The University of Hull

Epigeal invertebrates of Yorkshire allotments: The influence of urban-rural gradient and management style

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ABSTRACT

There is a growing interest in urban ecology but it can be a difficult environment for wildlife due to a range of anthropogenic pressures. Allotments could be used to study this issue but they have been rather neglected in terms of academic research, particularly in relation to their biodiversity value.

A questionnaire of plot-holders in east Yorkshire showed that whilst older men were still the principal plot-holders, there was reasonable interest from younger people. Respondents placed a high value on allotment wildlife, regardless of age or management style of their plots. Highly significant percentages were willing to allow sampling on their plot.

From the questionnaire data seven allotment sites were selected to represent an urban-rural gradient. The gradient was verified using a range of environmental factors suggested in part by the literature for gardens due to the similarities in habitat use.

Pitfall trapping for epigeal invertebrates on forty-two plots found a trend of increasing abundance from rural to urban plots, with beetles, woodlice and spiders constituting 79% of the catch. Diversity was highest on one suburban site, but lowest on another.

When the plots were split by either traditional or wildlife-friendly management style, woodlice and molluscs were more abundant on the wildlife-friendly plots, beetles more abundant on the traditional ones, whilst spiders, opilione and myriapods showed no significant difference.

Three allotment sites representing the urban-rural gradient were compared in relation to the individual spider, woodlice and beetle species present and management style. Whilst spider diversity did conform to the intermediate disturbance hypothesis, the beetles and woodlice did not. The majority of species found were generalists, thus conforming to the opportunistic species hypothesis. Most taxa could be categorised as either neutral or beneficial in terms of bio-control. Allotments offer great opportunities for further research regarding their biodiversity value.

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Author’s Declaration

The candidate confirms that the work submitted is her own work and the appropriate credit has been given where reference has been made to the work of others.

CHAPTER 1: URBAN ECOLOGY AND THE VALUE OF ALLOTMENTS

1.0 INTRODUCTION

1.1 Urban ecology and biodiversity

Urban ecology is still a relatively new science. Recently Picket *et al.* (2001) summed it up nicely when they said "*urban habitats constitute an open frontier for ecological research*" (see also Nilon *et al.,* 1999). Attitudes have slowly changed from the traditional viewpoint that nature should be confined to nature reserves and managed by experts such as ecologists and botanists (Folke *et al*., 1996), but this change is rather piecemeal.

Only a small proportion (c.13%) of the world's landmass is dedicated to nature reserves, so understanding and managing changes in biodiversity of man-made landscapes is a pressing priority for conservation (Niemela *et al*., 2000; Coad *et al*., 2008; World Database on Protected Areas, 2012). These non-reserve areas, e.g. gardens, parks and fields, make up a much higher proportion of the landmass and are where people are more likely to encounter wildlife, even if that wildlife is 'just' a squirrel in the local park. If people place a value on their local wildlife, they are more likely to demonstrate and/or develop greater understanding of wider conservation issues (Dow, 2000; McIntyre *et al.*, 2000). The Convention on Biological Diversity aimed to protect and enhance biodiversity; this was to be achieved partly through developing educational and public awareness programmes, thus providing high level strategies for local level action (UN, 1992). In addition, the Millennium Development Goals Report (2010) noted that although the target to reduce biodiversity loss by 2010 had failed, measures such as reducing the rates of deforestation had some success, due partly to tree re-planting schemes but also through wide-ranging educational initiatives (UN, 2010).

Urban ecology should reflect the importance, consciously or unconsciously, we all place on living in a healthy, green environment. As the pressure on land is generally greatest in cities, the few remaining 'green' areas are therefore all the more valuable. For example, in the UK, English Nature (now part of Natural England) recommended that people living in towns and cities should have an accessible natural greenspace less than 300 metres from home, a nature reserve at a minimum level of one hectare per 1,000 population, as well as one accessible 20 hectare site within 2 km of home (English Nature, 1996). However, greenspace within urban areas is not systematically monitored therefore basic data about the ecosystem benefits that could be derived from it cannot be quantified (UK National Ecosystem Assessment, 2011).

Cities are usually viewed in negative terms when discussed alongside biodiversity (Savard *et al.*, 2000), but Botkin and Beveridge (1997) have proposed that these attitudes need to change in order to practice biological conservation and create environments that are pleasant for people to live in. In their review of the history of city planning, they note that "*those who have written about cities have agreed on three points: 1. cities are the centres for innovation and creativity in civilization; 2. the more pleasant a city is, the more likely its residents will be innovative and creative; 3. vegetation is the key to making cities pleasant*" (Botkin and Beveridge, 1997). The last point may be the most neglected in countries such as the UK, which have huge pressures on the very limited land available for development. This means that as many small parcels of greenspace as possible should be protected from the developer to provide habitat heterogeneity and connectivity for a wide range of wildlife.

Urbanization has been defined as an area where there is an increase in human habitat, along with the corresponding increase in energy consumption and extensive alteration to the landscape (McDonnell and Pickett, 1990). The urban system tends to buy in its main resources e.g. water, food, shelter, whilst the people living there tend to do more specialized work, buying in their essentials for life (McDonnell and Pickett, 1990), rather then using the land in a sustainable way for their own needs. The geographer's definition of urban is based on 6.2 people per hectare, compared to rural areas which are defined as having 1 to <1 person per hectare (Bourne and Simmons, 1982 cited in McDonnell *et al*., 1997).

1.2 Urban habitats

Urban habitat modification can lead to substantial habitat heterogeneity, a situation not often found in the modern monoculture agriculture that is likely to surround the urban 'island'. As a result, the urban landscape can sometimes provide a refuge to species that struggle to thrive in vast fields of a single crop that are constantly mown or ploughed up and sprayed with chemicals. These 'new' urban species tend to be mobile generalists that can quickly take advantage of new feeding and breeding sites. For example, Small *et al.* (2003) found in a study of brownfield sites (which can be relatively species rich compared to the surrounding habitat e.g. roads, housing) that generalist species contributed a large proportion of the species found; indeed over 70% of the catch was composed of generalists, dominated by the ubiquitous black beetle

Pterostichus madidus. However, biodiversity of urban habitats is poorly documented in many cities and thus baseline information is scarce (Niemela, 1999_a). Specific sites such as remnant forests or meadows that have been engulfed by a city may be reasonably well studied (e.g. see Sewell and Catterall, 1998; Lehvavirta *et al*., 2006; Miller *et al*., 2009), but on the whole, green spaces and brownfields tend to be neglected with regard to their wildlife value.

Niemela (1999_a) neatly summarized the three main properties that Trepl (1995) proposed as distinguishing urban landscapes from natural ones. They are a) integration (organization, connectivity); b) succession and c) invasion by alien species. In addition, Niemela also added that (d) ecological scale also needs to be considered. To expand, he noted:
a) The lack of integration of natural or semi-natural habitat refers to the rather isolated 'green' spaces found in cities. These sites may at first appear to have a rather rich biodiversity, but if they are not linked to other nearby patches or have suitable corridors, they may actually act as sinks (Battin, 2004). Poorly dispersing species are especially at risk of extinction in such a situation.

b) Succession tends to be a poorly understood concept by professionals other than ecologists e.g. planners, councillors, the general public. As a result, many potential wildlife sites in cities tend to be frozen at one particular stage in succession e.g. mown grass or mature trees (Niemela, 1999_b), whilst scrub is seen as an abhorrent, unnatural state that must be 'tidied up' at all costs.

c) ‘Alien invasive’: these are non-native plants [and animals] which dominate a habitat to the exclusion of virtually everything else. In some areas of the UK, they are becoming a serious problem and will cost millions of pounds to eradicate (Manchester and Bullock, 2000); the most notorious of these being Japanese Knotweed (*Fallopia japonica*).

d) In addition, the ecological scale i.e. the size of the area/ecosystem under study, needs to be taken into account (see Gaston, 1996_b; McDonnell *et al.*, 1997; Niemela *et al.,* 2002) as it will have a bearing on the communities present. As many species, especially plants, appear to adapt well to anthropogenic habitats (Bradshaw, 1962; Pysek *et al*., 2004), an individual urban patch may appear to be relatively species-rich in comparison to an area of intense agriculture in the countryside. A closer look at the species composition will usually reveal, however, that many of the species planted in small urban core patches are non-native, hardy plants, often favoured by local authorities. Therefore, urban cores do generally have lower native species diversity when compared to suburban and rural areas.

1.3 Interdisciplinary approaches to urban ecology: professionals and the public

It is often forgotten that all biodiversity, not just urban biodiversity, includes people and it is people that are having the greatest impact upon most aspects of biodiversity (Grimm *et al.*, 2000) (see Figure 1.1). Thus, as urban ecosystems are dominated by high densities of people, it should be obvious that the desires and perceptions of urban residents should form an integral part of biodiversity management in those systems (Savard *et al*., 2000). Residents should feel that they are a viable part of the ecosystem in which they live, and not the opposition in a war between urban versus countryside. Therefore, any urban ecological research must include what is likely to be one of the biggest influences on any project, namely the anthropogenic impact.

Grimm *et al*. (2000) recognize that conceptual frameworks that specifically include humans will be much more likely to assist in environmental problem solving that those that exclude them. As well as studying the "traditional" ecosystem drivers such as energy flow, primary production etc, economic and social drivers such as power hierarchies, cultural values and demographics should also be considered (Grimm *et al.*, 2000) (see Figure 1.1).

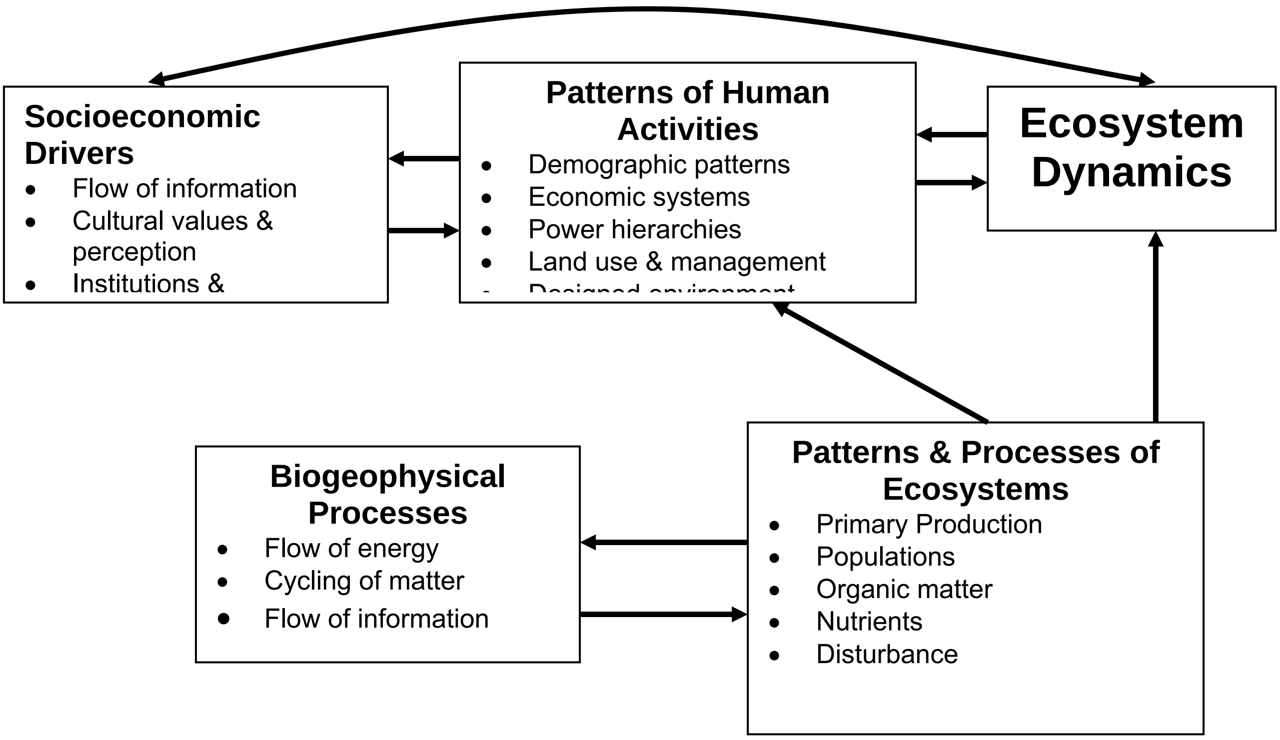


Figure 1.1 A comprehensive view of the drivers, interactions and feedbacks affecting ecosystem dynamics that recognize, in addition to biogeophysical drivers, socioeconomic drivers that determine patterns of human activity. Items listed under "patterns of human activities" are suggested core areas of long-term social science research (From Grimm *et al.*, 2000).

For example, land development due to urbanization has grown massively in the past two decades with about half the population living in urban areas, which in turn alters habitats and community composition, among many other things (Alberti *et al*., 2003; Cohen, 2006; McKinney, 2006). Thus, in an urban setting, people are perhaps the major cause of negative impacts on biodiversity. However, they are also the species most able to control and improve the situation (McIntyre *et al*., 2000). For example, by involving volunteers (as so called citizen scientists) in the collection of biodiversity data (which is becoming increasingly common (Lovell *et al*., 2009) and by involving residents in their own "patch" and making them more aware of local biodiversity projects, increased grass-roots level support for wider environmental issues could be gained. To illustrate this, a Chicago project incorporates thousands of local volunteers to monitor, manage, fund and publicize a series of habitat blocks in and around the city (Dearborn and Kark, 2010). This successful approach could then provide key empirical evidence allowing better decision-making by urban planners and scientists. However, delivering sustainable community projects such as this may be increasingly difficult in the UK given the economic squeeze on resources and short-term planning by politicians (Rotherham, 2010).

There is now the realization that no single specialist can cover the whole field of urban ecology; an interdisciplinary and hierarchical approach is required (McIntyre *et al.*, 2000; Lockaby *et al.*, 2005). Integration of the sciences and other disciplines is starting to happen. McIntyre *et al*., (2000) reviewed the differences in the use of the term "urban" between the social and natural sciences. They found that most of the ecological papers they reviewed were simply traditional plant or animal ecological studies conducted in urban settings, with humans considered to be major causes of disturbance. They then, however, went on to quote Parlange (1998) who said that urban ecology implicitly recognized the role that humans play in developing unique ecosystems, because urbanization is both an ecological and a social phenomenon.

Early investigations on the ecology of cities tended to focus on single biotopes and much work was done in Central Europe, especially Warsaw and Berlin, on plant succession on site ruins after bombing of Second World War areas (Sukopp, 2002). In addition, researchers have been studying urban ecology for some time and with relatively high levels of commitment is the USA. In 1980, America's National Science Foundations decided to fund some long-term ecological research (LTER) into a range of 'natural' habitats. This funding continues today and new sites are being added. As the bulk of people in the western world live in cities, two of these new areas of research are cities: Baltimore and Phoenix, where the role of humans, as well as that of other species, is studied in the urban setting (Grimm *et al.*, 2000). Humans are usually only viewed in terms of their negative impact on an environment (Parlange, 1998) so these studies can look at the positive, as well as the negative impacts of humans, in addition to the lots of smaller studies that cover a wide range of urban ecological topics. However, perhaps not all urban ecology studies fully appreciate the human dimension. Whilst the economic factors are also not usually considered as pressures on urban environments, for example Cornelis and Hermy (2004) and Giulliano *et al*. (2004) look at only environmental factors in their study of parks, both Alberti and Marzluff (2004) and Pickett *et al*. (2001) do recognize that socio-economic factors play an important role in urban biodiversity.

The above studies looked at a wide variety of urban environmental factors such as habitat heterogeneity, watersheds, groups of organisms and their habitat, to name a few (Parlange, 1998; Pickett *et al.*, 2001). At a strategic level, these studies also try to look at the city as a whole ecosystem (Parlange, 1998), rather than ecosystems within a city. However, they do recognize that to be successful, smaller components such as the examples given above must be studied as individual projects, which are in turn fed into the larger picture.

In the UK, there are relatively few studies of urban ecology and those that do exist tend to be on a much smaller scale than the LTER projects and lack the large-scale government-backed funding that exists in the USA. For example, Sheffield University set up the *Biodiversity in Urban Gardens of Sheffield* (BUGS) project which sampled the species richness and diversity and wildlife value of urban gardens in the city. Various aspects of urban biodiversity and attitudes to it were also sampled e.g. invertebrate richness, structural diversity, value of ponds, attitudes to long grass (Thompson *et al*., 2004; Gaston *et al*., 2005_a; Smith *et al*., 2005; Smith *et al*., 2006_a). Generally, they found that garden wildlife was both species rich and abundant, regardless of the use of native or non-native plants; size or proximity to the city centre had little impact and, unsurprisingly, long grass was not popular amongst the human population. These studies differ from the majority of invertebrate studies in the UK because, unusually, they focussed on both urban invertebrates and human attitudes towards them. One notable garden study that deserves mention is the one by

Jennifer Owen whom studied, among other things, the invertebrate fauna of her suburban garden over fifteen years. She documented over 1,700 species, many of them rare, using a variety of trapping methods (Owen, 1991). This rather rare example of a long-term garden invertebrate data set provides insight to the contribution domestic gardens could make to enhancing biodiversity if managed sympathetically with wildlife in mind.

1.4 Public attitudes to wildlife

Generally, the public still tend to think that wildlife is something for the countryside and have little idea of what the concept of biodiversity encompasses (Defra, 2003_b). For example, in a Defra survey, it was found that only 26% of the population sampled knew what the word "biodiversity" meant (although this was an increase from 22% in 1996) (Defra, 2003_b).

In the UK, there has been some change in the public's perception of the importance of wildlife and its place in their lives. This has been partly due to the huge success of projects such as the BBC's commitment to a range of programmes that not only talk about various aspects of wildlife, but actively encourage viewers to get out and do something positive for wildlife themselves (BBC, 2007).

Savard *et al.* (2000) stated "*that urban growth must now take into consideration the creation of large recreational zones, which often, upon the request of citizens, must remain as natural as possible*". However, in the UK at least, can the opposite also be true? Some people appear to want nature to be all but obliterated, or at least sanitized to a close-cropped lawn with a few mature parkland trees. This 'unnatural' form of nature is therefore kept partly at an early successional stage, e.g. mown grass which has relatively low wildlife value, whilst the other part is at climax stage e.g. old trees (Niemela, 1999_a). Many people do not seem to appreciate the many stages of succession and only want the aesthetically pleasing stages of it.

Both Rudd *et al*. (2002) and Savard *et al*. (2000) recognize that if a city's residents have some contact with nature in their own backyard or nearby greenspace, they are more likely to have a better awareness of wider conservation issues; a view that is also supported by Lyons (1997). Unfortunately, little research has been done so far on human perception and appreciation of urban wildlife (Savard *et al*., 2000). This is particularly the case in Britain, as the conflict between land for development and recreation/wildlife increases, perhaps these types of studies will hopefully be carried out in the not too distant future.

1.5 Habitat gradients

One widely employed method which is used to try and understand the dynamics of urban ecology (see Figure 1.2) is the application of urban-rural gradients. As noted by McDonnell *et al*. (1997), ecologists have not historically worked in heavily populated areas therefore the terms 'urban' and 'rural' have multiple meanings that can relate to issues such land cover, population density or the amount of impermeable surfaces. For the purposes of this thesis, a combination of these factors will be used to determine which sites are designated along the urban-suburban-rural gradient. These gradients are useful for studying many aspects of ecology because they have similar characteristics anywhere in the world e.g. urban areas are densely built and highly developed cores surrounded by areas of decreasing intensity of development i.e. suburbs and increasing 'naturalness' i.e. rural areas (Niemela *et al.*, 2000). The suburbs and beyond will still be highly modified land but will contain a few patches of 'natural' land. Beyond this, the land is less modified, usually farmland, nature reserves or similar less developed land.

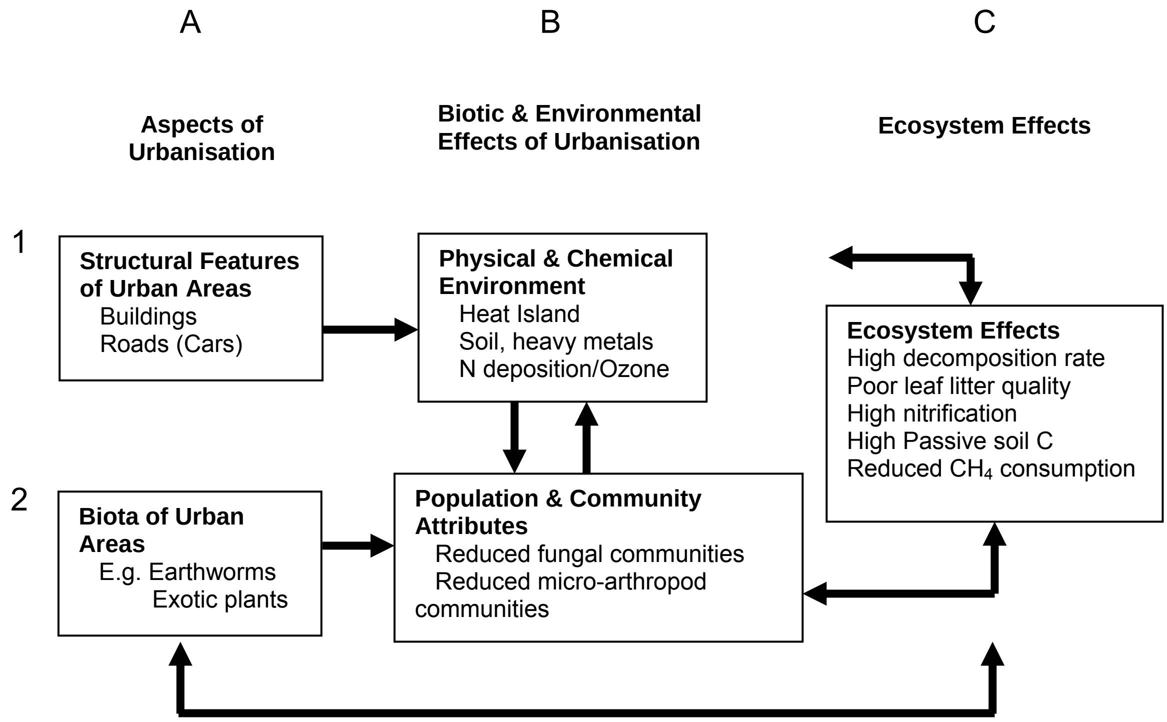


Figure 1.2 Model of the effects of urbanization, linking environmental factors with anthropogenic factors. (Adapted from McDonnell *et al.*, 1997: Urban LTER project, see Section 1.3 for details.)

Urban-rural gradients can be a useful tool for studying a range of ecological processes and species (Harrison *et al.*, 1992; Niemela *et al.*, 2000; Niemela *et al.*, 2002). The interactions among various anthropogenic factors and between anthropogenic and natural variables make urban-rural gradients potentially complex (McDonnell and Pickett, 1990). For example, McDonnell and Pickett (1990) suggest that the study of urban-rural gradients provides a new context in which to integrate humans as critical components of ecological systems. As stated earlier, humans, after all, play the biggest part in altering the environment to suit their needs, usually above the needs of all other species, especially in urban environments. The use of gradients will be discussed in more detail in the Section 1.9.

1.6 Pressures of urban living

Anthropogenic habitats can provide the ideal habitat for non-native colonist plants (Odegaard and Tommeras, 2000), However, in many cases urbanization causes a decrease in native species richness along urban-rural gradients (Weller and Ganzhorn, 2004) as the non-native colonists are joining an already impoverished fauna, compared to more rural or ‘natural’ landscapes. Also, there is often little chance for native species to colonize the urban core if there are no ‘green’ corridors or patches nearby. Weller and Ganzhorn (2004) provide a useful summary of the causes of decreased species diversity with increasing urbanization. The main ones are:

- Heat island effect
- Increased air pollution
- Increased heavy metals
- Increased traffic levels
- Habitat fragmentation and isolation
- Soil compaction

However, some species, including natives ones, appear to thrive in urban settings and as a result, may be termed ‘synanthropic’.

1.7 Synanthropy

Synanthropy is usually applied to plants or animals that live in man-made habitats. Polovny (1971) defined synanthropic as being "*applied particularly to flies and certain rodents coexisting with man over an extended period. A search for the origin of this term certainly provided differing opinions as to its meaning, but for the present let it suffice that the term 'synanthropy' has had long usage in the European literature*." This rather unhelpful definition does at least highlight that there is no single definition of either the word or the concept of synanthropy.

Nuorteva (1963) said that synanthropy is suspected to be an indication of the ability of a species to utilize the living conditions created by man. In addition, he had three categories:

- obligate synanthropy (one mode of life or action in a man-made setting)
- facultative synanthropy (can live in different conditions: both human and 'natural' situations)
- synbovile synanthropy (can only live near cattle/cattle dung,)

Building on these ideas, Schnack and Mariluis (2004) and Maldonado and Centeno (2003), among others, split the definition into the following three categories, again in relation to sanitary entomology and disease transmission:

- asynanthropic, (not synanthropic, therefore cannot survive in a human modified landscape)
- hemisynanthropic (partly synanthropic, therefore can survive in a human modified landscape)
- eusynanthropic (wholly synanthropic, therefore only survives in a human modified landscape)

This lack of a clear definition of the term ‘synanthropic’ outside of disease transmission is apparent in the literature on invertebrates and plants studied in urban ecology. In the current study, the term synanthropy will be used to mean species of plants or animals that live in close association with man i.e. depend on man-made habitats and or resources to maintain successful populations. This is similar to the term ‘commensal’ which relates to one species that benefits from another without harming its ‘host’ (Allaby, 1998); the key difference is that synanthropy specifically relates specifically to humans as the primary source of resources.

1.8 Urban invertebrates

The study of urban species and urban invertebrates in particular, is still something of a minority occupation for most ecologists. However, ignoring this rich field of investigation is somewhat remiss given that in the developed world and in the UK in particular, the vast majority of people live in urban environments (Pointer, 2005) so are therefore most likely to have the majority of their encounters with “nature” in their home cities and towns, as noted earlier.

Invertebrates have been used in a wide range of sampling studies to determine various aspects of biodiversity.   Many of these studies have focussed on the negative effect of some invertebrates as agents of crop damage (Aebischer, 1990) or the positive effects which result when invertebrates are utilised as a means of pest control (Chiverton and Sotherton, 1991; Thomas *et al*., 1991; Collins *et al*, 1997). The bulk of these studies have been carried out in rural areas; relatively little attention has been paid to urban invertebrates. The exception to this is usually in relation to the “charismatic” insects such as butterflies and dragonflies, which are widely studied in both rural and urban locations in the UK. An exception to this is in the city of Rome which has been quite well studied with regard to its insect biodiversity since the second half of the 19th century. The insect fauna of the city has been split into four main groups: 1. autochthonous (native) 2. extinct 3. synanthropic and 4. introduced species (Zapparoli, 1997).

More recently, Davis (1982) categorised three branches of the study of urban invertebrates; annotated inventories (effectively just species' lists); autecological studies i.e. studies based on a single taxa or population; and, synecological studies that look at whole communities. The latter includes the human management of invertebrates. He advocates that an autecological approach provides valuable insight to causal relationships among species associated with man-made features, rather than eurytopic species or survivors in semi-natural habitats (Davis, 1982).

Davis (1979;1982) also used an urban gradient to show that species diversity does decline between the urban fringe and city centre (see also Kuhnelt, 1982) and suggested reasons for this. He posited that increasing disturbance, reduction of suitable habitat area and diversity and other urban-induced factors such as the heat-island effect may all play a part. For soil and litter arthropods, he recognized three main categories: common woodland and litter species not adapted to the more disturbed habitats; eurytopic or soil species often present in parks and gardens but with no special affinity for them; and, an assortment of soil and compost/litter species which appear to flourish in artificial habitats (i.e. often synanthropic species). He quotes Tischler (1973), saying that he has pointed out the increasing degree of synanthropy among arthropods from the south towards the north of Europe through an association with refuse heaps, where temperatures are artificially raised.

Eversham *et al*. (1996) looks at how some carabid species have adapted from semi-natural habitats to survive in man-made habitats, which are of comparatively recent origin. Most of these habitats however are not particularly urban, tending in fact to be spoil heaps etc, but they do recognize that some species are either partly or wholly synanthropic, without defining the term or levels of synanthropy.

Recently, Clark and Samways (1997) have observed that despite the important influence of human-dominated landscapes on biodiversity conservation, little is known about how to sample biodiversity in this setting and how to effectively manage the urban landscape to maximize biodiversity. Their study found an impressive 821 arthropod species in a single botanic garden in South Africa. They only studied two sites, which were only 25m apart, using four different trapping methods (malaise, sticky and pitfall traps and sweep net) to catch a wide range of fauna. One site was a highly managed 'lawn' area, whilst the other was a relatively neglected area which had been left fallow. Surprisingly perhaps, there was no significant difference in number of species between the two plots, despite their very different 3D structure, but they only shared 151 species. The data for the pitfall traps on their own showed that the fallow plot contained higher diversity for the majority of taxa found, apart from Coleoptera and Acarina which were more abundant on the lawn plot. As the two plots were very close together, but had very different management styles, this study shows that even very small spatial scales, along with management style, can have a noticeable effect on invertebrate communities. Hardy and Dennis (1999) also found that the scale of sampling i.e. the area covered, along with bias of recorder effort, can have a significant effect on what urban butterfly species richness is recorded. Thus sampling may be biased to more accessible areas or areas known to have rich diversity.

1.9 Species change linked to disturbance and ecological theory

Overall, due to the various additional pressures of urban living discussed above, one would expect to find the highest native species diversity and abundance in rural areas, and the lowest native species diversity and abundance in urban cores, with intermediate levels in the suburbs. Grime's (1977) key paper, which included among other things, the disturbance effects on plants defined it as the "*mechanisms which limit the plant biomass by causing its destruction*". He defined three primary strategies that enabled plants to survive these disturbed habitats: competitive, stress-tolerant and ruderal: referred to as the CSR model (Grime, 1977). These theories have been developed to cover fauna as well as flora and disturbance (e.g. Townsend and Scarsbrook, 1997; Bongers *et al*., 2009), at its broadest level, may alter the diversity within an ecosystem directly by killing individuals or indirectly by changing resource quality and accessibility (New, 2005). However, the effect will vary depending on the scale (both spatial and temporal) of the system studied e.g. individual to ecosystem and landscape, and the consequences and mechanisms of disturbance are different at each hierarchical level (Pickett *et al*., 1989 and refs therein). Thus, the effects of disturbance on any community, regardless of position along the urban-rural gradient, are more complex than any single theory can determine.

For example, Donald and Evans (2006) note that when examining habitat connectivity and restoration projects in agri-environment schemes, the effects of issues such as fragmentation of habitats (e.g. changes in species composition, population dynamics, breeding success and a range of ecological and ecosystem processes) would also have to be taken into account. It is probably because of this complexity that the benefits of some agri-environment schemes, despite the large amount of funding ploughed into them, appear to be limited regarding the actual benefits for biodiversity (Kleijn *et al*., 2006).

Our understanding of the potential threats of habitat fragmentation have been refined from the theories developed by MacArthur and Wilson (1967), which were originally used to explain patterns of species richness and turnover on oceanic islands (Donald and Evans, 2006). It was recognized that 'islands' need not mean islands of land surrounded by a sea of water; the theories could apply to any defined habitat at any geographical scale that is separated or 'isolated' from other similar patches e.g. woodlands surrounded by fields (or vice versa) or a mountain top (Begon *et al*., 1996). A comparison of the ground beetle communities in an American agri-environment scheme to clearly showed separating of species between potato crop fields and surrounding non-crop areas (Gaines and Gratton, 2010). They noted that whilst the beetle abundance in the non-crop areas was on average six times greater than the crop areas, the latter had a higher diversity index value (evenness) despite containing lower species richness. It was suggested this may be due to frequent agricultural disturbance preventing species from ever becoming too common in the potato fields resulting in relatively even (diverse) assemblages compared to non-crop habitats that become dominated by one or two species (Gaines and Gratton, 2010).

Svensson (2010) notes that "*the most prominent model on the effects of disturbance on diversity is the intermediate disturbance hypothesis (IDH)*". It states that species diversity is highest at intermediate levels of disturbance (Connell, 1978; Roxburgh *et al*., 2004), which may also help explain variation in species distribution. Habitats such as allotment sites may have similar levels of regular disturbance but the amount of disturbance e.g. traffic, trampling etc in the area surrounding the sites would be expected to be highest in the urban area, lowest in the rural area and intermediate in the suburban area. As a result, it would be likely that both the competitive and dispersal abilities of invertebrates would be affected differently across the urban-rural gradient (Roxburgh *et al.*, 2004). The IDH would suggest therefore the suburbs would have the highest diversity in relation to this theory.

The opportunistic species hypothesis (OSH) (Gray, 1989; Magura *et al*., 2004) states that at high levels of disturbance, opportunist species are predicted to gain dominance. This hypothesis would therefore suggest that areas such as gardens and allotments would be dominated by generalist species, irrespective of location along the urban-rural gradient.

Niemela *et al*. (2002) put the gradient/diversity issues proposed in an earlier paper by Niemela *et al.* (2000) to the test by studying carabid beetles in forest remnants along urban-rural gradients in three cities: Helsinki, Finland; Sofia, Bulgaria and Edmonton, Canada, as part of the GLOBENET project. This project aimed to assess whether carabid communities respond in similar ways to urbanization in different parts of the world (Niemela *et al*., 2000; Niemela *et al*., 2002). They found that urbanization has an effect on carabid communities, but the intensity of effects varied and the effects of gradient *per se* were not particularly strong. The Finnish fauna showed a marked separation among sites along the urban-rural gradient, with the urban, suburban and rural faunas forming clear clusters. However, eleven carabid species were common across the gradient, and two species, *Pterostichus melanarius* and *P. oblongopunctatus*, were collected in large numbers at one urban site and all the rural sites. In their study of forest carabids along an urban-rural gradient in Japan, Ishitani *et al*. (2003) found a similar result: the lowest number of individuals and species were found in urban areas.

1.10 Invertebrate sub-sampling

Due to several constraints e.g. time, money, expertise, all species in all habitats simply cannot be studied at the level to which scientists would like. This means that effort must be concentrated as efficiently as possible. For example, Danks (1996) suggests ways to undertake relatively rapid, cost-effective invertebrate surveys that could provide valuable information on the status of some ecosystems. He advocates very careful planning of objectives, level of detail, costs and personnel involved, as well as careful taxa selection (i.e. potential use of indicator species), study duration and sampling methods before the actual sampling begins, as some species surveys are much more labour and cost intensive than others. By suggesting such methods and indicators, he highlights that countries that are relatively resource-poor or studies that are very time-limited, can still be done, and can yield useful data. These data can then be used to manage sites more effectively for their biodiversity value. By also using gradients in these situations, areas can be targeted more effectively, as discussed above.

1.11 UK allotments

After more than half a century of neglect and decline, allotments are on the brink of a great revival (Foley, 2004). Although still partly a bastion for 'old men in flat caps' (Biggs, 2007), they are increasingly managed by young women keen to grow organic crops and professional couples seeking an escape from the daily grind (Buckingham, 2005; pers. obs.). They may even now be the last word in political correctness (Foley, 2007) as they show a commitment to a 'greener' way of life, whilst putting everyone on a equal social footing (Foley, 2004).

The UK government produced a report in 1998 which highlighted the need to retain and maintain allotment provision, which was under threat due to pressures of land-use for development purposes (DETRA, 1998). Under Local Agenda 21 objectives, which concerns sustainability in all aspects of life (UN, 2005), they are also starting to realize the importance of the wildlife value that allotments can have if managed appropriately (English Nature, 2006). Allotments derive from the enclosure legislation of the 18th and 19th centuries and the word "allotment" originates from land being allotted to an individual under an enclosure award (DETRA, 1998 and references therein). The Allotment Act of 1922 defines the term 'allotment' garden as "*an allotment not exceeding forty poles in extent which is wholly or mainly cultivated by the occupier for the production of vegetable or fruit crops for consumption by* *himself or his family"* (Crouch *et al*., 2001). *"Forty poles is equivalent to 1,210 square yards or 1,012 square metres. One pole equals 30$_{1/4}$ square yards; the terms 'rod'; 'pole' and 'perch' are interchangeable"* (Crouch *et al*., 2001).

The First World War (1914-1919) prompted a huge growth in the number of allotments, from 600,000 to 1,500,000, although after the war, many of the temporary allotment sites were returned to their original use (DETRA, 1998). During the Second World War (1939-1945), the 'Dig for Victory' campaign saw a huge increase in allotments, but again numbers declined after the war (DETRA, 1998). Today, allotments are still often associated in the UK with railways, because areas of land owned by the railway companies were not large enough for general agricultural use, but were often allotted to the railway workers (Gilbert, 1991; Crouch and Ward, 1997).

1.12 Allotments, farming practices and gardening

Cultivation of allotments is comparable, in some ways to farming i.e. regularly disturbed soil, addition of chemical fertilizers or manure and the planting and harvesting of crops. Thus, many of the studies done on agricultural invertebrates may have at least some relevance to studies involving allotment invertebrates.

In recent years, there has been a great increase in the popularity of organic farming, both on a commercial and an individual basis. This increase has been reflected in a number of invertebrate studies that compares species richness of and abundance in traditional versus organic farming (Pfiffner and Niggli, 1996; Andersen and Eltun, 2000; Shah *et al*., 2003). For example, Schmidt *et al*.

(2005) found that wolf spiders (*Pardosa* spp.) were more than twice as abundant on organically managed farmland compared to traditionally managed farmland. In addition, the creation of field margin refuges, hedgerow restoration and beetle banks around arable fields as part of wider agri-environment conservation schemes has been show to enhance the within-field activity-density of polyphagous predators (Donald and Evans, 2006; Griffiths *et al*., 2008).

Whether a field is managed traditionally or organically, one of the main factors that will affect beetle populations in particular is the timing of cultivation. The particular life history of a species will determine how detrimental the ploughing of a field will be (e.g. Noordhuis *et al*., 2001). For example, many beetle species are known as either spring or autumn breeders (Sotherton, 1984), which then determines what time of year they emerge from their larval stage. When spring-breeding beetle larvae are at their post-emergence stage, they will avoid high mortality as they emerge in the summer months, after ploughing (Purvis and Fadl, 2002). However, a very common beetle such as *Nebria brevicollis* is an autumn-breeding species, which overwinters in the soil at its larval stage. If the land is cultivated in late spring, then mortality is high (Purvis and Fadl, 2002). Similar parallels could be drawn, on a smaller scale, for allotment cultivation, as the plots tend to get dug over on a regular basis, especially in spring and autumn.

Managing an allotment also has many parallels with gardening in that the plot is tended by a single individual or family for the purpose of personal enjoyment. Like an allotment, gardeners may choose to use or not use pesticides and are likely to change what is grown linked to the seasons. However, the plot is more likely to be subject to higher levels of disturbance, given the key role of the plot is to grow food.

As concern has deepened over the ecological side effects and health risks posed by intensive, chemically dependent farming techniques (Howe and Wheeler, 1999), the increasing interest in urban food growing offers people opportunities to regain control over their food intake. Gardens and allotments also provide many opportunities for wildlife, although allotments are presumed to have greater potential than individual gardens due to their larger size (Marshall, 2009).

The above research on the wildlife effects of changing management practices for agriculture and 'domestic' biodiversity in relation to urban-rural gradients, the greater use of organic methods of food growing, and the rise in popularity of vegetable growing in gardens and allotments has shown that there are gaps in knowledge regarding the biodiversity aspects of these activities, particularly in urban areas. Whilst there is a growing demand for allotment sites, there is an increasing pressure on the land for other uses, usually building residential and business use. For example, 300 statutory allotment sites have been disposed of since 1996, whilst an estimated 500 temporary sites have been disposed of in the same period (Crouch, 2011). However, allotment holders value their sites and where sites are threatened, they may put up vigorous campaigns to save them (e.g. Bird, 2008). Whilst the human health benefits of allotments are reasonably well recognized, (van den Berg *et al*., 2010) there is little data on their wildlife value, which could, if assessed effectively, could provide added weigh to their retention. In addition, if the ecological roles of key species present could be determined and shown to have an overall positive role to play on the allotment, it may help plot-holders realize that the bulk of the species they regard as pests are in fact beneficial. Steps could then be taken to encourage more provision for wildlife on the allotment sites. However, assessing the biodiversity benefits that allotments could bring would require an interdisciplinary approach.

1.13 General aims

This thesis has two overarching aims:

1) To assess the demographics of allotment plot-holders and their attitudes to the wildlife on their plots by using a questionnaire approach;

2) To determine the composition of the epigeal invertebrate communities present on individual allotment plots in relation to their position along an urban-rural gradient and in relation to individual plot management styles.

The first section of the thesis will adopt a social science approach, which comprises an analysis of a questionnaire to explore the research question:

Q1: Are there variations in management style and attitudes to on site allotment wildlife in relation to age or gender of plot-holders?

Whilst the relatively rare existing studies on the benefits of allotment gardening tended to focus on the human health benefits (e.g. Crouch and Ward, 1997; Milligan *et al*., 2004; van den Berg *et al*., 2010; see Section 1.12), the data from this thesis will provide a relatively new aspect in that the focus is mainly on peoples' attitudes to the wildlife value of 'their' allotment sites and any influence this may have on how individuals manage their plots. As they will be used to determine on which allotment sites epigeal invertebrate sampling can be carried out, the allotment holders' responses will allow the necessary interdisciplinary link required to the next stage of the thesis i.e. ecological research.

The next three sections of the study will use an ecological science approach to establish which epigeal invertebrate communities are present on allotments in relation to their position along an urban-rural gradient and allotment management style. For the purposes of this thesis, a combination of land cover, population density and the amount of impermeable surfaces along with some site specific factors will be used to determine where sites are designated along the urban-suburban-rural gradient. The management style will be determined from the questionnaire responses.

The second research question to be addressed is:

Q2: What is the composition of the epigeal invertebrate communities on allotments and do they vary in relation to position along an urban-rural gradient and/or to individual plot management style?

From the data gathered, additional aspects of epigeal invertebrate diversity will be analyzed to assess the biodiversity value of allotments, potential levels of synanthropy and allotment community structure. These sections of the thesis will provide empirical data on the epigeal invertebrate communities present from a much under-studied habitat from an ecological point of view i.e. allotments (Gilbert, 1991), in relation to community ecology theory. As allotments have the potential to provide a rich resource of biodiversity, particularly in urban areas, exploring the ecological role of the epigeal invertebrate communities will provide a key link in the food web that can provide the starting point for further studies in this habitat. As noted by McIntyre (2000), there has been surprisingly little attention paid to the study of urban arthropods despite their key role in various ecosystem functioning services e.g. pollination, nutrient recycling and decomposition). Specifically, each following Chapter will achieve these aims and address the research questions by:

(1) Analyzing questionnaires to explore the demographics of Yorkshire allotment holders (Chapter 2);

(2) Examining the invertebrate species ordinal abundance and diversity of allotments along an urban-rural gradient, having first explored a number of environmental variables to help establish the urban-rural gradient (Chapter 3);

(3) Comparing traditionally managed and wildlife-friendly allotment plots with respect to their invertebrate biodiversity (Chapter 4);

(4) Determining the species present of three representative Orders across the urban-rural gradient and test for conformity to the opportunistic species hypothesis and levels of disturbance (Chapter 5);

(5) Discussing the findings of the previous Chapters in relation to the biodiversity value of allotments and how this could be enhanced (Chapter 6).

(6) Conclusions of the main findings of this thesis (Chapter 7).

CHAPTER 2: THE VALUE OF ALLOTMENTS

2.0 INTRODUCTION

2.1 Popularity and use of allotments

As discussed in Chapter 1, allotments have had a long and chequered history. However, with the pressures of development, allotments can often occupy prime urban land. This reflects their history of social stability that spans the political and economic transformations of the past two centuries (Bellows, 2004). Interest in allotments has increased substantially in the past few years although the level of provision varies widely across the country (SAGS, 2007). Currently there are around 300,000 allotment plots in England and 6,300 plots in Scotland, some with long waiting lists (Lawton, 2007; SAGS, 2007; Barclay, 2010). Figures for Wales and Northern Ireland are not collated on a country-wide basis so comparisons cannot be made.

Allotments are a unique and little-studied habitat from a wildlife point of view, but do form a key part of many people's lives in the UK. Their uniqueness stems from the fact that they are not owned by individuals, merely rented. They also form a collective of 'hobby gardening' with a clear set of rules laid down for their management. The health benefits, such as exercise, social interaction and the production of "healthy" food, are increasingly being recognized (Crouch and Ward, 1997) along with the many other positive aspects that "owning" and managing an allotment can bring. One of these other benefits is being a member of a particular sub-set of the community i.e. those engaged in vegetable growing on an allotment site, which can be evidenced by the lively discussion and willingness to help others that any internet search for allotment fora will attest. Although there may be varying levels of participation and inclusion in this community group, there is a degree of ‘belonging’ and recognition of other members, similar to that of any other recreation or hobby. The social interaction on the allotment site can play a key part in some peoples’ lives and can even have the effect of dramatically changing peoples’ lives (pers. obs.).

Any research about allotment wildlife must first start therefore with the allotment plot-holders. Professor Harry Thorpe was the ‘champion of allotments’ and provided detailed information on the status of allotments through a range of reports (Thorpe, 1969) and case studies (Thorpe 1975; Thorpe *et al.,* 1976, 1977;). When giving a lecture in 1979, he suggested that allotments could be used for the teaching of ecology, but it would appear that they have largely been ignored by ecologists (Gilbert, 1991). When the current study commenced, urban ecology and allotment ecology in particular, were not important issues for the two key conservation agencies in England, English Nature (which became Natural England in 2006) and DEFRA. However, the former organization was persuaded by the author to hold a full day meeting on urban ecology, with a days’ workshop on allotments (run by the author), at one of their annual conference series in 2006. From that, wider interest in allotment wildlife and community wildlife projects on allotments in particular were generated (pers. obs.). In addition, English Nature went on to produce a booklet on wildlife allotments, with input from the author of the current study (English Nature, 2006).

One of the few studies that have included a small section on allotment wildlife was done by Marshall (2009). He used a questionnaire-based survey to assess garden and allotment biodiversity, along with attitudes to it in Buckinghamshire, UK. He found that, among other things, having direct contact with plants and wild animals in either a garden or allotment helped foster a wider interest in nature. Thus, allotments, because they typically represent a cross-section of a community, can offer an ideal opportunity to engage people on an individual or community level and allow them to take a greater interest in their local wildlife.

2.2 Aims of this Chapter

Research Q1: Are there variations in management style and attitudes to on site allotment wildlife in relation to age or gender of plot-holders?

The broader aims of this section of the study were to involve allotment holders in a survey to explore a broad range of topics related to allotments and their use within the study area. For example, the study assessed the demographics of plot-holders, their perceptions and attitudes to a number of aspects of their allotment. It also explored the level to which individual allotment holders were sufficiently interested in the biodiversity value of allotments to allow further study on their plots. Through the use of a postal questionnaire it was hoped that the attitudes and approaches to methods of allotment gardening e.g. organic, traditional, along with attitudes to the value of wildlife that the plots contained could be assessed.

It was also hoped that the quantitative information supplied would help identify demographics to test traditionally held beliefs that allotments were only for ‘old men in flat caps’, against growing evidence of an increasing trend for younger people of both sexes were taking up allotment gardening. This would be done by analysing the questions on age, gender, plot management style and attitudes to the value of wildlife.

2.2.1. Plot-holder demography and management styles

Specifically therefore, the objectives of this section of the thesis were to address the research question above by determining the responses to each individual question and use these to:

Objective 2.1 assess the demography of plot-holders by examining the gender and age profiles, then relate these to allotment husbandry style. The hypotheses tested were that there would be no gender or age bias to allotment plot ownership, nor to husbandry style;

Objective 2.2 determine the distance to plots from home. The hypothesis tested was that there would be no difference in the distance to the plot i.e. in all cases allotment holders would travel similar distances to access their plots (and an assumption would be made that these distances would be relatively short).

Objective 2.3 explore the length of ownership of their plots. The hypothesis tested was that there would be no difference in the amount of time the plots had been managed across the range of sample allotment sites;

Objective 2.4 determine information on how much of the plots were actually cultivated. The hypothesis being tested was that the same amount of the plot would be cultivated by all respondents;

Objective 2.5 determine how often plot-holders visited their plot. The hypothesis tested was there would be an even spread of responses and everyone would visit on a similar regular basis;

Objective 2.6 explore the knowledge base of plot-holders by examining how they learnt the techniques required to manage an allotment. The hypothesis being tested was that the plot-holders would have learnt allotment gardening skill from the same methods;

Objective 2.7 determine the main use of the plots. The hypothesis tested was that plot-holders would use their plots for the same types of activity;

Objective 2.8 determine the key reasons why people had a plot. Due to the scale of measurement used, this section was based on purely qualitative data;

Objective 2.9 determine their attitude to the wildlife on the site. The hypotheses tested were that plot-holders would place the same value on wildlife, regardless of gender or regardless of age.

Objective 2.10 explore management (husbandry) styles and assess what proportion of plot-holders managed their plots in a 'traditional' way or an organic/wildlife-friendly way. The hypothesis tested was that there would be an even spread of management styles;

Objective 2.11 if used, type and frequency of pesticide use. The hypotheses tested were that there would be an even spread of responses i.e. everyone would use similar types and application frequency of chemicals;

Objective 2.12 determine how many people would allow sampling to be undertaken on their plot;

Objective 2.13 explore the range of responses to an 'open' question, which encouraged general comments on allotments;

Objective 2.14 use Principle Components Analysis to explore the spread of the data and identify any trends or key determining factors that differentiated different groups of plot-holders. The hypothesis tested was that there would be an even spread of responses.

2.2.2 Determination of invertebrate sampling sites

Based upon analysis of the questionnaire, it was hoped that suitable sites for invertebrate sampling by pitfall trapping would then be identified. The work on invertebrate biodiversity is the subject of the remaining Chapters of this thesis. Therefore, after analysis of the questionnaire, the next step was to identify suitable sites for invertebrate sampling by pitfall trapping, carried out on the individual allotments.

This would be achieved by:

- assessing the number of questionnaire responses from each town, village or city and choosing sites with a sufficiently high number of responses to allow a suitable number of plots per allotment site to be surveyed;

- balancing responses to provide a mix of traditionally and wildlife-friendly managed plots;
- choosing a range of sites that would, using a common sense approach, represent an urban-suburban-rural gradient.

The two specific objectives of this section of the Chapter were to:

Objective 2.15 determine if plot-holders would agree to further, non-intrusive survey on their individual plots, then relate this to age and gender. The hypotheses tested were that there would be no difference in either age or gender.

Objective 2.16 determine sample sites for pitfall trapping epigeal invertebrates.

2.3 METHODS

2.4 Allotment questionnaire

A questionnaire was used as the first point of contact with plot holders to explore attitudes to allotment management styles and the importance of wildlife on the sites to individuals (see Figure 2.1). It cannot be stressed strongly enough that, as each plot on each site was managed by a different individual, great care and sensitivity was needed to approach them to try and ensure their co-operation and participation. It was also important to reassure all subsequent participants in the sampling stages that no damage would be done to their plot nor would there be any disruption to their planting schedule.

The questionnaire was also used to establish which plots could be sampled to assess their invertebrate abundance and diversity. In line with good practice (e.g. Coolican, 2004), a draft version was trialled on colleagues within Hull City Council and amendments made in order to try and make it as ‘user-friendly’ as possible. The questionnaire consisted mainly of fixed questions, with a smaller number of open-ended ones to allow respondents the opportunity to provide fuller information on a wider range of topics.

Ref: HU

Allotments Questionnaire

Name……………………………… Allotment site name…………………..Plot No…..

Address……………………………………………………………… Tel ……………………

Q1 What size is your allotment? (If you have more than one, please give dimensions of each one.)

[m] X [m] or [ft] X [ft]

Q2 How long have you had your plot(s)?

< 1 year ☐ 1-3 years ☐ 3-8 years ☐ > 8 years ☐

Q3 What is the main use of your plot(s)?

Growing vegetables ☐ Mix of veg and flowers ☐

Growing flowers ☐ Wildlife garden ☐

Other (please specify) [ ]

Q4 How much of your plot is actively used?

All of it ☐ About 2/3rds ☐

About half ☐ less than half ☐

Q5 How do you manage your plot?

Traditional ☐ Organic ☐

Wildlife-friendly ☐ Organic & Wildlife-friendly ☐

Q6 Do you use any pesticides on your plot?

