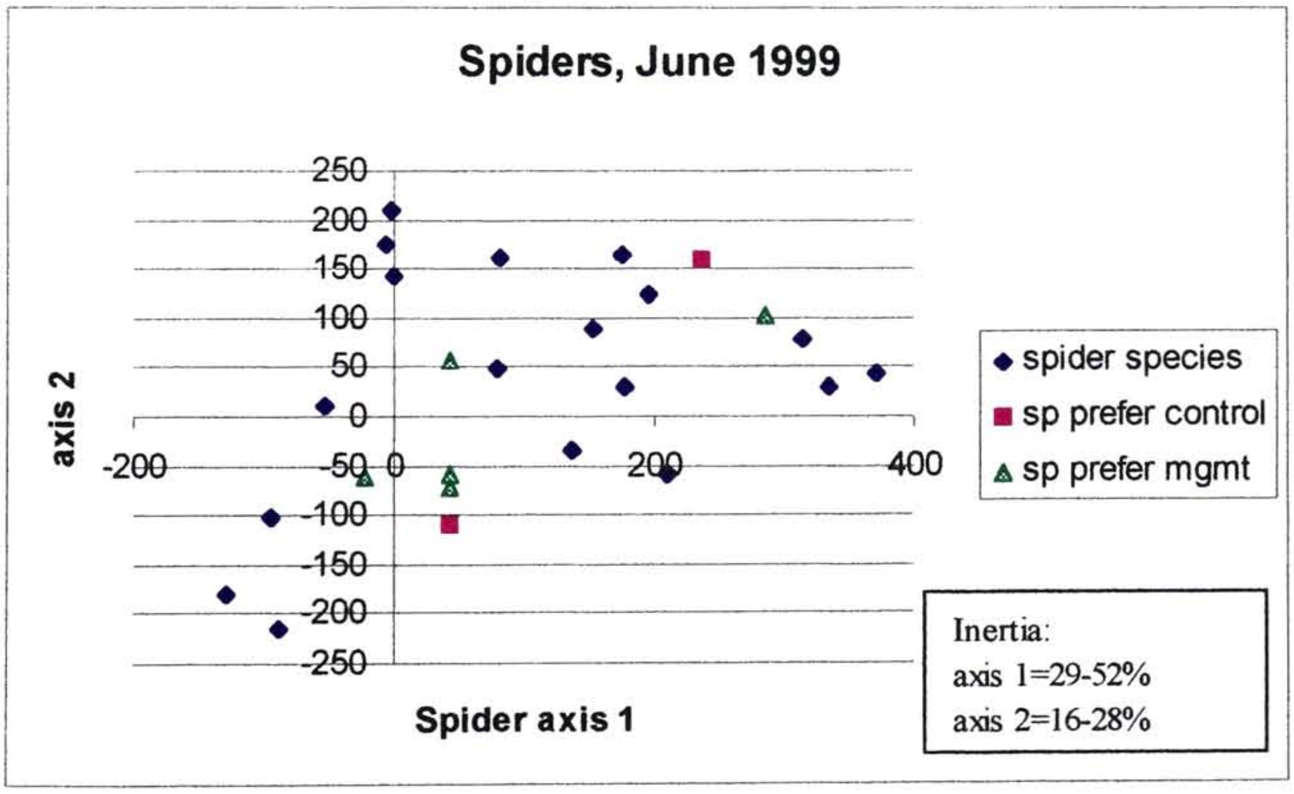


Figure 5.11 Decorana plot showing species ordinations for spiders, in June 1999, before management. Species which do better in managed or control plots are shown separately.

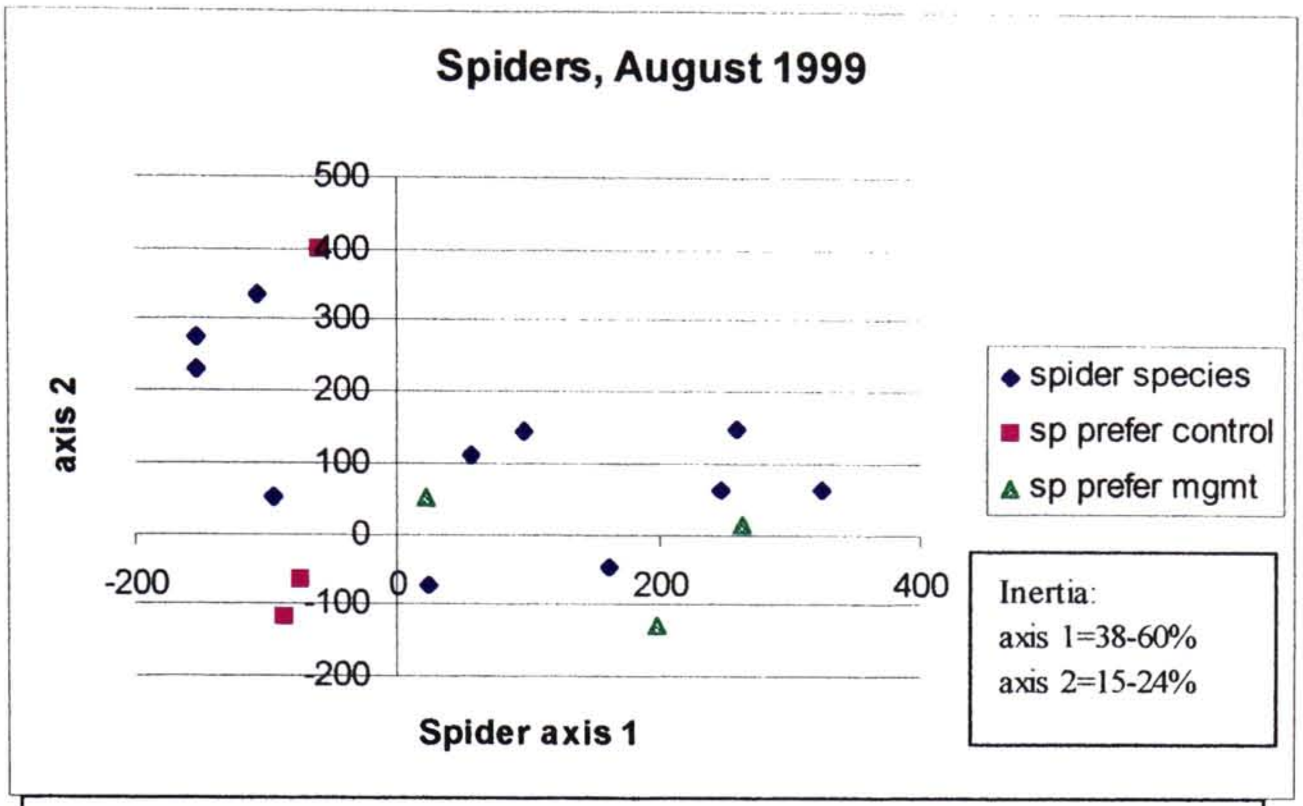


Figure 5.12 Decorana plot showing species ordinations for spiders, in August 1999, after management. Species which do significantly better in managed or control plots are shown separately.

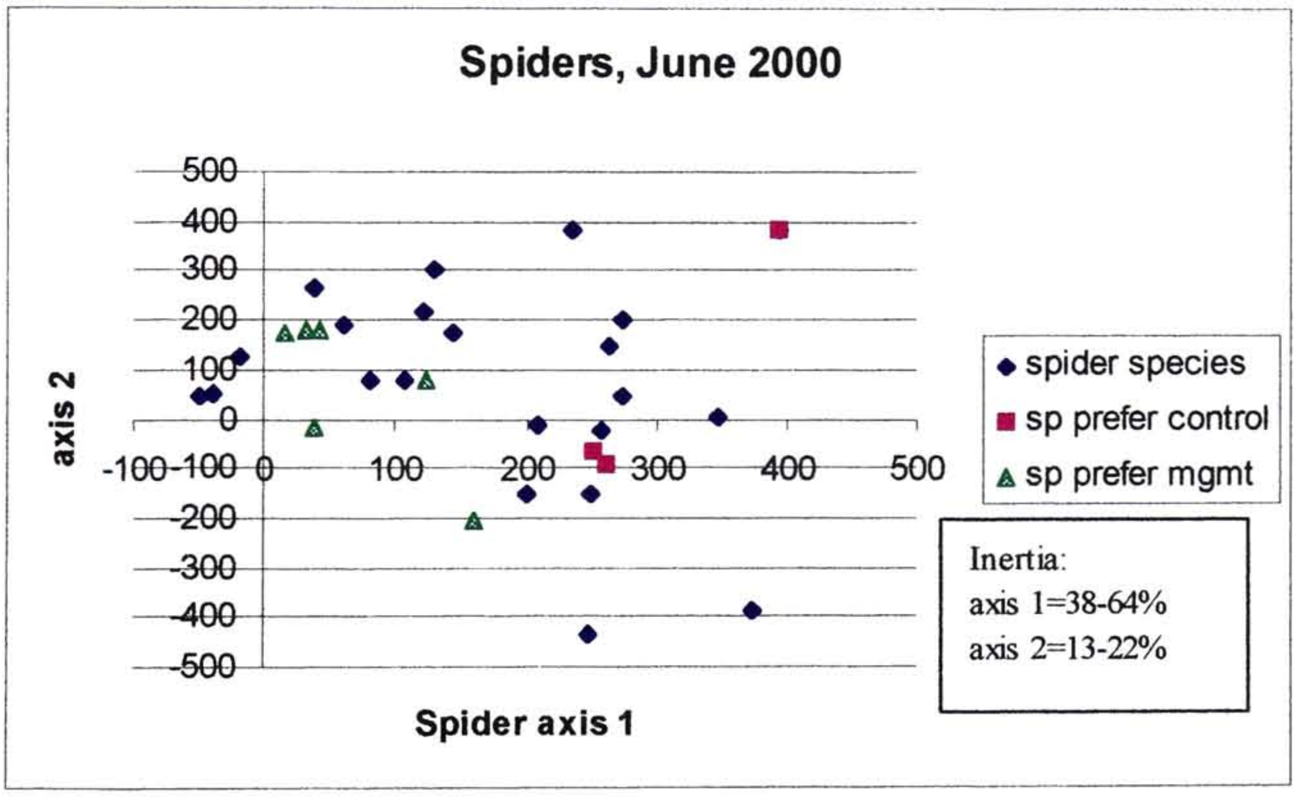


Figure 5.13 Decorana plot showing species ordinations for spiders, in June 2000, after management. Species which do significantly better in managed or control plots are shown separately.

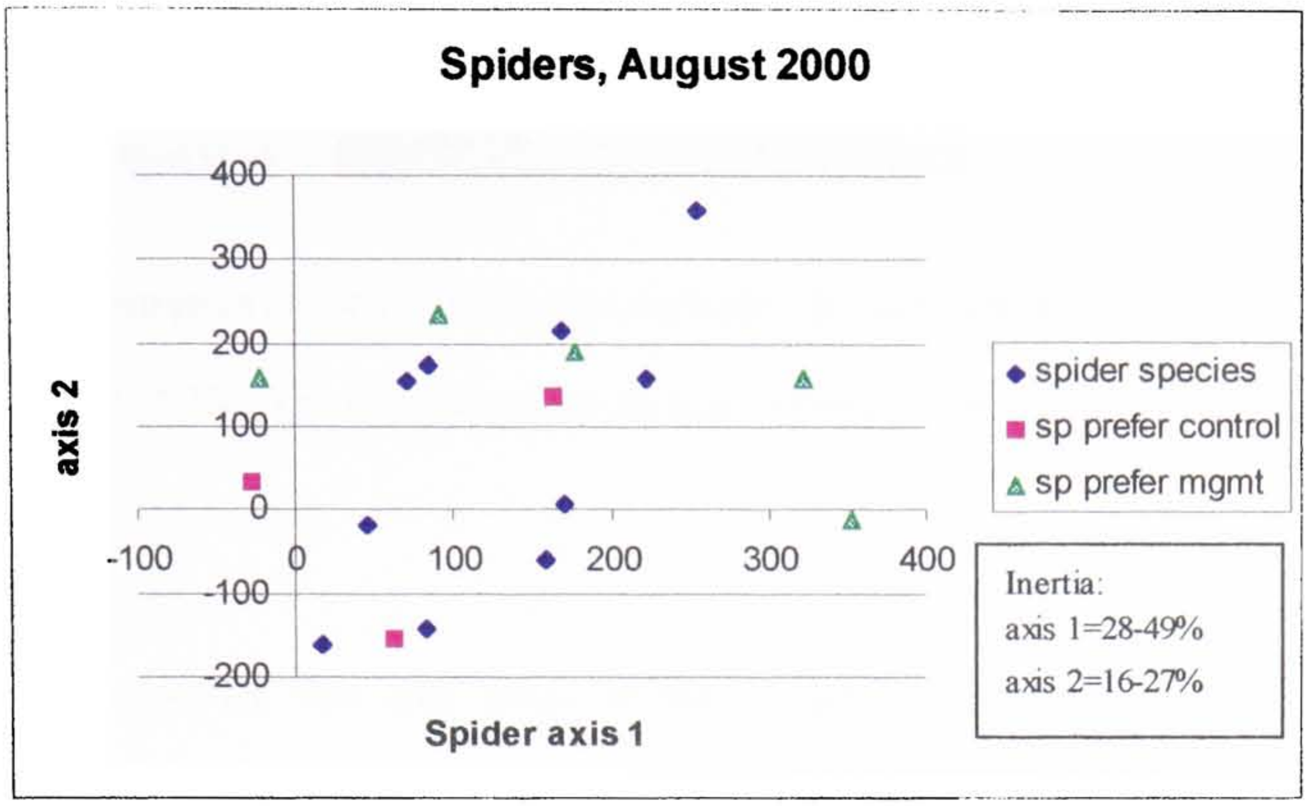


Figure 5.14 Decorana plot showing species ordinations for spiders, in August 2000, after management. Species which do significantly better in managed or control plots are shown separately.

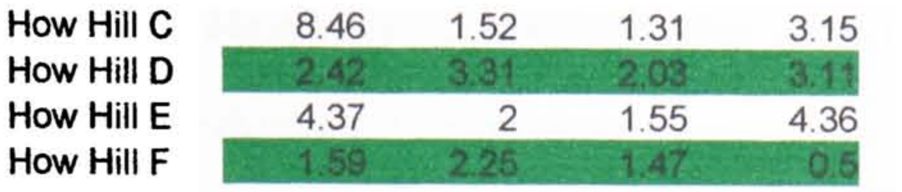
How diverse are the plots in terms of spider species composition, taking both number of species and relative abundance into account? How does this change over the sampling time?

The Simpson Diversity Indices for each plot for each sampling time are shown in Table 5.VII.

Table 5.VII Simpson's Diversity Index. Shaded plots were cut in July 1999.

Simpson Diversity Index, D

	Jun-99	Aug-99	Jun-00	Aug-00
Catfield A	1.42	2.25	1.31	0.03
Catfield B	5.04	1.36	6.15	0.27
Catfield C	1.53	2.28	5.11	0.36
Catfield D	4.14	1.36	1.59	2.36
Catfield E	0.24	6.11	5.09	2.25
Catfield F	5.61	2.11	4.33	3
Mallow A	3.5	2.39	0.07	2.47
Mallow B	3.41	4.14	3.58	3.31
Mallow C	3.27	0.17	3.56	4.11
Mallow D	1.78	2.56	5.18	1.01
Mallow E	5.37	1.47	6.43	4.56
Mallow F	2.12	2.11	5.69	5.26
How Hill A	2.75	4.11	3.78	2.33
How Hill B	6.06	4.31	4.82	2.6



How Hill C	8.46	1.52	1.31	3.15
How Hill D	2.42	3.31	2.03	3.11
How Hill E	4.37	2	1.55	4.36
How Hill F	1.59	2.25	1.47	0.5

The Simpson Diversity Indices for each plot for each sampling time are shown in Table 5.VII. The data ranges for each sampling, cut and control are shown in Table 5.VIII.

Table 5.VIII The data range of the Simpson Diversity Index for each treatment for each sampling time.

range	June 1999	August 1999	June 2000	August 2000
control	0.24-8.46	1.52-6.11	1.31-5.69	0.03-5.26
cut	1.59-6.06	0.17-4.31	0.07-6.43	0.27-4.56

Using a General Linear Model to compare the Simpson Diversity Indices of the cut and control plots between June 1999 and June 2000 and between August 1999 and August 2000 showed no significant difference (Table 5.IX).

Table 5.IX General Linear Model analysis of the Simpson Diversity Index results for cut and control plots between June 1999 and June 2000 and between August 1999 and August 2000

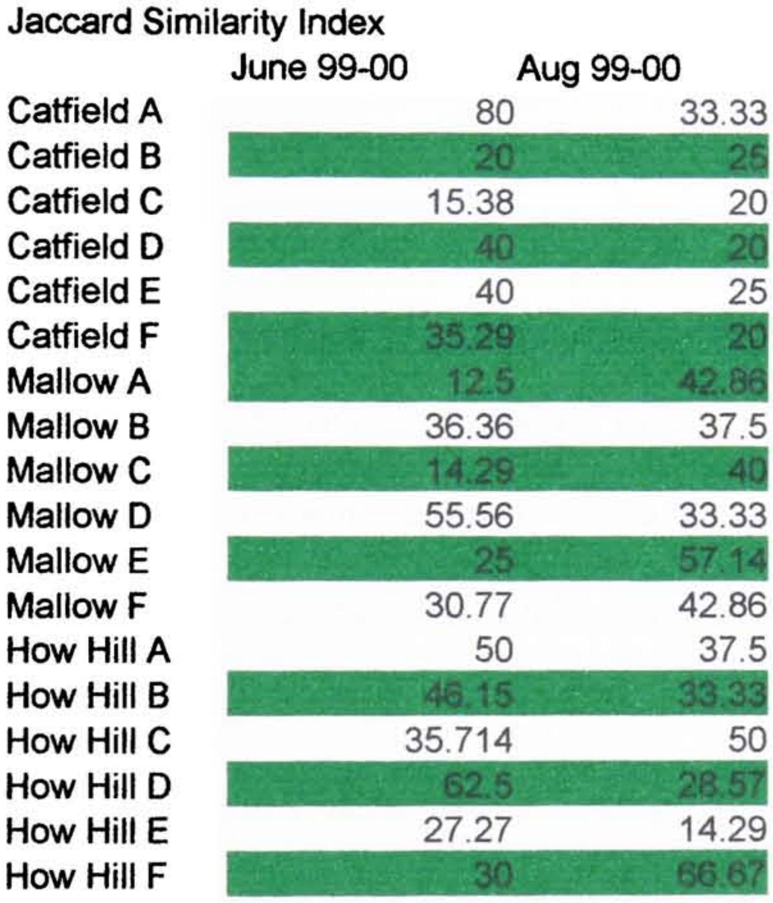
Effect of :

Year June 1999 to June 2000	F=0.00	p=0.998	ns
Treatment	F=0.54	p=0.473	ns
Interaction	F=1.12	p=0.305	ns
Year Aug 1999 to Aug 2000	F=0.01	p=0.935	ns
Treatment	F=0.76	p=0.395	ns
Interaction	F=0.99	p=0.335	ns

How similar are the plots to each other in terms of species composition? How similar are they to themselves one year on?

The plots are compared June 1999 to June 2000 and August 1999 to August 2000 in Table 5.X. Note the first column compares pre-cut plots with managed plots one year on whereas the second column compares like with like one year on.

Table 5.X The Jaccard Similarity Index values for each plot, comparing June 1999 with June 2000 and August 1999 with August 2000. Shaded plots were cut in July 1999.



Jaccard Similarity Index

	June 99-00	Aug 99-00
Catfield A	80	33.33
Catfield B	20	25
Catfield C	15.38	20
Catfield D	40	20
Catfield E	40	25
Catfield F	35.29	20
Mallow A	12.5	42.86
Mallow B	36.36	37.5
Mallow C	14.29	40
Mallow D	55.56	33.33
Mallow E	25	57.14
Mallow F	30.77	42.86
How Hill A	50	37.5
How Hill B	46.15	33.33
How Hill C	35.714	50
How Hill D	62.5	28.57
How Hill E	27.27	14.29
How Hill F	30	66.67

Most similar is Catfield A (control plot) at I=80 and most changed is Mallow A (experimental plot) at I=12.5 for the June-June comparison. For the August-August comparison most similar was How Hill F (experimental plot) with I=66.67 and least similar was jointly Catfield C (control plot) and Catfield D and F (experimental plots) with I=20.

The ranges for June control plots are between 15.38 and 80, whereas the cut plots range between 12.5 and 62.5. For August the control plots range between 14.29 and 50, whereas the cut plots range between 20 and 66.67.

A Mann Witney U Test to compare the Jaccard results from cut and control plots for the June to June and August to August results showed no significant difference (Table 5.XI).

Table 5.XI The Jaccard Similarity Index results analysed over each year, using a Mann Witney U test.

June-June: W=99.5 p=0.233 ns

Aug-Aug: W=81.0 p=0.724 ns

The change in similarity in species composition between plots was analysed using the Jaccard Similarity Index. The full results for each plot at each site at each sampling time are shown in Appendix 5.1. The Jaccard Similarity Index showed a rise in similarity between cut and control plots over the four sampling times for Catfield Fen, and a sharp rise followed by a drop for How Hill. Mallow Marsh (Figure 5.15) showed fairly consistent similarity between cut and control plots throughout the sampling times. The between site similarity for the control plots only showed all plots becoming more similar to each other in terms of spider composition, followed by a drop in similarity the following year (Figure 5.16).

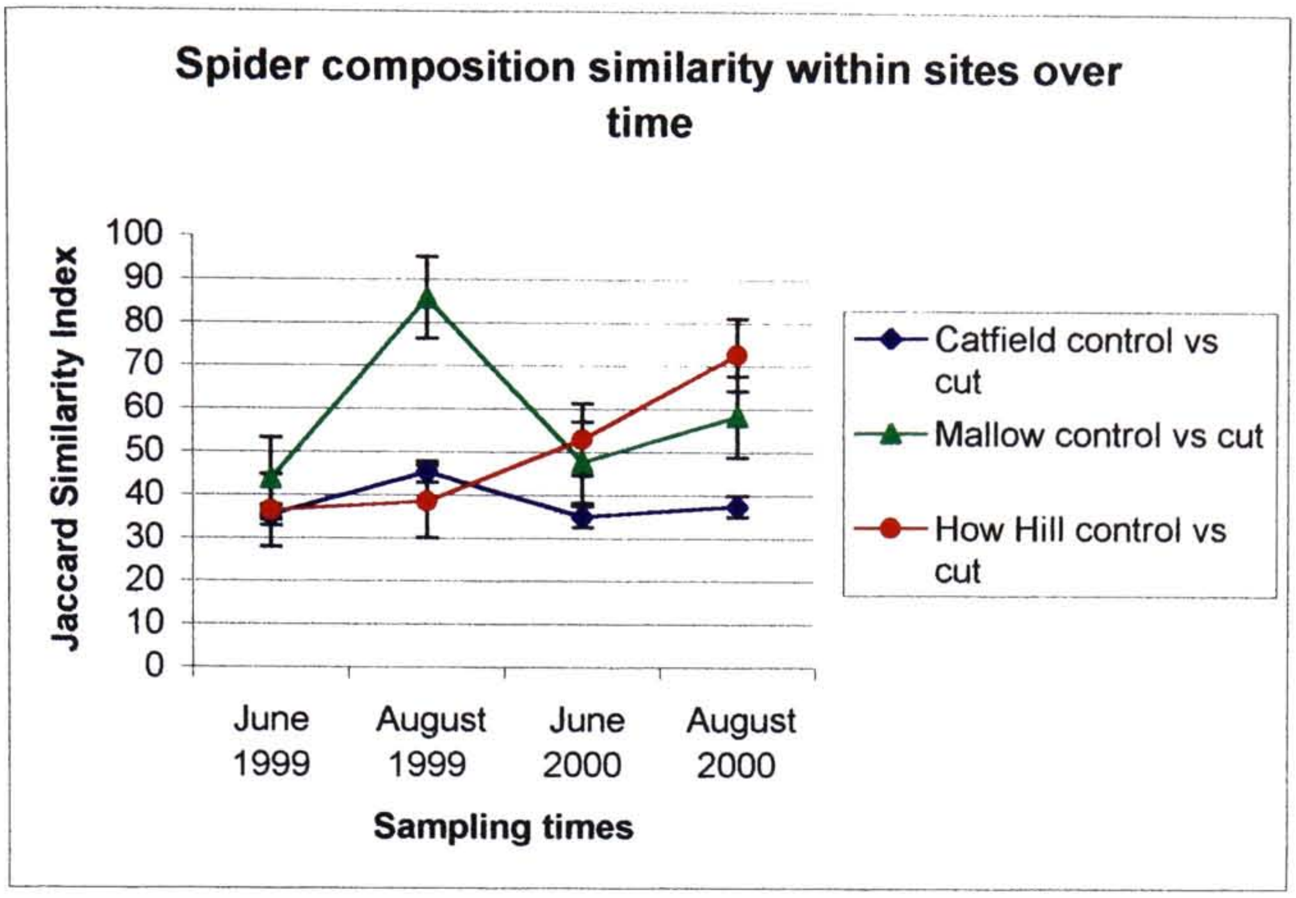


Figure 5.15 The change in the Jaccard Similarity Index within each site, over the four sampling times. Standard error bars are shown.

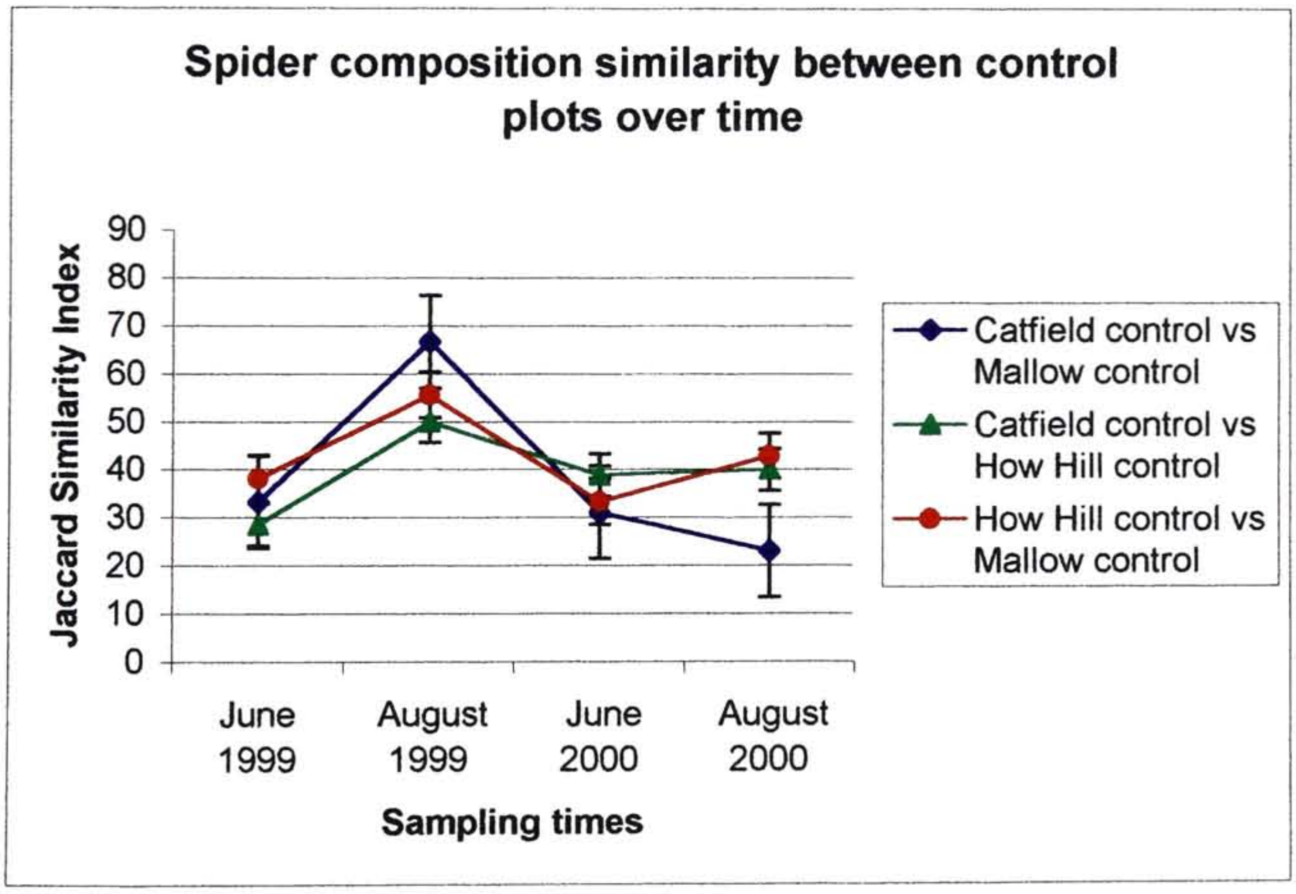


Figure 5.16 The change in the Jaccard Similarity Index between each site's control plots, over the four sampling times. Standard error bars are shown.

Using the Morisita-Horn Index of Similarity the numbers of individuals of each species can be taken into account when comparing the sites and treatments. The Morisita-Horn is fairly independent of sample size and so can be used for all but the smallest samples. The results are shown in Table 5.XII and graphically in Figures 5.17 and 5.18.

Table 5.XII The Morisita-Horn Index comparisons within and between sites.

site	spiders	Jun-99	Aug-99	Jun-00	Aug-00
Catfield control	Catfield cut	0.664	0.77	0.912	0.161
Mallow control	Mallow cut	0.795	0.174	0.574	0.416
How Hill control	How Hill cut	0.98	0.088	0.698	0.752
Catfield control	Mallow control	0.308	0.18	0.922	0.778
Catfield control	How Hill control	0.002	0.811	0.99	0.854
Mallow control	How Hill control	0.575	0.225	0.999	0.87

Similarity within sites is fairly high pre-cutting, but plummets to its lowest levels for Mallow and How Hill immediately post-cutting, before rising again. Catfield, however remains constant until August 2000 where the control and cut plots diverge. The Jaccard Similarity Index also showed Catfield holding constant, compared to the other two sites, but showed Mallow and How Hill as having quite different responses. In the Morisita-Horn analysis they appear to be tracking each other.

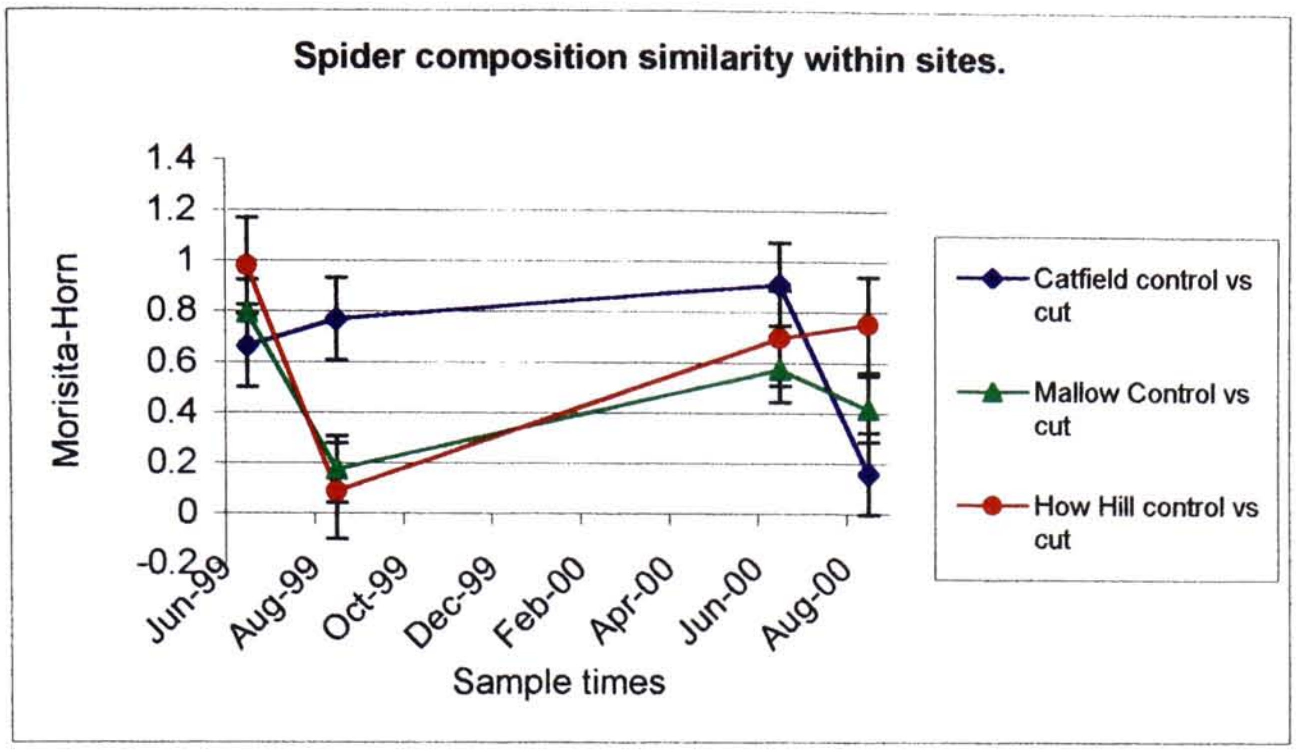


Figure 5.17 The Morisita-Horn Index showing the changes in spider community composition within sites over the sampling period.

The control plots at different sites start off independently from each other in the first year, but become surprisingly similar in the second year, after cutting. This dichotomy is not picked up by the Jaccard Similarity Index, which shows little differentiation between any of the control plots.

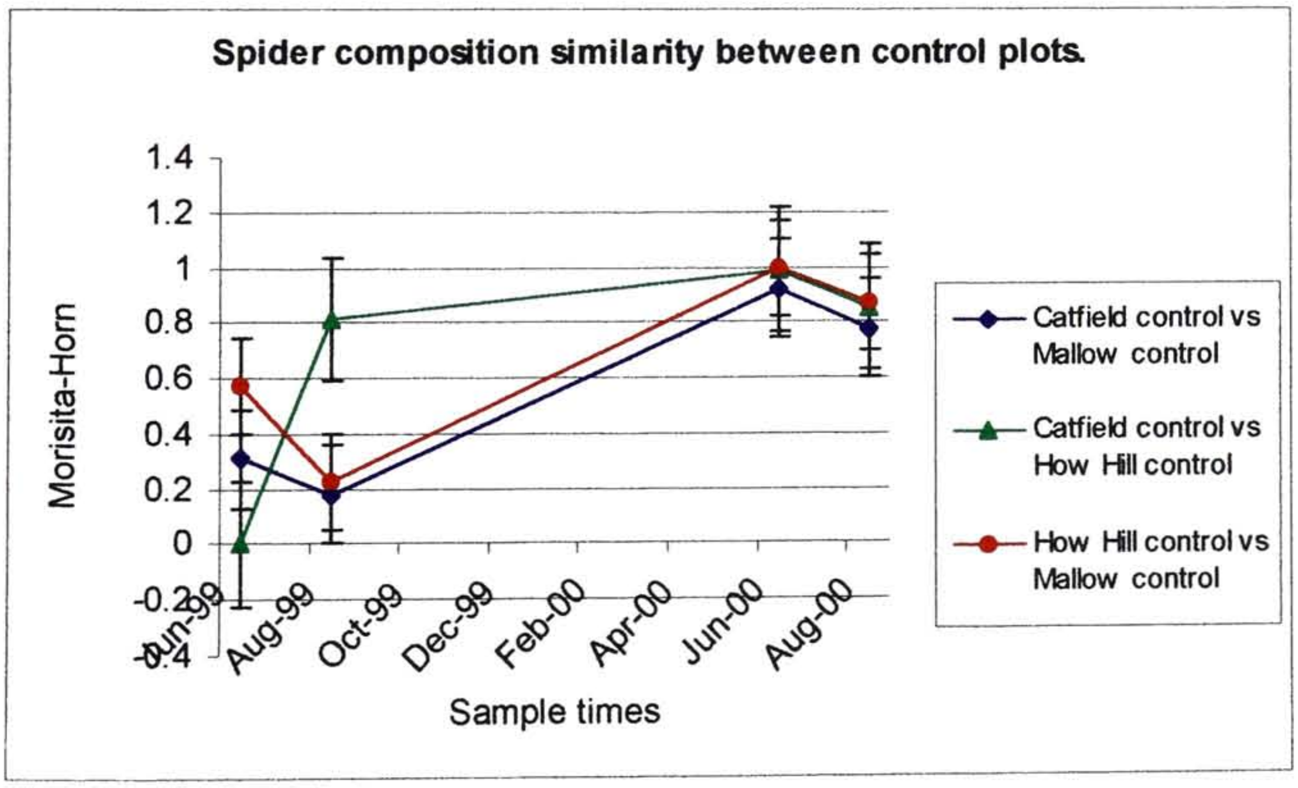


Figure 5.18 The Morisita-Horn Index showing the changes in spider community composition between control plots over time.

What are the responses of individual species to management?

Plotting the results of the Chi^2 analysis show that for individual species the effect of cutting is not uniform. All the species that had large enough sample sizes to analyse have been plotted. Figures 5.19 – 5.32 plot the numbers of individuals collected for all the species that had large enough sample sizes to analyse. The numbers of individuals of each species against sampling time for each site and treatment are presented as bar charts. The four sampling times are shown irrespective of whether sufficient data on that species had been gathered at that time. For example, *A. vidua* shows a strong presence in August, compared to June (Figure 5.19). *A. vidua* had fewer individuals in experimental plots than in control plots. *A. elegans*, shows mixed results, with no obvious trend between cut and control plots (Figure 5.20). *B. gracilis* (Figure 5.21) is slightly more common in June than August but shows a mixed response to cutting treatment.

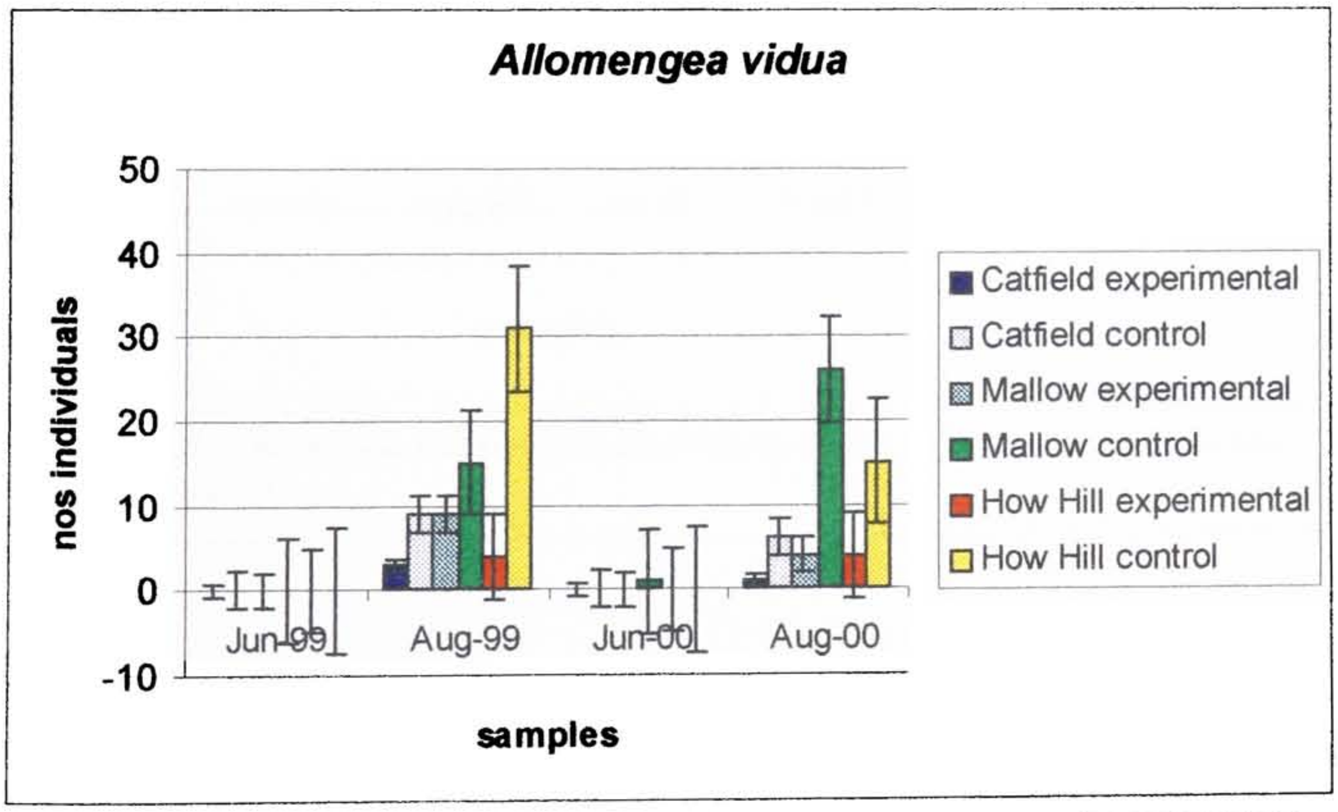


Figure 5.19 The numbers of individuals of *Allomengea vidua*. Standard error bars are shown.

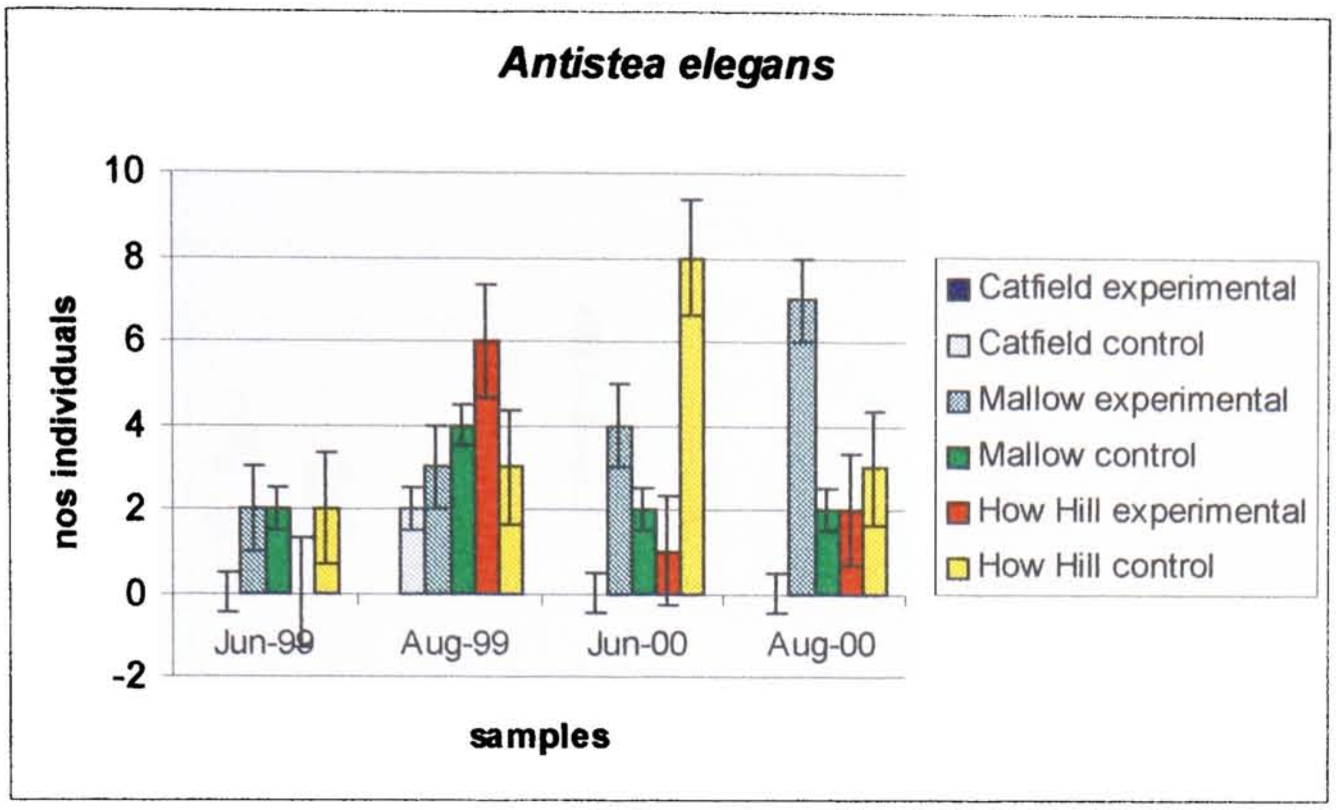


Figure 5.20 The numbers of individuals of *Antistea elegans.* Standard error bars are shown.

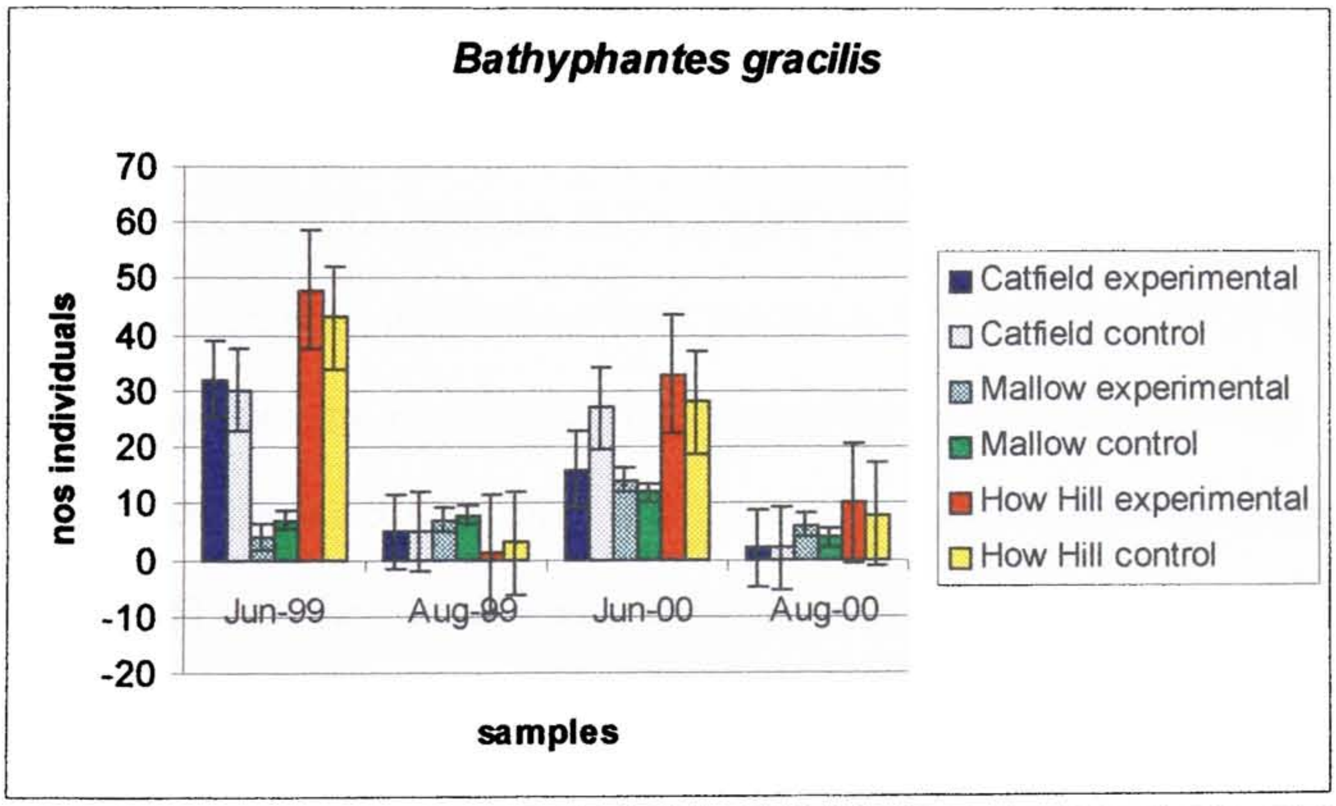


Figure 5.21 The numbers of individuals of *Bathyphantes gracilis.* Standard error bars are shown.

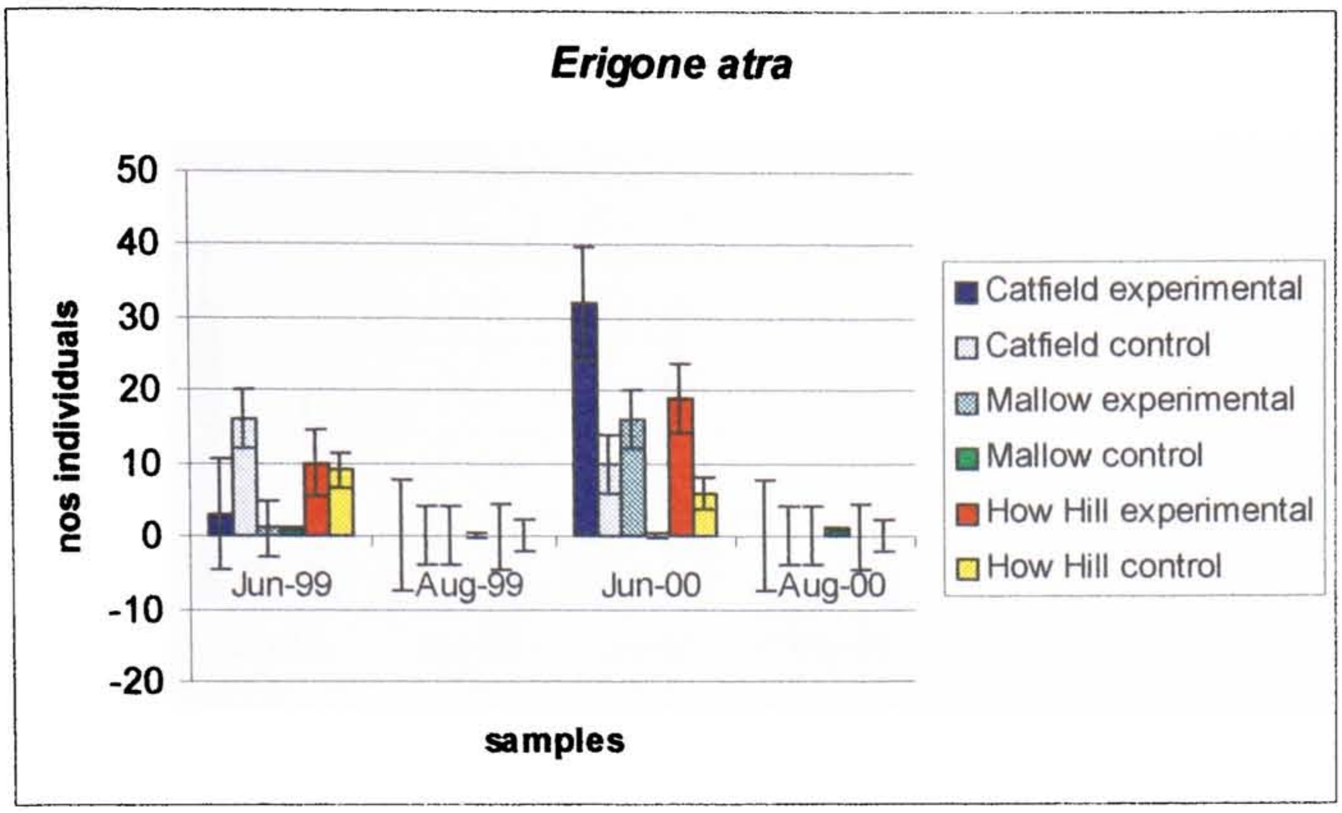


Figure 5.22 The numbers of individuals of *Erigone atra*. Standard error bars are shown.

E. atra (Figure 5.22) is strongly seasonal, occurring in June rather than August. It shows an increase in numbers where the reed has been cut, compared to the control plots. *G. dentatum* shows a significant difference pre-cutting (q.v. Chi^2, Table 5.II, page 169) in June 1999, but not in June 2000, though the trend is the same with the experimental plots producing more individuals than the control plots (Figure 5.23). *L. flavipes, L. punctatum,* and *O. gibbosus* (Figures 5.24 – 5.26) show few useful results, being only present in any numbers in June 1999, pre-cutting.

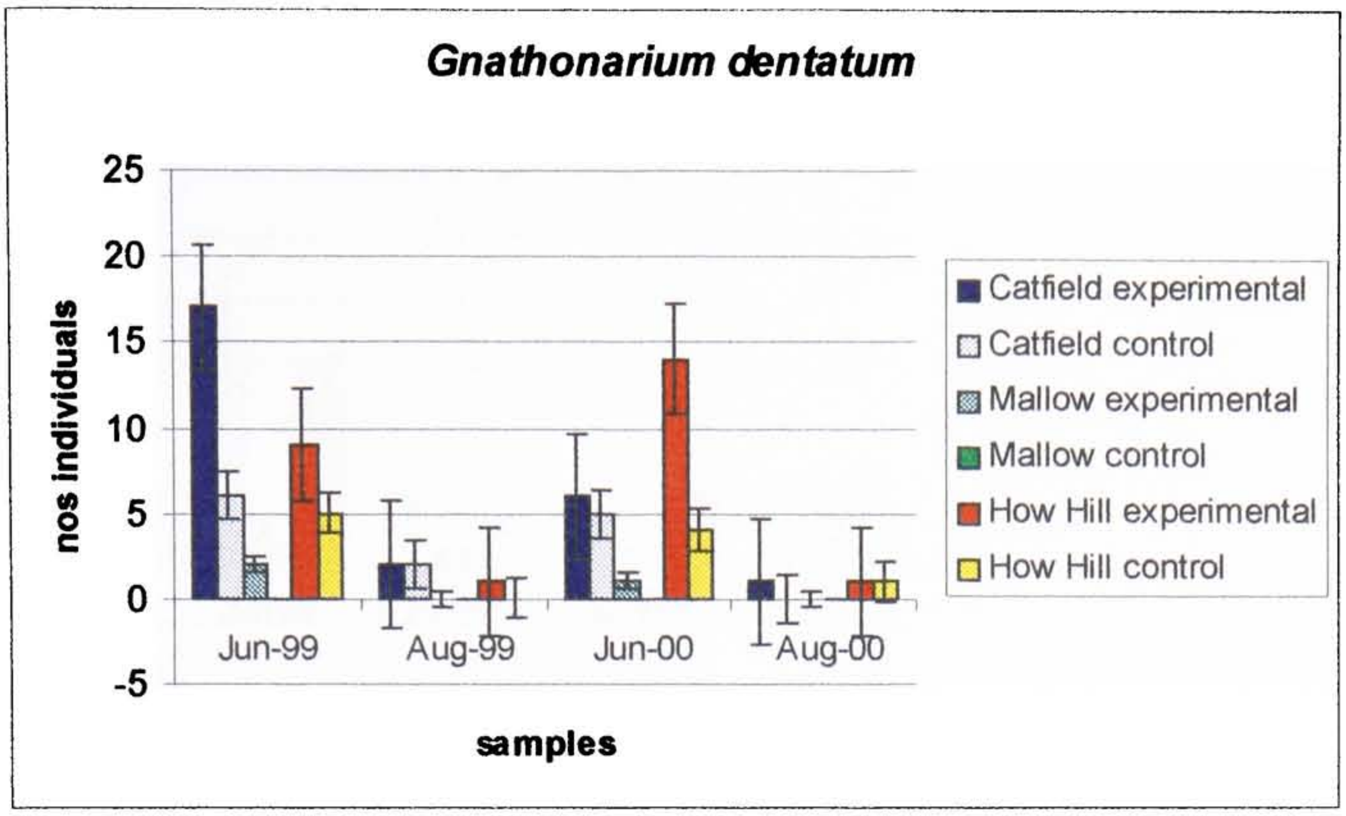


Figure 5.23 The numbers of individuals of *Gnathonarium dentatum*.

Standard error bars are shown.

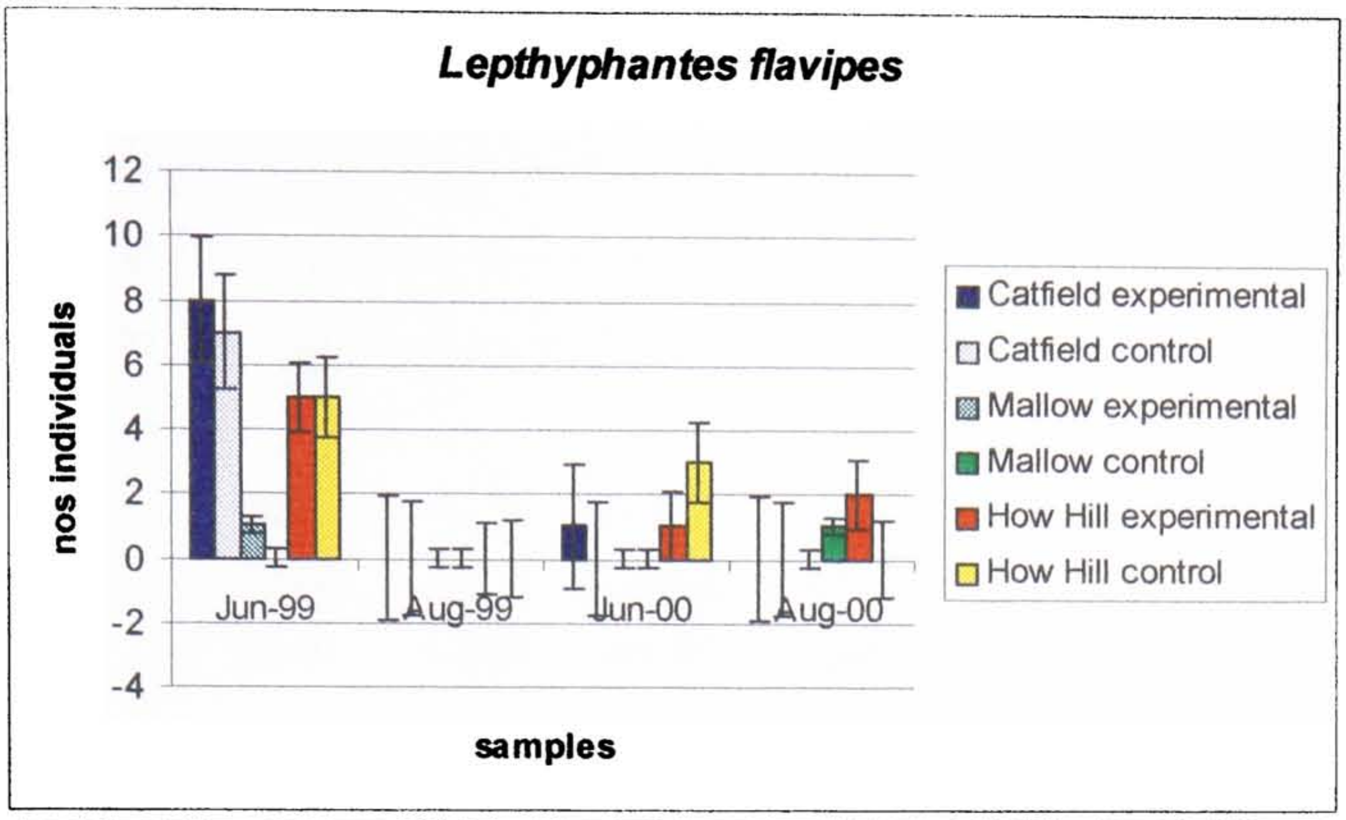


Figure 5.24 The numbers of individuals of *Lepthyphantes flavipes*. Standard error bars are shown.

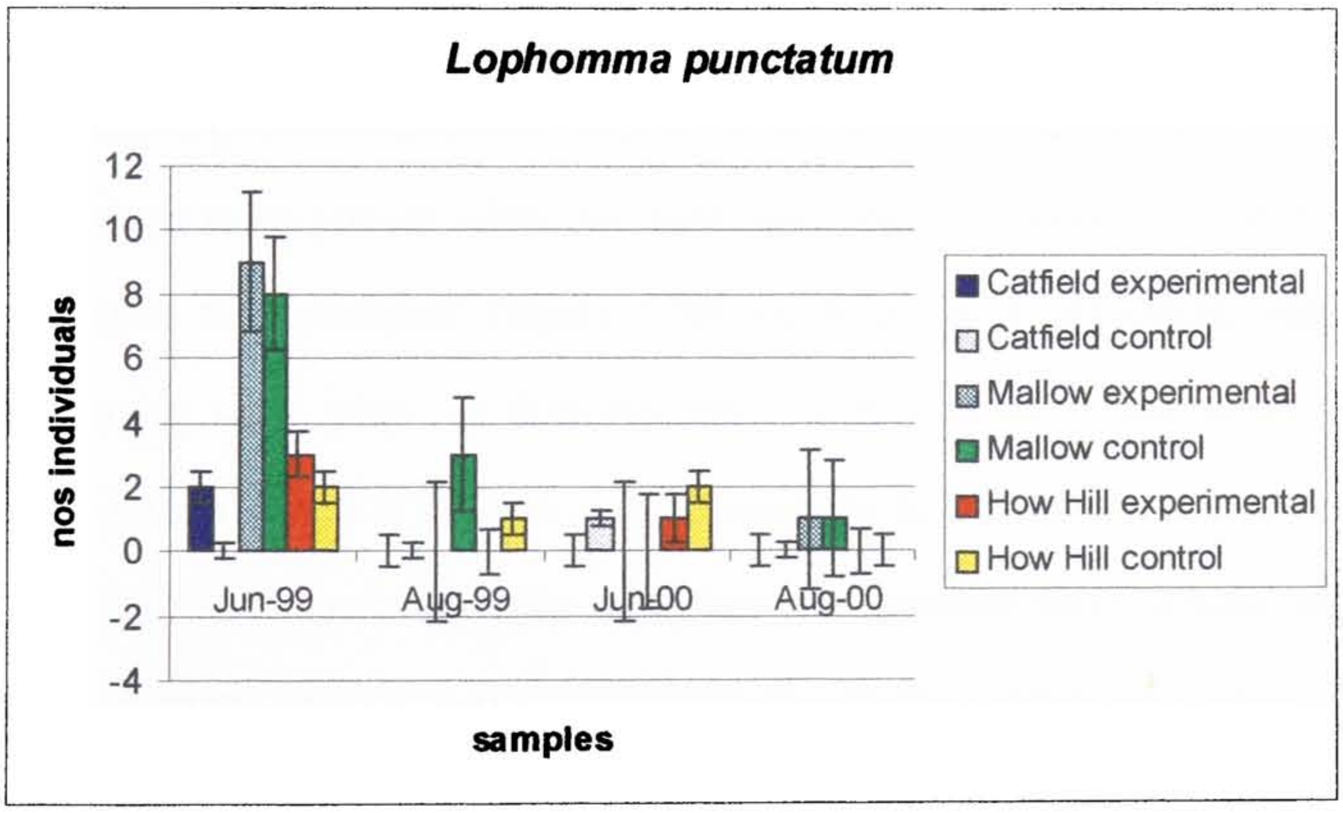


Figure 5.25 The numbers of individuals of *Lophomma punctatum*. Standard error bars are shown.

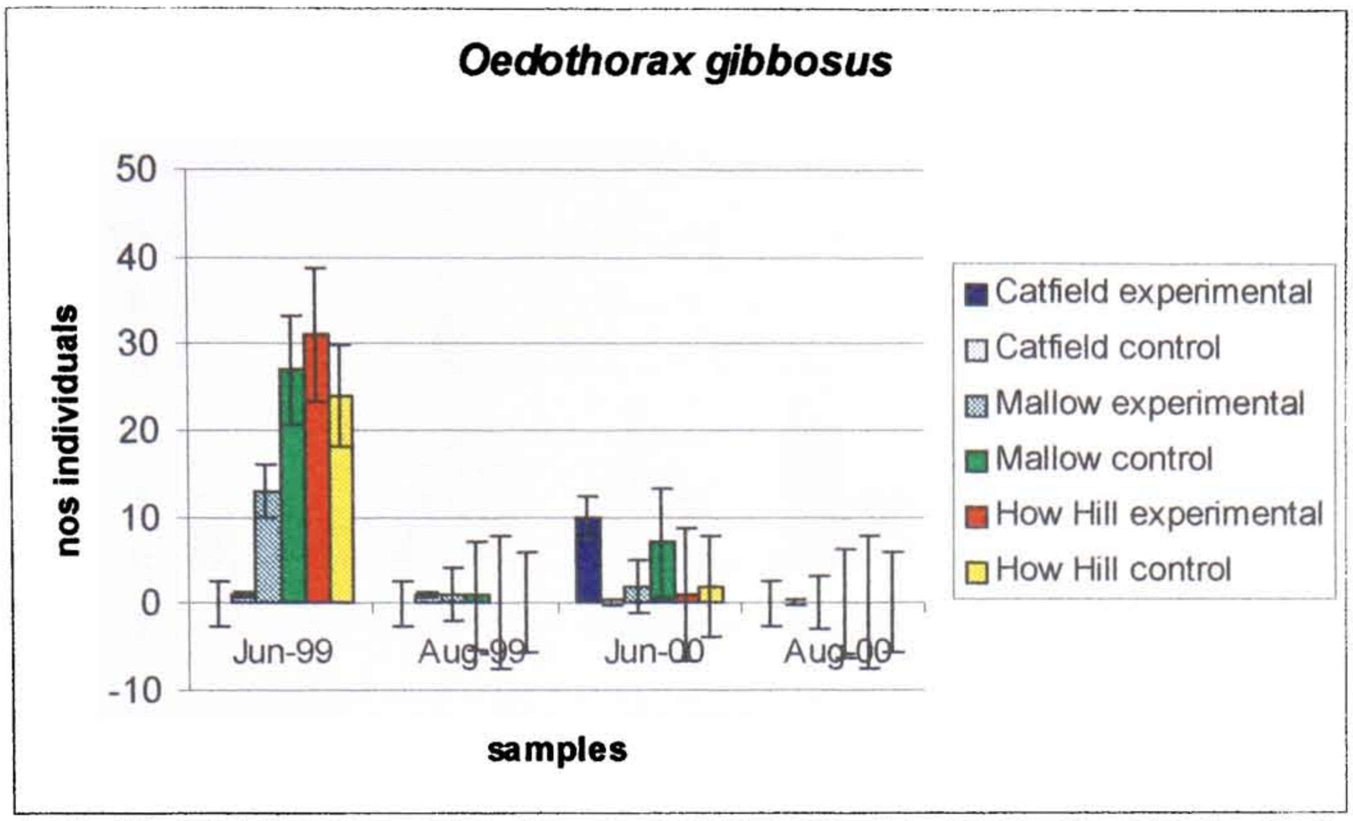


Figure 5.26 The numbers of individuals of *Oedothorax gibbosus*. Standard error bars are shown.

P. clercki (Figure 5.27) and *P. prativaga* (Figure 5.28) also shows mixed results, whereas *P. hygrophilus* (Figure 5.29) shows a strong trend for more individuals to be present where the plots have not been managed. This is in opposition to *P. piraticus*, (Figure 5.30) which has more individuals where cutting has taken place, as does the third member of the *Pirata* genus, *P. piscatorius* (Figure 5.31), which is only present in 2000. *P. pallidium*, (Figure 5.32) is present in small numbers throughout the sampling times, notably only found on control plots in August 1999 but in insufficient numbers to analyse.

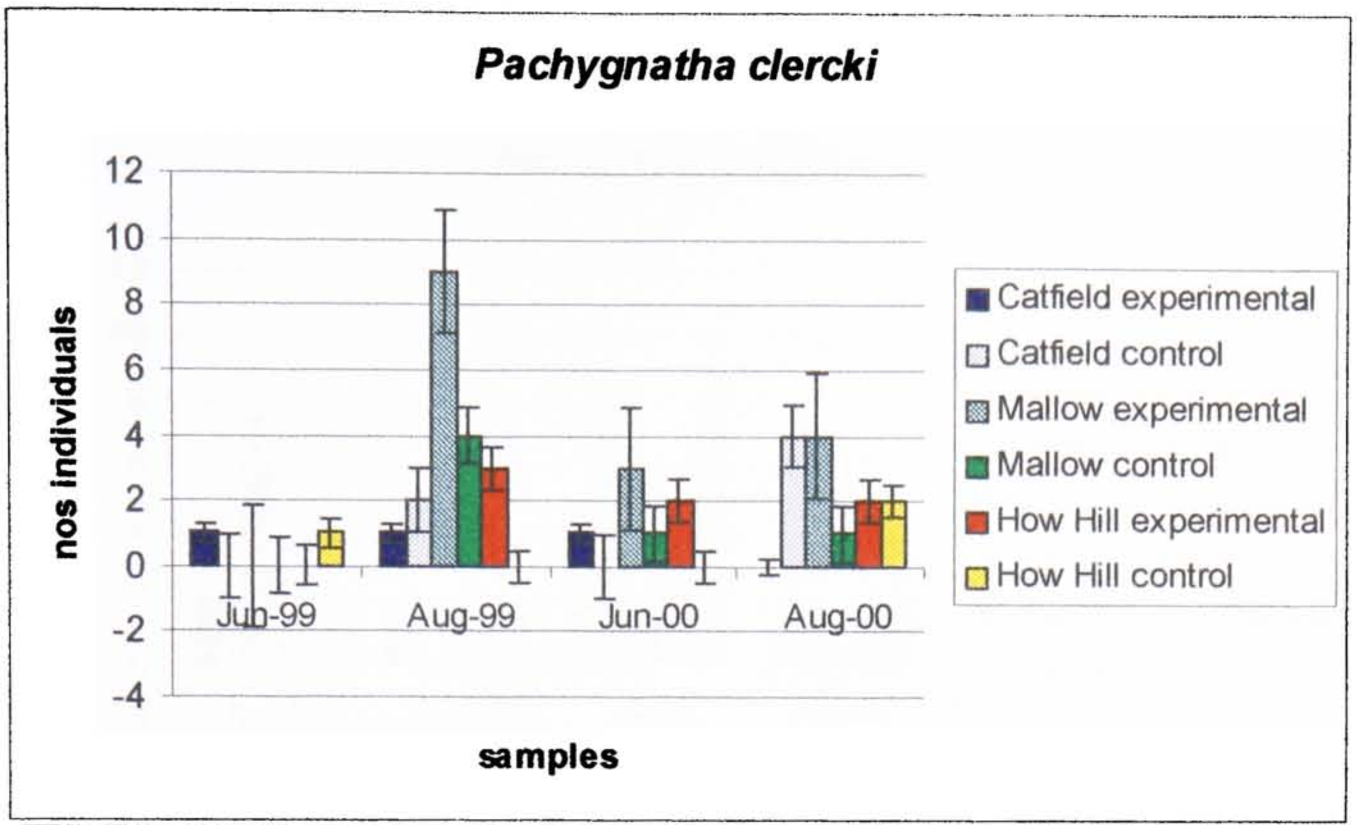


Figure 5.27 The numbers of individuals of *Pachygnatha clercki*. Standard error bars are shown.

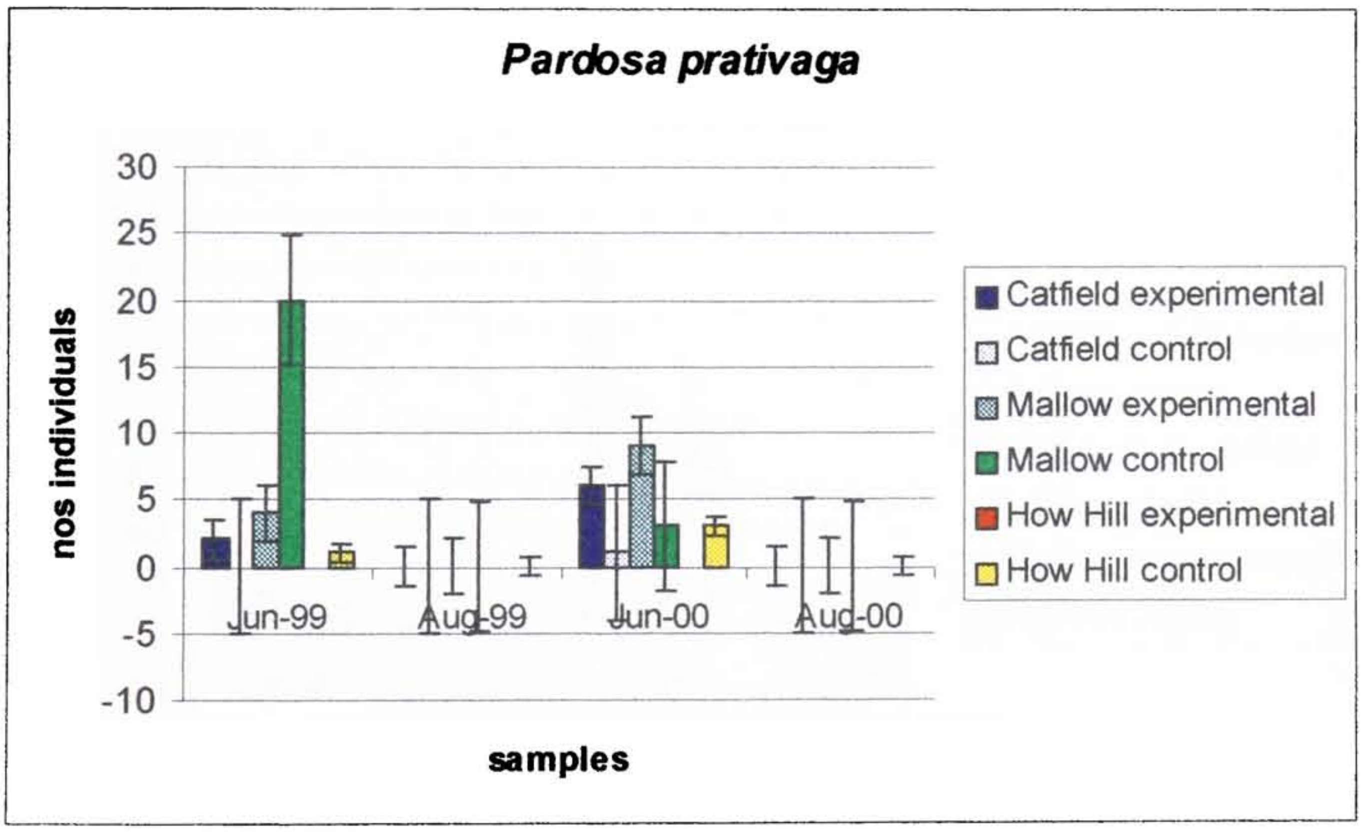


Figure 5.28 The numbers of individuals of *Pardosa prativaga*. Standard error bars are shown.

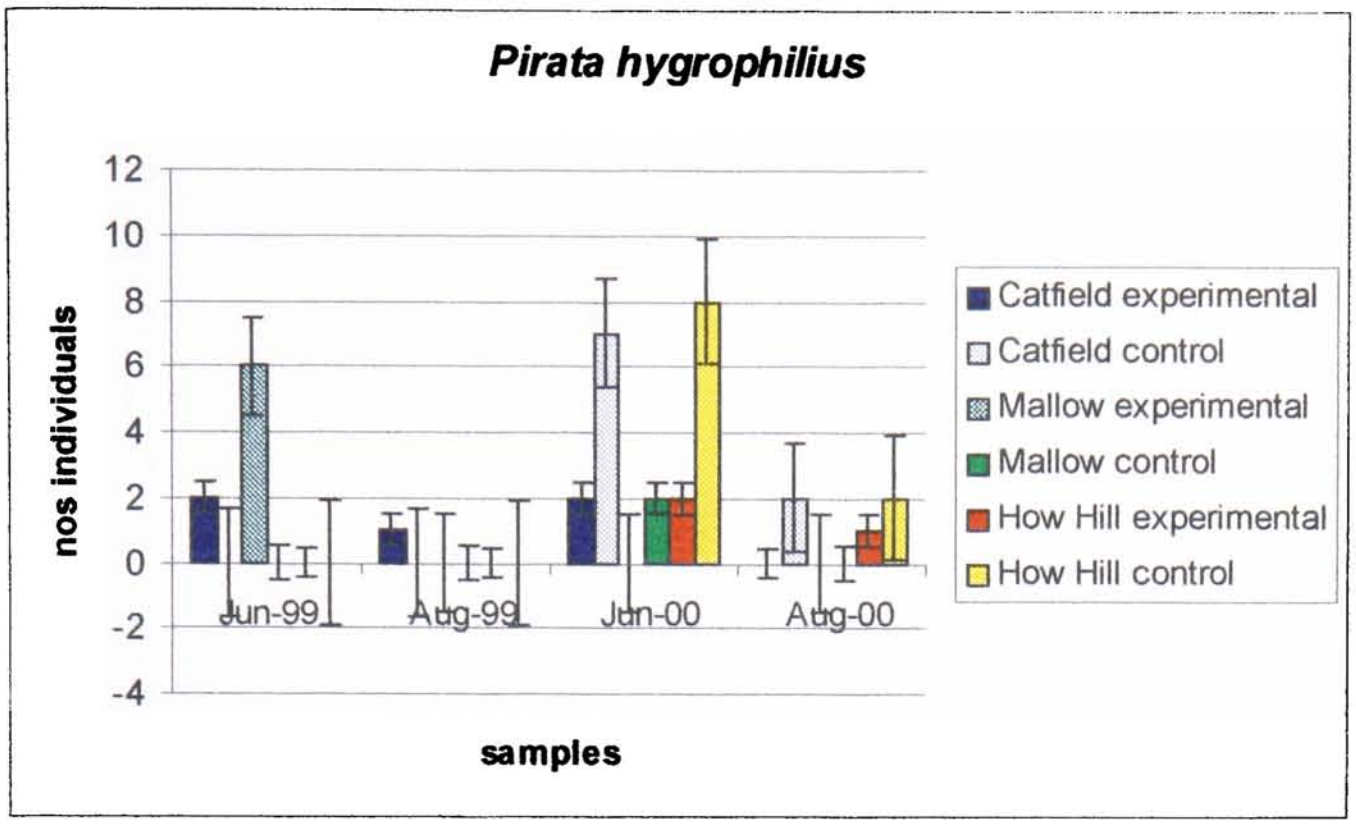


Figure 5.29 The numbers of individuals of *Pirata hygrophilus.* Standard error bars are shown.

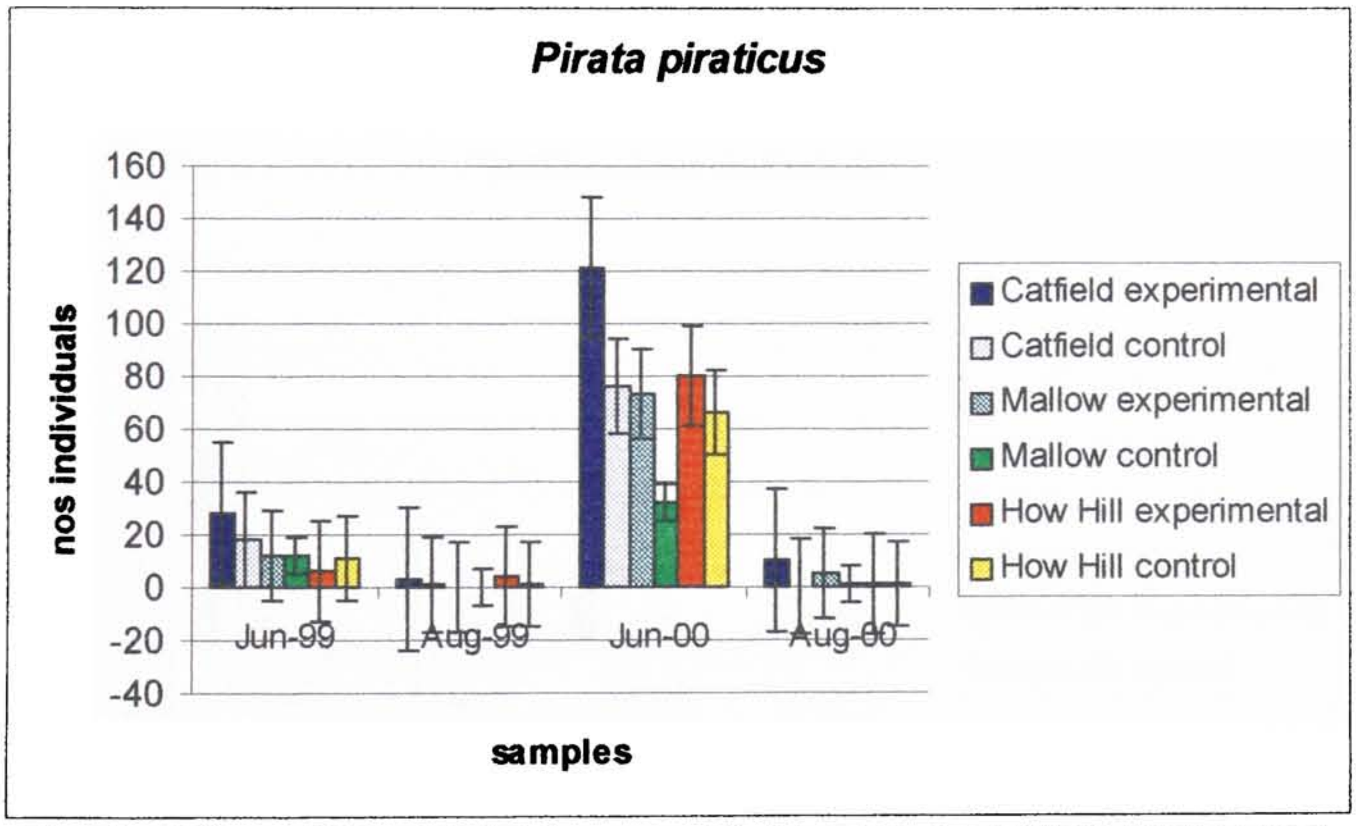


Figure 5.30 The numbers of individuals of *Pirata piraticus.* Standard error bars are shown.

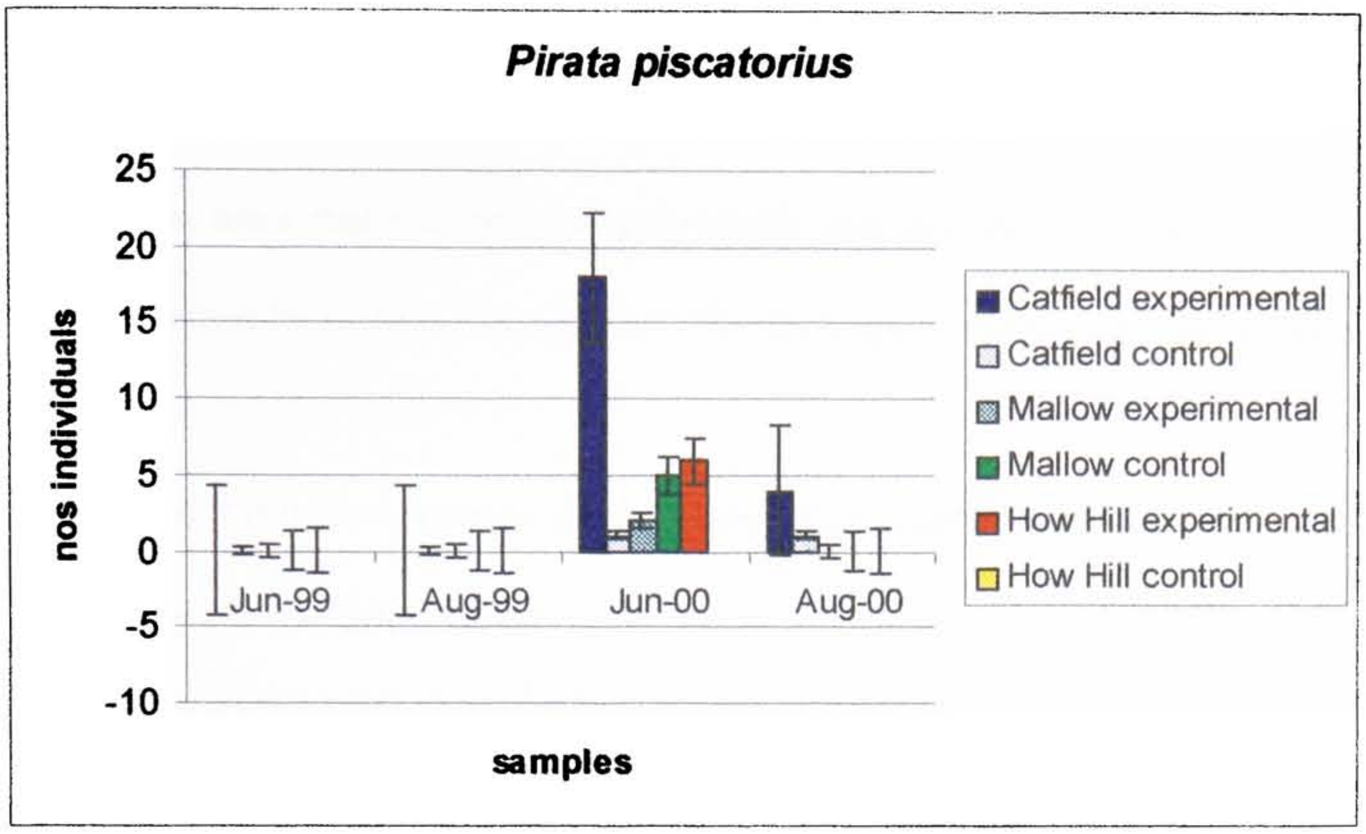


Figure 5.31 The numbers of individuals of *Pirata piscatorius*. Standard error bars are shown.