Yes ☐ Go to Q7 No ☐ Go to Q9

Q7 Which types of pesticide do you use? (Tick all that apply)

Slug pellets ☐ Pest killer ☐

Weed killer ☐ Fungicide ☐

Other (please specify) [ ]

Q8 How often do you usually use pesticides?

At least monthly ☐ About 4 times a year ☐

About twice a year ☐ Once a year ☐

Figure 2.1a Yorkshire allotment practices and attitudes questionnaire showing questions 1-8 (side one).

Q9 Please rank your main reasons for having an allotment (1 = most important, 7 = least important).

Enjoy growing veg/flowers ☐ Better tasting food ☐

Social contact ☐ Economic ☐

Enjoy being outdoors ☐ Peace and quiet ☐

Other (please specify) ☐

Q10 How often do you visit your plot?

At least daily ☐ 4-5 times a week ☐

2-3 times a week ☐ Once a week ☐

Once a fortnight ☐ Less often (please specify)……………………

Q11 How did you learn the techniques needed to manage an allotment?

From family ☐ From friends ☐

From other plot holders ☐ Self taught ☐

Q12 How important is the wildlife on the site to you?

Very important ☐ Important ☐

Neutral ☐ Not important ☐

Q13 Would you be willing to participate in some small-scale surveying on your plot? (This would not involve any invasive sampling or damage to crops.)

Yes ☐ No ☐

Q14 Please use this box to add any comments you think may be useful.

☐

Thank you very much for your help

This information will form part of my research at the University of Hull, looking at the wildlife value of allotment sites. It is hoped this data will help ensure the continued provision of allotment sites in Yorkshire and provide management guidelines to enhance their value.

Data Protection: the information you have provided will only be used to build up a better picture of allotment use. Your personal details will not be passed on to anyone else. <u>If you are willing to participate in further survey work, please ensure you have filled in your contact details at the top of the page overleaf.</u>

Figure 2.1b Yorkshire allotment practices and attitudes questionnaire showing questions 9-14 (side two).

QA How far to you have to go from home to get to your plot?

Less than ¼ mile	☐	Less than ½ mile	☐
Less than 1 mile	☐	1-3 miles	☐
More than 3 miles	☐		

QB What age group are you in?

Under 21	☐	21- 30	☐
31 – 40	☐	41- 50	☐
51-60	☐	Over 60 years	☐

QC Are you…?

Male	☐	Female	☐

Figure 2.1c Supplementary A5 sheet of allotment practices and attitudes questionnaire showing questions A-C.

As there were data protection issues regarding personal information, the questionnaires were sent out via various local and parish council officers (see Table 2.1). As a result, the questionnaire was sent out in January 2006 to all of the council-owned allotment holders in Hull (*c*. 1,000 people[1]), the East Riding of Yorkshire Council area (73 people), to holders of Driffield Town Council owned sites (113 people) and the nine plot-holders at Hunmanby, managed by Hunmanby Parish Council. Although outwith the scope of the other components of the wider project, questionnaires were also sent to Withernsea Allotment Association (70 people). Private allotment sites were not targeted as it was thought that there were a sufficient number of sites on council-owned land and that access would be easier to negotiate with a few local councils rather than with lots of individual private owners. Council-owned sites were also more likely to be statutory sites, therefore under less threat from imminent

1 Due to data protection issues, the questionnaire for Hull was sent out via Hull City Council's Allotment Officer. The officer tried to eliminate duplicates where plot-holders had more that one plot, hence exact numbers sent out cannot be given. Similarly, the Driffield questionnaires were sent out via the Town Council, so exact numbers cannot be given.

development. As personal information was being provided, ethical approval was obtained from the relevant university committee to comply with the data protection act procedures.

Table 2.1 Summary of number and location of questionnaires sent out

Town/City	Site Code	No. sent	Distribution Body	No.of Allotment Sites
Hunmanby	HN	11	Parish Council	1
Bridlington	BR	56	East Riding of Yorkshire Council	6
Driffield	DR	125	Driffield Town Council	3
Beverley	BV	17	East Riding of Yorkshire Council	3
Cottingham	CT	9	East Riding of Yorkshire Council	2
Hull	HU	1000	Hull City Council	22
Withernsea	WN	72	Withernsea Allotment Association	1
Total		1290		38

There was a mixture of question types; some were categorical (Q2-Q8, Q10-Q13, QA, B & C.), others were measured variables (Q1, Q9) whilst one was open (Q14). Although not stated, most questions required only one option to be ticked, as is common practice in questionnaire design (Bryman, 2008). Some questions had a mixture of both categorical option and also allowed respondents to make a statement. Two questions did encourage more than one option to be chosen. This range of question types allowed the respondents to provide richer, fuller information, without ambiguity as to their meaning (Coolican, 2004.)

Participants answering 'yes' to Question 13 ("*Would you be willing to participate in some small-scale surveying on your plot?*") allowed those plot-holders to be approached in order to gain permission to access their plots to conduct pitfall trapping (see Chapter 3, Section 3.7.1). Questions 6-8, which were about pesticide use, along with Q12, which explored attitudes to wildlife, allowed judgement to be made on the plot-holders' approach to husbandry styles. From this, a balanced choice of traditionally and wildlife-friendly managed plots could be selected for invertebrate sampling, as detailed in subsequent Chapters.

It is standard good practice to keep a questionnaire as short as possible (Childers and Ferrell, 1979). Thus, to try and encourage a good return rate, the number of questions asked was limited to two sides of A4 for the allotment questions, along with a separate A5 section with personal questions about the individuals, as was shown in Figure 2.1. Using coloured paper also helps to encourage a greater response rate (Edwards *et al*., 2002), therefore to convey the 'green' thinking behind the project, green paper was used, along with some outline drawings of plants and animals, as suggested by Kimball (1961), to make the questionnaire appear less formal. As the author worked for, and was supported by, Hull City Council at that time, *Freepost* envelopes were provided and sent out with the questionnaires, as research suggests that people would be more encouraged to return them than they would were they required to pay for postage themselves (e.g. Harrison *et al.,* 2002).

The questionnaires were sent out in January and February 2006, with an accompanying letter explaining the reason for the survey. The letter stated that the research was being carried out by the University of Hull. Research suggests that questionnaires originating from universities were more likely to be returned than questionnaires from other sources e.g. commercial organizations (Edwards *et al.,* 2002). In addition, the letter explained why the research was being carried out and mentioned that this work may help to ensure that quality greenspaces (such as allotments) remain protected from unwanted development. It was hoped that this provided an added incentive for people to reply, as ultimately, this work may have helped them by demonstrating the high value that they put on their allotments, along with its intrinsic wildlife value. Unlike many psychology or medical questionnaires (e.g. Meadows *et al*., 2000), the use of follow-up reminders was not used in this study to boost return rates, due partly to time and cost implications.

2.5 Study sites

It was envisaged that the sample sites would form an urban-rural gradient, following the South-North line of the Hull-Scarborough branch railway line (Figure 2.2). Permission was obtained from the various local and parish councils at the outset, to gain access to the allotment sites. Explorer 1:25,000 scale maps (301, 295 & 293) were used to assess the amount of greenspace, farmland and hard-standing surrounding each allotment site.

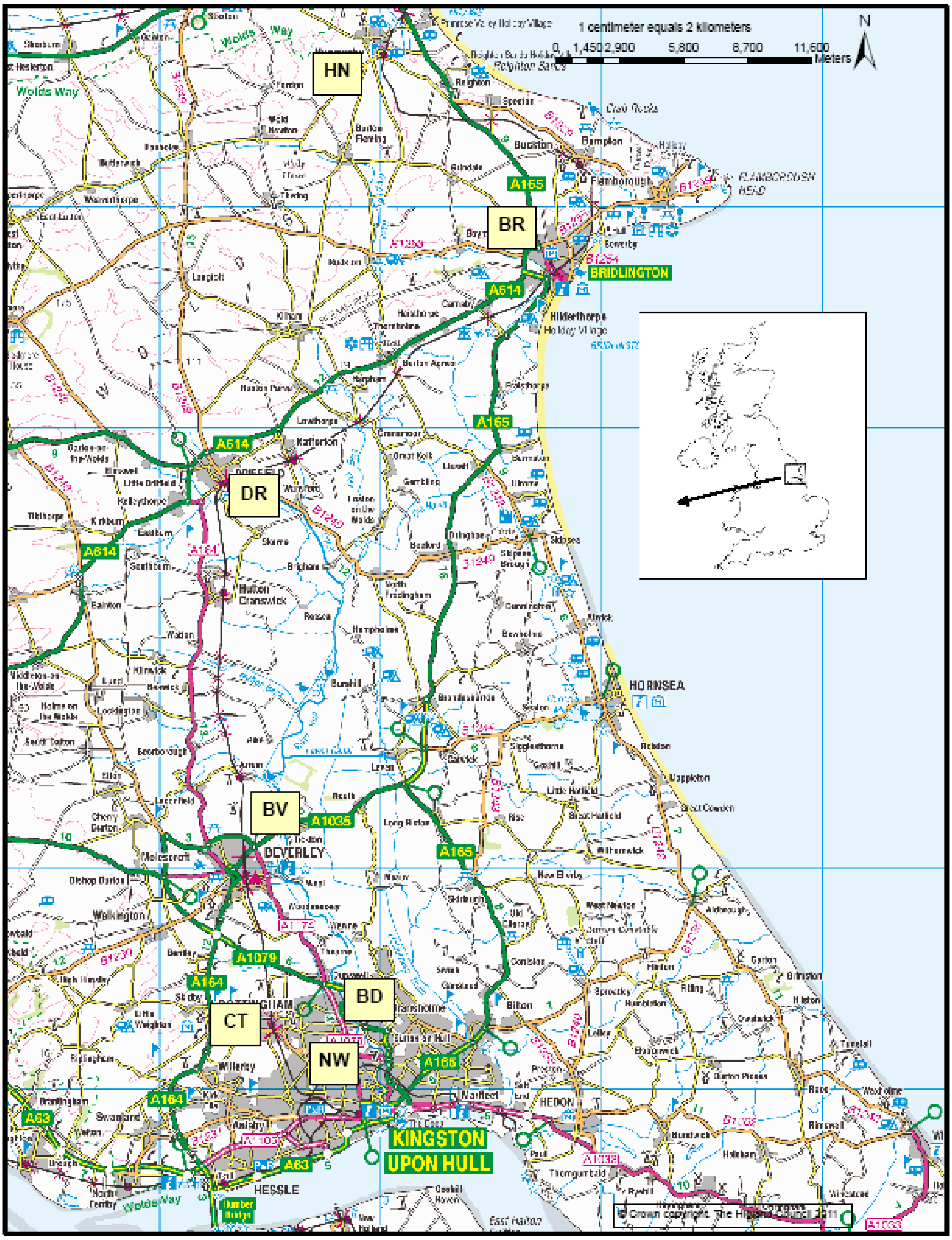


Figure 2.2 Map showing the seven allotment sampling sites in Yorkshire, England. (HN = Hunmanby; BR = Bridlington; DR = Driffield; BV = Beverley; CT = Cottingham; BD = Bude; NW = Newland)

Hull has twenty-two council-run allotment sites across the city, with around 1,800 plots, average size 250 m^2, managed by Hull City Council. One officer within the Council was the allocated allotments' officer, albeit as only part of their overall role. This meant that obtaining background information, access and contacts was relatively straightforward. Some of these Hull sites were part of larger greenspace local network of Sites of Nature Conservation Interest (SNCIs). They were also part of the Local Biodiversity Action Plan process, under the Gardens and Allotments Habitat Action Plan (HAP) for Hull (Marshall, 2002). The allotments lie within an area of glacial deposits on the Humber estuary (Pethick, 1984), therefore providing relatively rich, productive soils.

The Cottingham, Beverley and Bridlington sites were in the local authority area, and managed by, the East Riding of Yorkshire Council. The Driffield site was also in this local authority area but was managed by Driffield Town Council. At the time of sending out the questionnaires, the local authority had no dedicated allotments' officer and therefore obtaining background information was rather difficult. However, they were able to supply basic maps of each site used in the invertebrate sampling discussed in Chapters 3-5. Most of the land around these allotment sites was unallocated 'white' land, as per the various local plans (available on the Local Authorities' websites), as was the Hunmanby site. The latter site came under the jurisdiction of Scarborough Borough Council, but was managed by Hunmanby Parish Council. However, little information was available on the history of the site and no maps were available.

2.6 Statistical analysis

The questionnaire data were collated in Microsoft Excel and filters used to sub-divide site the data, as appropriate (Objectives 2.1-2.13, 2.15-2.16). These data were initially analysed to provide descriptive information on the number and percentage of each group of responses. These data were then analyzed using non-parametric and parametric tests: G-test, PCA, DECORANA and one and two-way ANOVA where appropriate (further detail given below). The questions were first summarized individually per response, followed by a range of multivariate methods to assess any trends arising from social demographics, site or allotment management style i.e. either traditional or wildlife-friendly husbandry of the plots.

In some cases, only a few questions had not been answered and were therefore not included in the relevant part(s) of the analysis, thus the response rate number will not be the same in all cases.

The responses to the questions were pooled by site. To analyze the frequencies of response options to individual questions, a G-test, with a Williams' correction (G_{adj}), was appropriate. It has some mathematical advantages over the chi-squared test and makes similar assumptions about the data (Fowler and Cohen, 1990). Thus, the G-test examines any difference between the *observed* frequencies with respect to a particular question in relation to the *expected* response frequency and provides a log-likelihood ratio goodness of fit (van der Maarel *et al*., 1995).

To test the hypotheses that men and women, regardless of age, managed their plots in similar ways ANOVA tests were used. Thus, the data regarding age and gender (independent variables) where analyzed using both one-way and two-way ANOVA with a number of the other responses to examine any differences in husbandry styles or attitudes to the value of wildlife on the sites (dependent variables). Where significant differences were found, Tukey tests were used *a posteriori* to identify the source of the significance, where there were three groups or more in the data (Ennos, 2007). First these data on age and gender were screened for any skew or kurtosis issues that may have biased the analyses. However, although the males outnumbered the females by approximately 3:1 and less than 3% of the responses were from people aged 30 or under, the samples were sufficiently large that that any such effects would be minimal (Tabachnick and Fidel, 2007).

To further explore the reasons for any variation in the responses and test the hypotheses that plot-holders would manage their plots in similar ways regardless of age, gender, geographic location etc. (i.e. an even spread of responses) a Principal Component Analysis (PCA) was then used (Objective 2.14). Thus, to asses the overall spread of the data, they were split by management style and site to explore any differences using PCA. Thus, all those that responded to the question “How do you manage you plot?” with *only* the answer “traditional” were split from those that responded as either “organic, wildlife-friendly or organic and wildlife-friendly.” Those that ticked the ‘traditional’ and any other option were excluded from this section of the analysis to provide a clearer picture between ‘conventional’ and organic/wildlife-friendly management practices and attitudes. Sites with less than four responses were not used in the PCA analysis as the number of cases to variables ratio was too small (Tabachnick and Fidel, 2007). Where a site name had not been provided (N=40), these responses were also excluded from the analysis. The data were log e (x + 1) transformed to account for the high dominance of some responses and the initial matrix was based on Euclidean distance (Clarke and Warwick, 2001; Henderson and Seaby, 2008).

To explore any relationship of the questionnaire responses to declared management style, a DECORANA was used to obtain an ordination of both the samples and the gradient (Henderson and Seaby, 2008). Finally, one-way ANOVAs were used to test management style responses to self-declared management style.

2.7 RESULTS

2.8 Questionnaire response rates

A total of 538 questionnaires were returned, which was a return rate of over 41% (Tables 2.2 & 2.3). This high response rate is on a par with other some other allotment questionnaire studies (e.g. Merton City Council, 2007: 43%) and better than others (e.g. Inglis, 2008: 36%). As key aims were to assess the demographics of plot-holders and capture their attitudes and perceptions to wildlife, the actual percentage of responses was not as important as the encouragingly high volume of responses, which allowed both assessments of trends to be made and the invertebrate sampling to take place. However, the Bridlington response rate was considerably lower (<20%). This may be for many reasons, but a key one may be that people from Bridlington were less willing to contribute information to a survey which may have appeared to be more biased towards Hull. (Bridlington is in a different local authority area to Hull.) This perception may have arisen due to the use of Hull City Council pre-paid return envelopes and the covering letter stating the work was part of the University of Hull's research, along with the fact that the researcher actually worked for Hull City Council, as also stated in the covering letter.

Encouragingly, there appeared to be virtually no 'spoilt' questionnaires; respondents appeared to be genuinely happy to complete them honestly. Thus, postal questionnaires were useful in that the respondents could complete them in the privacy of their own home, at their own pace, in their own words, without feeling pressured by an interviewer to 'say the right thing' (Bryman, 2008).

Table 2.2 Percentage of returned allotment questionnaires

Site	No. sent	No. replies	% replies
Hunmanby	9	4*	44.44
Bridlington	56	11	19.64
Driffield	125	41	32.80
Beverley	23	15*	65.22
Cottingham	9	5*	55.56
Hull	1000	432*	43.20
Withernsea	74	30	40.54
Total	1296	538	41.51

* includes people with more than one plot.

Table 2.3 Number of questionnaires returned per Yorkshire allotment site. (N/R = no allotment site name given.)

Site	Site Code	No. responses
N/R	100	40
Albert Cottage	1	39
Allotment Lane	2	30
Bacon Garth	3	4
Bilton Grove	4	6
Bude Rd.	5	28
Calvert Rd.	6	18
Clough Rd.	7	11
County Rd.	8	20
Field St.	9	1
Gipsyville	10	21
Hunmanby	11	4
Keldgate	12	11
Lamorna Ave.	13	32
Leads Rd.	14	30
Mappleton Grove	15	14
Marfleet Lane	16	2
National Ave.	17	20
Newland	18	57
Noddle Hill	19	2
North Bar Without	20	4
Oak Rd.	21	17
Perth St.	22	33
Pickering Rd.	23	28
Portabello St.	24	3
Queensgate	25	11
Richmond St.	26	18
Wansbeck Rd.	27	4
Withernsea	28	30
TOTALS		538

2.9 Individual question results' overview

Below, the results of each question are given. The figures and percentage responses were based on the number of actual responses to each individual question; percentages rounded to two decimal places. A discussion of each result will be followed by a graph showing the percentage of responses to each question option. In addition, the cumulative percentage will also be shown on the graph, where appropriate. Appendices A2.1 - A2.15 show a more detailed breakdown of these results by individual allotment site.

In some questions, respondents may have ticked more than one option e.g. some allotment holders may have said that they managed their plots in a traditional and organic way or that the plot was managed by a husband and wife team, therefore the total number of replies may be greater than the total number of actual questionnaires returned. The first three questions shown in Sections 2.10.1 – 2.10.4 were on a separate A5 sheet, stapled to the back of the main sheet (as shown in the Methods section, Figure 2.1c) and were about the plot-holders themselves.

The responses were grouped by theme and did not necessarily follow the same order as the questionnaire. The original questionnaire number is given in the heading of the subsequent discussion to allow for reference back to Figure 2.1 in the Methods section if required.

2.9.1 Questions not used in statistical analysis

On many sites, allotment plots are of a standard size (250-300m^2), therefore this may be the reason that many people did not complete question 1 which asked about plot size. Others stated that they did not know or were unsure of the size. For these reasons, this question was not used in any further analysis.

Question 9 asked participants to rank their responses. However, many did not, therefore this question will be dealt with separately to the rest (in Section 2.10.10) and will not be included in the various statistical analyses that follows. As question 14 was an open question that invited any comments that the plot-holders thought they should add, this will be discussed separately (in Section 2.10.17) and again will not be used in any statistical analysis.

2.10 Individual question responses

2.10.1 Gender (Question C: A5 supplementary questionnaire sheet)

A highly significant proportion (73.25%) of allotment holders were men, with only 26.75% women ($G_{adj} = 124.05$, $p < 0.01$). However, although the sample size for the non-Hull sites was small, women formed a much smaller percentage of plot-holders (c.19%) than the Hull sites (c. 29%), although this was not statistically significant [$F_{(1,26)} = 0.05$, $p = 0.827$] (see Appendix A2.1).

2.10.2 Age (Question B: A5 supplementary questionnaire sheet)

To test the hypothesis that plot-holders would be dispersed evenly across all age groups, a G-test with a Williams' correction was performed. The test does show that half of the respondents were over 60 years old (Figure 2.3). It may have been expected to have a high number of this age group managing allotments, but, conversely, it also showed that half the people using them were under sixty ($G_{adj} = 546.95$, $p < 0.01$). The second highest group of allotment users were in the 51-50 bracket, but a further 27% were aged between 21 and 50.

Of the Hull sites with more than 30 replies, Perth Street and Newland allotments had a greater spread of age ranges in comparison to other sites (see Appendix A2.2). In contrast, at Lamorna Avenue, over 70% of plot-holders were over sixty.

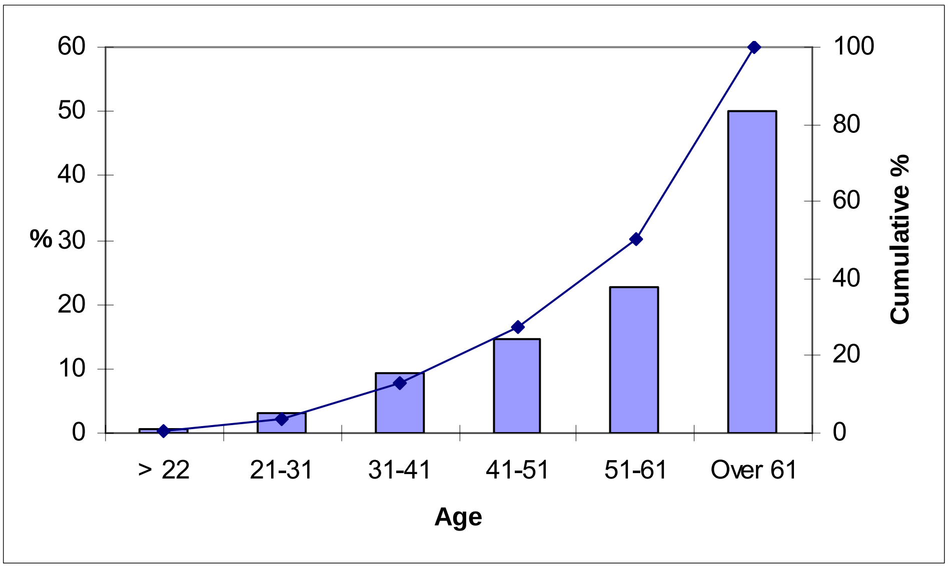


Figure 2.3 Percentage (bars) and cumulative percentage (line) of 528 responses to the question "What age group are you in?"

2.10.3 Age and gender correlations in relation to management style, further survey and perceived wildlife value (Objective 2.1)

The data regarding age and gender were analyzed to examine any differences in husbandry styles. Thus, to test any difference between age and gender in relation to management style (see Figure 2.12), a two-way between groups analysis of variance was conducted to compare the proportion of plot-holders who mange their sites in a wildlife-friendly way with the proportion managing them in a traditional way. Responses were grouped into three age groups (30 and under; 31-60; over 60), based on the number of responses in each group. There was a statistically significant main effect for age [$F_{(2, 450)} = 10.56$, $p < 0.001$); the effect size was relatively large (partial eta squared = 0.45) (Tabachnick and Fidel, 2007). *Post hoc* comparisons (Tukey HSD test, $p < 0.05$) indicated that the mean score for the under 30 age group (mean = 1.77 sd = 0.439) and the 31-60 age group (mean= 1.56, sd = 0.498) were significantly different from the over 60 age group (mean = 1.30, sd = 0.457). Thus, the over sixties were more likely to manage their plots in a traditional way, whilst the under sixties were more likely to manage their plots in a wildlife-friendly way. The main effect for gender [$F_{(1, 450)}$ = 2.53, p= 0.11] and the interaction effect of age [$F_{(2, 450)}$ = 0.33, p = 0.717] did not reach statistical significance; thus there was no significant difference in management style between males and females, linked to age.

The same procedure as above was repeated for age, gender and willingness to allow sampling on the plot-holders individual plots (see Section 2.10.16). However, in this case there were no significant differences between the age groups or gender [$F_{(2, 422)}$ = 0.25; p = 0.781) (Objective 2.15) suggesting that all categories of allotment-holder were equally receptive to the idea of making a contribution to this project.

Similarly, to examine any differences in gender and perceived value of the wildlife on their site (see Figure 2.11), a one-way ANOVA showed that there were no significant differences [$F_{(1, 426)}$ = 1.04, p = 0.308]. There were also no significant differences between age groups and the perceived importance of wildlife [$F_{(2, 425)}$ = 2.82, p = 0.061].

In summary, these results show that the hypotheses that there would be no significant difference in gender or age in relation to allowing further sampling on their plots and to the perceived value of wildlife are all upheld i.e. there are no differences in responses to these questions in relation to gender or age. There is however a significant difference in management style of plots depending on the age of the plot-holder, regardless of gender. Thus, the over sixties, were more likely to manage their plots in a traditional way and the under sixties in a wildlife-friendly way.

2.10.4 Distance travelled to plot (Question A: A5 supplementary questionnaire sheet) (Objective 2.2)

The highest percentage of people lived within a quarter of a mile from their plot, whilst nearly 70% of respondents lived less than a mile from their plot (G_{adj} = 132.93, $p < 0.01$; Figure 2.4). Therefore, the hypothesis that people would live a similar distance from their plot, was not upheld. This was probably unsurprising as an important factor for maintaining an allotment is regular attendance, which is made easier by ease of access. Some of the plot-holders in this study had their plot immediately at the bottom of their garden, as many sites were surrounded by houses, especially in the city and larger towns. At the other end of the scale, only 5% lived more than three miles away.

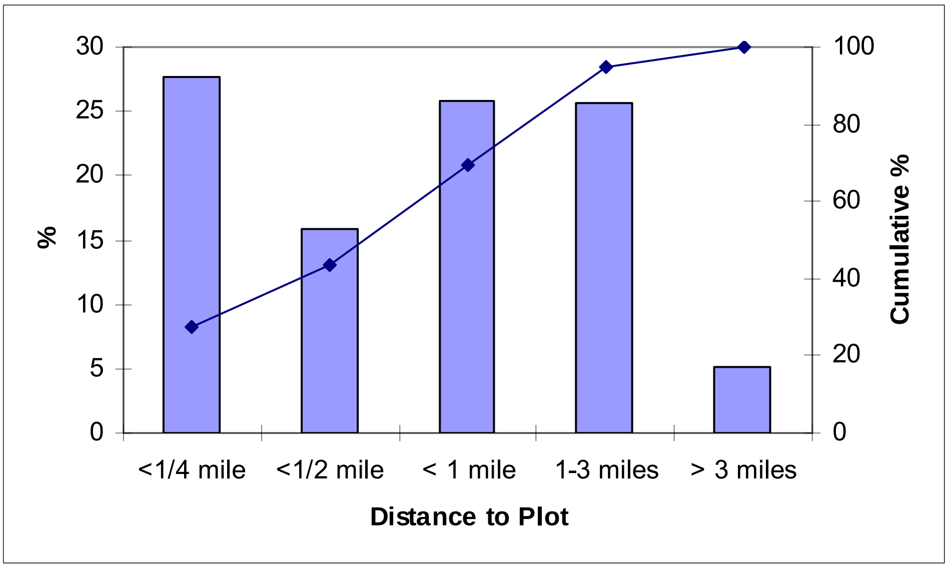


Figure 2.4 Percentage (bars) and cumulative percentage (line) of 528 responses to the question "How far do you have to go from home to get to your plot?"

2.10.5 Length of plot ownership (Question 2) (Objective 2.3)

To test the hypothesis that plot-holders would have had their plot for a similar amount of time, a G-test with a Williams' correction was performed. It demonstrated that a significantly greater proportion of plot-holders had been working their plot for over eight years (G_{adj} = 61.48, $p < 0.01$; Figure 2.5), therefore the null hypothesis was rejected. Although the question asked the time categories shown in the figure below (i.e. less than one year to over eight years) a number of respondents added that they had worked their allotment for over 30 years and one case that he had worked his plot for over 50 years.

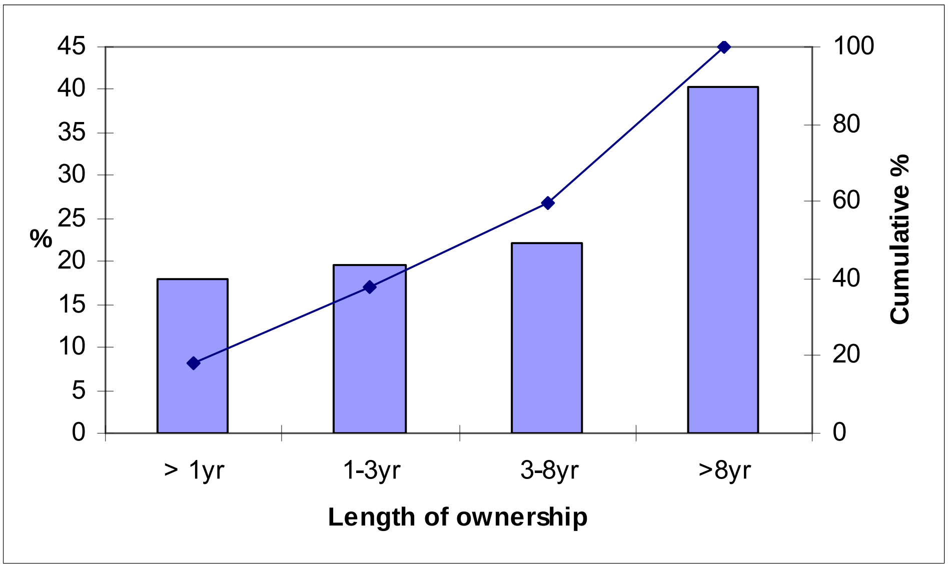


Figure 2.5 Percentage (bars) and cumulative percentage (line) of 532 responses to the question "How long have you had your plot(s)?"

2.10.6 Amount of plot actively used (Question 4) (Objective 2.4)

Again, a G-test with Williams correction to compare the proportion of individual plot use showed a significant majority (G_{adj} = 663.92, $p < 0.01$; Figure 2.6) of the respondents stated that their entire plot was actively used, whilst only two people did not respond to this question at all. Only around 4% said that that they used less than half and 5% about half of their plot, whilst nearly 15% said that they used around two thirds of their plot, therefore the null hypothesis was rejected.

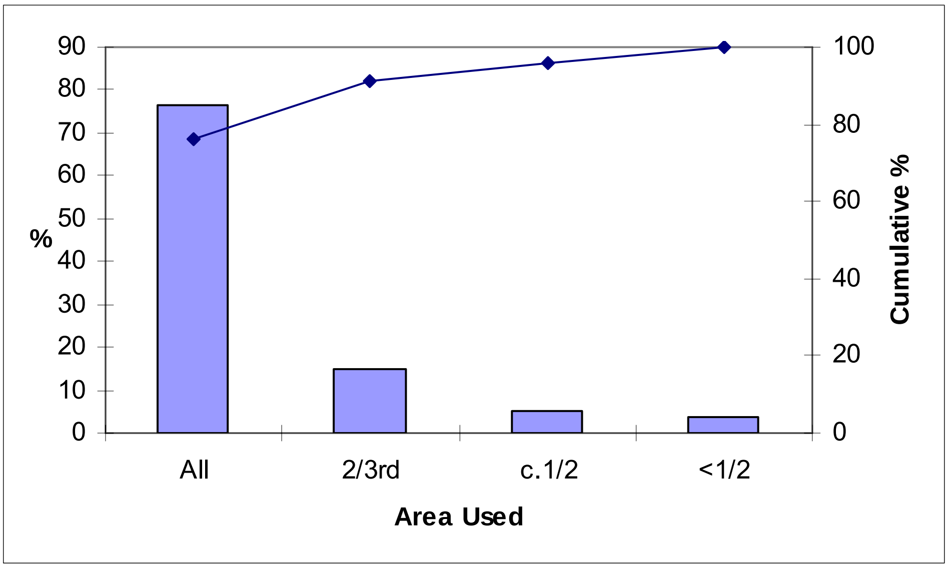


Figure 2.6 Percentage (bars) and cumulative percentage (line) of 536 responses to the question "How much of your plot is actively used?"

2.10.7 Frequency of visits to plot (Question 10) (Objective 2.5)

This question produced quite a spread of answers, but significantly more plot-holders visited their allotment at least 2-3 times a week ($G_{adj} = 411.42$, $p < 0.01$; Figure 2.7) compared to the other frequencies, therefore again the null hypothesis was rejected. Only 4% visited their plots once a fortnight or less. This question should have been clarified or split into spring/summer visits and autumn/winter visits as some respondents stated that their answer depended on the time of year.

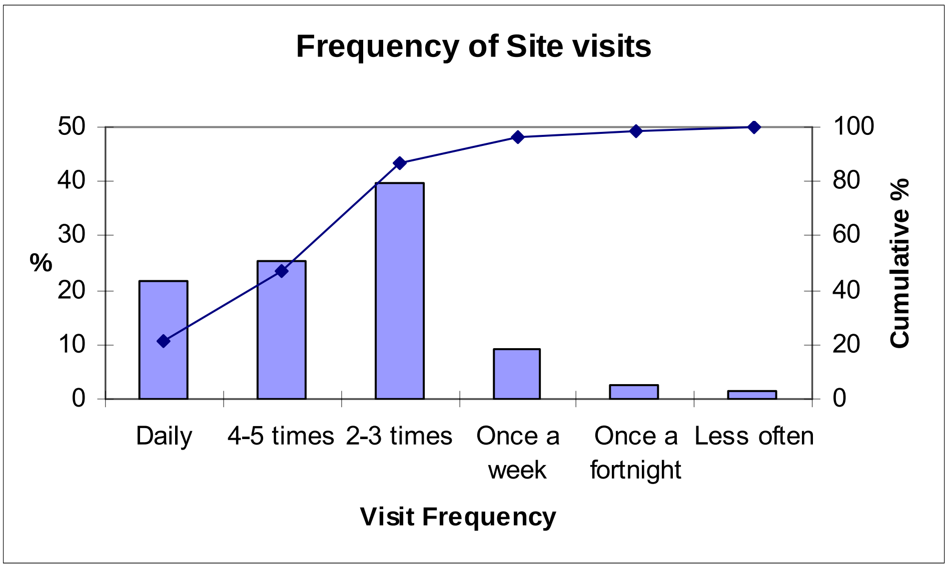


Figure 2.7 Percentage (bars) and cumulative percentage (line) of 546 responses to the question "How often do you visit your plot?"

2.10.8 How allotment skills were learnt (Question 11) (Objective 2.6)

The number of people that said they had taught themselves the skills needed to manage an allotment was quite high: significantly more decided they were self-taught rather than taught by others (43.79%; G_{adj} = 205.62, $p < 0.01$; Figure 2.8) therefore rejecting the null hypothesis. One may have expected more people to have learned from other family members, partly as anecdotal evidence suggests that some plots have passed down from generation to generation. Over 25% of plot-holders learned their skills from other plot-holders, which suggest that there is some social interaction among the plot-holders.

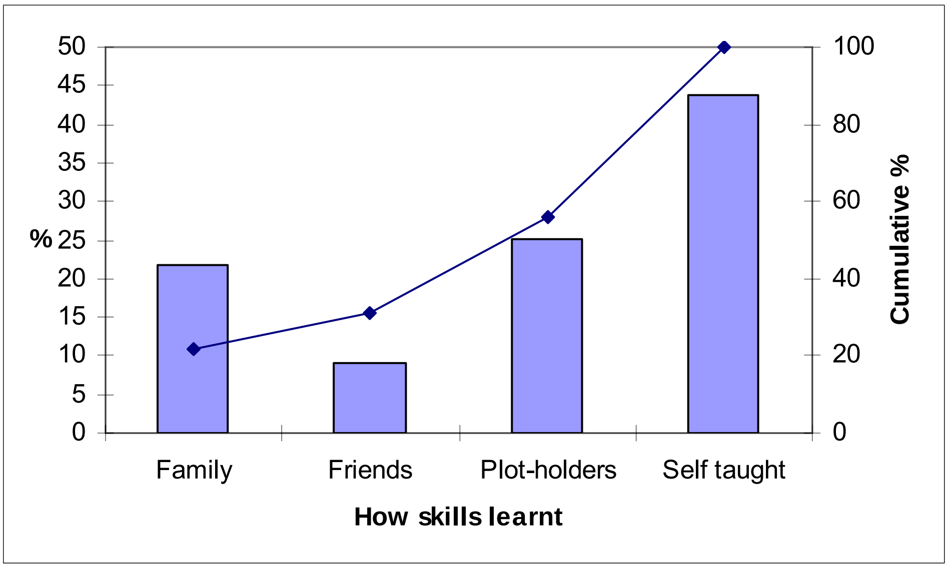


Figure 2.8 Percentage (bars) and cumulative percentage (lines) of 813 responses to the question "How did you learn the techniques needed to manage an allotment?"

2.10.9 Main use of plot (Question 3) (Objective 2.7)

Significantly more plots were used for growing vegetables (G_{adj} = 431.80, $p < 0.01$; Figure 2.9), followed by growing a mix of flowers and vegetables. The relatively high 'other' responses were usually to state that fruit and or herbs were grown. With hindsight, the growing of fruit should have been one of the options, or combined in a grouped option. Although only 6.0 % of respondents said that the main use of their plot was as a wildlife garden, this represented 20% of the Withernsea replies, 8.8% of the Hull replies and 6.6% of the other sample sites' replies (see Appendix A2.8). However, most respondents to this category also ticked other options, the majority of which were the mix of growing vegetables and flowers. Only one respondent said that their plot was solely used as a wildlife garden, whilst a few stated they had a pond or small orchard.

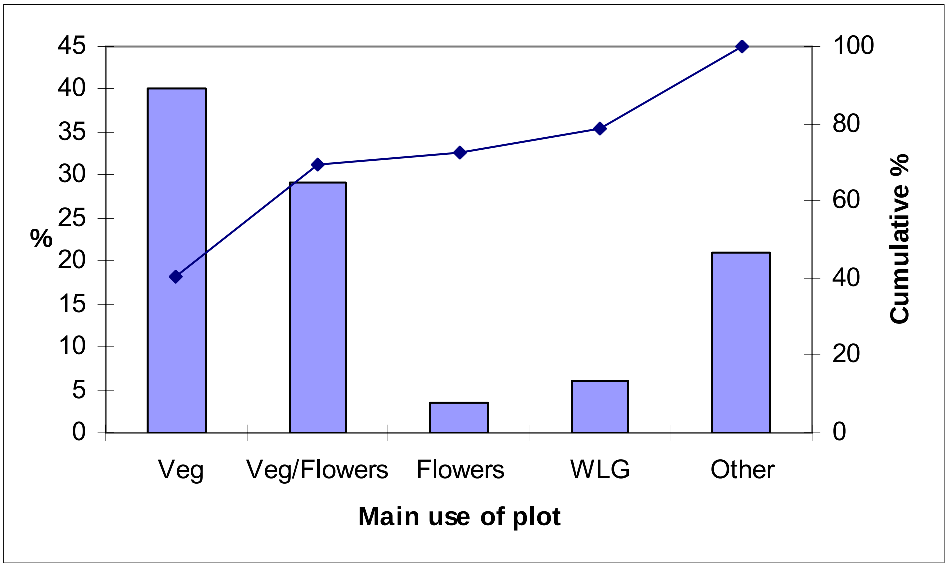


Figure 2.9 Percentage (bars) and cumulative percentage (lines) of 796 responses to the question "What is the main use of your plot(s)?"

2.10.10 Main reasons for having an allotment plot (Question 9) (Objective 2.8)

Whilst the previous question related to the main *use* of the plot, when asked the main reason for *having* an allotment, the results are not so clear. This question proved to be the one that many people failed to answer in the way intended i.e. ranking their responses between 1- 7 from the options available (Figure 2.10). Rank 1 was the *most* important reason, whilst rank 7 was the least important reason. Therefore, the option with the *lowest* score is the *most* popular. A summary of percentages could not be given, as per the other tables of responses; simple totals of rankings are shown.

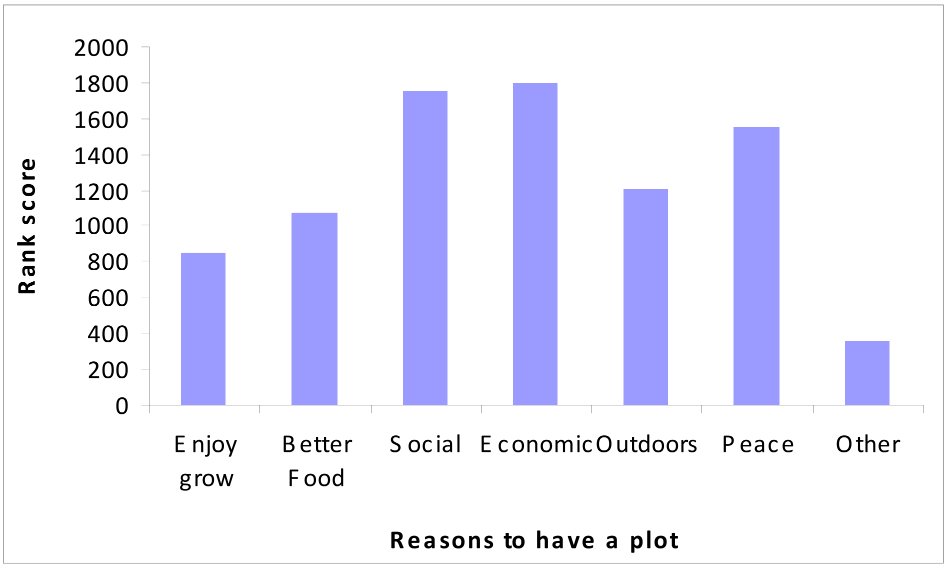


Figure 2.10 Number of ranked responses to the question *"What are the main reasons for having your plot(s)?"* (Ranked in reverse order therefore lowest score is most popular: see text for scoring details.)

In an earlier draft, this question was split into two questions, but in the trial of the questionnaire, this was found to be confusing. People tended to choose several options when asked for only one, then realized when they came to the second question that only one option should have been ticked in the previous question. To try and resolve this problem, the ranking format was used on a single question. However, this may have been poorly explained as relatively few people ranked each option in the manner intended i.e. most important reason for having an allotment would rank 1; the least important option would rank 7. Some respondents only ticked a few options; some only ranked a few options between 1 - 4 and left other options blank whilst a small number of respondents did rank the first six options. Thus, the totals shown above do not give any clear indication of the most popular reasons for having an allotment. However, disregarding the 'other' option, as many people did not fill in this section, there is at least a slight inference that people's favoured option was that they enjoyed growing vegetables, followed by the provision of better tasting food. The economic option was the least important issue, followed by the social aspect. This latter option is interesting in that, in as shown in Figure 2.8, just over a quarter of respondents said they had learned some of the techniques need to run an allotment from other plot-holders.

The common themes from the 'other' option were the benefits of:

- healthy exercise;
- chemical free food;
- interaction with wildlife;
- safe, educational place for children;
- peace and quiet.

Below, Table 2.4 shows a sample of the comments received, grouped by these general themes, although it can be seen that some comments are linked across several themes.

Table 2.4 Sample of typical responses to 'other' reasons in Question 9 asking why people had an allotment, listed by general theme.

Healthy exercise	Chemical free food	Interaction with wildlife	Safe, educational place for children	Peace and quiet
At my age I need the exercise	Knowing veg isn't covered with chemicals.	Enjoy the wildlife found there.	Valuable learning tool for our children.	To escape from the wife!!
Good for the health	No poisons in the vegetables	Madly interested in nature, means my whole life.	To get out the house and give the children something to do.	Just enjoy the peace and quite - a good place to think and relax.
Being unemployed at the moment, it has helped to keep my self esteem as well as keeping fit. Also I have met a broader band of interesting people.	We grow organically to avoid consuming vegetables which may be contaminated by harmful chemicals. This in turn is beneficial to the environment, whilst providing us with a means of healthy outdoor exercise in a friendly environment.	Importance of preserving green spaces in Hull and learning the ways of the land.	Also to teach our daughter the importance of growing fruit & vegetables and to get her interested in gardening/wildlife.	While at your plot you are in your own world, with peace & quiet.
The exercise helps to keep me reasonably fit.	Productive lifestyle/greener lifestyle/healthy	Enjoy watching birds and other wildlife.	Trying to get my son into a healthy way of life by eating organic, exercise and to enjoy the outside and the wildlife, birds and creepy crawlies.	In the middle of a city the allotments are a little bit of rural relief very relaxing.
Allotments are used as a group project for people with severe and enduring mental health problems. Encourage wildlife.	Enjoy gardening organically, veg+ flowers amongst the wildlife.	Exercise & wildlife e.g. watching hawk family performing in the sky.	To encourage my children to be involved in gardening aged 9 and 12 year old boys.	Just to be able to go down and forget the rest of the world for a few hours.

2.10.11 Importance of wildlife (Question 12) (Objective 2.9)

This question was the only one with an attitude scale. More people said that the wildlife on the site was either very important (50.95%) ($G_{adj} = 310.58$, $p < 0.01$) or important (31.68%) to them (Figure 2.11), again rejecting the null hypothesis. Only 14.50% had a neutral attitude and less than 3% of respondents thought that the site wildlife was not important to them. However, with hindsight, the scale was rather unbalanced; it would have been better if it had had two positive statements, one neutral and two negative values, as in the widely used Likert-type scales (Likert, 1932 in Coolican, 2004). At face value, it may be very encouraging from a biodiversity point of view that so many people valued the allotment wildlife, but the respondents may be a slightly biased sample of the wider population of allotment-holders, as discussed earlier. It is possible that those people that did not return the survey may have done so because they were not interested in the direction to which the questionnaire appeared to be heading i.e. wildlife-friendly bias.

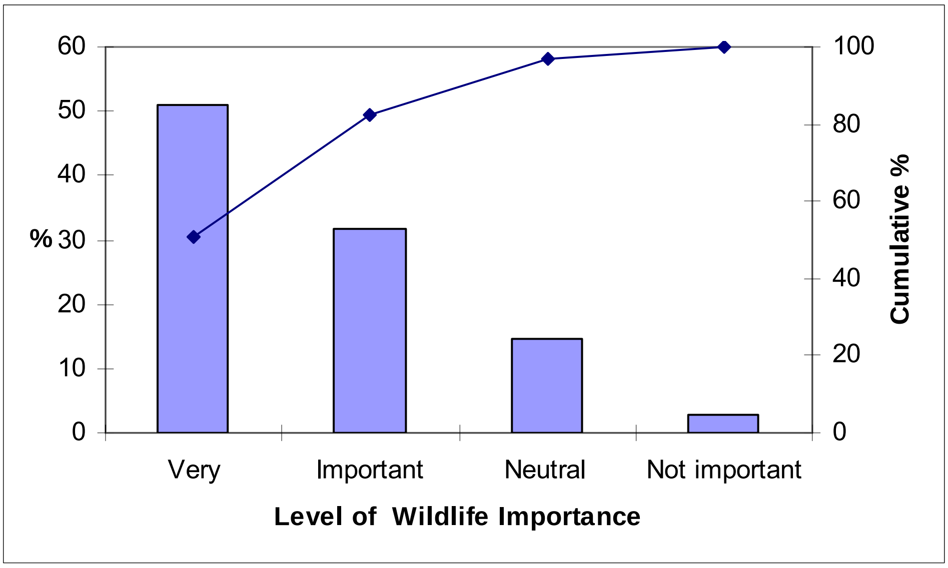


Figure 2.11 Percentage (bars) and cumulative percentage (line) of 524 responses to the question "How important is the wildlife on site to you?"

2.10.12 How the plot is managed (Question 5) (Objective 2.10)

Significantly more respondents (more than 53%) said that they managed their plot in a traditional way (G_{adj} = 255.56, $p < 0.01$; Figure 2.12), clearly rejecting the null hypothesis. Whilst no definition of traditional was given, it could be implied from the other options available; however, with hindsight, it may have been better to have provided a definition for clarity. Nearly 16% of respondents said that they managed their plot organically, although a few of these people (4) also ticked all of the other options. Of the nearly 10% of wildlife-friendly allotment holders, over half (5.85%) of them also said that they managed their plot in a traditional way. Of the 21% that responded that they were organic and wildlife-friendly, twelve people (19.67%) said that they also managed their plot in a traditional way. The classification of plots are either traditional or wildlife-friendly (the three other categories combined) will be used extensively in the subsequent Chapters to look at any differences in invertebrate abundance and diversity in relation to management style.

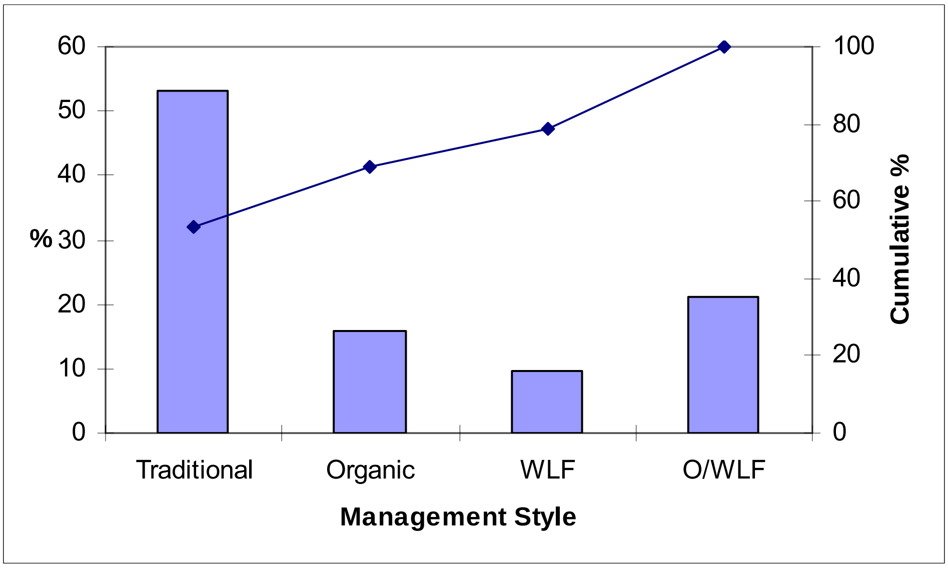


Figure 2.12 Percentage (bars) and cumulative percentage (line) of 632 responses to the question "How do you manage your plot?"

2.10.13 Use of pesticides (Question 6) (Objective 2.11)

From the 534 responses to the question "Do you use any pesticides on your plot?", only 4 people did not answer this question at all, which is perhaps surprising given the slightly sensitive nature of this question and the two that follow on from it. The majority of people did use some form of pesticide (67.42%; G_{adj} = 66.10, $p < 0.01$), therefore again rejecting the null hypothesis that everyone would use pesticides.

2.10.14 Type of pesticides used (Question 7) (Objective 2.11)

Perhaps unsurprisingly, slug pellets were the most commonly used pesticide. Significantly more people (40.72%) reported using these compared to other means of pest control (G_{adj} = 278.40, $p < 0.01$; Figure 2.13). Of those that did use pesticides, some appeared to be happy to admit to using a range of chemicals, others felt it necessary to qualify what they used, how much or how often, by adding extra text such as "*Bird-friendly slug pellets - not put on open ground. Very careful with weedkiller - not used on allotment*"; "*Glyphosate only for painting onto specific invasive species (Bindweed*)"; "*try to use organic products*".

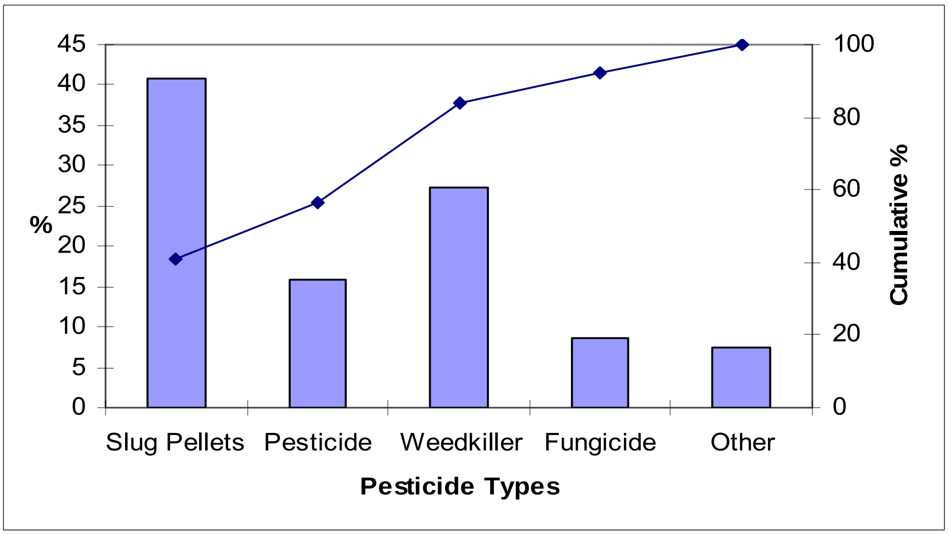


Figure 2.13 Percentage (bars) and cumulative percentage (line) of 727 responses to the question "Which types of pesticide do you use?"