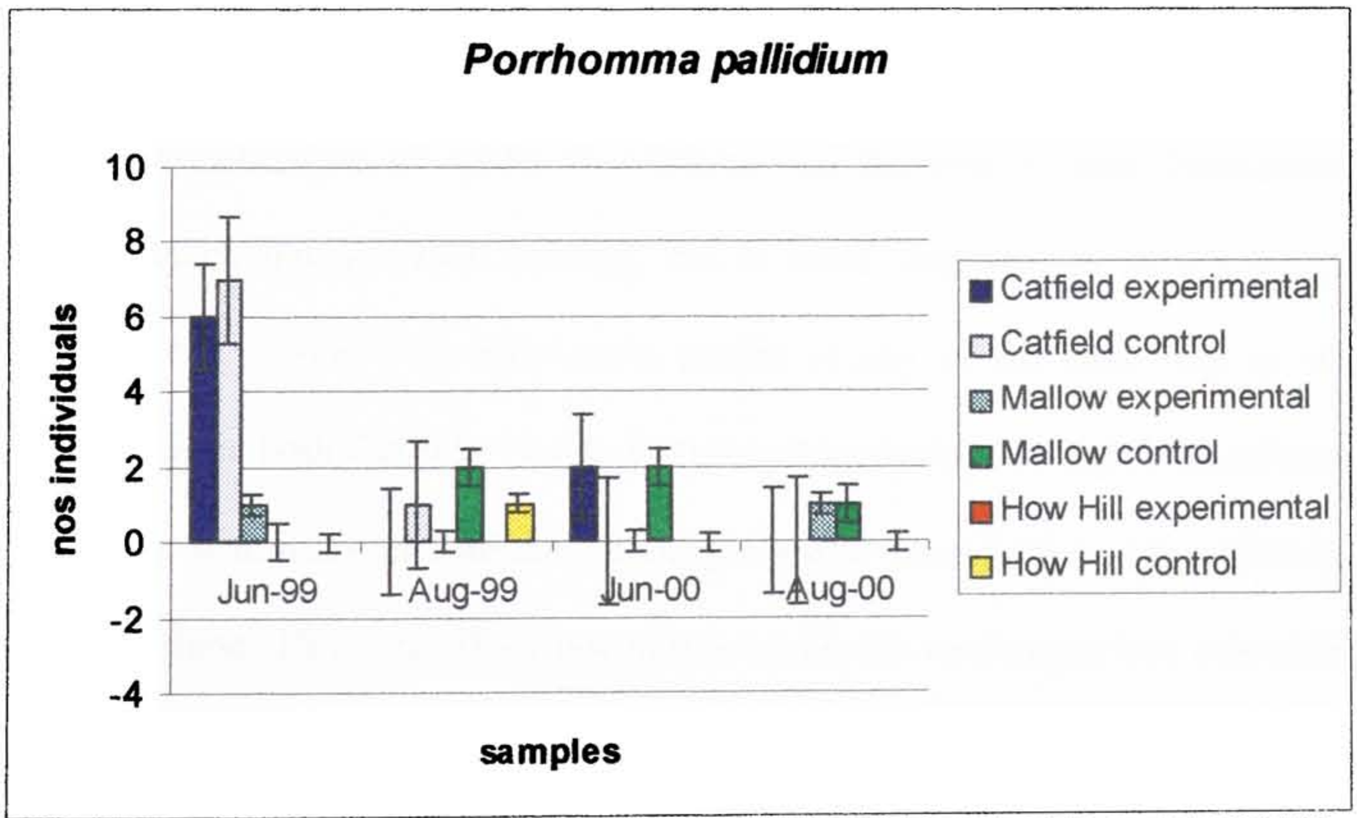


Figure 5.32 The numbers of individuals of *Porrhomma pallidium*. Standard error bars are shown.

5.8 Discussion

The hypothesis stated that Araneae are not management sensitive. The predictions were that numbers of individuals, and species composition would not be affected by habitat management. For the majority of species, this appears to be true.

Is there a difference between the numbers of individual spiders found on cut and control plots at each site?

Prior to experimental treatment there was no significant difference between the numbers of individuals on cut or control plots at any of the sites. Changes after treatment, all things being equal, must therefore be attributable either to the passage of time or to treatment. It was assumed that the influence of time and therefore season would be the same at each plot, and so the experimental treatment should be the cause of changes between cut and uncut plots.

The seasonal nature of spider populations and the year to year fluctuations must be taken into account. Bearing this in mind, cutting had no immediate effect on the numbers of individuals caught at any of the sites, but by the following June both Catfield Fen and Mallow Marsh showed highly significant differences with more individuals on cut plots than control plots. How Hill did not show these. How Hill does not however remain unchanged but statistical analysis grouping all the species together shows that gains and losses of different species on different treatments cancel each other out, leading to the non-significant result.

The August 2000 sampling shows that Catfield cut and control plots were no longer significantly different and that possibly recovery had taken place.

Mallow does not show this type of recovery, and this could be due to the vegetation differences between these two sites, or differences in the extent of flooding. The flooding of the pitfall traps for the August 2000 sampling makes the results here somewhat unreliable at the finer scale, though sites should be comparable with each other at this time nonetheless.

Johnson (1995a, 1996) describes some of the seasonality of spiders, finding diversity and density to peak around August. My findings contradict this, with nearly twice as many species recorded in June compared to August in both years (June 1999, 34 species; August 1999, 17 species; June 2000, 35 species; August 2000, 18 species – Table 5.I). Species level data is needed as it gives resolution at a finer scale (Davies and Margules 1998, Meyer *et al* 1995, Panzer and Schwartz 1998, van Jaarsveld *et al* 1998, Wettstein and Schmid 1999).

Species level studies show more disturbance effects and longer lasting effects than higher taxon studies (see assessment by Prance 1994). Recovery time for species level changes are longer, and species data can discern disturbance effects long after order level changes have returned to pre-disturbance levels. Recovery times after disturbance range from indiscernible the following year (e.g. Ditlhogo *et al* 1992) to still apparent after three to four years (e.g. York 1999). In this study changes are still apparent after two years at least at the species level, but less so at when the spider fauna is analysed together at the higher taxon level.

Is there a difference between the numbers of individuals of each species of spider found in cut and control plots at each site?

Prior to cutting only *Pardosa prativaga* is significant using Chi^2. It does not show significance after treatment, and significance may therefore be attributable to random population fluctuations. *P. prativaga* shows a significant difference due to seasonal variations (GLM analysis) but not due to treatment. A further eight species, numerous enough to analyse using Chi^2 in June 1999, show no significant difference pre-cutting. This shows a baseline even spread of species across the plots, suitable for study. The second sampling shows little change. *Allomengea vidua* (RDB local) is highly significant, and remains so one year on.

This is a possible candidate for an August wetland disturbance indicator species, being consistently more numerous in undisturbed plots, than in treated plots. It is however virtually absent from the environment in June, but GLM analysis of this species shows no significant differences in numbers due to seasonal fluctuations, treatment and an interaction of the two after applying a Bonferroni correction.

Pirata piraticus (RDB local –Appendix 5.2) is found to be significantly (using Chi^2) more numerous in the treated plots in both June and August 2000, and could be considered a wetland disturbance indicator species with a slightly longer useful activity period for habitat assessment. However it has a seasonal distribution and the GLM analysis showed no significant response to treatment or to an interaction of treatment and seasonal fluctuations. It is also not as clear cut as *A. vidua*.

The other June species that showed a significant response to the treatment were *Erigone atra, Pirata piscatorius* (RDB local) and *Pirata hygrophilus*. *E. atra* is the only species which continues to show a response to treatment*season after the application of the Bonferroni correction. *E. atra* does consistently better where the plots have been cut, whereas *P. hygrophilus* does not respond well to such disturbance. *E. atra* has a very clear positive response to cutting, and could be a successful wetland disturbance indicator species for June. The GLM analysis for *E. atra* showed a strong interaction between sample date and treatment, but that treatment on its own was not enough to produce a significant result. *P. hygrophilus* was only significant due to seasonal fluctuations before the Bonferroni correction.

Porrhomma pallidium was collected in insufficient numbers to analyse, however it was only collected from unmanaged plots in the sampling immediately following cutting. The GLM analysis suggested that this was due only to seasonal variation, not treatment. However where this species is more numerous it may well be an indicator species and care should be taken when managing an area to ensure refuges where this species can survive to recolonise post-management. The immature spiderlings, when grouped together in a multispecies class, showed a response to both time of year and an interaction between treatment and time of year.

The species ordinations show that spiders with a preference for undisturbed sites can be separated from those with a preference for disturbed sites using Decorana. Species which associate with species showing an analysable preference (Chi^2) for undisturbed areas include *Bathyphantes parvulus* and *Pardosa pullata*, neither of which was collected at a frequency allowing analysis. Further study would confirm whether these species suffer when cutting management is applied in their habitat. This initial study suggests that they may.

Interestingly, one species that associates loosely with species preferring unmanaged plots is *Clubiona phragmites*. This species is the only one which shows a difference in numbers (using GLM analysis) on management alone (as opposed to seasonal variation or a combination of the two). After the Bonferroni correction this was shown not to be significant, however.

What are the responses of individual species to management?

Spiders are mobile and invasive. Some species (e.g. *Erigone dentipalpes*, *Erigone atra, Oedothorax fuscus*, *Xysticus cristatus*) are invasive pioneers, whereas others are conservative. Knowing the autecology is an essential tool in interpreting the results. Few individual species have been studied in ecological depth in this environment and higher taxon generalizations are not accurate.

The life history of *Clubiona phragmites* shows it may initially respond well to management as it prefers emergent vegetation near standing water. However it requires *Phragmites* leaves to build a silken cocoon where it lays its eggs. Females can sometimes be seen guarding this. The complete destruction and removal of reed during cutting is likely to impact adversely on this species, at least in the short term. Only four specimens were collected of this species, and they were all in control plots.

Three of the species of *Pirata* collected in this study (*P. hygrophilus, P. piraticus and P. piscatorius*) showed both significant positive and negative responses to management. *P. hygrophilus* is not usually found near open water and this was the only *Pirata* species to prefer control plots. The other two *Pirata* species preferred managed plots. *P. piraticus* uses undergrowth to ambush prey (as is likely do most Lycosids), however it may be found in the open, which could explain its preference for managed plots.

Similarly *P. piscatorius* is an ambush predator, but this species builds a hide in moss to ambush prey from. This species requires standing water, and this could explain why it does well in managed plots, where *P. hygrophilus* avoids them. The action of cutting reed leaves wide spaces of open ground covered in reed litter, with pools of standing water, but little vegetation cover, for the remainder of the year following cutting.

Erigone atra is found most frequently in managed plots. This is a ubiquitous species capable of invading new areas quickly as an aeronaut. It requires low vegetation, as found in cut plots. There may however be a very simple explanation for the capture rate for this species. As a frequent aeronaut, found in many environments, this species could be ballooning in from surrounding areas, and even from vegetation on the control plots. In managed plots this spider would be more likely to be at ground level and to therefore be captured in the pitfall traps than if it ballooned into a control plot and landed on vegetation which could be over 2m tall. Further study is needed to assess ballooning probabilities.

In other studies Abensperg-Traun *et al* (1996) note that trampling and grazing affects lycosid spiders far less than mygalomorph spiders as the latter build deep permanent burrows, susceptible to trampling, whereas lycosids do not. McFerran *et al* (1994) showed grazing, and the corresponding change in structural architecture of the plant community, leads to an increase in disturbed habitat spider species, and an increase in colonizer species (e.g. many erigonine species).

Certain spiders are more often found in wetland habitats. Characteristic hygrophilous spiders include *Antistea elegans*, which has been suggested as an indicator species to monitor hydrological changes in bogs (Schikora 1994). The results of this study showed *A. elegans* gave a mixed response to treatment.

Mixed responses were also shown by *B. gracilis, L. flavipes, L. punctatum, O. gibbosus, P. clercki,* and *P. pallidium. Pirata piscatorius* was not present in 1999, which suggests strong population fluctuations from year to year. Most of the spider species found in this study are either hygrophilous or catholic, and therefore typical of wetlands.

Notable A [RDB] list spiders found in this study include *Hypomma fulvum* (Amber fen money spider), and *Donacochara speciosa* (Slender-palped fen money spider), both of which were found in Norfolk by Shardlow (1996) and *Entelecara omissa* (Appendix 5.2). *Hypomma fulvum* was recorded at all three sites, at Catfield and Mallow Marsh only pre-cutting, and at How Hill both pre- and post-cutting. Post-cutting it was found only in one plot, and this plot had been cut. This shows that *H. fulvum* is not eliminated from the environment by management of this sort.

Donacochara speciosa was recorded only at How Hill. One specimen pre-cutting and one post-cutting in a cut plot. Similarly to *H. fulvum, D. speciosa* is not eliminated from the environment by this sort of management.

Entelecara omissa was only recorded from Catfield Fen in a control plot. This species is often found in *Carex* tussocks, and these are present at Catfield, but not at the other two sites. Cutting with the fen harvester would be detrimental to this species because of the damage caused to the *Carex* tussocks. In this study the plots at Catfield Fen were cut by hand.

The RDB2 nationally vulnerable spider *Clubiona juvenis*, is a wetland spider found well established in the Broads. This spider probably has two generations a year. All three specimens of this species in this study were collected at Catfield, (it has been previously recorded from this fen), one pre-cutting, one in a cut plot and one in a control plot. Though hard to draw conclusions from such small sample sizes it tentatively indicates that management does not eliminate this spider from managed areas.

This is good news as the threats to this species, and the Notable A species collected in this study, include scrub encroachment. Cutting the fen would therefore be an appropriate management tool to keep areas clear of scrub, and the management itself should not affect these spiders. A longer term study of effects of management on rare species at these sites is recommended.

Is there a difference between the composition of spiders at each site, and between the different management treatments?

Indirect ordination techniques, such as PCA and Decorana (Hill 1979a) or Twinspan (Hill 1979b) have been able to easily separate habitats using multivariate species data. Studies using these techniques include those of Arnold and Ormerod (1997), Davies *et al* (1996), Debinski and Brussard (1994), Garono *et al* (www), Kurashov *et al* (1996), Tikkanen *et al* (1997), Wheater *et al* (2000) and many others. Decorana is the statistical tool of preference for this study, as it does not need information about the environment and habitat prior to ordination (Davies *et al* 1996), and so allows the species to speak for themselves. Environmental factors have been taken into account by plotting the vegetation ordination against the species ordinations in the form of a biplot (Wheater *et al* 2000) allowing the effect of the vegetation to be clearly seen.

The biplot illustrates that the vegetation at Catfield is different to that at How Hill and Mallow Marsh. This is reflected in the NVC classification , where How Hill and Mallow Marsh are typical S4 *Phragmites australis* reedbed, whereas Catfield is more S24 mixed reed fen. Post-cutting the differences in the vegetation communities are less obvious.

Before disturbance the spiders ordinate into clear site groups, with the exception of just one How Hill plot, which falls in with the Catfield point. This plot is vegetationally typical of How Hill, but has a spider community closer to Catfield. The ordination structure changes after cutting, but the sites are still grouped, with Mallow showing the least variation, Catfield having wider variation, but incorporating that shown by Mallow, and How Hill being the most diverse, and incorporating most of the diversity of the other two sites.

This indicates that the habitat differences between sites are more important than management practices, at least in the short term. There does not appear to be a management trend for Catfield or Mallow Marsh, but there does appear to be a subtle effect discernable at How Hill using Decorana. This is interesting as the Chi squared and bar chart analyses did not pick up any changes at How Hill, nor at any site in the year of the experimental treatment.

Even by the following June the sites show no clear management trend. Again when the vegetation is taken into account the groups overlap but can still be discerned, showing the spider fauna is getting more similar and homogenous than prior to disturbance. All sites are very similar in diversity and variation. The effect of the pitfall traps flooding is clearly seen in the poorly defined August 2000 results. Even taking the vegetation into account fails to fully separate the sites, let alone tease out the effect of management.

How diverse are the plots in terms of spider species composition, taking both number of species and relative abundance into account? How does this change over the sampling time?

The range in diversity amongst the plots in terms of spider species richness is not particularly large and the plots therefore yield similar levels of diversity for spider species richness. At each sampling time the highest diversity, as measured by the Simpson Diversity Index (D) was found in control plots, except in June 2000, and the lowest diversity in cut plots, except in August 2000, though with great overlap in possible D scores.

Managing the fen by cutting appears to decrease the apparent diversity of spiders, however GLM testing showed no significant difference between plots with respect to management, yearly fluctuations or interaction, so this apparent trend is not backed up statistically. The Simpson Diversity Index (Norris 1999) is relatively insensitive to sample size, which is an advantage in this study, where catch sizes vary between seasons, sites and weather conditions. Note again that the August 2000 results may be poor, due to flooding of the pitfall traps.

Average diversity did not change from year to year, but each plot's individual score fluctuated markedly with year, season and treatment. Within site similarity still appears to be higher in the majority of cases than between site similarity, or equal treatment similarity. Management appears to be a less strong influence than the history of the site, but greater sampling effort might lead to clearer results

The Simpson Index (Begon *et al* 1990) does not highlight the diversity changes shown in the Chi^2 analyses. However a shift in species composition doesn't necessarily change the composite diversity for a plot (Petterson 1996). This shows how different species assemblages can give the same biodiversity measure when analysed this way. The complexity of biodiversity is not fully picked up by the Simpson Diversity Index.

How similar are the plots, in terms of species composition? How similar are they to themselves one year on?

There is a subtle trend in management here. The pre-cutting data shows the highest limit of similarity with undisturbed plots one year on (of 80%). The cut plots sampled in August have less (<67%) similarity with the same plots one year on, but the undisturbed plots have the least (<50%) similarity. This indicates that management could be causing the managed plots to exhibit similar, possibly depauperate, communities of those hardy and pioneer spiders that do well after disturbance.

The comparison between control and treatment plots before and after cutting shows that they are becoming if anything more similar, within sites. This may be due to a decrease in variation, thus leading to an increase in similarity, however this is not obviously reflected in the majority of the Simpson Index results if so. Testing of the results (Mann Witney U test) showed that there is no significant difference in similarity between plots from June to June, or August to August 1999 to 2000.

Using the Jaccard Similarity Index (Southwood 1978), before cutting the within site similarity is not greater than the between site similarity, and the variation in similarity is fairly small. There is a seasonal shift in the values, with the August range being more variable than the June samples. By the final sampling the within site similarity is greater than the between site similarity indicating that the historical element to a site is more important than the management in terms of what determines species presence and absence.

Management does not appear to have a strong affect on within site similarity, in terms of spider species composition, though there does appear to be some slight seasonal fluctuation with all control plots more similar to each other in August 1999, and less in June 2000.

Comparing control plots each other shows that before cutting there is little difference between any comparison. After cutting the control plots tend to be more similar to each other than to the cut plots, at least for August 1999, but this trend is not continued, and by August 2000 the sites are more similar to each other than the control plots are to each other.

This indicates that management has an initial effect, immediately following cutting, but that by the following year these differences in presence or absence of species have become negligible. This indicates some sort of recovery, although the Jaccard Similarity Index does not take numbers of individuals into account.

The Morisita-Horn Index, on the other hand does include the numbers of individuals. Like the Jaccard Similarity Index the Morisita-Horn indicates that management has an initial effect, particularly at Mallow Marsh and How Hill, but less so at Catfield, followed by a return almost to pre-management levels of similarity. This does point at a very short term dip in the levels of diversity and numbers of individuals, but also at an inherent buoyancy in the populations to be able to return to almost pre-management levels within a year.

5.9 Conclusions

Spiders are not management sensitive as shown by this study. The hypothesis is shown to be true. The prediction that numbers of individuals would not increase or decrease following management was shown to be correct. Only *Erigone atra*, a notorious ballooner, showed a significant increase in the managed plots compared to the control plots. As the material was collected using pitfall traps it seems likely that this increase was at least partially due to an increased capture rate thanks to the increased motility on plots without tall standing vegetation. Whilst other spiders showed small rises or falls in the numbers of individuals, no increase or decrease was significantly large to be picked up by the GLM analysis.

The further prediction that there would be no change in population diversity following management is also shown to be correct. There are subtle differences, but no major changes in the biodiversity or similarity of the plots and sites as measured in this study.

It is clear that there is a strong historical element to environmental management. Even with drastic habitat management the habitat appears to be able to recover very quickly. The habitats surveyed here bounce back in terms of diversity to near pre-management levels, by the following year. It would be expected that the recovery would continue, and within a short space of time (a few years) it would be difficult to ascertain, without prior knowledge, whether a fen had been cut recently or not (discounting scrub regrowth). What lives in an environment tends to stay in the habitat, and even seemingly major disruptions are not likely to change much (Wheater *et al* 2000).

The community composition does change initially with management. Cutting increases the proportion of *E. atra*, *P. piraticus*, *P. piscatorius* and possibly *P. clercki*, and *P. pallidium* whilst decreasing the proportion of *A. vidua* and *P. hygrophilus* in the community. Some of these are pioneer species, taking advantage of the changes, (e.g. possibly *Erigone atra*) and these would be expected to fall in numbers as slower colonisers, but better competitors, move in to the new habitat, and as the later succession reed re-establishes. The habitat complexity will start to increase once again as the reed regrows and old growth reed becomes available for overwintering, nests and refuges, for example, and this will lead to further changes in the spider, and other species composition.

Ditlhogo *et al* (1992) note than "the families that appeared to be affected may show prompt or delayed responses to management; the latter could be mediated through altered oviposition or egg survival". Indeed many authors have pointed out that cutting affects overwintering and larval survival, particularly of those species which overwinter in *Phragmites* stems (Husak 1978, Mook 1971, van der Toorn and Mook 1982).

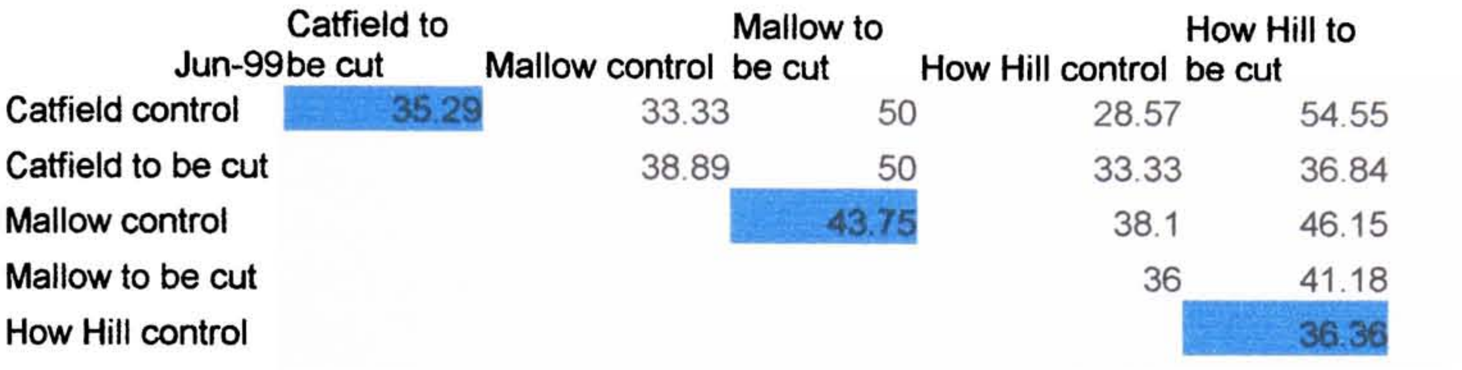
The implications for conservation management are important. Whilst the grouping of species indicates that diversity and species presence and absence are not affected, it appears that species composition is affected and different species react in different ways. For a range of species to be protected a range of habitats need to be provided. Small differences in habitat can be related to large differences in fauna. A mosaic of ages of reed need to be present including areas of unmanaged reed. Management should be rotational, allowing time for recolonisation of invertebrates between areas. Areas surrounded by barriers to recolonisation should not be managed all at the same time, as sensitive species (e.g. *Porrhomma pallidium, Allomengea vidua* and *Pirata hygrophilus*) may not easily recolonise a site and may be eliminated from an area completely by over zealous cutting.

There is no evidence that the rare species collected in this study (*Clubiona juvenis*, *Entelecara omissa*, *Donacochara speciosa* and *Hypomma fulvum*) are eliminated from managed areas after cutting. These species are most threatened by scrub encroachment and drainage of the fens. Maintaining the water table and managing the fens by rotational cutting in a patchwork is to be recommended for the further survival of these vulnerable wetland spiders.

5.10 APPENDIX 5.1

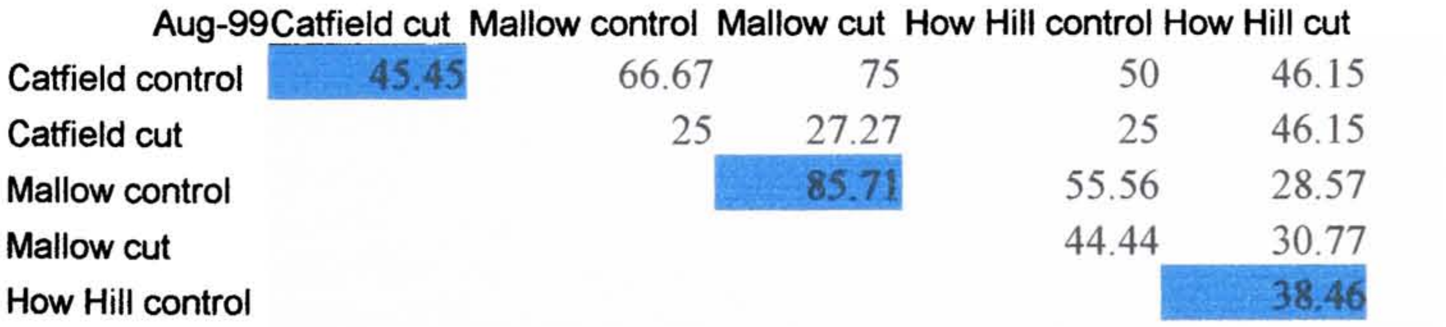
The Jaccard Similarity Index data for each site (accumulated cut and control values) for each sampling time.

Table 5.XIII Jaccard similarity Index for each site (accumulated cut and control values) for June 1999



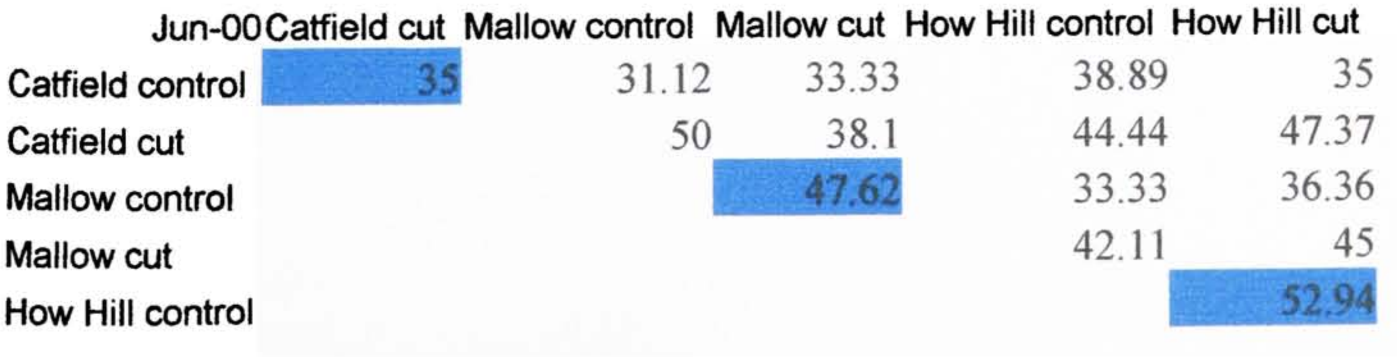
Jun-99	Catfield to be cut	Mallow control	Mallow to be cut	How Hill control	How Hill to be cut
Catfield control	35.29	33.33	50	28.57	54.55
Catfield to be cut		38.89	50	33.33	36.84
Mallow control			43.75	38.1	46.15
Mallow to be cut				36	41.18
How Hill control					36.36

Table 5.XIV Jaccard similarity Index for each site (accumulated cut and control values) for August 1999



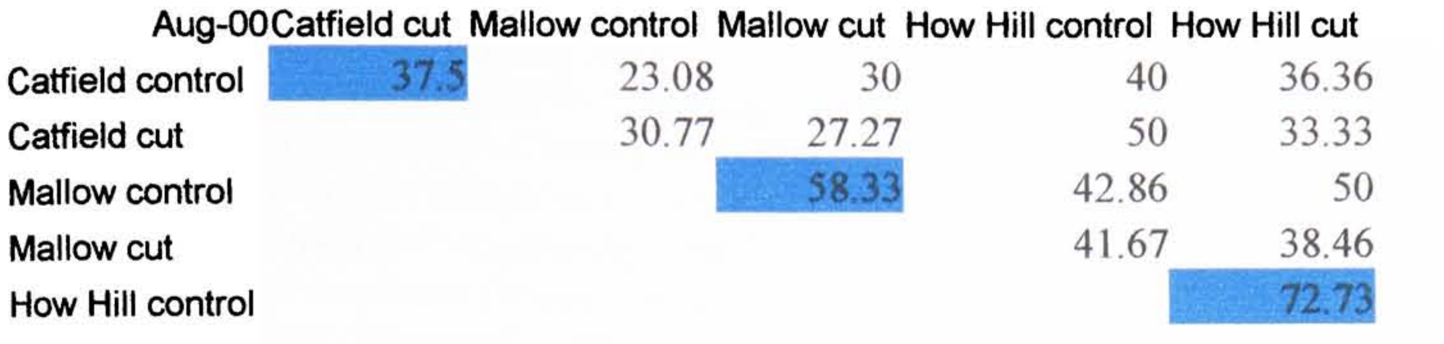
Aug-99	Catfield cut	Mallow control	Mallow cut	How Hill control	How Hill cut
Catfield control	45.45	66.67	75	50	46.15
Catfield cut		25	27.27	25	46.15
Mallow control			85.71	55.56	28.57
Mallow cut				44.44	30.77
How Hill control					38.46

Table 5.XV Jaccard similarity Index for each site (accumulated cut and control values) for June 2000



Jun-00	Catfield cut	Mallow control	Mallow cut	How Hill control	How Hill cut
Catfield control	35	31.12	33.33	38.89	35
Catfield cut		50	38.1	44.44	47.37
Mallow control			47.62	33.33	36.36
Mallow cut				42.11	45
How Hill control					52.94

Table 5.VI Jaccard similarity Index for each site (accumulated cut and control values) for August 2000



Aug-00	Catfield cut	Mallow control	Mallow cut	How Hill control	How Hill cut
Catfield control	37.5	23.08	30	40	36.36
Catfield cut		30.77	27.27	50	33.33
Mallow control			58.33	42.86	50
Mallow cut				41.67	38.46
How Hill control					72.73

5.11 APPENDIX 5.2

Araneae Checklist.

Checklist follows Merrett and Murphy (2000)

LINYPHIIDAE

Walckenaeria alticeps (Denis, 1952)	Local
Walckenaeria atrotibialis (O.P.-Cambridge, 1878)	Local
Walckenaeria kochi (O.P.-Cambridge, 1872)	Local
Walckenaeria vigilax (Blackwall, 1853)	Local
Entelecara omissa O.P.-Cambridge, 1902	Notable/Na
Gnathonarium dentatum (Wider, 1834)	
Tmeticus affinis (Blackwall, 1855)	
Dismodicus bifrons (Blackwall, 1841)	Local
Hypomma bituberculatum (Wider, 1834)	
Hypomma fulvum Bösenberg, 1902	Notable/Na
Metopobactrus prominulus (O.P.-Cambridge, 1872)	
Baryphyma trifrons (O.P.-Cambridge, 1863)	Local
Pocadicnemis juncea Locket and Millidge, 1953	
Hypselistes jacksoni (O.P.-Cambridge, 1902)	
Oedothorax gibbosus (Blackwall, 1841)	
Oedothorax fuscus (Blackwall, 1834)	
Oedothorax agrestis (Blackwall, 1853)	
Trichopterna cito (O.P-Cambridge, 1872)	
Silometopus elegans (O.P.-Cambridge, 1872)	Local
Cnephalocotes obscurus (Blackwall, 1834)	Local
Tapinocyba praecox (O.P-Cambridge, 1873)	
Lophomma punctatum (Blackwall, 1841)	Local
Savignia frontata Blackwall, 1833	
Diplocephalus picinus (Blackwall, 1841)	
Erigone atra Blackwall, 1933	
Donacochara speciosa (Thorell, 1875)	Notable/Na
Leptorhoptrum robustum (Westring, 1851)	
Porrhomma pygmaeum (Blackwall, 1834)	
Porrhomma pallidium Jackson, 1913	
Bathyphantes approximatus (O.P.-Cambridge, 1871)	Local
Bathyphantes gracilis (Blackwall, 1841)	
Bathyphantes parvulus (Westring, 1851)	
Taranucnus setosus (O.P.-Cambridge, 1863)	Local
Lepthyphantes tenuis (Blackwall, 1852)	
Lepthyphantes zimmermanni Bertkau, 1890	
Lepthyphantes flavipes (Blackwall, 1854)	
Lepthyphantes tenebricola (Wider, 1834)	
Microlinyphia impigra (O.P.-Cambridge, 1871)	Local
Allomengea vidua (L. Koch, 1879)	Local

TETRAGNATHIDAE

Tetragnatha extensa (Linnaeus, 1758)	
Pachygnatha clercki Sundevall, 1823	

LYCOSIDAE	
Pardosa pullata (Clerck, 1757)	
Pardosa prativaga (L. Koch, 1870)	
Pardosa saltans Töpfer-Hofmann, 2000 (pseudonym P. lugubris (Walckenaer, 1802)	
Alopecosa pulverulenta (Clerck, 1757)	
Pirata piraticus (Clerck, 1757)	Local
Pirata tenuitarsis Simon, 1876	Local
Pirata hygrophilus Thorell, 1872	
Pirata piscatorius (Clerck, 1757)	Local
CYBAEIDAE	
Argyroneta aquatica (Clerck, 1757)	Local
HAHNIIDAE	
Antistea elegans (Blackwall, 1841)	Local
CLUBIONIDAE	
Clubiona reclusa O.P.-Cambridge, 1863	
Clubiona phragmitis C.L. Koch, 1843	Local
Clubiona juvenis Simon, 1878	RDB2
Clubiona subtilis L. Koch, 1867	Local

THE SHORT TERM EFFECT OF CUTTING AS A FEN MANAGEMENT PRACTICE ON THE BEETLE (COLEOPTERA) BIODIVERSITY OF THE NORFOLK BROADS

6.1 Abstract

- The study sought to discover whether summer cutting of reedbeds changed the biodiversity of beetles in managed areas compared to control areas.
- Species level changes were also investigated in order to identify any specific level responses to management.
- Beetles were collected from 18 plots at three S4 reedbed sites, half of which had been managed by cutting. Beetles were identified to species level.
- Beetles are speciose, habitat sensitive and show seasonal fluctuations with an increase in diversity and abundance in June compared to August.
- There is a significant difference in diversity between June 1999 and June 2000, but no significant difference in diversity between August 1999 and August 2000. There is no significant difference in diversity due to management, or to an interaction between management and year.
- Each plot was as similar to itself in terms of species presence and absence one year on, irrespective of the management or lack of it received.
- Beetles are management sensitive. The number of *Coleostoma orbiculare, Cyphon phragmiteticola* and *Euconnus hirticollis* increase after cutting, whereas *Stilbus oblongus* numbers decrease after cutting management when analysed using Chi^2. The stringent GLM statistical test, however shows no significant differences.

- *Coleostoma orbiculare* becomes absent from unmanaged plots once managed plots become available.

6.2 Introduction

One of the most commonly used habitat indicators in ecological studies are the Coleoptera (e.g. Pearson and Cassola 1992). Beetles are a useful tool in diversity studies because they are themselves diverse, numerous, easy to collect and relatively easy to identify, having an established taxonomy and available keys (Brown 1991). They are sensitive to environmental change and have been used in a variety of habitats and situations. Their response to disturbance has been well documented (Abensperg-Traun *et al* 1996, Kotze and Samways 1999, Menéndez 2000, Samways 1996,), as has the effect of grazing (Batzer and Wissinger 1996, Gibson *et al* 1992, Meyer *et al* 1995, Mishra and Rawat 1998) though with mixed results. Abensperg-Traun *et al* (1996) found disturbance increased diversity and species richness of beetles, whereas Gibson *et al* (1992) recorded an intermediate response. Meyer *et al* (1995) and Downie *et al* (1999) found cutting and grazing to have a negative effect on the diversity of the beetle fauna.

As for spiders, different grazers seem to have different effects on beetle fauna (Abensperg-Traun *et al* 1996) and these are not necessarily the same as the effects of burning (Aitchison-Benell 1994, Chambers and Samways 1998, Ditlhogo *et al* 1992, Johnson 1996, York 1999) or cutting. The effect of cutting on invertebrates has been studied in several environments (Chapter 5, page 155)

The vast majority of studies where structural complexity of the habitat was measured, show that it is a significant factor in determining species composition and diversity for invertebrates (Gibson *et al* 1992, Kurashov *et al* 1996, Norris 1997, O'Connor 1991, Rushton *et al* 1990, Webb 1989, Wettstein and Schmid 1999, Wheater *et al* 2000). Studies show an increase in community complexity and diversity with and increase in plant structural diversity (e.g. Wettstein and Schmid 1999).

Partly because of this, beetles tend to exhibit strong habitat specificity (Blades and Marshall 1994, den Boer 1990, Marshall and Finnamore 1994, Perfecto *et al* 1997, Runtz and Peck 1994). Rykken *et al* (1997), on the other hand, found that the majority of beetles were generalists in their study. Like spiders, different species compositions are found in bogs as opposed to fens (Dondale and Redner 1994), and between individual bogs and peatlands (Blades and Marshall 1994, Koponen 1994, Marshall and Finnamore 1994, Runtz and Peck 1994). Rushton *et al* (1990) as well as Fråmbs (1994) found beetle and beetle fauna in wetlands depended on hummocks or tussocks in the environment in order to overwinter. Foss and Connell (1998) specifically recommend that tussocks should not be damaged during fen management for this reason. One of the problems associated with the use of the fen harvester as a cutting tool is its non-selectivity. It is known to damage tussocks.

6.3 Hypothesis

Based on the results of the pilot study the hypothesis is as follows:

- Coleoptera (beetles) are not sensitive to habitat management.

From the pilot study results it can be predicted that numbers of individuals will not decline following management. It can also be predicted that the species composition of the beetle community will not alter following management.

6.4 Aims

This investigation looked at the Coleoptera diversity of three sites in the Norfolk Broads, two managed the BA (Mallow Marsh and How Hill) and the third by the NWT (Catfield Fen). The aims of this investigation were to ascertain whether cutting management affects the biodiversity of beetle species in the first year following management of reedbeds. Both biodiversity and the individual responses of species were investigated. Beetles are sensitive indicator species and have been used in several studies as such (Pearson and Cassola 1992). They respond to disturbance (e.g. Downie *et al* 1999) and are therefore useful tools in assessing habitat quality and monitoring environmental change.

This project set out to quantify the effects of cutting management on the Coleopteran diversity of the fen. To this aim the following questions were asked:

o Is there a significant difference between the numbers of individual beetles found on cut and control plots at each site?

o Is there a significant difference between the numbers of individuals of each species of beetle found in cut and control plots at each site?

o Is there a difference between the composition of beetles at each site, or between the different management treatments?

o How diverse are the plots in terms of beetle species composition, taking both number of species and relative abundance into account?

o How does beetle diversity change over the sampling time?

o How similar are the plots to each other in terms of species composition?

- How similar are the plots to themselves one year on?
- What are the responses of individual species to management?

6.5 Autecology

The autecology of individual species is virtually non-existent, unfortunately. Ecology of the genus of selected species is given below where available. There is detailed information available for the Chrysomelid *Apthona nonstriata*, and notes for certain other species.

Acrotrichis sitkaensis (Motschulsky, 1845)

Status – common. Distribution Widespread and common (Johnson 1990) – Habitat –Ptillid feather-wing beetles. Wetland species in all kinds of marsh litter from ings, bogs, reservoirs, ponds etc. (Johnson 1990). Most of this genus (24 British spp) found in decaying plant matter, in humid environments. Mould feeder. Marshland species found between spring and autumn.

Agonum thoreyi Dejean, 1828

Status – Distribution – Habitat – 22 British spp – mostly found in wet and marshy areas. nr water, damp woods. Hibernate as adults, reproduce in spring.

Anacaena limbata (Fabricius, 1792)

Status – Distribution – Whole of the palaearctic and C Europe. Habitat – common in and at the edge of all types of stagnant water

Apthona nonstriata (Goeze, 1777)

Status – common. Distribution –widespread throughout England and Wales, also found in much of E Europe, Scandinavia, the Middle East, Russia and China. Habitat – species occurs near water, in fens and reedbed, grazed and ungrazed fen pasture, carr, broads, *Carex* and *Juncus*, ponds ditches, drains, open pits m peat cuttings, estuaries, woodland, heathland, shingle and dunes. The adults eat narrow longitudinal strips from the leaves, by removing the epidermis between leaf veins. These areas then turn white. Some adults can fly, others are brachyopterous. Adults are found all year round. They over winter in grass tussocks and moss, emerging in April. There is one generation annually. The new generation emerges between July and September. Oviposition is likely to be between mid-May – mid-June, with hatching at the end of May. Pupation probably occurs within an earthen cell towards the end of June.

Atheta fungi (Gravenhorst, 1806)

Status – Distribution – much of holarctic, incl C Europe. Habitat –Ground litter. Parthenogenetic.

Cantharis thoracica (Olivier, 1790)

Status – Distribution – Habitat – 15 British spp. Adults on bushes, flowers, grasses and cereal plants, and leafy trees for some spp. Some in damp situations e.g. *C. fusca*. Alexander (2002a) describes the species as being widespread in fen and reed-bed vegetation, and in marshes such as those around lowland lakes. All recent Scottish records are from the extreme south. Can be confused with the paler form of *C. nigra*. Adults may be found from June to mid August.

Coelostoma orbiculare (Fabricius, 1775)

Status – Distribution – the only sp of this genus in C Europe. Habitat – shallow stagnant water, moss and detritus at the water's edge.

Cyphon phragmiteticola Nyholm, 1944

Status – Distribution – 12 spp in C Europe. Habitat – larvae live in shallow water, beetles found on waterside plants, in debris, and in the winter in moss, under bark, in rush stems.

Euconnus hirticollis (Illiger, 1798)

Status – Distribution – 6 spp in Britain, 17 in Europe altogether. Habitat – wetland

Glischrochilus hortensis (Fourcroy, 1785)

Status – Distribution – Habitat –usually at sappy stumps, in fungi, or amongst chippings from broad leaved trees or conifers (Alexander 2002b).

Oxypoda elongatula Aubé, 1850

Status – Distribution – 60 spp Europe, 27 Britain. Habitat – ground litter and decaying matter, some spp associated with underground nests of mammals and Hymenoptera. Wetland species (Derek Lott, pers. comm).

Paederus riparius (Linnaeus, 1758)

Status – Distribution – 10 spp Europe, 4 Britain. Habitat – sandy ground by water, nimble runners, with abdomen erect, common river banks and marshes everywhere in C Europe. Wetland species (Derek Lott, pers. comm). Predatory Staphylinid rove beetles. Endosymbiontic chemical defences (Kellner, 1999) limited (mostly) to females. Hibernates as adult.

Silis ruficollis (Fabricius, 1775)

Status – Distribution – Species has recently returned to the west of England, though it is unclear if local extinction, followed by recolonisation had occurred, or if the population had merely dropped to low levels. Locally common in south Wales and Somerset. Habitat –Alexander (2002a) states that this species is found in fens and reedbeds. Adults can be found between mid-June and the end of July.

Stenus juno (Paykull, 1789)

Status – Distribution – Habitat – wetland species (Derek Lott, pers. comm) Genus of this Staphylinid family comprises 1800 species. Found worldwide in damp environments (Betz 1999). Predator which ambushes, stalks and chases prey. Up to 20 eggs layed in minute gaps in the ground, beneath plant debris or within dead hollow stalks. This species lays dense clusters of eggs. Behaviour covered in detail by Betz (1999) includes feigning death, and chemical defences. This species can walk on water and swim at the water surface.

Stenus latifrons Erichson, 1839

Status – Distribution – 114 spp Europe, 72 Britain. Habitat – majority spp waterside and wet places such as marshes, some on edge of snow fields, in forest litter, heaths, or ants nests. Wetland species (Derek Lott, pers. comm).

Genus of this Staphylinid family comprises 1800 species. Found worldwide in damp environments (Betz 1999). Predator which ambushes, stalks and chases prey. Up to 20 eggs layed in minute gaps in the ground, beneath plant debris or within dead hollow stalks. Behaviour covered in detail by Betz (1999) includes feigning death, and chemical defences. This species can very rapidly skim along the water surface by releasing a chemical. It also swims at the water surface.

Stilbus oblongus (Erichson, 1835)

Status – Distribution – 3 spp, all common. Habitat – nothing known about development / larvae.