2.10.15 Frequency of pesticide use (Question 8) (Objective 2.11)

The highest percentage of people used pesticides about twice a year (43%), with 24.29% and 22.57% using them four times a year or once a year respectively (G_{adj} = 79.38, $p < 0.01$; Figure 2.14). Those that used pesticides monthly were 10% of the total and interestingly perhaps, none of the Withernsea plot-holders said that they used pesticides on a monthly basis (see Appendix A2.14).

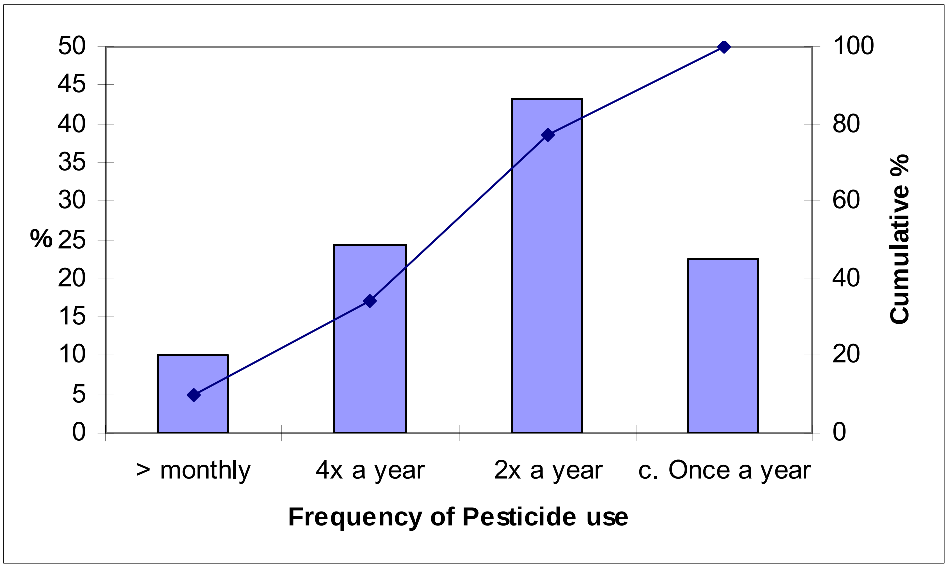


Figure 2.14 Percentage (bars) and cumulative percentage (line) to 350 responses to the question "How often do you usually use pesticides?"

2.10.16 Allow sampling on plot? (Question 13) (Objective 2.12)

A gratifying 85% of participants said they would be willing to help with the next stage of the research, with less than 15% declining (G_{adj} = 283.13, $p < 0.01$). As mentioned above, the respondents may have been more likely to support the work as they had already made the commitment to fill in and return the questionnaire.

2.10.17 Any comments you think may be useful? (Question 14) (Objective 2.13)

This final question on the main survey sheet gave plot-holders the opportunity to add or clarify any aspects they felt had not been fully covered or explained in the other questions. The data provided was qualitative, with just under 20% of respondents completing this question. It highlighted a few trends in opinion. For example, some people used this opportunity to provide more details on some of the species they enjoyed seeing on their allotment site, whilst others used it to point out species they considered to be a 'pest' (see Table 2.5). Others made neutral comments about the previous plot's history or management issues.

Table 2.5 Sample of responses to Q14: *Please use this box to add any comments you think may be useful*.

Negative wildlife statements	Neutral/mixed statements	Positive wildlife statements
As an allotment holder for over 30 yrs; I find that traditional gardening assists wildlife and many so called organic gardeners with the misplaced ideas destroy allotments and cause a poor environment for wildlife.	We have only had this allotment a few months and it was allowed to become very overgrown by previous tenant. We are just clearing it at the moment really but hope to have a couple of raised beds in by April-ish! Lots of fruit bushes on it.	For your info: enjoy the wildlife around the allotments, mainly various kinds of birds, also we have a family of foxes around the allotments and enjoy seeing them around, especially when the new ones arrive. Although a few of the allotment holders don't like them around & householders which back on to the allotments.
More involvment from the council - more of an effort to let plots - vacant plots should be cultivated - at present they are left to return to natural state - is this a ploy to attract wildlife? It certaily does not attract clients. Are you glad you asked!!	The person who had the plot before me operated a no-dig system for raised beds, which I am continuing for at least the 1st year. The council deposit leaves every autumn which are v. beneficial for compost.	Although my plot(s) are mainly for vegetables, I am constructing a wildlife pond and planting shrubs to provide shelter for creatures. I leave some grass long for the grasshoppers etc, and grow companion plants to encourage pollinators. I found an Elephant Hawkmoth caterpillar summer before last.
These allotments were purely designed to grow vegetables and I tend to get upset when I see allotment holders using a least half of their plot for flowers.	If the rubbish bins were cleared on a more regular basis and people prevented from tipping household rubbish on their allotments, the whole area would be more environmentally friendly for man and beast!!	We have seen much more wildlife in our garden than the allotment, although we have seen owls, a hedgehog, birds of prey occasionally. N.B. My wife is the main allotment worker, so I would pass you on to her if further research needed.
Am surrounded by unkempt plots, = more weeds and slugs.	I've been on these plots 51 yrs; Hon Sec for 34 yrs until 1992.	We have a spare allotment maintained as a bird sanctuary.
I try to keep wildlife off my allotment e.g. rabbits, moles, cats, pigeons, cabbage white butterflies, mice, rats.	I have worked my plot for 41 years but over the last few years theft and vandalism have tended to put me off but I will carry on.	Very interested in wildlife although I have only had my plot less than a year, it is very intersting to notice the diversity of wildllife in such a small area.
The problem is to control the detrimental (to gardeners) aspect of wildlife - Moles, Rabbits, Slugs, snails and birds on the fruit.	I won the best newcomer award 2 years ago but unfortunately I may not be able to spend as much time this year due to work and family commitments.	I would like to garden organic. I attract wildlife like hedgehogs (to eat slugs & snails) and not use any pesticides. Now I have retired from work I will find the time to strim the path edges & stop using weedkiller. I also will probably put some nesting boxes up for small birds.
In Q12 you ask how imp wildlife is on site .very imp. But probably not in way you think; rabbits devastate our crops as birds do. I have a lot of toads; is this good or bad?	A bit more help from the council, on site maintenance would be appreciated by everyone on site.	I am very careful when spraying to limit the danger to wildlife and especially if ladybirds are present. I also appreciate that slugs etc may be a source of food to certain wildlife - I am extremely bird friendly and assist the RSPB with home surveys etc.
The site at present is infested by rabbits, pigeons, doves and moles/rats making the growing of produce very difficult.	My wife and I gain great satisfaction from having an allotment.	I believe that there is not much point in having an allotment if you are going to spray it all with pesticides. I try to garden responsibly so there is a balance of crops, wildlife and good soil. I would use pesticides on flowers on a small scale, if the problem was really severe, at home; but never on plants for human consumption. Also, always try to use organic or alternative pest control.

2.11 Summary of questionnaire responses

To summarize the results of the responses to the questionnaire, it has been shown that:

- There is no significant gender bias in any of the responses;
- The over 60s are more likely to manage their plot in a traditional way;
- Around 70% of respondents live within a mile of their plot;
- Just over 40% had had their plot for over eight years;
- 75% managed all of the plot;
- 40% visited two to three times a week;
- 45% stated their allotment skills were self-taught;
- Plots are largely used for growing vegetables (40%) or vegetables and flowers (29%);
- Key reasons for having a plot were that plot-holders enjoyed growing vegetables and wanted better tasting food;
- 82% thought the wildlife on the allotment site was either very important (51%) or important (31%);
- 53% managed their plots in a 'traditional' way;
- 67% used pesticides, with slug pellets being the most commonly used one (41%);
- Pesticides were most commonly used about twice a year (43%);
- 85% said yes to allowing further sampling on their plot;
- An interesting range of comments to the open question demonstrated a diversity of views, but all show a commitment to their allotment plots.

2.12 Combined analysis of the questionnaire responses to compare traditional and wildlife-friendly management style (Objective 2.14)

2.12.1 Principle Component Analysis

Principle Components Analysis (PCA) with Oblimin rotation using SPSS and CAP 3.1 was used to explore the combined questionnaire data and test the hypothesis that the plot-holders were a homogenous group and would respond in a similar way to all of the questions. PCA allows the correlation variables to be reduced to a few principle components and thus aids interpretation of the questionnaire responses. As discussed in the Sections 2.9 and 2.9.1, these data are based on the number of responses to questions 2-4, 6-8, 10-13 and QA-C from 498 questionnaires (see Section 2.6: those who ticked more than one option along with traditional management were excluded from the 538 original questionnaires) (57 variables in total), with answers pooled per allotment site. The aim of the PCA was to explore any trends in the data or any key determining factors that differentiated different groups of plot-holders.

Prior to performing PCA, the suitability of the data for factor analysis was assessed. Inspection of the weightings of the 57 variables in a correlation matrix revealed the presence of many coefficients of $\boldsymbol{R} > 0.3$ (see Appendix A2.16 for component matrix) therefore above the cut-off threshold suggested by Tabachnick and Fidel (2007) and thus suitable for factor analysis.

PCA revealed seven components with an eigenvalue exceeding 1, explaining 86.49 % of the variance (see Table 2.6). An inspection of the scree plot (see Appendix A2.17) revealed a break after the second component. As these two components accounted for 72.68 % of the variation, this was the most parsimonious explanation of the data variance (Tabachnick and Fidel, 2007). The regression factor scores for the first two components are shown in Table 2.7 i.e. the component loadings are the correlations between the variable and the components, with possible values between -1 and +1. The un-rotated loadings for all seven components and table of communalities are shown in Appendices A2.18 and A2.19 respectively. A plot of the variables is shown in Figure 2.15.

2.12.2 Factor rotation: Oblimin rotation

As shown above, two principle components were optimal and were therefore subject to Oblimin rotation to assist with the interpretation of the factors. This oblique rotation method simplified the factors by minimizing the sum of cross-products of the squared loadings in the pattern matrix, permitting fairly high correlations among factors (Tabachnick and Fidel, 2007). Thus, it shows how strongly inter-correlated factors actually are. As the loading factors were >0.3, this confirmed that Oblimin rotation was the optimal reporting solution (Pallant, 2005) (see Table 2.8). The rotated solution identified the nature of the underlying latent variables represented by each component i.e. it shows, for example, if plots managed traditionally were more likely to be owned by men or if wildlife-friendly plots were more likely to be managed by women. Oblimin rotation produces a pattern matrix with Kaiser Normalization; it shows the unique contribution made by each factor to the variance of the variables (Table 2.9). In addition, a structure matrix is produced, which shows the overlap between factors (Appendix 2.20). For ease of interpretation, the ten highest coefficients for the two components are shown in Table 2.10.

Table 2.6 Variance explained by the first seven components of PCA on allotment questionnaire responses.

Total Variance Explained			
	Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %
1	37.687	66.117	66.117
2	3.743	6.566	72.683
3	2.090	3.668	76.351
4	1.849	3.245	79.595
5	1.542	2.706	82.301
6	1.253	2.198	84.499
7	1.136	1.992	86.492

Table 2.7 Regression factor scores for the two highest components for a PCA of allotment questionnaire responses. Most components load quite strongly (above 0.4) on the first component, whilst none are below 0.3 on the second component, thereby supporting the decision to retain the first two components.

	Component Matrix			Component Matrix	
	1	2		1	2
Survey Yes	0.990		No pest	0.847	0.390
Veg	0.979		<1/4 mile	0.847	
self taught	0.977		c. Once a year	0.842	
Veg/Flower	0.958		Pesticide	0.841	
family	0.957		2/3rd	0.831	
Male	0.956		Organic	0.822	
Trad	0.947		Female	0.815	0.302
very imp	0.947		4x a year	0.812	
Pesticide Yes	0.945		51-60	0.803	
All	0.941		<1/2 mile	0.785	
>8yr	0.925		Fungicide	0.784	-0.326
2-3 times	0.924		friends	0.781	
Survey No	0.922		GrowOther	0.778	
4-5 times	0.920		neutral	0.777	
Weedkiller	0.915		OtherPest	0.727	
Slug Pellets	0.913	-0.333	>monthly	0.726	
3-8yr	0.912		c1/2	0.711	
WLF	0.907		< 1yr	0.703	0.357
plot-holders	0.902		Flowers	0.684	
Over 60	0.899		Grow WLG	0.657	0.449
2x a year	0.886		21-30	0.611	0.420
41-50	0.882		>3 miles	0.592	0.491
Daily	0.871		Once a week	0.589	
important	0.870		<1/2		0.800
O/WLF	0.861	0.356	31-40	0.427	0.622
<1mile	0.856		Less often		
1-3 miles	0.855		Once a fortnight	0.505	
1-3yr	0.854		not imp	0.477	
			Under 21	0.395	0.461

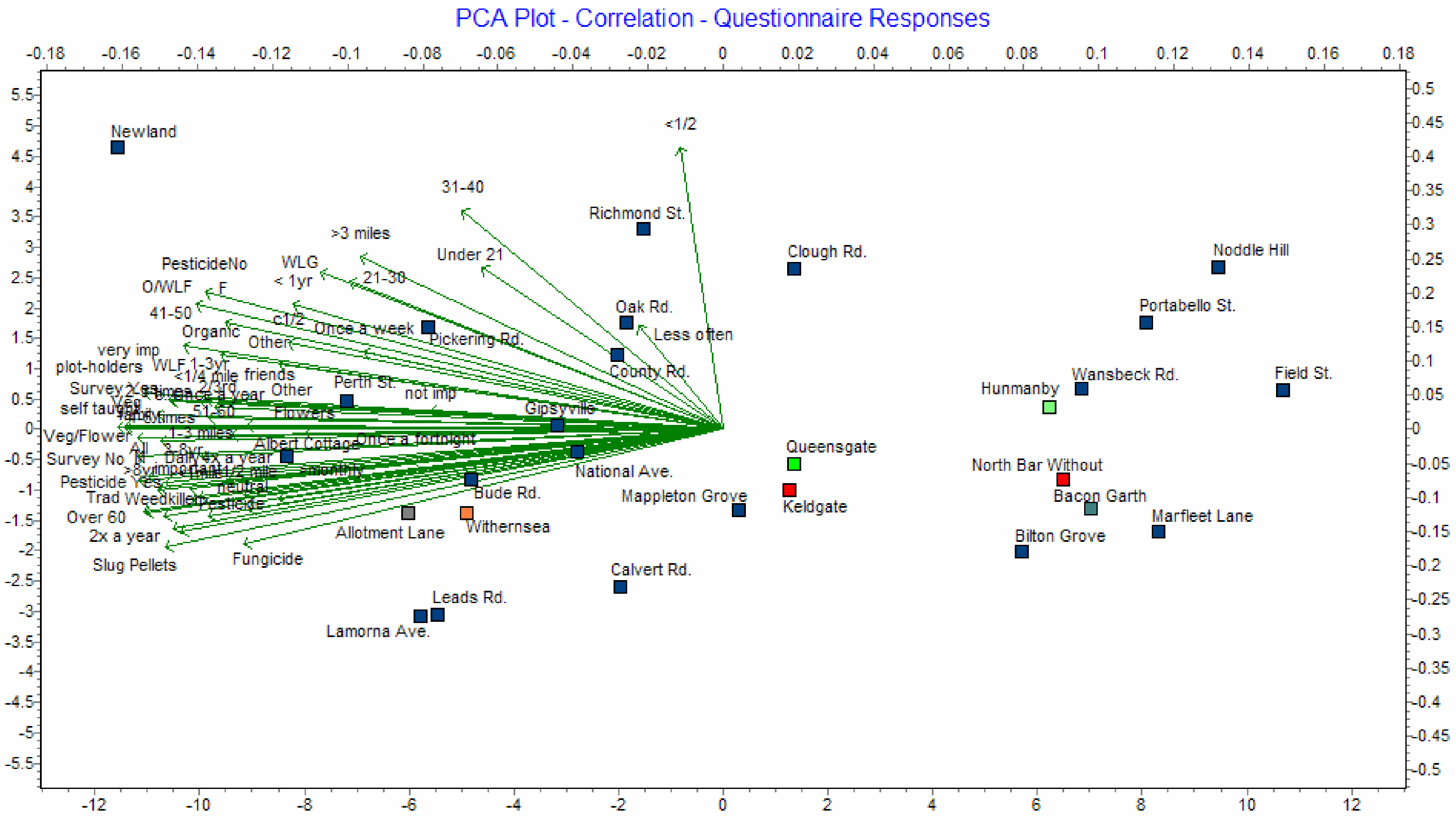


Figure 2.15 Principle Components Analysis plot of questionnaire responses. PC1 and PC2 account for 72.68 % of the variance between responses. Distance grouping values based on Euclidean distance. Site, age, gender, management style linked to pesticide use were key determining factors (see text for details).

Table 2.8 Component Correlation Matrix after Oblimin rotation with Kaiser Normalization for PCA extraction method. This table shows that the two extracted components are quite strongly correlated.

Component Correlation Matrix		
Component	1	2
1	1.000	0.363
2	0.363	1.000

Table 2.9 Pattern matrix of PCA after rotation by Oblimin with Kaiser Normalization. This table shows the unique contribution made by each factor to the variance of the variables.

	Component	
	1	2
Slug Pellets	1.033	
Pesticide Yes	1.016	
Trad	1.016	
Over 60	0.995	
Weedkiller	0.993	
2x a year	0.986	
Male	0.981	
>8yr	0.965	
All	0.960	
Survey No	0.957	
Veg/Flower	0.947	
3-8yr	0.941	
Survey Yes	0.937	
self taught	0.926	
important	0.926	
Veg	0.923	
Pesticide	0.923	
family	0.920	
Daily	0.911	
Fungicide	0.908	
<1mile	0.907	
4-5 times	0.890	
2-3 times	0.856	
neutral	0.851	
1-3 miles	0.850	
very imp	0.847	
4x a year	0.844	
<1/2 mile	0.837	
WLF	0.819	
plot-holders	0.815	
>monthly	0.788	
c. Once a year	0.784	
1-3yr	0.773	
51-60	0.770	
<1/4 mile	0.761	
2/3rd	0.758	
GrowOther	0.734	
41-50	0.718	0.362
friends	0.700	
Organic	0.675	0.325
Flowers	0.656	
O/WLF	0.640	0.484
Female	0.623	0.421
No pest	0.610	0.518
OtherPest	0.597	
c1/2	0.554	0.346
Once a fortnight	0.528	
< 1yr	0.490	0.465
Once a week	0.449	0.305
not imp	0.425	
<1/2	-0.333	0.861
31-40		0.715
>3 miles	0.317	0.595
Grow WLG	0.400	0.558
Under 21		0.540
21-30	0.371	0.521
Less often		0.330

Table 2.10 Top 10 component coefficients for components 1 & 2 extracted by Direct Oblimin rotation for allotment questionnaire responses. It shows, for example, that the over 60 yr males that had had their plot for over 8 years were most likely to manage all of their plots in a traditional way using a range of pesticides. Women under 40 were more likely to manage about half of their plot as a wildlife garden in an organic, wildlife-friendly way.

Pattern Matrix	Component	
	1	2
	Traditional	O/WLF
Top 10 component 1		
Slug Pellets	**1.033**	-0.245
Pesticide Yes	**1.016**	-0.139
Trad	**1.016**	-0.134
Over 60	**0.995**	-0.192
Weedkiller	**0.993**	-0.154
2x a year	**0.986**	-0.202
Male	**0.981**	-0.041
>8yr	**0.965**	-0.073
All	**0.960**	-0.027
Survey No	**0.957**	-0.061
Top 10 component 2		
Female	0.623	**0.421**
< 1yr	0.490	**0.465**
O/WLF	0.640	**0.484**
No pest	0.610	**0.518**
21-30	0.371	**0.521**
Under 21	0.145	**0.540**
Grow WLG	0.400	**0.558**
>3 miles	0.317	**0.595**
31-40	0.094	**0.715**
<1/2	-0.333	**0.861**

2.12.3 Interpretation of PCA

The Table of Communalities (Appendix A2.19) shows that all of the variables have relatively high values and therefore are well represented in the common factor space. The final communality values represent the proportion of the variance in a variable that is predictable from the factors underlying it (Tabachnick and Fidel, 2007).

The regression factor scores for the first two components (from Table 2.7) show that most components load quite strongly (above 0.4) on the first component, whilst scores for the second component lie between ± 0.3 to 0.80. This further supports the decision to retain the first two components (Tabachnick and Fidel, 2007).

The PCA graph (Figure 2.15) shows a demarcation between site size, with the larger sites located on the left hand side along axis 1, medium-sized sites nearer the centre and the smaller sites towards the right hand side of axis. This means key determinants along axis 1 (PC1 = 66.12 % of variance) were linked to the larger number of responses from larger sites. PC2 is linked to management style (PC2 = 6.57 % of variance); the eigenvectors along axis 2 differentiate between the amount of the plot actually cultivated, age, gender and management style (see also Tables 2.7 and 2.9); both components are examined in more detail below.

The eigenvectors shown in Figure 2.15 are a measure of the strength of the variables. Elements such as various pesticide usage, being over 60 and managing the plot traditionally, were located to the lower left (negative direction) of the axis. In contrast, the eigenvectors along axis 2, show a positive direction linked to plot-holders that are generally younger, more likely to be wildlife-friendly and perhaps only cultivate about half of their plots. Central eigenvectors were the actual use of the plot for growing vegetables or vegetables and flowers, being self-taught and being between 1-3 miles from their plots.

The rotated solution (Table 2.9) identified the nature of the underlying trend in the data; high loadings on component one correspond to low loadings on component two and *vice versa*. There were a number of strong loadings, with many variables loading substantially on only one component, although some variables did have cross loadings. Table 2.9 also shows how unique each variable is in contributing to the component. To aid interpretation of these loadings, the top ten for each component are shown in Table 2.10 and the structure matrix (Appendix 2.20) shows the correlation between the variables and the factors. Thus, looking at the factors with the highest loadings, generally, older men that had had their plot for over eight years were most likely to manage their all of their plots in a traditional way using a range of pesticides. People under forty, particularly women, were more likely to manage about half of their plot as a wildlife garden in an organic, wildlife-friendly way.

2.12.4 Questionnaire responses in relation to management style

To test whether the self-declaration of management style i.e. traditional or organic/wildlife-friendly related to actual management practices, a DECORANA was carried out. The resulting plot shows a clear separation between the relationships of the two management styles (see Figure 2.16).

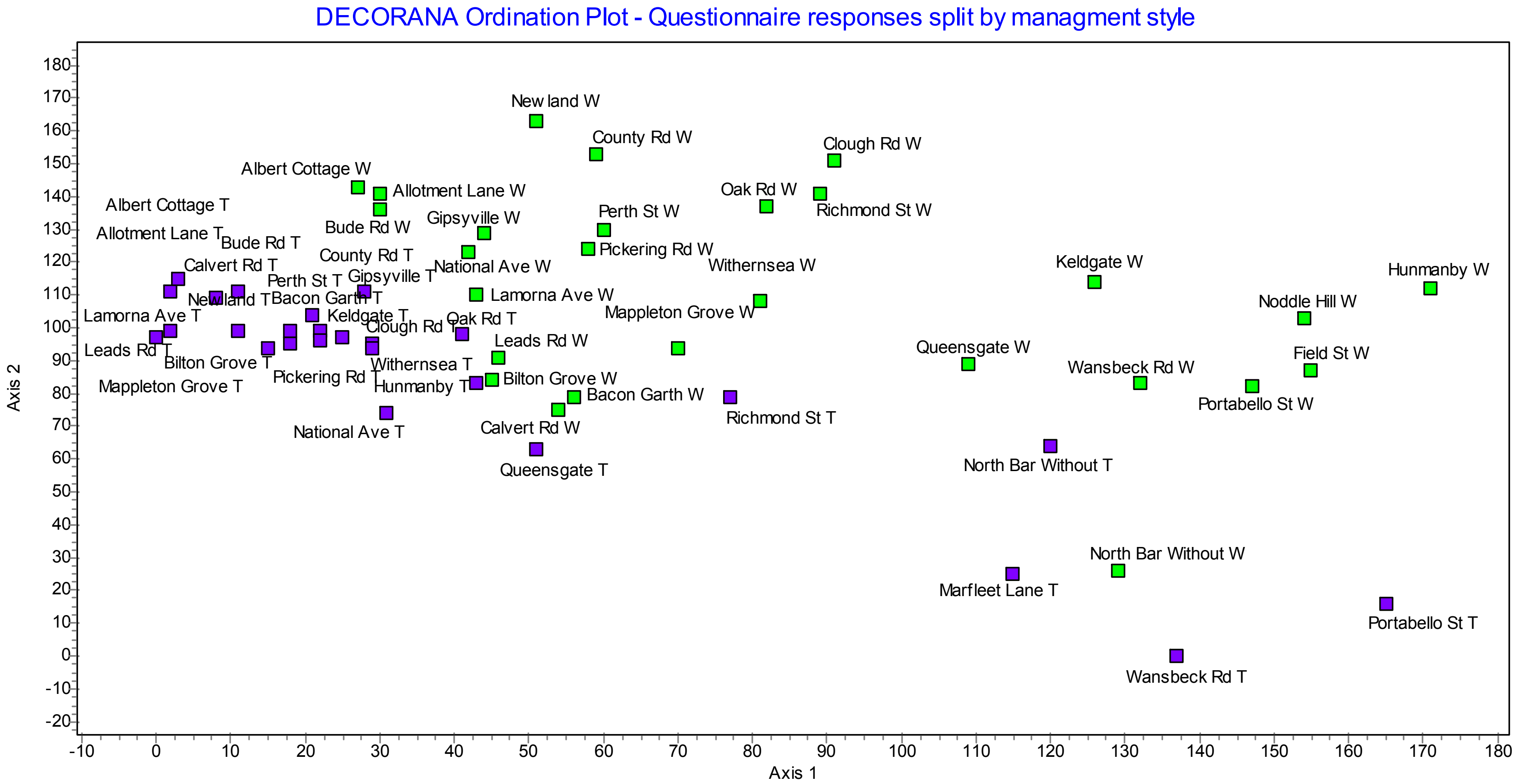


Figure 2.16 DECORANA plot of the questionnaire responses for each allotment site split by management style.

One-way ANOVA was used to compare the responses made by the questions about pesticide use (type) and the length of plot tenure by people employing the two management styles (i.e. management style was the dependant variable) to further elucidate the differences between the two groupings revealed by the DECORANA. As Table 2.11 shows, these tests revealed that there was a statistically significant difference in the use and range of pesticides used between the traditional and the wildlife-friendly plot-holders with the exception of the 'other' category. The traditional plot-holders use a range of pesticides. The only non-significant answer was for the 'other' category. This could however include some pest reduction measures that could be classed as organic/wildlife-friendly. For example, some respondents noted on their questionnaire comments such as "*Organic (chillies, ponders soft soap, soda, garlic)"* and *"try to use organic products"* in response to the 'other' option in question 7 (see Figure 2.1 in Section 2.4). In addition, only those plot-holders that have had their plot for more than eight years are also statistically more likely to manage their plot in a traditional way.

Table 2.11 One-way ANOVA to compare mean number of questionnaire responses to a) if pesticides use and type of pesticide; b) length of tenure of the plot.

	Mean no. of responses per site				Management (1 df)		
	Traditional		Wildlife-friendly				
	Mean	sd	Mean	sd	MS	F	p
Pesticide use: yes	8.35	6.31	2.81	2.60	405.25	17.67	0.00
Pesticide use: no	1.27	1.25	4.11	5.26	106.97	7.18	0.01
Slug pellets	7.04	5.23	2.11	2.12	321.58	20.46	0.00
Pesticides	3.31	3.33	0.44	0.70	108.59	19.08	0.00
Weed killer	5.04	4.41	1.19	1.47	196.66	18.47	0.00
Fungicide	1.85	2.05	0.26	0.53	33.35	15.11	0.00
Other	0.96	1.00	0.67	1.00	1.15	1.15	0.29
< 1yr	1.15	1.16	1.67	1.73	3.48	1.59	0.21
1-3yr	1.50	1.36	1.78	2.34	1.02	0.28	0.60
3-8yr	2.27	2.13	1.41	1.69	9.84	2.67	0.11
>8yr	4.62	4.01	2.04	2.38	88.05	8.18	0.01

To summarize, the main difference between the responses to the questionnaire related to number of responses linked to site size, along with management style i.e. traditional or wildlife-friendly, linked to age and gender in relation to questions 6-8 regarding pesticide use. The self-declaration of management style appears to be borne out by the actual management practises adopted by the plot-holders. As management style was likely to be the key defining factor for the type of invertebrate communities found on the allotment plots, it will be explored in further detail in Chapter 4.

2.13 Site choice

As was shown in Section 2.10.16, 85% of participants were willing to allow further surveying on their plot. This meant that there was a sufficient range of sites to choose from to move forward to the next stage of the research. Sites were needed for carrying out epigeal invertebrate sampling that contained both traditionally and wildlife-friendly managed plots. These sites were also required to represent an urban-rural gradient, based partly on a 'common sense' approach, at this stage. Therefore, from the information provided, seven sites were chosen to sample the allotment invertebrate abundance (Objective 2.16) using pitfall traps. The rationale for each site choice is given in Table 2.12 and further details of these sites are shown in Table 2.13.

Table 2.12 Rationale for site choice, based largely on information provided by questionnaire responses.

Location	Allotment Site Name	Reasons for selection
Hunmanby	Hunmanby allotments	Only site in village; I had a plot there; on the Hull-Scarborough railway line
Bridlington	Queensgate	Site with most replies; on the Hull-Scarborough railway line
Driffield	Allotment Lane	Site with most replies; on the Hull-Scarborough railway line
Beverley	Keldgate	Site with most replies; on the Hull-Scarborough railway line
Cottingham	Bacon Garth	The only site to reply; effectively a 'suburb' of Hull; on the Hull-Scarborough railway line
Hull	Bude	Site closest to outskirts of the city; I had built up a good network of contacts on site; good number of plots to chose from; on the Hull-Scarborough railway line
Hull	Newland	Site closest to city centre; close to the university; I had built up a good network of contacts on site;good number of plots to chose from; on the Hull-Scarborough railway line

Table 2.13 Allotment sample site summary information; % urban v % greenspace approx. values only.

City/Town	Population*	Site Code	Grid Ref.	Area (Ha)	No. of plots	No. unused plots	%Urban v. %Greenspace surrounding area: 100m	%Urban v. %Greenspace surrounding area: 500m	%Urban v. %Greenspace surrounding area: 1km	Comments
Newlands, Hull	243,589	NW	TA 078311	8.30	280	None	95:5	80:20	75:25	Surrounded by housing on all sides near city centre
Bude, Hull	243,589	BD	TA 093343	2.24	74	None	40:60	50:50	65:35	Housing/Shopping centre on 2 sides at edge of a large park, near city boundary.
Cottingham	17,263	CT	TA 039324	1.40	9	None	100:0	80:20	50:50	Surrounded by housing on all sides in a village
Beverley	17,549	BV	TA 033391	2.50	17	None	70:30	60:40	40:60	Surrounded by housing on all sides in a market town
Driffield	11,477	DR	TA 032587	3.10	113	N/K	5:95	25:75	30:70	Edge of town; cemetery one side, fields 3 sides
Bridlington	33,837	BR	TA 178673	1.50	56	N/K	85:15	70:30	75:25	Surrounded by housing on all sides in middle of seaside town.
Hunmanby	6,000	HN	TA 104772	1.00	10	3	30:70	25:75	20:80	Open site at edge of village: Industrial park one side, part of larger field on the 3 other sides.
Open Wawne**	N/A	OW	TA 084371	N/A	N/A	N/A	0:100	10:90	15:85	Veg patch in farm garden
Open Hunmanby**	N/A	OH	TA 071787	N/A	N/A	N/A	0:100	0:100	0:100	Grassy track leading to farm house

* 2001 Census; ** Open country sites

2.14 DISCUSSION

The aims of this section of the study were to assess the demographics of plot-holders, the key types of allotment use, along with perceptions and attitudes to the wildlife on the allotment sites by means of a questionnaire (Objectives 2.1-2.15). From these data, allotment sites could be chosen for further study (Objective 2.16). Generally it has been found in this study that allotments are still largely the preserve of older men that manage their plots in a traditional way.

The level of response and the encouraging volume of returns to the questionnaire, given the caveat that no reminders or follow up was done, highlights the interest Yorkshire plot-holders have in their allotments. Some individual sites have a much higher response percentage than others; this is especially true of the Hull sites in comparison to most of the non-Hull sites. The possible reasons for this were discussed in Section 2.8.

2.15 Age and gender effects

As the results for age and gender highlight that the highest proportion of plot-holders were men aged over sixty, there is some evidence that the traditional stereotype of "old men in flat caps", as discussed in Section 2.2, may still hold true. Conversely, as just less than half were not men over sixty, the demographic may be changing. This study has also shown that age and to a lesser extent gender, do appear to have a bearing on management style. Although still largely a male-dominated pastime, the gender split among allotment holders was larger in the sites that may be generally thought of as rural and suburban (73% men: 27% women), compared to city sites. The city sites contained 10% more women. In addition, younger women were more likely, if not statistically significantly, to have had their plot for a shorter time and manage it in a wildlife-friendly way. This may be partly due to the larger city sites having a greater capacity to host community groups, which were often run by paid female project workers (pers. obs.).

Crouch and Ward (1997, Chapter 5) discuss at some length the long, male-dominated history of allotment gardening. "*It was considered as an annexe to the working-man's club or the betting shop*" (Garner, 1984, in Crouch and Ward, 1997). Indeed, Crouch and Ward (1997) recount that as late as the mid 1980s, it was rather sensational news that not only did a woman in Lancashire have an allotment, but she had won prizes for her produce! One would like to think that attitudes have since moved on and Buckingham (2005) suggests that indeed the British allotment "*is becoming, by degrees, embourgeoised and more socially diverse, with many more women entering allotment gardening*". Her questionnaire approach using extracted data gathered from a number of London boroughs to examine the gender bias and attitudes to 'urban food growing', did highlight differences in approach to allotment management and attitude. She found that women were much more likely to use less or no pesticides, were likely to have a higher educational level and be younger than their male counterparts on the allotment sites. However, her study was confined to two of the more affluent boroughs of London.

Although there was a highly significant difference in the actual numbers of males to females responding to the questionnaire, there were no *significant overall* gender differences in responses to the actual questions. However, for some questions, there was a trend for older males to be more likely to manage their plot in a traditional way. Similarly, Caro *et al*. (2003) found no difference in response to a survey of attitudes to biodiversity conservation between male and female students.

The trend for older people, especially men, to cultivate the whole of their plot and visit it relatively frequently, i.e. at least 2-3 times a week, was to be expected. A number of respondents lamented those plots left unattended, as weeds were allowed to drift onto neighbouring, well-tended plots: "*Am surrounded by unkempt plots = more weeds and slugs*". In contrast, younger people were more likely to state that they only actively used a proportion of their plot. In Crouch and Wards' (1997) seminal allotment book "*The Allotment: Its Landscape and Culture*", they noted that "*we take for granted the stereotype of the allotment as an exclusively male side of family life in Britain*." Yet evidence of the gradual change in allotment demographics is noted on the same page by their noting that among Latvian and Ukrainian immigrants in Hull, the whole family would come to work the plots at Newlands Park (Crouch and Ward, 1997, p 93).

Given the commitments of time and effort required to manage an allotment, if done with a measure of success, it was unsurprising that half of the respondents were over sixty years old. These plot-holders are therefore more likely to be retired and have the time required. This also means however that the other half were not in this age bracket, therefore some at least were more likely to be combining managing their allotment with paid employment. Overall, this study had shown that a wide range of ages and both sexes appear to be enjoying the benefits of allotment gardening. Similarly, Armstrong *et al.* (2010) find in their Local Authority survey of Newcastle allotment demographics in relation to gender that the percentage of male gardeners has decreased from 85% male gardeners in 2001 to 70% in 2008. They also note that there is a steady increase in those under forty, keen to secure a sustainable, organic and fresh source of fruit and vegetables and a decrease of those aged over sixty-five.

2.16 Ownership and use of allotments

When it came to how long people had had their plots, there were extremes of responses. Some people were very new to the whole allotment growing experience, having had their allotment for less than a year. It was also interesting to note that in the current study, 16.67% of those that had had their plot for less than a year also had a wildlife garden section, compared to only 6.16% of the total number of respondents. At the other end of the scale, a number of respondents stated they had had their allotment for over 30 years and in one case, for over fifty years. These results are similar to those of Atkinson *et al*. (1979) who found that 49% of plot-holders had over thirty years experience of allotment gardening.

Perhaps contrary to what one would expect, passing on knowledge amongst each other on the allotment site does not appear to be the main way in which plot-holders learn their craft. Many stated that they had learnt the techniques required to run an allotment from range of sources, but ‘self taught’ was by far the most popular option. One respondent stated “*Apart from being in the forces in wartime I have been on the land all my life and working on farms*.” Another noted "*I am always willing to give advice or take it*." It is possible that some people may feel that they learn most by doing, as Aristotle noted (Ruach, 2005). As that process involves much more effort than listening to advice or reading a book that is likely to be the most memorable way that plot-holders feel they have learnt their allotment gardening skills. The social aspect ranked poorly as a reason for having an allotment, which is similar to the results found by van den Berg *et al*. (2004). They noted that only 17% of respondents rated social contact as very important in their study of the range of perceived benefits of allotment gardening. These results suggest therefore that allotment sites are not the fully integrated communities as often portrayed in the popular media (e.g. SAGS, 2007; Anon., 2009) as many plot-holders do not appear to be sharing their wisdom with other fellow plot-holders.

Question three asked about the main use of the plot, with five options. However, there was no direct option for 'growing fruit' which, with hindsight, should have been included; possibly along with a mention of herbs. A clearer assessment of the data could have been made if respondents were asked to tick only one box. A better grouping of variables used (e.g. an option for growing vegetables, fruit and flowers) would also have lead to clearer data. One respondent seemed most upset that some people were growing flowers on their plot, as noted in Table 2.5. One may presume therefore that they would also be unhappy about the trend for community wildlife allotment plots and other such non-vegetable uses, which in some cases would take up several plots, especially at Newland allotments in Hull.

2.17 Reasons for having an allotment, attitudes to wildlife and management styles

People provided a mixture of interesting responses when asked why they had an allotment. The most commonly stated reason, that people enjoyed growing vegetables, was no surprise. This along with a desire for better tasting, chemical-free food, healthy exercise and somewhere to enjoy wildlife and peace and quiet were also ranked relatively highly. This suggests that allotment sites are valued as calm oases, particularly in urban settings where such spaces are relatively limited. As well as the direct benefits of providing food, the allotments are therefore providing a range of other physical and mental benefits for the plot-holders. Similarly, van den Berg *et al*. (2010) noted that for plot-holders aged sixty-two and over, those with an allotment scored more highly on a range of well-being measures such as stress levels and physical health scores.

However, it was interesting that the *least* popular reason was economic. These findings concur with those of Howe and Wheeler (1999) who noted that the primary motivation for most allotment growers was leisure rather than economic. As there has been a major recession since the current survey was undertaken in early 2006, it would be interesting to find out if this reason would move up in popularity. Articles in the popular media have suggested that the economic downturn has been responsible for an increase in thefts of produce from allotments, which in turn has led to an increase in "*veg-ilantes*" patrolling their plots to protect their crops (Sutherland, 2008).

The questionnaire provided an insight into the range of perceptions of plot-holders to their activity, which in particular can be related to attitudes to the biodiversity conservation value of the allotment sites. It was noted that a high proportion of respondents had a positive attitude to the wildlife on the site. However, the term wildlife was not explained on the questionnaire sheet. This means that some people may be more likely to associate 'wildlife' with relatively charismatic species such as birds and mammals and not invertebrates, which are much more likely to be viewed as 'pests' (Marshall, 2009). Perhaps, with hindsight, had the term 'wildlife' included some examples that specifically included some common invertebrates, the responses may have differed. In addition there may have been an element of bias, as those more kindly disposed to wildlife are more likely to have returned the questionnaire compared to those that were not. However, the self-declaration of allotment plot management style appears to be borne out by the actual management practises adopted by the plot-holders as shown by Figure 2.16 in Section 2.12.4, which provides evidence for the validity of the self-declaration. In addition, like Tunstall's (2000) study of the public perceptions of the environmental changes to the Thames Estuary (Tunstall, 2000), the questionnaire did capture the nature and range of perceptions and attitudes that previously had little empirical data. The current study is also suitably robust to allow a range of statistical analyses that identifies trends in the data.

Of the 67% of plot-holders that used pesticides, protection against slug damage was by far the most common reason given. These are similar results again to those of Atkinson *et al*. (1979) whom reported slugs to be twice as frequent as any other pest. It would therefore be interesting to compare the number of slugs on the 'traditional' plots compared to the 'wildlife-friendly' managed plots, which will be discussed in Chapter 4, Section 4.13.7.

Atkinson *et al*. (1979) noted that *c*.16% of respondents to an allotment questionnaire preferred not to use chemicals. Today, some newer sites that have been, or are in the process of, being set up stipulate an organic approach for the whole site (pers. obs.). In addition Marshall (2009) noted that more widespread organic gardening would contribute to higher biodiversity, with a mix of 'pests' and predators. Having talked to quite a number of plot-holders during the course of the current study, it was evident that strong views were held for both extremes regarding whether to use chemicals or not e.g. "*I would like to garden organic. I attract wildlife like hedgehogs (to eat slugs & snails) and not use any pesticides. Now I have retired from work I will find the time to strim the path edges & stop using weedkiller. I also will probably put some nesting"* to "*the problem is to control the detrimental (to gardeners) aspect of wildlife - Moles, Rabbits, Slugs, snails and birds on the fruit*".

2.18 Additional information provided and further work

As noted at the start of this discussion, many people added additional information to the basic questions asked, which further suggested they were keen to share their knowledge on the issue of their allotment. In particular, where respondents added information in the 'open' question which invited general comments, the range of responses provided an interesting insight into issues of importance for individual plot-holders. This open question also allowed respondents to provide richer, fuller, unambiguous information, without the constraint of a fixed-choice answer (Coolican, 2004). Having picked up on the general theme of the questionnaire, many people chose to add further information regarding the species they had either seen on their allotment site or had made particular effort to attract. Other respondents used the opportunity to complain about wildlife they saw as pests and in some cases, provided suggestions on how the local authority could help deal with them. A third general theme was the provision of interesting information on how people had managed their plots, or were intending to, if quite new tenants or details about how they used their plot: "*Sometimes I take a flask and sit and watch the world go by*". All of the comments helped provide a richer insight to value that plot-holders placed on their plot and the wider allotment site and allotment community.

In the current survey, 85% of plot-holders agreed to participate in further survey work, thus suggesting that people were also keen to be further involved in a project that focused specifically on their plot. This may be due, in part, to the wording in the covering letter that went out with the survey which stated that the ultimate aim of the research was to try and ensure that allotment sites remain valued and protected for the benefit of both wildlife and local people. Thus, respondents could see a personal value in returning the questionnaires. Similarly, Schley *et al.* (2004) found a 72% and 92% response rate respectively from hunters and foresters to a questionnaire about badger distribution in Luxembourg. As these groups of people thought that there were now too many badgers and the law should be changed to allow culling, they realized that by participating, their data may help lead to the(ir) required law-change.

Biological scientists are increasingly turning to the general public (and occasionally their own students, e.g. Scott *et al*., 2008) for help in finding baseline data on a range of wildlife and biodiversity issues (Caro *et al*., 2003; Schley *et al*., 2004). For example, Woods *et al*. (2003) used a questionnaire to provide some empirical data on the amount of wildlife predation by domestic cats in Great Britain. Thus, in a similar way that cat lovers were keen to participate in a study relating to their pets, allotment holders seemed to be keen to be involved in projects about their plot.

2.19 Determining sample sites

Another vital part of the questionnaire process was to obtain individuals' contact details to carry out epigeal invertebrate sampling. Although an initial 'common sense' approach helped identify likely sites, the plot-holders dictated to a certain extent which sites and plots could actually be sampled. It was hoped, that because there are historical reasons for allotments being found in conjunction with railways (Crouch and Ward, 1997), suitable sites along the Hull-Scarborough branch line could be used. Luckily, there were sufficient responses, although much lower in both number and percentage, from the non-Hull sites, to allow this. The impact of management style and the urban-rural gradient on epigeal invertebrate abundance and diversity will thus be covered in the following Chapters, thanks to the allotment plot-holders' generosity.

2.20 Summary

- Interest in allotments appears to be continuing to grow, as the enthusiastic response to the current research questionnaire suggests, along with the number of popular books published and the continuing demand for new sites.

- Although a significant proportion of plot-holders are still likely to be retired men, the demographics do appear to be changing. Age does appear to have a bearing on management style, with younger people more likely to have had their plot for a shorter time and manage in a wildlife-friendly way. This demographic change appears to be more evident on urban allotment sites. Conversely, people over sixty are more likely to manage their plots in a traditional way, using a variety of pesticides.

- Many people appear to be willing to participate in further research to help protect and promote their allotments. This therefore allowed a choice of sampling sites to be made to examine the epigeal invertebrate communities on allotment sites, as discussed in the following Chapters.

CHAPTER 3: ABUNDANCE & DIVERSITY OF ALLOTMENT INVERTEBRATES IN RELATION TO URBAN-RURAL GRADIENT

3.0 INTRODUCTION

3.1 Allotment and garden wildlife along urban-rural gradients

Allotments have traditionally mainly been regarded in terms of their value for growing food (Crouch and Ward, 1997), with little thought about the other benefits they can bring (Gilbert, 1991). However, they can play a valuable part in providing access to greenspace, as well as meeting a number of healthy eating and exercise agendas (e.g. Biggs, 2007; Foley, 2007).

Allotments can also be valuable oases for wildlife, especially in urban areas, where such land is often at a premium. The prevalent and sophisticated use of herbicides on farmland means that allotments are now a major refuge for many formerly more widespread species of cultivated ground (Gilbert, 1991). However, as discussed in Chapter 2, Section 2.1, there are very few references to allotment wildlife specifically in the peer reviewed literature (e.g. Baweja, 1939; English Nature, 2006; Marshall, 2009), other than in negative terms as pests (Atkinson *et al*., 1979; Von Albert and Wolff, 2000;) therefore it is a relatively uncharted area of research. However, as many allotments are in urban areas and there has been some research into the variation of levels of biodiversity with different levels of urbanization (Jokimaki, 1999; Connor *et al.,* 2002) this may be a useful starting point at looking at the diversity of urban allotments, utilizing the benefits of an urban-rural gradient.

The main pressures on species, particularly urban ones, were detailed in Chapter 1, Sections 1.6 and 1.9. To briefly re-cap, they include increased temperatures, air pollution, higher traffic levels, habitat fragmentation and a range of other disturbance-related issues that can cause, among other things, changes in species composition, population dynamics and breeding success. Any species that can thrive in an urban setting in particular therefore has to overcome a variety of challenges not usually encountered in a more 'natural' setting in the wider countryside (e.g. Huck *et al*., 2008; Fuller *et al*., 2009). For example, Davison *et al.* (2009) found that urban badgers (*Meles meles*) tended to have much smaller home ranges than badgers living in the wider countryside. They also found that the badgers were using gardens principally for foraging, whilst using scrub land and allotments as corridors for moving between foraging patches.

Another commonly found urban mammal, the hedgehog, was found to have difficulty in foraging in gardens when it encountered larger networks of roads in urban areas (Rondinini and Doncaster, 2002). These anthropogenic habitats can however provide the ideal habitat for some *non-native* colonist plants (Odegaard and Tommeras, 2000). In addition, some animals, including a few natives ones, appear to thrive in urban settings e.g. pigeons, rats and cockroaches, which are generally considered to be synanthropic species (Obukhova, 2001; Gailis *et al*., 2003; Kataranovski *et al*., 2007). However, in many cases, urbanization causes a *decrease* in native species richness along urban-rural gradients (Weller and Ganzhorn, 2004; McKinney, 2008) as non-native colonists are joining an already impoverished fauna, compared to more rural or 'natural' landscapes and can out-compete native species. Also, there is often little chance for native species to colonize the urban core if there are no 'green' corridors or a suitable habitat matrix nearby. Overall, therefore, one may expect to find reduced species abundance and diversity in highly urbanized areas.

Gardens can perform a valuable biodiversity service in towns and cities as many streets have gardens joined both along a street and back-to-back with an adjoining street, effectively forming mini nature reserves (Buglife, 2009). (Chapter 5, Section 5.17 discusses a potentially similar effect on allotments.) To examine the potential wildlife value of gardens, a project in Sheffield undertook a survey of the cities gardens called " Biodiversity in Urban Gardens in Sheffield" (BUGS), which is discussed in more detail in Section 3.5 (Gaston *et al*., 2005_b; Smith *et al*., 2005).

The examples above show that both an autecological (badgers; hedgehogs) and a synecological (non-native plants; BUGS research) approach can yield useful information in supporting the importance of urban ecology. It also highlights that many gaps remain in key areas that could increasingly become wildlife 'hotspots' as demand for prime building land grows.

3.2 Aims of this Chapter

The following study aimed to examine the relative abundance and diversity of the macro-epigeal invertebrate fauna found on allotment sites in Yorkshire along an urban-rural gradient to answer the first part of the second research question:

Q2: What is the composition of the epigeal invertebrate communities on allotments and do they vary in relation to position along an urban-rural gradient?

This was achieved by the following objectives:

3.2.1 Establishing the urban-rural gradient

Objective 3.1 The first stage was to establish, using Principal Component Analysis, an urban – rural gradient across the chosen allotment sites and what key factors defined it.

3.2.2 Invertebrate taxonomic abundance

Objective 3.2 Next, the overall taxonomic abundance of epigeal invertebrates at seven allotment sites was determined. The objective was to determine any difference in invertebrate taxa abundance between the seven allotment sites. The null hypothesis was that the sites would contain similar invertebrate communities, regardless of site.

Objective 3.3 Using the previously defined urban-rural gradient, any variance in mean abundance of the seven allotment sites in relation to the position on the urban-rural gradient was examined. The null hypothesis was that taxa would be similarly distributed between the urban, suburban and rural sites.

3.2.3 Invertebrate taxonomic diversity

Objective 3.4 Building on the results above, the relative diversity and evenness of the taxa of each of the seven allotment sites was determined. The null hypothesis was that the sites would contain similar invertebrate diversity and evenness, regardless of site.

Objective 3.5 Finally, any variance in diversity and evenness of the seven allotment sites in relation to the position on the urban-rural gradient were examined. Any variation in the individual taxa variation between the sites was explored. The null hypothesis was that all taxa would be found in similar proportion at all sites, regardless of urban-rural gradient.

3.3 METHODS

3.4 Study sites

To investigate the abundance and diversity of macro-epigeal invertebrates on six plots each from seven allotment sites, a series of pitfall traps were used. For the rationale and the background information on site choice, see Chapter 2, Section 2.13. To summarize, the sites involved in this study are: Hunmanby (HN); Bridlington (BR); Driffield (DR); Beverley (BV); Cottingham (CT) and in Hull, two sites: Bude (BD) and Newland (NW). (See Appendix 3.1 for example allotment site photographs.) These sites lie on the North-South railway line between Scarborough and Hull. Throughout this Chapter individual plots at these sites are referred to as 'traditional' (T) or 'wildlife-friendly' (W) based upon the criteria discussed in Chapter 2, Section 2.10.12.

3.5 Allotments and gardens

Allotments have many features in common with gardens, e.g. clearly defined boundaries, regularly disturbed or replanted, small-scale management, so they may share similar features that can be measured in similar ways. Smith *et al*. ($2006_{a,b}$) measured a large number of parameters to determine 'urban-ness' in their study of Sheffield gardens when investigating urban biodiversity in their Biodiversity in Urban Gardens in Sheffield (BUGS) project. Of the many variables measured by the BUGS research, they found that only a few had any relevance in relation to invertebrate community abundance and diversity (Smith *et al*., $2006_{a,b}$). Therefore as allotments are similar to gardens in many ways, only those identified by BUGS as being pertinent to epigeal invertebrates were measured for the current study at each allotment site, along with some parameters that were particular to allotments e.g. plot size. Site parameters which were also used by Smith *et al*. (2006_b) are indicated with an asterisk in the following list. The factors used in the current study were:

- population of each city/town/village*;
- site area (ha)*;
- area of hard surface (%) within 500 m radius*;
- area of hard surface (%) within 1 km radius*;
- area of hard surface (%) within 2 km radius;
- number of trees >2m height on site*;
- number of trees greater than 2 metres height in surrounding 100 metres.
- Number of allotments sites in the village/town/city
- number of plots on site;
- average plot size;
- Land allocation as per the local authority plan
- Land allocation in the surrounding 1 km as per the local authority plan
- Percentage farmland in the surrounding 1 km.

In particular, one of the key factors found to be important to invertebrate abundance and diversity in the BUGS studies was the amount of hard surface surrounding the study sites. To calculate this, the proportion of cells having more than 25% coverage by hard surface i.e. residential or industrial zones in 100m x 100m cells in a circular area of 10,000m^2 (1 ha), centred on each allotment site, were judged from O.S. 1:25,000 scale maps (see Smith *et al.*, 2006_b for similar). In addition, the Local Authority maps for each area were used to determine the land allocation according to the authorities' local plans. This included the term 'unallocated' if the land was not designated for a particular use.

3.6 Statistical analysis of environmental data

All of the physical data (see list above and Table 3.1 in Section 3.10) were root transformed and subjected to Principle Components Analysis (PCA), using SPSS version 16, Primer version 6 and CAP version 3.1 to determine any similarities or differences in the sites and thus reveal any potential urban-suburban-rural gradient (Objective 3.1). All three packages were used as each yielded different useful aspects to the processing and interpretation of the data. Significance levels for *p* are 0.05 and 0.01; numbers rounded to two decimal places, where appropriate, for all data, unless otherwise stated.

Clarke and Warwick (2001) and Pallant (2005) recommend that correlation-based Principle Component Analysis is used to provide an empirical summary of environmental data sets. Prior to PCA, an examination of the draftsman plots (Appendix A3.2) highlighted the need to root-transform the environmental variables data. (The process shows how skewed each pair of variables are (Clarke and Gorley, 2006)). PCA was then performed to assist in defining the urban-rural gradient. It was a particularly useful technique in this context as any potential collector bias to probable groupings of the samples does not affect the outcome of the analysis (Scott *et al*., 2001). To facilitate interpretation of the data, the strength of the two principal components produced by PCA was examined using orthogonal rotation, using SPSS.

Pearson product-moment correlation was used to provide a numerical summary of the direction and strength of the linear relationship between the taxonomic abundance along the urban-rural gradient, in relation to management style (Pallant, 2005; Tabachnick and Fidel, 2007).

3.7 Biological data

3.7.1 Pitfall trapping

The most commonly used method for sampling epigeal ground fauna is pitfall trapping (e.g. Chiverton and Sotherton, 1991; de Snoo, 1999; Schmidt *et al*., 2005; Jimenez-Valverde and Lobo, 2007) (see Figure 3.1). Although there is literature highlighting the limitations of this method, e.g. digging in effects; body size of species attracted; taxa attracted to the trap, (Luff, 1975; Nilsson *et al.*, 1988; Jarosik, 1992; Duelli and Obrist, 1998; Raworth and Choi, 2001) it remains the most cost effective way and popular way of sampling. Pitfall trapping does not sample all epigeal taxa equally; rather, it is more a measure of *relative* activity and *relative* abundance, hereafter referred to as abundance in this study. Many of the limitations highlighted in the literature can be minimized by applying a few simple steps in the methodology, as discussed below.

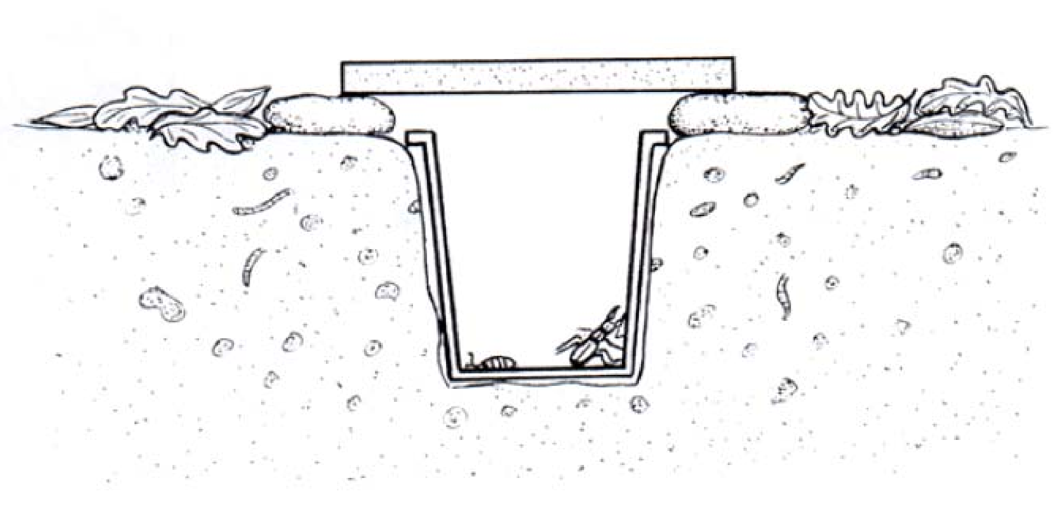


Figure 3.1 Example of a pitfall trap *in situ.* (Source: Cary Institute of Ecosystem Studies, 2010)

3.7.2 Timing of trapping

As it would be unfeasible to sample continuously throughout the summer due to gaining access to the plots issues and the vast number of individual organisms that would be collected, a compromise had to be made. The Isopoda and Myriapoda are most active in spring and autumn (Richards, 1995) whilst many spiders become most conspicuous by May (Roberts, 1996). Den Boer and Den Boer-Daanje (1990) had long term pitfall data sets (>10 years) from which it could be deduced that sampling in May and September in the current study would be expected to result in the capture of all the beetle families likely to be encountered. It was therefore decided that sampling in May and September would be the optimum times to set the pitfall traps on the allotment plots on the site discussed in Section 3.4, and that these data would be pooled as a representative sample of the ground fauna of the sites in subsequent analyses.

3.7.3 Trap position

Each of the forty-two allotment plots was mapped using an appropriate scale on graph paper, split into squares representing 2 x 2m, usually equating to around 1-30 squares, depending on plot size. A random number was generated from this range for each plot. This number then became the starting point for the location of the pitfall traps. The traps were set 2m apart in a 2 x 3 array. If the proposed location for a pitfall trap fell on a hard surface, e.g. concrete path or a shed, the nearest suitable location was chosen. It must be borne in mind that these traps were set on working allotments, belonging to different individuals on each plot, therefore disruption to their working of the plot had to be treated sensitively. In most cases, the plot-holders gave complete free reign as to where the pitfall traps could be set and as the chosen random square was of a reasonable size, there was some flexibility in how close they were to existing crops. Only in one case did the plot-holder ask for the traps to be set in a section other than the one allocated by the random number technique.

3.7.4 Trapping technique

In May 2006, each plot had six plastic vending cups (max. diameter 7.3 cm x 9.6 cm depth) sunk to ground level over a number of days prior to making them active. The cups had been dug in over the previous few days to try and avoid the effects of 'digging in' (Greenslade, 1973) i.e. some species may initially be attracted to the trap because the site has recently been disturbed. Lids were placed over the cups to prevent rain getting in and to deter larger animals such as toads from falling in and to lessen the chances of the contents being drunk by larger mammals such as dogs. The lids were made from Petri dishes with short lengths of pea canes super-glued on to form a small supporting tripod (see Appendix 3.3). As traps were set, these lids were pushed into the ground so that they remained closed until needed.

On the 1st May, 2006 the traps were set as 'live' with c.100 ml of propylene glycol at 20% solution, with 1% detergent and salt added to break the water tension and break down slug/snail slime, respectively. Propylene glycol was deemed to be the least environmentally harmful chemical that could realistically be used, which was important as half of the plots to be sampled were managed organically.

The live traps were left *in situ* for a week, before removing them on the 8th May 2006 to collect their contents. The contents of each trap were then rinsed with water and put into 4% formalin for four days to 'fix' the samples. Fixed samples were then stored in 70% IMS prior to identification. The process was repeated in September 2006, giving a total of 528 samples. Due to the large volume of invertebrates collected, only three samples per plot were analyzed, whilst the other half formed an "insurance policy" in the event of vandalism or other disturbance to the pots. Due to some vandalism and suspected tampering with some of the pitfall traps, data from ten plots could not be used. In the BUGS studies (e.g. Smith *et al*., 2006$_{a,b}$.), only three pitfall traps were used per garden and the data were pooled (ave. garden size $79.5 \pm 81.5m^2$; Loram *et al*., 2007), therefore three pots were deemed to be an acceptable sample size in this study, pooled per allotment plot.

All collected organisms were removed from the pots and recorded to morpho-species level. The target taxa that were examined were: Arachnida (Araneae); Isopoda (Oniscidea); Chilopoda; Diplopoda; Coleoptera (Carabidae) and Gastropoda (the same taxa that were studies in the BUGS project (Smith *et al*., 2006 $_{a,b}$.)). Some taxa found were relatively rare, e.g. bugs, bees, worms and pseudoscorpions. These species are not traditionally caught using pitfall traps (e.g. see Paoletti, 1999; Standen, 2000; Eremeeva and Sushchev, 2005; Smith *et al*., 2006$_{a}$), so they may be seen as 'incidental by-catch', and were therefore not considered any further in this study. Similarly, although there were quite high numbers of Diptera, again they are not usually counted as epigeal and would therefore not usually be sampled by pitfall traps (e.g. Wheater and Cook, 2003). A few pots contained high numbers of ants, but these were not included in the analysis, as ants tend to follow each other's trails, so if a pot initially contained a few ants, it is likely that many more would follow them in, inflating the numbers, creating bias (Davis and Utrop, 2010). Again, they would not normally be sampled using only pitfall traps (e.g. York, 2000).

Collembola made up c.23% of the catch; however, this number only represents the number of individuals remaining after the fixing process. Some individuals were small enough to pass through the sieving process, therefore final numbers recorded do not constitute a true reflection on the total numbers present, therefore the data on Collembola will not be considered in any further detail.

The specimens were identified using stereo-microscopes, a camera microscope and the following keys:

- Arachnida: Roberts, M.J. (1996) *Spiders of Britain and Europe*, Collins, London.
- Isopoda: Hopkin, S. (1991) *A Key to the Woodlice of Britain and Ireland*, FSC, Preston Montford.
- Myriapoda – Lee, P. (2005) *Provisional Keys to British Millipedes v. 2* (unpublished draft); Barber, A.D. (2003) *A guide to the identification of British centipedes*: Aidgap Test Version 2003, FSC, Preston Montford (unpublished draft).
- Coleoptera: Luff, M.L. (2007) *The Carabidae (ground beetles) of Britain and Ireland*. RES Handbooks, Vol. 4, Part 2 (2nd Ed.) Field Studies Council, Shrewsbury; Forsythe, T.G. (2000) *Ground Beetles*, Naturalists' Handbooks 8, Richmond Publishing Co. Ltd., Slough; Unwin, D.M. (1988) *A key to the families of British beetles*. Field Studies Council, Shrewsbury.

- Mollusca – Cameron, R. (2003) *Land Snails in the British Isles*, Aidgap and FSC, Preston Montford; Kerney, M. and Cameron R.A.D. (1979) *A Field Guide to the Land Snails of Britain and North-west Europe*, Collins, London; Sankey, J. (1987) *How to begin the study of Slugs and Snails*, Richmond Publishing Co., Richmond.

For the first stage of the data analysis, taxa were identified mainly to Order, except in the case of the centipedes, millipedes or spiders, (identified to Class). Hereafter, these groups of species will collectively be generally referred to as 'taxonomic richness' or simply 'taxa' or 'morphospecies' where appropriate. (Subsequent analysis in Chapter 5 will involve identification of the taxa down to Genus or species where possible.)

3.8 Statistical analysis of biological data

SPSS version 16 and Pisces Conservation Ltd 'Species Diversity and Richness IV v. 4.0' were used for the statistical analysis.

To test the hypothesis that all sites would have the same invertebrate abundance, a chi-square test for differences was carried out (Tabachnick and Fidell, 2007) (Objective 3.2). The mean abundance of morpho-species was examined using one-way ANOVA, testing the hypothesis that all sites have the same mean invertebrate abundance. Where significant differences were found, Tukey tests were used *a posteriori* to identify the source of the significance (Ennos, 2007). The same procedure was then used to examine any variation between the individual taxa at each site i.e. were similar proportions of beetles, for example, found at all sites?

Correlation analysis, using the Pearson product-moment correlation coefficient, was then used to explore the strength and direction of any linear relationship between the total numbers of individuals found to the principal components, which represent the urban-rural gradients (Objective 3.3).

The Species Richness & Diversity III v. 3.0 package (Pisces Conservation Ltd) was used to test the hypothesis that all sites would have the same species diversity and evenness, the diversity among the different taxa was examined using a range of indices (Objective 3.4). The most commonly used diversity measure is the Shannon-Wiener diversity index (H), which measures the rarity and commonness of species in a community (Magurran, 2004). As the methods used in this study may be replicated to allow a quick assessment of similar sites, it was useful to use indices that were both familiar and popular, therefore, the Shannon-Wiener diversity index (Equation 1) and Pielou's evenness index (Equation 2) were used to assess relative species diversity and evenness in this section of the study.

$$H = - \Sigma p_i \ln (p_i) \qquad \textit{Equation 1}$$

where p_i = the proportion of a particular species in a sample which is multiplied by the natural logarithm of itself (Fowler and Cohen, 1990).

Pielou's equitability index (Clarke and Warwick, 2001) was then calculated: where H(s) = the Shannon-Wiener index H(s); H(max) = the theoretical maximum value for H(s) if all species in the sample were equally abundant:

$$j = \frac{H(s)}{H(max)} \qquad \textit{Equation 2}$$

One-way ANOVAs were then used to examine any differences in taxa diversity (DV) along the urban-rural gradient (IV) (Objective 3.5). The null hypothesis tested was that all taxa would be found in similar proportion regardless of position on the gradient. Again, where significant differences were found, Tukey tests were used *a posteriori* to identify the source of the significance.

3.9 RESULTS

3.10 Establishing the urban-rural gradient

A ‘common sense’ approach to classify the chosen allotment sites as urban, suburban or rural, based mainly on population and size, would suggest that the most urban sites would be in Hull (Newland and Bude), a large city, possibly with Bridlington being classified as relatively urban too. The most rural sites would likely be Driffield and Hunmanby, due to their location on the edge of small villages or towns, whilst Cottingham and Beverley were most likely to be classed as suburban. The range of data gathered to support these assumptions is summarized in Table 3.1 (see Methods Section 3.5 for details). These data show considerable variation between the physical parameters of each allotment site and are used to assess whether or not these assumptions were true or not regarding the presence of an urban-rural gradient.

Table 3.1 Physical parameters for each allotment site used for PCA. (HN=Hunmanby; BR=Bridlington; DR=Driffield; BV=Beverley; CT=Cottingham; BD=Bude; NW=Newland.) (See Section 3.5 for details.)

	HN	BR	DR	BV	CT	BD	NW
Population	6000	33837	11477	17549	17263	243589	243589
Site area (ha)	1.00	1.50	3.10	2.50	1.40	2.24	8.30
No. of plots	10	56	113	17	9	74	280
Ave. plot size	76	300	300	270	200	250	350
% hard surface 500m	66.25	82.50	37.50	95.00	93.75	70.00	87.50
% hard surface 1km	45.63	85.94	31.56	71.56	70.00	76.88	91.56
% hard surface 2km	12.31	60.38	25.77	54.62	48.85	75.77	95.00
No. of trees on site	1	0	0	1	0	0	62
No. of trees in 100m	400	22	208	11	23	1	180
No. allotment sites	1	2	2	3	3	22	22
% famland 1 km	40	0	75	0	5	0	0
Land allocation: site	1	3	1	2	1	5	3
Land allocation: 1 km	1	8	9	1	1	4	4

The thirteen physical variables were subjected to Principle Components Analysis with Varimax rotation using both SPSS Version 16 and CAP 3.1 to establish the relationships between allotment sites. Although the data matrix was relatively small (ninety-one cases), most of the loading values exceeded 0.8 (see Appendix A3.4), therefore the test was sufficiently robust (see Tabachnick and Fidell, 2007), as the objective of the PCA was simply data exploration, to confirm whether or not distinct urban-rural groupings existed.

Prior to performing PCA the suitability of data for factor analysis was assessed. Inspection of the weightings of the twelve variables in a correlation matrix revealed the presence of many coefficients of ***R*** = > 0.3 and above (the cut-off threshold suggested by Tabachnick and Fidell, (2007)), therefore their factorability was suitable.

PCA revealed the presence of three components with eigenvalues greater than 1, explaining 52.32, 24.18 and 13.13 % of the variance respectively. An inspection of the screeplot (see Appendix A3.5) revealed a clear break after the second component and as these two components accounted for 76.49 % of the variation, this was the most parsimonious explanation of the data variance (Tabachnick and Fidell, 2007). The regression factor scores for the first two components are shown in Table 3.2.

Table 3.2 Regression factor scores for the two highest components for a PCA of allotment physical characteristics.

	Component	
	1	2
Area of hard surface (%) within 2 km radius	0.973	
Population	0.893	
No. of allotment sites per town	0.867	
Hard surface (%) 1 km	0.825	-0.481
Land allocation: site	0.821	
Farmland (%) 1 km	-0.797	0.582
Ave. plot size	0.713	
Site area (ha)	0.706	0.575
Hard surface (%) 500 m	0.455	-0.751
No. of plots	0.680	0.728
No. of trees 100 m	-0.459	0.654
Land allocation: surrounding		0.622
No. of trees on site	0.620	0.397

The regression factor scores of the individual sites for the first two principle components are plotted in Figure 3.2a. PC1 clearly splits the sites into urban, suburban and rural, showing the relative distance apart between the sites (Objective 3.1). The very clearly separated Hull site, Newland (NW) allotments, equates to an ‘urban’ classification; Beverley (BV), Cottingham (CT) and Bridlington (BR) group together in a ‘suburban’ group, with Bude (BD) slightly separated from this group, whilst Driffield (DR) is in a ‘rural’ classification, with Hunmanby (HN) somewhat separated from it, but still in the rural category.

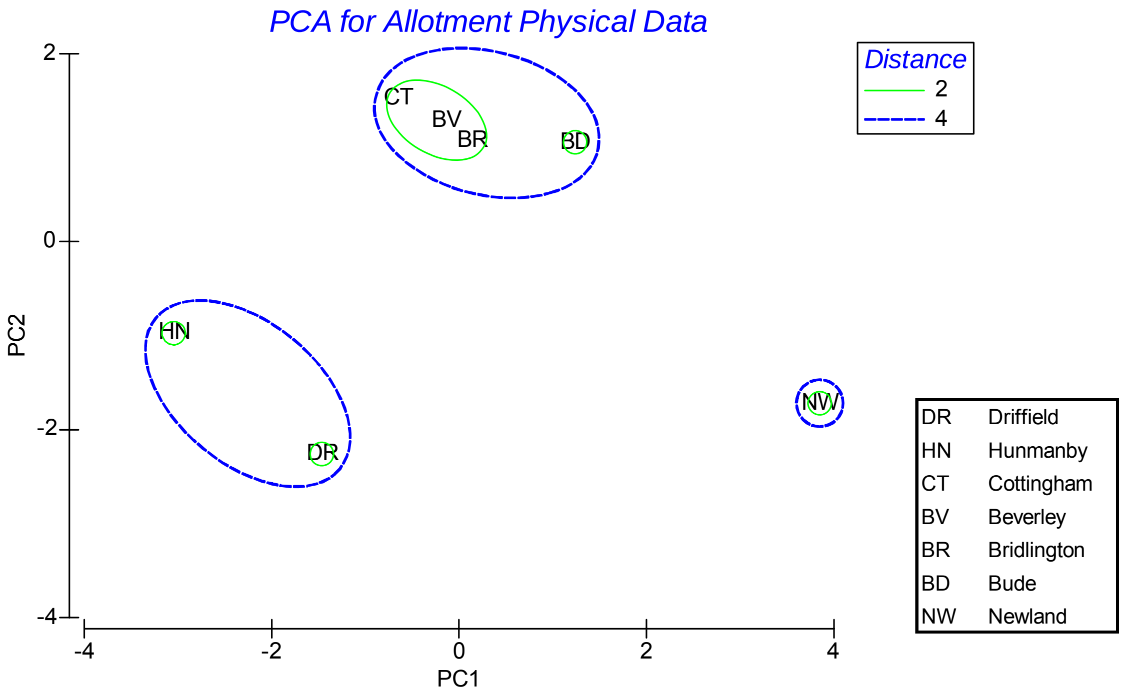


Figure 3.2a Principle Components Analysis plot of physical data to highlight any potential urban-rural gradient. PC1 and PC2 account for 82.7 % of the variance between sites. Distance grouping values based on Euclidean distance. NW represents the most urban site; BD, BR, BV & CT represent suburban sites; DR and HN, represent the most rural sites (see text for details).

To show the key factors defining the urban-suburban-rural gradient, the PCA results are re-plotted showing the thirteen factors in Figure 3.2b. The results show that most urban site(s) are most likely to have a higher proportion of hard surface in the surrounding 2 km diameter of the allotment site; higher human population; a greater number of allotment sites; a higher proportion of hard surface in the surrounding 1 km diameter of the allotment site; surrounding land allocated as residential; a higher site and higher plot area and finally, to a slightly lesser degree, a higher number of trees on the allotment site. In this case, Newland allotments is by far the most urban.

The rural sites are most likely to have the highest percentage of farmland in the surrounding 1 km diameter of the allotment site; the least amount of hard surface in the surrounding 500m; a higher number of trees surrounding the site and the surrounding land classed as “unallocated”. In this case, Driffield and Hunmanby would be classed as rural. Intermediate characteristics are classified by the site area and the number of plots. Under these groupings, Cottingham, Beverley, Bridlington and to a lesser extent, Bude, would be classed as suburban, although Bude lies somewhat towards the more urban category than the former three sites.

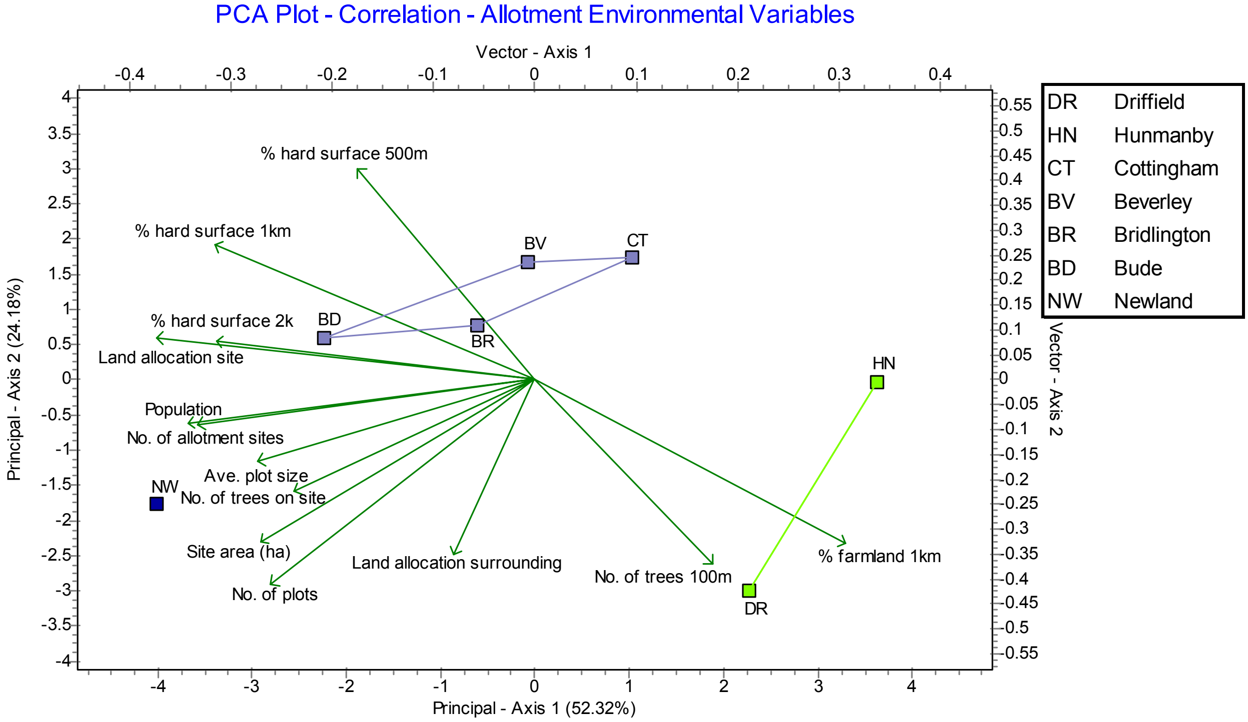


Figure 3.2b Principle Components Analysis plot of physical data to highlight any potential urban-rural gradient, showing contribution of each vector (see text for details; full vector details are in Section 3.5).

As shown above, two principle components were optimal and were therefore subject to Varimax rotation. The rotated solution identified the nature of the underlying latent variable represented by each component i.e. were they mainly urban, suburban or rural (see Table 3.3). There were a number of strong loadings, with some variables loading substantially on only one component, although some variables did have cross loadings. The two-component solution explained a total of 76.50 % of the variance, (the same as the un-rotated PCA) with Component 1 contributing 39.98% and Component 2 contributing 36.52%. Thus, the rotated solution shows that the number of plots, site area and number of trees on site were the highest three contributors to urban sites respectively, with no cross loading. This was followed by population and number of allotment sites contributing equally, but both had a level of cross loading. The percentage of farmland and the number of trees within 100m were the highest two contributors to rural sites respectively, with no cross loading. The amount of hard surface within 1 km, 500m and 2 km respectively were effectively double negative values, indicating that rural sites has the least amount of hard standing surrounding the sites.

Table 3.3 Pattern/structure for coefficients: Varimax Rotation with Kaiser Normalization of Two Factor Solution for Allotment Physical Characteristics. Component 1 indicates urban loadings, component 2 rural loadings: see Figure 3.1b above.

Rotated Component Matrix		
Characteristic	**Component**	
	1	2
No. of plots	0.991	
Site area (ha)	0.910	
Population	0.773	0.475
No. of allotment sites	0.755	0.455
No. of trees on site	0.728	
Ave. plot size	0.726	
Land allocation: surrounding	0.568	-0.328
Farmland (%) 1km		-0.964
Hard surface (%) 1km		0.907
Hard surface (%) 500m		0.864
No. of trees 100m		-0.794
Hard surface (%) 2k	0.632	0.755
Land allocation: site	0.522	0.648

3.10.1 PCA results summary

To summarize, most of the environmental factors measured played a part in explaining the variation in the urban-suburban-rural gradient. The number of plots, site area and number of trees on site respectively contributed the highest three factors to describe urban sites. The amount of farmland in the surrounding 1 km and the number of trees surrounding the site contributed most of the variation to describe rural sites, whilst the other factors were intermediate. It appears therefore that an urban-rural gradient was apparent to some extent in the study sites chosen, based on the physical data. Newland is therefore classed as the urban site, Bude, Bridlington, Beverley and Cottingham the suburban sites, whilst Driffield and Hunmanby were classed as rural. These classifications will be used throughout the remaining Chapters.

3.11 Invertebrate abundance per site

Pitfall trapping resulted in the collection of 11,718 individual organisms from the eight target taxa on seven allotment sites (see Appendix A3.6). A chi-square test to test the hypothesis that invertebrate abundance would be even across all sites (Objective 3.2) showed that there were significant differences in the total invertebrate abundance observed per site ($\chi^2 = 1327.06$, $p<0.001$). The null hypothesis was therefore rejected.

In relation to individual abundance per plot on each site, there was a significant difference in the mean number of individuals [$F_{(6, 67)} = 3.01$, $p<0.01$; Tukey $p = 0.05$], (Figure 3.3; sites grouped as per gradient suggested in Figure 3.1) (Objective 3.3). The rural Driffield (DR) was statistically different, with the lowest abundance, from the urban Newland (NW) site with the highest abundance. Although none of the other sites were statistically different from each other, there was a trend towards an increase in mean abundance moving towards to the city centre (Figure 3.3).

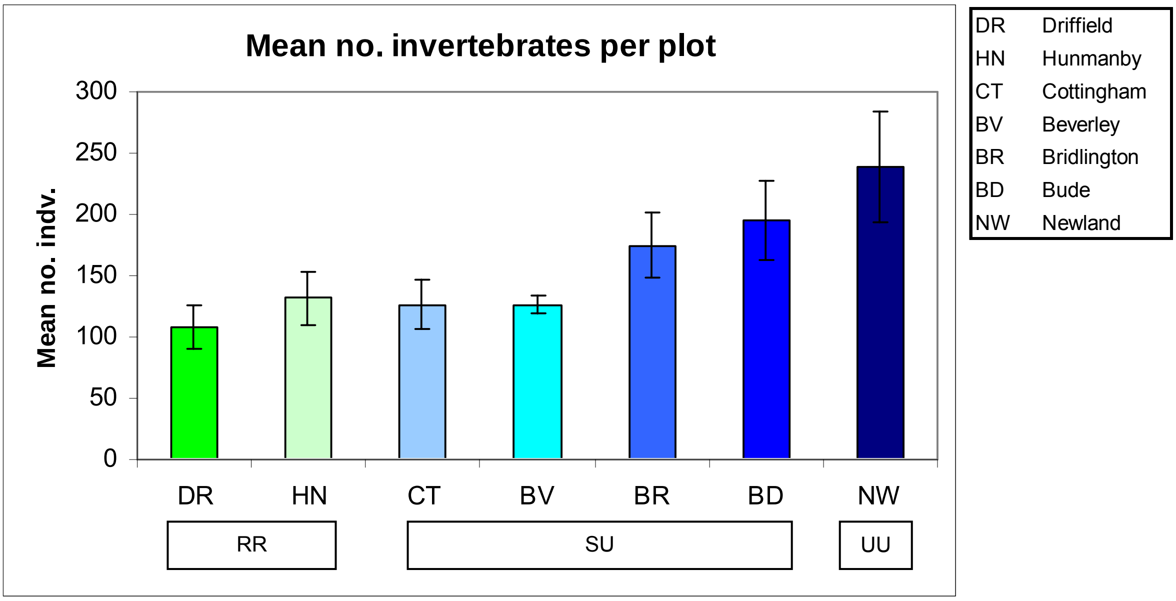


Figure 3.3 Mean number of individuals per site (+ SE), based on individual plot totals (N=74), grouped per urban-rural gradient. (RR=rural; SU=suburban; UU=urban)

3.12 Invertebrate abundance along the urban-rural gradient

The relationship between the urban-rural gradient, as shown by PC1 and mean abundance was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity (Pallant, 2005). There was a strong negative correlation between the two variables ($r = -0.87$, $n = 7$, $p < 0.05$), with high invertebrate abundance associated with low rural environmental variables. The linear regression in Figure 3.4 below shows the relationship between these two variables. The coefficient of determination is 75.2% i.e. the level of 'urban-ness' explains 75% of the level of mean abundance.

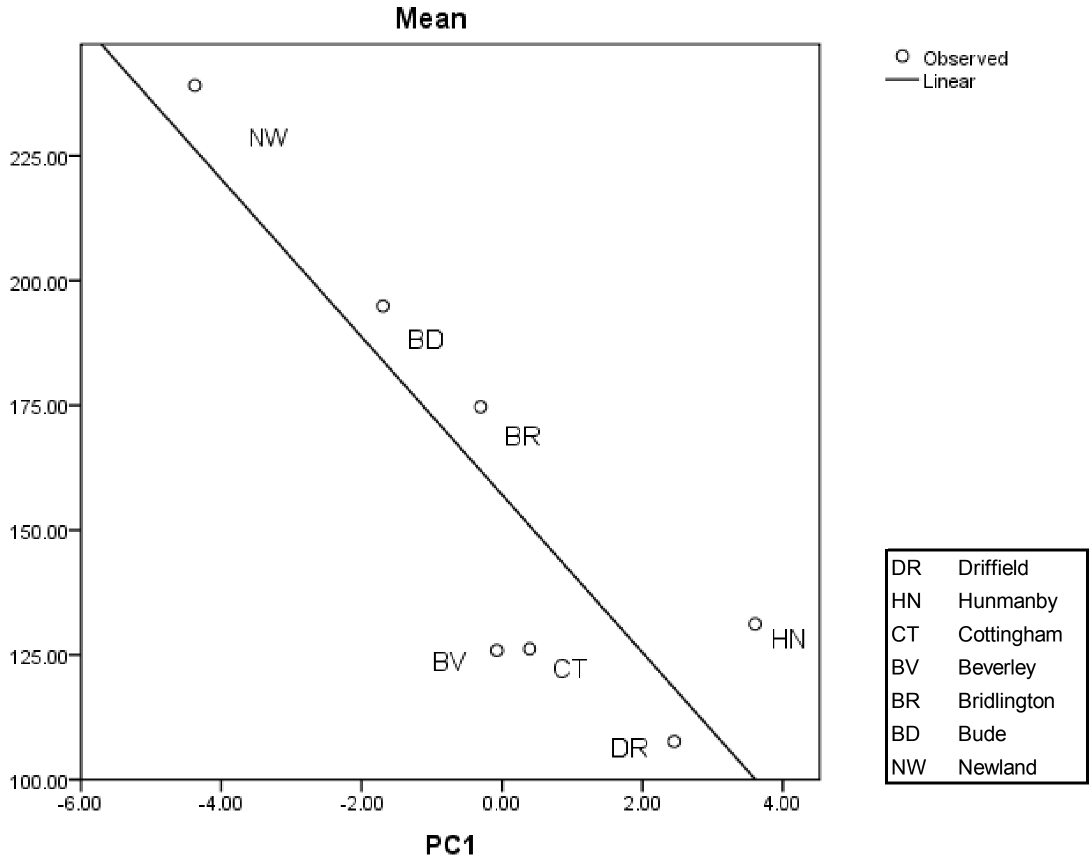


Figure 3.4 Linear regression between PC1 (see Figure 3.2) and the mean number of invertebrate individuals (y-axis) found per allotment site.

3.13 Invertebrate abundance per taxa

The most abundant taxa were beetles, woodlice and spiders (see Figure 3.5) (Objective 3.2). They constituted 37.95%, 24.03% and 16.93% of the catch respectively. The other five taxa ranged between 0.73%-8.96% of the total catch.

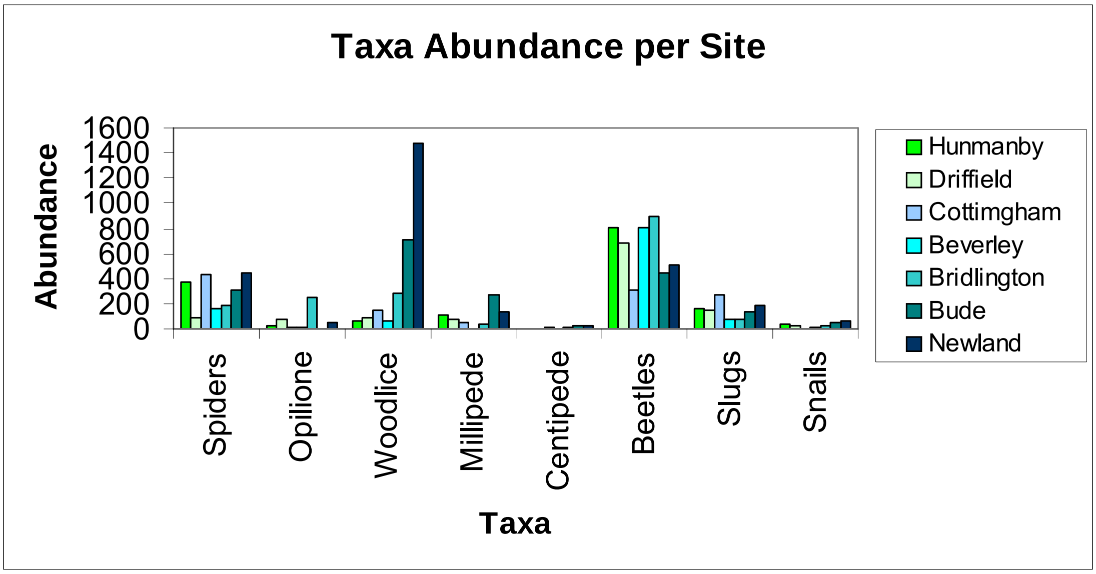


Figure 3.5 Total numbers of individuals of each taxon for each of seven sampled allotment sites. (See Figure 3.6 for individual graphs per taxon and site.)

3.14 Individual taxa abundance

Each of the eight taxa was examined individually to see if there was any significant difference in abundance across the seven sites and the three gradient classifications: rural, suburban, urban, as discussed below.

3.14.1 Spider abundance

A total of 1,984 spiders were found across all the allotment sites. The highest abundance was at Cottingham and the lowest was at Driffield. The mean numbers of spiders per plot are shown in Figure 3.6a; the overall mean per allotment site was 26.81 (±3.50). There was no significant difference between the numbers of spiders found across the different allotment sites [$F_{(6, 67)}$ = 1.94, p=0.09].

3.14.2 Opilione abundance

A total of 439 opilione were found across all the allotment sites. The highest abundance, by far, was at Bridlington and the lowest was at Bude.

The mean numbers of opilione per plot are shown in Figure 3.6b; the overall mean per allotment site was 5.93 ($\pm$2.76). There was no significant difference between the numbers of opilione found across the different allotment sites [$F_{(6, 67)}$ = 1.41, p=0.22].

3.14.3 Woodlice abundance

A total of 2,816 woodlice were found across all the allotment sites. The highest abundance was, by far, at Newland and the lowest was at Hunmanby, closely followed by Driffield. The mean numbers of woodlice per plot are shown in Figure 3.6c; the overall mean per allotment site was 38.05 ($\pm$8.68). There was a significant difference between the numbers of woodlice found across the different allotment sites [$F_{(6, 67)}$ = 5.54, p>0.05]. The *post hoc* Tukey tests showed that the Newland plots were significantly different from all of the other sites, apart from Bude, due to its relatively high abundance. There were no other significant differences in mean abundance between any of the other sites.

3.14.4 Millipede abundance

A total of 692 millipedes were found across all the allotment sites. The highest abundance was at Bude and the lowest was at Beverley. The mean numbers of millipedes per plot are shown in Figure 3.6d; the overall mean per allotment site was 9.35 (±1.83). There was a significant difference between the numbers of millipedes found across the different allotment sites [$F_{(6, 67)} = 3.87$, $p>0.05$]. The *post hoc* Tukey tests showed that the Bude plots were significantly different, with high abundance, from all of the other sites apart from Newland. There were no other significant differences in mean abundance between any of the other sites.

3.14.5 Centipede abundance

A total of 86 centipedes were found across all the allotment sites. The highest abundance was at Bude and the lowest was at Driffield, closely followed by Hunmanby. The mean numbers of centipedes per plot are shown in Figure 3.6e; the overall mean per allotment site was 1.16 (±0.19). There was a significant difference between the numbers of centipedes found across the different allotment sites [$F_{(6, 67)} = 3.21$, $p>0.05$]. The *post hoc* Tukey tests showed that the Bude plots were significantly different from Hunmanby and Cottingham, whilst there were no other significant differences in mean abundance between any of the other sites.

3.14.6 Beetle abundance

A total of 4,447 beetles were found across all the allotment sites. The highest beetle abundance was at Bridlington and the lowest was at Cottingham. The mean numbers of beetles per plot are shown in Figure 3.6f; the overall mean per allotment site was 60.09 (±4.86).

There was a significant difference between the numbers of beetles found across the different allotment sites [$F_{(6, 67)} = 3.64$, $p>0.05$]. The *post hoc* Tukey tests showed that the Cottingham plots were significantly different with the lowest abundance, from the Bridlington and Beverley sites with relatively high abundance. There were no other significant differences in mean abundance at any of the other sites.

3.14.7 Slug abundance

A total of 1,050 slugs were found across all the allotment sites. The highest abundance, by far, was at Cottingham and the lowest was at Beverley, closely followed by Bridlington. The mean numbers of slugs per plot are shown in Figure 3.6g; the overall mean per allotment site was 14.19 ($\pm$1.59). There was a significant difference between the numbers of slugs found across the different allotment sites [$F_{(6, 67)} = 3.79$, $p>0.05$]. The *post hoc* Tukey tests showed that the Bridlington plots were significantly different from Driffield and Beverley each other, whilst there were no other significant differences in mean abundance at any of the other sites.

3.14.8 Snail abundance

A total of 204 snails were found across all the allotment sites. The highest abundance was at Newland and the lowest was at Driffield. The mean numbers of snails per plot are shown in Figure 3.6h; the overall mean per allotment site was 2.76 ($\pm$0.54). There was no significant difference between the numbers of snails found across the different allotment sites [$F_{(6, 67)} = 1.73$, $p=0.13$].

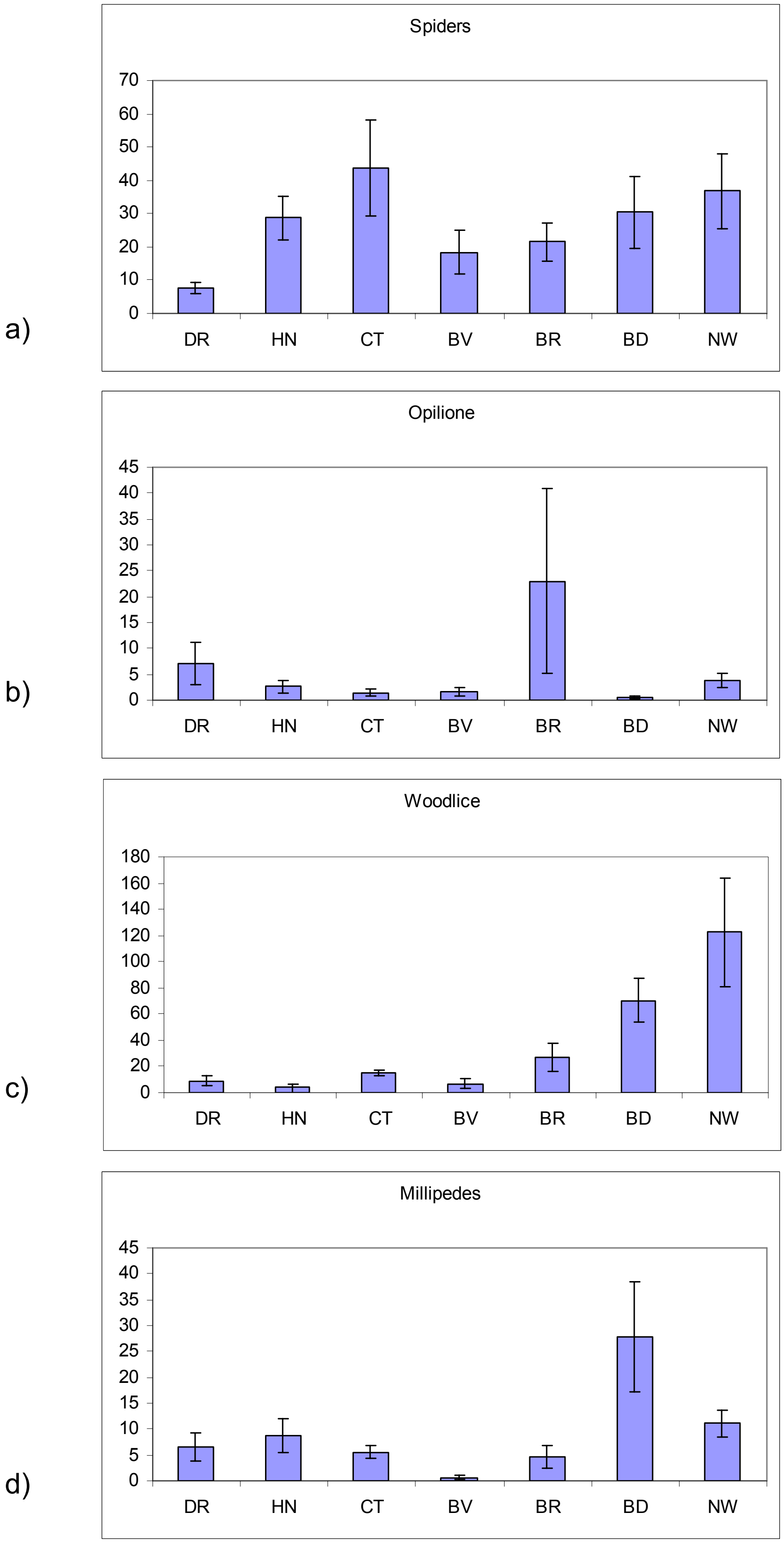


Figure 3.6 Mean plot invertebrate taxon abundance per allotment site (±SE).

e)
f)
g)
h)

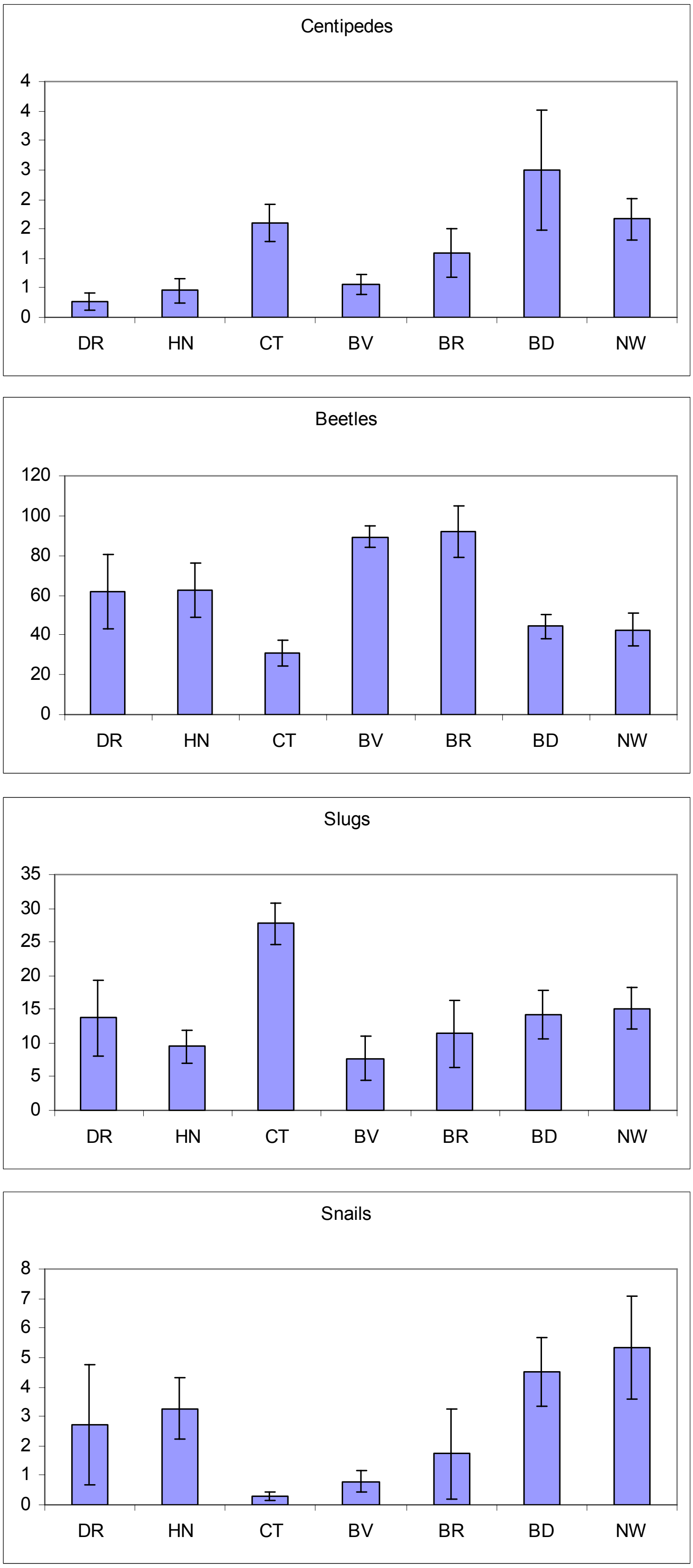


Figure 3.6 (cont) Mean plot invertebrate taxon abundance per allotment site (±SE).

3.15 Taxa diversity

The diversity and evenness of the taxa were investigated using the Shannon-Wiener diversity index and Pielou's evenness scores (see Section 3.8). Each index was calculated using the total number of individuals per plot (N=74) to generate the H and J values, grouped by allotment site (Objective 3.4). From these values, the mean and standard error was calculated per site (see Figure 3.7). A one-way ANOVA tested the null hypothesis that there would be no significant variation between the Shannon values at different allotment sites. This showed that there was a significant difference between sites ($F_{(6,67)} = 4.69$, $p<0.05$) (Objective 3.5).

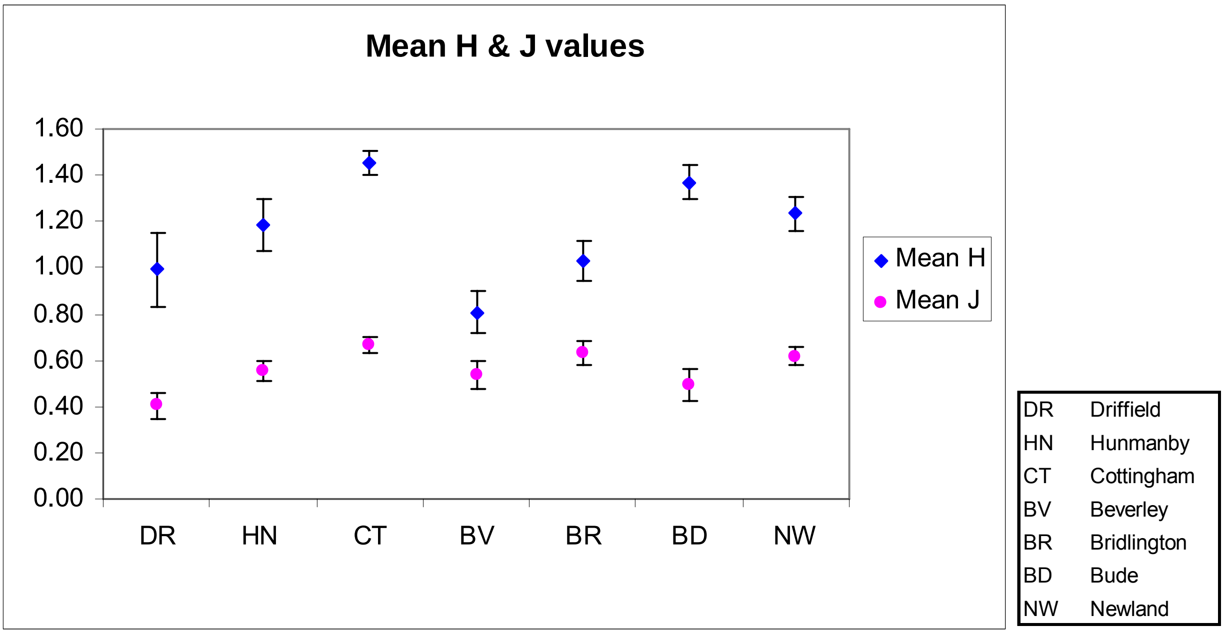


Figure 3.7 Diversity (H) and evenness values (J) for each allotment site based on the mean H and J values for each plot (N=74). (RR=rural; SU=suburban; UU=urban)

A *post hoc* Tukey test (p = 0.05) illustrated that Cottingham had the highest diversity. This site was significantly more diverse than Driffield or Beverley. The Bude site was also significantly more diverse than Beverley; the latter site has the lowest overall diversity score. These were no significant differences in H value between the other sites.

The Tukey results for the Pielou evenness scores did not show the same pattern of differences. The largest variation showed a significant difference between the lowest values at Driffield compared to the highest scores at Cottingham, Bridlington and Newland respectively. There were no significant differences in evenness between any of the other sites.

3.16 Overall results summary

To summarize, it has been shown that the environmental variables have identified an urban-rural gradient among the seven allotment sites. The key components of an urban site are the number of plots, site area and number of on-site trees along with site area, whilst the main elements of a rural site are the amount of farmland in the surrounding 1 km and the number of trees in the surrounding 100 m.

The epigeal invertebrates on the allotment sites vary in their abundance and diversity. Urban sites support the highest number of individuals, suburban sites are intermediate and rural sites have the lowest abundance.