6.6 Methods

Three sites were sampled Catfield Fen, Mallow Marsh and How Hill. These were all (NVC) S4 reedbed, though Catfield had more S24 tendencies. The sites each had six plots A-F, half of which were cut in July 1999. At Catfield and How Hill the plots A, C and E were control plots (uncut) and B, D and F were cut plots. At Mallow Marsh A, C and E were cut and B, D and F were control. Samples were taken from each plot before management in mid-June 1999, and post-cutting at the end of August 1999, mid-June 2000 and end August 2000.

Vegetation surveys were also taken in 1999 before cutting and one year later in the summer of 2000. One hundred 25x25 cm quadrats were taken in each plot. Presence and absence of each plant species was noted, and this gave accurate frequency of occurrence data for each plot at each site.

Beetles were collected using pitfall traps containing 50% antifreeze and water with a small amount of washing up liquid to break the surface tension. Eight pitfall traps were left out for a week at each plot on each site in June and August 1999 and 2000. The beetles were preserved in 100% ethanol and identified to species by R. Marsh (Audisio 1993, Balfour-Browne 1940, Clarke 1973, Luff 1990, Pope 1977). The species data, combined with the vegetation survey data, were analysed using DECORANA (Hill 1979a) from the Vespan III program (licensed by A Malloch 1990), Chi^2 tests, rank abundance, Simpson Diversity Index (Begon *et al* 1990), Morisita-Horn (Krebs, 1989, Southwood and Henderson, 2000) and the Jaccard Similarity Index (Southwood 1978). Further analyses on the indices included the Mann Witney U test and General Linear Model (Fowler *et al* 1998). Vegetation and beetle multivariate analyses were combined using a two-way biplot. Plotting the two against one another enabled a visual representation of the different influences of the vegetation and beetle composition on the biodiversity to be differentiated. Inertia levels were calculated for each multivariate axis (Dixon 1992).

6.7 Results

Over a thousand individuals (1007) were collected in the four sampling seasons. The data collected are shown in Table 6.I.

Table 6.I The numbers of beetle species and individuals collected.

Sample date	June 1999	August 1999	June 2000	August 2000
Numbers species	73	41	81	39
Numbers individuals	431	117	360	99

Is there a difference between the numbers of individual beetles found on cut and control plots at each site?

The first parts of Tables 6.II-6.V, look at the difference in numbers of individuals collected in control and experimental plots at each sample date, regardless of species, of Coleoptera. Before cutting, in June 1999, (Table 6.II) and immediately post cutting in August 1999, (Table 6.III) there is no significant difference between the cut and control plots in terms of individuals collected. One year after cutting in June 2000 (Table 6.IV) both Catfield and How Hill show a significant difference with more individuals being found on cut plots at Catfield and control plots at How Hill. In August 2000, (Table 6.V) How Hill and Mallow Marsh showed a significance difference, with more beetles being found on cut plots at both sites.

Table 6.II Chi squared analysis of beetle distribution before cutting in June 1999. The top part of the table show the differences between the numbers of individuals found on each treatment at each site. The second half of the table shows the differences in the numbers of individuals of each species found on plots of different treatments.

Chi^2 June 1999 Beetles

Sites	cut	uncut	expected	Chi^2	sig
Catfield	39	40	39.5	0.01	ns
Mallow Marsh	105	106	105.5	0	ns
How Hill	69	72	70.5	0.06	ns

Species	cut	uncut	expected	Chi^2	sig
Acrotrichis sitkaensis	33	45	39	1.85	ns
Atheta fungi	69	37	53	9.66	p=0.005
Cantharis thoracica	9	8	8.5	0.06	ns
Ocyusa maura	6	8	7	0.29	ns
Oxypoda elongatula	0	11	5.5	11	p=0.001
Paederus riparius	16	28	22	3.27	ns
Stenus latifrons	3	8	5.5	2.27	ns
Stilbus oblongus	10	13	11.5	0.39	ns

Using a Bonferroni correction on the significant values, the species are significant at $p<0.006$, so both *A. fungi* and *O. elongatula* have significant differences between the numbers of individuals found in plots to be cut compared to those found in the control areas.

Table 6.III Chi squared analysis of beetle distribution after cutting in August 1999. The top part of the table show the differences between the numbers of individuals found on each treatment at each site. The second half of the table shows the differences in the numbers of individuals of each species found on plots of different treatments.

Chi^2 August 1999 Beetles

Sites	cut	uncut	expected	Chi^2	sig
Catfield	9	10	9.5	0.05	ns
Mallow Marsh	10	16	13	1.38	ns
How Hill	36	36	36	0	ns

Species	cut	uncut	expected	Chi^2	sig
Acrotrichis sitkaensis	6	7	6.5	0.33	ns
Agonum thoreyi	8	10	9	0.29	ns
Euconnus hirticollis	14	7	10.5	2.33	ns
Paederus riparius	10	14	12	1.09	ns

Table 6.IV Chi squared analysis of beetle distribution after cutting in June 2000. The top part of the table show the differences between the numbers of

individuals found on each treatment at each site. The second half of the table shows the differences in the numbers of individuals of each species found on plots of different treatments.

Chi^2 June 2000 Beetles

Sites	cut	uncut	expected	Chi^2	sig
Catfield	104	45	74.5	23.36	p=0.001
Mallow Marsh	72	56	64	2	ns
How Hill	30	53	41.5	6.37	p=0.025

Species	cut	uncut	expected	Chi^2	sig
Acrotrichis sitkaensis	9	7	8	0.25	ns
Agonum thoreyi	8	11	9.5	0.47	ns
Anacaena limbata	11	6	8.5	1.47	ns
Coelostoma orbiculare	11	0	5.5	11	p=0.001
Cyphon phragmiteticola	15	3	9	8	p=0.005
Euconnus hirticollis	16	3	9.5	8.89	p=0.005
Ocyusa maura	8	11	9.5	0.47	ns
Paederus riparius	28	28	28	0	ns
Stilbus oblongus	1	11	6	8.33	p=0.005

Using a Bonferroni correction on the significant values, the sites are significant at p<0.0167. The species are significant at p<0.0055, so both the sites Catfield and How Hill, and the species shown as significant in Table 6.IV have significant differences between the numbers of individuals found in managed plots compared to those found in the control areas.

Table 6.V Chi squared analysis of beetle distribution after cutting in August 2000. The top part of the table show the differences between the numbers of individuals found on each treatment at each site. The second half of the table shows the differences in the numbers of individuals of each species found on plots of different treatments.

Chi^2 August 2000 Beetles

Sites	cut	uncut	expected	Chi^2	sig
Catfield	6	12	9	2	ns
Mallow	29	11	20	8.1	p=0.005
How Hill	27	14	20.5	4.12	p=0.05

Species	cut	uncut	expected	Chi^2	sig
Coelostoma orbiculare	12	0	6	12	p=0.001
Ocyusa maura	8	2	5	3.6	ns

Using a Bonferroni correction on the significant values, the sites are significant at $p<0.0167$. The species are significant at $p<0.025$, so Mallow and species *C. orbiculare* have significant differences between the numbers of individuals found in managed plots compared to those found in the control areas. How Hill does not show a significant difference.

The effect of cutting vs not cutting, and effects of sampling time i.e. June vs August and 1999 vs 2000, plus any interaction between treatment and sampling time are tested using the General Linear Model (GLM). A significance score of $p<0.05$ for sampling time indicates seasonal or year to year fluctuations. A significance score of $p<0.05$ for treatment indicates either an increase or decrease in numbers of individuals of that species following treatment. A significance score of $p<0.05$ for an interaction between treatment and sampling time indicates the reaction of the species in question is influenced by both processes. This is shown in Table 6.VI.

Table 6.VI The effect of sampling date, treatment and an interaction between the two, tested using a General Linear Model. Species showing a significance level <0.05 are shown.

Species	effect of sample date		effect of treatment		sample*treatment	
	F value at d.f. 3	sig level	F value at d.f. 1	sig level	F value at d.f 3	sig level
Acrotrichis sitkaensis	4.21	<0.05	0.21	ns	0.21	ns
Agabus unguicularis	2.94	<0.05	0.12	ns	0.12	ns
Anacaena limbata	3.55	<0.05	0.66	ns	0.37	ns
Apthona nonstriata	2.91	<0.05	3.37	ns	2.91	<0.05
Atheta fungi	7.76	<0.001	0.58	ns	0.77	ns
Atomaria fuscicollis	3.78	<0.05	0.06	ns	0.85	ns
Atomaria gutta	3.05	<0.05	0.91	ns	3.52	ns
Bryaxis bulbifer	1.52	ns	0	ns	3.05	<0.05
Canthatris thoracica	5.72	<0.005	0.02	ns	0.02	ns
Cercyon convexiusculus	7.45	<0.001	0.84	ns	0.22	ns
Coelostoma orbiculare	1.44	ns	5.31	<0.05	1.44	ns
Euconnus hirticollis	3.56	<0.05	4.15	ns	1.45	ns
Glischrochilus hortensis	3.66	<0.05	0.16	ns	0.26	ns
Hydroporus angustatus	3.27	<0.05	0.36	ns	0.36	ns
Hydroporus longicornis	2.94	<0.05	0.12	ns	0.12	ns
Oxypoda elongatula	2.86	<0.05	2.86	ns	2.86	<0.05
Paederus riparius	4.56	<0.05	0.11	ns	0.05	ns
Silis ruficollis	3.56	<0.05	0.57	ns	0.44	ns
Stenus juno	2.29	ns	6.4	<0.05	2.29	ns
Stenus latifrons	10.2	<0.001	3.51	ns	2.14	ns
Stilbus oblongus	3.53	<0.05	1.07	ns	0.45	ns

Using a Bonferroni correction on the significant values, the species are significant at p<0.002, so just *A. fungi*, *C. convexiusculus* and *S. latifrons* have significant differences due to seasonality, at this most stringent level of testing.

Is there a difference between the numbers of individuals of each species of beetle found in cut and control plots at each site?

The second part of Tables 6.II – 6.V show the difference between numbers of individuals of each species (of those species where sufficient data was collected to carry out analysis) collected in control and experimental plots at each sample date. In June 1999, pre-cutting (Table 6.II), both *Atheta fungi* and *Oxypoda elongatula* showed a significant difference in the numbers found on the 'to be cut' and the control plots. Neither of these two species occur in sufficient numbers to be analysed in any other sampling.

By August 1999 (Table 6.III) no species showed any response in terms of numbers to the management. One year post cutting, June 2000, (Table 6.IV) *Coelostoma orbiculare*, *Cyphon phragmiteticola*, *Euconnus hirticollis* and *Stilbus oblongus* all showed responses, with more individuals being found in managed plots for the first three species, but more individuals found in control plots for *Stilbus oblongus*. *Coelostoma orbiculare* continued to show significant changes into the August 2000, (Table 6.V) sampling, with more beetles still in the managed plots. This species was not found in the control plots.

Is there difference between the composition of beetles at each site, or between the different management treatments?

A multivariate Decorana plot of vegetation before management shows a group comprising Mallow Marsh and How Hill together and more spread out group of the Catfield points (Figure 4.3, page 122). After cutting in summer 2000 (Figure 4.4, page 122), the groups are less discernable though Catfield still falls to the right-hand end of axis 1.

Looking at the multivariate distribution of beetles before management (Figure 6.1), the Catfield points form a spread out group to the right hand side of axis one and Mallow points form a tighter group to the left hand end. The How Hill points are spread along the length of axis one, but fall below the Mallow points on axis 2. There is no obvious management trend.

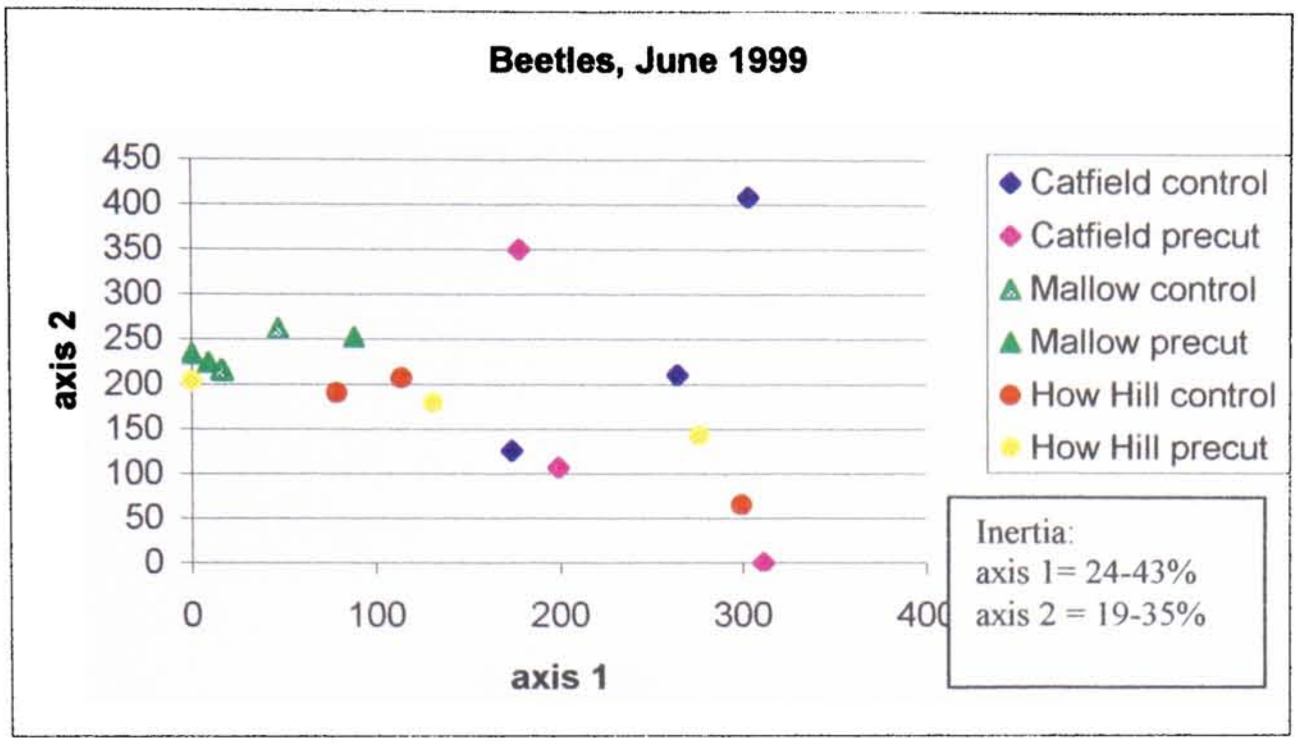


Figure 6.1 Decorana plot of beetle distribution in June 1999, before management.

Plotting the beetle analysis against the vegetation analysis, (Figure 6.2), the Catfield points form a cluster at the top end of both axes. The other two sites have similar vegetation scores, but differ in their beetle composition, with Mallow Marsh forming a cluster at the lower end of both axes, and How Hill being spread along the beetle axis.

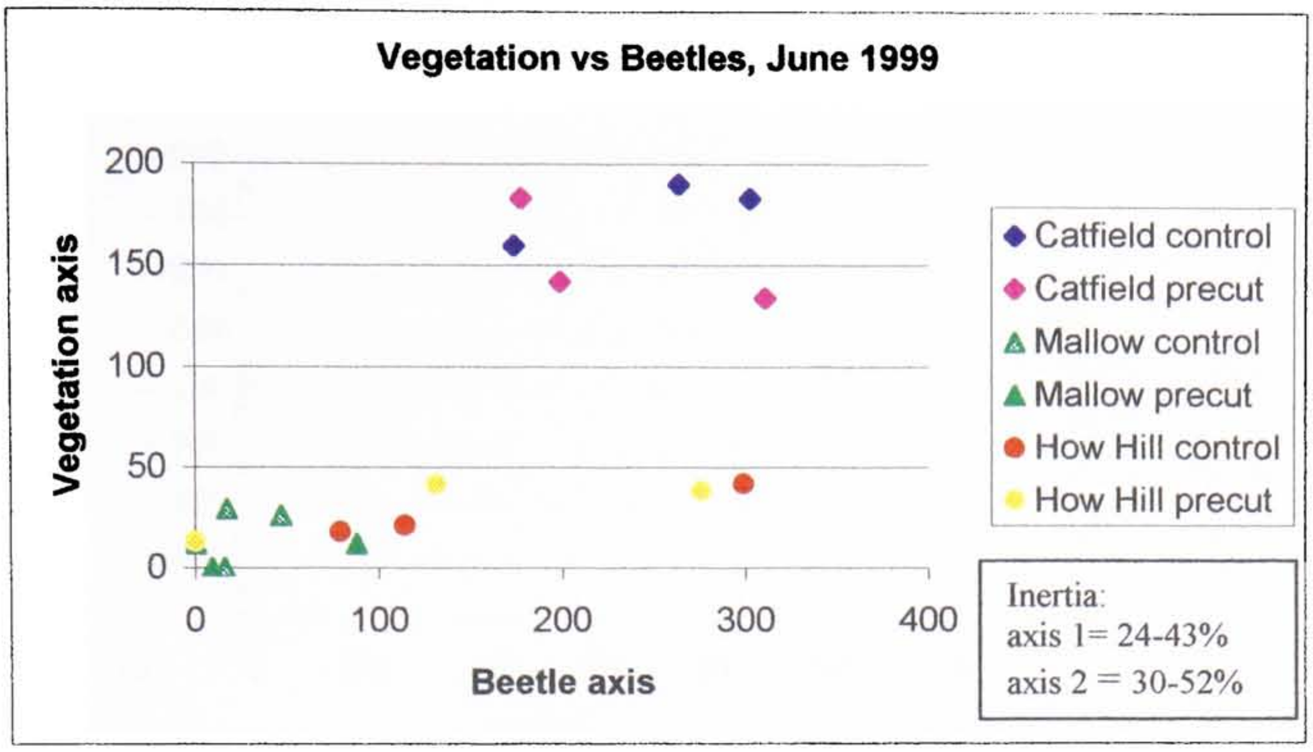


Figure 6.2 Decorana biplot of beetle versus vegetation distribution in June 1999, before management.

One site at Catfield, August 1999, (Figure 6.3) appears to have such an unusual composition of beetles that all other signals are swamped, to the point where negative scores are found. This plot (Catfield F) had three species not collected from any other plot during that sampling. These are *Heterocerus obsoletus* (a species with local distribution), *Oodes helopioides* (Notable B) and *Xantholinus linearis.* Plotting against vegetation does not give greater definition to the relationship between the other plots sampled (Figure 6.4).

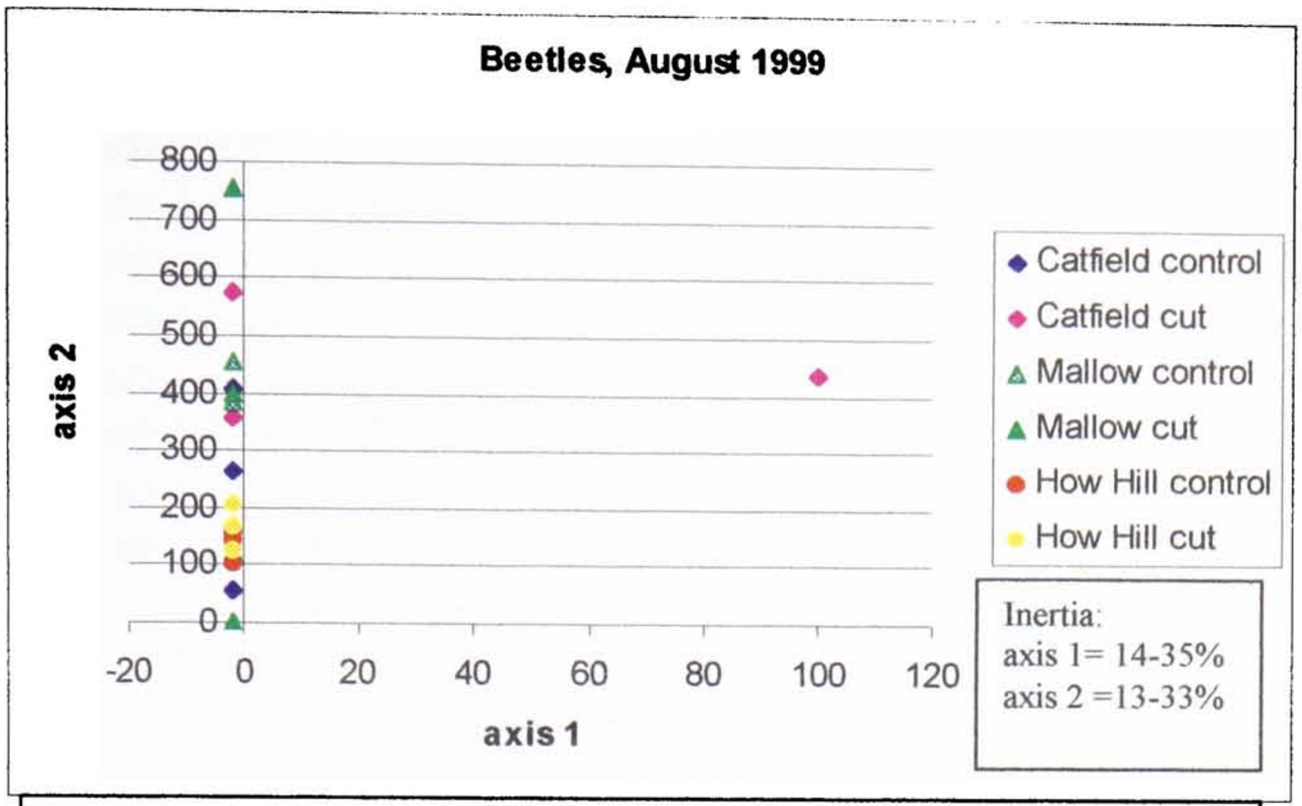


Figure 6.3 Decorana plot of beetle distribution in August 1999, after management.

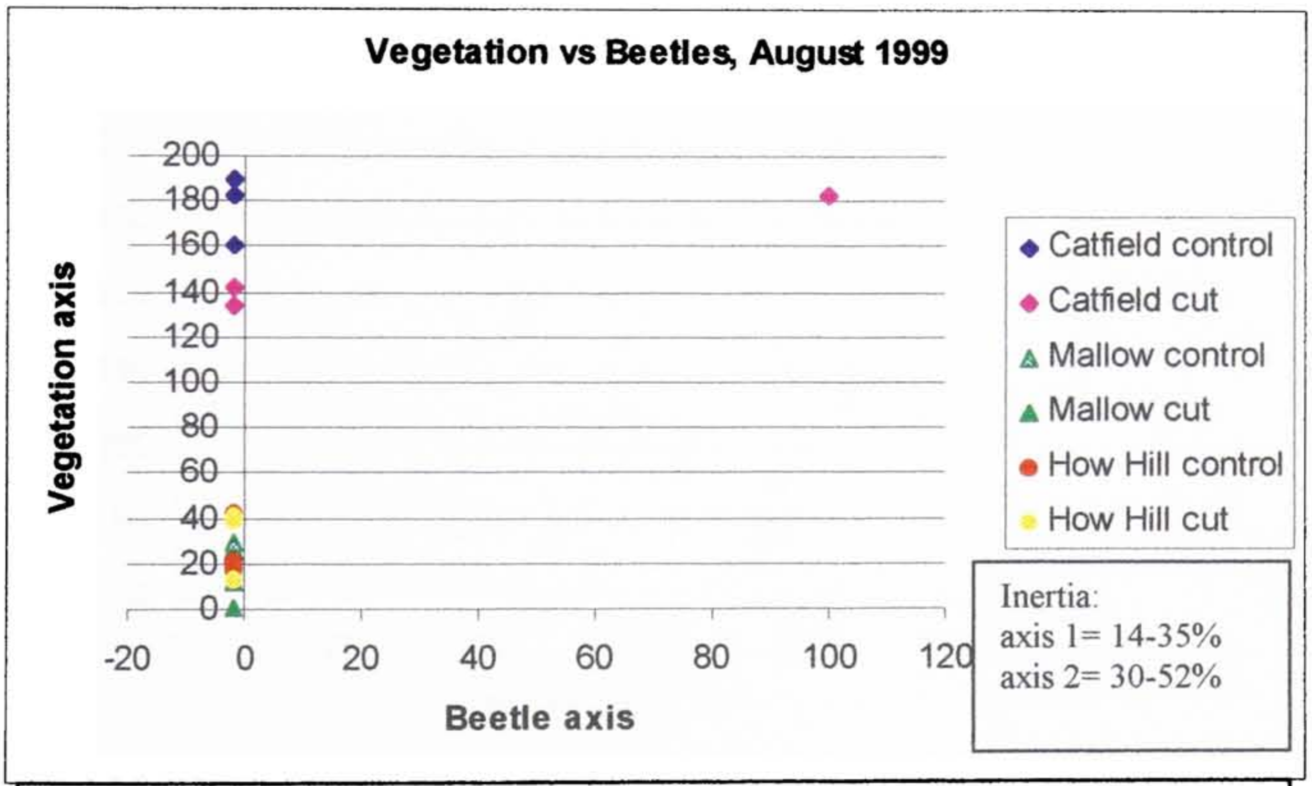
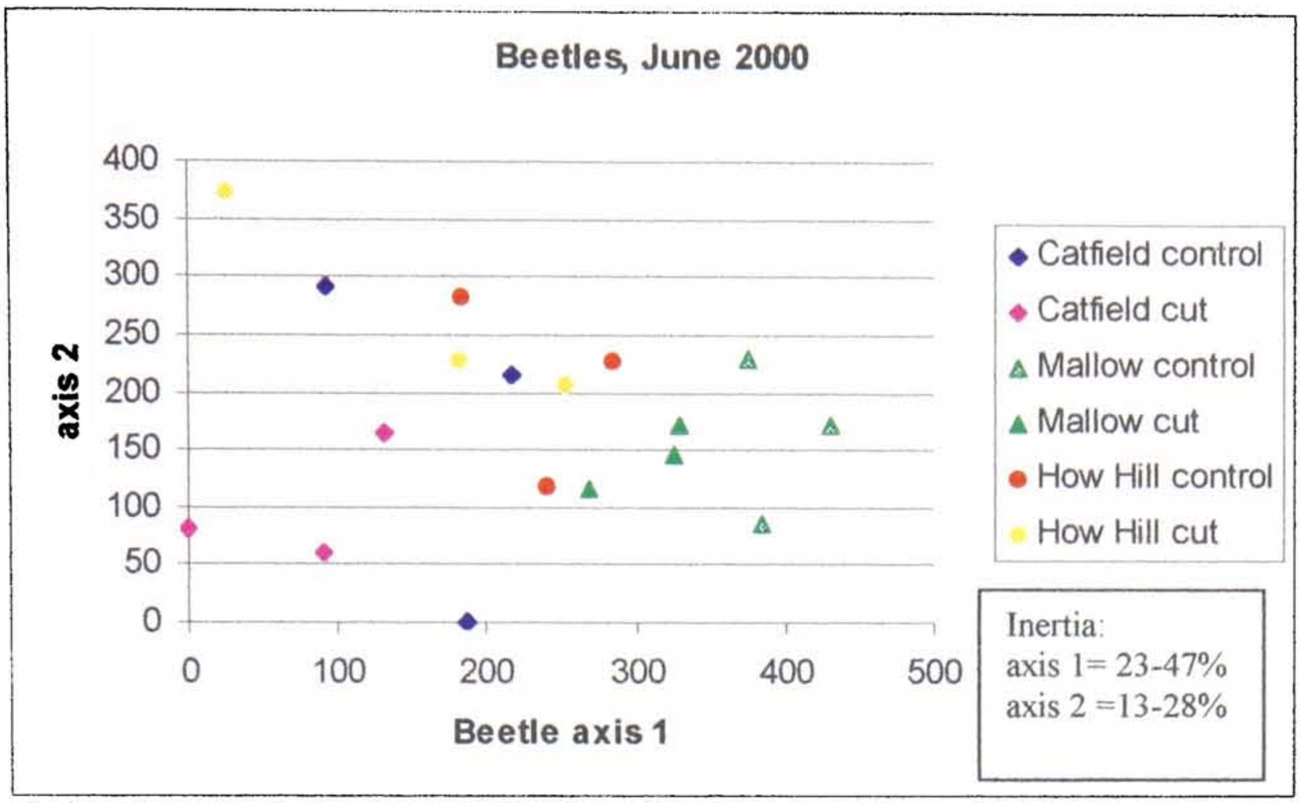


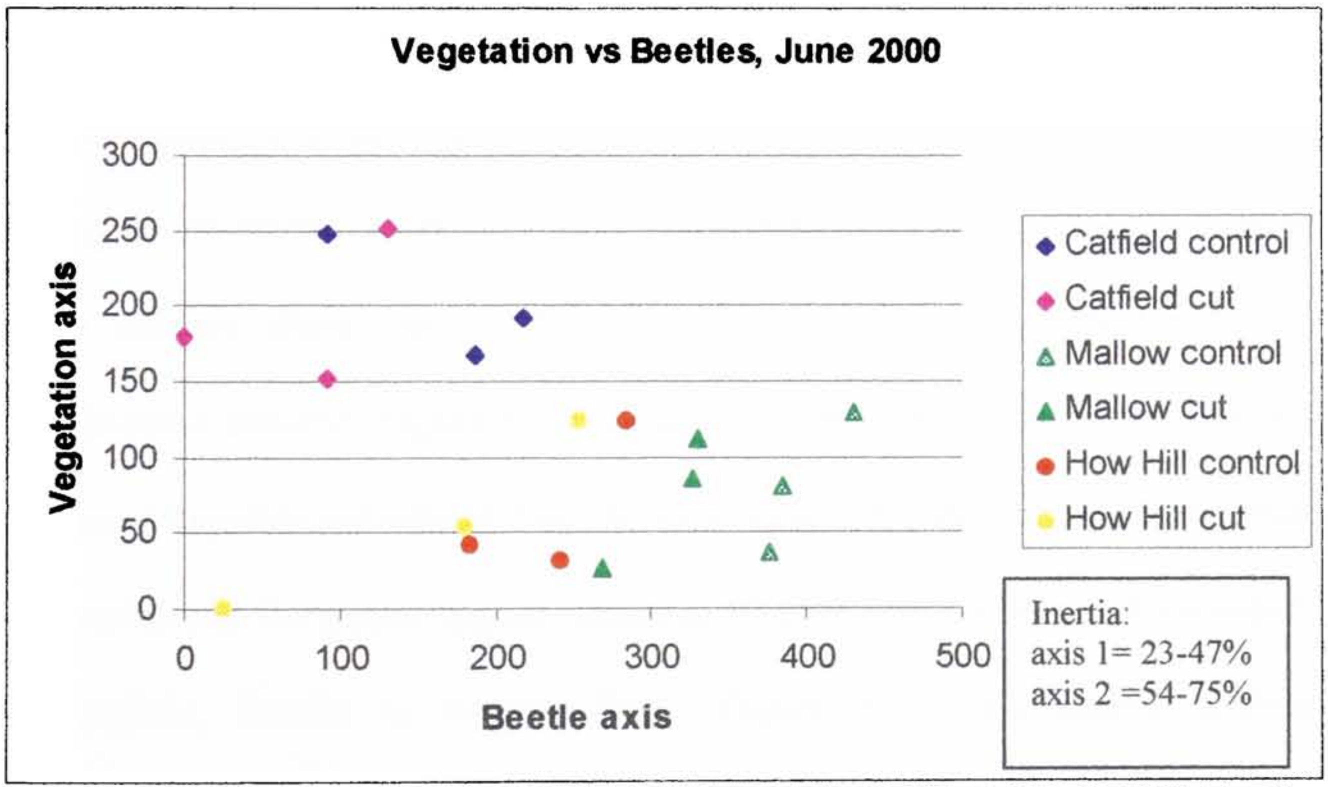
Figure 6.4 Decorana plot of beetle versus vegetation distribution in August 1999, after management.

By June 2000, (Figure 6.5), the points for each site still fall out in clusters but the points relating to cut plots generally fall to the left of those relating to control plots, within each site. Plotting this against vegetation, (Figure 6.6), it becomes clearer, particularly at Mallow Marsh.



Inertia:
axis 1= 23-47%
axis 2 =13-28%

Figure 6.5 Decorana plot of beetle distribution in June 2000, after management.



Inertia:
axis 1= 23-47%
axis 2 =54-75%

Figure 6.6 Decorana biplot of beetle versus vegetation distribution in June 2000, after management.

Unfortunately the trend is lost in August 2000, as flooded pitfall traps made the data unreliable (Figure 6.7). Not even the sites can be clearly separated, though the focus improves slightly when plotted against vegetation, (Figure 6.8), as this data was not affected by the flooding.

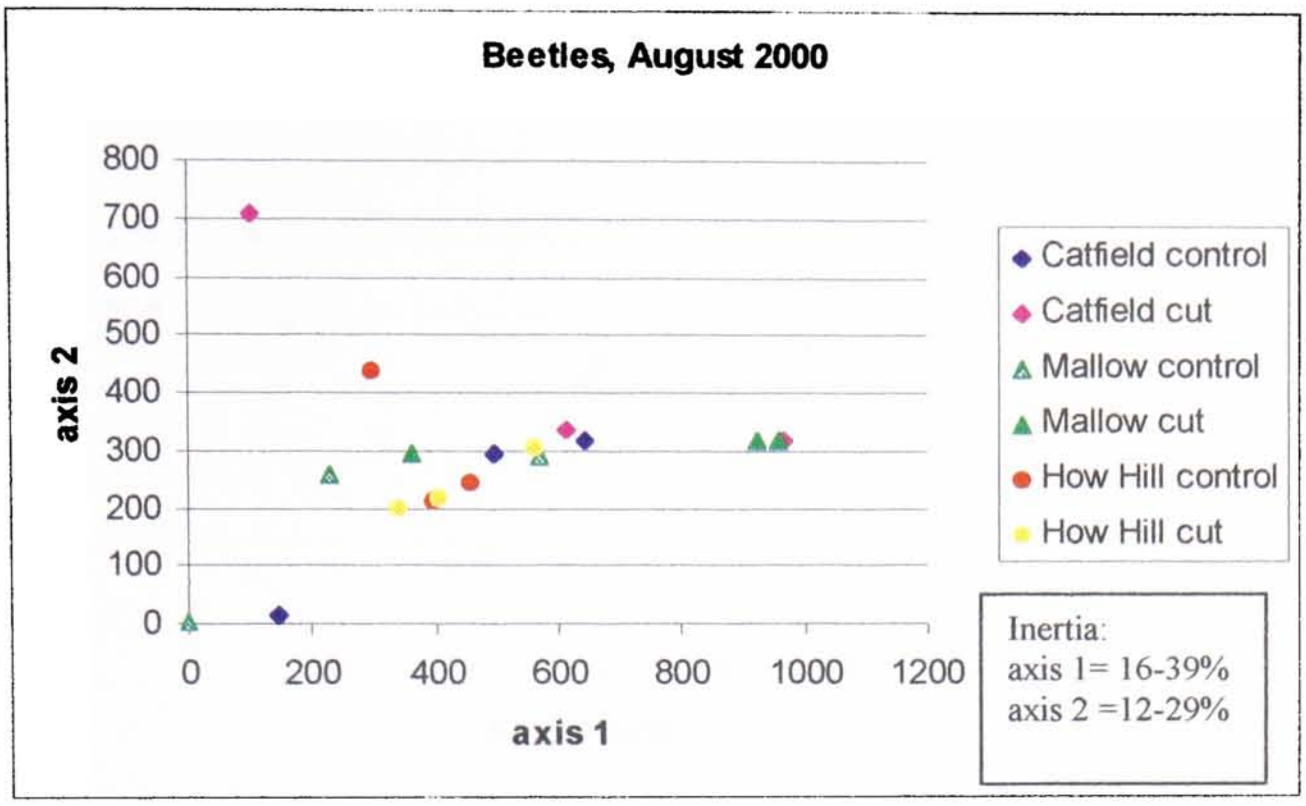


Figure 6.7 Decorana plot of beetle distribution in August 2000, after management.

The species ordinations for the beetles show initially that species preferring control areas overlap with species preferring managed areas in the pre-management environment (Figure 6.9). Immediately after cutting management three species stand out – *Heterocerus obsoletus*, *Oodes helopioides* and *Xantholinus linearis* (Figure 6.10) all at the point (100, 435). These species are all found together at Catfield Fen. the following June, there is no clear clumping of species and the points appear scattered (Figure 6.11) in terms of management preferences. Finally in August 2000, (Figure 6.12), the species preferring control plots are much more closely related than the species preferring managed plots.

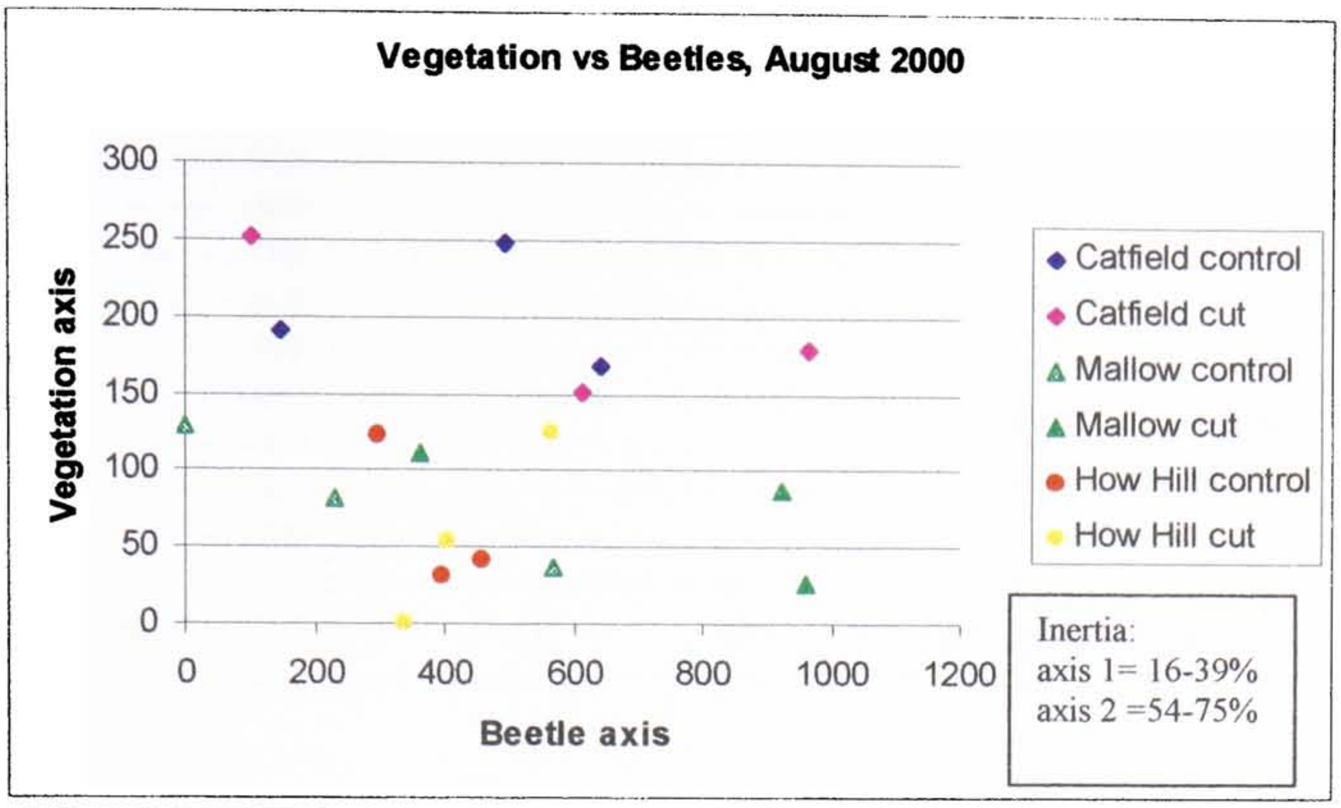


Figure 6.8 Decorana biplot of beetle versus vegetation distribution in August 2000, after management.

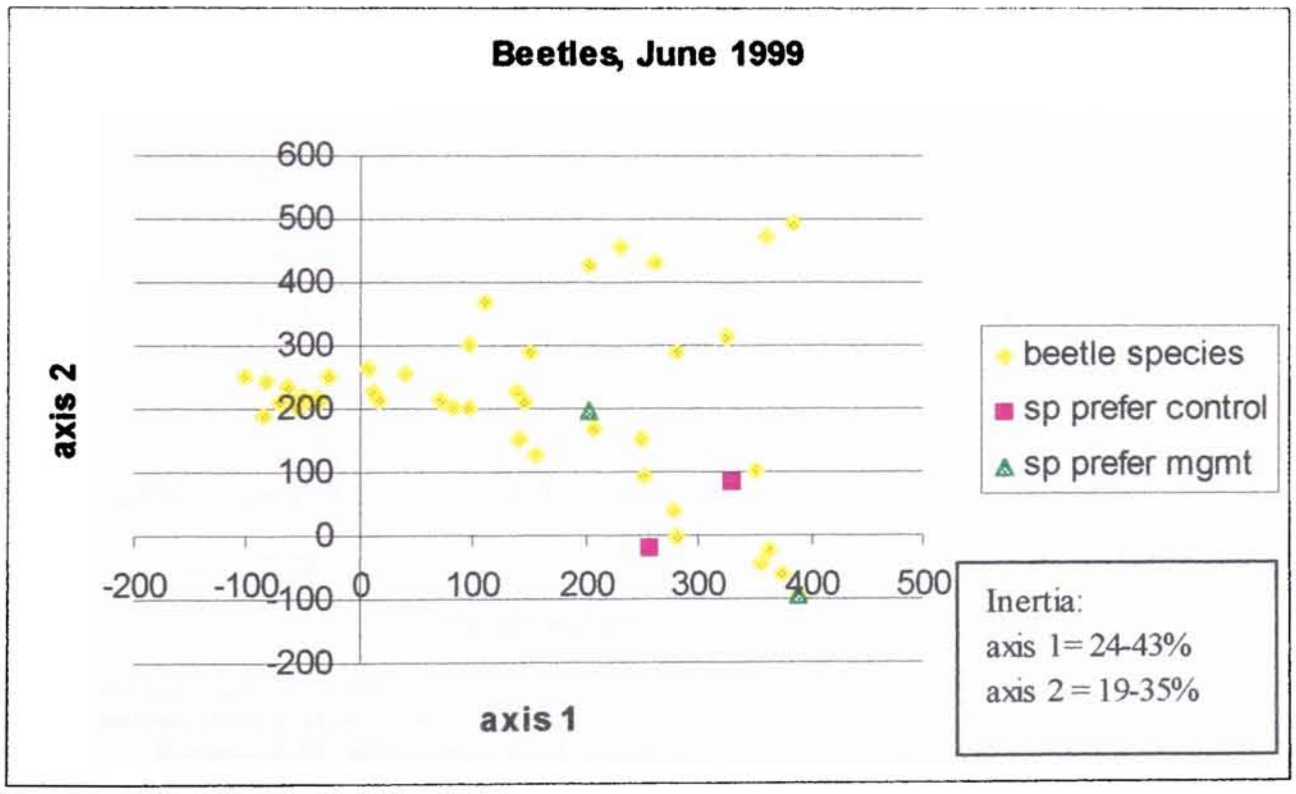


Figure 6.9 Decorana plot showing species ordinations for beetles, in June 1999, before management. Species which do better in managed or control plots are shown separately.