With regard to diversity, the suburban sites contained sites with both the highest diversity and the lowest whilst the lowest evenness score was found on a rural site. There results illustrate therefore that Cottingham, a suburban site, had both the highest diversity and evenness. Beverley, also a suburban site had the lowest diversity and Driffield, a rural site, had the lowest evenness. All other sites were intermediate in diversity and evenness (see Table 3.4).

Table 3.4 Summary of main results of an epigeal invertebrate survey on seven Yorkshire allotment sites along an urban-rural gradient.

Site	Gradient	Abundance	Diversity	Evenness
Driffield	Rural	↔	↔	↓
Hunmanby	Rural	↓	↔	↔
Cottingham	Suburban	↔	↑	↑
Beverley	Suburban	↔	↓	↔
Bridlington	Suburban	↔	↔	↔
Bude	Suburban	↔	↔	↔
Newland	Urban	↑	↔	↔

Symbol	Score
↑	highest
↔	intermediate
↓	lowest

3.17 DISCUSSION

3.18 Establishing the urban-rural gradient

This Chapter established an urban-rural gradient (Objective 3.1) among the seven Yorkshire allotment sites and the relationship between the invertebrate taxa abundance (Objective 3.2) and diversity (Objective 3.4) that varied across that urban-rural gradient (Objectives 3.3 & 3.5). The PCA appears to largely support the initial ‘common sense’ approach to defining the urban-rural gradient in that the most apparently urban site, Newland (NW), was classified as such. However, whilst it may have been expected that Hunmanby would have been classified as the most rural site due to its location, smaller population and size and lower percentage of hard surface in the surrounding 2 km (Table 3.1), the most apparently rural site was Driffield (DR), then Hunmanby. This was mainly due to the higher percentage of surrounding farmland and the amount of surrounding trees (Figure 3.1b). Four of the sites formed a relatively tight ‘suburban’ group (Cottingham, Beverley, Bridlington and Bude). However, any conclusions reached in this study regarding gradient effects must follow the caveat given by McKinney (2008), which states that urban-rural gradient studies are a simplification of the complex patterns produced by urbanization.

3.19 Invertebrate abundance, diversity and evenness along the gradient

The sheer numbers of individuals found on the seven allotment sites (see Appendix A3.6) (Objective 3.2) suggests that allotments are valuable spaces for invertebrates, particularly in urban areas (Objective 3.3). The relative diversity and evenness of the taxa of each of the seven allotment sites (Objective 3.4) showed that one of the four suburban sites (Cottingham) had the highest diversity and evenness (Objective 3.5). Another suburban site (Beverley) had the lowest diversity, whilst rural Driffield had the lowest evenness. Once the urban-rural gradient had been established and the invertebrate abundance and diversity determined, these data were compared with the range of environmental variables to investigate any correlation between the gradient categories (see Figures 3.4 & 3.5), as discussed below.

Overall, there was a trend of increased abundance at the most urban site, which was not the result that may have been predicted (Objective 3.3). Intuitively, one would expect the rural areas to have the highest abundance, the suburban areas to be intermediate and the urban areas to have the lowest abundance, for the various reasons discussed in Section 3.1. The reasons for the reversal found may in part be due to the urban allotments being similar to island patches in an otherwise hostile landscape; the urban site was completely surrounded by housing, as were several of the suburban sites (see Table 3.1).

Many studies have found a link between urban invertebrate abundance and patch size (e.g. Jokimaki, 1999; Giuliano *et al*., 2004; Watts and Lariviere, 2004; Wolf and Gibbs, 2004) whilst others have not found patch size to be an important factor (Burghardt *et al*., 2008). In the current study, the site area (i.e. patch size) was one of the strongest positive factors in helping define urban sites (see Table 3.3). The other important factors were the number of plots on site and population. Thus, it would suggest that heavily residential areas should have a network of larger allotment sites to provide refuge for wildlife. However, as populations of different taxa on a site increase (species source), there is limited space for them to expand into, thus higher concentrations may be found until such time as the site may end up a species sink (Begon *et al*., 1996). This could have important implications for protecting existing urban sites and should be considered when new housing developments are proposed in heavily populated areas. These issues will be explored further in Chapter 6.

3.20 General Discussion

3.20.1 Allotment invertebrates and comparative studies

The composition of the taxa found in the current study was similar to that of the BUGS gardens studies discussed in more detail below, but the actual proportions of some of the taxa were quite different. For example, whilst Smith *et al*. (2006_b) found that the three most abundant taxa of the pitfall traps were woodlice (45%), beetles (25%) and slugs (19%) respectively, they constituted 24%, 38% and 9% respectively in the current study. In addition, spiders contributed 17%., compared to less than 5% in the BUGS study. The reasons for these differences are likely to be many. However, in the case of the slugs, it is more likely that this species would be much more actively discouraged from allotments, due to their primary *raison d'etre* as a means of growing food crops (see Chapter 2, Section 2.10.9) and as shown by the prevalent use of slug pellets (see Chapter 2, Section 2.10.14).

There are very few published studies specifically on allotment invertebrates (as discussed in Section 3.1), partly because, like private householders' gardens, allotment plots are outside the immediate control and management remit of local government and administrative authorities (Loram *et al*., 2007). This means there has been little interest in funding research and, as found by the Sheffield gardens (BUGS) project detailed at the end of Section 3.1, may reflect the difficulties in systematically obtaining data from a fragmented, rather inaccessible resources with multiple owners and tenants (Thompson *et al*., 2003; Thompson *et al*., 2004; Smith *et al*., 2005; Loram *et al*., 2007). Fortunately for the current study, one local authority, Hull City Council, along with the University of Hull, saw the value of such a study of allotments using the interdisciplinary approach advocated by Grimm *et al*. (2000) (see Chapter 1, Section 1.3). This was due in part to their close links to Local Biodiversity Action Plans and the potential not only to collect previously un-gathered scientific data, but for community engagement and participation, across local authority boundaries.

There were however some urban garden and wider urban greenspace studies that could be used for some comparisons. For example, Smith *et al*. (2006$_{a,b}$) studied a range of environmental and ecological factors, including the abundance and diversity of pitfall trapped invertebrates, in urban gardens in Sheffield, Yorkshire to determine their biodiversity value (BUGS project). They found that a broad range of factors operated at the individual garden scale, across geographic scales and per garden management styles, but different factors were important for the relative abundance of different species (Smith *et al*., 2006$_{a,b}$).

3.20.2 Exploring invertebrate abundance and diversity along the urban-rural gradient

Blair (1999) found in a study of butterflies and birds along an urban-rural gradient that the two groups differed in abundance. Whilst butterfly abundance did decrease as the sites become more urbanized, the birds were most abundant at the suburban sites. Similarly, a study by Eremeeva and Sushchev (2005) found that the city centre plots in Kemerovo, Russia, contained a higher abundance (but lower diversity) of butterflies than the suburbs. The trend was similar in the current study as that for the butterflies in the two discussed above, as the urban areas had the highest invertebrate abundance, followed by the suburban sites.

With regard to diversity, Zapparoli (1997) found a rich invertebrate fauna in the heavily urbanized city of Rome, which was partly explained by the mosaic pattern of urban environments caused by urbanization over the last 140 years, river modification (which caused flooding), land reclamation and disease vector control. He found that the main invertebrate reservoirs were parks and historical villas, urban and semi-natural greenspaces and archaeological sites, some of which formed 'green corridors'. However, researchers such as Kuhnelt (1982) have found that in general, the number of invertebrate species (species richness) diminishes from the outskirts to the centre of the city. In the current study, the results were rather mixed, with an overall trend towards highest diversity on most suburban sites (see Figure 3.7). In a review of the effects of urbanization on species richness, McKinney (2008) found that for invertebrates, about 30% of the studies had shown moderate levels of urbanization related to the intermediate disturbance hypothesis (IDH) (Connell, 1978). Thus, the current results, whilst not fully agreeing, do provide some evidence for the intermediate-disturbance hypothesis (Connell, 1978; Collins *et al.,* 1997; Eckert and Walz, 1998), which suggests that areas with a moderate degree of disturbance will be more diverse than either an undisturbed or a highly disturbed area. The IDH and other factors of disturbance (see Section 3.19 above) will be examined in greater detail in relation to individual species found in Chapter 5 and discussed further in Chapter 6.

According to the theory of MacArthur and Wilson (1963), the number of species on islands is the result of an equilibrium between immigration and extinction rates, which are determined by, among other things, the size of the island (Schaefer, 1982). Faeth and Kane (1978) have suggested that the same may be true for green islands in the urban area. Logically therefore, that is what one would expect to find on urban patches (effectively islands surrounding by hard surface) due to the increasing range of anthropogenic pressures (as discussed in the previous Chapters and summarised in Section 3.1) as one gets closer to a city centre. Although patch size is a somewhat simplistic explanation, it does go some way to help explain the current results found. These aspects will be more fully explored in Chapter 5 in relation to individual species.

The epigeal invertebrate abundance and diversity found on the Yorkshire allotments, especially in the city centre, would seem to compare favourably with other urban invertebrate studies in that the sites were relatively abundant and diverse. This is particularly true for the Hull sites, Newland and Bude, as Hull was built mainly on the floodplain, with the allotments forming a greenspace refuge matrix, similar to the findings of Zapparoli (1997) discussed above. The following Chapters will explore the abundance and diversity of the invertebrates in relation to allotment management style (Chapter 4) and any effects at individual species level for selected taxa (Chapter 5), along with management and climatic implications (Chapter 6) therefore will not be discussed in further detail here.

3.21 Summary

- From a range of measured environmental and biological variables, a pattern emerged showing groupings of allotment sites which could be classed as urban, suburban or rural. The key urban determinants were the amount of surrounding hard surface, site area and human population, whilst the main rural determinants were the amount of surrounding farmland and number of surrounding trees. The suburban sites were mainly characterized by site area and the number of plots on site.

- Beetles, woodlice and spiders constituted almost 79% of the total catch, with slugs, millipedes, opilione, snails and centipedes making up the other 21% respectively.

- The urban site contained the highest proportion of epigeal invertebrate abundance, which may not have been the expected result due to the higher anthropogenic pressures on such sites. Reasons for this are likely to be complex, but may be related to the lack of alternative suitable habitat, allowing invertebrates to congregate in urban allotment patches with limited option for dispersal. Invertebrates on more rural sites have greater dispersal opportunities due to greater availability of suitable habitat. The suburban sites appeared to be intermediate.

- Cottingham, a suburban site, had both the highest diversity and evenness. Beverley, also a suburban site, had the lowest diversity and Driffield, a rural site, had the lowest evenness. All other sites were intermediate in diversity and evenness.

CHAPTER 4: MORPHO-SPECIES ABUNDANCE AND DIVERSITY IN COMPARISON TO HUSBANDRY STYLE

4.0 INTRODUCTION

4.1 The influence of changing management practices on agriculture

Recent decades have witnessed a change in agricultural practices and attitudes generally to food growing. This has been reflected by a great increase in the popularity of organic and wildlife-friendly crop cultivation, caused partly by a desire for chemical-free food (Gifford and Bernard, 2006; Shreck *et al.,* 2006; Best, 2008; Phillips, 2009). More recently, there may also be a stronger economic factor, due to the world-wide 'credit crunch' (Morris, 2008).

Conventional farming methods, which are based on large inputs of synthetic fertilizer along with herbicide and pesticide use, still dominate (Bengetsson *et al*., 2005; Pimentel *et al*., 2005). However organic agriculture has become an increasing part of the food growing sector. For example, organic production from 1992 -1997 doubled in the USA (Dimitri and Greene, 2002) whilst in the UK, by mid 2003, it accounted for 4% of the agricultural land area with nearly 4000 farms managing some 720,000 hectares (Living Countryside, 2010). Pimental *et al.'s* (2005) study, which made a comparison of the benefits of organic farming versus conventional farming, found a range of biological, social and economic benefits related to organic systems.

The increase in the popularity of organic farming, both on a commercial (farm level) and an individual (garden, allotment) basis, has also been reflected in a number of studies that compare invertebrate species richness and abundance found in traditional versus organic farming contexts (Pfiffner and Niggli, 1996;

Andersen and Eltun, 2000; Shah *et al*., 2003). For example, Schmidt *et al*. (2005) found that wolf spiders (*Pardosa* spp.) were more than twice as abundant on organically managed farmland compared to traditionally managed farmland. Whether a field is managed traditionally or organically is also one of the main factors that will affect beetle populations (Shah *et al*., 2003).

In addition, Bengtsson *et al*. (2005) find that when reviewing published data on farming method comparisons, organic farms usually have, on average, 30% higher species richness and organisms are 50% more abundant compared to conventional farms. The figures for abundance were particularly prominent at the plot and field scale. In relation to food web scale, Macfadyen *et al*. (2009) also found that organic farms have significantly more species at three trophic levels: plant; herbivore; parasitoid. At the individual crop level, Letourneau and Goldstein's (2001) study of pest damage and arthropod community effects on a singe crop, tomato, also found species richness and natural enemy abundance was higher on organic farms.

At a wider community level, Eyre *et al.* (2009) noted that when investigating management styles on different crop types, organic farm plots contained greater Carabidae beetle and spider (Araneae) abundance, whilst conventional farm plots had higher Staphylinidae beetle, money spider (Linyphiidae) and parasitoid wasp (Braconidae) abundance.

The studies above therefore suggest that organic farming is generally seen as more socially sustainable than conventional agriculture, given the benefits of higher species diversity and abundance (Pimentel *et al.,* 2005; Shrek *et al.,* 2006).

4.2 Domestic agriculture: allotment gardening

As mentioned in Chapter 1, Section 1.12, cultivation of allotments is comparable in some aspects to agricultural farming i.e. regularly disturbed soil, addition of chemical fertilizers or manure and the planting and harvesting of crops. Due to the economic value of farming, many studies have therefore been carried out on invertebrate pests and potential bio-control value. In other ways, allotment gardening is similar to domestic gardening at home, albeit, the main focus on an allotment is usually food production as opposed to flowers and other leisure uses of a garden. Thus, there are parallels with both agriculture and domestic gardening, with allotments combining elements of both, although it is difficult to ascribe a particular and specific 'meaning' to allotment gardening (Ducker, no date). In line with agricultural and gardening practices therefore, one would expect that different management practices i.e. conventional versus organic, would have different effects on invertebrate populations on the allotment sites.

In the previous Chapter, it was shown that allotment epigeal invertebrate abundance varied along an urban-rural gradient and different taxa dominated at different sites. Using the same samples, this Chapter will explore any synecological or autecological variation in invertebrate abundance and diversity in relation to whether individual allotment plots are managed traditionally (termed 'conventionally' by some authors) or managed in an organic, wildlife-friendly way.

4.3 Aims of this Chapter

The aims of this Chapter were to explore any differences in invertebrate taxa abundance and diversity between allotment sites along an urban-rural gradient on plots that were either traditionally or wildlife-friendly managed. This Chapter examined the possibility that allotment husbandry/cultivation practices may influence epigeal invertebrate abundance and diversity at the morpho-species level. Specifically it tests the hypothesis that those sites managed in an organic/wildlife-friendly way will support a larger and more diverse epigeal community, based on the eight taxa identified in Chapter 3, Section 3.14. It aims to address the second research question:

Q2: What is the composition of the epigeal invertebrate communities on allotments and do they vary in relation to position along an urban-rural gradient and/or to individual plot management style?

4.3.1 Invertebrate abundance and diversity in relation to management style

Specifically, the aims were met by the following objectives to:

Objective 4.1 Test the hypothesis that overall invertebrate taxa abundance between the seven allotment sites along the urban-rural gradient, split by either traditional or wildlife-friendly management style, would be the same across all sites. The null hypothesis was that taxa had similar abundance, regardless of site or position along the urban-rural gradient.

Objective 4.2 Test any variation in the abundance of each individual taxon between the seven allotment sites along the urban-rural gradient, split by either traditional or wildlife-friendly management style. The null hypothesis would be that each taxon on each site would have similar abundance, regardless of site or position on the urban-rural gradient.

Objective 4.3 Test any variation in diversity of invertebrate taxa between the seven allotment sites along the urban-rural gradient, split by either traditional or wildlife-friendly management style. The null hypothesis would be that taxa would have similar diversity, regardless of site or position on the urban-rural gradient.

Objective 4.4 Test variation of the evenness of invertebrate taxa between the seven allotment sites along the urban-rural gradient, split by either traditional or wildlife-friendly management style. The null hypothesis would be that the invertebrates on each site would have similar evenness, regardless of site or position on the urban-rural gradient.

4.4 METHODS

4.5 Study sites

Much of the methodology in this Chapter followed the same techniques used in Chapter 3 regarding the timing, location and method of pitfall trapping and the taxa examined, using the same samples. However the data were considered differently in this Chapter in that it explored the possibility of differences in epigeal invertebrate abundance with regard to allotment plot management style i.e. either traditional or wildlife-friendly. The null hypothesis was that there would be no difference in invertebrate abundance between plots managed either way.

Exploration of any difference was also examined in relation to the urban-rural gradient established in the previous Chapters. It tested, for example, if a higher proportion of invertebrates are found on rural, suburban or urban sites which were managed in a wildlife-friendly way compared to those managed in a traditional way. The null hypothesis was that there would be no difference in the proportion of invertebrate abundance on plots managed in a wildlife-friendly way, in relation to traditionally-managed plots, regardless of geographic location.

From the seven study sites chosen, the seventy-four individual plot holders were assigned as either traditional or wildlife-friendly, as discussed in Chapter 2, Section 2.10.12. To recap, ‘traditional’ plot-holders classified themselves as ‘traditional’ in their cultivation methods in the questionnaire they completed and were the ones that tended to use a variety of pesticides. The wildlife-friendly plot-holders classified themselves as such and generally did not use any chemicals. Three 'traditional' (T) and three wildlife-friendly (W) plots were sampled on each of the seven allotment sites where possible. An example of each completed type is shown in Appendices 4.1 & 4.2. In some cases, there may only be two traditional plots and three wildlife-friendly managed plots or vice versa per site, due to the compromised plots as discussed in Chapter 3, Section 3.7.4. Individual plot identifiers are based on the site codes (e.g. HN, DR, etc) followed by the actual plot number as supplied by the plot-holders in the questionnaire (see Appendix 4.5 for an example).

4.6 Statistical analysis

Non-metric Multi-Dimensional Scaling (NMDS) using Pisces Conservation Ltd Community Analysis Package (CAP) version 3.0 was used to elucidate any differences in invertebrate taxa abundance between the traditionally and wildlife-friendly managed plots (Objective 4.1). This method provides a good representation model for species abundance (Henderson and Seaby (2008). NMDS is also flexible and makes few assumptions about the form of the data or the inter-relationship of the samples (Clarke and Warwick, 2001).

Prior to running the model, the data were pre-tested using a random starting point and 1000 iterations to check that the algorithm used was suitable to find the minimum stress solution (see Henderson and Seaby, 2008). The default number of iterations (200) were run in order to find the lowest stress values as the pre-test showed there was little advantage in selecting a higher iteration number (Henderson and Seaby, 2008). The dissimilarity measure used was Bray Curtis because it is useful for biological data on community structure and it down-weights the importance of highly abundant species (Clarke and Warwick, 2001). Stress values were kept < 0.2 to ensure that the ordination did not produce any misleading interpretations (Sheremetyeva and Sheremetyev, 2008; Clarke and Warwick, 2001) and provided the best goodness of fit (Kruskal, 1964). Pre-testing also showed that PCA was the appropriate starting point, as opposed to a random starting point. The data were root transformed to reduce the impact of outliers (Tabachnick and Fidel, 2007). The resulting plot mapped the most similar samples closest together and the least similar samples furthest apart. To explore any relationship of the invertebrate communities in relation to management and gradient, a DECORANA was used as it produces an ordination of both the samples and the variables and is particularly effective for samples derived from along a gradient (Henderson and Seaby, 2008).

4.6.1 Abundance Comparison: Traditional v. Wildlife-friendly

The first hypothesis to be tested was that all the sites would have no significant difference in overall abundance, regardless of management style (Objective 4.1). One-way analysis of variance (ANOVA) was used to compare mean abundance data between the traditional and wildlife management style of the plots. The data regarding site (independent variable) and husbandry method (independent variable) were then analyzed using two-way ANOVA with total taxa abundance (dependent variable) to examine any geographical or husbandry differences. Where significant differences were found and where there were three groups or more in the data, Tukey tests were used *a posteriori* to identify the source of the significance (Ennos, 2007). Although these data did not meet the Levene's test, the samples sizes were such that any effect would be minimal (Tabachnick and Fidel, 2007).

4.6.2 Abundance in relation to management style and gradient

In order to compare the allotment sites by management style and urban-rural gradient, sites were coded by combining the coding used in the previous Chapter for management style (traditional = 1; wildlife = 2) and gradient (urban = 1; suburban= 2; rural = 3) into a matrix of values to produce a single identifier for each group of plots based on its location along the urban-rural gradient and its management style (see Table 4.1).

Table 4.1 Site codes for allotment sites grouped per gradient (urban, suburban, rural) and management style (traditional or wildlife-friendly).

Code	Abbv.	Site/Management type	Sites included
1	RRT	Rural Traditional	Hunmanby; Driffield
2	RRW	Rural Wildlife-friendy	Hunmanby; Driffield
3	SUT	Suburban Traditional	Cottingham; Beverley; Bridlington; Bude
4	SUW	Suburban Wildlife-friendly	Cottingham; Beverley; Bridlington; Bude
5	UUT	Urban Traditional	Newland
6	UUW	Urban Wildlife-friendly	Newland

Two-way ANOVA was then used to examine differences in mean invertebrate abundance of each taxon (DV) between allotment sites (IV) and husbandry styles (IV) i.e. traditional or wildlife-friendly (Objective 4.2). This method would allow examination of any variation in attitude to allotment management along the urban-rural gradient i.e. would urban-dwellers be more likely to be wildlife-friendly? This method explores the possibility of an ‘interaction effect’ i.e. to examine if one independent variable (e.g. husbandry style) on the dependant variable (e.g. invertebrate abundance) depends on the level of a second independent variable (e.g. site) (Pallant, 2005). The data assumptions are the same as those for one-way ANOVA (Ennos, 2007). Profile plots are used to provide a useful visual exploration of the variations in the data between the traditional and wildlife-friendly plots.

4.6.3 Invertebrate diversity and evenness

The Shannon-Wiener Diversity Index and Pielou's evenness index were used to assess relative morpho-species diversity and evenness (see Chapter 3, Section 3.8). One-way ANOVA was used to test any difference in diversity and evenness respectively in relation to management style (Objectives 4.3 & 4.4 respectively). All values were presented to two decimal places where appropriate. Significance values are $p \leq 0.05$ unless otherwise stated.

4.7 RESULTS

4.8 Invertebrate abundance: traditional v. wildlife-friendly comparison

Non-metric Multidimensional Scaling (NMDS) results, as shown in Figure 4.1, provides a useful map of the allotment sites in relation to invertebrate abundance per management style (Objective 4.1). It groups those most similar sites closest together, using the Bray Curtis similarity measure, based on individual plot average root-transformed taxa abundance.

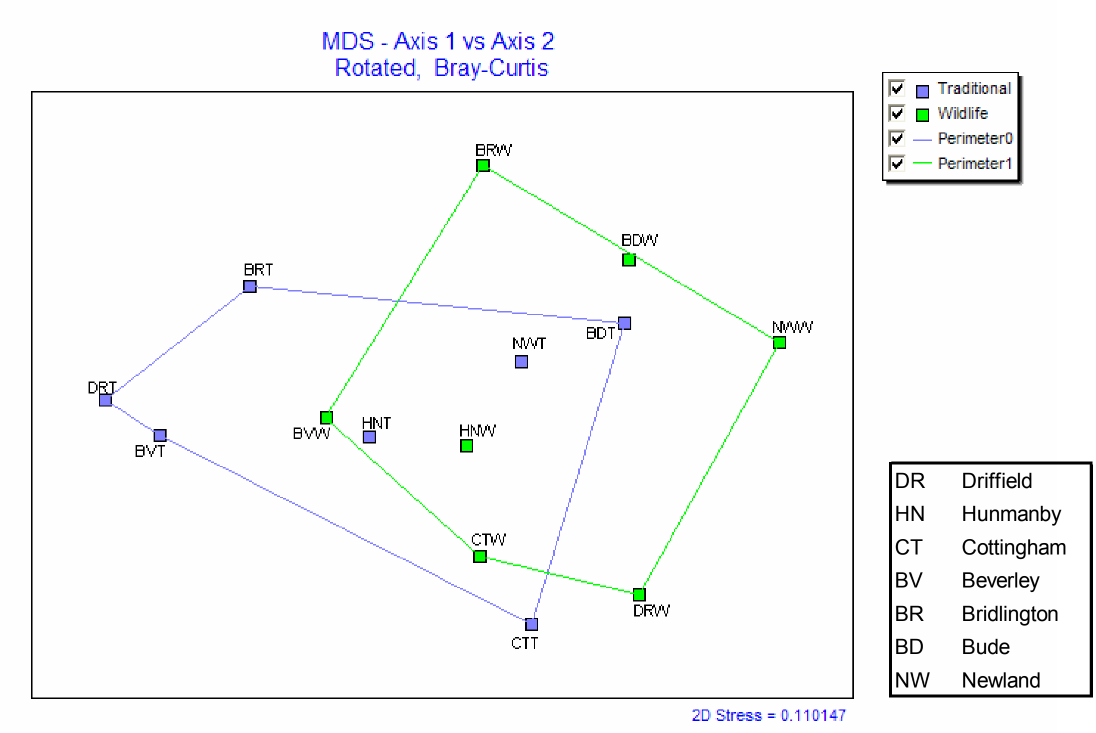


Figure 4.1 Ordination (NMDS) graph of root-transformed data of invertebrate abundance of traditional and wildlife-friendly managed allotment plots (T=traditional; W=wildlife-friendly); most similar sites are mapped closest together.

Figure 4.1 indicates the existence of a cluster of traditional plots grouped at the left hand side of the graph and a group of wildlife-friendly managed plots on the right hand side. There is however, some overlap of management styles in the middle of the graph (i.e. BVW, HNT and HNW respectively). This suggests there are some differences in relative invertebrate abundance in relation to management style, but only at some sites. This is particularly evident for the Driffield plots; they are separated by a considerable distance along both axes, indicating a significant difference in invertebrate abundance in relation to management style. The variation along the axes does not imply any causal relationship; it simply provides groupings based on similarity or dissimilarity of abundance (Henderson and Seaby, 2008). This will be explored in more detail in subsequent sections of this Chapter.

To show the effects of gradient and management on the invertebrate groups at the community level, DECORANA was appropriate (see Figure 4.2). It further suggests there are differences between some of the invertebrate communities depending partly on whether the plots are managed in a traditional or organic/wildlife-friendly way. It also clearly shows that where beetles are abundant there are few woodlice and *vice versa*. In addition, the beetles tend to be more abundant in location to the traditionally-managed plots. Similarly, where spiders are abundant, there are few opilione and *vice versa*. The slugs, millipedes and centipedes tend to be in relatively close proximity to each other whilst the snails tend to be more abundant on similar sites to the woodlice which is also towards the wildlife-friendly managed sites. Each individual taxon will be discussed in Section 4.13 below.

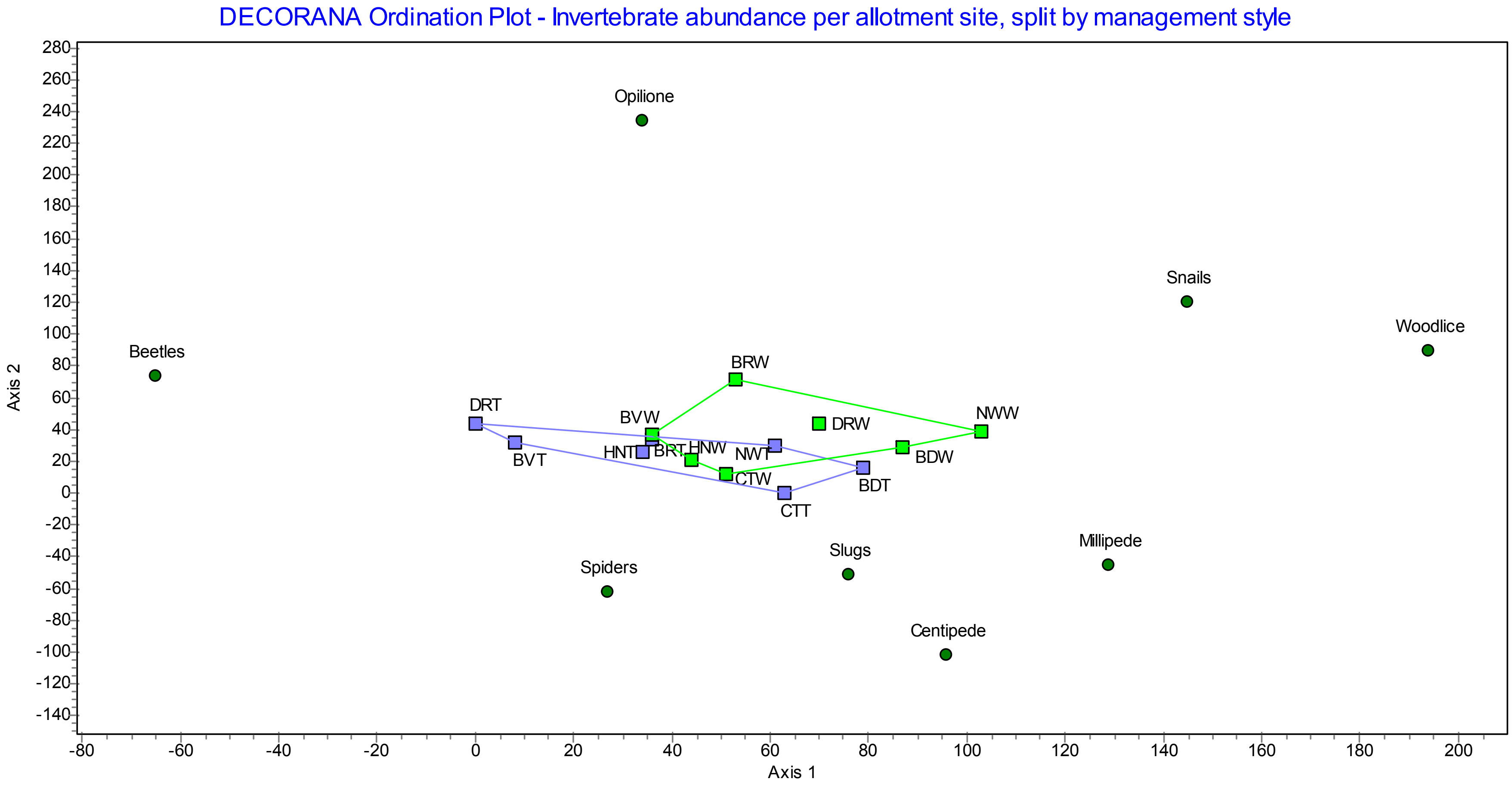


Figure 4.2 DECORANA plot of invertebrate abundance per allotment site, split by management style.

4.9 Comparison of total invertebrate abundance, split by management style

From the eight taxa studied, a total of 5,533 individual invertebrates were collected from traditional plots (47.22% of the total sample), whilst the wildlife-friendly plots contained 6,185 individuals (52.78% of the total sample) (Table 4.2). Thus, when comparing *overall* total mean abundance between traditional and wildlife-friendly values, a one-way ANOVA demonstrated that there was no significant difference in management styles [$F_{(1, 72)} = 2.33$, $p > 0.05$]. The null hypothesis is therefore upheld (Objective 4.1).

Table 4.2 Percentage of total invertebrate abundance per allotment site, grouped by management style (T = traditional and W = wildlife-friendly).

Site T	%	Site W	%
DRT	5.42	DRW	4.69
HNT	6.66	HNW	6.77
CTT	5.25	CTW	5.52
BVT	5.04	BVW	4.63
BRT	6.46	BRW	8.45
BDT	9.90	BDW	6.73
NWT	8.48	NWW	16.00
Total	47.21		52.79

DR	Driffield
HN	Hunmanby
CT	Cottingham
BV	Beverley
BR	Bridlington
BD	Bude
NW	Newland

4.10 Comparison of total invertebrate abundance grouped by position along the urban-rural gradient in relation to management style

A one-way ANOVA was used to test any variation in invertebrate abundance according to their location on the plots along the urban-rural gradient and split by management style (see Table 4.1 in Section 4.6.2). This showed that the invertebrate taxa on the rural and suburban sites had similar average abundance per plot respectively, but significantly more invertebrates were collected from the urban plots [$F_{(5,68)} = 4.58$, $p = 0.001$] (see Figure 4.3).

Post hoc comparisons (Tukey HSD $p < 0.05$) demonstrated that the source of the variations were the urban wildlife-friendly plots, which were significantly different from all other plots, *apart from* the urban traditional plots, which were different at $p < 0.1$. There was therefore an overall trend towards increased abundance at the urban wildlife-friendly managed plots, but this trend was not as strong on urban sites compared to rural or suburban plots.

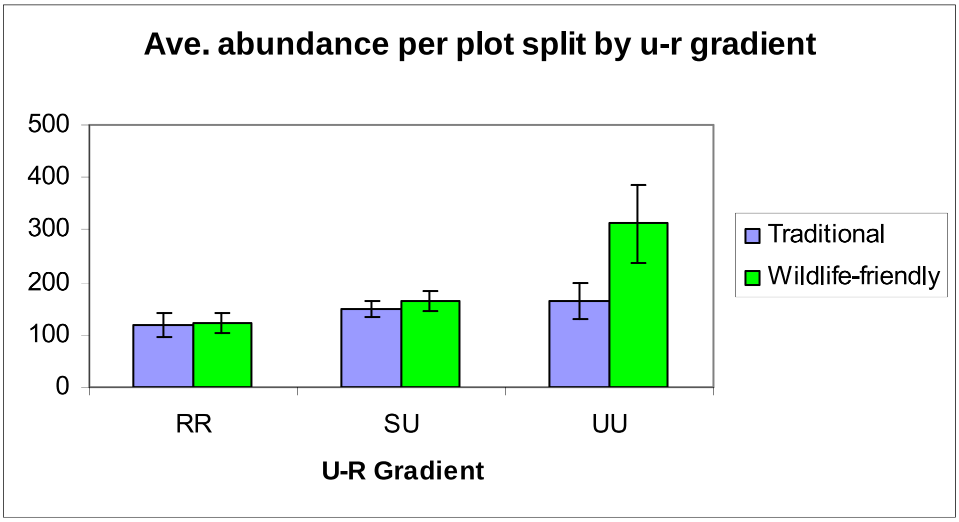


Figure 4.3 Average abundance per plot (±SE), grouped by gradient (rural: RR, suburban: SU and urban: UU) and allotment management style.

4.11 Comparison of invertebrate abundance in relation to individual allotment site and management style

Two-way between groups ANOVA was conducted with mean invertebrate (morphospecies) abundance as a dependent variable and plot position on the urban-rural gradient and husbandry as independent variables to test interaction effects between these variables. The analysis revealed a significant effect of gradient ([$F_{(6, 60)} = 3.05$, $p = 0.01$] but no effect of husbandry [$F_{(1, 60)} = 2.33$, $p = 0.13$] and consequently no gradient*husbandry interaction [$F_{(6, 60)} = 0.99$, $p = 0.44$].

Post hoc comparisons (Tukey HSD p < 0.05) indicated the source of the variation to be the Newland site (mean = 239.08, sd = 156.31), which was significantly different from the Driffield site (mean = 107.64, sd = 59.15). Thus, the city centre Newland site had higher invertebrate abundance than the Driffield site, but this was due to gradient effects not management style, whilst there were no significant differences between the other sites.

4.12 Variation in taxa abundance: the role of management style and urban-rural gradient.

The abundance of each of the eight individual taxa studied on traditional and wildlife-friendly managed plots was compared using one-way ANOVA (Table 4.3) (Objective 4.2). (Tables showing summaries of the actual invertebrate numbers and percentages are given in Appendices 4.3 & 4.4.) Graphs showing the mean abundance of each taxon are shown in Figure 4.4.

Table 4.3 One-way ANOVA to compare mean abundance of specific taxa on traditionally and wildlife-friendly managed allotment plots. (*significant at p < 0.05; **highly significant at p < 0.01)

	Mean abundance				Management (1 df)		
	Traditional		Wildlife-friendly				
	Mean	sd	Mean	sd	MS	F	p
Spiders	27.77	34.62	25.74	24.64	75.74	0.08	0.77
Opilione	1.31	2.42	11.09	33.98	1763.61	3.22	0.08
Woodlice	21.00	31.46	57.06	100.77	23981.90	4.51	*0.04
Millipedes	7.95	13.67	10.91	17.92	162.23	0.65	0.42
Centipedes	1.38	1.96	0.91	1.04	4.08	1.61	0.21
Beetles	70.85	48.33	48.11	29.32	9531.72	5.82	*0.02
Slugs	10.03	11.73	18.83	14.31	1429.41	8.44	**0.01
Snails	1.59	3.19	4.06	0.96	112.30	5.46	*0.02

From Table 4.3 it can be seen that beetles were the only taxon found to be significantly more abundant on traditional plots. The traditional plots also contained the highest percentage of beetles from the total catch of all invertebrates (23.6%). In contrast, the woodlice, slugs and snails are all significantly more abundant on plots that are managed in a wildlife-friendly way. Spiders, opilione, millipedes and centipedes show no significant difference in management style.

To test any further difference in individual taxon abundance between sites in relation to urban-rural gradient, as determined by PC1 in Chapter 3, Section 3.10, along with management style, two-way ANOVA was performed (Table 4.4). As well as the significant effects for management in relation to beetle, woodlice, slug and snail abundance as shown in the one-way ANOVAs above (Table 4.3), these results above also show a significant effect for position on the urban-rural gradient for some taxa (Objective 4.2). Table 4.4 shows that the beetles, woodlice, slugs, millipedes and centipedes also show an effect for gradient. However, when the two effects are combined i.e. management style and gradient, only the woodlice show a significant combined effect.

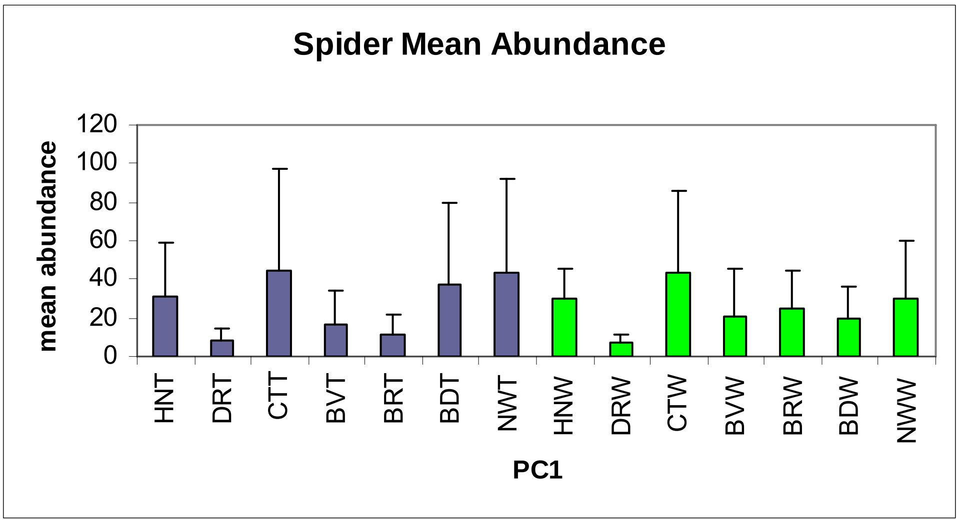
Table 4.4 Variation in mean abundance of taxa (DV), the effect of position on the urban-rural gradient (Gradient) (IV), of husbandry style (Management) (IV) and the interaction of these two independent factors (Gradient*Management). (*significant at p < 0.05; ** highly significant at p < 0.01)

	Gradient (6 df)			Management (1 df)			Gradient x Management (6 df)		
	MS	F	p	MS	F	p	MS	F	p
Spiders	1609.14	1.77	0.12	97.20	0.11	0.75	283.42	0.31	0.93
Opilione	769.01	1.54	0.18	1717.63	3.45	0.07	846.75	1.70	0.14
Woodlice	22470.08	7.63	**0.00	20109.91	6.83	*0.01	11833.91	4.02	**0.00
Millipedes	781.88	3.68	**0.00	207.45	0.98	0.33	83.37	0.39	0.88
Centipedes	5.77	2.79	*0.02	4.49	2.17	0.15	2.80	1.35	0.25
Beetles	5155.45	4.15	**0.00	8719.18	7.02	*0.01	2010.80	1.62	0.16
Slugs	442.46	3.38	**0.00	1250.23	9.54	**0.00	275.63	2.10	0.07
Snails	36.21	1.81	0.11	110.21	5.51	0.02	10.28	0.51	0.80

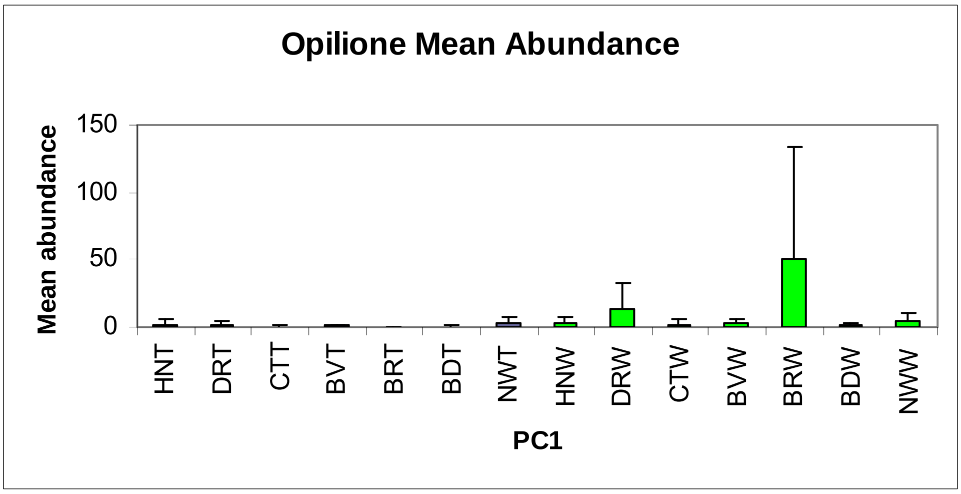
4.13 Mean individual taxon abundance per position along the urban-rural gradient.

The data in Tables 4.3 and 4.4, along with graphs of mean abundance (+sd) of the number of each individual taxon per allotment site as shown in Figure 4.4 below, are discussed in more detail below for each individual taxon.

a)



b)



c)

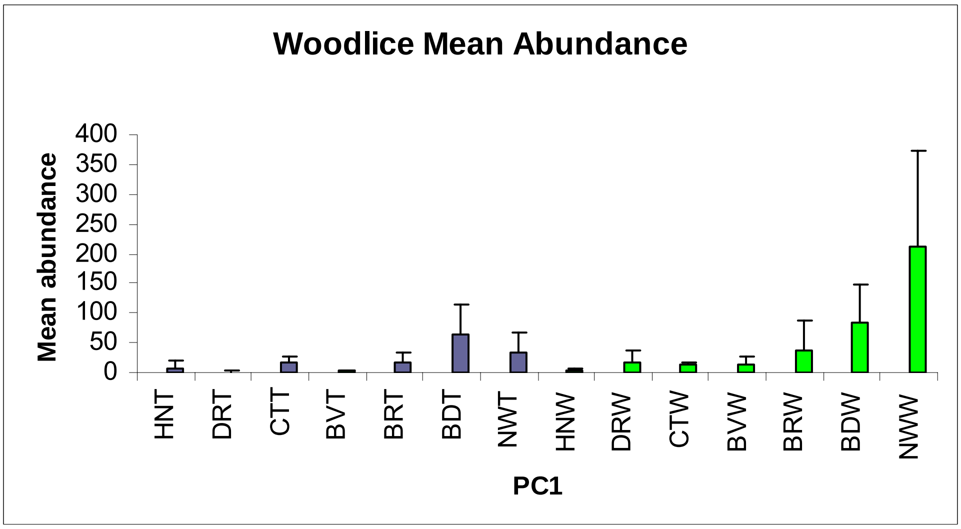


Figure 4.4 Graphs of individual taxon mean abundance (+ sd) per site and management style. (T=traditional; W=wildlife-friendly) (Note varying y-axis scales.)

d)
e)
f)

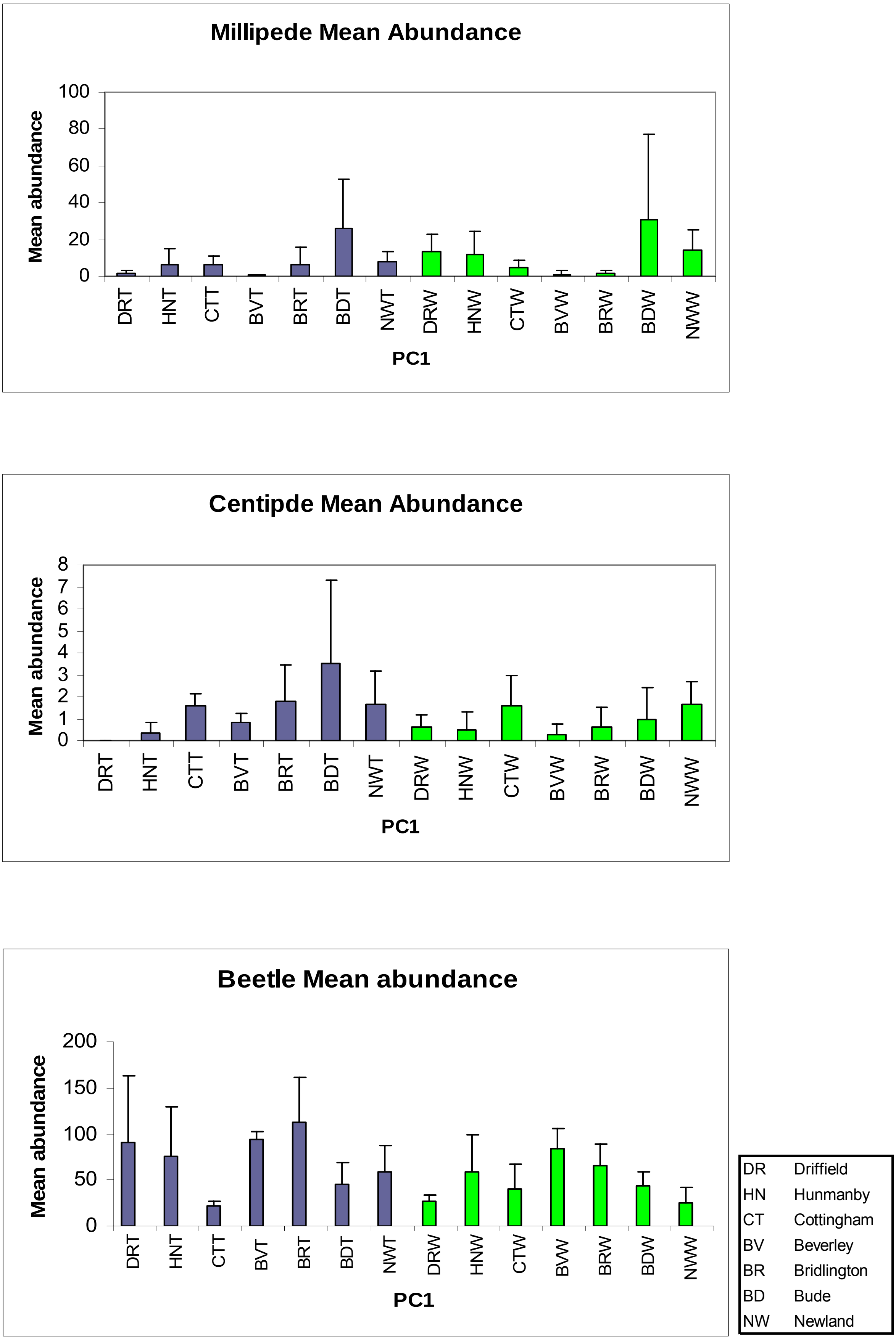
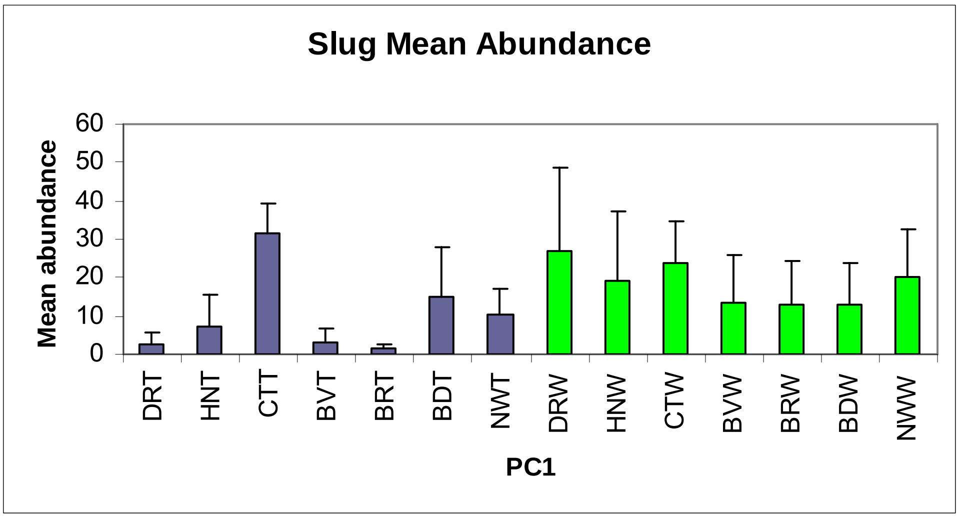


Figure 4.4 (cont) Graphs of individual taxon mean abundance (+ sd) per site and management style. (T=traditional; W=wildlife-friendly) (Note varying y-axis scales.)

g) 

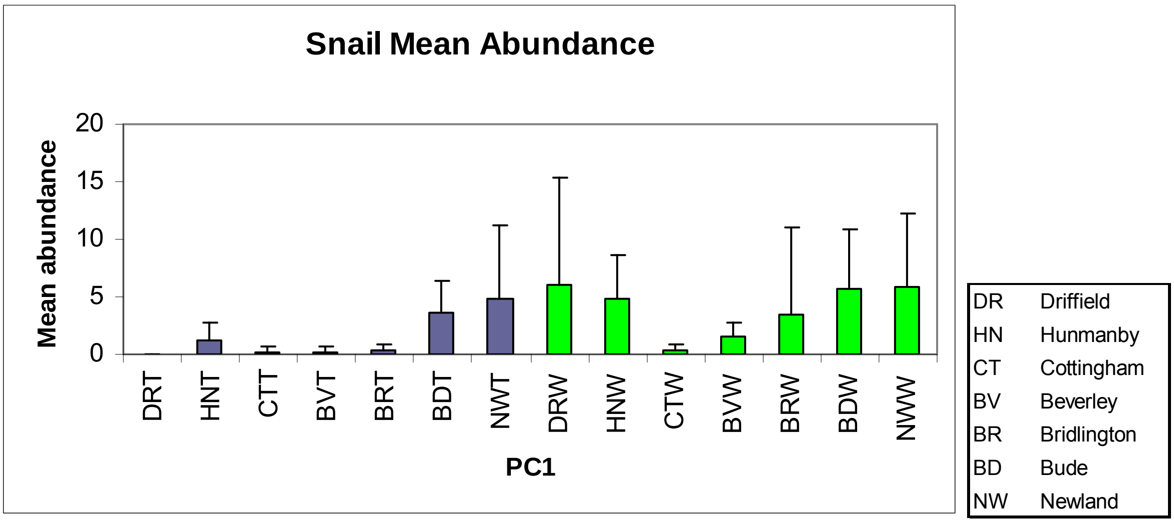
h) 

Figure 4.4 (cont) Graphs of individual taxon mean abundance (+ sd) per site and management style. (T=traditional; W=wildlife-friendly) (Note varying y-axis scales.)

4.13.1 Variation in spider abundance in relation to gradient and management style

Table 4.3 shows there is no significant difference in the mean number of spiders on the traditional plots (1,083) compared to the wildlife-friendly plots (901) (see also Appendix Table A4.3). The spiders are the third most abundant taxon, with 9.24% of the total catch found on traditional plots and 7.69% found on wildlife-friendly plots.

Two-way ANOVA also shows no difference in mean plot abundance in relation to gradient and management style (Table 4.4). Figure 4.4a shows how closely matched the mean spider abundance is on the rural sites and two of the suburban sites (Cottingham and Beverley) under both management styles. Although not statistically significant, there were however nearly twice as many spiders on the two suburban Bridlington and Bude traditionally-managed plots. In addition, on the urban plots at Newland, there were around a third more spiders on the traditionally-managed plots.