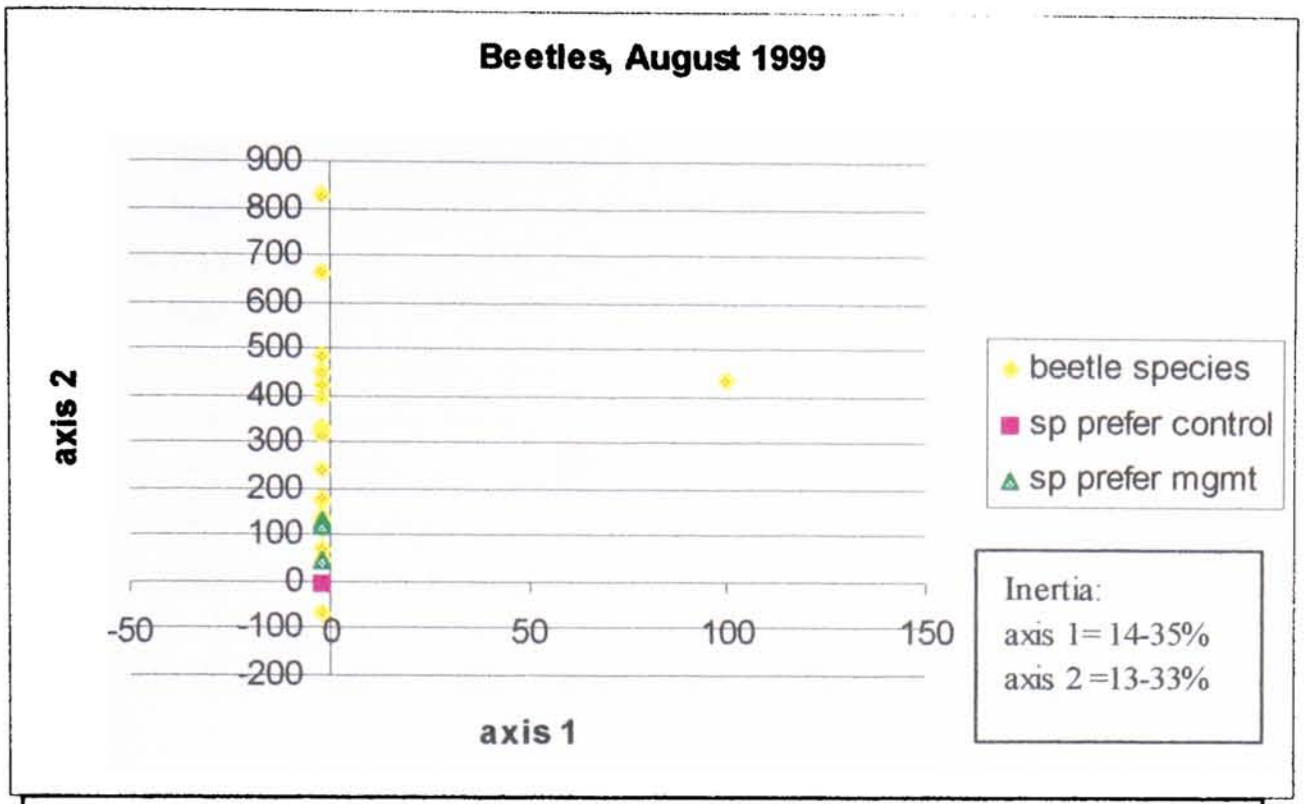


Figure 6.10 Decorana plot showing species ordinations for beetles, in August 1999, after management. Species which do better in managed or control plots are shown separately.

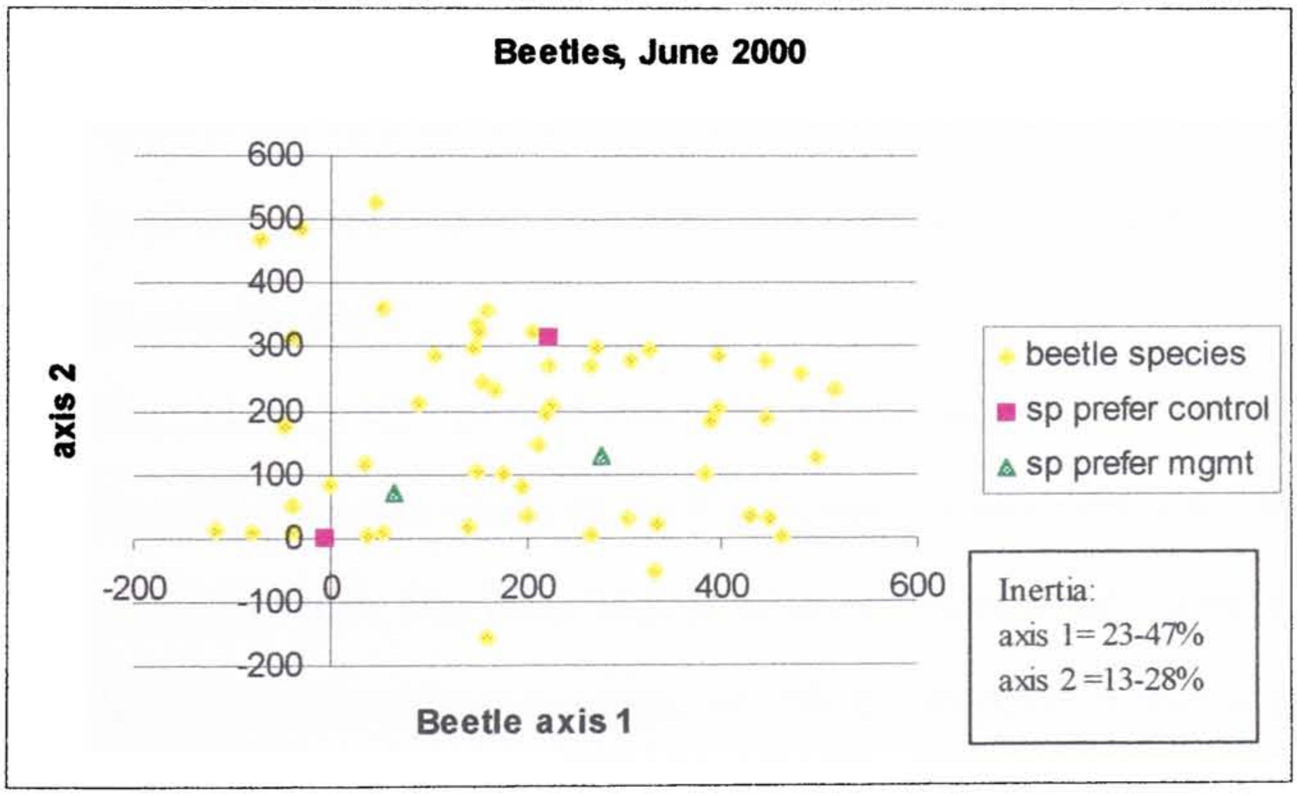


Figure 6.11 Decorana plot showing species ordinations for beetles, in June 2000, after management. Species which do better in managed or control plots are shown separately.

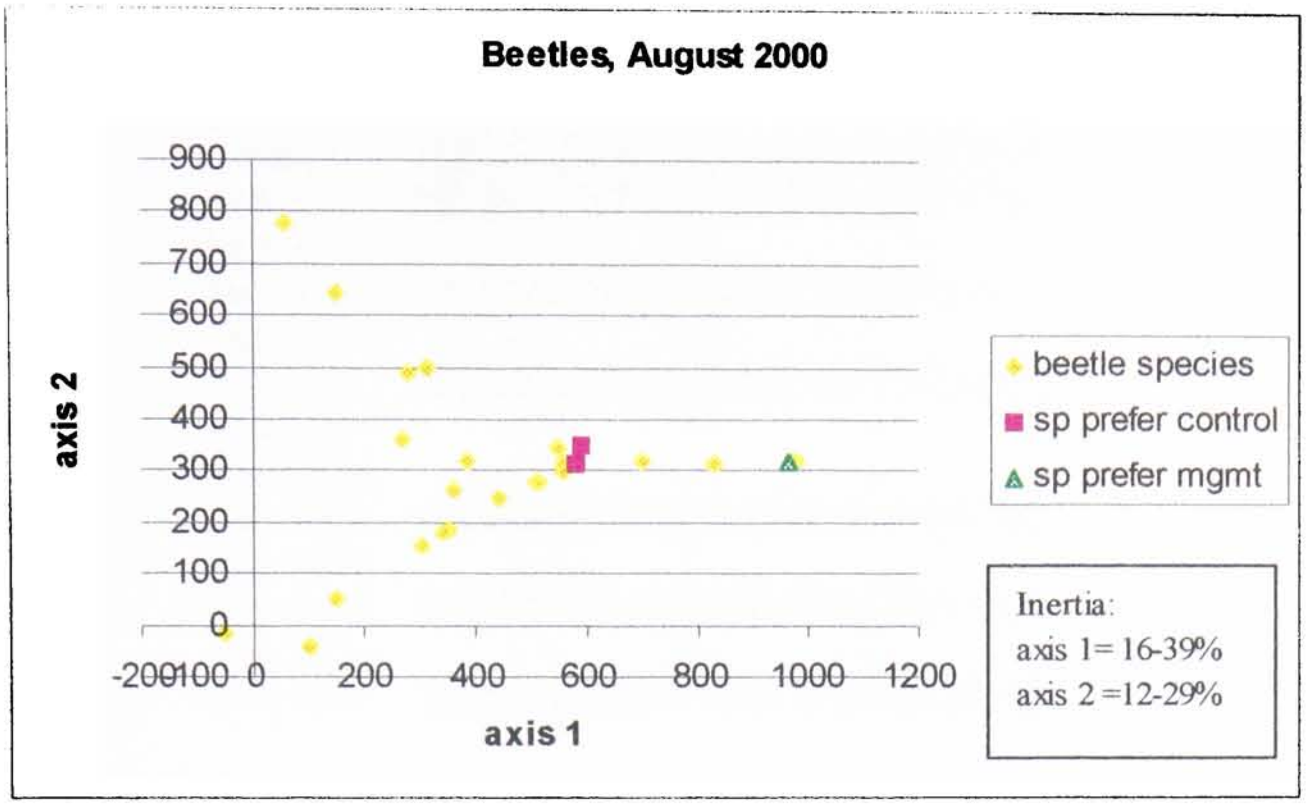


Figure 6.12 Decorana plot showing species ordinations for beetles, in August 2000, after management. Species which do better in managed or control plots are shown separately.

How diverse are the plots in terms of beetle species composition, taking both number of species and relative abundance into account? How does this change over the sampling time?

The Simpson Diversity Indices for each plot for each sampling time are shown in Table 6.VII. The data ranges for each sampling, cut and control are shown below in Table 6.VIII. The lower limit on diversity is consistently lower in cut plots than in the equivalent control plots. In 1999 the upper limit is also lower in cut plots, but in 2000 the trend is reversed and cut plots have a higher highest diversity than the equivalent control plots.

Table 6.VII Simpson's Diversity Index. Shaded plots were cut in July 1999.

Simpson Diversity Index, D

	Jun-99	Aug-99	Jun-00	Aug-00
Catfield A	5	3	5.12	2
Catfield B	8.33	2	8.45	1

Catfield C	8.53	1.6	9.62	3
Catfield D	6.13	2.67	11.98	3
Catfield E	7.2	3	5.44	2
Catfield F	6.25	3	11.66	2
Mallow A	3.54	3.57	11.21	3.06
Mallow B	6.23	3.57	3.74	2.67
Mallow C	4.84	2	3.93	2
Mallow D	5.41	2.58	9.14	1.8
Mallow E	4.02	3.77	4.76	4.76
Mallow F	3.19	1.8	7.76	4
How Hill A	8.26	4.19	9.66	4.5
How Hill B	2.90	4.17	3.57	6
How Hill C	6.91	4.5	4	1.8
How Hill D	2.27	1.25	6.37	3.6
How Hill E	3.75	2.78	5.45	3
How Hill F	4.26	1.6	4.76	3.95

Table 6.VIII The range of values found in the Simpson's Diversity Index for each treatment at each sampling.

range	June 1999	August 1999	June 2000	August 2000
control	3.75-8.53	1.6-4.5	3.74-9.66	1.8-4.5
cut	2.27-8.33	1.25-4.17	3.57-11.98	1-4.76

Using a General Linear Model to compare the Simpson Diversity Indices of the cut and control plots between June 1999 and June 2000 and between August 1999 and August 2000 showed a significant difference between diversity in June 1999 and June 2000 (Table 6.IX).

Table 6.IX General Linear Model analysis of the Simpson Diversity Index results for cut and control plots between June 1999 and June 2000 and between August 1999 and August 2000.

Effect of :

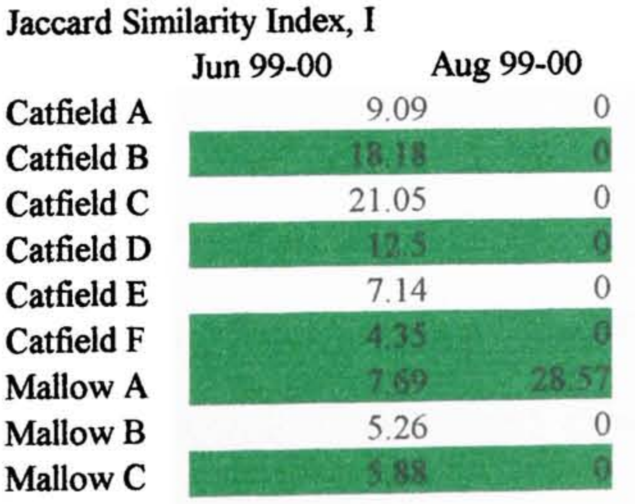
Year June 1999 to June 2000	F=5.91	p=0.027	sig *
Treatment	F=0.09	p=0.769	ns
Interaction	F=2.36	p=0.144	ns
Year Aug 1999 to Aug 2000	F=0.27	p=0.612	ns
Treatment	F=0.04	p=0.838	ns
Interaction	F=1.62	p=0.222	ns

Using a Bonferroni correction on the significant values, significance is reset at p<0.0167. This invalidates the claim that there is a significant difference between the Simpson's Diversity Indices for June 1999 and 2000.

How similar are the plots to each other in terms of species composition? How similar are they to themselves one year on?

The plots are compared June 1999 to June 2000 and August 1999 to August 2000 in Table 6.X. Note the first column compares pre-cut plots with managed plots one year on whereas the second column compares like with like one year on.

Table 6.X The Jaccard Similarity Index values for each plot, comparing June 1999 with June 2000 and August 1999 with August 2000. Shaded plots were cut in July 1999.



Jaccard Similarity Index, I

	Jun 99-00	Aug 99-00
Catfield A	9.09	0
Catfield B 🟩	18.18	0
Catfield C	21.05	0
Catfield D 🟩	12.5	0
Catfield E	7.14	0
Catfield F 🟩	4.35	0
Mallow A 🟩	7.69	28.57
Mallow B	5.26	0
Mallow C 🟩	5.88	0

Mallow D	15.79	0
Mallow E	15	0
Mallow F	5.26	0
How Hill A	18.52	0
How Hill B	15.38	0
How Hill C	0	16.67
How Hill D	11.11	0
How Hill E	14.29	16.67
How Hill F	14.29	0

Most similar is Catfield C (control plot) at I=21.05 and most changed is How Hill C (also control plot) at I=0 for the June-June comparison. For the August-August comparison the flooding made the results unreliable and most plots scored zero. Most similar of the results collected was Mallow Marsh A (experimental plot) with I=28.57. There were seven control plots and eight experimental plots scoring 0.

A Mann Witney U Test to compare the Jaccard results from cut and control plots for the June to June and August to August results gave no significant results (Table 6.XI).

Table 6.XI The Jaccard Similarity Index results analysed over each year, using a Mann Witney U test.

June-June: W=83.5 p=0.895 ns

Aug-Aug: W=89.0 p=0.683 ns

The change in similarity in species composition between plots was analysed using the Jaccard Similarity Index. The full results for each plot at each site at each sampling time are shown in Appendix 6.1. The Jaccard Similarity Index showed a rise in similarity between cut and control plots over the four sampling times for How Hill, whereas Mallow Marsh showed a sharp drop, followed by a return almost to initial levels. Catfield (Figure 6.13) showed fairly consistent similarity, though with a slight decline, for beetles species composition similarity between cut and control plots throughout the sampling times. The between site similarity for the control plots only showed a seemingly seasonal trend with all plots becoming more similar to each other in terms of spider composition in June, followed by a drop in similarity in August (Figure 6.14). Catfield and Mallow retain a 25% similarity in 1999 but this declines in line with the seasonal trend in 2000.

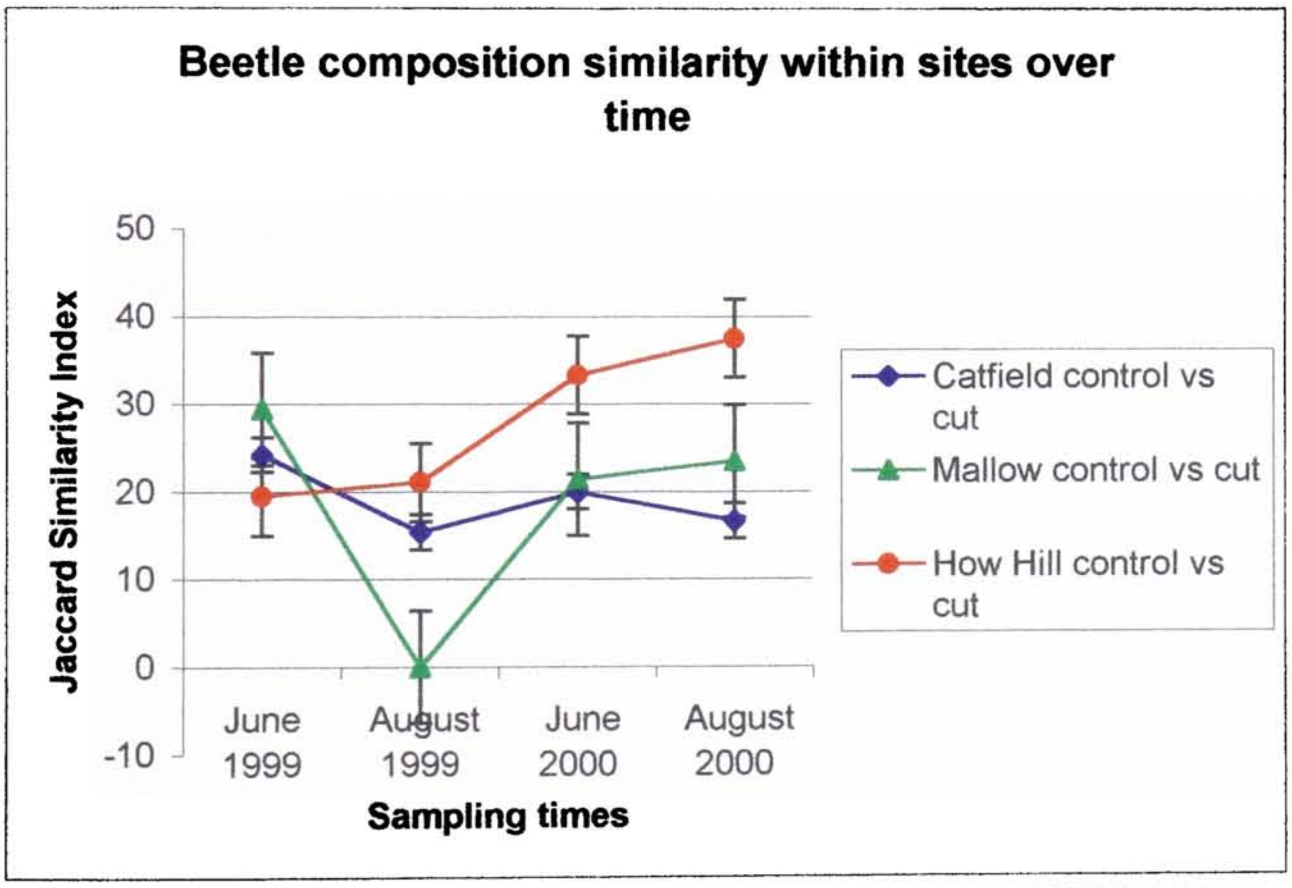


Figure 6.13 The change in the Jaccard Similarity Index within each site, over the four sampling times. Standard error bars are shown.

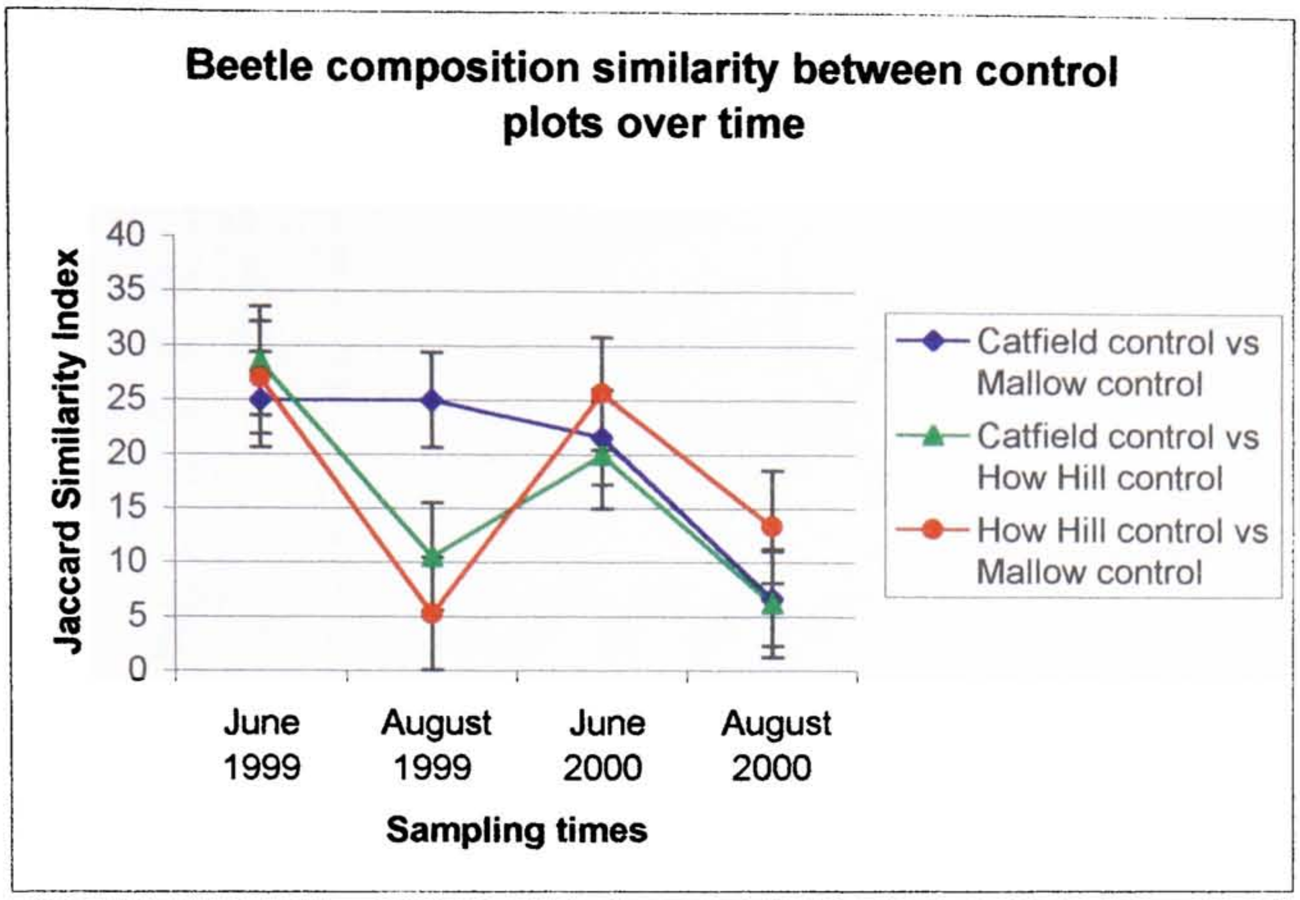


Figure 6.14 The change in the Jaccard Similarity Index between each site's control plots, over the four sampling times. Standard error bars are shown.

Analysing the same data using the Morisita-Horn Index of Similarity (Krebs, 1989, Southwood and Henderson, 2000) shows that within sites after cutting there is no consistent trend in response. How Hill exhibits almost a mirror image of the response found at Mallow Marsh (Table 6.XII, Figures 6.15 and 6.16).

Table 6.XII The Morisita-Horn results for within and between sites over the sampling period.

site	beetles	Jun-99	Aug-99	Jun-00	Aug-00
cat control	cat cut	0.636	0.478	0.362	0.261
mallow control	mallow cut	0.875	0	0.733	0.157
how control	how cut	0.73	0.888	0.2	0.607
cat control	mallow control	0.326	0.482	0.248	0.052
cat control	how control	0.593	0.13	0.21	0.341
mallow control	how control	0.613	0.009	0.447	0.112

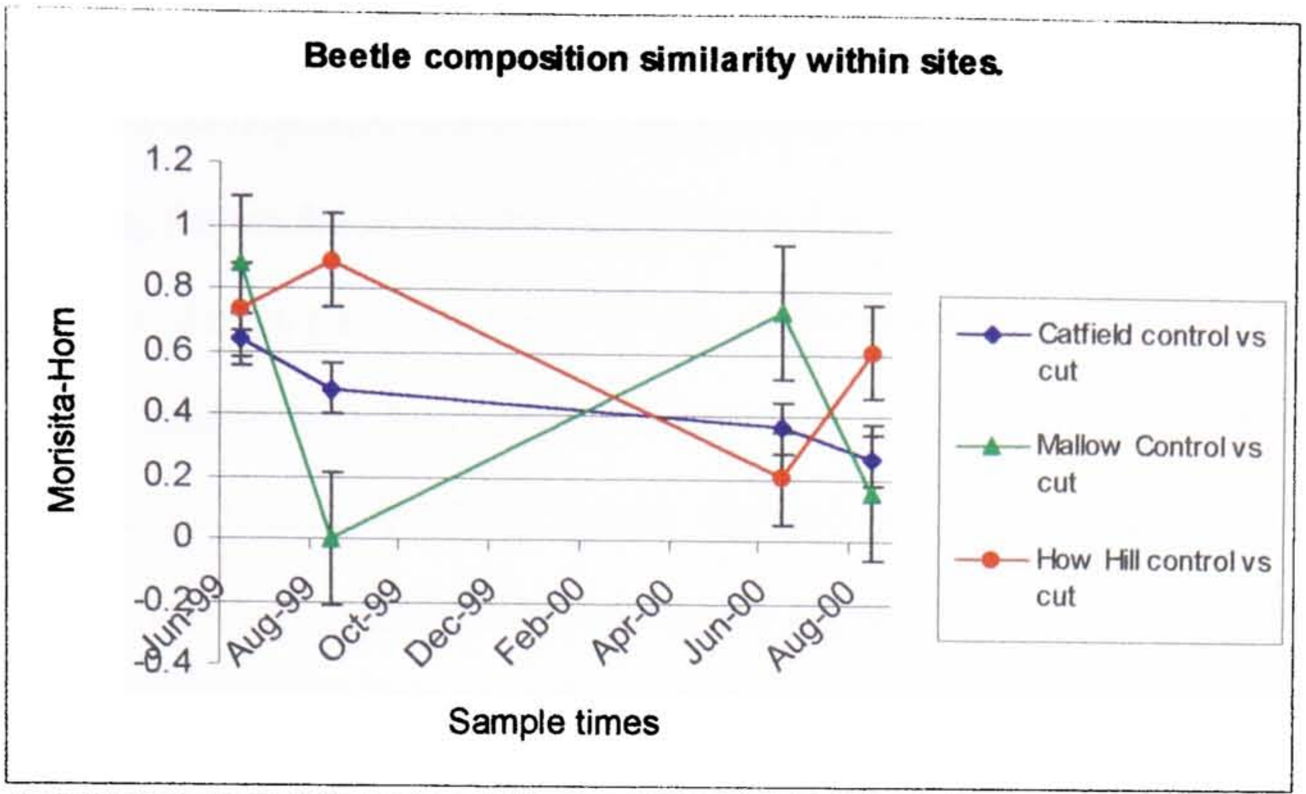


Figure 6.15 The Morisita-Horn Index within plots over the sampling period.

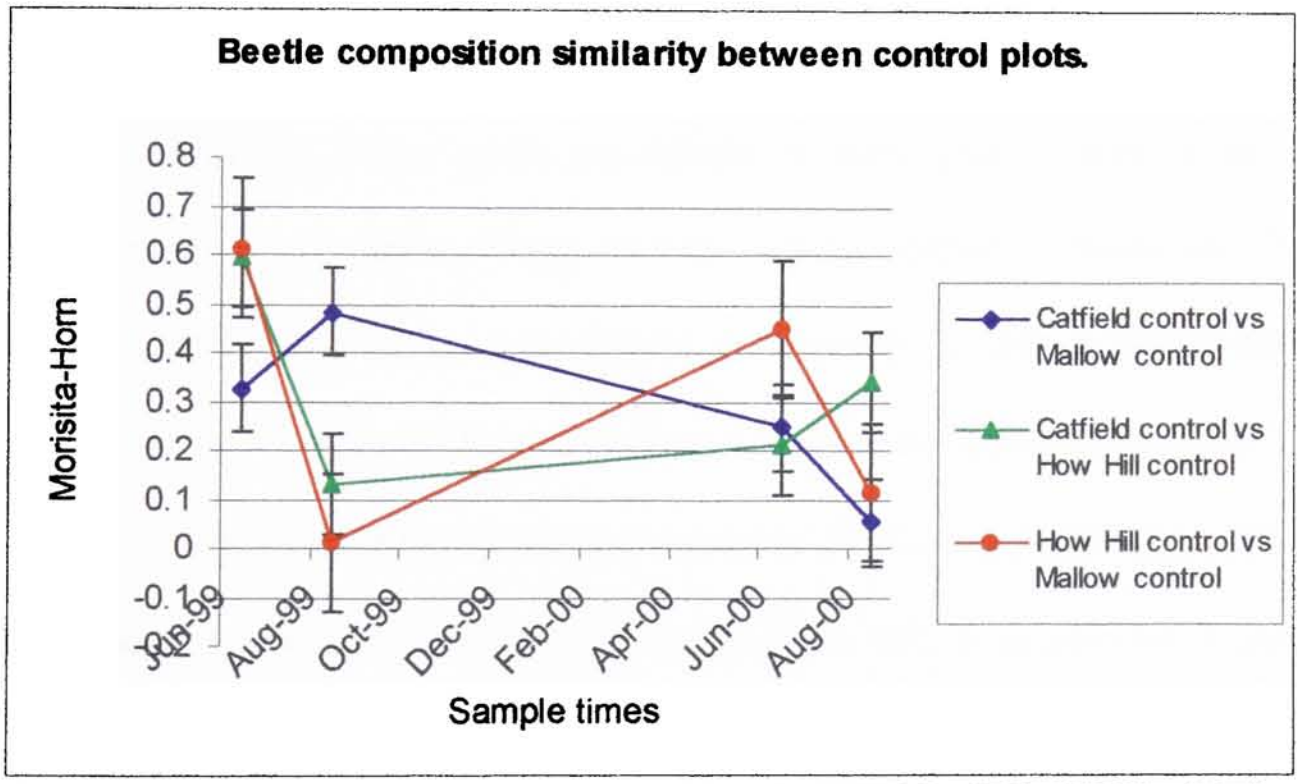


Figure 6.16 The Morisita-Horn Index between control plots on different sites over the sampling period.

Similarly the between site results do not show a consistent trend. How Hill becomes less similar to the other sites, and at the end of the sampling period all sites are less similar to each other than they were. These are all control plots so this is the natural change without management, over the sampling period.

What are the responses of individual species to management?

Plotting the results of the Chi^2 analysis and show that for individual species the effect of cutting is not uniform. All the species that had large enough sample sizes to analyse have been plotted. Figures 6.17 – 6.29 plot the numbers of individuals collected for all the species that had large enough sample sizes to analyse. The four sampling times are shown irrespective of whether sufficient data on that species had been gathered at that time. *Acrotrichis sitkaensis* (Figure 6.17) shows no clear management trend, although the largest numbers were collected pre-cutting, these levels were not repeated in the other samples. *Agonum thoreyi* (Figure 6.187) also shows little clear response to management. *Anacaena limbata* (Figure 6.19) shows a patchy distribution, being present in small numbers in a few plots and absent in most plots. There is no clear management trend. *Atheta fungi* (Figure 6.20), *Cantharis thoracica* (Figure 6.21) and *Oxypoda elongatula* (Figure 6.26) show a similar distribution to *Acrotrichis sitkaensis*, in that the highest numbers are collected in June 1999, with very few found in the subsequent samples. *Coelostoma orbiculare* (Figures 6.22) does much better where the fen has been cut. It is possibly a pioneer species. It does not occur in the control plots when cut plots are close by. *Cyphon phragmiteticola* (Figure 6.23) is seasonal, occurring mostly in June, but doesn't appear to be unduly affected by management. *Euconnus hirticollis* (Figure 6.24) does better where the fen has been managed. This is particularly clear in June 2000, but pitfall trap flooding means the August 2000 results are unlikely to be a true representation of actuality, and means it is inappropriate to draw conclusions about recovery in the same year. *Ocyusa maura* (Figure 6.25), *Paederus riparius* (Figure 6.27) and *Stenus latifrons* (Figure 6.28) show no consistent management trend. *Stilbus oblongus* (Figure 6.29) however does better in control plots, being virtually absent in managed plots. This is most clear in June 2000.

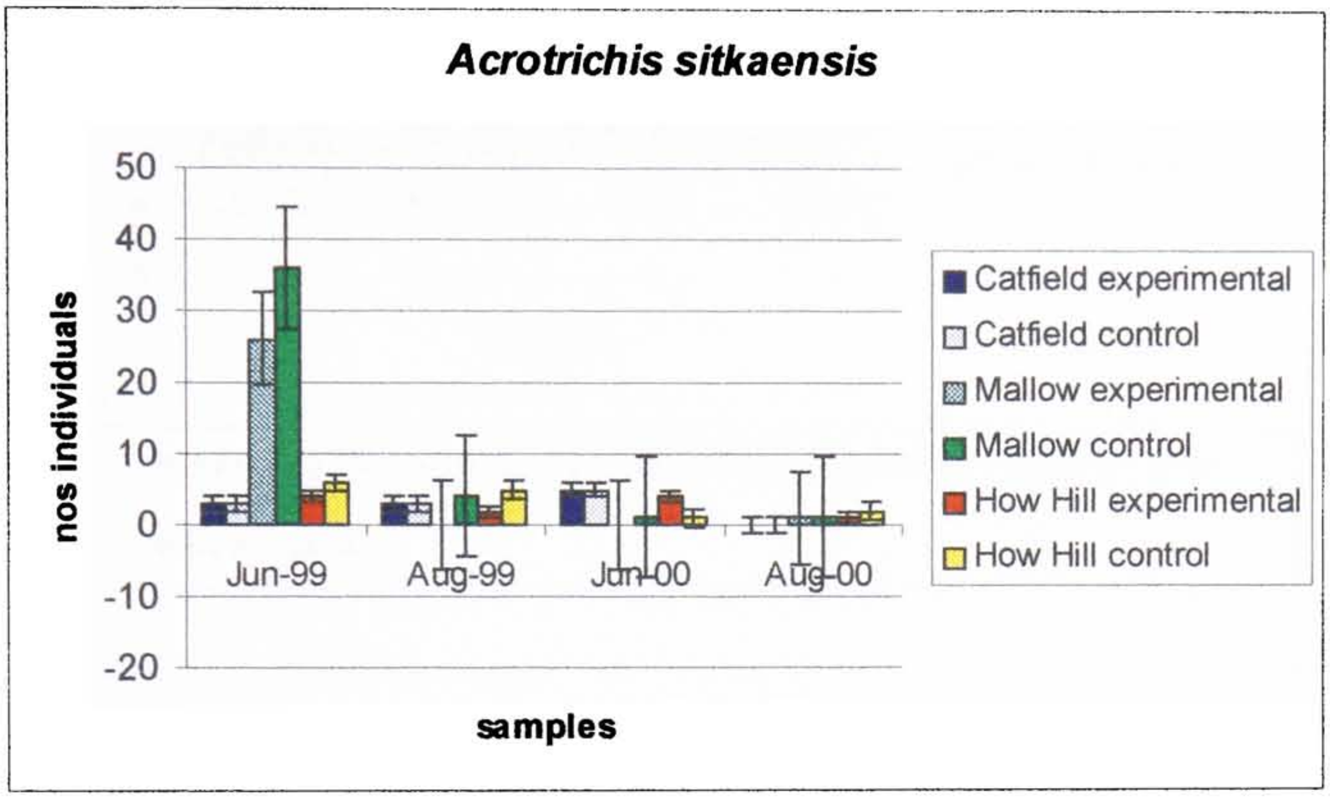


Figure 6.17 Numbers of individuals of *Acrotrichis sitkaensis*. Standard error bars are shown.

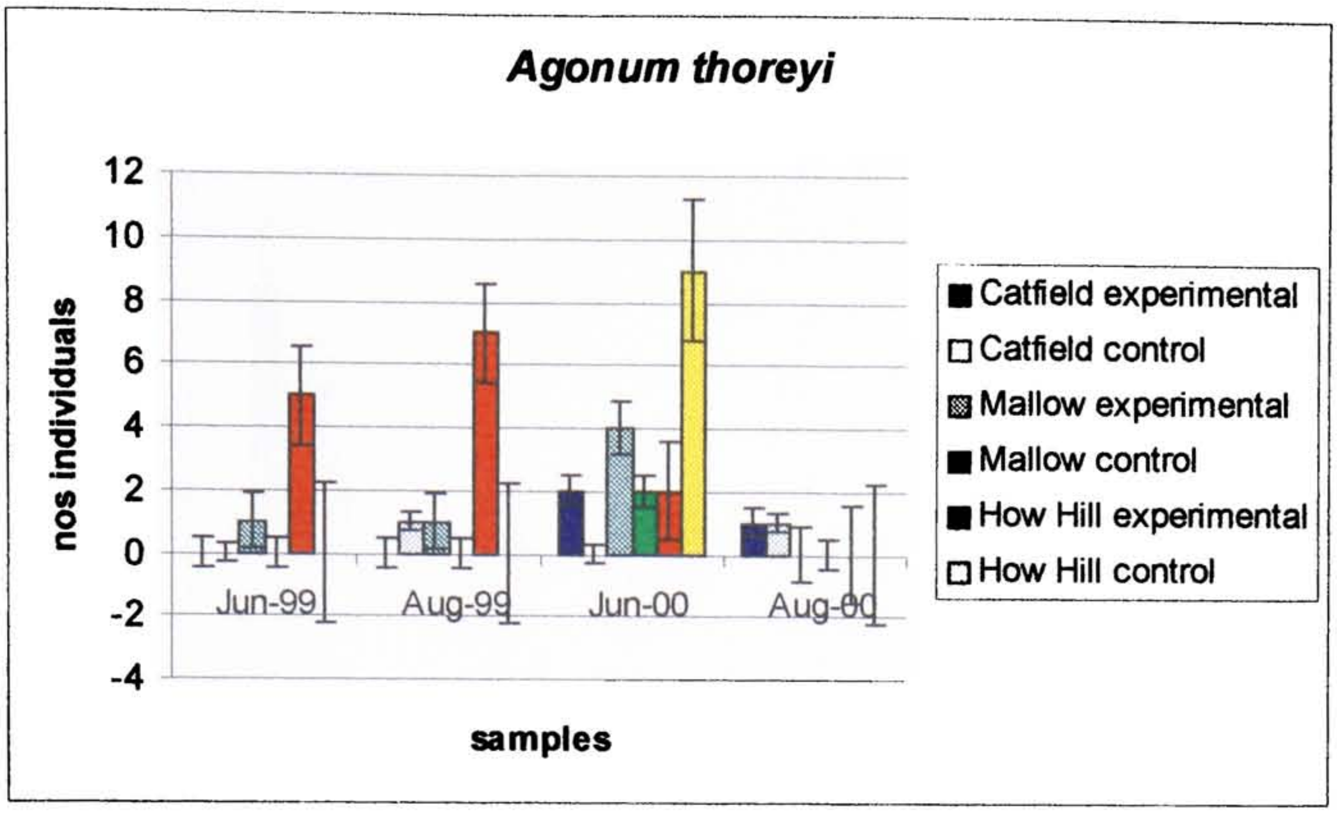


Figure 6.18 Numbers of individuals of *Agonum thoreyi*. Standard error bars are shown.

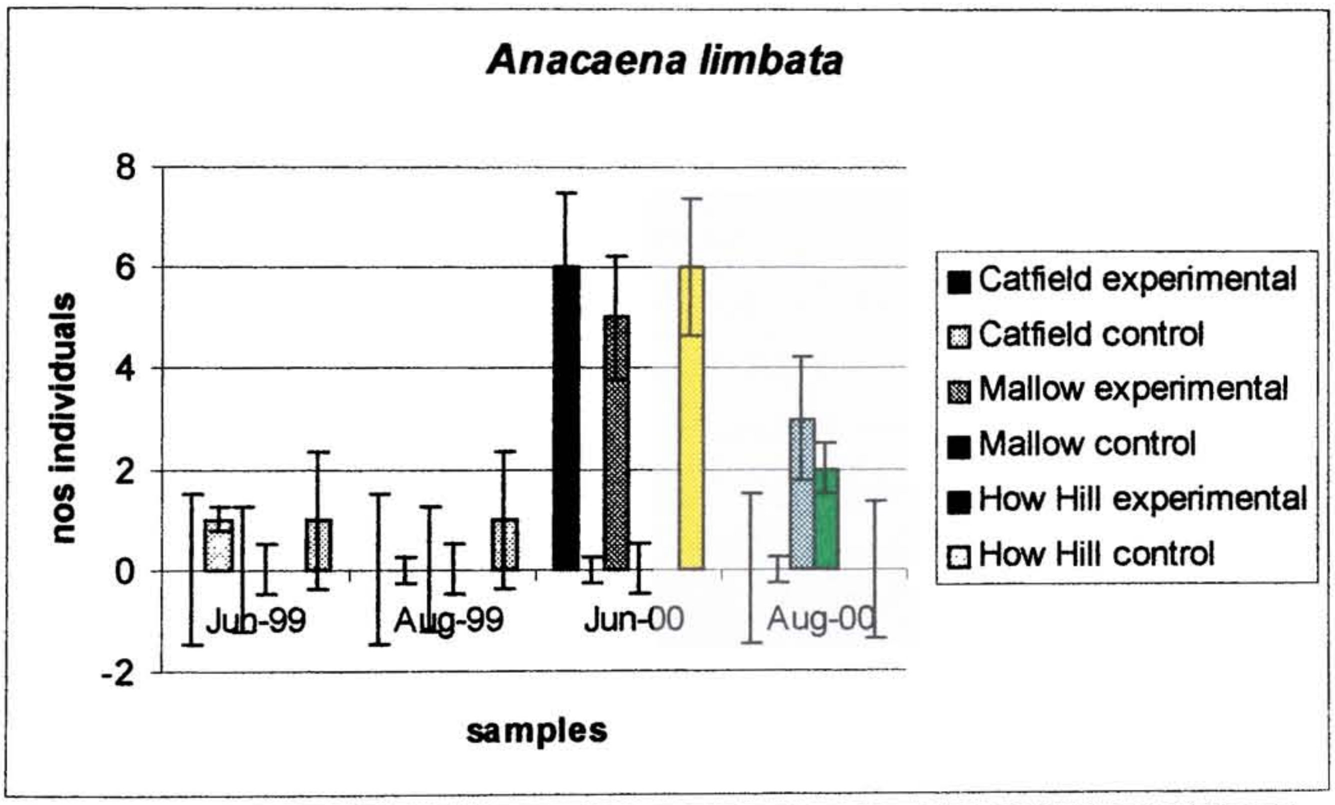


Figure 6.18 Numbers of individuals of *Anacaena limbata*. Standard error bars are shown.

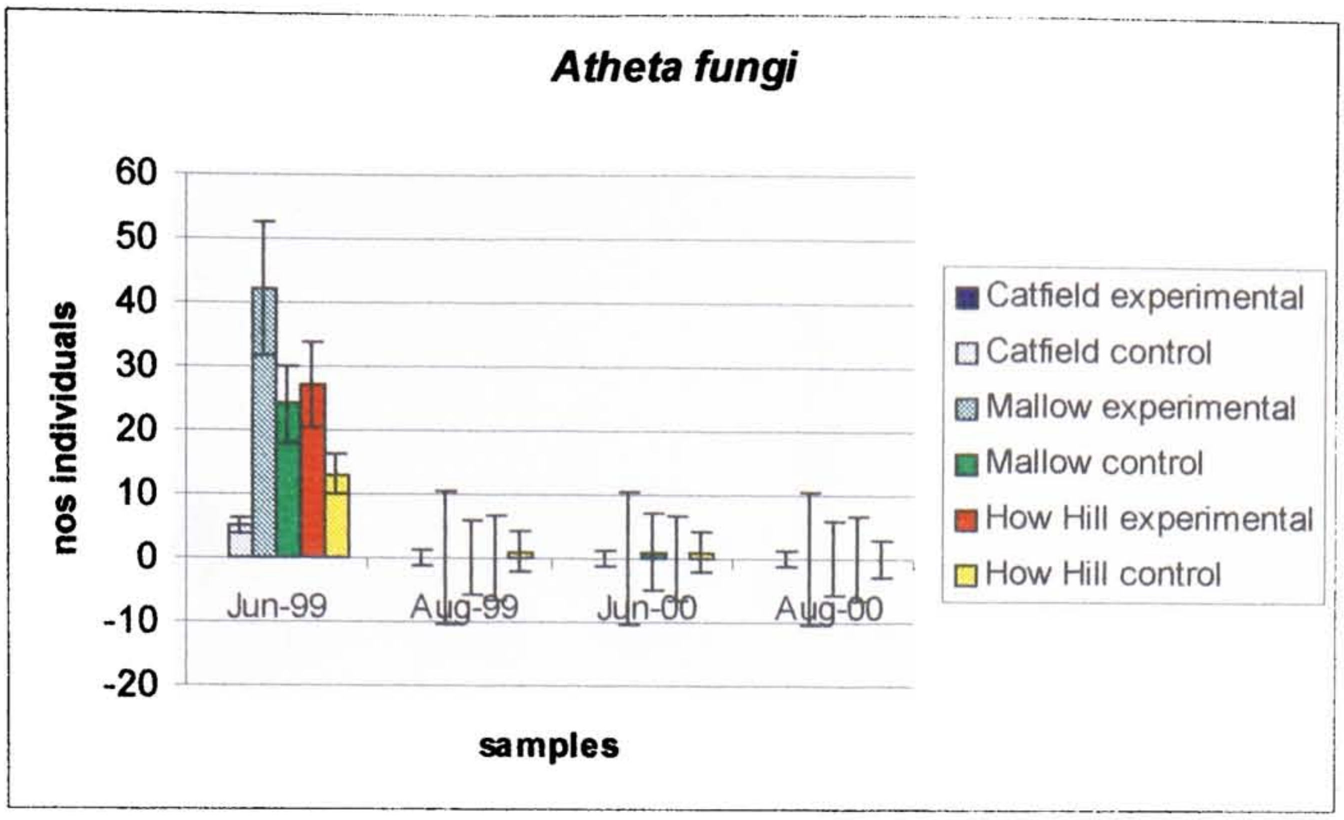


Figure 6.20 Numbers of individuals of *Atheta fungi*. Standard error bars are shown.

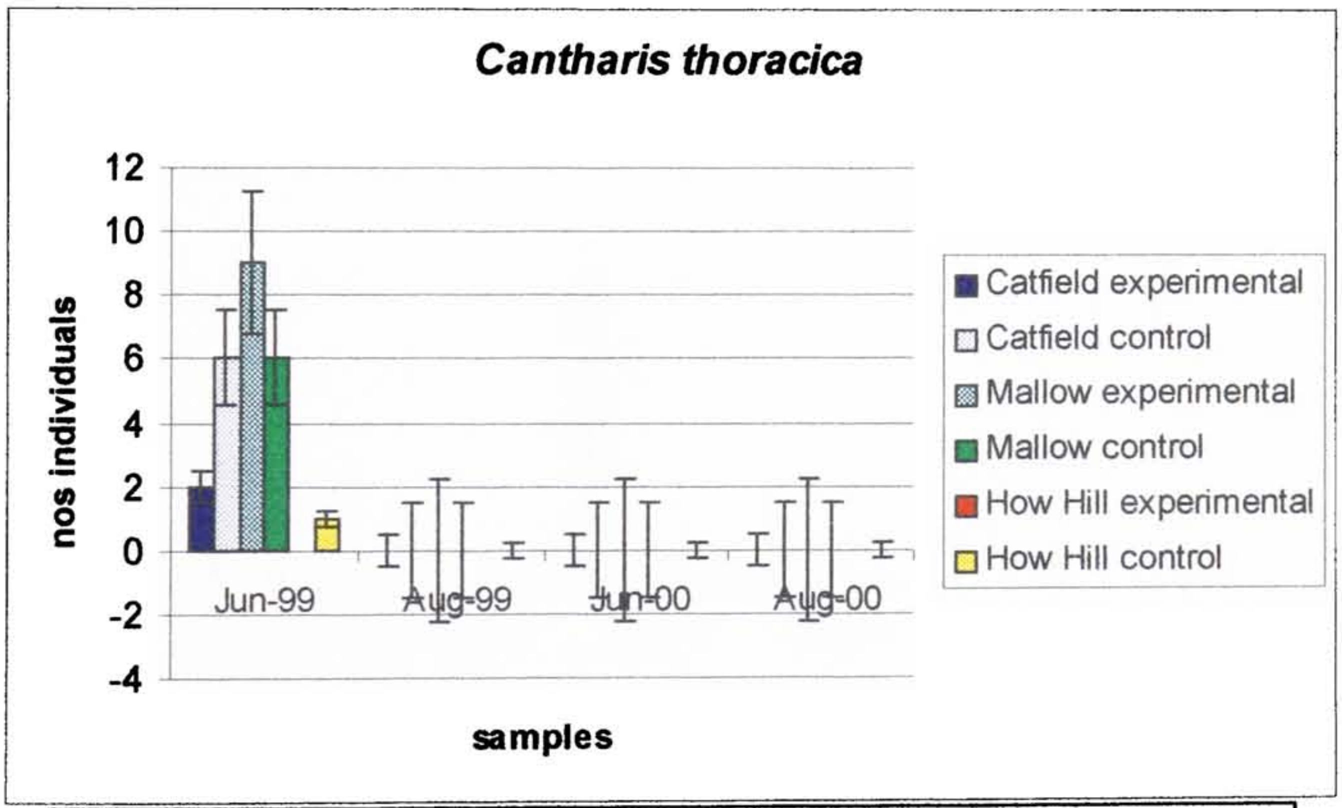


Figure 6.21 Numbers of individuals of *Cantharis thoracica*. Standard error bars are shown.

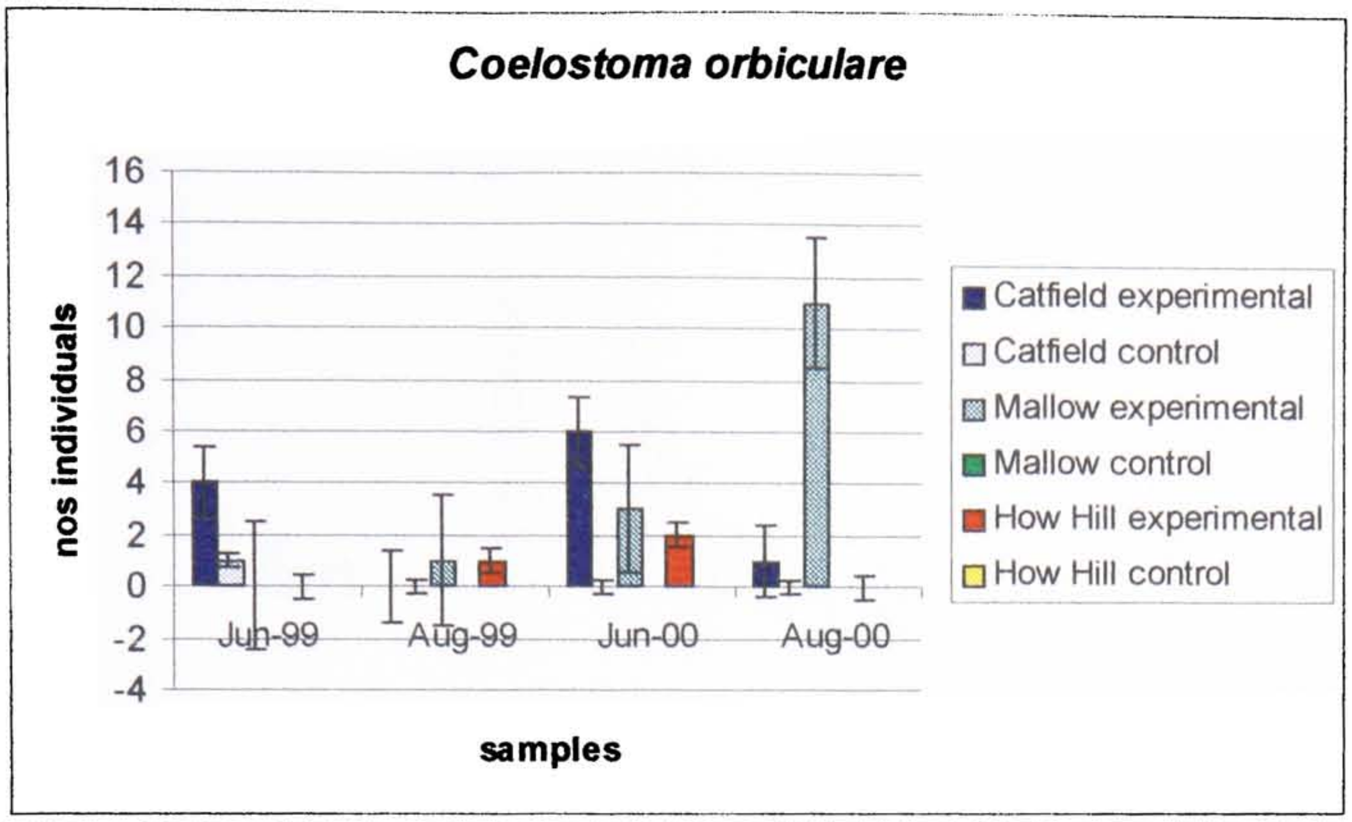


Figure 6.21 Numbers of individuals of *Coleostoma orbiculare.* Standard error bars are shown.

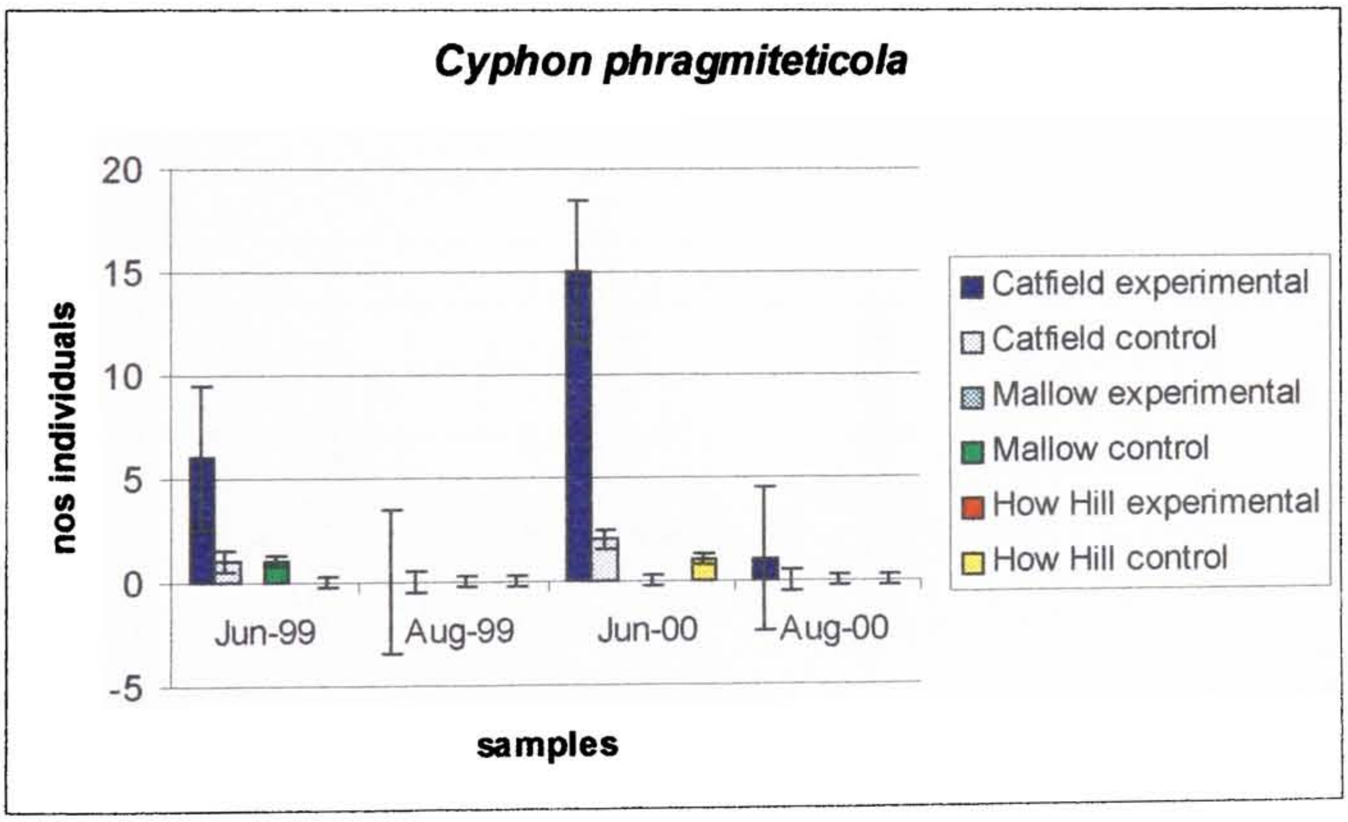


Figure 6.23 Numbers of individuals of *Cyphon phragmiteticola.* Standard error bars are shown.

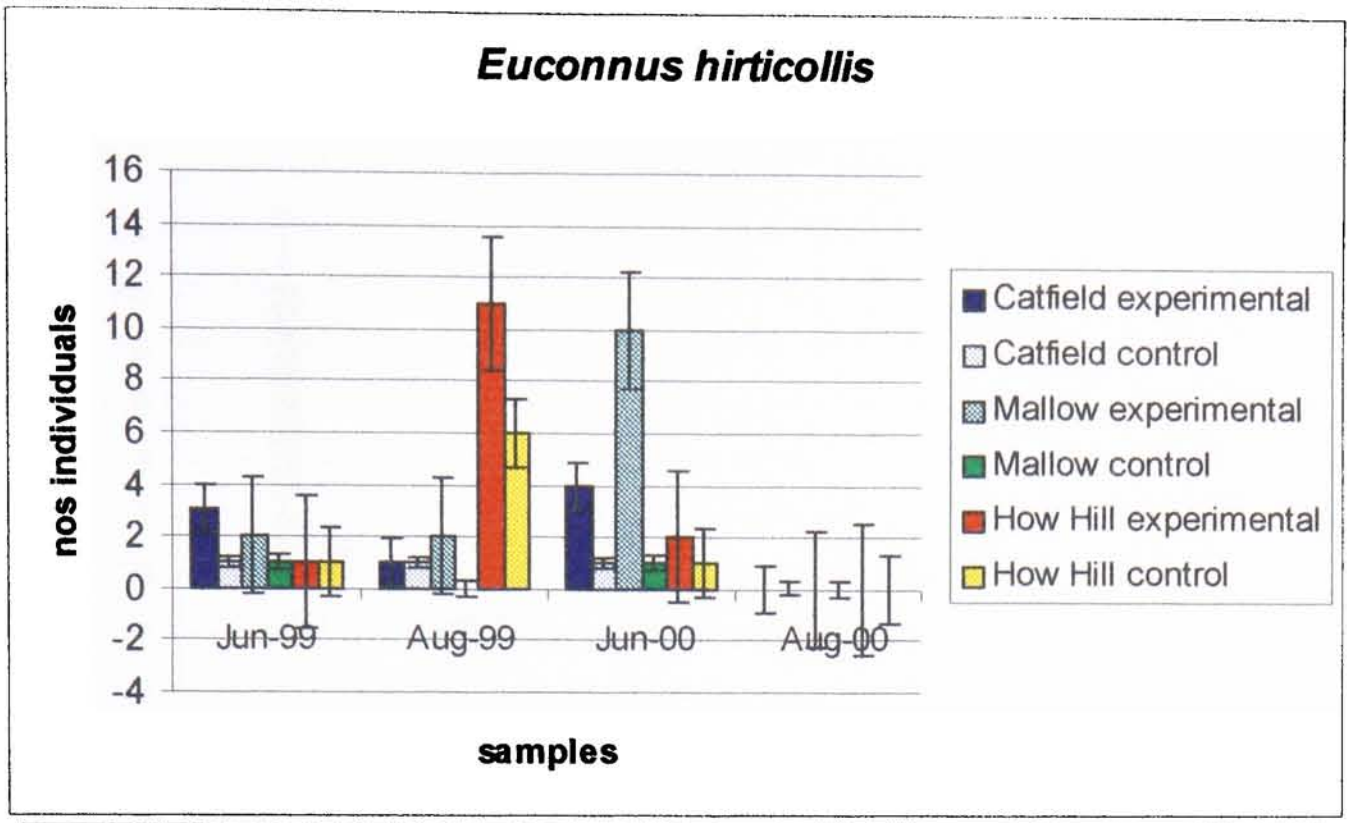


Figure 6.24 Numbers of individuals of *Euconnus hirticollis*. Standard error bars are shown.

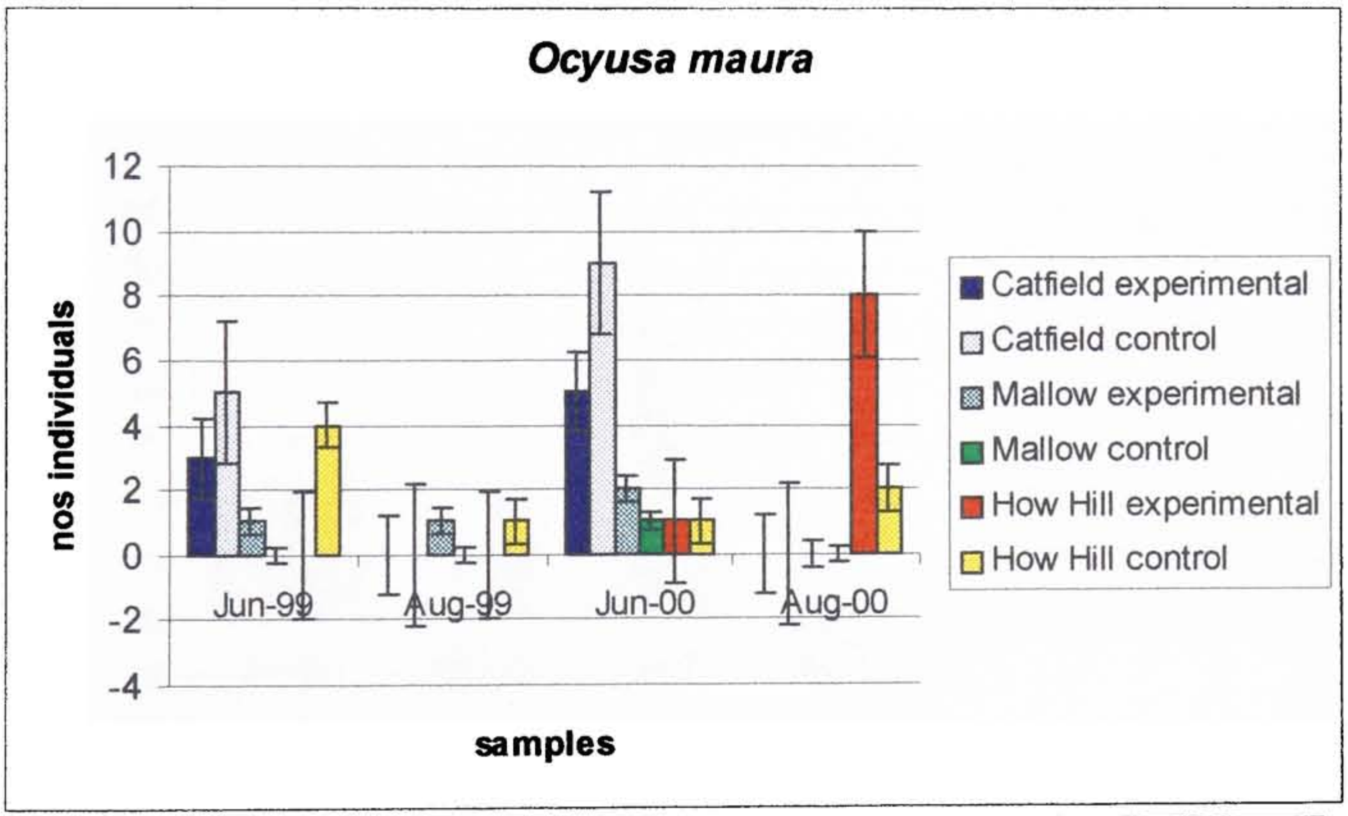


Figure 6.25 Numbers of individuals of *Ocyusa maura*. Standard error bars are shown.

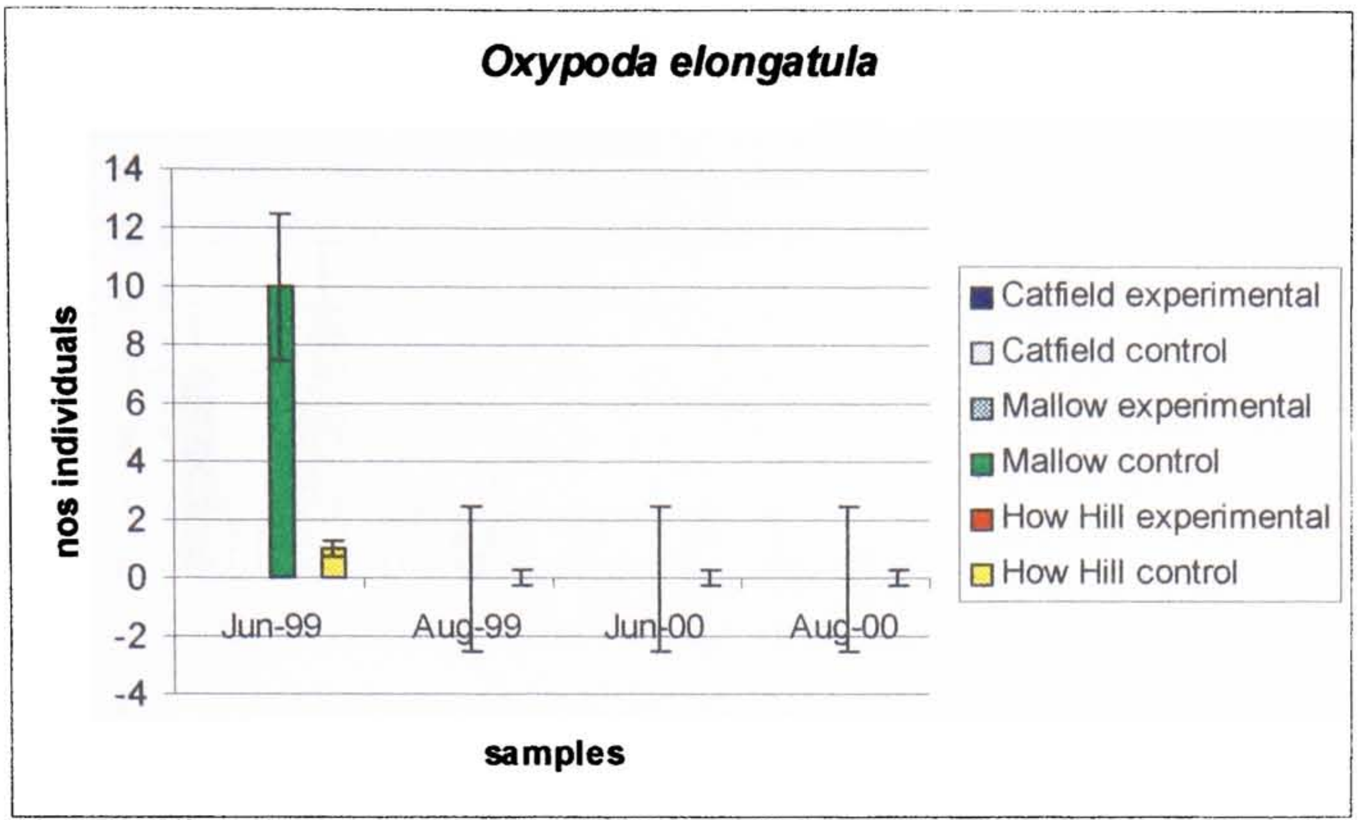


Figure 6.26 Numbers of individuals of *Oxypoda elongatula*. Standard error bars are shown.

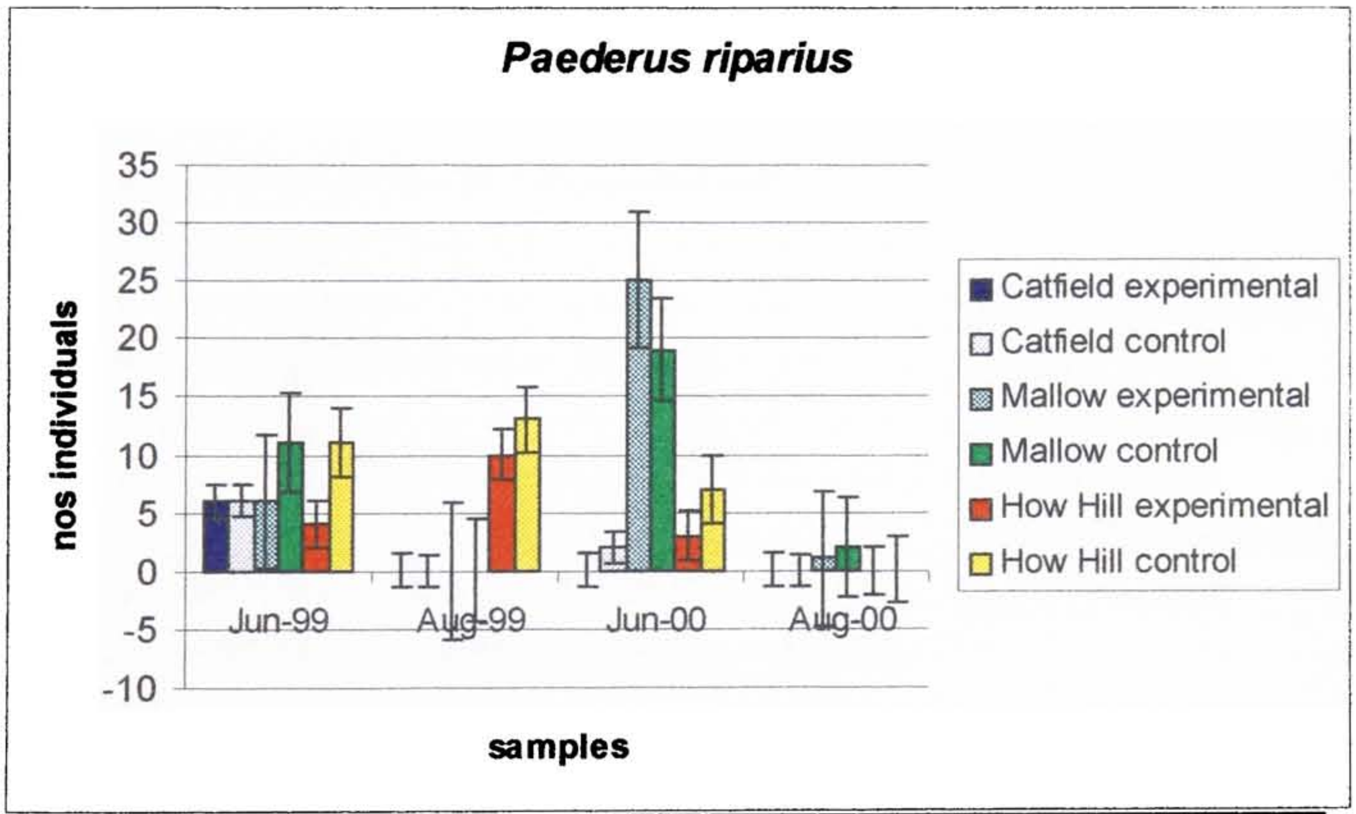


Figure 6.27 Numbers of individuals of *Paederus riparius*. Standard error bars are shown.

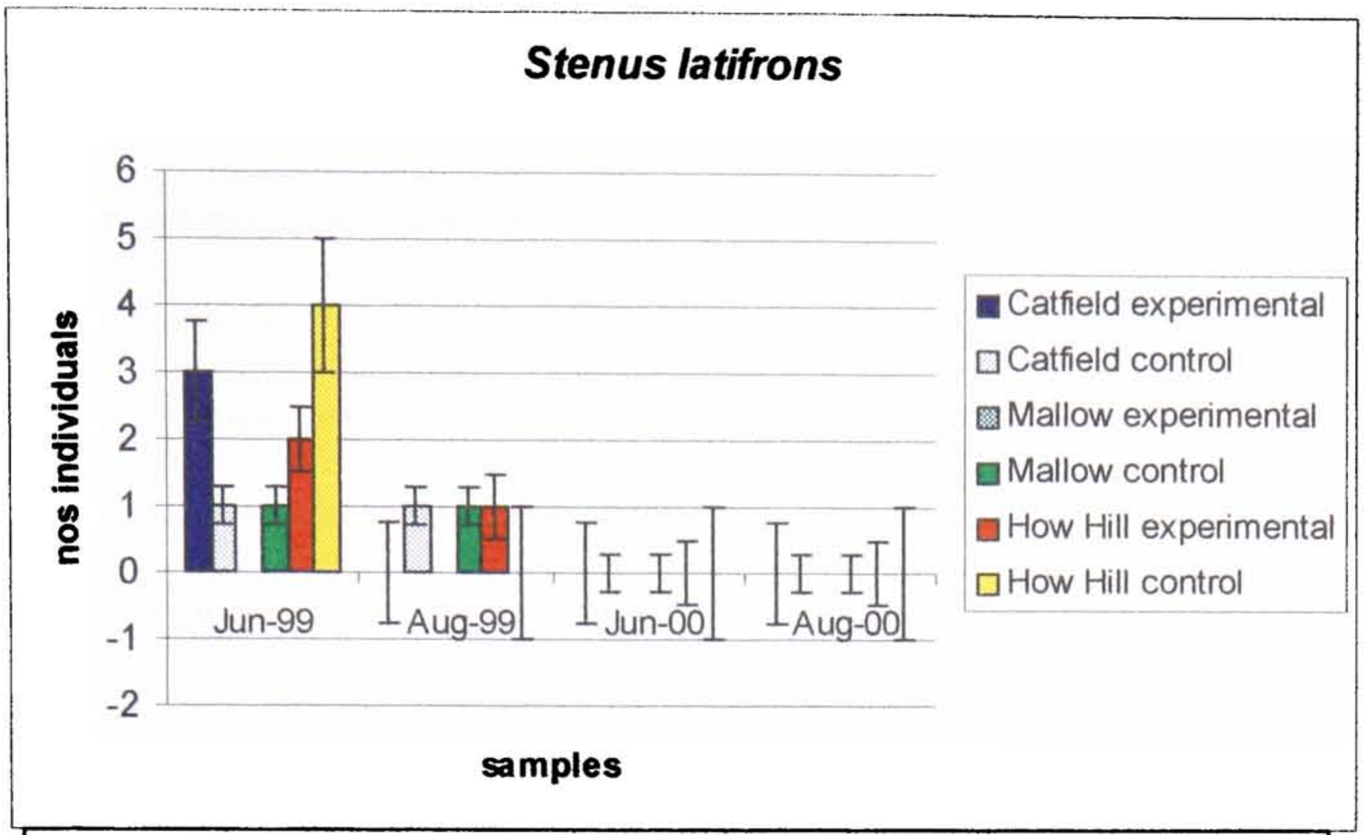


Figure 6.27 Numbers of individuals of *Stenus latifrons*. Standard error bars are shown.

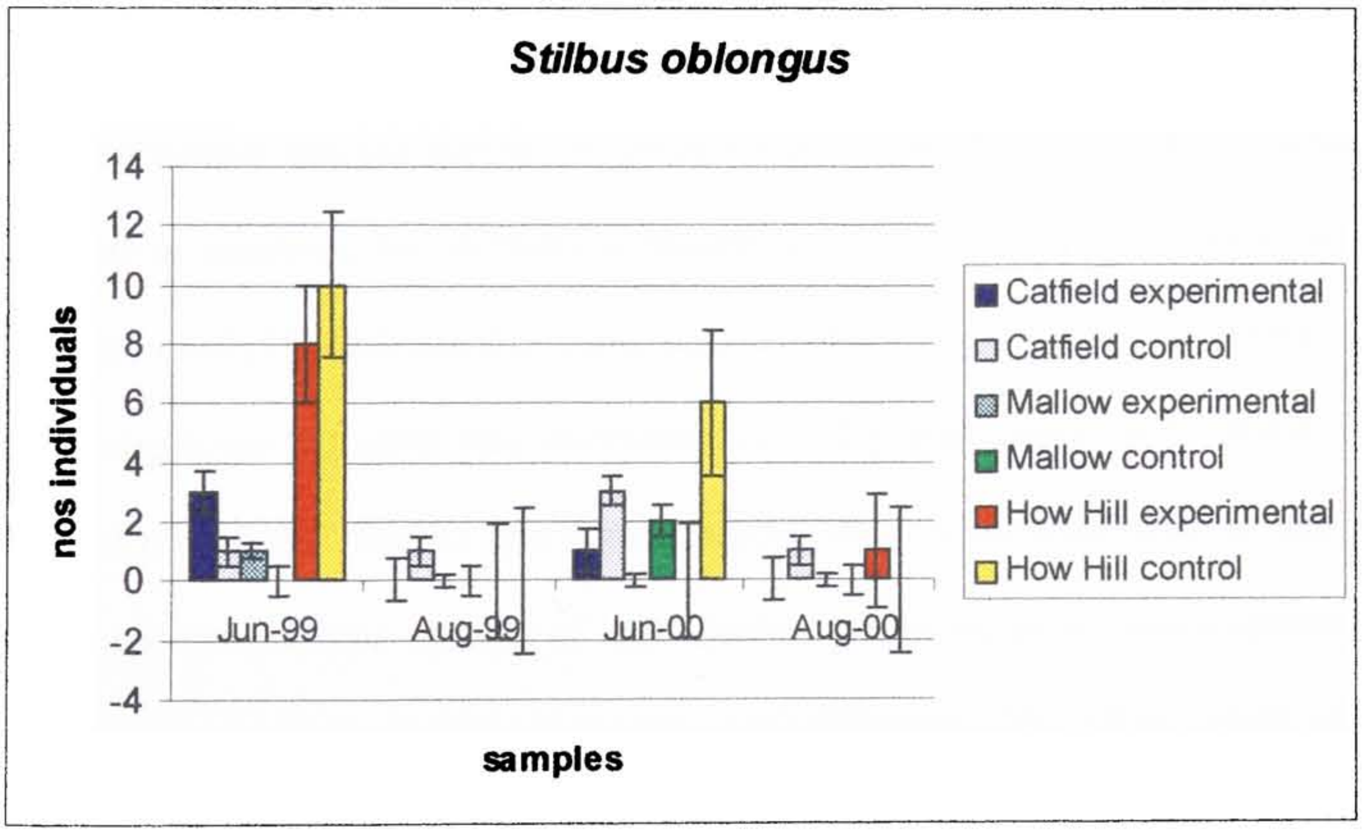


Figure 6.28 Numbers of individuals of *Stilbus oblongus*. Standard error bars are shown.

6.8 Discussion

The hypothesis that beetles are not management sensitive appears to be true for this study. The prediction that numbers of individuals would not change following management was correct. No beetle species were shown to increase or decrease significantly (GLM) after management due to either management or an interaction of management and season.

Similarly no changes in diversity or similarity (Simpson, Jaccard, Morisita-Horn) between the plots could be statistically shown either year on year, between treatments or between plots. The prediction was shown to be correct.

Is there a difference between the numbers of individual beetles found on cut and control plots at each site?

The flooding of the pots in August 2000 lead to a decrease in the numbers of both individuals and the number of species found. The difference was not large in terms of numbers, but included a completely different species composition. Ditlhogo *et al* (1992) found that water beetle numbers were positively related to water depth on the sites they surveyed. More Hydrophiliidae were found in flooded pitfall traps than in non-flooded pitfall traps. More than twice as many beetle species and also number of individuals were collected in June compared to August in both years, indicating a seasonal difference. The GLM results did not indicate that any one species is responsible for the seasonal differences.

The June results showed that one year on the diversity of beetles had increased slightly in cut plots, but the numbers of individuals had decreased. In general where a significant difference was found, more individuals were collected on cut plots than control plots, with the exception of How Hill, June 2000, though this was at a lower significance value. This difference does not manifest until one year post cutting, which indicates a delayed response of beetles to management. It is possible that cutting interferes with overwintering (Hawke and José 1996, Husak 1978, Mook 1971, van der Toorn and Mook 1982) for the species that decreased in managed areas. It is also possible that dispersal in the spring and early summer is enhanced by short reed for the species that increased in managed areas. The initial July 1999 cutting would have been too late in the year to affect such dispersal in 1999. New reed may be advantageous in some species, and predators may be discouraged by the cut plots, though this seems intuitively unlikely as it would be expected that the lack of cover in short reed would lead to a higher predation rate. There may be an effect on the pitfall trap catch rate in that enhanced motility in the short reed may lead to higher numbers being caught compared to the control plots.

Is there a difference between the numbers of individuals of each species of beetle found in cut and control plots at each site? What are the responses of individual species to management?

After management *Coelostoma orbiculare* was only found in managed areas. The cut areas appear to be preferred and this species does better in managed areas. It is a potential indicator. It does occur in control areas, pre-cutting, but not in any great numbers and further research into its habitat preferences would clarify whether this species shows as strong a preference for managed habitat as might be inferred from this result. The GLM analysis of this species showed that it was affected by management (invalidated by Bonferroni correction) but not by sampling date or an interaction of the two. A similar result was found for

Stenus juno using GLM, though this did not show up on the Chi^2 analysis due to low sample numbers. *S. juno* was only found in one undisturbed plot following management, but in three locations prior to management.

The other species which showed a preference are *Cyphon phragmiteticola*, *Euconnus hirticollis* and *Stilbus oblongus*. *C. phragmiteticola* and *E. hirticollis* showed a preference for cut plots, though not as clearly as *C. orbiculare*. *S. oblongus*, a Phalacrid, on the other hand, was virtually absent from cut areas, showing a strong decline in managed plots. It decreased in cut plots from 10 individuals (June 1999) to one individual (June 2000) whereas the control plot numbers decreased comparatively from 13 to 11 over the same time span. This is a potential negative indicator of disturbance. Notably none of these species were identified using GLM analysis as being sensitive to anything other than season. Three species were highlighted as showing a sample date / treatment interaction. These were *Apthona nonstriata*, *Bryaxis bulbifer* and *Oxypoda elongatula*. *B. bulbifer*, together with *C. orbiculare* and *S. juno* did not show significant seasonal variations, unlike the other species tested. After management *B. bulbifer* and *A. nonstriata* were only found on control plots. *O. elongatula* was only collected in June 1999 prior to management, and then only in plots which were subsequently left uncut. It seems unlikely that the absence of this species in the following samplings was due to habitat management. *A. nonstriata* overwinters in tussocks, and so damage to these during cutting could account for this species absence from managed plots.

Rarer species may also be adversely affected by management, but numbers are too small to analyse at this level of sampling. The species collected indicate a good quality wetland area (R. Marsh pers. comm.) with several Nationally

Notable, Red Data Book species found. These include *Agabus striolatus* (RDB2) *Hydroporus scalesianus* (RDB2), *Hydraena palustris* (RDB2), *Ptenidium intermedium* (an ancient wetland indicator), *Stenus longitarsis* (RDB1), *Philonthus fumaris, Atheta zosterae, Silis ruficollis* (Nb), *Atomaria gutta* (a very scarce wetland species), *Quedius balticus* (RDB1), *Stenus longitarsus* (RDB1), *Psephaulax dresdensis* (Nb), *Corylophus cassioides* (local), *Heterocerus obsoletus* (local) and *Laccornis oblongus* (pRDB3) which is restricted to Norfolk. None of these occurred in numbers sufficient for statistical analysis. JNCC (www) note that *Quedius balticus* is endangered due to loss of, and changes in the wetlands it inhabits. Appendix 6.2 shows the status of nationally notable beetles found in this study.

Is there a difference between the composition of beetles at each site, and between the different management treatments?

Indirect ordination techniques, such as PCA and Decorana (Hill 1979a) or Twinspan (Hill 1979b) have been able to easily separate habitats using multivariate species data. Studies using these techniques include those of Arnold and Ormerod (1997), Buckton and Ormerod (1997), Kotze and Samways (1999), Ottesen (1996), Painter (1999) and Rushton *et al* (1990) amongst others. Environmental factors have been taken into account by plotting the vegetation ordination against the species ordinations in the form of a biplot (Wheater *et al* 2000) allowing the effect of the vegetation to be clearly seen.

The biplot illustrates that the vegetation at Catfield is different to that at How Hill and Mallow Marsh (Chapters 4 and 5). For the beetles the results for August 1999 show that plot F at Catfield provides seemingly different niche opportunities. Three species of beetles occurred there which were not found in other plots. This unusual species composition includes a local species *Heterocerus obsoletus* and a Notable B list species *Oodes helopioides* and also the unusual *Xantholinus linearis*, not found elsewhere.

The data for August 2000 is strong on Hydrophiliidae and other aquatic species. The composition of the pitfall traps is quite different to the other sampling times probably due to flooding. It has smaller numbers of individuals collected (99 individuals compared with 117 for the same time the year before and 39 species compared with 41). The points in Figure 6.12 appear to have a tendency to fall out along a 45 degree line. This indicates that axis 1 and 2 are measuring similar, or overlapping parts of the variation. Technically it cannot be exactly the same variation as Decorana adjusts for axis folding. Effectively a 45 degree line indicates a lack of variation in the data. This lack of variation is most likely to be due to the flooding of the pitfall traps during this sampling.

The species ordinations complement the site ordinations. There is very little to be learned from those few species which showed management preferences. The species ordination did not separate out control preferring species clearly from management preferring species at any sampling except the last one. Unfortunately with just one species in this August 2000 sample showing management preference it is hard to base any firm conclusions on this result.

How diverse are the plots in terms of beetle species composition, taking both number of species and relative abundance into account? How does this change over the sampling time?

The Simpson Diversity Index is relatively insensitive to sample size (Norris 1999), which is an advantage in this study, where catch sizes vary between seasons, sites and weather conditions.