4.13.2 Variation in opilione abundance in relation to gradient and management style

There was no statistically significant difference in the mean number of opilione on the traditional plots (51) compared to the wildlife-friendly plots (388), as shown in Table 4.3 (see also Appendix Table A4.3). Although the wildlife plots contained 88% of the total Opilione catch, the majority of the opilione came from one site; the Bridlington wildlife-friendly plots as shown in Figure 4.4b above. This highlights although not statistically significant, the difference in abundance on this site compared to all other sites. The traditional sites contained only

0.44% of the total of all invertebrates caught, whilst the wildlife-friendly plots contained 3.31% of the total invertebrate catch.

The two-way ANOVA for opilione abundance in relation to gradient (PC1) and management style (T or WLF) shows no significant effect for either or an interaction effect between the two (Table 4.4).

4.13.3 Variation in woodlice abundance in relation to gradient and management style

The two-way ANOVA to compare mean woodlice abundance, as shown in Table 4.4, reveals a significant effect for the interaction between gradient and management style; the effect size is large (partial eta squared = 0.29). P*ost hoc* Tukey HSD indicated that the mean scores for Newland (mean =122.75, sd ± 144.12) were significantly different from all the other sites apart from Bude (mean = 70.50, sd ± 54.09). This suggests that plots managed in a wildlife-friendly way are influenced by being found in the city centre and vice versa. Figure 4.4c illustrates the large difference between the urban wildlife-friendly site and the other sites. The wildlife-friendly plots at Newland contain a mean of 210.50, sd ±161.58 individuals whilst the mean for the traditional plots is only 35, sd ± 33.29. The large standard deviation in the former shows that the results are skewed due to the range of woodlice numbers (51 – 420 individuals) between these wildlife-friendly plots (see also Appendix Table A4.3).

4.13.4 Variation in millipede abundance in relation to gradient and management style

There was no significant difference in the mean number of millipedes on the traditional plots (310) compared to the wildlife-friendly plots (382), as shown in Table 4.3 (see also Appendix Table A4.3). Millipedes constituted 5.91% of the total invertebrate catch, with 2.65% on the traditional plots and 3.26% on the wildlife-friendly plots. Two-way ANOVA for mean millipede abundance in relation to gradient (PC1) and management style (T or WLF) shows a highly significant effect for gradient and the effect size is large (partial eta squared = 0.27) (Table 4.4).

Post hoc Tukey HSD indicated that the mean score for the Bude site (mean = 27.80, sd $\pm$ 33.27) was significantly higher than the Bridlington (mean = 3.60, sd $\pm$ 6.93), Beverley (mean = 0.67, sd $\pm$ 1.32), Cottingham (mean = 5.50, sd $\pm$ 3.95) and Driffield (mean = 6.64, sd $\pm$ 8.93) sites (see Figure 4.4d). However, the main effect for management style and the interaction effect between management and gradient were not significant.

4.13.5 Variation in centipede abundance in relation to gradient and management style

There is no significant difference in the mean number of centipedes on the traditional plots (54) compared to the wildlife-friendly plots (32) (Table 4.3) (see also Appendix Table A4.3). They constitute less than 1% of the total invertebrate catch, with slightly higher abundance on the traditional plots (0.46%) compared to the wildlife-friendly plots (0.27%). Two-way ANOVA for mean centipede abundance in relation to gradient (PC1) and management style

(T or WLF) shows a highly significant effect for gradient) (Table 4.4); effect size was medium (partial eta squared = 0.22). *Post hoc* Tukey HSD indicates that the mean score for the Bude site (mean = 2.50, sd ± 3.21) was significantly higher than the Driffield (mean = 0.27, sd ± 0.47), and Hunmanby (mean = 0.42, sd ± 0.67) sites (see Figure 4.4e). However, the main effect for management style and the interaction effect between management and gradient are not significant.

4.13.6 Variation in beetle abundance in relation to gradient and management style

The two-way ANOVA for mean beetle abundance as shown in Table 4.4 reveals a significant effect for urban-rural gradient and the effect size is large (partial eta squared = 0.29). This demonstrates that beetles are much more abundant on some sites but conversely, much scarcer on other sites. *Post hoc* Tukey HSD on the gradient effects indicate that the mean beetle abundance for the suburban Cottingham site (mean = 31.10, sd ± 20.56) is significantly lower from the suburban Bridlington (mean = 89.10, sd ± 43.32) and Beverley (mean = 89.33, sd ± 16.13) sites. This shows that the Cottingham traditional and wildlife-friendly plots respectively contain significantly less beetles compared to the Bridlington and Beverley traditional and wildlife-friendly plots respectively. In addition, the urban Newland plots (mean = 42.50, sd ± 28.34) are significantly lower from the suburban Bridlington plots (mean = 89.10, sd ± 43.32) in terms of invertebrate abundance in relation to position along the gradient (see Figure 4.4f).

There is also a significant effect for management at some sites. The Bude, Beverley, Cottingham and Hunmanby sites respectively show little variation in invertebrate abundance between the traditionally and wildlife-friendly managed plots. However, the Driffield, Bridlington and Newland plots show a larger difference in abundance between management styles (see Figure 4.4f). However, the main interaction effect for management style and gradient are not significant i.e. there is no link between changes in invertebrate abundance linked to gradient in relation to management style and *vice versa*.

4.13.7 Variation in slug abundance in relation to gradient and management style

Interestingly, Table 4.3 shows there are a highly significantly greater number of slugs on the wildlife-friendly plots (659) compared to the traditional plots (391) (see also Appendix Table A4.3). The traditional sites contain only 3.34% of the total invertebrate catch, whilst the wildlife-friendly plots contained 5.62% of the total invertebrate catch. As was shown in Chapter 2, Section 2.10.13, 67% of respondents said they used pesticides and of those, 41% used slug pellets (Section 2.10.14), by far the most common pesticide used. This may go some way to explain the variation found.

Two-way ANOVA for mean slug abundance in relation to gradient (PC1) and management style (T or WLF) shows a significant effect for gradient; effect size was large (partial eta squared = 0.25) (Table 4.4). *Post hoc* Tukey HSD indicated that the mean score for the Cottingham site (mean = 27.70, sd $\pm$ 9.89) was significantly higher than the Bridlington (mean = 7.20, sd $\pm$ 9.61) and Beverley (mean = 7.67, sd $\pm$ 9.80) sites (see Figure 4.4g).

With regard to management, as shown above, there was also a significant large effect (partial eta squared = 0.14) with greater numbers of slugs on wildlife-friendly managed plots. However, the main effect for management style and the interaction effect between management and gradient are not significant.

4.13.8 Variation in snail abundance in relation to gradient and management style

Similar to the slugs, Table 4.3 shows there are a significantly higher number of snails on the wildlife-friendly plots (62) compared to the traditional plots (32) (see also Appendix Table A4.3). Whilst the snails constitute 2.29% of the total invertebrate catch on the wildlife-friendly plots, they only account for 1.21% on the traditional plots. Thus, although the actual amount is quite small, there were more than twice as many snails on the wildlife-friendly plots (Figure 4.4h).

Two-way ANOVA for mean snail abundance in relation to gradient (PC1) and management style (T or WLF) shows no significant effect for gradient and the main effect for management style and the interaction effect between management and gradient are not significant (Table 4.4).

4.14 Individual taxon summary

In summary, the taxa which appeared to be affected by management practices were woodlice, beetles, slugs and snails. Of these, only beetles were significantly more abundant on traditionally-managed plots, whilst woodlice, slugs and snails were significantly more abundant on wildlife-friendly managed plots.

When looking at the combined effect of management and urban-rural gradient, only woodlice showed a significant interaction effect. The Newland wildlife-friendly managed urban plots in the city centre of Hull had by far the highest woodlice abundance, significantly higher that all other sites regardless of management style, apart from the plots at Bude, which are also located in Hull.

4.15 Diversity and evenness: traditional v wildlife-friendly comparison

The diversity and evenness of the traditionally managed plots was compared with the diversity and evenness of the wildlife-friendly managed plots using the Shannon-Wiener diversity index (H) and Pielou's evenness scores (J) (see Methods Section 4.6.3). Each index was calculated using the total number of individuals per plot (N=74 plots) to generate the H and J values, grouped by management style and allotment site (N=14 sites) (see Appendix 4.5). From these H and J, the mean and standard error was calculated per site, split by management style (Figure 4.5).

One way ANOVA to examine any difference in diversity in relation to allotment site, split by management style, showed that there were highly significant differences in the Shannon diversity index (H) [$F_{(13, 60)} = 8.66$, $p < 0.01$; Tukey $p=0.05$] (Objective 4.3). The *post hoc* Tukey test showed that wildlife-friendly plots on five of the allotment sites were *only* significantly different from traditionally managed plots (see Table 4.5). Thus, both of the rural sites, Driffield and Hunmanby, along with all of the suburban sites except Beverley, contained wildlife plots that contained significantly higher diversity compared to the traditionally managed plots on these sites. Both the urban Newland site and the suburban Beverley sites did not have significantly different diversity in relation to management style.

The traditionally managed plots on all sites were significantly different from a mix of traditional and wildlife sites, generally with lower diversity compared to the wildlife sites.

Interestingly, Driffield allotments contained the highest diversity score (H = 1.836) on the wildlife-friendly plots and the lowest diversity score on the traditionally managed plots (H = 0.272). The former plots were only significantly different to the wildlife-friendly managed plots in Driffield, Beverley and Bridlington. The latter plots were significantly different to plots from all sites, of both management styles.

Whilst the wildlife-friendly plots in Beverley contained no significant difference in diversity to any other plots, the traditional plots at this site were significantly different to the same group of plots are the Driffield traditional plots discussed above (see Table 4.5).

The Newland and Cottingham traditional plots were significantly lower compared to the Driffield, Beverley and Bridlington traditional plots, but not to any of the wildlife-friendly managed plots.

Table 4.5 *Post hoc* Tukey results on Shannon H values showing which allotment sites are significantly different from each other in bold. (Site codes as per Figure 4.1; T = traditional; W = wildlife-friendly)

	DRT	DRW	HNT	HNW	CTT	CTW	BVT	BVW	BRT	BRW	BDT	BDW	NWT	NWW
DRT		**0.000**	0.477	**0.000**	**0.000**	**0.000**	1.000	0.397	0.987	**0.005**	**0.000**	**0.013**	**0.000**	0.082
DRW	**0.000**		0.101	1.000	1.000	1.000	**0.000**	0.398	**0.011**	0.995	1.000	0.995	1.000	0.506
HNT	0.477	0.101		0.097	0.121	**0.037**	0.629	1.000	0.999	0.772	**0.041**	0.873	0.153	1.000
HNW	**0.000**	1.000	0.097		1.000	1.000	**0.000**	0.415	**0.009**	0.998	1.000	0.997	1.000	0.523
CTT	**0.000**	1.000	0.121	1.000		1.000	**0.000**	0.442	**0.013**	0.997	1.000	0.997	1.000	0.557
CTW	**0.000**	1.000	**0.037**	1.000	1.000		**0.000**	0.209	**0.003**	0.950	1.000	0.955	1.000	0.267
BVT	1.000	**0.000**	0.629	**0.000**	**0.000**	**0.000**		0.525	0.996	**0.011**	**0.000**	**0.028**	**0.000**	0.153
BVW	0.397	0.398	1.000	0.415	0.442	0.209	0.525		0.991	0.975	0.247	0.989	0.532	1.000
BRT	0.987	**0.011**	0.999	**0.009**	**0.013**	**0.003**	0.996	0.991		0.231	**0.003**	0.353	**0.016**	0.854
BRW	**0.005**	0.995	0.772	0.998	0.997	0.950	**0.011**	0.975	0.231		0.976	1.000	1.000	0.996
BDT	**0.000**	1.000	**0.041**	1.000	1.000	1.000	**0.000**	0.247	**0.003**	0.976		0.978	1.000	0.313
BDW	**0.013**	0.995	0.873	0.997	0.997	0.955	**0.028**	0.989	0.353	1.000	0.978		1.000	0.999
NWT	**0.000**	1.000	0.153	1.000	1.000	1.000	**0.000**	0.532	**0.016**	1.000	1.000	1.000		0.657
NWW	0.082	0.506	1.000	0.523	0.557	0.267	0.153	1.000	0.854	0.996	0.313	0.999	0.657	

One-way ANOVA to examine any difference in evenness in relation to site also showed that there were highly significant differences in the Pielou (J) values [$F_{(13, 60)}$ = 6.24, p < 0.0; Tukey p=0.05] (Objective 4.4). The *post hoc* Tukey test showed that again, five of the wildlife sites were *only* significantly different from traditional sites but the traditional sites were significantly different from a mix of traditional and wildlife sites (see Table 4.6). However, this time, in contrast to the diversity scores discussed above, the Hunmanby and Newland traditional plots and the Beverley wildlife-friendly plots were not significantly different with regard to their evenness.

The overall diversity on wildlife-friendly plots had a range and relatively even proportion of taxa, thus giving relatively high evenness scores (e.g. for DR109 TS, J = 0.883), whilst the traditional plots were dominated by beetles, giving relatively low evenness scores (e.g. DR93 TM, J = 0.169) (see Appendix A4.5).

Table 4.6 *Post hoc* Tukey results on Pielou J values showing which allotment sites are significantly different from each other in bold. (Site codes as per Figure 4.1; T = traditional; W = wildlife-friendly)

	DRT	DRW	HNT	HNW	CTT	CTW	BVT	BVW	BRT	BRW	BDT	BDW	NWT	NWW
DRT		**0.005**	0.319	**0.004**	**0.006**	**0.001**	1.000	0.828	1.000	**0.028**	**0.002**	0.116	**0.022**	0.877
DRW	**0.005**		0.897	1.000	1.000	1.000	**0.001**	0.729	**0.030**	1.000	1.000	1.000	1.000	0.373
HNT	0.319	0.897		0.922	0.926	0.680	0.073	1.000	0.691	0.996	0.856	1.000	0.997	1.000
HNW	**0.004**	1.000	0.922		1.000	1.000	**0.001**	0.765	**0.029**	1.000	1.000	1.000	1.000	0.391
CTT	**0.006**	1.000	0.926	1.000		1.000	**0.001**	0.774	**0.038**	1.000	1.000	1.000	1.000	0.425
CTW	**0.001**	1.000	0.680	1.000	1.000		**0.000**	0.484	**0.010**	1.000	1.000	0.995	0.998	0.174
BVT	1.000	**0.001**	**0.073**	**0.001**	**0.001**	**0.000**		0.405	0.995	**0.004**	**0.000**	**0.024**	**0.003**	0.429
BVW	0.828	0.729	1.000	0.765	0.774	0.484	0.405		0.977	0.955	0.669	0.996	0.960	1.000
BRT	1.000	**0.030**	0.691	**0.029**	**0.038**	**0.010**	0.995	0.977		0.125	**0.018**	0.336	0.112	0.992
BRW	**0.028**	1.000	0.996	1.000	1.000	1.000	**0.004**	0.955	0.125		1.000	1.000	1.000	0.753
BDT	**0.002**	1.000	0.856	1.000	1.000	1.000	**0.000**	0.669	**0.018**	1.000		1.000	1.000	0.293
BDW	0.116	1.000	1.000	1.000	1.000	0.995	**0.024**	0.996	0.336	1.000	1.000		1.000	0.947
NWT	**0.022**	1.000	0.997	1.000	1.000	0.998	**0.003**	0.960	0.112	1.000	1.000	1.000		0.753
NWW	0.877	0.373	1.000	0.391	0.425	0.174	0.429	1.000	0.992	0.753	0.293	0.947	0.753	

The three sites with the lowest mean *H* values were all classed as traditional sites and had by far the lowest species diversity values (H = 0.6-0.9) (Figure 4.5). However, the same cannot be said for the sites with the highest mean H values. Whilst the highest ranking site, comprising Driffield wildlife plots, was managed as wildlife-friendly (*H* = 1.8), the following four sites (BDT; BRW; NWT; BDW) had the same values (1.6) and were an even split of two wildlife-friendly and two traditionally managed pooled plots per site. A further two sites had a value of 1.5: the Cottingham traditional and wildlife plots. This suggests that whilst the actual species composition may be different on plots with the same diversity value, the proportions of the taxa were similar. Overall, this suggests that there was no clear cut division between traditional and wildlife-friendly mean diversity across the allotment sites.

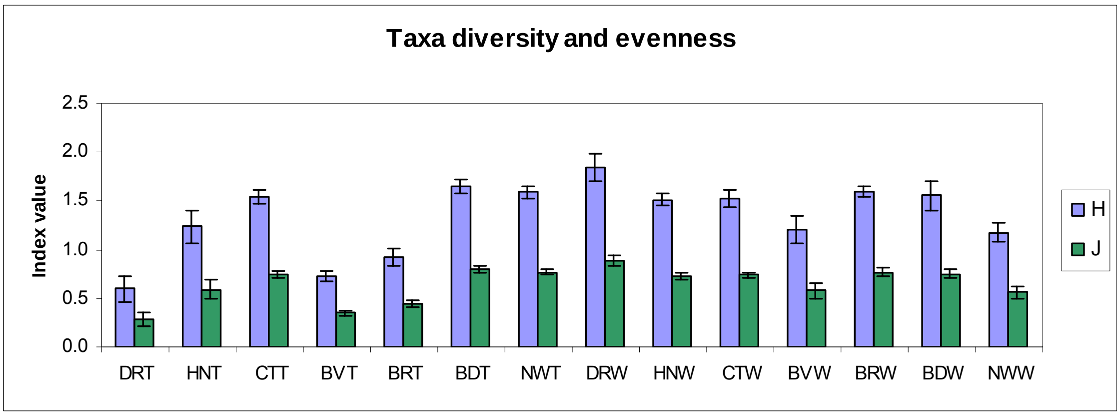


Figure 4.5 Mean Shannon (*H*) diversity index (+SE) and Pielou (*J*) evenness score (+SE) for the taxa abundance per site, split by management style. **(**Site codes as per Figure 4.1; T = traditional management; W = wildlife-friendly management)

Interestingly, the Driffield traditional plots had the lowest Shannon and Pielou values, whilst the Driffield wildlife-friendly plots had the highest. Although *H* and J values can be thought of as an ordinal scale (Fowler and Cohen, 1990), they do indicate that the wildlife plots on that site had the highest diversity and evenness, whilst the traditionally managed plots had the lowest diversity and evenness. These Driffield wildlife plots were the most even due to the spread of the abundance of species found, whilst the traditional Driffield sites were dominated by beetles, which constituted nearly 86% of the total catch.

4.16 Taxa diversity summary in relation to management style

Overall, it has been shown that different taxa dominated with differing management styles across varying geographic scales. A trend was identified to show that the wildlife-friendly managed plots were significantly more diverse than the traditionally-managed plots on the five of the seven allotment sites. These five sites were rural and suburban; no management effect was identified on the urban site and one suburban site. Similar results were found for evenness.

4.17 Overall results summary: abundance in relation to management style

The aims of this section were to explore any differences in invertebrate taxa abundance and diversity between allotment sites along an urban-rural gradient on plots that were either traditionally or wildlife-friendly managed. With regard to *overall* taxa abundance, it was found that *overall* abundance was not significantly different between the two management styles. However, there were significant differences between the urban wildlife plots and several other traditionally-managed plots along the urban-rural gradient (Figure 4.3). The former had the highest morpho-species abundance.

When examining the abundance of individual taxa, there were mixed results:

- Variation in spider abundance showed no significant effect of either management style or gradient, although some sites have many more than others;
- Opilione also showed no significant difference in either management style or gradient, although they were most abundant on the Bridlington wildlife-friendly plots;
- Woodlice dominated urban, wildlife-friendly managed sites;
- Millipedes were most abundant on Bude allotments, regardless of management style;
- Centipedes were also most abundant on Bude allotments, but only on traditionally-managed plots;
- Beetles were more abundant on traditionally-managed plots;
- Slugs were significantly more abundant on wildlife-friendly plots;
- Snails were also significantly more abundant overall on wildlife-friendly plots, but there was no gradient effect.

4.18 Overall results summary: diversity and evenness in relation to management style

With regard to the Shannon diversity indices for each of the seven allotment sites, split by management style i.e. N=14, five of the wildlife-friendly managed sites were only significantly different to traditionally-managed sites, with sub-urban Beverley and urban Newland being the exceptions. In contrast, the traditionally-managed sites had a mix of significantly different diversity to both traditionally and wildlife-friendly managed sites, but generally contained lower diversity compared to the wildlife sites. Similar results were found for the Pielou evenness scores.

4.19 DISCUSSION

4.20 Invertebrate abundance in relation to management style

The aims of this section of the study were to examine invertebrate abundance and diversity between different taxa and within the same taxa on both the same sites and between different sites along the urban-rural gradient with different management styles i.e. variation in both α and β diversity. Thus, the specific objectives were to determine the extent of any differences in *overall* invertebrate abundance, regardless of location, depending on management style i.e. traditional or wildlife-friendly (Objective 4.1); whether there was any difference in invertebrate abundance depending on management style from plots on different allotment sites (Objective 4.2); whether there was any difference in invertebrate diversity depending on management style in relation to urban-rural gradient of sites (Objective 4.3); and whether there was any difference in invertebrate evenness depending on management style in relation to urban-rural gradient of sites (Objective 4.4).

It is evident from the current Chapter that although the overall total difference in invertebrate abundance between the two management styles, traditional and wildlife-friendly, was not significant (Objective 4.1), there was a trend of increased abundance on urban wildlife-friendly plots (Objective 4.2). There was a trend for increase diversity on rural wildlife-friendly plots (Objective 4.3), as well as interesting differences between individual taxa i.e. variation in both α and β diversity (Objective 4.4) as discussed below.

The most noticeable difference in species abundance in relation to management style was found for the Isopoda. Woodlice were the second most abundant taxa in the current study, with by far the highest densities found on wildlife-friendly plots in the city centre and the lowest on the traditional rural plots (see Figure 4.2). They were significantly more abundant on wildlife-friendly managed plots at Newland due largely to the vast number of woodlice found on one plot. The reason for the variation found is likely to be the differences in small-scale habitat variation found at allotment site level (e.g. higher number of compost heaps; relative amount of mulch). Paolettie and Hassall (1999) also found woodlice abundance to be higher in organically managed orchards in comparison to conventionally managed ones. Hassall and Tuck (2007) have observed that when conditions are particularly favourable, these isopods tend to cluster together in refugia in response to microclimate variation. Although individual species will be discussed more fully in the next Chapter, it can be noted here that the bulk of the aggregations of woodlice were of the species *Porcellio scaber*. Schmalfuss (1984) classified these isopods as 'clingers' (as opposed to 'rollers' or 'runners') and therefore tend to aggregate strongly, much more so than some of the other common species that may occur on allotments (Warburg, 1968; Hassall and Tuck, 2007). This species is also synanthropic and the one most likely to enter houses (Hopkin, 1991), therefore one would expect to find it relatively more abundant in the urban-suburban sites, as in the case of the current study.

The traditional plots with the highest abundance were on the Bude site, which was ranked second in the overall total abundance, irrespective of management style, followed by the traditional Newland plots (Table 4.2). Although Bude was classified as suburban in the previous Chapter, it was the site closest in the PCA mapping to the urban Newland site (see also Figure 4.1). This shows that overall, the urban site, and to a slightly lesser extent, the suburban sites, are an important 'reservoir' of invertebrate biodiversity in terms of abundance. This aspect will be discussed in greater detail in Chapter 6.

4.21 Invertebrate diversity in relation to management style

Driffield traditional sites contained the lowest diversity and evenness values. These results are partly explained by the relatively low abundance on the traditional plots at this site and the dominance of one taxon, the Coleoptera, which constituted nearly 86% of the total catch. In contrast, the Driffield wildlife-friendly plots contained the highest diversity and evenness values, despite these plots also containing relatively low overall abundance in comparison to the other sites. Although this abundance was low compared to most of the other sites, the diversity of taxa was relatively evenly distributed, with a reasonable spread of abundance of the various taxa, rather than dominance by one. These two significantly different extremes on the same site would require further investigation to try and identify the potential causes; however, this is one site where management style would appear to be a factor.

4.22 General Discussion

Although allotments are generally more intensively managed than most gardens, they still provide a range of habitats for many types of invertebrate, as evidenced by the current study and also noted by Wheater (1999). Prior to the BUGS studies discussed earlier (Smith *et al*., 2006 $_{a,b}$) (see Chapter 3, Section 3.5), there was little information on the ecology of gardens, apart from the notable extensive study of a single garden by Owen (1991), as discussed at the end of Chapter 1, Section 1.3. However, agricultural fields, because of their methods of cultivation, can also be regarded as habitats subject to frequent major disturbances (Lovei and Sarospataki 1990), in a similar way to allotments. This suggests that previous studies comparing the abundance and diversity of invertebrate fauna from organic farms and traditional farms may provide useful comparisons to the current allotment results, as useful comparative allotment studies cannot be readily found.

The variations found in the abundance and diversity of individual taxa were not however that similar to those found in some studies of conventional versus organic farming (e.g. Minarro *et al*., 2009); other studies have found mixed results (Tonhasca, 1993; Bengtsson *et al.*, 2005). For example, in the current study, ground beetles tended to be more abundant on the traditionally managed plots, unlike Shah *et al*. (2003) who found that abundance was higher on organic farms in southern England, when compared to conventional management (but diversity was lower due to the dominance of a single ground beetle species, namely *Pterostichus melanarius)*. In contrast, spider density was not significantly different between management styles in the current study, whereas Clough *et al*. (2007) found lower between site β-diversity in organic fields compared to conventionally managed fields. Schmidt *et al.* (2005) found that whilst organic agriculture did not increase the number of spider species found, it did enhance spider density by 62%.

The current research found allotment invertebrate abundance was significantly related to factors which operated across geographic scales, management style and landscape-level effects, which is similar to the BUGS studies in gardens (Smith *et al*., 2006 $_{a,b}$). Although the results were mixed, when the overall abundance of the plots was examined in relation to both management style i.e. traditional or wildlife-friendly and urban-rural gradient, the results, although not statistically significant, did show a trend towards a clustering of urban-suburban wildlife sites and rural-suburban traditional sites (see Figure 4.1). There was also a trend of increased abundance in the wildlife-friendly sites as the plots got closer to the city centre (see Figure 4.3). This highlights the biodiversity value of such sites at a time when both wildlife issues and allotments are becoming recognized as increasingly important in terms of addressing political and social agendas (e.g. Bellows, 2004). When gains can be made by providing healthy food and exercise, along with enhancing the wildlife value of urban greenspace, allotments can address a number of socio-economic issues.

As the taxa considered in this study tend to roam over several meters, or even tens of meters, in search of food, shelter or mates (Uetz, 1977; Foelix, 1996; Forsythe, 2000), they are able to wander across allotment plots within an allotment site, regardless of management style. This suggests therefore that differences in traditionally or wildlife-friendly managed plots at this scale are unlikely to be fully detected. However, at the wider geographic scale, the greatest abundance in comparison along the urban-rural gradient was statistically significant, being highest on the wildlife-friendly plots in the city centre. Potential reasons for this will be explored further in Chapter 6.

4.23 Summary

- Overall, there is no significant difference between traditionally and wildlife-friendly managed plots with regard to overall epigeal invertebrate abundance.

- At a regional geographic scale, there is a trend that is the reverse of what may have been expected. The urban wildlife-friendly managed plots contained a significantly higher abundance of woodlice compared to rural and suburban sites. Slugs and snails also showed a significant management effect; they were more abundant on wildlife-friendly managed plots. Centipedes and beetles were the only taxa found to be significantly more abundant on traditionally managed plots.

- With regard to species diversity, five of the seven wildlife-friendly managed sites contained significantly higher diversity than traditional plots, with the highest diversity at the Driffield wildlife-friendly plots. The other two wildlife-friendly sites that were not significantly more diverse were the urban Newland and the suburban Beverley sites. In contrast, all the traditional plots contained significantly lower diversity to a mix of both other traditional and wildlife-friendly managed plots. In particular, the Driffield traditional plots contained the lowest diversity.

- The factors causing the variation are complex, but may be due, in part, to each taxa displaying different responses depending on ground cover suitability and their own ecological requirements, as this data and other studies have shown (e.g. Shah *et al*., 2003; Minarro *et al*., 2009). This will be explored in more detail at individual species level in the next Chapter.

CHAPTER 5: COMPARISON OF INDIVIDUAL SPECIES OF THREE TAXA ALONG AN URBAN-RURAL GRADIENT

5.0 INTRODUCTION

5.1 Invertebrate species distributions

Data on the individual species composition of epigeal invertebrate fauna of allotments are not widely available, but in some respects can be compared to agricultural land. For example, Wallin (1988) noted that cereal fields are unstable habitats in which survival of a particular carabid species should be related to its dispersal tendencies. Thus species associated with unstable habitats (e.g. allotments) are generally considered to have a higher dispersal capacity than those from more stable habitats (e.g. woods) (Wallin, 1988 and refs therein). It is likely therefore that allotments would provide largely unstable habitat, with small oases of stable habitat in the form of compost heaps, boundary hedges etc.

For non-flying epigeal insects in agricultural landscapes, dispersal between local populations that maintains a metapopulation is dependent upon field boundary permeability and has been shown to have a theoretical optimum depending on the frequency and intensity of pesticide use on the farm (Sherratt and Jepson 1993 in Holland *et al*., 2005). This is likely to hold true for insects in urban/suburban situations albeit perhaps with different boundary types. In addition, taxa with limited mobility are less able to exploit spatially varying resources and avoid local disturbance (Hilty and Merenlender 2000) and thereby provide a clear signal of local changes. Allotments would therefore make the ideal study habitat to explore these issues.

When conducting invertebrate sampling to species level, it is often necessary to examine only a proportion of the species caught as even limited sampling of invertebrates can yield an enormous number of specimens and an immense array of species (Ward and Lariviere, 2004; New, 2005). Ward and Lariviere (2004) also note this sub-sampling is necessary due to time, cost and expertise limitations but the detailed study of a limited number of carefully chosen taxonomic groups is more productive and realistic than attempting to evaluate a larger number of groups superficially (New, 1996). Ideally, a suite of taxa would represent, among other things, major functional guilds and would convey as much information as possible on the sampled sites (New, 1998).

The opportunistic species hypothesis (Gray, 1989; Magura *et al*., 2004) states that at high levels of disturbance, opportunist species are predicted to gain dominance. This hypothesis would therefore suggest that allotments would be dominated by generalist species. In addition, as allotments are usually regularly disturbed habitats due the nature of their purpose and management i.e. regular digging over and harvesting of crop (see Chapter 1, Section 1.9). This could cause changes in invertebrate species composition, population dynamics, breeding success and a range of ecological and ecosystem processes (Donald and Evans, 2006). Smaller allotment sites may be at greater risk of species' extinctions due to the smaller population size of any given species as the dynamics of small populations are governed by a high level of uncertainty (Begon *et al*., 1996). At an even smaller scale, each allotment plot is managed individually, therefore may act as a factor for further habitat fragmentation, especially for species that only travel a few metres in their lifetime and fragmentation can also lead to changes in species structure and turnover (e.g.

see Margules and Milkovits, 1994). The theory of island biogeography (MacArthur and Wilson, 1967) predicts an equilibrium number of species on 'islands' and this theory has been used to predict that fewer species will persist in small more remote habitat remnants compared to larger, well connected ones (Margules and Milkovits, 1994). However, as noted in Chapter 1, Section 1.9, the effects of disturbance on any community, regardless of position along the urban-rural gradient, are more complex than any single theory can combine. A variety of abiotic and biotic factors may act as agents of disturbance (Svensson *et al*., 2007). Whilst Grime (1977) defined disturbance as partial or total destruction of biomass, Pickett and White (1985) have a broader definition where disturbance is "any relative discrete event in them that disrupts ecosystems, community or population structure and changes resources, substrate availability or the physical environment" (in Svensson *et al*., 2007). Thus, epigeal invertebrates on an urban-rural gradient would also be likely to conform to the intermediate disturbance hypothesis (Connell, 1978; Roxburgh *et al*., 2004) which states that species diversity is highest at intermediate levels of disturbance. It would therefore be predicted that diversity would be highest on suburban allotments.

If a clear picture of the actual species composition of allotment epigeal invertebrates could be built up it could serve a number of useful purposes. For example, predictions could be made about their resilience to issues such as climate change and invasion by non-native species (e.g. Harlequin ladybird), more appropriate management choices could be made and the biodiversity value of allotments could be increased.

5.2 Aims of this Chapter

The first aim of this Chapter was to determine which individual species of spiders, woodlice and beetles were present on three Yorkshire allotment sites. Next, the species abundance and diversity of these species were compared across an urban-rural gradient, in relation to two different allotment management styles: traditional and wildlife-friendly. The aims were defined in relation to the second research question:

Q2: What is the composition of the epigeal invertebrate communities on allotments and do they vary in relation to position along an urban-rural gradient and/or to individual plot management style?

5.2.1. Invertebrate species abundance

Specifically, the aims were addressed by the following objectives to:

Objective 5.1 Identify the epigeal community of spiders, woodlice and beetles to species level;

Objective 5.2 Explore the distribution of these species along the urban-rural gradient established in Chapter 3, in relation to management style as determined at Family level in Chapter 4. The null hypothesis tested is that each species will have similar abundance regardless of position on the urban-rural gradient or management style.

5.2.2. Invertebrate species diversity

Objective 5.3 Investigate the diversity of spiders, woodlice and beetles respectively across the urban-rural gradient. The null hypothesis tested is that each species will have similar diversity regardless of position on the urban-rural gradient or management style.

Objective 5.4 Investigate the relationship between species evenness of spiders, woodlice and beetles respectively in relation to allotment management style. The null hypothesis tested is that each species will have similar evenness regardless of position on the urban-rural gradient or management style.

Objective 5.5 Test the opportunistic species hypothesis to determine if, at high levels of disturbance the opportunistic species would dominate (Gray, 1989). The null hypothesis tested is species found in the urban areas are more likely to be opportunistic than those in the suburban and particularly the rural allotment sites.

Objective 5.6 Investigate the relationship between species presence/absence and abundance, along with allotment management style in relation to position along the urban-rural gradient in relation the intermediate disturbance hypothesis (Connell, 1978). The null hypothesis tested is species diversity will be similar highest on the suburban allotment sites, regardless of management style i.e. measures of disturbance.

5.3 METHODS

5.4 Sampling regime

The relationships between epigeal species distribution and allotment context ('urban-ness' and management style) were investigated. Sub-samples of the invertebrate communities collected as part of Chapters 3 and 4 of this thesis were identified to the lowest possible taxon.

For this more taxonomically detailed investigation, one allotment site from each of the three levels of urban-ness identified in Chapter 3 were selected (Table 5.1). This sub-sampling was necessary because time constraints did not allow the identification to species level of the total invertebrate data set. When surveying terrestrial invertebrates to species level, sub-sampling is commonly and effectively used (e.g. Dogramaci *et al*., 2010). Any limitations in sampling technique would apply equally across all the study sites because sampling was done contemporaneously within all plots at each study site (Collett and Schoenborn, 2005).

From each of the three allotment sites chosen, three pots from five plots (N=45) were selected for analysis, using the same invertebrate samples from Chapters 3 and 4, as noted above. The three Orders chosen were Arachnida, Isopoda and Coleoptera to provide a range of feeding guilds and ecological roles on the allotment sites.

Table 5.1 Site and management style labels. This table details the labels used for each allotment site along with the management style of plots and the codes used in statistical analysis and data presentation.

Abbv.	Site	Management Style	Code
DR T	Driffield	Traditional	1
DR W	Driffield	Wildlife-friendly	2
BV T	Beverley	Traditional	3
BV W	Beverley	Wildlife-friendly	4
NW T	Newland	Traditional	5
NW W	Newland	Wildlife-friendly	6

5.5 Identification of invertebrates

Prior to identification, the invertebrates were stored in 70% IMS and re-stored in 70% IMS post identification. Juvenile stages were not included in the identification process unless identification was certain. A reference collection will be made in due course and the data gathered submitted to the local record centre. Some of the early Isopoda records were sent to the national recording scheme and provided useful data for the latest woodlice atlas (see Gregory, 2009). In addition, a summary report will be provided to Hull City Council regarding the species found to add to their biodiversity action plan for allotments. Chapter 6 will discuss, among other things, some of the potential management options that could be applied to enhance the biodiversity value of allotment sites.

Identification was done (Objective 5.1) using the range of identification guides listed below and a stereoscopic microscope (Cooter, 2006).

- Arachnida: Roberts, M.J. (1996) *Spiders of Britain and Europe*, Collins, London. Harvey *et al*. (2002) *Provisional Atlas of British Spiders* (Arachnida, Araneae) Vols. 1 & 2. Biological Records Centre, Huntingdon.
- Isopoda: Gregory, S. (2009) *Woodlice and Waterlice (Isopoda: Oniscidea & Asellota) in Britain and Ireland*. Natural Environment Research Council, Wallingford; Hopkin, S. (1991) *A Key to the Woodlice of Britain and Ireland*, FSC, Preston Montford.
- Coleoptera: Duff, A.G. (2008) *Checklist of Beetles of the British Isles*. www.colepoterist.org.uk (Accessed 17/02/2011); Luff, M.L. (2007) *The Carabidae (ground beetles) of Britain and Ireland*. RES Handbooks, Vol.

4, Part 2 (2nd Ed.) Field Studies Council, Shrewsbury; Forsythe, T.G. (2000) *Ground Beetles*, Naturalists' Handbooks 8, Richmond Publishing Co. Ltd., Slough; Unwin, D.M. (1988) *A key to the families of British beetles*. Field Studies Council, Shrewsbury; Harde, K.W. (1984) *A Field Guide in Colour to Beetles*. Octopus Books Ltd, London.

Nomenclature was based on Roberts, (1996) (spiders), Gregory (2009) (woodlice) and Luff (2007) (beetles) and the authority and date for each species was given in the appropriate table.

5.6 Statistical analysis: overview

In Chapter 4, Table 4.4, it was noted that overall spider, woodlice and beetle abundance and diversity were affected in different ways to either geographical location along the urban-rural gradient or management style. Therefore it was appropriate to test each taxon's abundance in relation to individual species composition for any variation by the methods detailed below.

5.6.1 Ordination of taxon abundance

Non-metric Multi-Dimensional Scaling (NMDS) (using Pisces Conservation Ltd Community Analysis Package (CAP) version 3.0) was used to elucidate any differences in overall invertebrate species composition between the allotment plots for each taxon (Objective 5.2). This method of displaying an ordination diagram of samples was appropriate as the data varied greatly in the magnitude of abundance of some species (Henderson and Seaby, 2008). NMDS is also flexible and makes few assumptions about the form of the data or the inter-relationship of the samples (Clarke and Warwick, 2001).

Prior to running the model, the data were root-transformed to reduce the impact of outliers (Tabachnick and Fidel, 2007). The data were also pre-tested using a random starting point and 1000 iterations to check that the algorithm used was suitable to find the minimum stress solution (see Henderson and Seaby, 2008). The default number of iterations (200) were run in order to find the lowest stress values as the pre-test showed there was little advantage in selecting a higher iteration number (Henderson and Seaby, 2008).

The dissimilarity measure used was Bray Curtis because it is useful for biological data on community structure and it down-weights the importance of highly abundant species (Clarke and Warwick, 2001). Stress values were kept < 0.2 to ensure that the ordination did not produce any misleading interpretations (Clarke and Warwick, 2001; Sheremetyeva and Sheremetyev, 2008) and provided the best goodness of fit (Kruskal, 1964). Pre-testing also showed that PCA was the appropriate starting point, as opposed to a random starting point. The resulting plot mapped the most similar samples closest together and the least similar samples furthest apart.

5.6.2 Pre-screening and non-parametric methods

Following on from the NMDS plot, all the species abundance data were then pre-screened for normality by determining skewness and kurtosis levels (Pallant, 2005) using the SPSS 16 descriptive statistics function. Where some individual pitfall traps contained none of the target taxa, these were removed from the analysis where appropriate. Data that did not meet pre-screening tests were re-analysed using various data transformations (e.g. root, log10 (x+1)) to try and achieve normal distribution. When the data still did not meet these tests, the data were analyzed using the following non-parametric measures. These were Mann-Whitney *U*-test (Fowler and Cohen) on un-transformed data, Kruskal-Wallis dispersion analysis and the Z-test (*sensu* Ivask *et al*., 2008; Paritsis and Aizen, 2008; see below for further details) (Objective 5.2 cont). These latter data were root(x+1)-transformed for the abundance data to reduce the impact of outliers (Tabachnick and Fidel, 2007) and to address the issues of skewed and zero data (Henderson and Seaby, 2008).

In common with other biological studies separate analysis on individual species were undertaken only on the most abundant species; singletons were not considered further (e.g. Bonham *et al*., 2002; Jennings and Pocock, 2009).

The diversity and evenness data were also pre-screened for skewness and kurtosis values using SPSS v16 prior to testing with parametric tests if the data were normal or non-parametric tests when the data did not meet the assumptions for parametric tests (Objectives 5.3 & 5.4). Transformation of the diversity and evenness data was not required as the Species Diversity & Richness III package v 3.0 (Pisces Conservation Ltd) is designed for species counts therefore only whole numbers were used. To explore the diversity and evenness of each taxon, it was appropriate that all species were included (Magurran, 2004).

Using the results gained from the methods above, the species composition was then discussed in relation to the opportunistic species hypothesis (Objective 5.5) and the levels of disturbance (IDH) in relation to position on the gradient and management style (Objective 5.6). See below for further details on the statistical treatment of each taxon.

5.7 Statistical analysis of each taxon

5.7.1 Spider species abundance in relation to gradient and management style

There are about 700 spider species in northern Europe (Jones, 1983) and nearly 600 of those are found in the UK (Tilling, 1987). As the *Linyphiidae* are notoriously difficult to identify to species level without substantial expert help (Roberts, 1996), these spiders were identified to family only. Doubtful specimens were kindly verified by Edward Milner, through the Open University iSpot project. Nomenclature was based on Roberts (1996).

It was shown in Chapter 4 that there was no significant difference in overall spider abundance in relation to either gradient or management style (see Section 4.12). However, the same for individual spider species could not be assumed. To assess the overall individual species abundance, pooled per plot (N=15) in relation to gradient and management style, an NMDS plot was undertaken, as detailed in Section 5.6.1 above, to provide a useful plot of the species' abundance. A Mann-Whitney *U*-test compared the spider communities in relation to management style. It was appropriate because as the test is distribution-free, is suitable for data which are not normally distributed and takes account of samples sizes that are unequal (Fowler and Cohen, 1990).

The first hypothesis to be tested was that the allotment sites would have the same spider abundance for individual spider species, regardless of gradient or management style. As pre-screening had shown the spider abundance data (N=45) were highly negatively skewed, the Kruskal-Wallis ANOVA test was appropriate. This is a non-parametric alternative to a one-way ANOVA (Zar, 1999) therefore was appropriate when testing for any effects of gradient. The Kruskal-Wallis tests were undertaken on the three most abundant species/families (*Pardosa amentata*, *Xysticus cristatus* and the *Linyphiidae* respectively) to examine any difference in individual species' abundance across the urban-rural gradient.

The non-parametric Z-test (Fowler and Cohen, 1990) was appropriate to test any effect of management style on individual species abundance (N=45) (this is similar to the Mann-Whitney U-test but is used when N > 30).

5.7.2 Spider diversity in relation to gradient and management style

In order that the results can readily be interpreted and taken forward by non-specialists for management practices e.g. LA allotment officers, the diversity indices used were those that are commonly used and understood. The Shannon-Wiener diversity index (H) was appropriate, as used in Chapters 3 and 4. Whilst they point out some miss-use of the index, Spellerberg and Fedor (2003) noted, "*of the many species diversity indices used in the literature, the Shannon Index is perhaps most commonly used*." This index has been quoted in many papers in relation to invertebrate diversity (e.g. Hull, 1997; Gardiner and Hill, 2006; Ivask *et al*., 2008; Paritsis and Aizen, 2008) therefore easily fits these criteria. In addition, the Pielou's evenness (J) was also used again in this

Chapter. Pielous' evenness is an index of species diversity that not only measures the number of species but also the evenness or equitability of the abundances of those species (Smith *et al.*, 2006_c).

The diversity (Shannon-Weiner's H) and evenness (Pielou's J) scores for the spider data (N=45) were calculated and explored for variation using Pisces Conservation Ltd's package '*Species Richness and Diversity v4*'. After pre-screening for normality (skewness and kurtosis values), the H and J scores were then used to test whether the sites or plots were significantly different from each other regardless of urban-rural gradient using one-way ANOVA. (These two factors, gradient and management, were combined in a single value: see Table 5.1.) Where significant differences were found, Tukey tests were used *a posteriori* to identify the source of significance (Ennos, 2007).

5.7.3 Woodlice species abundance in relation to gradient and management style

Although there are forty recognized species of woodlice in the UK, with a few additional non-native species confined to greenhouses, there are five species that are commonly encountered (Gregory, 2009). These are known as '*The Famous Five*' (after the Enid Blyton series of books) (e.g. Blyton, 1969). No further verification of species was required. Nomenclature was based on the systematic list provided in Gregory (2009) and as he noted, the phylogenetic relationships between many of the species are poorly understood so they are listed in alphabetical order rather than evolutionary order.

Previous Chapters have shown that collectively, the woodlice were highly significantly more abundant on the urban plots, especially those managed in a wildlife-friendly way. An NMDS plot of the individual species abundance (N=15) across the three allotment sites provided a helpful initial plot of their distribution.

The first hypothesis to be tested was that the allotment sites would have the same woodlice abundance for individual woodlouse species, regardless of gradient. As pre-screening had shown the woodlice data (N=45) were highly skewed, the Kruskal-Wallis test was appropriate. Kruskal-Wallis tests were therefore undertaken on the two most abundant species (*P. scaber* and *O. asellus* respectively) to examine any difference in individual species' abundance across the urban-rural gradient (N=45). A Z-test then compared any effects of management style on these individual species abundance.

5.7.4 Woodlice diversity in relation to gradient and management style

The diversity (Shannon-Weiner's H) and evenness (Pielou's J) scores of each of the woodlice were calculated as per the spiders detailed above. Pre-screening these data for normality (skewness and kurtosis values) showed these data were highly skewed and had a highly peaked distribution (Pallant, 2005). As a result, to test whether the sites or plots were significantly different from each other regardless of urban-rural gradient the non-parametric Kruskal-Wallis test (*sensu* Sundufu and Dumbuya, 2008) was appropriate.

5.7.5 Beetle species abundance in relation to gradient and management style

There are about 4,000 species of beetles known to occur in the UK (Harde, 1984), with 351 ground beetles species recorded (Forsythe, 2000). With regard to beetle identification, only the ground beetles will be considered any further, in common with many other studies of more than one invertebrate Order e.g. (Perner and Malt, 2003; Pfiffner and Luka, 2003; Davis and Utrup, 2010). Nomenclature was based on Luff (2007).

Some of the species collected would not generally be considered as epigeal e.g. Coccinellidae (ladybirds), Curculionoidea (weevils), Meligethinae (pollen beetles). Although Staphylinidae were also present, these rove beetles "can be difficult to identify and the student will have to acquire a range of non-British literature to achieve this" as noted in '*The Coleopterist's Handbook* (4th Ed) (Williams, 2004). More widely, Uehara-Prado *et al.* (2009) stated that only 1.3% of Staphylinidae could be identified to species level in their study of Brazilian terrestrial arthropods. Due to time and expertise constraints these beetles will not be considered any further.

The hypotheses to be tested were that the allotment sites would have the same ground beetle (hereafter referred to as beetles only) abundance for individual the beetle species, regardless of gradient or management style. As pre-screening had shown the beetle data (N=45) were highly skewed, the Kruskal-Wallis test was appropriate. Kruskal-Wallis tests were therefore undertaken on the five most abundant species to examine any difference in individual species' abundance across the urban-rural gradient (N=45). A Z-test then compared any effects of management style on these individual species abundance.

The diversity indices discussed above were then tested on the beetle data as per the spiders and woodlice. After pre-screening for normality, the Shannon-Weiner and Pielou's evenness scores were then used to test whether the sites or plots were significantly different from each other in relation to management style. The Shannon scores were tested using parametric one-way ANOVA whilst the Pielou scores were tested using the non-parametric Kruskal-Wallis test.

5.8 RESULTS

5.9 Overall species abundance

A total of 2,510 individuals were identified across three Orders: Araneae (511), Isopoda (900) and Coleoptera (1,099, of which 427 were Carabidae), from the three allotment sites representative of the urban-rural gradient (Table 5.2) (Objective 5.1).

Figures 5.1(a-c) below shows that the abundance data for the spiders and woodlice in particular are highly skewed therefore were analyzed using non-parametric methods only. These data are based on five plots from each allotment site, split by management style: three traditional plot and two wildlife-friendly plots on each site. Further detail of each taxon analysis is given in the various sections below.

Table 5.2 Overview of the abundance and number of species of each taxon at three Yorkshire allotment sites. Data are based on five plots for each site.

	Spiders		Woodlice		Beetles		Ground Beetles	
	Total	No. spp.	Total	No. spp.	Total	No. spp.	Total	No. spp.
Driffield (DR)	29	5	15	3	396	11	145	14
Beverley (BV)	162	5	17	4	441	9	151	14
Newland (NW)	320	8	868	5	262	14	131	17
Total	511		900		1099		427	

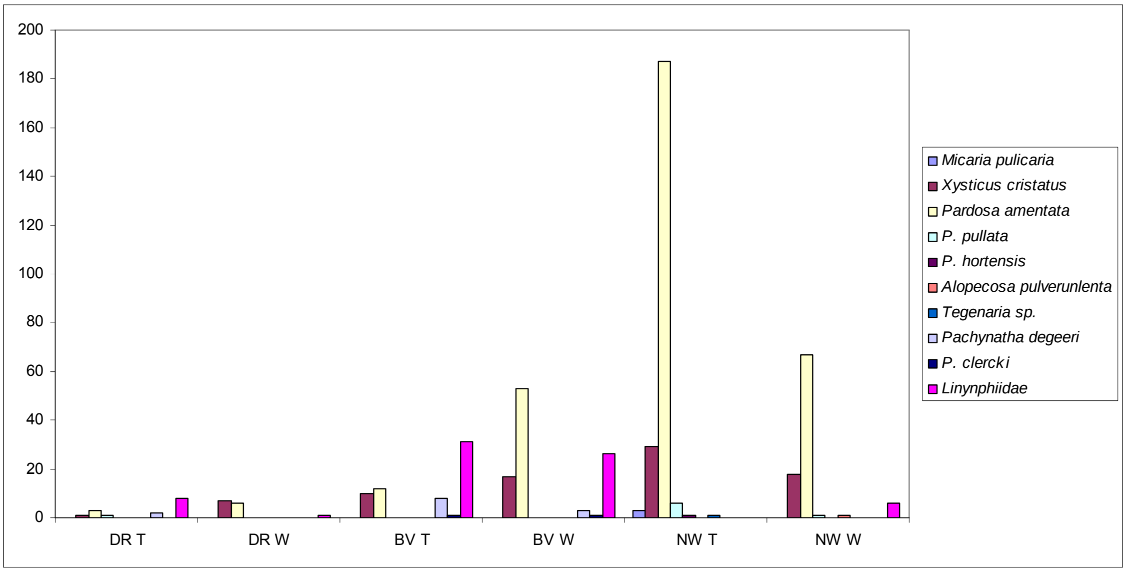


Figure 5.1a Spider species abundance pooled from five plots each on three allotment sites, split per management style. Note the strong negative skew in the data. (Site codes as per Table 5.1)

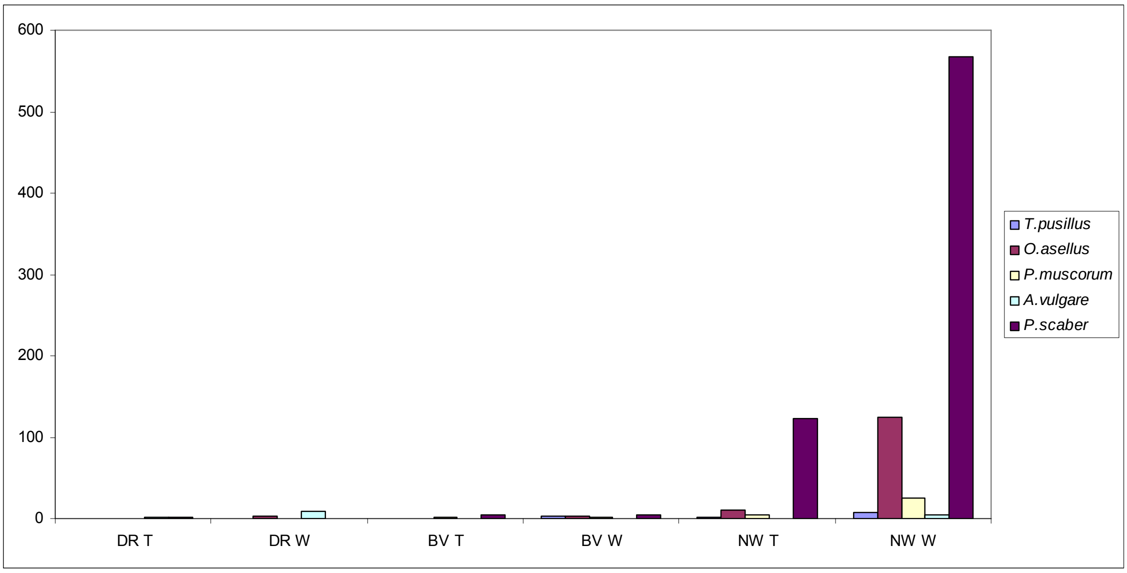


Figure 5.1b Woodlice species abundance pooled from five plots each on three allotment sites, split per management style. Note the strong negative skew in the data. (Site codes as per Table 5.1)

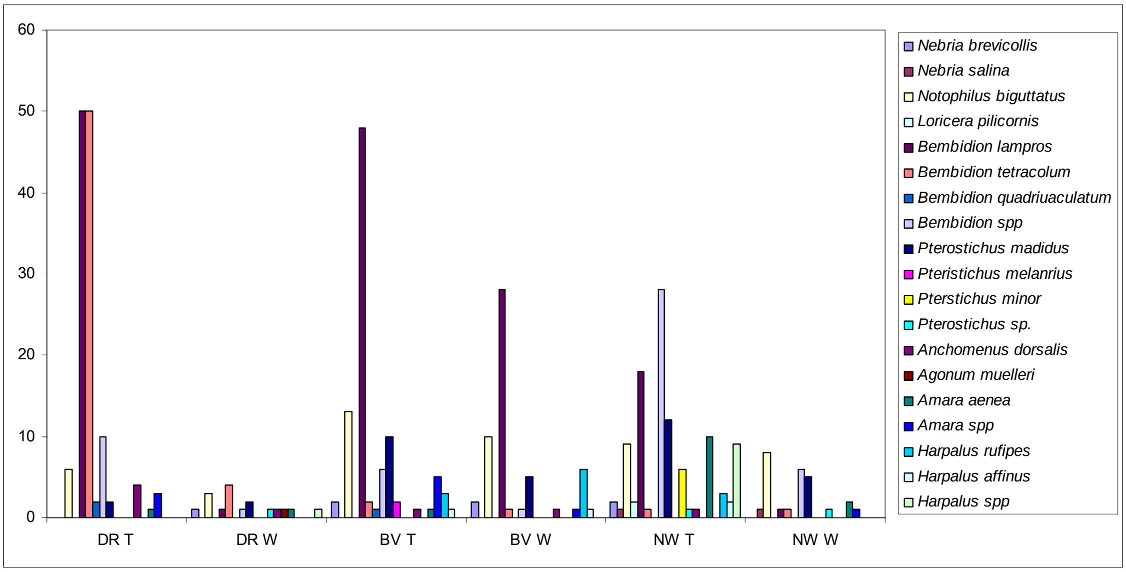


Figure 5.1c Beetle species abundance pooled from five plots each on three allotment sites, split per management style. Note the positive skew in the data and differing scales. (Site codes as per Table 5.1)

5.10 Spider species abundance

A total of 511 spiders from six families were identified across the three allotment sites (Table 5.3) (Objective 5.1). Three taxa (*Pardosa amentata*, *Xysticus cristatus*, *Linyphiidae*) composed 94.33% of the total spider catch from the three allotment sites. The other eleven species, listed in table 5.3 below, ranged from 0.20% (one individual) to 2.54% (13 individuals) of the catch. As these eleven species were in such low abundance, they were not suitable for most statistical analysis techniques (Tabachnick and Fidel, 2007). These latter species were however included in the community analysis and diversity analysis as detailed in Section 5.10.2.

Table 5.3 Abundance, percentage, mean and <u>+</u>SE of individual spider species from three Yorkshire allotment sites (DR = Driffield; BV = Beverley; NW = Newland)

Family	Species	Authority/Date	DR	BV	NW	Total	%	Mean	SE
Gnaphosidae	*Micaria pulicaria*	(Sundevall, 1831)	0	0	3	3	0.59	1.00	1.000
Thomisidae	*Xysticus cristatus*	(Clerck, 1757)	8	27	47	82	16.05	27.33	11.260
Lycosidae	*Pardosa amentata*	(Clerck, 1757)	9	65	254	328	64.19	109.33	74.118
	P. pullata	(Clerck, 1757)	1	0	7	8	1.57	2.33	2.333
	P. hortensis	(Thorell, 1872)	0	0	1	1	0.20	0.33	0.333
	Alopecosa pulverunlenta	(Clerck, 1757)	0	0	1	1	0.20	0.33	0.333
Agelenidae	*Tegenaria sp.*	n/a	0	0	1	1	0.20	0.33	0.333
Tetragnathidae	*Pachynatha degeeri*	Sundevall, 1830	2	11	0	13	2.54	4.33	3.383
	P. clercki	Sundevall, 1823	0	2	0	2	0.39	0.67	0.667
Linyphidae	*Linynphiidae*	n/a	9	57	6	72	14.09	23.67	16.190
	Total		29	162	320	511	100.00		

As the spiders were caught by pitfall trapping, it is not surprising that most of the species encountered were ambush hunters (Foelix, 1996) rather than web-builders. Both the Lycosidae (wolf spiders) and the Thomisidae (crab spiders) tend to sit and wait for prey to pass them or they can actively chase prey (Roberts, 1996; Persons and Uetz, 1997). The Linyphiidae (money spiders) in contrast, make sheet webs (Roberts, 1996).

A useful plot of the distribution of the spider species abundance grouped by allotment site and management style is shown in Figure 5.2 (Objective 5.2). This NMDS plot shows that the Newland urban plots are relatively similar to each other and are clearly separated from the Beverley suburban and Driffield rural plots. The traditionally managed plots are positioned before the wildlife-friendly managed sites along axis one. The suburban plots each have three plots, which are quite similar, with two much further apart. The Driffield plots are rather widely scattered, with a loose grouping of three sites and two outliers. However, the abundance on this site was low in comparison with the other two sites. As noted at the end of Section 5.6.1, the plot does not imply cause, it simply plots the most similar plots closest together based on species abundance.

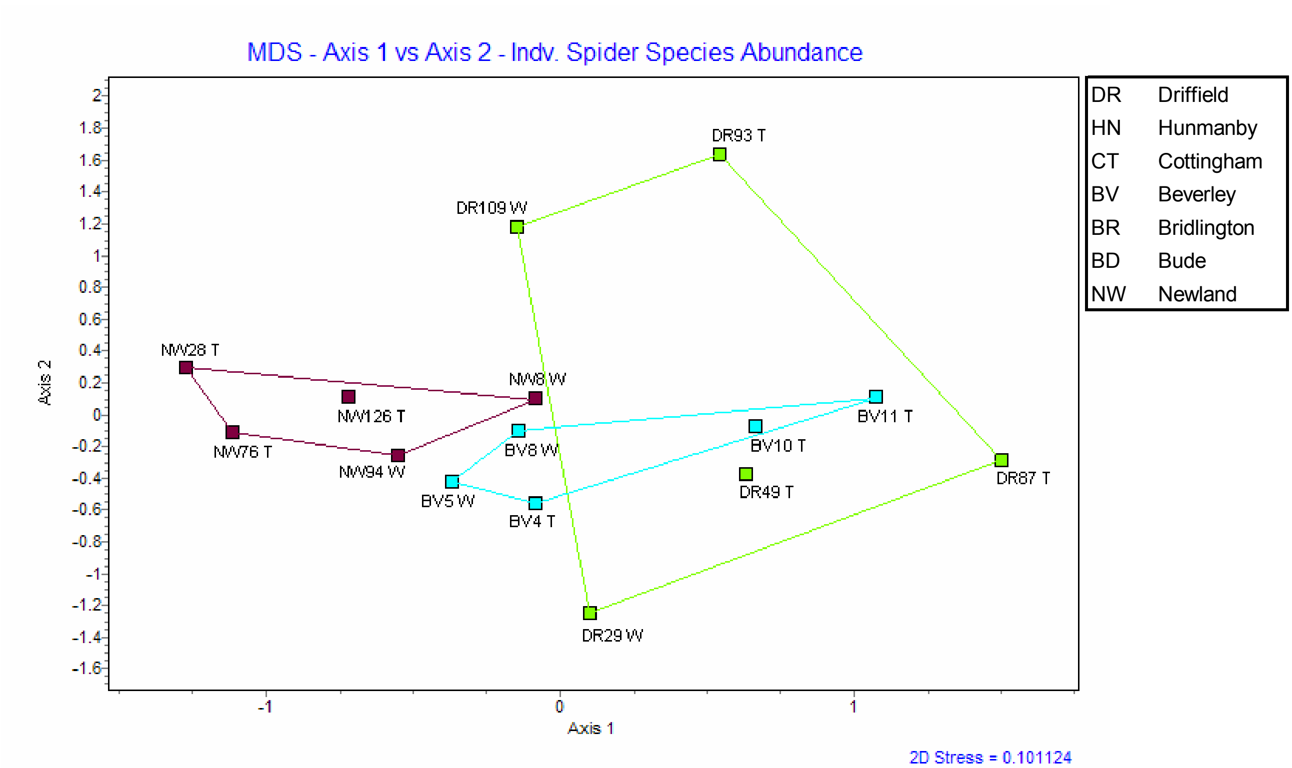


Figure 5.2 NMDS plot on root-transformed individual spider species abundance; data pooled per allotment plot (N = 15) (T = traditional; W = wildlife-friendly management).

Although the MDS plots shows a rather tight grouping of the wildlife-friendly managed plots, the urban and suburban plots contained 62.62% and 31.70% of the spider species respectively, therefore the data were skewed (see Table 5.4 below). The non-parametric analysis a Mann-Whitney test showed there were no significant differences in management style between the medians of the spider abundance (U= 19.5; p>0.05 Mann-Whitney U-test). The following non-parametric methods on root (x+1) transformed data are also appropriate for the following section of the spider data analysis.

Table 5.4 Skewness and Kurtosis values (+SE) for spider species. This table shows the data are highly skewed therefore subject to non-parametric analysis.

	Skewness		Kurtosis	
	Statistic	SE	Statistic	SE
Micaria pulicaria	3.595	0.354	11.433	0.695
Xysticus cristatus	1.537	0.354	2.598	0.695
Pardosa amentata	3.058	0.354	12.086	0.695
P. pullata	5.014	0.354	28.245	0.695
P. hortensis	6.708	0.354	45.000	0.695
Alopecosa pulverunlenta	6.708	0.354	45.000	0.695
Tegenaria sp.	6.708	0.354	45.000	0.695
Pachynatha degeeri	5.275	0.354	30.601	0.695
P. clercki	4.575	0.354	19.811	0.695
Linyphiidae	2.981	0.354	10.292	0.695

5.10.1 Individual spider species abundance variation per allotment site

By far the most common individual species was the wolf spider *Pardosa amentata*, which comprised almost 64% of the total catch and was found in every sample. A Kruskal-Wallis test (N=45) shows that the abundance of this species was significantly different across the three allotment sites, which in turn were sub-divided by management style. An examination of the rank scores shows the this spider was found in significantly higher abundance on the Newland traditional plots (Kruskal-Wallis ANOVA $F_{(1,5)} = 27.94$, $p < 0.001$). Driffield traditional plots contained the lowest abundance whilst the suburban Beverley plots were intermediate. A table of ranks is shown in Table 5.5 below.

Xysticus cristatus was the second most abundant individual (12% of the total catch). Members of the *Thomisidae* family, these spiders are usually called crab spiders due to their flattened bodies and scuttling walk (Preston-Mafham, 2003). The results for *X. cristatus* were very similar to *P. amentata* above: again it was found in significantly higher abundance on the Newland traditional plots (Kruskal-Wallis ANOVA $F_{(1,5)} = 27.15$, $p < 0.001$). Again, the plots with the lowest abundance according to their rank scores were the Driffield traditionally-managed plots. The Driffield and Beverley wildlife-friendly plots contained intermediate rank abundance (see Table 5.5).

The *Linyphiidae* composed 19.2% of the catch. Known as Dwarf or Money spiders (McGavin, 2000), they were not identified further as discussed in the methodology section. The Kruskal-Wallis test showed that these spiders were most abundant on the suburban plots, and the traditionally-managed ones in particular (Kruskal-Wallis ANOVA $F_{(1,5)} = 25.36$, $p < 0.001$).

Table 5.5 Kruskal-Wallis results and rank scores for *P. amentata, X. cristatus* and *Linyphiidae* abundance at three allotment sites along an urban-rural gradient. (DR = Driffield; BV = Beverley; NW = Newland; T = traditional; W = wildlife-friendly management style)

	Site	N	Mean Rank	Chi-square (df 5)	Asysmp. Sig
Pardosa amentata	DR T	9	11.67	27.94	<0.001
	DR W	6	13.58		
	BV T	9	15.94		
	BV W	6	31.08		
	NW T	9	36.50		
	NW W	6	31.67		
Xysticus cristatus	DR T	9	11.83	16.53	0.005
	DR W	6	20.08		
	BV T	9	19.50		
	BV W	6	26.83		
	NW T	9	33.94		
	NW W	6	27.67		
Linynphiidae	DR T	9	21.28	25.36	<0.001
	DR W	6	13.42		
	BV T	9	35.00		
	BV W	6	33.83		
	NW T	9	11.00		
	NW W	6	24.33		

Z-tests demonstrated that there was no significant difference in abundance of any of the three species in relation to management style (*P. amentata*: Z = -1.04, p = 0.30; *X. cristatus*: Z = -0.82, p = 0.42; *Linyphiidae:* Z = -0.70, p = 0.70).

5.10.2 Spider diversity and evenness variation per allotment site

The Shannon diversity indices (H) and Pielou evenness scores (J) for the spider species (N=45) were calculated then tested for normality. The mean scores per site and management style (±se) are shown in Figure 5.3 (Objectives 5.3 & 5.4). This figure clearly shows that the Beverley wildlife-friendly plots were the most diverse (ANOVA $F_{(1,5)}$ = 4.44, p = 0.003), the Driffield plots (regardless of management style) were the least diverse and the Newland plots were intermediate, but more similar to the Beverley plots. Tukey *post hoc* tests showed that these plots were significantly different from both of the traditionally and wildlife-friendly managed Driffield plots. This suggests that the spiders do conform to the IDH, regardless of management style. However, the urban Newland plots had the highest spider species richness but were dominated by one species: *Pardosa amentata*.

The Beverley wildlife-friendly plots were also the most even (ANOVA $F_{(1,5)}$ = 4.29, p = 0.003). However, this time, the Tukey tests showed that the Driffield traditionally-managed plots were significantly different from both types of management at Beverley and the traditionally managed plots at Newland. This variation was due to the very low relative abundance of most species on the Driffield plots compared to the other two sites.

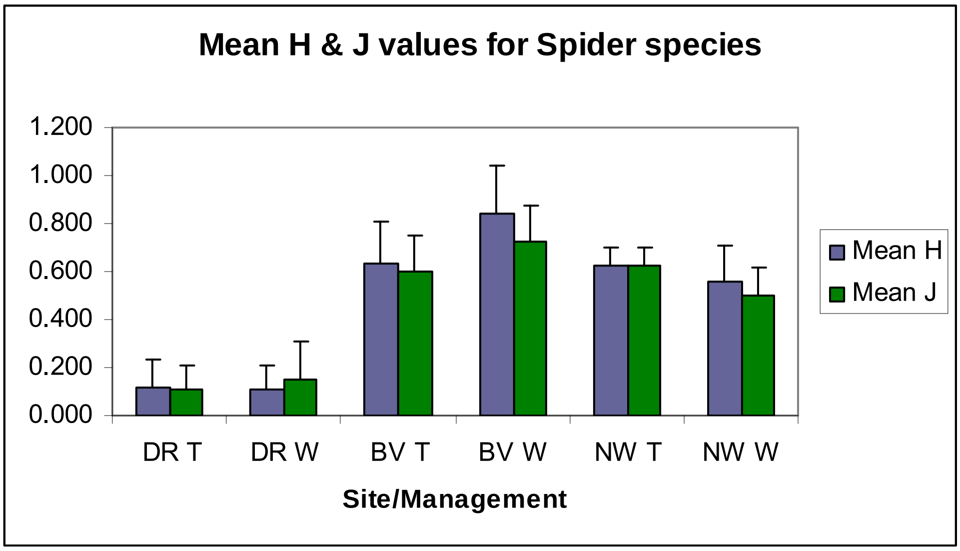


Figure 5.3 Mean Shannon (H) and Pielou scores (±se) for individual spider species per allotment site, split by management style. (Site codes as per Table 5.1)

Only the wolf spider *Pardosa pullata* was unique to the Driffield site, with one individual. Beverley contained *Pachygnatha clercki* which was unique to that site. Newland, in contrast, contained four species not found on the other sites: *Micaria pulicaria, Pardosa hortensis, Alopecosa pulverulenta, Tegenaria* sp..

5.11 Woodlice species abundance

A total of 900 woodlice from five families and five species were identified across the three allotment sites (Table 5.6) (Objective 5.1). Two species, *Porcellio scaber* and *Oniscus asellus*, compromised 92.73% of the total woodlice catch from the three allotment sites. Both of these species were the only ones to be found on all three allotment sites.

The other three species, *Trichoniscus pusillus*; *Philoscia muscorum* and *Armadillidium vulgare* ranged from 1.33% (12 individuals) to 3.44% (31 individuals) of the catch. As these three species were present in such low abundance they were not suitable for most statistical analysis techniques

(Tabachnick and Fidel, 2007). These latter species were however included in the community analysis and diversity analysis as detailed in Section 5.11.2.

Table 5.6 Abundance, percentage, mean and +SE of individual woodlice species from three Yorkshire allotment sites (DR = Driffield; BV = Beverley; NW = Newland)

Family	Species	Authority/Date	DR	BV	NW	Total	%	Mean	SE
Trichoniscidae	*Trichoniscus pusillus*	Brandt, 1833	0	3	9	12	1.33	0.267	0.129
Oniscidae	*Oniscus asellus*	Linnaeus, 1758	3	3	135	141	15.67	3.133	1.386
Philosciidae	*Philoscia muscorum*	(Scopoli, 1763)	0	2	29	31	3.44	0.689	0.235
Armadillidiidae	*Armadillidium vulgare*	(Latreille, 1804)	11	0	4	15	1.67	0.333	0.156
Porcellionidae	*Porcellio scaber*	Latreille, 1804	1	9	691	701	77.89	15.578	5.536
	Total		15	17	868	900	100.00		

Of all the woodlice species, *P. scaber* and *O. asellus* are two of the most sympatric (e.g. see Zimmer and Topp, 2000) therefore finding them both to be relatively abundant together on the allotments is not unsurprising; both are also strongly synanthropic. Gregory (2009) noted that these are the two most widely recorded (but not necessarily most abundant) species in the UK.

Whilst *Philoscia muscorum* was far less abundant in the current study, it too can be readily found in synanthropic areas such as allotments. Gregory (2009) notes this species has a strong preference for grassy sites, yet it was still found to be most abundant on the urban allotments in the current study.

A useful plot of the distribution of the woodlice species abundance grouped by allotment site and management style is shown in Figure 5.4 (Objective 5.2). This NMDS plot clearly shows that the urban plots in particular are closely similar to each other. (One plot at Driffield is not shown as it did not contain any woodlice therefore N = 14.) The rural and suburban plots each have three plots which are quite similar, with one outlier each.

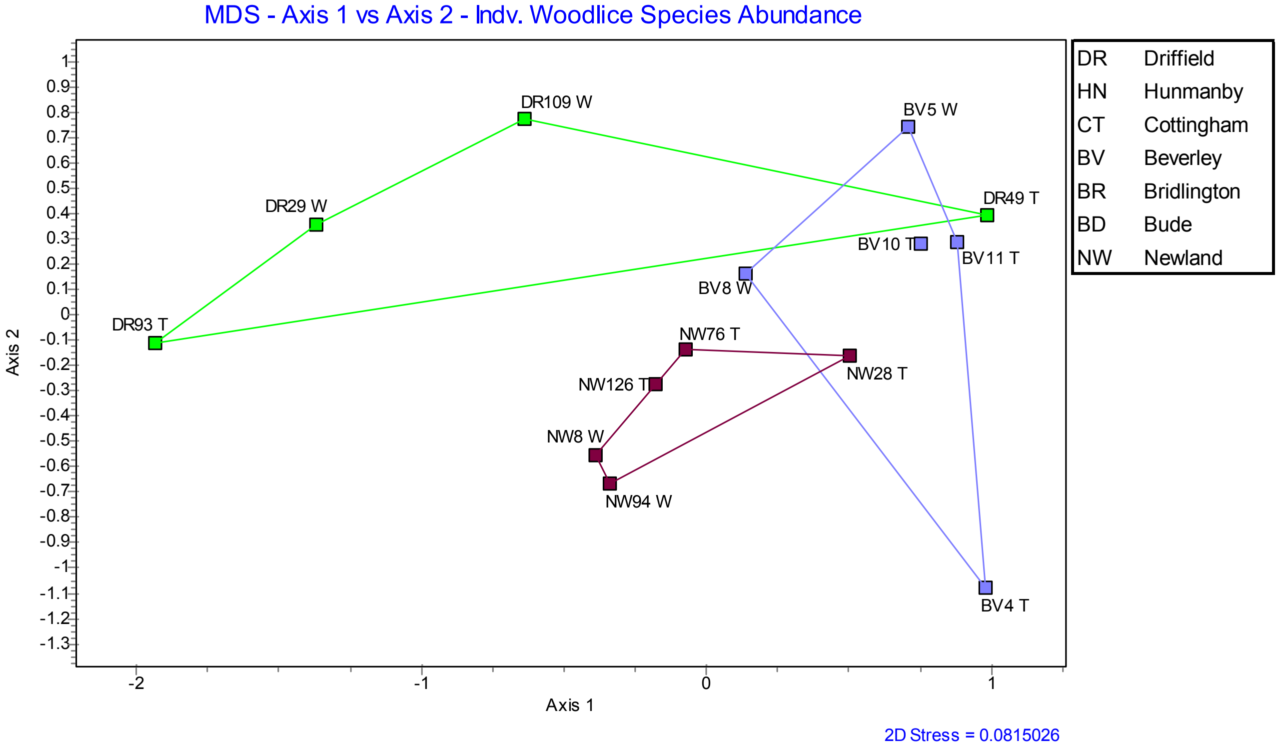


Figure 5.4 NMDS plot on root-transformed individual woodlice species abundance; data pooled per allotment plot (N = 14) (T = traditional; W = wildlife-friendly management).

The bulk of all woodlice species found (96.25%) were from urban plots, therefore the data were highly skewed (see Table 5.7 below) so non-parametric analysis on root (x+1) transformed data was appropriate for this part of the analysis.

Table 5.7 Skewness and Kurtosis values (+SE) for woodlice species. This table shows the data are highly skewed therefore subject to non-parametric analysis.

	Skewness		Kurtosis	
	Statistic	SE	Statistic	SE
Trichoniscus pusillus	3.433	0.354	11.160	0.095
Oniscus asellus	4.042	0.354	17.493	0.095
Philloscia muscorum	2.538	0.354	5.578	0.095
Armadillidium vulgare	3.535	0.354	12.252	0.095
Porcellio scaber	2.858	0.354	8.272	0.095

5.11.1 Individual woodlice species variation per allotment site

A Kruskal-Wallis test (N=45) shows that *P. scaber* was found in significantly higher abundance on the Newland wildlife-friendly plots (Kruskal-Wallis ANOVA $F_{(1,5)} = 35.49$, $p < 0.001$). Driffield wildlife-friendly plots contained the lowest abundance whilst the suburban Beverley plots were intermediate. A table of ranks is shown in Table 5.8 below.

The results for *O. asellus* were very similar: again it was found in significantly higher abundance on the Newland wildlife-friendly plots (Kruskal-Wallis ANOVA $F_{(1,5)} = 27.15$, $p < 0.001$). However, this time, the sites with the lowest abundance according to their rank scores were shared between the Driffield and Beverley traditionally-managed plots. The Driffield and Beverley wildlife-friendly plots contained intermediate rank abundance (see Table 5.8).

Table 5.8 Kruskal-Wallis results and rank scores for *P. scaber* and *O. asellus* abundance at three allotment sites along an urban-rural gradient. (Site codes as per Table 5.5)

	Site	**N**	**Mean Rank**	**Chi-square (df 5)**	**Asysmp. Sig.**
P.scaber	DRT	9	12.67	35.494	<0.001
	DRW	6	11.00		
	BVT	9	18.28		
	BVW	6	21.00		
	NWT	9	34.72		
	NWW	6	42.00		
O.asellus	DRT	9	15.50	27.154	<0.001
	DRW	6	24.25		
	BVT	9	15.50		
	BVW	6	21.92		
	NWT	9	25.06		
	NWW	6	42.25		

A Z-test showed that there was no significant difference in abundance of *P. scaber* in relation to management style ($Z = -0.74$, $p = 0.46$). However, for O. *asellus*, there was a significant difference in its abundance in relation to management style (Z = -3.22, $p < 0.001$). This species was statistically more abundant on wildlife-friendly managed plots.

5.11.2 Woodlice diversity and evenness variation per allotment site

The Shannon diversity indices (H) and Pielou evenness scores (J) for the woodlice species on each plot (N=45) were calculated and the mean scores per site and management style (+se) are shown in Figure 5.5 (Objectives 5.3 & 5.4). This figure shows that the Newland wildlife plots were the least diverse (Kruskal-Wallis ANOVA $F_{(1,5)} = 30.45$, $p < 0.001$) and the least even (Kruskal-Wallis ANOVA $F_{(1,5)} = 30.45$, $p < 0.001$), which is due to the high dominance of *P. scaber*. In contrast, the plots on the rural and suburban sites have similar diversity and evenness values due to the relatively much lower abundance and similar species composition in comparison to the urban plots.

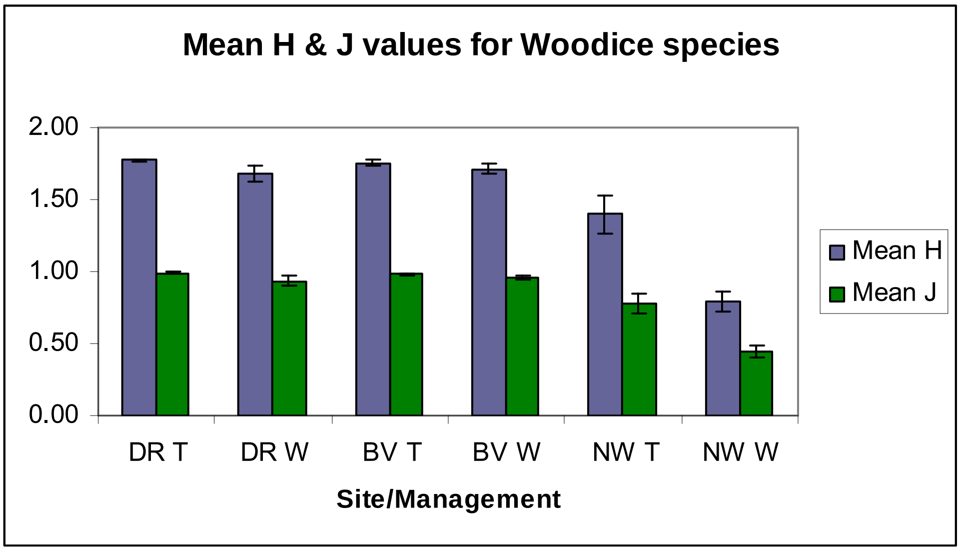


Figure 5.5 Mean Shannon (H) and Pielou scores (+se) for individual woodlice species per allotment site, split by management style. (Site codes as per Table 5.1)

All species found on both the rural Driffield and suburban Beverley sites were also found on the urban Newland sites. However, when comparing just the species composition of Driffield and Beverley, the actual species composition is not that similar. The suburban Beverley site contains two species (*T. pusillus, O. asellus*) not found at the rural Driffield site. In contrast, the Driffield site was dominated by *A. vulgare*, which was not found on the Beverley site.

5.12 Beetle species abundance

A total of 427 ground beetles (Carabidae) comprising 19 species were identified across the three allotment sites (Table 5.9) (Objective 5.1). Five species constituted 80.10% of the total ground beetle catch from the sites. Of these, *Bembidion* species made up 60.89%. The *Bembidion* genus contains 54 species and they are common across a range of habitats, including gardens and agricultural habitats (Luff, 2007). By far the most abundant of these species was *Bembidion lampros* (34.19%), followed by *B. tetracolum* then *Bembidion spp.* With the exception of *B. quadrimaculatum* (0.70%) the *Bembidion* beetles were found across all three sites, but were more abundant at Driffield (see below for further detail).

Notiophilus biguttatus comprised 11.48% of the catch. This distinctive, attractive species can often be found in gardens, arable land and woodland (Luff, 2007 & 1998). Its main prey are Collembola (Bauer, 1981), which were present in high numbers in the pitfall traps, as discussed in Chapter 3, Section 3.7.4.   *Pterostichus madidus* (8.43%) was the largest beetle found and conforms to what many people may imagine a 'typical' British beetle to look like. The other 13 species range from 0.23% to 3.51% of the catch. Of these, seven species were found in such low numbers they were not included most of the statistical methods in this section of the analysis, apart from the MDS plot. They were used however in the diversity analysis section below.

Table 5.9 Abundance, percentage, mean and $\pm$SE of individual beetle species from three Yorkshire allotment sites (DR = Driffield; BV = Beverley; NW = Newland)

Family	Species	Authority/Date	DR	BV	NW	Total	%	Mean	SE
Carabidae	*Nebria brevicollis*	(Fabricius, 1792)	1	4	2	7	1.64	0.159	0.056
	Nebria salina	Fairmaire & Laboulbene, 1854	0	0	2	2	0.47	0.045	0.032
	Notiophilus biguttatus	(Fabricius, 1779)	9	23	17	49	11.48	1.114	0.230
	Loricera pilicornis	(Fabricius, 1775)	0	0	2	2	0.47	0.045	0.045
	Bembidion lampros	(Herbst, 1784)	51	76	19	146	34.19	3.318	0.657
	Bembidion tetracolum	Say, 1825	54	3	2	59	13.82	1.341	0.717
	Bembidion quadrimaculatum	(Linnaeus, 1761)	2	1	0	3	0.70	0.068	0.050
	Bembidion spp.	n/a	11	7	34	52	12.18	1.182	0.316
	Pterostichus madidus	(Fabricius, 1775)	4	15	17	36	8.43	0.818	0.173
	Pterostichus melanrius	(Illiger, 1798)	0	2	0	2	0.47	0.045	0.045
	Pterostichus minor	(Gyllenhal, 1827)	0	0	6	6	1.41	0.136	0.115
	Pterostichus sp.	n/a	1	0	2	3	0.70	0.068	0.038
	Anchomenus dorsalis	(Pontoppidan, 1763)	5	2	1	8	1.87	0.182	0.059
	Agonum muelleri	(Herbst, 1784)	1	0	0	1	0.23	0.023	0.023
	Amara aenea	(De Geer, 1774)	2	1	12	15	3.51	0.341	0.112
	Amara spp.	n/a	3	6	1	10	2.34	0.227	0.102
	Harpalus rufipes	(De Geer, 1774)	0	9	3	12	2.81	0.273	0.088
	Harpalus affinus	(Schrank, 1781)	0	2	2	4	0.94	0.091	0.044
	Harpalus spp.	n/a	1	0	9	10	2.34	0.227	0.145
	Totals		145	151	131	427	100.00		

A useful plot of the distribution of the beetle species abundance grouped by allotment site and management style is shown in Figure 5.6 (Objective 5.2). This NMDS plot clearly shows that the suburban plots are relatively similar to each other, followed by most of the urban plots with exception of NW 8W. The rural plots however have little similarity to each other apart from plots DR49 T and DR 87 T.

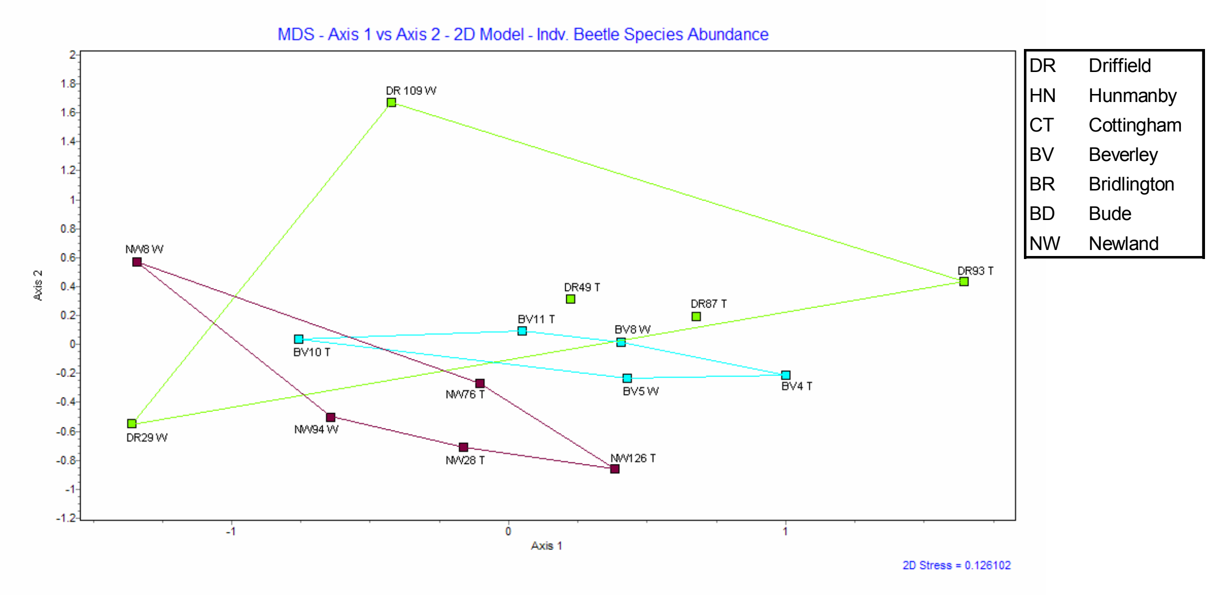


Figure 5.6 NMDS plot on root-transformed individual beetle species abundance; data pooled per allotment plot (N = 15) (T = traditional; W = wildlife-friendly management).

Nine species were found on all three allotment sites. Unlike the spiders and woodlice, there was a relatively even spread of beetle abundance across these sites. These data were however skewed in relation to the distribution of individual species (see Table 5.10 below) so non-parametric analysis on root (x+1) transformed data was appropriate for this part of the analysis.

Table 5.10 Skewness and Kurtosis values (+SE) for beetle species. This table shows the data are highly skewed therefore subject to non-parametric analysis.

	Skewness		Kurtosis	
	Statistic	SE	Statistic	SE
Nebria brevicollis	1.931	0.357	1.807	0.702
Nebria salina	4.520	0.357	19.306	0.702
Notiophilus biguttatus	2.708	0.357	8.763	0.702
Loricera pilicornis	6.633	0.357	44.000	0.702
Bembidion lampros	1.744	0.357	2.473	0.702
Bembidion tetracolum	4.459	0.357	19.530	0.702
Bembidion quadrimaculatum	5.237	0.357	28.345	0.702
Bembidion spp.	2.964	0.357	10.949	0.702
Pterostichus madidus	2.409	0.357	8.642	0.702
Pterostichus melanrius	6.633	0.357	44.000	0.702
Pterostichus minor	6.284	0.357	40.452	0.702
Pterostichus sp.	3.548	0.357	11.094	0.702
Anchomenus dorsalis	1.709	0.357	0.961	0.702
Agonum muelleri	6.633	0.357	44.000	0.702
Amara aenea	2.520	0.357	6.254	0.702
Amara spp.	3.452	0.357	11.991	0.702
Harpalus rufipes	2.803	0.357	10.007	0.702
Harpalus affinus	2.947	0.357	7.004	0.702
Harpalus spp.	4.455	0.357	19.395	0.702

5.12.1 Individual beetle species variation per allotment site

A Kruskal-Wallis test (N=45) shows that *only B. lampros and the Bembidion spp* has significantly higher abundance at some sites. For *B. lampros*, is was more abundant on the Driffield traditionally managed plots (Kruskal-Wallis ANOVA $F_{(1,5)} = 22.39$, $p < 0.001$). Interestingly, the lowest mean rank was at the Driffield wildlife-friendly plots, whilst the other plots were more on a par with DR T (see Table 5.11).

The results are much more mixed for the *Bembidion* spp. By a relatively narrow margin, the *Bembidion* spp are ranked significantly more abundant on the Newland traditional plots (NW T) (Kruskal-Wallis ANOVA $F_{(1,5)} = 12.04$, $p = 0.03$), closely followed by the Driffield traditional plots. The lowest abundance rank is shared between the Driffield wildlife plots and the Beverley wildlife plots with the other two sites/plots intermediate (see Table 5.11).

The other four species tested do not show any significant different in their abundance across the allotment sites, split by management style:

N. biguttatus: (Kruskal-Wallis ANOVA $F_{(1,5)} = 6.10$, $p = 0.296$),

B. tetracolum: (Kruskal-Wallis ANOVA $F_{(1,5)} = 9.70$, $p = 0.084$),

P. madidus: (Kruskal-Wallis ANOVA $F_{(1,5)} = 8.269$, $p = 0.142$),

A. aenea: (Kruskal-Wallis ANOVA $F_{(1,5)} = 10.01$, $p = 0.075$).

Table 5.11 Kruskal-Wallis results and rank scores for the seven most abundant beetle species three allotment sites along an urban-rural gradient. (Site codes as per Table 5.5.)

	Site	N	Mean Rank	Chi-square (df 5)	Asysmp. Sig.
N. biguttatus	DR T	8	20.81	6.103	0.296
	DR W	6	17.25		
	BV T	9	30.33		
	BV W	6	22.25		
	NW T	9	23.17		
	NW W	6	17.50		
B. lampros	DR T	8	34.50	22.390	<0.001
	DR W	6	9.25		
	BV T	9	26.28		
	BV W	6	27.67		
	NW T	9	22.28		
	NW W	6	9.25		
B. tetracolum	DR T	8	31.50	9.700	0.084
	DR W	6	24.67		
	BV T	9	19.56		
	BV W	6	20.17		
	NW T	9	19.11		
	NW W	6	20.17		
Bembidion spp	DR T	8	29.06	12.042	0.034
	DR W	6	15.25		
	BV T	9	19.89		
	BV W	6	15.25		
	NW T	9	30.50		
	NW W	6	20.17		
P. madidus	DR T	8	15.88	8.269	0.142
	DR W	6	17.33		
	BV T	9	22.89		
	BV W	6	21.33		
	NW T	9	30.67		
	NW W	6	24.83		
A. aenea	DR T	8	20.06	10.013	0.075
	DR W	6	20.92		
	BV T	9	19.78		
	BV W	6	17.50		
	NW T	9	30.56		
	NW W	6	24.33		

To examine any effects of management only, Z-tests demonstrated that there was a significant difference in abundance of *B. lampros*, Z =-3.118, p = 0.002 and *Bembidion* spp. Z = -2.649, p = 0.008. Both species were significantly more abundant on traditionally-managed plots. However, there was no significant difference for the other three species (*B. tetracolum*: Z = -0.472, p = 0.637; *N. biguttatus*: Z = -1.595, p = 0.111; P*. madidus*: Z = -0.623, p = 0.533 respectively).

5.12.2 Beetle diversity and evenness variation per allotment site

The Shannon diversity indices (H) and Pielou evenness scores (J) for the beetle species (N=45) were calculated and the mean scores per site and management style (±se) are shown in Figure 5.7 (Objectives 5.3 & 5.4). This figure shows that the Newland traditional plots were the most diverse (ANOVA $F_{(5, 38)} = 3.38$, $p = 0.013$). Interestingly, *post hoc* Tukey tests show that these plots are significantly more diverse than the Newland wildlife-friendly plots, as well as the Driffield wildlife-friendly managed plots. There is also a trend for the highest diversity being found on the traditionally managed plots and the lowest diversity on the wildlife-friendly plots.

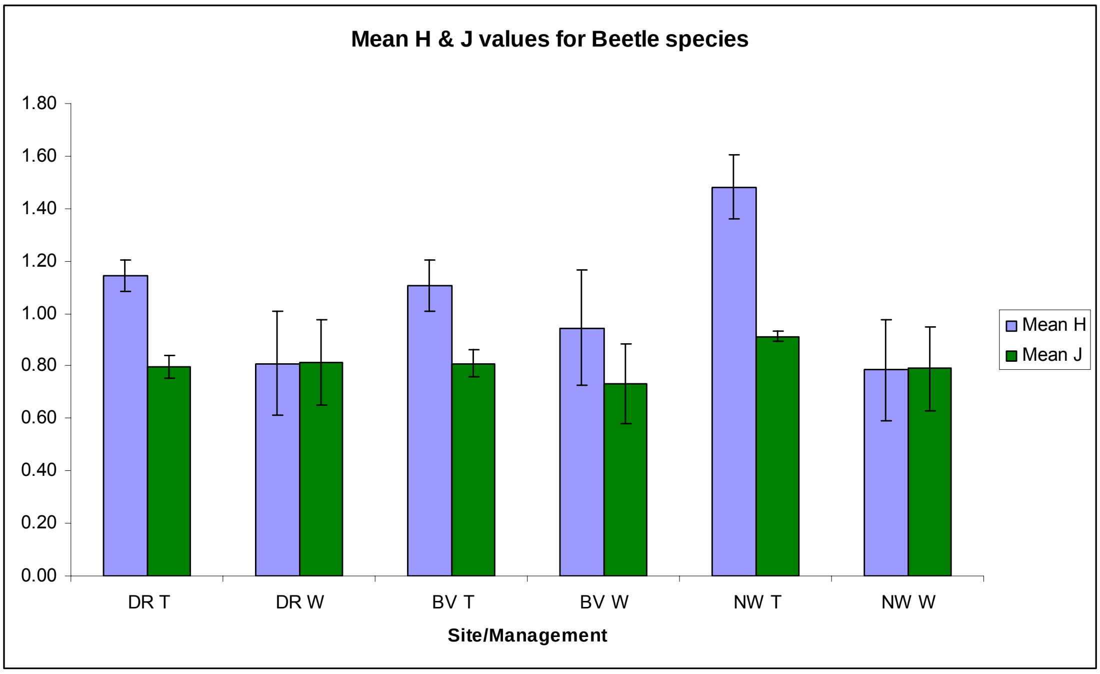


Figure 5.7 Mean Shannon (H) and Pielou scores (±se) for individual beetle species per allotment site, split by management style. (Site codes as per Table 5.1)

With regard to evenness, Kruskal-Wallis ANOVA shows that there is no significant different across the sites and management styles (K-W ANOVA $F_{(1,5)} = 7.405$, $p < 0.186$).

5.13 Overall results summary: abundance in relation to gradient and management effects

The aims of this section were to explore any differences in individual invertebrate species abundance and diversity from allotment plots from three Orders along a previously defined urban-rural gradient in relation to management style.

It was found that abundance of the spiders and woodlice were highly skewed due to the high numbers of individuals found on the urban plots, particularly wildlife-friendly managed ones, compared to the suburban and rural plots. This was due largely to the dominance of the spider *Pardosa amentata* and the woodlouse *Porcellio scaber*. Whilst the beetles had similar abundances across the three sites, the data were highly skewed in relation to individual species. *Bembidion lampros* dominated on suburban and to a lesser extent rural plots but was much less abundant on urban plots. *B. tetracolum* dominated the rural plots but was uncommon on either the suburban or urban plots.

5.14 Overall results summary: diversity and evenness in relation to gradient and management effects

Most of the species identified would generally be classed as rather common, generalist species, with a few locally common generalist species (see Appendix A5.1-3). None would be classed as rare therefore the results concur with Gray's (1989) opportunistic species hypothesis (Objective 5.5).

Spider diversity and evenness was highest on the suburban Beverley plots, especially those that were managed in a wildlife-friendly way. The urban plots had slightly lower diversity whilst the rural Driffield plots had very low diversity and evenness. For woodlice, the lowest diversity and evenness was found on the Newland site plots managed in a wildlife–friendly way due to the high dominance of *P. scaber*. The Driffield and Beverley sites had similar diversity and evenness scores but the actual species composition was different. With regard to the beetles, the Newland traditional plots were by far the most diverse whilst evenness values were similar across all three sites. There was also a trend towards higher diversity on traditionally-managed plots across the sites. These results suggest therefore that whilst some species (spiders) do conform to the intermediate disturbance hypothesis, others do not (woodlice and beetles) (Objective 5.6), given the caveats discussed in Section 5.1 i.e. there are other forms of disturbance that are likely to affect the invertebrate communities found. These aspects will be discussed further below and in Chapter 6.

5.15 DISCUSSION

5.16 Species found on Yorkshire allotments

The first aim of this section of the study was to identify the individual epigeal spider, woodlice and ground beetle species present on three Yorkshire allotment sites. The second aim was to determine the abundance of these species across the urban-suburban-rural gradient, as determined in Chapter 3, Section 3.10, in relation to management style. Next, the diversity and evenness of these species was explored in relation to urban-rural gradient then allotment management style. Finally the results were tested for conformity to the opportunistic species hypothesis (OSH: at high levels of disturbance, opportunist species are predicted to gain dominance) (Gray, 1989) and levels of disturbance, linked to the intermediate disturbance hypothesis (Connell, 1978) as determined by management style and gradient.

A total 28 species were identified to species level, five to Genus and one to Family (subsequently referred to collectively as species) (Objective 5.1). The results demonstrate that the mean number of species recorded per allotment plot was relatively low (mean = 12.46) compared to the number of species found across all plots (34). This indicates therefore a degree of turnover in species composition between allotment plots and sites. In comparison, the mean number of species of beetles, woodlice and spiders found per garden in the BUGS garden pitfall studies (Smith *et al.*, 2006_{ab}) (as detailed in Chapter 3, Section 3.5) was 17.90 but they found 204 species in total across 60 gardens. Thus, a much higher turnover in species composition was noted by Smith *et al.* (2006_{a}) in their study of garden epigeal invertebrate diversity and will be discussed in more detail for each Order below.

Most species are found in relatively low abundance per plot, but for each Order, one common generalist species tended to dominate (making the data skewed therefore only suitable non-parametric statistical analysis (*sensu* Jordan and Jones, 2007; Stella *et al*., 2010; Hansen *et al*., 2011)). In particular, the spider *P. amentata* was more abundant on urban plots making up 49.7 % of the total spider catch. The woodlouse *P. scaber* was also much more abundant on urban plots (76.1 % of the total woodlice catch), but only on those plots managed in a wildlife-friendly way. With regard to the beetles, *B. lampros* was most abundant on the suburban plots (17.8% of the total beetle catch). The results suggest there may be both gradient and management effects (Objectives 5.2 & 5.6) and that the results do concur with the OSH (Objective 5.5), all of which will be discussed in more detail below.

5.16.1 Spider species found on allotments (Objectives 5.2-5.4)

The results show that the urban plots in particular were dominated by one species of wolf spider: *Pardosa amentata* (Table 5.3). After overwintering as sub adults (Hof *et al.*, 1995), the beginning of May is the peak time for the activity of both males and females (Alderweireldt and Maelfait, 1988). This may help explain the high numbers found on the allotments as sampling was conducted in early May. Whilst there was no significant variation in rank abundance of this species between the Driffield and Newland plots in relation to management style, the Beverley plots did have noticeable higher abundance on the wildlife-friendly managed plots (see Table 5.5). The latter’s rank scores were very similar to those on the Newland wildlife-friendly plots. However, as the urban plots only had higher abundance on two of the three traditional plots, which collectively had the highest rank score, this suggests management effects *per se* are not strong for this species. This also suggests however that *P. amentata* fits with the OSH as the gradient effect was strong. However, as the sample size was relatively small, further detailed sampling would be required to determine if management style or gradient were key contributing factors to *P. amentata's* abundance on allotments.

P. amentata is a generalist predator, whose diet contains aphids, therefore it has biological control value and thus may be welcomed by allotment holders. This species has been investigated for its bio-control value in agriculture systems. For example, Kuusk and Ekbom (2010) find a large variation in aphid predation rates by *P. amentata*. This variation is linked to the availability of alternative prey, e.g. Diptera, Collembola, but interestingly, the proportion of *Collembola* taken remains constant, at around 20%. They suggest that high densities of alternative prey could therefore have a negative impact on biological control of aphids. As Collembola were present in high numbers on the allotments in the current study, it suggests that whilst *P. amentata* may be a useful predator of aphids that value may be limited where Collembola densities are high. As an allotment site has a higher proportion of boundary features such as hedges, fences and open, wooden compost bins, there is greater habitat heterogeneity compared to agriculture fields therefore likely to be a wider mix of alternative prey available for *P. amentata*.

Suwa (1986) notes that *P. amentata* is a member of the ground-active spiders, *Lycosidae*, which are raptorial predators that wander on the ground surface, chiefly utilize space horizontally and tend to be diurnal. However, whilst the name wolf spider suggests these animals roam the allotment site in active search of prey, Ford (1978) finds that in laboratory conditions, *P. amentata* is only active for about 0.003% of any given day and adopts a 'sit-and-wait' strategy. Either way, when this species is on the move, being diurnally ground-active, it would be particularly susceptible to pesticide use.

Interestingly, Hof *et al.* (1995) found that male wolf spiders are affected to a greater extent by the impact of pesticides compared to females. They have shown in laboratory based experiments with both field and laboratory-bred *P. amentata* that when testing a novel pesticide, male mortality was considerably higher than that of the females, but no explanation is offered as to why this may be the case. If various pesticides cause such an imbalance on other species, it could lead to a change in the community composition of species and subsequent knock-on effects for ecosystem functioning at the allotment scale, for example. However, further research on this specific issue is required as maintenance of ecological integrity rather than just species diversity is important for the resilience of an ecosystem (see Samways *et al*., 2010).

The crab spider *Xysticus cristatus* is found at all three sites, but, like *P. amentata*, its abundance steadily increased from the rural to the urban sites, with no clear discernable inter-site variation. Foelix (1996) notes that the crab spider *X. cristatus* is similar to *P. amentata* in that it is an ambush predator that does not build a web; however, the former tend to sit motionless on leaves or in blossoms rather than hunting directly on the ground. *X. cristatus* is stenophagic to a degree, but will prey on ants, spiders, aphids and beetles, as reviewed by Nentwig (1986). This species is therefore beneficial on the allotments, as it can help reduce aphid numbers.

The high abundance of the money spiders on the allotments can be partly attributed to their ability to rapidly such recolonise disturbed habitats (Cole *et al.,* 2005 and refs therein). In addition, Downie *et al*. (1998) finds that highly disturbed agricultural sites are most likely to be dominated by Linyphiidae. The Linyphiidae were significantly more abundant on the suburban plots, regardless of management style, but with no clear intra-site management pattern, nor any clear gradient effect between the rural and urban sites. The suburban Beverley site is a high-walled, enclosed site, close to the ancient Beverley Minster (built/completed 1425) and its grounds (Beverley Minster, 2012). Once individuals had ballooned in to the allotment site, it would be a relatively enclosed environment. Although capable of small-scale cursorial dispersal, they generally disperse by ballooning (Halley *et al*., 1996).

Linyphiidae have fragile, horizontal sheet webs, usually around 1-74 cm^{-2} surface area, which may have evolved primarily for interception of small, soft-bodied insects such as collembolans, dipterans and aphids (Nyffeler and Sunderland, 2003). As Collembola were found in high numbers in the pitfall traps they are likely to have formed a main part of the Linyphiidae diet. These money spiders, also known as dwarf spiders (McGavin, 2000) are key components of the predator-prey relationship due to the large proportion of aphids in their diet, especially on European field crops, where they dominate (Nyffeler and Sunderland, 2003).