The Simpson Index (Begon *et al* 1990) does not highlight the diversity changes shown in the Chi^2 analyses. However a shift in species composition doesn't necessarily change the composite diversity for a plot (Petterson 1996). The results of analysing the Simpson's Diversity Indices showed that there is a significant change in diversity from June 1999 to June 2000, but that this is irrespective of and independent from the treatment the plots received. There is no significant change in diversity from August 1999 to August 2000, irrespective of treatment or any interaction between time and treatment. It would be interesting to see if higher numbers of individuals and species collected in June compared to August contributed directly to these results, and if greater sampling effort would produce similar year to year effect for August. As a recommendation for this type of management of the reedbed, it cannot be said that any noticeable change has been inflicted on the Coleopteran biodiversity *per se*.

How similar are the plots to each other in terms of species composition? How similar are they to themselves one year on?

The analysis of the Jaccard Similarity Index showed that there is no significant change in similarity between cut plots year on year compared to similarity between control plots year on year. Of course this doesn't mean that they are not both changing in the same direction at the same speed, but that the treatment the plots received has not altered the composition at a greater or slower rate than is happening naturally in the unmanaged plots. Which species change cannot be measured by this index, and it is possible that there is a directional change in cut plots compared to a random change in control plots, with an increase in certain species and an elimination of one. However from the analysis of the Jaccard results it appears that presence or absence of species is not significantly affected by management in cut plots compared to control plots, one year after cutting.

Initially within site similarity is not higher or lower than between site similarity. There appears to be a strong reaction to cutting at the Catfield site, immediately post-management, however this plummet in similarity quickly returns to levels of similarity close to those observed before management. Other sites do not exhibit such a strong response. This may possibly be due to the particular fauna found at Catfield. Least similar are plots with different management regimes at different sites, which shows management and site have an effect, though this is not significant (Appendix 6.1). By 14 months post cutting the within site similarity is clearly higher than the between site similarity. This parallels the findings for the Araneae (q.v. Chapter 5 page 155). Management has an effect, but the original fauna on the site has more of an effect on what is found at any one site after management. Catfield and Mallow Marsh control plots get gradually less similar over time, whereas How Hill control plots are less similar to the other two sites' controls in August compared to the June samplings, showing a seasonal fluctuation. There are likely to be beetles present at How Hill in August which are not present at the other sites. These could include a selection of the rarer beetles (Appendices 6.2 and 7.1) not present in sufficient numbers to analyse using the Chi squared test, but which still add an equal weight to the Jaccard Index analysis, as this analysis only tests presence and absence data.

The Morisita-Horn analysis also concluded that there is no directional difference in similarity due to management. The fluctuations between the control plots at different sites were as large than the within plot fluctuations. Within plot fluctuations has no pattern to them, showing this sort of management does not have a predictable effect on beetle diversity.

6.9 Conclusions

Coleoptera are not management sensitive, in general. Not one species was shown to react in terms of an increase or decrease in numbers of individuals to a statistically testable level (GLM) following habitat management.

Similarly the biodiversity of the beetle assemblage did not change following management. There was no year to year effect, and only three Coleopteran species showed a seasonal response. These were *Atheta fungi, Cercyon convexsculus* and *Stenus latifrons*. Cutting management does not damage or significantly alter the beetle biodiversity of fens and reedbed in the short-term.

The results of the vegetation analyses show that the S4 plots at Mallow Marsh and How Hill are more similar to each other in terms of vegetation than the more S24 plots at Catfield Fen. In particular the driest, most distinct plot (Catfield F) turns up a unique selection of beetles in the August 1999 sampling. This indicates how strongly habitat sensitive beetles are. Beetles are speciose, and have seasonal fluctuations, showing an increase in diversity (numbers of species collected) and abundance (numbers of individuals collected) in June compared to August, for both years sampled.

There is no significant difference in diversity between June 1999 and June 2000 or between August 1999 and August 2000. There is no significant difference in diversity due to management, or to an interaction between management and year, as tested using the Simpson Diversity Index.

Each plot was as similar to itself (tested using the Jaccard Similarity Index and Morisita-Horn) in terms of species presence and absence, or numbers of individuals one year on, irrespective of the management or lack of it received. Similarity was on the whole quite low, and this reflects the species richness of the beetles, compared to the other groups studied (q.v. Chapters 4 and 5)

Despite the lack of significant results when the whole group is analysed together in terms of diversity and species presence and absence there are some changes to the fauna following management. Some beetles are subtly management sensitive. The number of *Coleostoma orbiculare, Cyphon phragmiteticola* and *Euconnus hirticollis* increase after cutting. These may be pioneer species, but they were all present in the habitat before management. *Coleostoma orbiculare* shows the most striking response to opening up the habitat, being more numerous in managed plots. It was not found in unmanaged plots post-cutting. *Stilbus oblongus* numbers decrease after cutting management, indicating that, as for the other invertebrate groups studied (q.v.), a mosaic of ages and a patchwork of management is required to conserve a range of species.

6.10 APPENDIX 6.1

The Jaccard Similarity Index data for each site (accumulated cut and control values) for each sampling time.

Table 6.XIII Jaccard Similarity Index for each site (accumulated cut and control values) for June 1999.

Jun-99	Catfield to be cut	Mallow control	Mallow to be cut	How Hill control	How Hill to be cut
Catfield control	24.24	25	20	28.57	20
Catfield to be cut		48.28	25	26.32	21.88
Mallow control			29.41	27.03	26.67
Mallow to be cut				25.64	3
How Hill control					19.44

Table 6.XIV Jaccard Similarity Index for each site (accumulated cut and control values) for August 1999.

Aug-99	Catfield cut	Mallow control	Mallow cut	How Hill control	How Hill cut
Catfield control	15.38	25	11.76	10.53	28.57
Catfield cut		7.69	12.5	5.26	21.43
Mallow control			0	5.26	13.33
Mallow cut				14.29	23.53
How Hill control					21.05

Table 6.XV Jaccard Similarity Index for each site (accumulated cut and control values) for June 2000.

Jun-00	Catfield cut	Mallow control	Mallow cut	How Hill control	How Hill cut
Catfield control	20	21.62	15.79	20	16.13
Catfield cut		15.09	27.66	23.4	20.93
Mallow control			21.43	25.64	16.22
Mallow cut				16.29	20
How Hill control					33.33

Table 6.XVI Jaccard Similarity Index for each site (accumulated cut and control values) for August 2000.

Aug-00	Catfield cut	Mallow control	Mallow cut	How Hill control	How Hill cut
Catfield control	16.67	6.67	5	6.25	16.67
Catfield cut		7.69	11.76	7.14	0
Mallow control			23.53	13.33	5
Mallow cut				15.79	8.33
How Hill control					37.5

6.11 APPENDIX 6.2

Coleoptera Checklist.

CARABIDAE

Agonum fuliginosum (Panzer, 1809)	
Agonum gracile Sturm, 1824	Local
Agonum thoreyi Dejean, 1828	Local
Agonum viduum (Panzer, 1796)	
Amara lunicollis Schiödte, 1837	Local
Bembidion assimile Gyllenhal, 1810	
Bembidion fumigatum (Duftschmid, 1812)	Notable/Nb
Bembidion lampros (Herbst, 1784)	
Bembidion minimum (Fabricius, 1792)	
Bembidion unicolor Chaudoir, 1850 [synonym of mannerheimii Sahlber CR, 1827]	
Blethisa multipunctata (Linnaeus, 1758)	Notable/Nb
Carabus granulatus Linnaeus, 1758	Local
Dromius longiceps Dejean, 1826	Na
Elaphrus cupreus Duftschmid, 1812	
Loricera pilicornis (Fabricius, 1775)	
Odacantha melanura (Linnaeus, 1767)	Notable/Nb
Oodes helopioides (Fabricius, 1792)	Notable/Nb
Pterostichus diligens (Sturm, 1824)	
Pterostichus madidus (Fabricius, 1775)	
Pterostichus minor (Gyllenhal, 1827)	Local
Pterostichus niger (Schaller, 1783)	
Pterostichus nigrita agg (Paykull, 1790)	
Pterostichus rhaeticus Heer, 1837/8	
Pterostichus strenuus (Panzer, 1796)	
Pterostichus vernalis (Panzer, 1795)	Local
Pterostichus versicolor (Sturm, 1824) [new genus Poecilus]	Local

DYTISCIDAE

Agabus bipustulatus (Linnaeus, 1767)	
Agabus striolatus (Gyllenhal, 1808)	RDB2
Agabus sturmi (Gyllenhal, 1808)	
Agabus unguicularis (Thomson, 1867)	Notable/Nb
Hydroporus angustatus Sturm, 1835	
Hydroporus longicornis Sharp, 1871	Notable/Nb
Hydroporus memnonius Nicolai, 1822	
Hydroporus scalesianus Stephens, 1828	RDB2
Hygrotus inaequalis (Fabricius, 1777)	
Hyphydrus ovatus (Linnaeus, 1761)	
Ilybius ater (De Geer, 1774)	
Ilybius guttiger (Gyllenhal, 1808)	Notable/Nb
Ilybius quadriguttatus (Lacordaire, 1835)	
Laccornis oblongus (Stephens, 1835)	pRDB3

HYDROPHILIDAE

Anacaena globulus (Paykull, 1798)	
Anacaena limbata (Fabricius, 1792)	
Cercyon convexiusculus Stephens, 1829	Notable/Nb
Cercyon marinus Thomson, 1853	Local
Cercyon sternalis Sharp, 1918	Notable/Nb
Cercyon tristis (Illiger, 1801)	Notable/Nb
Coelostoma orbiculare (Fabricius, 1775)	
Cryptopleurum minutum (Fabricius, 1775)	
Cymbiodyta marginellus (Fabricius, 1792)	Local
Enochrus coarctatus (Gredler, 1863)	Local
Hydrobius fuscipes (Linnaeus, 1758)	
Megasternum obscurum (Marsham, 1801)	

HELOPHORIDAE

Helophorus brevipalpis Bedel, 1881	

HYDRAENIDAE

Hydraena palustris Erichson, 1837	RDB2
Hydraena riparia Kugelann, 1794	Local
Hydraena testacea Curtis, 1830	Notable/Nb
Ochthebius minimus (Fabricius, 1792)	

PTILIIDAE

Acrotrichis atomaria (De Geer, 1774)	
Acrotrichis cognata (Matthews, A. 1877)	Naturalised
Acrotrichis fascicularis (Herbst, 1793)	
Acrotrichis grandicollis (Mannerheim, 1844)	
Acrotrichis henrici (Matthews, A. 1872)	Naturalised
Acrotrichis sitkaensis (Motschulsky, 1845)	
Ptenidium fuscicorne Erichson, 1845	Local
Ptenidium intermedium Wankowicz, 1869	Local
Ptenidium nitidum (Heer, 1841)	
Ptenidium pusillum (Gyllenhal, 1808)	

SILPHIDAE

Nicrophorus vespilloides Herbst, 1783	Local
Nicrophorus vespillo (Linnaeus, 1758)	

SCYDMAENIDAE

Euconnus hirticollis (Illiger, 1798)	Local

STAPHYLINIDAE

Aleochara bipustulata (Linnaeus, 1761)	
Alianta incana (Erichson, 1837)	Local
Aloconota gregaria (Erichson, 1839)	
Aloconota languida (Erichson, 1837) [new genus Disopora]	Notable/Nb
Amischa analis (Gravenhorst, 1802)	
Anotylus rugosus (Fabricius, 1775)	
Anotylus sculpturatus (Gravenhorst, 1806)	
Atheta elongatula (Gravenhorst, 1802) [new genus Philhygra]	

Atheta fungi (Gravenhorst, 1806)	
Atheta graminicola (Gravenhorst, 1806)	
Atheta laticollis (Stephens, 1832) [new genus Mycetota]	
Atheta nigra Kraatz, 1856 [new genus Datomicra]	
Atheta zosterae (Thomson, C.G. 1856) [new genus Datomicra]	Notable/Nb
Bryaxis bulblifer (Reichenbach, 1816)	
Carpelimus corticinus (Gravenhorst, 1806)	
Carpelimus elongatulus (Erichson, 1839)	
Carpelimus rivularis (Motschulsky, 1860)	
Dinaraea angustula (Gyllenhal, 1810)	Local
Disopora languida (Erichson, 1837)	
Erichsonius cinerascens (Gravenhorst, 1802)	Local
Euaesthetus laeviusculus Mannerheim, 1844	Local
Euaesthetus ruficapillus Boisduval & Lacordaire, 1835	Local
Gabrius pennatus Sharp, 1910 [synonym of breviventer (Sperk, 1835)]	
Lathrobium brunnipes (Fabricius, 1792)	
Lathrobium impressum Heer, 1841	
Leptusa pulchella (Mannerheim, 1830)	Local
Liogluta spp	
Mycetoporus lepidus (Gravenhorst, 1806)	
Myllaena dubia (Gravenhorst, 1806)	
Myllaena infuscata Kraatz, 1853	
Myllaena kraatzi Sharp, 1871	Notable/Nb
Myllaena minuta (Gravenhorst, 1806)	
Ocyusa maura (Erichson, 1837)	Local
Olophrum piceum (Gyllenhal, 1810)	
Othius laeviusculus Stephens, 1833	
Oxypoda elongatula Aubé, 1850	
Oxypoda haemorrhoa (Mannerheim, 1830)	
Pachnida nigella (Erichson, 1837)	Local
Paederus riparius (Linnaeus, 1758)	Local
Philonthus cognatus Stephens, 1832	
Philonthus fumarius (Gravenhorst, 1806)	Notable/Nb
Philonthus marginatus (Müller, O.F., 1764)	
Philonthus micans (Gravenhorst, 1802)	
Philonthus quisquiliarus (Gyllenhal, 1870)	
Philonthus varians (Paykull, 1789)	
Philonthus varius (Gyllenhal, 1810) [synonym of carbonarius (Gravenhorst, 1802)]	
Platydracus stercorarius (Olivier, 1795)	Local
Pselaphaulax dresdensis (Herbst, 1792)	Notable/Nb
Quedius balticus Korge, 1960	RDB1
Quedius curtipennis Bernhauer, 1908	
Quedius fuliginosus (Gravenhorst, 1802)	
Quedius semiaeneus (Stephens, 1833)	
Rugilus rufipes Germar, 1836	
Rybaxis longicornis (Leach, 1817)	
Staphylinus compressus (Marsham, 1802) [synonym of Tasgius morsitans (Rossi, 1790)]	
Stenus bifoveolatus Gyllenhal, 1827	Local

Stenus brunnipes Stephens, 1833	
Stenus carbonarius Gyllenhal, 1827	Notable/Nb
Stenus cicindeloides (Schaller, 1783)	Local
Stenus juno (Paykull, 1789)	
Stenus latifrons Erichson, 1839	
Stenus longitarsis Thomson C.G., 1851	RDB I
Stenus lustrator Erichson, 1839	Local
Stenus nitens Stephens, 1833	Local
Stenus palustris Erichson, 1839	Notable/Nb
Tachyporus chrysomelinus/dispar (Linnaeus, 1758/Paykull, 1789)	
Tachyporus hypnorum (Fabricius, 1775)	
Tachyporus nitidulus (Fabricius, 1781)	
Tachyporus transversalis Gravenhorst, 1806	Local
Tachyusa atra (Gravenhorst, 1806)	Local
Trissemus impressus (Panzer, 1803)	Local
Xantholinus linearis (Olivier, 1795)	
Zyras collaris (Märkel, 1842)	
SCIRTIDAE	
Cyphon coarctatus Paykull, 1799	
Cyphon hilaris Nyholm, 1944	Local
Cyphon ochraceus Stephens, 1830	
Cyphon padi (Linnaeus, 1758)	Local
Cyphon phragmiteticola Nyholm, 1955	Local
Cyphon variabilis Thunberg, 1787	
Microcara testacea (Linnaeus, 1758)	
HETEROCERIDAE	
Heterocerus obsoletus Curtis, 1828	
CANTHARIDAE	
Cantharis thoracica (Olivier, 1790)	Local
Rhagonycha testacea (Linnaeus, 1758)	
Silis ruficollis (Fabricius, 1775)	Notable/Nb
MELYRIDAE	
Cerapheles terminatus (Menetries, 1832)	Na
CRYPTOPHAGIDAE	
Atomaria basalis Erichson, 1846	
Atomaria fuscicollis Mannerheim, 1852	
Atomaria gutta Newman, 1834	
Atomaria lewisi Reitter, 1877	
Atomaria linearis Stephens, 1830	
Atomaria mesomela (Herbst, 1792)	Local
Atomaria nitidula (Marsham, 1802)	
Atomaria testacea (Stephens, 1830)	
PHALACRIDAE	
Stilbus oblongus (Erichson, 1845)	Local

CORYLOPHIDAE	
Corylophus cassidoides (Marsham, 1802)	Local
LATRIDIIDAE	
Aridius bifasciatus (Reitter, 1877)	Naturalised
CHRYSOMELIDAE	
Aphthona nonstriata (Goeze, 1777)	Local
Epitrix pubescens (Koch, 1803)	Local
Galerucella calmariensis (Linnaeus, 1767)	Local
Lythraria salicariae (Paykull, 1800)	Notable/Nb
Phyllotreta exclamationis (Thunberg, 1784)	Local
CURCULIONIDAE	
Euophryum confine (Broun, 1881)	Naturalised
Sitona lineatus (Linnaeus, 1758)	
DRYOPIDAE	
Dryops sp	
NITIDULIDAE	
Glischrochilus hortensis (Geoffroy in Fourcroy, 1785)	
COCCINELLIDAE	
Scymnus redtenbacheri (Mulsant, 1846) [new genus Nephus]	
Thea 22-punctata (Linnaeus, 1758) [new genus Psyllobora]	
RHIZOPHAGIDAE	
Rhizophagus dispar (Paykull, 1800)	
CLAMBIDAE	
Clambus armadillo (De Geer, 1774)	
ANOBIIDAE	
Anobium punctatum (De Geer, 1774)	
SCARABAEIDAE	
Aphodius rufipes (Linnaeus, 1758)	

GENERAL DISCUSSION

7.1 Overview

Three groups of invertebrates were studied, Mollusca, Araneae and Coleoptera, to see whether the biodiversity of each group was affected by cutting management in S4 reedbed. The study was carried out in the Norfolk Broads on reedbed at three different sites, Catfield Fen, Mallow Marsh and How Hill. Vegetation surveys were also conducted at each site. The numbers of individuals of each species collected were recorded in June and August 1999 and 2000, and the data analysed. The raw data is compiled in Appendix 7.1. Diversity changes and changes in similarity in terms of presence and absence of species between plots with different experimental treatments, and also between the same plots one year on were calculated. The responses of individual species to management were also noted.

7.2 Findings

Some of the species of each of the three groups of fauna studied, Mollusca, Araneae and Coleoptera were found to be habitat sensitive. There was a large amount of overlap in the wetland fauna found at the three sites, however there were noticeable differences. The slight difference in flora between Catfield Fen (S24 reedbed) and the other two sites, How Hill and Mallow Marsh (S4 reedbed), was clearly seen in the vegetation analyses. One plot at Catfield also turned up a unique set of beetles during the August 1999 sampling, *Heterocerus obsoletus, Oodes helopioides* and *Xantholinus linearis*. However, even though How Hill and Mallow Marsh had the same

NVC classification certain species occurred at one site rather than the other (e.g. *Aplexa hypnorum* was found only at How Hill, and *Anisus leucostoma* was virtually absent from Mallow Marsh).

Spiders and beetles are found to be highly seasonal, with very different communities in August compared to June. More species, and more individuals were found in June compared to August for both groups. Snails were more evenly spread, with similar numbers of species and numbers of individuals in June compared to August in any one year.

Overall diversity doesn't change due to management treatment as measured by the Simpson's Diversity Index for any of the groups. Nor does it change due to year to year fluctuations, or due to any interaction between treatment and year for any of the groups studied.

Overall similarity, as measured by the Jaccard Similarity Index presence or absence of species on a plot, and by the Morisita-Horn Index of Similarity, taking numbers of individuals into account, was not found to change due to treatment. The plots do not change measurably in terms of similarity due to the management or lack of it that they received.

There is a strong historical basis to a site's biodiversity. What is already present at a site appears to be the strongest influence on what is likely to occur at that site in the future. Management has a subtle effect, however, by influencing individual species, rather than the biodiversity at a site. Individual species do change with respect to management in the short term of this study.

The species found in this study to be positively affected by cutting management are *Lymnaea palustris, Anisus leucostoma* (Mollusca), *Erigone* *atra, Pirata piraticus, Pirata piscatorius* (Araneae) and *Coleostoma orbiculare, Cyphon phragmiteticola,* and *Euconnus hirticollis* (Coleoptera). The species found in this study to be negatively affected by cutting management are *Nesovitrea hammonis* (Mollusca), *Pirata hygrophilus, Allomengea vidua* (Araneae) and *Stilbus oblongus* (Coleoptera). These could make potential indicator species for wetland disturbance. In particular *C. orbiculare,* which is absent from unmanaged sites, whilst being found frequently in managed areas.

Changes in these species taken together would be a strong indication of disturbance in a good quality wetland area. Many of these species are classified as RDB local and are therefore of interest in themselves. Scarcer species may also be affected by management, which may be particularly important for conservation purposes, but numbers are too low to permit analysis in this study. Indeed if a particularly rare species (e.g. *Quedius balticus* or *Clubiona juvenis*) is present at a site then any management should be carried out sensitively and with caution.

In many cases there is an immediate response to management in terms of the species diversity. Changes in numbers of individuals studies do not become obvious until several months post cutting, the following year. Changes in habitat structure, and changes affecting overwintering or larval survival lead to reductions in the numbers of some of the species studied, for example those that overwinter in tussocks (e.g. *Entelecara omissa* and *Apthona nonstriata*), whereas opening up habitat leads to opportunities for pioneers. It appears to take some time for pioneers to take advantage of these opportunities, as much as it takes a couple of seasons for adverse effects on numbers of individuals of certain species to be measurable.

There is limited evidence of recovery in some species 14 months post-cutting and a return to pre-management levels (e.g. *Anisus leucostoma*). Other species (such as *Nesovitrea hammonis*) do not appear to be returning to pre-management levels within the time studied. Different species have different recovery times, and these may well be linked to other factors in the environment, such as availability of dead reed stems for larvae, or plant structural complexity. Simply equating recovery time with migration rates into a disturbed area is unlikely to yield accurate information.

7.3 Species versus higher taxon surrogates

The idea that higher taxa could act as a surrogate for species was tested by Prance (1994). Prance noted how useful it would be in biodiversity assessment studies if higher taxa exhibited the same patterns of diversity as species level data. He looked at family and generic level plant data and came to the conclusion that generic level data was more useful than family level data in assessing biodiversity. This finding was echoed by Panzer and Schwartz (1998), although Reid (1998) found higher taxon surrogates to be a better predictor of species level diversity than many of the other proposed surrogates, such as environmental variables, land classes or vegetation classes.

A great many studies have used higher taxa as a substitute for species level data. Invertebrates in particular seem prone to grouping at the higher taxonomic level. York (1999) looked at the effects of burning, but only at the order level. He found recovery within three to five years for spiders and beetles, but the evidence from this thesis does not support higher taxon surrogates as an accurate method of measuring changes in the environment. Grouping at the higher taxonomic level is not sensitive enough to discern species level changes as a change in biodiversity. Conservation management decisions based on order level results are likely to be inappropriate.

Ditlhogo *et al* (1992) found no difference in invertebrate family level diversity one year after cutting and burning areas in wetlands. Buckton and Ormerod (1997) however did find changes in family level diversity for carabids, lycosids, linyphiids and tetragnathids following wetland liming. These studies are examples of analysis at the family level, and conclusions based on these results are likely to be erroneous for species level conservation.

Van Jaarsveld *et al* (1998) found that surrogacy at higher taxonomic levels was not supported. They showed that complementary sets representing genera and families contained little overlap (<30%) with species based complementary sets across taxa. Maximum overlap between genera and species based sets was found in plants and birds, not invertebrates. Additionally they showed that the patterns of overlap between different taxa are inconsistent, with changing hierarchical levels. They go on to say that "selecting conservation areas by genus or family level data cannot result in efficient species-level conservation" and further that higher taxon surrogate information is useless at a scale relevant to practical conservation planning.

This study backs van Jaarsveld *et al*'s (1998) findings. There are species level changes and changes in the invertebrate communities for all three groups studied, despite a lack of evidence for changes in diversity (Simpson's Diversity Index), presence absence similarity (Jaccard Similarity Index), or similarity in numbers of individuals of each species (Morisita-Horn), due to the effect of cutting management when the groups are analysed as a whole.

Both Meyer *et al* (1995) and Davies and Margules (1998) found similar results in that there were species level changes and changes in assemblages following disturbance. They both found that different species reacted in different ways to disturbance. This study also supported these findings. Within each of the groups studied, there were species that reacted differently to management. Indeed within the Araneae different reactions to cutting management were observed between different species within the genus *Pirata*. This implies that species specific reactions to management is likely to be a widespread phenomenon across many groups of taxa.

7.4 Limitations imposed by experimental design

The experimental design of the pilot study was seriously flawed in many respects. The lack of controls caused the data from several of the sites to be unusable, and caused serious problems at the other sites where only one control plot was allocated for four experimental plots. Despite this some useful information could be gleaned and the main project was much more rigorously designed.

The main project was intended to have three sites with the same vegetation classification which could be grouped together for the purposes of the study. The fauna on these three sites was broadly similar, and this was repeatedly tested throughout the study by comparing the sites. There was no striking difference at any point between the fauna of any of the three groups at different sites. The communities studied all fell into the broad category 'wetland' species, and each site had a selection of these species, with the common ones being present at all the sites and rarer species being mostly present at all the sites (Site x Species Tables, page 285). Two exceptions to this are *Aplexa hypnorum*, which was only present at How Hill, and *Anisus leucostoma*, which was virtually absent from Mallow Marsh.

The three pairs of replicates across the three sites made nine pairs of replicates. The power analysis, page 52, showed that for 95% certainty in a result, nine replicates is more than adequate, when looking at species composition. However, when looking at numbers of individuals, over 1500 replicates would be needed in order to ascertain a 95% confidence in the result. That scale of project was not feasible in terms of time or resources, and so data referring to numbers of individuals is not as robust as that looking at the changes in species composition.

The data referring to the numbers of individuals was frequently condensed into the treatments at each site i.e. the data from all the control plots was summed at each site, similarly for the cut plots. The rationale behind this was firstly to increase the numbers of 'expected' individuals in order to conduct Chi^2 tests, and secondly to highlight any differences in the way each site behaved in response to management. Looking at the data in this way can provide information and can highlight trends in the data, even when a power analysis recommends further repeats of sampling.

Further repeats of the sampling would allow information to be gathered about the changes in numbers of individuals in the short-term following cutting. The project design cannot decisively catalogue changes in individual numbers, as small changes at this level are not significant unless repeated over a much larger scale. The small changes seen in response to management may well be significant on a larger scale, and only further work would clarify this.

7.5 Magnitude of treatment effect versus annual variability

The results from the main study show that there is little overall response to management in terms of either increase or decline in the numbers of individuals (however, see previous section). There is no statistically significant change in the composition of species following management, and whilst many species are seasonal, there seems to be no testably significant change from year to year in composition.

This leads to two conclusions: the magnitude of treatment effect is too small to be picked up by this study in the short-term. It may become clearer after a number of years. Further the annual variability is not great enough to be statistically significant in the majority of species, and only a larger scale study would show species (number of individuals) differences on a year to year basis.

As the power analysis showed species composition to be a robust indicator of change, so it seems likely that there is little year to year change in this environment, with certain seasonal species such as *Oxychilus alliarius* excepted.

7.6 Assessment of response to management and post-management recovery

The short-term nature of this project limits the conclusions that can be drawn from the data. Response to management appears to be limited to a handful of species, most of which appear to benefit from cutting (e.g. *Lymnaea palustris*), rather than declining following the major habitat disturbance that cutting causes. The changes that could be seen may not be the only changes wrought, and further study may unearth more complex changes in the habitat over a longer term.

A positive feedback mechanism of ecological change would cause small changes to multiply over a longer period of time. Chaos theory (Gleick 1997) shows that small changes subjected to positive feedback can have unknown consequences in the longer term. He uses weather systems to illustrate this phenomenon. If rainfall next Tuesday cannot be predicted with accuracy, then for the same reasons species composition in ten years time cannot either.

Only monitoring the environment for that time would give the accurate answers required. Without monitoring, and with few other studies to guide (e.g. Morris and Rispin 1988, Thomas and Jepson 1997), predicting the species changes over a much longer term is little more than guesswork if a positive feedback mechanism is acting on the system. The best indication, from the information available, is that what is already in the environment is likely to persist, which indicates that for the majority of species small changes are subject to negative feedback.

However this hypothesis predicts that there would be no change in species following a disturbance, and this is unlikely to be true dependant on the nature and frequency of the disturbance. The larger, or more frequent the disturbance, the more likely it is that there will be change in the system. It is possible that small changes are subject to negative feedback, but large ones to positive feedback. The questions then posed are: How large is large? and which side of the divide do the species in this project fall?

The answer to the first question is likely to be different for each species, with more sensitive, and possibly rarer species reacting more strongly at lower disturbance levels. Again, further study on individual species is needed to answer this fully.

Answering the second question is equally difficult. Long term monitoring is the only reliable method of discovering how sensitive each species is to disturbance. It is difficult to infer whether the small changes that have been caused by cutting the fen would persist into the following year, or decade, or whether they would vanish altogether within a couple of seasons. It seems intuitively likely that the latter would be the case, as the initial responses in the short term were small, however management decisions should not be based on that assumption. Further monitoring of the sites should be carried out to assess the duration of changes, and post-management recovery.

7.7 Recommendations for habitat management

The species specific responses to management of taxa within an assemblage make habitat conservation decisions difficult. Indeed it does not seem possible to manage habitat to the advantage of every species, particularly if just one management technique is to be employed. In order to conserve a range of species, a patchwork of habitat areas needs to be provided. Management needs to provide as varied a selection of habitats as possible, with management practices spread both spatially and temporally.

Most data in this thesis supports the current practice of rotational cutting. Many species benefit either in the short term as they take advantage of the open habitat, or in the longer term as scrub encroachment is prevented, and the habitat preserved. A few species appear to suffer in the short term, and as a precaution to these species that are adversely affected management should be applied as a patchwork. Wetland habitat should include a mosaic of ages of reed, including both unmanaged and managed areas, as cutting management benefits species such as *Lymnaea palustris, Coleostoma orbiculare* and *Pirata piscatorius*, but hinders others such as *Nesovitrea hammonis, Allomengea vidua* and *Stilbus oblongus*.

Areas should be left as refuges from which recolonisation can occur, and barriers to recolonisation e.g. dykes, should not separate managed and unmanaged areas. Areas surrounded by such barriers should not be cut all at one time. A long rotation is recommended as differences in invertebrate fauna are still apparent after five seasons. Conservation management advice (e.g. Hawke and José 1996) suggest 3-15 years as an appropriate length of time for rotational cutting, but further work is required to determine the effects in different habitats of length of time set aside.

Management should not be too 'tidy'. The advantage of 'messy management' is that areas are left deliberately from which species can recolonise. Areas should be left undisturbed as refuges for overwintering, such as tussocks for carabids (Foss and Connell 1998, Fråmbs 1994, Rushton *et al* 1990) (NB *Apthona nonstriata* is a Chrysomelid with the same requirements), and certain spiders (e.g. the scarce *Entelecara omissa*)or as cover for birds and banks of rarer species which may be adversely affected by cutting. Scrub regrowth should not be completely removed as this is very good for both invertebrates and certain species of bird such as Cetti's warbler (*Cetti cetti*). Messy management would ensure some scrub regrows. Deadwood stands are excellent habitat for invertebrates. Similarly with coppicing (a common way of controlling scrub), different areas can be cut each year on a 10+ yearly rotation, but management should enable a network of different aged coppice to lattice through a scrub stand, allowing poor colonisers, reliant on a certain age of coppice to have corridors of access from one aged stand to another.

Management of open fens and reedbed should leave swathes of uncut reed criss-crossing a cut area, complete with the invertebrate fauna, which would otherwise have to recolonise a much greater distance from the edges of the managed area inwards. This would speed up recovery to a certain extent, and reduce the chances of a rare species being eliminated from a site. Also for this reason smaller areas should be managed rather than larger ones. What constitutes 'smaller' is open to further study.

Finally management should be aimed at the species level. If decisions must be made for conservation practices based on higher taxonomic data, then close monitoring of the species potentially affected should follow, in order to prevent the loss of sensitive species from a site, and a long-term change in the assemblages of species present in the area managed.

7.8 APPENDIX 7.1
Site x Species Tables

Table 7.I
The numbers of individuals of each species of snail found in total at each site.

Snails	Hickling	Horning	Long Gores	Catfield Fen	Mallow Marsh	How Hill	Broad Fen	Whitlingham
Anisus leucostoma	0	0	0	254	1	387	0	0
Aplexa hypnorum	0	0	0	0	0	92	0	1
Carychium minimum	0	0	0	0	2	10	0	3
Carychium tridentatum	0	0	0	0	0	13	0	0
Cochlicopa lubrica	0	0	0	0	0	1	0	0
Collumella edantula	6	0	0	0	0	0	0	0
Euconulus alderi	0	0	0	0	10	5	1	8
Lymnaea palustris	0	0	0	229	409	775	2	21
Lymnaea peregra	0	0	0	4	11	21	0	0
Lymnaea truncatula	0	0	0	1	0	1	0	1
Nesovitrea hammonis	5	0	0	17	19	1	0	0
Oxychilus alliarius	0	0	0	28	33	30	0	0
Punctum pygmaeum	0	0	0	0	13	11	0	13
Succinid	0	0	0	7	18	21	5	47
Valvata cristata	0	0	0	1	1	2	0	0
Vertigo antivertigo	0	0	0	4	5	13	0	2
Vertigo pygmaea	0	0	0	0	1	5	0	0
Viviparus viviparus	0	0	0	0	4	0	0	0
Zonitoides nitidus	0	0	0	3	2	1	0	0

Table 7.II
The numbers of individuals of each species of spider found in total at each site.

Spiders	Hickling	Horning	Long Gores	Catfield Fen	Mallow Marsh	How Hill
Allomengea vidua	0	1	0	12	140	77
Alopecosa pulverulenta	0	0	2	0	0	0
Antistea elegans	0	5	0	1	61	42
Argyroneta aquatica	0	0	0	0	1	0
Baryphyma trifrons	0	0	0	0	1	1
Bathyphantes approximatus	0	0	0	0	3	6
Bathyphantes gracilis	1	4	2	116	97	176
Bathyphantes parvulus	11	9	1	1	4	5
Clubiona juvenis	0	0	0	3	0	0
Clubiona phragmites	0	1	0	0	1	7
Clubiona reclusa	0	0	0	0	1	0
Clubiona spp	0	0	0	0	0	1
Clubiona stagnatalis	0	0	0	0	1	0
Cnephalocotes obscurus	0	0	2	1	0	0
Diplocephalus picinus	0	0	0	1	2	0
Dismodicus bifrons	0	0	0	0	0	1
Donacochara speciosa	0	0	0	0	0	2

Drepanotylus uncatus	0	0	0	0	1	0
Entelecara omissa	0	0	0	1	0	0
Erigone atra	1	2	0	90	26	47
Glyphesis cottonae	0	0	0	0	3	0
Gnathonarium dentatum	0	0	0	42	7	85
Hypomma bitularculum	0	0	0	0	1	0
Hypomma fulvum	0	0	0	1	1	5
Hypselistes jacksoni	0	0	0	0	0	2
immature spiders	22	23	33	642	585	240
Kaestneria pullata/Helophora insignis	0	0	0	0	0	1
Lepthyphantes flavipes	0	0	0	16	2	13
Lepthyphantes pallidus	1	0	0	0	0	0
Lepthyphantes tenebricola	0	0	0	1	2	0
Lepthyphantes tenuis	3	1	1	1	3	1
Lepthyphantes zimmermanni	0	1	0	0	0	1
Leptorhoptrum robustum	0	0	0	0	0	1
Lophomma punctatum	0	1	0	3	32	11
Metopobactrus prominulus	0	0	0	0	1	0
Microlinyphia impigra	0	0	0	0	0	1
Oedothorax agrestis	0	0	0	0	0	1
Oedothorax fuscus	0	0	0	0	2	0
Oedothorax gibbosus	0	2	0	12	63	114
Pachygnatha clercki	0	1	0	9	24	17
Pardosa piscatorius	0	0	0	24	7	6
Pardosa prativaga	2	1	0	11	75	32
Pardosa pullata	0	0	0	1	1	1
Parsdosa lugubris	0	0	0	1	0	0
Pirata hygrophilus	8	1	0	14	6	19
Pirata piraticus	0	0	0	276	224	321
Pirata tenuitarsis	0	0	0	1	2	0
Pocadicnemis juncea	1	0	0	0	0	2
Porhomma pallidium	0	0	0	18	7	1
Porrhomma pygmaeum	0	0	0	0	1	1
Savigyna frontata	0	0	0	0	0	1
Silometopus elegans	0	0	0	1	0	0
Tapinocyba praecox	0	0	0	0	1	0
Taranucnus setosus	0	0	0	0	1	0
Tetragnatha extensa	0	0	0	0	1	0
Tmeticus affinis	0	0	0	1	0	1
unidentified	0	0	0	1	4	3
Walckenaeria alticeps	0	0	0	0	0	1
Walckenaeria atrobialis / Hypomma cornutum	0	0	0	1	0	0
Walckenaeria kochi chk sp	0	0	0	1	1	1
Walckenaeria unicornis	0	0	0	0	0	1
Xysticus cristatus	0	0	0	0	0	1
Zora spinimana	1	0	0	0	0	0

Table 7.III
The numbers of individuals of each species of beetle found in total at each site.

Beetles	Hickling	Horning	Long Gores	Catfield Fen	Mallow Marsh	How Hill
Acrotrichis atomaria	0	0	0	3	7	0
Acrotrichis cognata	1	11	0	0	5	5
Acrotrichis fascicularis	0	0	0	0	6	5
Acrotrichis grandicollis	0	0	0	0	3	4
Acrotrichis henrici	0	0	0	2	6	3
Acrotrichis sitkaensis	0	20	0	22	69	23
Agabus bipustulatus	0	0	0	0	4	4
Agabus striolatus	0	0	0	0	1	0
Agabus sturmi	0	0	0	0	1	0
Agabus unguicularis	0	0	0	2	0	3
Agonum fuliginosum	0	0	0	4	7	0
Agonum gracile	0	0	0	0	2	0
Agonum thoreyi	0	1	0	5	10	37
Agonum viduum	0	0	0	1	0	0
Aleochara bipustulatus	0	0	0	0	0	1
Aleochara indet	0	0	0	0	1	0
Aleocharine spp	0	0	0	0	0	1
Aleocharine spp/O. maura	0	0	0	0	0	2
Alianta incana	0	0	0	0	0	1
Aloconota gregaria	0	0	1	2	3	3
Amara lunicollis	0	0	7	0	0	0
Amischa analis	1	0	0	1	1	3
Anacaena globulus	0	1	0	5	2	1
Anacaena limbata	0	3	0	7	14	13
Anobium punctatum	0	0	0	0	0	1
Anotylus rugosus	0	0	0	0	4	0
Anotylus sculpturatus agg	0	0	0	0	5	0
Aphodius rufipes	0	1	0	0	0	0
Aphthona nonstriata	0	0	0	2	2	1
Aridius bifasciatus	0	0	0	0	0	1
Atheta (Datomicra) nigra	0	2	0	0	0	0
Atheta elongatula	0	0	0	2	0	4
Atheta fungi	10	0	1	0	81	47
Atheta graminicola	0	0	0	1	1	12
Atheta laticollis	0	0	0	0	1	4
Atheta zosterae	0	0	0	1	0	0
Atomaria basalis	0	0	0	0	0	1
Atomaria fuscicollis	0	0	0	5	5	2
Atomaria gutta	0	0	0	0	2	7
Atomaria lewisi	0	0	0	0	1	0
Atomaria linearis	0	0	0	1	0	0
Atomaria mesomela	0	0	0	0	4	1
Atomaria nitidula	0	0	0	0	1	0
Atomaria spp	0	0	0	0	0	3

Atomaria testacea	0	0	0	2	1	0
Bembidion assimile	0	0	0	0	0	1
Bembidion fumigatum	0	0	0	0	0	2
Bembidion lampros	0	0	0	0	0	1
Bembidion minimum	0	0	0	0	0	0
Bembidion unicolor	0	0	0	0	1	0
Blethisa multipunctata	0	0	0	2	0	0
Bryaxis bulblifer	0	0	0	0	6	2
Cantharis thoracica	0	0	0	1	15	1
Carabus granulatus	1	1	11	4	8	1
Carpelimus corticinus	0	0	0	0	2	0
Carpelimus elongatus	0	0	0	0	0	1
Carpelimus rivularis	0	0	0	2	0	0
Cerapheles terminatus	0	0	0	2	3	2
Cercyon convexiusculus	0	0	0	2	5	3
Cercyon marinus	0	0	0	5	0	3
Cercyon sternalis	0	0	0	0	1	5
Cercyon tristis	0	0	0	1	2	1
Chrysomelid to id Aphthona	0	0	0	0	1	0
Clambus armadillo	0	1	0	0	1	0
Coelostoma orbiculare	0	0	0	3	15	5
Corylophus cassidoides	0	0	0	0	1	4
Cryptopleurum minutum	0	1	0	1	0	0
Cymbiodyta marginella	0	0	0	3	1	3
Cyphon coarctatus	0	0	0	0	0	2
Cyphon hilaris	0	0	0	3	8	5
Cyphon ochraceus	0	0	0	2	0	1
Cyphon padi	0	0	0	3	0	1
Cyphon phragmiteticola	0	0	0	21	1	1
Cyphon variabilis	0	0	0	1	0	0
Dinaraea angustula	0	0	1	0	2	2
Disopora languida	0	0	0	0	1	0
Dromius longiceps	0	0	0	0	1	1
Dryops sp	0	0	0	1	0	0
Elaphrus cupreus	0	0	0	3	0	2
Enochrus coarctatus	0	0	0	0	1	0
Epitrix pubescens	0	0	0	0	1	2
Erichsonius cinerascens	0	0	0	1	4	2
Euaesthetus laeviusculus	0	6	0	1	0	2
Euaesthetus ruficapillus	0	0	0	2	4	5
Euconnus hirticollis	0	11	0	10	17	25
Euophryum confine	0	0	0	2	0	0
Gabrius pennatus	0	0	0	0	0	2
Galerucella calmariensis	0	0	0	0	1	0
Glischrochilus hortensis	0	0	0	3	2	2
Helophorus brevipalpis	1	0	0	0	0	0
Heterocerus obsoletus	0	0	0	1	0	0
Hydraena palustris	0	0	0	1	0	0
Hydraena riparia	0	0	0	0	2	2
Hydraena testacea	0	0	0	0	1	0

Hydrobius fuscipes	0	0	0	6	0	0
Hydroporus angustatus	0	0	0	0	0	3
Hydroporus longicornis	0	0	0	0	5	1
Hydroporus memnonius	0	0	0	0	0	2
Hydroporus scalesianus	0	0	0	4	3	0
Hygrotus inaequalis	0	0	0	0	0	1
Hyphydrus ovatus	0	0	0	0	1	0
Ilybius ater	0	0	0	2	2	0
Ilybius guttiger	0	0	0	0	1	0
Ilybius quadriguttatus	0	0	0	2	6	0
Laccornis oblongus	0	0	0	0	1	0
Lathrobium brunnipes	0	0	0	0	0	4
Lathrobium impressum	0	2	0	0	0	0
Leptusa pulchella	0	0	0	0	0	1
Liogluta spp	0	0	0	0	0	1
Loricera pilicornis	0	0	1	1	2	1
Lythraria salicariae	0	0	0	0	9	0
Megasternum obscurum	0	2	0	1	1	0
Microcara testacea	0	0	0	0	0	1
Mycetoporus lepidus	0	0	1	0	0	0
Myllaena dubia	0	0	0	0	0	1
Myllaena infuscata	0	0	0	1	0	1
Myllaena kraatzi	0	0	0	2	0	0
Myllaena minuta	0	0	0	0	1	2
Nicrophorus vespillo	0	0	0	0	2	0
Nicrophorus vespilloides	0	0	0	0	9	0
Ochthebius minimus	0	0	0	5	1	0
Ocyusa maura	0	0	0	23	6	21
Odacantha melanura	0	0	0	4	0	5
Olophrum piceum	0	0	0	0	0	1
Oodes helopioides	0	0	0	11	3	0
Othius laeviusculus	0	0	0	0	1	0
Oxypoda elongatula	0	0	0	0	10	1
Oxypoda haemorrhoa	0	0	0	0	1	2
Pachnida nigella	0	0	0	0	0	24
Paederus riparius	0	1	0	14	158	65
Philonthus cognatus	0	0	2	0	0	0
Philonthus fumarius	0	0	0	1	2	1
Philonthus marginatus	0	0	0	0	1	0
Philonthus micans	0	1	0	0	0	0
Philonthus quisquiliarus	0	0	0	1	0	2
Philonthus varians	0	0	0	0	2	0
Philonthus varius	0	0	0	0	1	0
Phyllotreta exclamationis	0	0	0	0	2	0
Platydracus stercorarius	0	0	1	0	0	0
Pselaphaulax dresdensis	0	0	0	1	1	0
Ptenidium fuscicorne	0	6	0	5	0	0
Ptenidium intermedium	0	0	0	0	1	0
Ptenidium nitidum	0	0	0	2	2	1
Ptenidium pusillum	0	1	0	0	0	0

Pterostichus diligens	0	0	0	0	1	0
Pterostichus madidus	2	0	0	0	0	0
Pterostichus minor	0	7	0	0	4	1
Pterostichus niger	20	0	8	0	0	0
Pterostichus nigrita agg	0	2	0	3	5	1
Pterostichus rhaeticus	0	0	0	3	4	0
Pterostichus rhaeticus/nigrita agg	0	0	0	0	5	0
Pterostichus strenuus	1	0	0	0	0	0
Pterostichus vernalis	0	0	0	0	1	0
Pterostichus versicolor	0	0	4	0	0	0
Quedius balticus	0	0	0	0	0	1
Quedius curtipennis	1	0	0	0	0	0
Quedius fuliginosus	0	0	0	1	1	0
Quedius semiaeneus	0	0	0	0	1	0
Rhagonycha testacea	0	0	0	0	0	1
Rhizophagus dispar	0	0	0	0	0	1
Rugilus rufipes	7	0	0	0	0	0
Rybaxis longicornis	0	0	0	2	1	5
Scymnus (Nephus) redtenbacheri	0	0	1	0	0	0
Silis ruficollis	0	0	0	2	2	4
Sitona lineatus	0	0	0	0	4	0
Staphylinus compressus	1	0	0	0	0	0
Stenus bifoveolatus	0	0	0	0	0	1
Stenus brunnipes	0	0	0	0	0	2
Stenus carbonarius	0	0	0	1	0	0
Stenus cicindeloides	0	0	0	0	3	0
Stenus juno	0	0	0	1	2	5
Stenus latifrons	0	0	0	5	3	8
Stenus longitarsis	0	0	0	0	0	1
Stenus lustrator	0	0	0	0	2	0
Stenus nitens	0	0	0	0	5	1
Stenus palustris	0	0	0	0	2	1
Stilbus oblongatus	0	0	0	1	0	4
Stilbus oblongus	0	0	0	9	3	25
Tachyporus chrysomelinus/dispar	0	0	0	0	1	0
Tachyporus hypnorum	0	0	0	1	0	0
Tachyporus nitidulus	0	1	0	0	0	0
Tachyporus transversalis	0	2	0	0	0	0
Tachyusa atra	0	0	0	0	1	0
Thea 220punctata	0	0	1	0	0	0
Trissemus impressa	0	0	0	0	1	0
Trissemus impressus	0	0	0	0	0	2
Xantholinus linearis	0	0	0	1	0	0
Zyras collaris	0	1	0	0	0	0

Table 7.IV
The flora species recorded as present at each site are marked p, and those not recorded are marked -.

Vegetation	Catfield Fen	Mallow Marsh	How Hill
Agrostis canina	*p*		-
Alnus glutinosa	*p*	*p*	
Angelica sylvestris			*p*
Berula erecta	*p*	*p*	*p*
Bryophytes	*p*	*p*	*p*
Calamagrostis canes	-	*p*	*p*
Calamagrostis epigejos	*p*	-	
Caltha palustris	-	-	*p*
Calystegia sepium	*p*	*p*	*p*
Cardimine pratensis	*p*	*p*	-
Carex acutiformes	-	*p*	*p*
Carex sp	*p*	*p*	*p*
Cirsium palustre	*p*	-	
Cladium mariscus	*p*	-	
Dryopteris carthus		*p*	-
Dryopteris sp		*p*	-
Epilobium palustre	-	*p*	-
Epilobium parviflorum		*p*	*p*
Epilobium sp	*p*		
Eupatorium cannabinum	*p*	*p*	*p*
Filipendula ulmaria	*p*	*p*	*p*
Galium palustre	*p*	*p*	*p*
Hydrocotyle vulgaris	*p*	*p*	*p*
Iris pseudocorus	*p*	*p*	*p*
Juncus subnodulosus	*p*	*p*	
Lemna sp	-	*p*	*p*
Lychnis flos-cuculi	-	*p*	*p*
Lycopus europaeus	*p*	*p*	
Lysimmachia vulgaris	-	*p*	*p*
Lythrum salicaria		*p*	*p*
Mentha aquatica	*p*		-
Myosotis laxa			*p*
Myrica gale		*p*	-
Oenanthe fistulosa	*p*		-
Oenanthe lachenellii	*p*	-	-
Persicaria sp	-	*p*	*p*
Peucedenum palustre	*p*	*p*	*p*
Phalaris arundinacea	-	*p*	
Phragmites australis	*p*	*p*	*p*
Potentilla erecta	-	*p*	
Potentilla palustris		*p*	
Ranunculus lingua	-	-	*p*
Rosa canina agg	*p*	-	-

Rumex hydrolapathum	*p*	*p*	-
Salix cinerea	-	*p*	-
Salix sp	*p*		-
Scutellaria galericulata	*p*	*p*	*p*
Scrophularia arriculata	-	-	*p*
Sium latifolium	-	*p*	*p*
Solanum dulcamara	*p*	*p*	*p*
Stellaria palustris	-	*p*	
Thalictrum flavum	*p*		
Thelypteris palustris		*p*	-
Typha angustifolia	*p*	-	*p*
Typha latifolia	*p*		*p*
Urtica dioica	-	-	*p*
Valeriana dioica	*p*	-	-
Valeriana officinalis		-	*p*

7.9 APPENDIX 7.2

The numbers of each species collected in the main study; snails, spiders and beetles.

Site and plot	Species	June 1999	August 1999	June 2000	August 2000
Snails					
Catfield A	Oxychilus alliarius	-	-	-	3
	Anisus leucostoma	1	-	15	9
	Lymnaea palustris	2	2	15	8
	Nesovitrea hammonis	-	1	-	-
	Vertigo antivertigo	-	1	-	-
	Succinid	2	-	-	-
	Lymnaea perrigra	3	-	-	-
Catfield B	Succinid	-	-	-	1
	Anisus leucostoma	3	5	54	7
	Lymnaea palustris	1	6	84	12
	Oxychilus alliarius	-	-	-	3
	Nesovitrea hammonis	-	1	-	1
Catfield C	Succinid	-	-	-	1
	Anisus leucostoma	4	-	3	5
	Lymnaea palustris	1	-	2	17
	Nesovitrea hammonis	-	7	-	7
	Oxychilus alliarius	-	9	1	7
	Zonitoides nitidus	-	2	1	-
	Vertigo antivertigo	1	1	-	-
Catfield D	Lymnaea palustris	3	5	27	15
	Anisus leucostoma	1	-	25	13
	Oxychilus alliarius	-	5	-	-
	Valvata cristata	-	1	-	-
Catfield E	Lymnaea truncatulata	-	-	-	1
	Succinid	-	-	-	3
	Anisus leucostoma	9	5	15	26
	Lymnaea palustris	2	3	7	6
	Lymnaea perrigra	-	-	1	-
Catfield F	Anisus leucostoma	7	28	10	9
	Lymnaea palustris	5	1	4	-
	Vertigo antivertigo	-	1	-	-
Mallow A	Nesovitrea hammonis	-	-	-	1
	Lymnaea palustris	17	15	66	26
	Oxychilus alliarius	1	-	1	7
	Lymnaea perrigra	-	-	1	-
	Succinid	-	-	1	-
	Anisus leucostoma	-	1	-	-
Mallow B	Lymnaea palustris	-	17	7	9
	Oxychilus alliarius	-	1	-	4
	Succinid	-	-	1	1

	Carychium minimum	-	-	-	1
Mallow C	Oxychilus alliarius	-	-	-	1
	Lymnaea palustris	-	14	58	17
	Lymnaea perrigra	-	-	6	1
	Viviparus viviparus	-	-	2	-
Mallow D	Lymnaea palustris	2	6	13	5
	Lymnaea perrigra	-	-	1	1
	Nesovitrea hammonis	-	2	-	6
	Oxychilus alliarius	-	-	1	5
	Pea mussel	-	-	-	1
	Carychium minimum	-	-	-	1
Mallow E	Nesovitrea hammonis	1	-	-	1
	Zonitoides nitidus	-	-	1	2
	Succinid	1	-	3	1
	Viviparus viviparus	-	-	1	1
	Lymnaea perrigra	-	-	-	1
	Lymnaea palustris	2	3	75	29
	Oxychilus alliarius	-	-	-	9
	Valvata cristata	-	-	1	-
Mallow F	Succinid	-	-	-	2
	Nesovitrea hammonis	1	1	1	4
	Euconulus alderi	-	-	1	1
	Lymnaea palustris	-	7	3	-
	Oxychilus alliarius	-	-	4	-
How Hill A	Anisus leucostoma	-	7	18	45
	Lymnaea palustris	3	3	6	9
	Aplexa hyponorum	1	5	3	4
	Nesovitrea hammonis	-	-	-	3
	Oxychilus alliarius	3	-	2	-
	Zonitoides nitidus	-	-	1	-
	Carychium minimum	1	-	-	-
How Hill B	Anisus leucostoma	-	-	15	11
	Lymnaea palustris	-	4	4	10
	Aplexa hyponorum	-	-	3	9
	Nesovitrea hammonis	1	-	-	2
	Oxychilus alliarius	-	10	-	-
	Euconulus alderi	-	1	-	-
	Succinid	1	-	-	-
How Hill C	Anisus leucostoma	4	-	13	48
	Lymnaea palustris	3	15	19	92
	Aplexa hyponorum	-	-	2	16
	Nesovitrea hammonis	-	-	-	5
	Lymnaea perrigra	-	1	-	6
	Valvata cristata	-	-	-	1
	Euconulus alderi	-	1	-	-
	Oxychilus alliarius	-	3	-	-
How Hill D	Aplexa hyponorum	1	3	7	13
	Anisus leucostoma	3	13	17	17
	Lymnaea perrigra	-	-	1	1
	Lymnaea palustris	4	9	38	41

	Oxychilus alliarius	-	2	-	-
How Hill E	Lymnaea palustris	-	12	24	12
	Anisus leucostoma	-	1	13	19
	Aplexa hyponorum	-	1	2	3
	Lymnaea perrigra	6	-	1	-
	Vertigo antivertigo	-	1	-	-
	Carychium tridentatum	1	-	-	-
How Hill F	Anisus leucostoma	4	3	41	91
	Lymnaea palustris	3	22	52	38
	Aplexa hyponorum	-	-	8	11
	Lymnaea perrigra	-	-	3	2
	Succinid	-	1	-	-
Spiders					
Catfield A	Pirata piraticus	3	-	17	-
	Bathyphantes gracilis	4	-	8	-
	Erigone atra	1	-	2	-
	Gnathonarium dentatum	2	-	5	-
	Pachygnatha clercki	-	1	-	-
	Pirata hygrophilus	-	-	1	-
	Oedothorax gibbosus	-	1	-	-
	Allomengea vidua	-	2	-	6
Catfield B	Hypomma fulvum	1	-	-	-
	Bathyphantes gracillis	16	2	7	-
	Clubiona juvenis	1	1	-	-
	Porrhomma pallidium	3	-	1	-
	Gnathonarium dentatum	5	-	1	-
	Lophomma punctatum	1	-	-	-
	Pachygnatha clercki	1	-	-	-
	Pirata piraticus	-	3	37	7
	Erigone atra	-	-	19	-
	Lepthyphantes flavipes	-	-	1	-
	Oedothorax gibbosus	-	-	1	-
	Pardosa prativaga	-	-	3	-
	Pardosa lugubris	-	-	1	-
	Pirata hygrophilus	-	-	1	-
	Pirata piscatorius	-	-	7	2
Catfield C	Bathyphantes gracillis	18	2	13	2
	Porrhomma pallidium	2	-	-	-
	Gnathonarium dentatum	-	1	1	-
	Pachygnatha clercki	-	-	-	3
	Pirata piraticus	8	-	37	-
	Erigone atra	11	-	4	-
	Lepthyphantes flavipes	2	-	-	-
	Oedothorax gibbosus	1	-	-	-
	Allomengea vidua	-	6	-	-
	Antistea elegans	-	1	-	-
	Pirata piscatorius	-	-	1	-
	Pirata hygrophilus	-	-	5	-
	Bathyphantes parvulus	-	-	1	-
	Cnephalocotes obscurus	-	-	1	-

Catfield D	Bathyphantes gracillis	6	-	5	1
	Porrhomma pallidium	1	-	-	-
	Gnathonarium dentatum	3	2	2	1
	Pachygnatha clercki	-	1	-	-
	Pirata piraticus	18	-	51	3
	Erigone atra	1	-	9	-
	Oedothorax gibbosus	-	-	2	-
	Pardosa prativaga	1	-	-	-
	Walckenaria kochi	1	-	-	-
	Allomengea vidua	-	3	-	-
	Pirata piscatorius	-	-	5	2
	Pirata hygrophilus	-	-	1	-
Catfield E	Bathyphantes gracillis	8	3	6	-
	Clubiona juvenis	-	-	1	-
	Porrhomma pallidium	5	1	-	-
	Gnathonarium dentatum	4	1	1	-
	Lophomma punctatum	-	-	1	-
	Pachygnatha clercki	-	1	-	1
	Pirata piraticus	7	1	22	-
	Erigone atra	4	-	4	-
	Lepthyphantes flavipes	5	-	-	-
	Allomengea vidua	-	1	-	-
	Antistea elegans	-	1	-	-
	Entelecara omissa	-	-	1	-
	Pirata hygrophilus	-	-	1	2
	Pirata piscatorius	-	-	-	1
Catfield F	Bathyphantes gracillis	10	3	4	1
	Porrhomma pallidium	4	-	1	-
	Gnathonarium dentatum	9	-	3	-
	Lophomma punctatum	1	-	-	-
	Pachygnatha clercki	-	-	1	-
	Pirata piraticus	10	-	33	-
	Erigone atra	2	-	31	-
	Lepthyphantes flavipes	8	-	-	-
	Oedothorax gibbosus	-	-	7	-
	Pirata hygrophilus	2	1	-	-
	Pardosa prativaga	1	-	3	-
	Diplocephalus picinus	1	-	-	-
	Lepthyphantes tenebricola	1	-	-	-
	Silometopus elegans	1	-	-	-
	Allomengea vidua	-	-	-	1
	Pardosa pullata	-	1	-	-
	Pirata piscatorius	-	-	6	-
	Tmeticus affinis	-	-	1	-
	Pirata tenuitarsis	-	-	1	-
	Lepthyphantes tenuis	-	-	-	1
Mallow A	Bathyphantes gracillis	3	1	-	3
	Porrhomma pallidium	-	-	-	1
	Lophomma punctatum	6	-	-	-
	Pachygnatha clercki	-	3	-	1

	Pirata piraticus	3	-	12	3
	Erigone atra	-	-	4	-
	Oedothorax gibbosus	-	1	-	-
	Pardosa prativaga	1	-	-	-
	Diplocephalus picinus	1	-	-	-
	Antistea elegans	2	2	-	2
	Tetragnatha extensa	1	-	-	-
	Allomengea vidua	-	6	-	-
Mallow B	Bathyphantes gracillis	2	1	4	-
	Porrhomma pallidium	-	-	1	-
	Gnathonarium dentatum	-	-	-	1
	Lophomma punctatum	5	1	-	-
	Pachygnatha clercki	-	3	-	1
	Pirata piraticus	4	-	7	-
	Erigone atra	1	-	1	1
	Oedothorax gibbosus	6	1	-	-
	Pirata hygrophilus	-	-	2	-
	Pardosa prativaga	6	-	-	-
	Silometopus elegans	-	-	-	-
	Hypomma fulvum	1	-	-	-
	Antistea elegans	1	1	1	2
	Allomengea vidua	-	6	-	4
	Bathyphantes parvulus	-	-	2	-
Mallow C	Bathyphantes gracillis	-	4	8	1
	Gnathonarium dentatum	1	-	-	-
	Lophomma punctatum	5	-	-	-
	Pachygnatha clercki	-	3	-	1
	Pirata piraticus	3	-	33	1
	Erigone atra	-	-	5	-
	Lepthyphantes flavipes	1	-	-	-
	Oedothorax gibbosus	7	-	2	-
	Pirata hygrophilus	4	-	-	-
	Pardosa prativaga	3	-	-	-
	Antistea elegans	-	-	2	1
	Allomengea vidua	-	-	-	3
	Pirata piscatorius	-	-	1	-
	Porrhomma pygmaeum	-	-	1	-
	Argyroneta aqustica	-	-	1	-
Mallow D	Bathyphantes gracillis	2	6	4	1
	Porrhomma pallidium	-	1	-	-
	Lophomma punctatum	2	2	-	-
	Pachygnatha clercki	-	1	-	-
	Pirata piraticus	7	-	11	-
	Oedothorax gibbosus	9	-	3	-
	Pardosa prativaga	2	-	1	-
	Antistea elegans	1	2	1	-
	Allomengea vidua	-	6	1	12
	Pirata piscatorius	-	-	1	-
	Baryphyma trifrons	-	-	1	-
Mallow	Bathyphantes gracillis	1	2	6	2

E	Porrhomma pallidium	1	-	-	-
	Gnathonarium dentatum	-	-	1	-
	Lophomma punctatum	2	-	-	1
	Pachygnatha clercki	-	3	3	2
	Pirata piraticus	3	-	28	1
	Erigone atra	1	-	6	-
	Oedothorax gibbosus	9	-	-	-
	Pardosa prativaga	-	-	9	-
	Diplocephalus picinus	1	-	-	-
	Lepthyphantes tenebricola	-	-	1	-
	Silometopus elegans	-	-	-	-
	Antistea elegans	-	1	2	4
	Allomengea vidua	-	3	-	1
	Metopobactrus prominulus	-	-	1	-
	Pirata piscatorius	-	-	1	-
	Clubiona phragmites	-	-	1	-
	Bathyphantes parvulus	-	-	1	-
	Clubiona reclusa	-	-	-	1
Mallow F	Bathyphantes gracillis	3	1	4	2
	Porrhomma pallidium	-	1	1	1
	Lophomma punctatum	4	-	-	1
	Pachygnatha clercki	-	-	1	-
	Pirata piraticus	1	-	14	1
	Lepthyphantes flavipes	-	-	-	1
	Oedothorax gibbosus	12	-	4	-
	Pardosa prativaga	12	-	2	-
	Walckenaria kochi	1	-	-	-
	Lepthyphantes tenebricola	-	-	1	-
	Allomengea vidua	-	3	-	10
	Pirata tenuitarsis	-	-	2	-
	Tapinocyba praecox	-	-	1	-
	Pirata piscatorius	-	-	4	-
	Bathyphantes parvulus	-	-	1	-
	Pardosa pullata	-	-	-	1
How Hill A	Bathyphantes gracillis	11	1	11	4
	Porrhomma pallidium	-	1	-	-
	Gnathonarium dentatum	-	-	-	-
	Lophomma punctatum	2	1	2	-
	Pirata piraticus	4	1	28	-
	Erigone atra	3	-	2	-
	Lepthyphantes flavipes	4	-	1	-
	Oedothorax gibbosus	13	-	2	-
	Pirata hygrophilus	-	-	8	1
	Antistea elegans	1	3	-	2
	Oedothorax agrestis	1	-	-	-
	Leptorhoptrum robustum	1	-	-	-
	Allomengea vidua	-	22	-	7
	Hypselistes jacksoni	-	-	1	-
	Metopobactrus prominulus	-	-	1	-
	Lepthyphantes tenuis	-	-	-	1

How Hill B	Bathyphantes gracillis	8	-	14	5
	Gnathonarium dentatum	1	-	2	-
	Pachygnatha clercki	-	1	-	-
	Pirata piraticus	5	-	16	-
	Erigone atra	1	-	4	-
	Lepthyphantes flavipes	1	-	1	2
	Oedothorax gibbosus	22	-	1	-
	Pirata hygrophilus	-	-	2	1
	Antistea elegans	-	1	1	2
	Tmeticus affinis	1	-	-	-
	Hypomma fulvum	1	-	-	-
	Bathyphantes parvulus	-	-	-	1
	Allomengea vidua	-	4	-	4
	Pocadicnemis juncea	-	1	-	-
	Bathyphantes parvulus	-	2	-	-
	Pardosa pullata	-	1	-	-
	Clubiona phragmites	-	-	2	-
How Hill C	Bathyphantes gracillis	16	2	8	3
	Gnathonarium dentatum	3	-	2	-
	Pachygnatha clercki	1	-	-	1
	Pirata piraticus	7	-	14	-
	Erigone atra	4	-	-	-
	Lepthyphantes flavipes	1	-	1	-
	Oedothorax gibbosus	8	-	-	-
	Pirata hygrophilus	-	-	-	1
	Silometopus elegans	-	-	-	-
	Antistea elegans	2	2	5	1
	Baryphyma trifrons	1	-	-	-
	Hypselistes jacksoni	1	-	-	-
	Pocadicnemis juncea	1	-	-	-
	Hypomma fulvum	1	-	-	-
	Donacochara speciosa	1	-	-	-
	Allomengea vidua	-	8	-	5
	Bathyphantes parvulus	-	1	-	-
How Hill D	Bathyphantes gracillis	23	-	14	3
	Gnathonarium dentatum	2	1	7	1
	Lophomma punctatum	1	-	1	-
	Pirata piraticus	1	4	31	1
	Erigone atra	7	-	12	-
	Lepthyphantes flavipes	3	-	-	-
	Oedothorax gibbosus	5	-	-	-
	Antistea elegans	-	2	-	-
	Clubiona phragmites	-	1	-	-
	Donacochara speciosa	-	1	-	-
	Hypomma fulvum	-	-	1	1
How Hill E	Bathyphantes gracillis	16	-	9	1
	Gnathonarium dentatum	-	-	2	1
	Pachygnatha clercki	-	-	-	1
	Pirata piraticus	-	-	34	1
	Erigone atra	2	-	4	-

	Lepthyphantes flavipes	-	-	1	-
	Oedothorax gibbosus	3	-	-	-
	Pardosa prativaga	1	-	3	-
	Allomengea vidua	-	1	-	3
	Antistea elegans	-	1	3	-
	Bathyphantes parvulus	-	-	-	2
	Hypomma fulvum	1	-	-	-
How Hill F	Bathyphantes gracillis	17	1	5	2
	Gnathonarium dentatum	6	-	5	-
	Lophomma punctatum	2	-	-	-
	Pachygnatha clercki	-	2	2	2
	Pirata piraticus	-	-	33	-
	Erigone atra	2	-	3	-
	Lepthyphantes flavipes	1	-	-	-
	Oedothorax gibbosus	4	-	-	-
	Clubiona phragmites	-	1	1	-
	Pirata piscatorius	-	-	6	-
Beetles					
Catfield A	Acrotrichis atomaria	-	1	-	-
	Acrotrichis sitkaensis	3	-	-	-
	Agonum thoreyi	-	-	-	1
	Anacaena globulus	-	-	2	-
	Atomaria fuscicollis	-	-	2	-
	Cercyon convexiusculus	-	-	1	-
	Cercyon tristis	1	-	-	-
	Cyphon phragmiteticola	-	-	2	-
	Euconnus hirticollis	-	1	-	-
	Myllaena kraatzi	-	-	2	-
	Ocyusa maura	2	-	4	-
	Paederus riparius	1	-	-	-
	Stenus latifrons	2	-	-	-
	Stilbus oblongus	1	1	-	1
Catfield B	Acrotrichis atomaria	1	-	-	-
	Acrotrichis sitkaensis	-	1	2	-
	Agonum fuliginosum	-	-	2	-
	Anacaena limbata	1	-	-	-
	Blethisa multipunctata	-	-	1	-
	Cantharis thoracica	-	-	-	-
	Carpelimus rivularis	-	-	1	-
	Cerapheles terminatus	-	-	1	-
	Cercyon marinus	-	-	3	-
	Coelostoma orbiculare	2	-	6	1
	Cyphon phragmiteticola	1	-	10	-
	Euaesthetus ruficapillus	1	1	-	-
	Euophryum confine	-	-	2	-
	Hydraena palustris	1	-	-	-
	Ilybius atar	-	-	1	-
	Ochthebius minimus	-	-	1	-
	Ocyusa maura	2	-	1	-
	Odacantha melanura	-	-	3	-

	Oodes helopioides	2	-	5	-
	Paederus riparius	3	-	-	-
	Philonthus quisquiliarus	-	-	1	-
	Pterostichus nigrita	-	-	1	-
	Stilbus oblongus	1	-	-	-
Catfield C	Acrotrichis atomaria	1	-	-	-
	Acrotrichis henrici	-	-	-	1
	Acrotrichis sitkaensis	-	3	5	-
	Agonum thoreyi	-	1	-	-
	Aloconota gregaria	-	-	1	-
	Amara lunicollis	-	-	-	-
	Atheta zosterae	1	-	-	-
	Atomaria fuscicollis	-	-	2	-
	Atomaria testacea	-	-	2	-
	Cercyon convexiusculus	1	-	-	-
	Cyphon hilaris	-	-	-	1
	Cyphon ochraceus	-	-	2	-
	Cyphon padi	-	-	2	-
	Euconnus hirticollis	2	-	1	-
	Hydroporus scalesianus	1	-	-	3
	Ocyusa maura	2	-	3	-
	Paederus riparius	4	-	2	-
	Ptenidium fuscicorne	2	-	-	-
	Ptenidium nitidium	-	-	2	-
	Rybaxis longicornis	2	-	-	-
	Stenus carbonarius	-	-	-	1
	Stenus latifrons	1	-	-	-
	Stilbus oblongus	1	-	2	-
	Tachyporus hypnorum	-	-	1	-
Catfield D	Acrotrichis sitkaensis	3	2	-	-
	Agonum thoreyi	-	-	2	1
	Agonum viduum	-	-	1	-
	Anacaena globulus	-	-	-	1
	Anacaena limbata	-	-	5	-
	Atheta graminicola	-	-	1	-
	Atomaria fuscicollis	-	-	1	-
	Atomaria linearis	-	-	1	-
	Blethisa multipunctata	-	-	1	-
	Carpelimus rivularis	-	-	1	-
	Cercyon marinus	-	-	1	-
	Cymbiodyta marginella	-	1	-	-
	Cyphon hilaris	2	-	-	-
	Cyphon phragmiteticola	2	-	4	1
	Euconnus hirticollis	1	1	1	-
	Glischrochilus hortensis	-	-	1	-
	Hydrobius fuscipes	-	-	6	-
	Ilybius quadriguttatus	2	-	-	-
	Megasternum obscurum	-	-	1	-
	Ochthebius minimus	-	-	4	-
	Ocyusa maura	3	-	4	-

	Odacantha melanura	-	-	1	-
	Oodes helopioides	-	-	1	-
	Pselaphaulax dresdensis	-	-	1	-
	Stenus latifrons	1	-	-	-
	Stilbus oblongus	-	-	1	-
Catfield E	Agabus unguicularis	-	-	-	2
	Agonum fuliginosum	-	1	-	-
	Anacaena globulus	-	-	-	2
	Atheta elongatula	1	1	-	-
	Cantharis thoracica	1	-	-	-
	Cryptopleurum minutum	-	-	1	-
	Cymbiodyta marginella	2	-	1	-
	Cyphon padi	-	-	1	-
	Dryops sp	1	-	-	-
	Ocyusa maura	-	-	2	-
	Oodes helopioides	-	-	1	-
	Paederus riparius	1	-	-	-
	Ptenidium fuscicorne	3	-	-	-
	Silis ruficollis	1	-	-	-
	Stenus juno	1	-	-	-
	Stenus latifrons	-	1	-	-
	Stilbus oblongus	1	-	1	-
Catfield F	Acrotrichis henrici	1	-	-	-
	Acrotrichis sitkaensis	-	-	3	-
	Agonum fuliginosum	-	-	1	-
	Aloconota gregaria	-	-	1	-
	Amischa analis	-	-	-	1
	Anacaena limbata	-	-	1	-
	Aphthona nonstriata	-	-	1	1
	Carabus granulatus	-	-	4	-
	Cerapheles terminatus	1	-	-	-
	Cyphon phragmiteticola	-	-	1	-
	Cyphon variabilis	1	-	-	-
	Elaphrus cupreus	-	-	3	-
	Erichsonius cinerascens	-	-	1	-
	Euconnus hirticollis	-	-	3	-
	Glischrochilus hortensis	1	-	1	-
	Heterocerus obsoletus	-	1	-	-
	Ilybius atar	-	-	1	-
	Loricera pilicornis	-	-	1	-
	Myllaena infuscata	1	-	-	-
	Oodes helopioides	-	1	1	-
	Paederus riparius	3	-	-	-
	Philonthus fumarius	-	-	1	-
	Pterostichus nigrita	-	-	2	-
	Quedius fuliginosus	1	-	-	-
	Silis ruficollis	-	-	-	-
	Xantholinus linearis	-	1	-	-
Mallow A	Acrotrichis sitkaensis	12	-	-	-
	Agonum thoreyi	-	1	2	-

	Anacaeana limbata	-	-	3	-
	Aphthona lutescens	1	-	-	-
	Aphthona nonstriata	-	-	1	-
	Atheta fungi	22	-	-	-
	Atomaria fuscicollis	-	-	1	2
	Atomaria nitidula	-	-	1	-
	Bryaxis bulbifer	1	-	-	-
	Cantharis thoracica	6	-	-	-
	Carpelimus corticinus	-	-	2	-
	Cercyon convexiusculus	-	-	1	-
	Cercyon sternalis	-	-	-	1
	Cercyon tristis	-	-	-	1
	Clambus armadillo	1	-	-	-
	Coelostoma orbiculare	-	1	1	7
	Erichsonius cinerascens	-	-	1	-
	Euconnus hirticollis	1	2	3	-
	Hydraena riparia	1	-	-	-
	Ilybius quadriguttatus	-	-	1	-
	Loricera pilicornis	-	-	1	-
	Ochthebius minimus	-	-	1	-
	Paederus riparius	3	-	6	-
	Philonthus fumarius	-	-	1	-
	Phyllotreta exclamationis	-	-	1	-
	Pselaphaulax dresdensis	-	-	1	-
	Pterostichus rhaeticus	-	1	-	3
	Stenus palustris	1	-	-	-
Mallow B	Acrotrichis grandicollis	1	-	-	-
	Acrotrichis henrici	-	2	-	-
	Acrotrichis sitkaensis	5	1	-	-
	Agabus bipustulatus	1	-	-	-
	Agonum thoreyi	-	-	2	1
	Amischa analis	-	-	1	-
	Anacaena globulus	-	-	1	-
	Anacaena limbata	-	-	-	2
	Anotylus sculptuatus	2	-	-	-
	Atheta fungi	-	-	1	-
	Cantharis thoracica	4	-	-	-
	Cercyon tristis	1	-	-	-
	Cyphon hilaris	-	-	1	-
	Erichsonius cinerascens	-	-	1	-
	Euconnus hirticollis	1	-	-	-
	Hydraena testacea	-	-	-	1
	Hyphydrus ovatus	-	-	1	-
	Myllaena minuta	-	1	-	-
	Paederus riparius	1	-	12	-
	Ptenidium intermedium	-	1	-	-
	Stenus cicindeloides	-	-	3	-
	Stenus juno	1	-	-	-
	Stilbus oblongus	-	-	2	-
	Tachyporus chrysomelinus/dispar	1	-	-	-

Mallow C	Acrotrichis sitkaensis	4	-	-	-
	Agonum gracile	-	-	1	-
	Agonum thoreyi	1	-	-	1
	Aloconota gregaria	-	-	1	-
	Anacaena limbata	-	-	1	-
	Anotylus rugosus	2	-	1	-
	Atheta graminicola	1	-	-	-
	Cantharis thoracica	1	-	-	-
	Cerapheles terminatus	1	-	-	-
	Cercyon convexiusculus	-	-	1	-
	Coelostoma orbiculare	-	-	2	4
	Cyphon hilaris	-	1	-	-
	Euconnus hirticollis	-	-	4	-
	Galerucella calmariensis	-	-	1	-
	Ocyusa maura	-	-	1	-
	Paederus riparius	6	-	12	-
	Pterostichus nigrita	-	-	-	1
	Pterostichus vernalis	-	-	1	-
	Stilbus oblongus	1	-	-	-
	Tachyusa atra	-	1	-	-
Mallow D	Acrotrichis atomaria	-	3	-	-
	Acrotrichis sitkaensis	6	3	1	-
	Agonum gracile	-	-	1	-
	Anacaena globulus	-	-	1	-
	Atheta laticollis	1	-	-	-
	Atheta fungi	12	-	-	-
	Atomaria mesomela	2	-	1	-
	Bryaxis bulbifer	-	-	1	-
	Cantharis thoracica	1	-	-	-
	Cercyon convexiusculus	-	-	1	-
	Cyphon phragmiteticola	1	-	-	-
	Euconnus hirticollis	-	-	1	-
	Glischrochilus hortensis	-	-	1	-
	Hydroporus longicornis	-	-	-	2
	Ilybius quadriguttatus	-	-	3	-
	Oxypoda elongatula	5	-	-	-
	Paederus riparius	6	-	3	1
	Ptenidium nitidum	2	-	-	-
	Silis ruficollis	1	-	-	-
	Stenus juno	-	-	1	-
	Stenus lustrator	-	1	-	-
	Stenus nitens	-	-	1	-
Mallow E	Acrotrichis fascicularis	-	-	-	1
	Acrotrichis sitkaensis	10	-	-	-
	Agabus bipustulatus	1	-	-	-
	Agonum fuliginosum	1	-	-	-
	Agonum thoreyi	-	-	2	-
	Anacaena limbata	-	-	1	3
	Anotylus sculpturatus	2	-	1	-
	Atheta fungi	20	-	-	-

	Atomaria fuscicollis	-	-	1	-
	Atomaria gutta	1	-	-	-
	Atomaria mesomela	1	-	-	-
	Bryaxis bulbifer	1	-	-	-
	Cantharis thoracica	2	-	-	-
	Cercyon convexiusculus	-	-	1	-
	Cymbiodyta marginella	-	-	-	1
	Enochrus coarctatus	-	-	1	-
	Erichsonius cinerascens	-	-	1	-
	Euaesthetus ruficapillus	-	3	-	-
	Euconnus hirticollis	1	-	3	-
	Hydroporus longicornis	-	-	-	2
	Ilybius ater	-	1	-	-
	Ilybius quadriguttatus	-	1	-	-
	Ocyusa maura	1	1	-	-
	Oodes helopioides	-	-	-	1
	Paederus riparius	3	-	7	1
	Pterostichus diligens	1	-	-	-
	Pterostichus minor	-	1	-	-
	Silis ruficollis	1	-	-	-
Mallow F	Acrotrichis atomaria	-	2	-	-
	Acrotrichis henrici	1	-	-	-
	Acrotrichis sitkaensis	25	-	-	-
	Atheta fungi	12	-	-	-
	Atomaria fuscicollis	-	-	1	-
	Atomaria gutta	1	-	-	-
	Bryaxis bulbifer	-	-	1	-
	Cantharis thoracica	1	-	-	-
	Corylophus cassidoides	-	-	1	-
	Cyphon hilaris	-	-	1	-
	Hydraena riparia	-	-	1	-
	Ilybius guttiger	-	-	1	-
	Ilybius quadriguttatus	-	-	1	-
	Ocyusa maura	-	-	1	-
	Oxypoda elongatula	5	-	-	-
	Paederus riparius	4	-	4	1
	Pterostichus nigrita	1	-	-	-
	Quedius fuliginosus	-	-	-	1
	Quedius semiaeneus	-	-	-	1
	Sitona lineatus	-	-	-	1
	Stenus latifrons	1	1	-	-
	Stenus nitens	-	-	2	-
	Stenus palustris	-	-	1	-
How Hill A	Acrotrichis cognata	-	-	2	-
	Acrotrichis henrici	-	-	-	2
	Acrotrichis sitkaensis	3	-	-	-
	Agonum thoreyi	-	3	4	-
	Amischa analis	-	-	-	1
	Anacaena limbata	-	1	3	-
	Atheta fungi	9	1	1	-

	Atomaria basalis	1	-	-	-
	Atomaria fuscicollis	1	-	-	-
	Atomaria gutta	3	-	1	-
	Bryaxis bulbifer	-	-	1	-
	Cerapheles terminatus	-	-	2	-
	Cercyon convexiusculus	-	-	1	-
	Cercyon sternalis	-	-	2	-
	Coelostoma orbiculatus	-	1	-	-
	Corylophus cassidoides	1	2	-	-
	Cymbiodyta marginella	-	-	-	1
	Cyphon hilaris	1	-	-	-
	Cyphon phragmiteticola	-	-	1	-
	Dromius longiceps	1	-	-	-
	Euconnus hirticollis	-	3	-	-
	Hydraena riparia	1	-	-	-
	Hydroporus longicornis	-	-	-	1
	Hydroporus memnonius	-	-	-	1
	Myllaena dubia	1	-	-	-
	Ocyusa maura	1	-	-	-
	Olophrum piceum	-	1	-	-
	Oxypoda elongatula	1	-	-	-
	Pachnida nigella	1	-	3	-
	Paederus riparius	5	11	7	-
	Philonthus fumarius	-	1	-	-
	Quedius balticus	-	1	-	-
	Rhagonycha testacea	-	-	1	-
	Stenus latifrons	1	-	-	-
	Stenus palustris	1	-	-	-
	Stilbus oblongus	2	-	2	-
How Hill B	Acrotrichis grandicollis	2	-	-	-
	Acrotrichis henrici	-	-	-	1
	Acrotrichis sitkaensis	3	2	4	-
	Agonum thoreyi	2	3	-	-
	Anacaena limbata	-	-	-	1
	Aphthona nonstriata	-	-	1	-
	Atheta fungi	26	-	-	-
	Atheta graminicola	-	1	-	-
	Atomaria spp	3	-	-	-
	Atomaria gutta	-	-	1	-
	Cercyon sternalis	-	-	-	1
	Coelostoma orbiculare	-	1	-	-
	Cymbiodyta marginella	-	1	-	-
	Cyphon hilaris	-	1	-	-
	Euconnus hirticollis	1	3	-	-
	Gabrius pennatus	-	1	-	-
	Hydraena riparia	-	-	-	1
	Hydroporus angustatus	-	-	-	1
	Ocyusa maura	-	-	1	-
	Oxypoda haemorrhoa	1	-	-	-
	Pachnida nigella	4	-	-	-

	Paederus riparius	3	10	3	-
	Ptenidium nitidum	1	-	-	-
	Stilbus oblongus	-	-	-	1
How Hill C	Acrotrichis sitkaensis	3	-	-	-
	Agonum thoreyi	-	-	2	-
	Anacaena limbata	-	-	3	1
	Atheta fungi	4	-	-	-
	Atheta graminicola	-	1	-	-
	Atomaria gutta	1	-	-	-
	Cantharis thoracica	1	-	-	-
	Cercyon convexiusculus	-	-	1	-
	Cercyon tristis	1	-	-	-
	Euconnus hirticollis	-	1	1	-
	Glischrochilus hortensis	-	-	1	-
	Loricera pilicornis	1	-	-	-
	Myllaena minuta	-	1	-	-
	Ocyusa maura	1	-	-	2
	Paederus riparius	6	2	-	-
	Rybaxis longicornis	1	-	-	-
	Stenus juno	1	-	-	-
	Stenus latifrons	1	-	-	-
	Trissemus impressus	1	-	-	-
How Hill D	Acrotrichis grandicollis	-	-	1	-
	Agabus unguicularis	-	-	-	2
	Agonum thoreyi	3	1	2	-
	Atheta graminicola	-	-	-	1
	Cercyon sternalis	-	-	1	-
	Coelostoma orbiculare	-	-	2	-
	Euconnus hirticollis	-	8	2	-
	Hydroporus angustatus	-	-	-	1
	Ocyusa maura	-	-	-	2
	Paederus riparius	1	-	-	-
	Rybaxis longicornis	-	-	2	-
	Silis ruficollis	-	-	1	-
	Stenus latifrons	1	-	-	-
How Hill E	Acrotrichis sitkaensis	-	-	1	-
	Agonum thoreyi	-	2	3	-
	Alianta incana	-	-	1	-
	Anacaena limbata	1	-	-	1
	Atheta graminicola	-	1	-	1
	Elaphrus cupreus	-	-	1	-
	Euconnus hirticollis	1	2	-	-
	Hydroporus angustatus	-	-	-	1
	Ocyusa maura	2	-	1	-
	Odacantha melanura	-	-	1	-
	Pachnida nigella	1	-	-	-
	Silis ruficollis	-	-	1	-
	Stenus latifrons	2	-	-	-
	Stenus nitens	1	-	-	-
	Stilbus oblongus	8	-	4	-

	Trissemus impressus	1	-	-	-
How Hill F	Acrotrichis grandicollis	-	-	1	-
	Acrotrichis sitkaensis	1	-	-	-
	Agabus unguicularis	-	-	-	1
	Agonum thoreyi	-	3	-	-
	Aloconota gregaria	-	-	-	1
	Atheta fungi	1	-	-	-
	Atheta graminicola	-	-	-	4
	Cymbiodyta marginella	-	-	2	-
	Cyphon padi	1	-	-	-
	Erichsonius cinerascens	1	-	1	-
	Euaesthetus ruficapillus	-	-	1	-
	Hydroporus memnonius	-	-	-	1
	Hygrotus inaequalis	-	-	-	1
	Microcara testacea	1	-	-	-
	Myllaena minuta	1	-	-	-
	Ocyusa maura	-	-	-	6
	Odacantha melanura	-	-	3	-
	Pachnida nigella	1	-	1	-
	Silis ruficollis	2	-	-	-
	Stenus latifrons	1	1	-	-
	Stenus longitarsis	-	-	-	1
	Stilbus oblongus	8	-	-	-

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