The other spiders found on the allotment plots were also generally diurnal ground active species that do not build webs (Roberts, 1996), which is unsurprising given they were captured using pitfall traps. The Tetragnathid spider *Pachygnatha degeeri* was found mainly on the suburban Beverley plots along with the only two individuals of *P. clercki*. The relative abundance of these species on the Beverley plots may therefore be partly due to the combination of low vegetation and suitable humid microhabitat (Harvey *et al*., 2002), the latter may be caused in part by the high-walled enclosed site, as discussed above. Like the Linyphiidae, *P. degeeri* preys on Collembola; Hardwood *et al.* (2004) notes that although this spider constituted only 6% of the spider population numerically in a UK study of winter wheat, the males contained 37% of total aphid proteins, within all spiders screened; significantly more than their density would predict. As these species were found in low abundance in the current study, no clear pattern can be discerned regarding gradient or management effects.

The three other wolf spiders, *P. pullata*, *P. hortensis* and *Alopecosa pulverulenta* were also mainly found on the urban plots with the exception of a single immature *P. pullata* found at Driffield. However, again due to low abundance, no discernable intra or inter-site variation could be determined. *P. pullata* in particular has very similar habitat requirements and ecology *P. amentata*, but is slightly smaller (females max. 6mm). Interestingly, it is noted by Roberts (1996) that this species is as equally common as *P. amentata* therefore why was it not found in greater abundance in the current study? The habitat requirements, although overlapping, are not exactly the same. Whilst *P. pullata* is perhaps most found in long-established tussocky grassland, *P. amentata* is usually the commonest species found in gardens (Harvey *et al*., 2002). Given the similarity of allotments to gardens, as previously discussed in Chapter 1, Section 1.2 and Chapter 3, Section 3.5, this indicates at least a contributing factor. In their study of carabids and spiders along a forested urban-rural gradient in Finland, Alaruikka *et al*. (2002) only find *A. pulverulenta* (and *X. cristatus*) in the urban area, although both were represented by a single individual. They note that these two species are classified as having a preference for open habitats, as found in the current study.

The attractive little *Gnaphosidae M. pulicaria* was also only found on two of the three the urban plots and has an active, diurnal lifestyle. It is by far the commonest and most widespread of the genus found in the UK (Roberts, 1996). It is found at ground level and especially likes habitats such as sunny gardens (Jones, 1983). Roberts (1996) notes that this species runs about like an ant; a behavioural characteristic which may deter predators. Although not discussed in this thesis for the reasons given in Chapter 3, Section 3.7.4, ants were found in relatively high abundance at the Newland site, but as only three individuals of the spider were recorded, no inferences can be made regarding potential plot management effects.

The *Tegenaria* (Agelenidae) species found is likely to be *T. saeva*, but its appearance can very variable and is very similar to two others in the genus (Edward Milner, pers comm), especially *T. duellica*. As only one female specimen was found, the verifier could not be certain. However, both *T. saeva* and *T. duellica* are strongly synanthropic in Yorkshire (Roberts, 1996). *Tegenaria* spp. are distinguished by their very long legs. Whilst some species do build webs, others are more ground-based. The closely related *T. domestica* is the well-know house spider so often found, usually unwanted, in the bath!

5.16.2 Summary of spider alpha and beta diversity and bio-control value

Overall, with regard to alpha diversity, the epigeal spider species recorded suggests that allotments tend to be dominated by a few common species, which can be numerically dominant (see Appendix A5.1). The beta diversity results show that diversity is limited but highest on urban sites. The species found represent useful elements of bio-control, especially with regard to aphids (see below). By taking a synecological and autecological approach, the results of this section of the study have shown the epigeal spiders conform to the intermediate disturbance hypothesis and the opportunistic species hypothesis, as discussed in more detail below.

Spiders generally have a bad press, no matter where they are found, although the reason for such widespread dislike is difficult to uncover (Chinery, 1993). However this universal loathing may be misplaced on a working allotment. Spiders can be a useful element of bio-control of pests. Because of their high abundance and predominantly insectivorous feeding habits, spiders are suspected to play an important predatory role in agro-ecosystems, woodland and other terrestrial ecosystems (Nyffeler and Sunderland, 2003 and refs therein). However, Downie *et al.* (1998) found that spider species richness decreased significantly with increased management intensity on Scottish agricultural land. They noted that a more diverse and stable species pool ensured a proportion of the predatory fauna would adapt to otherwise catastrophic changes (e.g. in farming practice, climate change). Regardless of position along the urban-rural gradient, allotment spiders will be subject to similar levels of disturbance. However, the suitability and stability of the surrounding habitat is likely to vary, thus affecting the species composition at the allotment scale. The implications of habitat, management and ecological role will be discussed further in Chapter 6.

5.16.3 Woodlice species found on allotments (Objectives 5.2-5.4)

On the allotment sites, the two most abundant woodlice species are *P. scaber* and *O. asellus*. These two sympatric woodlice can be abundant in compost heaps, especially *O. asellus*, whilst *P. scaber* can readily ascend trees in the summer months (Hopkin, 1991). Both species perform a vital role on the compost heaps by chewing dead plants into small fragments, ingesting them and then deposit faecal pellets which decompose rapidly (Hopkin, 1991). They should therefore be welcomed on the allotment plots.

P. scaber however far outnumbered O. *asellus* (see Table 5.6). In addition, whilst the former is relatively abundant on urban Newland traditionally-managed plots (17% of the total species catch) it particularly dominated on Newland wildlife-friendly managed plots (81%). Only one individual was found on the Driffield plots and nine on the Beverley plots. This further supports the strongly synanthropic nature of this species as noted by Richards (1995) who observed a trend for a higher proportion of *P. scaber* in synanthropic Sheffield sites in comparison to *O. asellus*, but acknowledged that much overlap occurs. That both *P. scaber* and *O. asellus* thrive in urban environments may be partly because predators of synanthropic species that would normally reduce densities and thus competition, are absent or greatly diminished in urban communities (Faeth *et al*., 2011).

The woodlice *O. asellus* dominated the Newland urban wildlife-friendly plots, which contained 88% of the total catch for that species. This supports the synanthropic nature of this species as noted by Wang and Schreiber (1999) in their study of the population genetics of *O. asellus* in central Europe. Although it has considerable overlap with *P. scaber*, it prefers damper micro-sites close to ground level, such as compost heaps as mentioned above (Gregory, 2009). *O. asellus* also tends to shred leaf litter in its juvenile stages, whilst juvenile *P. scaber* grazes the leaf litter and its associated microbiota, allowing the two species to co-exist without competing for food (Zimmer and Topp, 2000).

The significant difference in abundance in relation to management style for both these species is likely to be due to a variety of factors. As Newland is a large site and the two wildlife-friendly plots sampled are not close to each other in comparison to the other two allotment sites, it does suggest that some variation in the way these plots are managed in comparison to the traditionally managed plots may be a contributing factor. For example, it may be that wildlife-friendly managed plots are more likely to have thicker mulches for water-retention and weed-suppression, areas of fewer disturbances specifically to benefit wildlife and a greater tolerance of their presence, thus the micro-habitat management of these plots may be particularly attractive to this species.

The medium-sized (max. 11mm) *Philoscia muscorum* and the small (max. 5mm)*Trichoniscus pusillus* aggregate were also found mainly on the urban plots wildlife-friendly plots, but represented only 3% and 1% of the catch respectively. Gregory (2009) noted that *P. muscorum* is never as abundant as *O. asellus* or *P. scaber* in gardens and similar synanthropic localities therefore the findings of the current study provide further evidence of this. This suggests that allotments are more like gardens than farmland with respect to isopod abundance and diversity. *P. muscorum* is not uncommon in compost heaps, but its UK range declines beyond Yorkshire and it becomes restricted to mainly coastal sites (Gregory, 2009).

It should be noted that the common *T. pusillus* is now known to exist as two distinct races (one with a 1:1 sex ratio, one parthenogenetic) but are still generally recorded simply as *T. pusillus* aggregate (Gregory, 2009), as in the current study. Like all the species discussed above, Gregory (2009) notes that *T. pusillus* is also tolerant of high levels of disturbance and therefore found in a variety of synanthropic sites, but is not so closely associated with compost heaps.

Unlike the species discussed above, *Armadillidium vulgare* was most abundant on the rural Driffield plots, where this species is almost at its most northern range apart from a few isolated coastal records further north (Gregory, 2009). As it was only recorded on two plots (one traditional, one wildlife-friendly) no inference can be made about any management effects. This species is a large pill-woodlouse (max. 18mm), able to form a perfect sphere will all appendages concealed (Gregory, 2009). Whilst Gregory (2009) states this species is usually found with other large species such as *P. muscorum* or *P. scaber*, only a single *O. asellus* was found with the eleven *A. vulgare* on the Driffield site.

5.16.4 Summary of woodlice alpha and beta diversity and nutrient recycling value

The *alpha* diversity of the woodlice species recorded suggests that allotments tend to be dominated by a few very common species, which can be numerically dominant. The *beta* diversity results are similar as no single species was restricted to a single allotment site, but, like the spiders, diversity was highest on urban sites, as is abundance. The species found play a key role in decomposition processes and nutrient recycling; they accelerate the process of humification by breaking down plant litter mechanically and chemically, enriching it with microorganisms (Zimmer, 2002; Bigler *et al.*, 2011) (see Appendix A5.2). For these reasons, woodlice should be welcome on allotments.

By taking a synecological and autecological approach, the results of this section of the study have shown the woodlice do not conform to the intermediate disturbance hypothesis. However, the largely synanthropic species found in the current study are the species that may have been expected and do strongly conform to the opportunistic species hypothesis. Whilst the useful role of isopods has been explored to some degree in gardens and compost heaps (Hopkin, 2003), little empirical evidence exists regarding their value on allotments. This issue will be explored further in Chapter 6.

5.16.5 Beetle species on allotments (Objectives 5.2-5.4)

The distinctive beetle *Bembidion lampros* is by far the most abundant beetle species found and is found across all three allotment sites. Whilst it is significantly more abundant on the rural traditionally-managed plots at Driffield, the overall abundance is highest on the Beverley suburban site, when both management styles are combined. Whilst it is least abundant on the urban Newland site, most individuals are found on the traditionally-managed plots. This species is ubiquitous in Britain, especially in gardens and agriculture land (Luff, 2007) (although it has not been recorded so widely in Scotland (Luff, 1998)). This therefore is another species that can be considered as being synanthropic, as also noted by Langor and Larson (1983) who have shown that Canadian populations are limited to areas in and around human habitation.

As a small species (max. 4mm), *B. lampros* prey mainly small arthropods like springtails or eggs and young larval stages of various other arthropods (Lovei and Sunderland 1996; Bilde *et al*., 2000) therefore may be beneficial on allotments. *B. lampros* has also been shown to be a useful predator of the eggs of *Hylemya brassicae* (Bouche) i.e. cabbage root fly (Obadofin, 1976). However, Obadofin also notes that the use of non-selective pesticides to control *Brassica* pests may also lead to a reduction of *B. lampros* and a consequent increase in cabbage maggot attack. However, it is also likely that the pesticides used in Obadofin's study are no longer available in the same strength or consistency, although the active ingredients still appear to be in use (Reigart and Roberts, 1999).

The beetles *B. tetracolum* and *Bembidion* spp. are significantly more abundant on traditionally-managed plots. *B. tetracolum* is only found in high abundance on one traditionally-managed plot at the rural Driffield site, therefore drawing conclusions regarding management style may be misleading, therefore requires further investigation.

The largest beetle found (max. 18mm), *Pterostichus madidus*, was found to be more abundant in suburban and urban sites, and less common on the rural site (Table 5.9), irrespective of site management style. This nocturnal, flightless beetle is sometimes known as the Strawberry Beetle (Chinery, 2004 & 2005) therefore is not likely to be popular with most allotment-holders. Empirical evidence of damage is shown by Luff (1974), who notes that, at a beetle density of 4.2 per m^2 throughout the fruiting season, it results in a peak of 13% of the strawberries being damaged. In addition, whilst Tuovinen *et al*. (2006) found that fruit injuries were correlated slightly with *P. melanarius* (and *P. niger*) numbers, but damage was not specified, their results do not allow any conclusions of the possible pest status of the species. However, in contrast they also noted that strawberry root weevils (*Otiorhynchus* spp.) are economically an important potential prey species of *Pterostichus* spp. and *Carabus* spp. (Tuovinen *et al*. (2006) and references therein). So, on the allotment, *P. madidus* may also have a beneficial role.

Rather confusingly perhaps, *Harpalus rufipes* is also known as the Strawberry Beetle (Mann and O'Toole, 2004) and although Kabacik-Wasylik (1971) (in Tuovinen *et al*., 2006) found that this beetle was attracted to fruits, no correlation with fruit damage was observed. In the current study, this species, along with *H. affinus*, was confined to the suburban and urban plots but was not present in high numbers (see Table 5.9) and neither showed any significant management effects. This species is generally found in open, dry habitats, especially arable fields, waste ground and gardens (Luff, 1998 & 2007).

Like *H. affinus* above, *Nebria brevicollis* was mainly found on the suburban and urban sites, with one individual on the rural site and did not show any significant management effects. However, unlike most of the species above which are mainly found in open habitats, this species is characteristic of woodland litter (Greenslade, 1964). This is another beetle that feeds on Collembola; this species in particular appears to actively seek these prey items in favour of others readily available e.g. mites (Penney, 1966).

Notiophilus biguttatus is another unmistakable species, due to its large eyes and shiny elytra with the large elytral spaces between the second striae, giving the beetle flattened-back appearance. It was found on every plot bar one, with no discernable difference in abundance due to management style. It is ubiquitous through Britain, being found in gardens, woodland, grassland and arable land and is another active hunter of Collembola (Luff, 2007).

Amara aenea was most abundant on the urban site, whilst the *Amara* spp. were slightly more abundant on the suburban site (Table 5.9) but numbers were too low to allow determination of any significant management effects. This species is another widespread species, being found in gardens, dry grasslands, dunes and waste land (Luff, 2007). *Amara* spp. are small (ave. 8mm), oval bronzy or metallic beetles frequently seen running about grass when disturbed by the mower (Mann and O'Toole, 2004), therefore appears to be more typical of garden type habitats which further suggests allotments are more similar in their species composition to gardens than agricultural land.

It is virtually impossible to confuse the beetle *Anchomenus dorsalis* with any other species found in the UK. Its head and pronotum are metallic greeny blue with reddish brown elytra which has the apical half green or blue except at the margins. When disturbed, this beetle releases a strong odour, perceived by humans, which acts as chemical defence against predators (Bonacci *et al*., 2011). It is common in town gardens, where it can form large aggregations (Andersen, 2000; Luff, 2007). However, in the current study, it was most abundant on the rural site (5 individuals), decreasing in abundance towards the city centre site, but showed no influence of management style as such low overall abundance (8 individuals).

Agonum muelleri was represented by a single individual on a Driffield wildlife-friendly plot. This species is not very hygrophilious and occurs mainly on agricultural land and gardens (Luff, 2007).

Finally, although only two individuals of *Loricera pilicornis* were found at the urban site, it was found at some of the other sites sampled e.g. Hunmanby, but recorded in the general beetle abundance results in Chapters three and four. Again, this species is unmistakable due to the long antennal setae and is the only member of the Genus found in Europe (Luff, 2007). This species also feeds on Collembola, but unusually, the antennal setae are used to trap and hold its prey (Hintzpeter and Bauer, 1986).

5.16.6 Summary of beetle alpha and beta diversity and bio-control value

Overall, with regard to alpha diversity, the ground beetle species recorded suggests that each allotment site is reasonably diverse, with a few common species, which can be numerically dominant (see Appendix A5.3). The sites with the highest diversity are shared between the suburban and urban sites (mean = 7.8) when compared to the rural site (mean = 6.0). The beta diversity results show that the urban sites contained the highest number of species (16) and the highest number of unique species (3), whilst the other two sites each had one unique species (see Table 5.9). In comparison to the BUGS garden studies (mean = 9.4) detailed in Chapter 3, Section 3.5, the overall mean diversity is slightly lower on the allotment sites (mean = 7.2).

By taking the synecological approach it has been shown the beetles do not conform to the intermediate disturbance hypothesis. The autecological results however, demonstrate that beetles on allotments do conform to the opportunistic species hypothesis to some degree.

For some people, beetles, like the spiders and woodlice, generally may be thought of in negative terms. This may be partly due to widely known, highly damaging species like the Colorado beetle (*Leptinotarsa decemlineata* (Say)) (Alyokhin *et al*., 2008). However, ground beetles can serve as important agents of biological control (Dritschilo and Erwin, 1982; Hance, 1990; Holland *et al*., 2005), as discussed above. Of the 19 beetle species found in the current study, most are beneficial or neutral for the control of pests (see Appendix A5.3). Only two could be reasonably deemed to be pests to some extent, but even they prey on pest species, as well as some of the crops grown.

Whilst the overall beetle abundance is similar across all three sites, some of the individual species' distribution dominated at particular sections of the gradient and may therefore play different ecological roles in relation to their prey choice. Management effects were found for both alpha and beta diversity for some species, with a trend for increased diversity on traditionally managed plots moving from the lowest diversity on the rural plots to highest on the urban plots.

The variety of beetle species found in the current study demonstrates an overlap with agricultural and especially garden beetle communities (Thomas *et al*., 2001; Smith, 2006_a). As most of the species found may be regarded as beneficial rather than pests, their ecological role on allotments should be examined further and will be discussed in Chapter 6.

5.17 General discussion

The vast majority of species found in the current study could be classed as opportunistic/generalist as opposed to specialist, which is unsurprising given the amount of anthropogenic disturbance associated with an allotment (see Chapter 3, Section 3.1 & Chapter 4, Section 4.2). This study therefore further supports the opportunistic species hypothesis and would classify allotments as disturbed habitats. The regular digging over, cropping of produce and re-planting that occurs on most allotments means that the bulk of the habitat is frequently disturbed. It follows that the communities of invertebrate species found on allotments, in common with those on agricultural land and in gardens, are subject to repeated disturbance. Consequently this community is likely to include many organisms pre-adapted, through their dispersal strategy, to the spatial and temporal pattern of disturbance in such habitats (Halley *et al*., 1996; Goddard *et al*., 2009). Species in these habitats therefore have to be able to withstand such disturbance or be suitably mobile that they can move into undisturbed areas for overwintering, breeding *etc*. More stable micro-environments would be found in boundary hedges, under sheds and other more permanent features on the allotment site, which would offer some safer over-wintering habitats. This is similar to the protection offered by grassy field margins and hedgerows in agricultural systems (Kiss *et al.*, 1993; Hof *et al.*, 2010). These aspects will be discussed further in Chapter 6.

The opportunistic species hypothesis was similarly demonstrated by Magura *et al*. (2004), who examined carabid beetle assemblages along an urbanisation gradient of forest patches in the city of Debrecen, Hungary. They found that urban forest patches contained a significantly higher proportion of generalist beetle species compared to rural and suburban patches. Magura *et al*. (2008) found a similar clear separation for Hungarian woodlice in remnant old forest; both woodlice abundance and diversity was highest in urban patches, but total diversity was limited to six species. They did however interestingly classify *P. scaber* as an urban environment specialist (rather than a generalist), whilst *A. vulgare* was classified as a generalist species. The latter constituted 72% of the total catch, whilst the current study found *P. scaber* by far the most abundant species (77%); this difference is likely to be largely due to the different habitats sampled.

Whilst the intermediate disturbance hypothesis (IDH) (Roxburgh *et al*., 2004; Connell, 1978) would predict that diversity would be highest on suburban allotments, this has been shown not to be the case in the current study for the woodlice or beetles species. The results show that urban allotments support the slightly higher beetle diversity and woodlice had similar diversity across all three sites; only the spiders had the highest diversity on the suburban plots. (In addition, management style of the plots had a significant effect for a few individual species, but most did not display a significant effect in that most species were equally abundant on traditionally managed plots as those on wildlife-friendly managed plots.) Similarly, Magura *et al.'s* (2004) results for beetles did not agree with the IDH. In their study, as mentioned above, they found a clear separation in the beetle species' communities, with highest diversity on the rural patches. Whilst the results in the current study are not quite as clear cut (see Figure 5.6), there is relatively little overlap in communities between the three allotment sites along the urban-suburban-rural gradient. However, in direct contrast to Magura *et al.'s* (2004) results, the highest beetle species diversity was found on the urban plots, but as the two studies were carried out in different habitats (forests versus allotments), it may be a key factor in explaining the differences found.

Whilst allotments have many parallels with gardens in the way they are utilized, they offer the added biodiversity benefit of increased size. The average UK garden size is around 150m^2 (Gaston *et al.*, 2005), smaller than an average individual allotment plot (250m^2), plus each allotment plot is adjacent to other plots. Thus, each allotment plot is connected to at least one other, often four others if it is not on the edge of the site, which forms a connected habitat, but with individually managed plots (i.e. sub-habitats). Goddard *et al*. (2009) advocated trying to find a way of having a landscape ecology framework to study and manage gardens which would view them as patches of interconnected habitat rather than as independent units. However, they acknowledge this would require collaboration between ecologists, social scientists, urban planners and households. In addition, in order to enhance the biodiversity value of a habitat or group of habitats, you first of all need baseline data. The current study has gone some way to address the issues raised by

Goddard *et al.* (2009), albeit for allotments rather than gardens; as noted above, the allotment sites are in effect a series of individual plots, similar to individual managed gardens. These allotments are however more closely connected as the boundaries between plots are usually less formal that those of individual gardens, thus allowing greater movement of species between plots. This also provides the added benefit of 'scaling-up' (Goddard *et al.'s* term, 2009) due to both the larger individual patch size of allotment plots and the fact they are adjacent to other plots, in comparison to most contemporary urban gardens. In the current study, the Newland site in Hull is by far the largest site in the city with 245 plots and a site area of 7.4 hectares (Hull City Council, 2011), which has considerable wildlife value.

The larger scale of an allotment site compared to a garden also means that there are many competing management styles within one area e.g. from extensive pesticide use to none at all. This may have varying effects on the species present. For example, Baatrup and Baley (1993 and refs therein) have shown the various effects of pesticides in laboratory tests on spiders taken from meadowland. To illustrate, they noted that metabolic disruption, abnormal invertebrate ovarian development and reduced egg numbers can shape the invertebrate communities found and therefore shape the ecosystem functioning of the site. However, for most species in this section of the study, management style appears to have little effect. This is may to be due to different management styles co-existing in very close proximity. Thus, if a species is affected by pesticides on one plot, the plot can be re-colonized from a nearby one that does not have pesticides applied. Three species (O. asellus & *B.*

lampros & Bembidion spp.) did however did show an effect for management style, as discussed above.

5.18 Summary

- The species identified show that Yorkshire allotments support relatively abundant and diverse communities of spider, beetle and woodlice populations. From each of these three taxa, one species tended to dominate: *Pardosa amentata*, *Porcellio scaber* and *Bembidion lampros* respectively.

- Many of the species found are generalists, therefore supporting the opportunistic species hypothesis. The urban plots supported the highest diversity of beetle species, whilst the woodlice had similar diversity across all three sites, therefore the results do not agree with the intermediate disturbance hypothesis. Spider diversity was highest on the suburban plots, which did concur with the intermediate disturbance hypothesis.

- The data gathered will help update the species' atlases for the three Orders, as has already been shown in the case of the recent woodlice records (see Gregory, 2009). Most of the species found tend to be either beneficial or neutral regarding their ecological impact on the allotments i.e. pest control value or decomposers. The management implications and bio-control roles of the species found in relation to biodiversity value will be discussed in the following Chapter.

CHAPTER 6: GENERAL DISCUSSION

6.0 INTRODUCTION

6.1 Why are allotments so special?

Allotments are fascinating habitats. They provide a wide range of health and social benefits for the plot-holders (Crouch and Ward, 1997; Milligan *et al*., 2004; van den Berg *et al*., 2010) whilst having the capacity to support a diverse range of wildlife (English Nature, 2006; Marshall, 2009). However the empirical evidence for the latter is rather lacking for the latter category.

To assess allotment plot-holders attitudes to the wildlife on their sites and to determine if individual plot management style or plot location along an urban-rural gradient plays any bearing on the epigeal communities present, the following research questions were posed:

Q1: Are there variations in management style and attitudes to on site allotment wildlife in relation to age or gender of plot-holders?

Q2: What is the composition of the epigeal invertebrate communities on allotments and do they vary in relation to position along an urban-rural gradient and/or to individual plot management style?

To answer these questions, both social and ecological scientific approaches were required. Thus, the aims of the first section of this thesis (Chapter 2) were to use social science methods to determine demographic data on the plot-holders and whether this linked to how they managed their plot and their attitudes to on-site wildlife.

6.2 Social sciences approach to allotment attitudes and practices

In order to make any progress in the field of urban ecology, an interdisciplinary approach is vital, as discussed in Chapter 1, Section 1.3. To illustrate, both Alberti *et al.* (2003) and May (2004) also stressed that perspectives from the humanities and social sciences can help shed light on urban processes such as energy balances, biological distributions and urban sustainability. Engaging with the public in urban environmental initiatives (such as community allotment projects) also gives them the opportunity to play a key part in adapting to the pressures that will be faced by issues such as climate change (Rotherham, 2010). The current study embraces these combined elements of both the social and biological approaches and indeed, could not have taken place without doing so.

First of all, in order to gain access to allotments, site owners, usually the Local Authority, need to be involved. Next, the plot-holders themselves are vital to allow acceptable access to survey, sample or monitor as appropriate. These people are likely to shape how any academic research project will evolve, based on their levels of acceptance, engagement and willingness to share their local knowledge. This element of social science is a fascinating topic in its own right and could lead to many avenues of academic study.

To initiate progress, a commonly used method for gathering initial data that would allow sampling on, for example allotment sites, is the questionnaire approach. This has been used by a number of Local Authorities to provide data for their Allotment Strategies (e.g. Merton City Council, 2007; Newcastle City Council, 2010). This is a relatively cheap and effective means of making initial contact with plot-holders; the benefits and disadvantages of this approach are discussed in Chapter 2, Section 2.4. The data gathered can then give an indication of plot-holders' age, gender, management practices and general attitudes to allotment gardening across a range of sites. From these data, further relationships can be built up between the plot-holders and the researchers, trends can be explored and follow up ecological sampling can be undertaken, as permitted and required.

6.3 The recent rise of allotment popularity

As noted in Chapter 2, Section 2.1, since the commencement of the current study, there has been a surge of interest in domestic vegetable growing and allotments. This is evidenced by the plethora of books now published offering advice on most aspects of how to grow vegetables and manage your allotment (e.g. Foley, 2004 & 2007; Forbes, 2008; Russell-Jones, 2008; Stokes, 2009). To illustrate this phenomenon, when the word 'allotment' was placed in the search box of a well known online book supplier (Amazon) in December 2011, only 10% of the top 100 books listed were published prior to 2005. Of 90% of the post-2005 titles, the majority were published between 2008-2010. Another measure of the popularity of 'allotmenteering' is the fact that the BBC became involved with a national 'Dig In' project in 2009-2010, which provided free seeds, video guides, T.V. programmes and a plethora of information on vegetable growing and cooking via their website (www.bbc.co.uk/gardening/digin/). This increased popularity suggests that it was an opportune time to collect the data on allotments, plot-holders and the wildlife on the sites. It can provide empirical evidence for emerging trends among plot-holders as well as valuable biodiversity data on less popularly studied invertebrate groups. The increase in popularity of allotments means that there will be more allotments managed but trends on how these plots are managed e.g. levels of intensity of management or husbandry styles, cannot be determined without further research.

The increase in published books has not been matched by an increase in the number of journal articles produced which consider allotments or, more specifically, allotment wildlife. For example, Buckingham's (2005) allotment gender study had to rely on articles from popular magazines for much of the background data. A similar search of 'key words' in many of the on-line journal repositories still returns either none or very few papers *exclusively* on allotments. Of those that are found, very few are actually of any relevance to allotment gardening as practiced in the UK. A rare example is Atkinson *et al*. (1979), who conducted a study on common crop pests in allotment gardens around Leeds. Marshall (2009) also considered three allotment sites in Buckinghamshire during his study of the contribution to biodiversity from rural areas, but the main focus was domestic gardens. These two examples are rather rare in their allotment focus in the growing body of research on urban ecology.

6.4 Allotments' potential contribution to sustainability

According to Howe and Wheeler (1999) there are three primary environmental benefits of urban food growing: preserving biodiversity, tackling waste and reducing transport. A DEFRA paper on food security in the UK noted that "*the self-sufficiency ratio of domestic production to consumption has been in notable decline over the last decade*" (Defra, 2006). It provided an indicative figure of

60% self-sufficiency for Britain since the turn of this century. However, when considering vegetables alone, that figure was less than 50% for 2003; this was a fall from approximately 80% in 1978. (It is not clear if small-scale ‘domestic’ vegetable growers are included in the figures.) Additionally, the term ‘food security’ is beginning to be used outside of government circles; people appear to be showing greater interest in where their food comes from, as shown by a survey commissioned by the National Farmers’ Union (Newsquest Media Group, 2010). Cowell and Parkinson (2003) researched the possibility that “*localization of food production leads to more sustainable societies*”. Although much more data on crop yields and energy requirements in relation to agricultural production were required, they found this may be a feasible idea. These papers (Cowell and Parkinson, 2003; Defra, 2006) may therefore suggest that by examining domestic vegetable production, there may be great potential for allotments to contribute to a number of national sustainability and health agendas relating to food security, health promotion and biodiversity conservation, as advocated by Howe and Wheeler (1999) above. In order to fulfil the last agenda item i.e. biodiversity conservation, baseline data must be available. The current study therefore provides a wealth of ecological and biodiversity data on which further allotment studies could be built. In addition, it provides plot-holder profile and attitude to wildlife data that could feed into social studies, along with some health-related comments provided by plot-holders that show physical benefits of vegetable growing (i.e. exercise, mental health) as well as healthy food production.

6.5 Ecological theory, urban greenspaces and allotment invertebrates

The aims of Chapters 3-5 of this thesis were to use ecological scientific methods to assess the epigeal invertebrate communities present on allotments in relation to community ecology theory linked to urban-rural gradient (i.e. geographic effects) and the effects of management style (i.e. a form of disturbance) to answer the second research question (see section 6.1 above).

Disturbance theory, largely based on the seminal paper on plant biomass by Grime (1977) would suggest that allotment epigeal invertebrate communities would be adapted to high levels of disturbance due to the nature of the primary reason for allotments i.e. growing food. As noted previously, disturbance and habitat alteration is not exactly the same issue, but in this context, repeated alteration of the allotment might result in similar effects. As discussed in Chapter 1, Section 1.9, the three primary strategies proposed by Grime (1977) that enabled plants to survive disturbed habitats are: competitive, stress-tolerant and ruderal (the CSR model). As also noted in Chapter 1, these theories have been extended to cover many different types of species i.e. not just plants, in a range of habitats (e.g. Ladd and Facelli, 2005) and can be summarized as growth (≅C), survival (≅S) and fecundity (≅R) (Silvertown *et al*., 1992). On an allotment habitat therefore, one would expect to find that the epigeal species present would adopt one (or more) of these strategies to survive such as disturbed site, dependant on current abiotic and biotic factors. As has been previously discussed in Chapter 3, Section 3.19, ecological theory would also predict that habitats such as allotments would be relatively biodiverse, compared to other urban areas such as car parks and industrial sites. Taking this further, the intermediate disturbance hypothesis (Connell, 1978; Roxburgh *et al*., 2004: see Chapter 1, Section 1.9) would predict that suburban sites would have the highest diversity. As noted previously, disturbance and habitat alteration are not the same thing, but in the context, repeated alteration might result in similar effects. In addition, the opportunistic species hypothesis (Gray, 1989; Magura *et al*., 2004) would predict that opportunist species would gain dominance at high levels of disturbance. These hypotheses suggest therefore that suburban plots would have the highest levels of diversity but urban plots would be the ones most likely to be dominated by generalist rather than specialist species.

Basic ecological theory would also suggest it is obvious that urban greenspaces would harbour relatively high levels of biodiversity compared to the non-green urban areas due to their relative habitat heterogeneity (Begon *et al*., 1996). Thus, we instinctively expect urban 'green' areas such as gardens and allotments to be good places for wildlife as they may act as oases in an otherwise relatively hostile environment. However, few empirical studies have been carried out to verify this (as discussed in Chapter 2, Section 2.1). This is particularly true for the less charismatic species such as epigeal invertebrates in gardens and on allotments. A key reason for this lack of data is possibly due to the relative difficulty in access to such sites because doing so required permission to be granted by multiple owners/tenants. Engaging directly with these people is key to making progress in this area of ecological study.

One project that got around the accessibility problem was the *Biodiversity in Urban Gardens of Sheffield* (BUGS) project, which dealt with the issue of access by only working with a pool of householders derived from contacts among staff at the University of Sheffield and from members of the public at lectures or displays (Thompson *et al*., 2004). This series of studies sampled the species richness and diversity and wildlife value of urban gardens of university staff (for ease of access) in the city in relation to a wide range of environmental factors (Thompson *et al*., 2004; Gaston *et al*., 2005_a; Smith *et al*., 2005; Smith *et al*., 2006_a). Generally, they found that garden wildlife was both species rich and abundant, regardless of the level of planting of native or non-native plants; garden size or proximity of the garden to the city centre. These studies differ from the majority of invertebrate studies in the UK because, unusually, they focussed on, among other things, both urban invertebrates and human attitudes towards them.

6.6 A summary of the results of this study with critique and further work suggestions

The work reported in this study compromises five key elements to investigate aspects of the biodiversity value of allotments; plot-holder profiles and attitudes towards wildlife (phase 1); allotment site environmental variables (phase 2); allotment epigeal invertebrate community analysis and any effects of urban-rural gradients (phase 3) and management style on them (phase 4). Finally, the effects of urban-rural gradient and management style on individual species of allotment epigeal spiders, woodlice and beetles (phase 5).

6.6.1 Plot-holder profiles and attitudes to wildlife: results summary linked to critique of study and further work (phase 1)

Whilst some garden and allotment plot owners go to great lengths to strictly control what grows (and lives) in their plots, a lot of incidental wildlife is present

(Gilbert, 1991). However, as has been mentioned, a lack of empirical data means that the current study helps redress this in relation to the epigeal invertebrate communities present on Yorkshire allotments along an urban-rural gradient. It also considers the effect of allotment management style upon these communities. However, no definition of 'traditional' style management of the allotment plot was given in the questionnaire: an assumption was made that individuals would either identify with that style of management or not. With hindsight, it may have been better to have given either a definition or used another term. For clarity, it may have also have been better to ask respondents to chose only one option when stating their management style. However, subsequent analysis of the self-declared management styles in relation to questions on if and what type of pesticides were used highlighted statistically significant differences in the use and range of pesticides used by the traditional plot-holders compared to their lack of use by the wildlife-friendly plot-holders. This therefore provided empirical evidence for the classification of the plots as either traditional or wildlife-friendly managed as subsequently sampled in Chapters 3-5.

The results of the questionnaire discussed in Chapter 2 show that some of the traditional perceptions about allotment-holders may still be true; many respondents were older men. On the other hand, the results also reveal an interest in allotments from younger people and from women. These younger people were more likely to manage their plot in a wildlife-friendly way as opposed to a traditional way involving pesticide use. It would be interesting therefore to re-survey the same people over a few decades to see if these attitudes change. Do they get fed up with crops being eaten by pests and change to a more traditional approach, using a range of pesticides? As there are no significant differences in abundance or diversity for most of the species studied in relation to management style is it still fair/reasonable to promote “wildlife-friendly” management is ‘better’ when the current evidence does not really support this for most taxa? This aspect will be discussed further in Section 6.6.4.

Whilst the 538 returned questionnaires were dominated by male respondents (73%), there were no significant gender biases in most of the answers given. Half the respondents were over 60 years old, with a further 23% aged between 51-60 years. The main reasons stated for having an allotment were the enjoyment of growing food and having better tasting food. Saving money (economics) was the lowest priority. Given the recent economic downturn experienced across Europe and beyond after this survey was carried out, it would be interesting to repeat this aspect of the questionnaire to see if this answer may now lie higher up the rankings.

Whilst 67% of respondents used pesticides, the type used and frequency of application varied. Those that stated they managed their plot in a traditional way were more likely to use a variety of pesticides, with slug killer being the most popular one in use. Some people added information to show that they tried to be as careful as possible not to kill specific types of wildlife e.g. “*bird-friendly slug pellets*”. However, regardless of management style, a very large percentage of respondents did state that the wildlife on the allotment site was important to them (82%) as discussed in Chapter 2, Section 2.10.11. It is was clear from Table 2.5 in Chapter 2, Section 2.10.17 peoples’ perceptions of ‘wildlife’ varied greatly. For example, some appeared to think mainly of mammals and birds: “*I try to keep wildlife off my allotment e.g. rabbits, moles, cats, pigeons, cabbage white butterflies, mice, rats*.” Others seemed to be much more aware of the important role of invertebrates: “*Although my plot(s) are mainly for vegetables, I am constructing a wildlife pond and planning shrubs to provide shelter for creatures. I leave some grass long for the grasshoppers etc and grow companion plants to encourage pollinators. I found an Elephant Hawkmoth caterpillar summer before last*”. 85% of respondents agreed to allow further sampling on their plot. Even if this figure is biased as respondents had already shown a commitment by returning the questionnaire in the first place, it is still a very positive outcome. This source of knowledge and willingness to participate is a fantastic resource that could be tapped into to explore further many of the themes and issues raised by the baseline data presented in the current study.

Some of the limitations of individual questions in the questionnaire were discussed in the relevant sections in Chapter 2, but overall, the approach adopted in early 2006 appears to have been subsequently mirrored across a number of local authorities. They have undertaken similar questionnaires in order to provide baseline data for the many new allotment strategies that have appeared since 2008 (e.g. Merton City Council, Durham County Council, Bathford Parish Council), albeit the focus has been mainly on the demographics and rules and procedures on the sites rather than attitudes to wildlife. Today, however, most surveys tend to be done electronically by the ‘survey monkey’ software package (e.g. www.surveymonkey.com/s/Allotment_Survey). This method has the benefits of easy distribution and collation of data. At the time of the questionnaire for the current survey however, wide-spread use of such packages were not so prevalent; this is likely to be especially true among the plot-holders given the high proportion of over fifties that took part.

The questionnaire data allowed access to seven allotment sites to help determine a range of environmental variables (phase 2) and allow sampling of epigeal invertebrates (phases 3-5).

6.6.2 Environmental variables data: results summary linked to critique of study and further work (phase 2)

The helpful publication of the BUGS data (Smith *et al*., 2005_a) during the early stages of the current study helped refine the amount of environmental factors recorded. As noted by Samways *et al.* (2010), it is all too easy to attempt to measure as many environmental variables as possible without understanding the rationale for so doing. Given the range of species found and that most depend largely on micro-climate factors (Samways *et al.*, 2010), considerable time and effort were saved by not recording a wide range of environmental variables that were likely to have little obvious bearing on the communities present.

From the environmental data gathered in the current study, the most important aspects for classifying the sites along the gradient could be copied and applied to classifying other allotment sites. Thus, by keeping the number of physical factors measured down to only a few, it may make it easier for conservation planners to replicate aspects of this study in order to assess the biodiversity value other allotment sites. For example, the current study had shown that the easily measured factors:

- Number of trees both on site and in the surrounding 100m;
- Percentage of surrounding hard surface and farmland;
- Number of plots on site and the size of the site;

can predict if a site is more likely to be urban, suburban or rural in characteristic. For urban sites, it demonstrated that the key defining factors were a higher number of plots, larger site area and a higher number of trees on the site. Rural sites were mainly defined by the higher percentage of surrounding farmland within 1 km and a higher number of trees in the surrounding 100m of the sites. The suburban sites were intermediate, but showed closer affinity to urban rather than rural sites (see Figure 3.2b in Chapter 3, Section 3.10). Thus, the protocol used for the adapted range of environmental variables supported therefore the 'common sense' approach to defining the urban-rural gradient and provided a relatively sound basis for next stage i.e. invertebrate sampling using pitfall traps along the urban-rural gradient.

From these assessed environmental factors, it may then be possible to develop a simple numerical index which would allow simple classification of allotment sites. Following on from this, it could be predicted that a large urban site, for example, is likely to support a higher mean abundance of epigeal invertebrates than a rural allotment site, whilst diversity is likely to be highest on a suburban site, supporting the intermediate disturbance hypothesis. It could also be used to help determine where the best option for locating future allotment sites would be and what its invertebrate wildlife value would likely be. These indices could be backed up by a limited number of ground-truthing studies, once the protocol was replicated and refined, as necessary. Several years of data may be required as other abiotic factors such as weather and management style are thought to have a greater effect on generalist invertebrate species composition than for example, predator-prey interactions (Symondson *et al.*, 2002 and references therein). However, devising such an index was not appropriate in the current study as it captured data from only one year and did not measure any detailed meteorological data.

Given the current rapid rate of climate change, understanding how insects and other wildlife respond to their abiotic environment has become particularly important (Chown and Nicholson, 2004). Although current patterns are not clear, evidence suggests that in Britain, insect diversity is being dramatically affected as a result of synergistic human-induced impacts linked to climate change and landscape patterns (Samways, 2005). For example, climate change may have played a part in the success of the relatively recent rapid spread of the Asian Harlequin ladybirds (*Harmonia axyridis*) across England since 2004 (along with its deliberate introduction for bio-control) (Brown *et al*., 2007). This species colonized the Newland allotment site by about 2007 (pers. obs.) and is likely to be found on other Hull allotment sites. This invasive species may out-compete native coccinellids as well as affecting many non-target pest species, damage fruit crops and be a nuisance to humans due to their large unsightly aggregations, along with causing some people to have an allergic reaction to the ladybird bites (Kenis *et al*., 2008).

If additional research on allotments therefore included meteorological data to the other environmental factors suggested above, a clearer picture of the effects of climate change on invertebrate communities and any subsequent effects on crop-growing could be assessed. In addition, with potential effects of climate change gaining wider public understanding, (e.g. increased drought conditions) plot-holders may provide a valuable resource in how to adapt urban food growing techniques. This knowledge needs to be tapped whilst there are still enough of the 'older generations' alive to pass it on.

6.6.3 Invertebrate communities (I): abundance and diversity (phase 3)

As touched upon in Section 6.5, based on similar results for gardens (e.g. Davis, 1979; Gilbert, 1991; Smith *et al*., 2006$_{a,b}$; Marshall, 2009) it may be expected that pitfall trapping for epigeal invertebrates on allotments would yield reasonably abundant and diverse faunal communities. The sheer number of individuals caught was still rather a surprise, although New (2010) does warn that "*it is very easy to collect far more material in an insect survey than can be appraised realistically during the planned life or budget of that project*".

This section of the study focused on 11,718 individuals of eight taxa (spiders, opilione, woodlice, millipedes, centipedes, beetles, slugs and snails). Given the many additional pressures faced by wildlife in urban areas compared to those in rural ones (discussed in Chapter 1, Section 1.6), one may have expected abundance to be lower in the city centre. However, the total abundance showed a clear trend of increasing from rural to urban sites i.e. the opposite of what may have been expected. Thus, the perhaps initially surprising result of higher epigeal invertebrate abundance on the urban sites is not so surprising when one considers the trend for large scale monoculture and the prevalent use of pesticides in rural environments (Thompson, 2007). Urban and suburban habitats in contrast, offer complex habitats with greater 3D structure and a wider variety of host plants. The results suggest therefore that greater attention should be paid to these urban/suburban patches as they can play a valuable role in enhancing the biodiversity, which in turns plays a key role in ecosystem services (Bolund and Hunhammar, 1999; Lawton, 2007) and human well-being (Faeth *et al*., 2011).

Within the eight taxa sampled, the abundance of *individual* taxa varied across the sites with no overall clear trend. The most notable observation was the dominance of woodlice on urban sites. Whilst beetles were relatively abundant across all sites, they were significantly more so on two of the suburban sites. Spiders were also relatively abundant across all sites. These three taxa constituted 79% of the total catch, whilst the other five taxa (centipedes; snails; opilione; millipedes; slugs) ranged between 0.73 – 8.96% respectively. With regard to diversity and evenness, the results were rather mixed; whilst one suburban site supported the highest diversity (and evenness), another suburban site had the lowest. The lowest evenness score was found on a rural site. These results will be discussed in relation to management styles below.

6.6.4 Invertebrate communities (II): the influence of management style (phase 4)

No significant difference in the *total* abundance of all taxa recorded from sites managed in a traditional or wildlife-friendly was found. However, there were significant individual site effects in relation to gradient and management style for some individual taxa. Five of the wildlife-friendly managed sites had significantly higher diversity levels compared to traditionally-managed sites, indicating a general trend for traditional sites to have lower diversity and evenness. In addition, there were interesting patterns in the taxa distributions in relation to both gradient and management style. At the community level, DECORANA showed that where beetles were abundant there were relatively few woodlice and *vice versa*. In addition, the beetles tend to be more abundant in location to the traditionally-managed plots whilst the woodlice were more abundant on the wildlife-friendly managed sites (see Chapter 4, Section 4.8).

At the individual taxon level, the woodlice were also found at significantly higher abundance levels on wildlife-friendly managed urban plots. As there were also statistically significant higher slug and snail abundances on the wildlife friendly plots (approximately double for both taxa), as shown in Chapter 4, Sections 4.13.7 & 8, it would be interesting to explore this further. Perhaps by using a questionnaire approach to determine more detailed management practices, perceived levels of mollusc damage, along with crop yield information and detailed sampling of abundance and diversity, clearer information could be gained on the species present, levels of damage and interaction with plots that use a range of slug control.

There were no significant differences in abundance or diversity for spiders, opilione, millipedes and centipedes in relation to management style, whilst beetles were more abundant on the traditionally-managed plots. Thus the popular pronouncement that “wildlife-friendly” management is ‘better’ is not really supported by the current study, except for woodlice, slugs and snails. However, on the scale of an allotment site, it is likely that as both management styles i.e. traditional and wildlife-friendly, co-exist cheek-by-jowl so the more mobile species may simply colonize from one plot to another if conditions are proving less favourable on one management type. This has parallels in agriculture where stochastic events, such as cultivation, harvesting and application of agrochemicals as studies have shown that some species of generalist predator that are well adapted to the transient environments created by annual crops may be adversely affected, temporarily, on a local scale by such events, but will persist on a larger scale and can re-invade from adjoining patches of field (Symondson *et al*., 2002).

6.6.5 Invertebrate communities (III): Individual species' distribution along the urban-rural gradient in relation to management style (phase 5)

The individual species composition of three allotment sites, representing the urban-rural gradient, was determined. A total of 1,838 individuals of three taxonomic Orders recorded 511 spiders, 900 woodlice and 427 ground beetles. These species exhibit a range of ecological roles on the allotments. The majority of the species found were common, synanthropic species which suggests that the invertebrate communities are most similar to 'ruderal' equivalent of Grime's CSR model (Grime, 1977), as discussed in Section 6.5 above. As noted in Chapter 1, Section 1.9, disturbance factors on allotment sites are many and varied but the results indicate that both gradient and management style (i.e. disturbance factors) do play roles in determining species composition on the allotment sites.

6.6.5.1 Spider species and their potential bio-control value on allotments

Three taxa, *Pardosa amentata (64%)*, *Xysticus cristatus (12%)*, *Linyphiidae (19.2%*), composed 94% of the total spider catch from the three allotment sites. *P. amentata* and *X. cristatus* increased in abundance from the rural to urban sites. Linyphiidae were on average eight times more abundant on the suburban sites compared to the other two sites. Potential reasons for this were discussed in Chapter 5, Section 5.16.1 i.e. possibly due to inability to disperse from the high-walled site. Sunderland *et al*. (1986) has shown that Linyphiidae play a useful role in controlling aphids in various crops in the UK and Switzerland such as cereals, potatoes and sugar beet in agricultural situations. Even when other prey such as Collembola are widely available, a sizable percentage (12-56%) of aphids are still taken (Nyffler and Sunderland, 2003), showing that they are a useful predator to have on the allotment sites. In addition, Swiss Lycosids' prey compromised around 30% aphids (Nyffler and Sunderland, 2003), therefore suggesting they too are useful allotment predators.

The suburban wildlife-friendly managed plots contained the highest diversity and evenness, thereby conforming to the intermediate disturbance hypothesis. However, most of the spider species did not display any significant management effect. None of the species found would be classed as rare; most were common generalists species that prey on soft-bodied species such as Collembola and do little harm to allotment crops. Further research into the usefulness of epigeal spider bio-control on allotments could be combined with other web-spinning spiders to assess the overall effectiveness of arachnid bio-control.

6.6.5.2 Woodlice species and their potential recycling value on allotments

Although 900 woodlice of five species were identified from the three allotment sites, two species, *Porcellio scaber* (77%) and *Oniscus asellus* (15%), composed 93% of the catch. Both of these species were the only ones to be found on all three allotment sites. However, their abundance was by far the greatest on the urban, wildlife-friendly plots, where they constituted 76% of the total woodlice catch. As a result of this numerical dominance, species diversity and evenness was very low at the urban site, in comparison to both the rural and suburban sites. These sympatric species are synanthropic; Magura *et al*. (2008) goes so far as to term them 'urban specialists', where they provide a valuable role on the allotment by decomposing leaf litter and recycling nutrients (Zimmer, 2002; Bigler *et al.*, 2011).

Woodlice tend to be maligned as garden pests (Marren and Mabey, 2010; pers. obs.), yet little evidence exists for their bad reputation. Although they can be a minor pest inside glasshouses (Hopkin, 2003_a), (of which there are few on most allotment sites sampled) they tend to be key components in the process of decomposition and nutrient recycling (Gregory, 2009). Given their close links with anthropogenic habitats and their useful ecological role via their recycling and soil-enhancing activities, they should be welcome on the allotment sites and could be used as an educational species to promote the value of allotment epigeal invertebrates.

To examine if it was mere coincidence that the wildlife-friendly plots contained significantly higher abundance of woodlice it may be useful to do some follow-up research with a larger sample size. As woodlice also demonstrated a significant gradient effect, being far more abundant on urban sites, it would be worthwhile to combine these two factors. In addition, all the woodlice species found were synanthropic to a degree (Gregory, 2009) and all are also found in gardens in particular, which suggests allotments are similar to garden with regard to their isopod communities. It would be useful therefore if the additional sampling discussed above could be done in conjunction with gardens; both could use a mix of sites with and without compost heaps to add another dimension to the research. With hindsight, it may have been helpful to ask a question on compost heaps in the questionnaire to explore any correlation. Paoletti and Hassall (1999) observed a significant difference in isopod abundance when comparing conventional and organic farming systems. The fact that the current study yielded similar results suggests further parallels with allotments and agriculture, as well as gardens.

6.6.5.3 Beetle species and their potential ecological role on allotments

Of the 427 beetles identified, five species constituted 80% of the catch, of which almost 61% were *Bembidion* species. Unlike the spiders and woodlice, their abundance was relatively similar across all three site types, but highly skewed in relation to individual species.

Bembidion lampros was the numerically dominant species (34%) and was significantly more abundant on the rural (Driffield) traditionally-managed plots. This rather small species (3-4 mm) is common across a range of habitats including gardens (Luff, 2007). Its presence on allotments, in conjunction with the medium sized (5-6 mm) *Notiophilus biguttatus* (11%) and the large (14-18 mm) *Pterostichus madidus* (8%) suggests the common allotment beetle fauna has parallels with garden communities (Luff, 2007) and contains mainly synanthropic species.

There was a trend for increased beetle diversity on all of the traditionally-managed plots, with the highest diversity on the traditionally-managed urban plots. Most species tended to be either neutral or beneficial on the allotments therefore the negative perception of them by some plot-holders may be misguided. Marshall (2009), whilst acknowledging the brevity of the allotment section of the survey (three sites), found that of the 19 beetle species recorded, five were uncommon. Although a range of other pest species are discussed, none are beetles.

Of the eight taxa examined in this study, the ground beetles are perhaps the most widely used as ecological indicators. In the UK especially, their taxonomy is widely understood (Kotze *et al*., 2011) and they fit most of the accepted tests (McGeoch, 1998) of a 'good' ecological indicator. Further studies could therefore focus on the ground beetles to determine if a core group of species are present on allotments and the ecological role they play. The current results suggest that the majority of species found are either neutral or beneficial with regard to their bio-control value.

Previous studies have shown carabid abundance and species richness decreased from rural to urban sites and only smaller-sized species were found in the urban areas (Ishitani *et al*., 2003). It would be interesting therefore to explore further the allotment ground beetle communities along the urban-rural gradient in relation to their body size. In the current study, the largest beetle found, *Pterostichus madidus*, was actually slightly more abundant on the urban site compared to the suburban site, whilst it was in much lower abundance on the rural site.

6.7 The benefit of generalist invertebrate species on allotments

Overall, the majority of the species found in the current study would be classed as generalists therefore supporting the opportunistic species hypothesis, but in most cases the intermediate disturbance hypothesis was not supported. However, with regard to Grime's (1977) CSR model, the bulk of the species found are synanthropic generalists i.e. could be classed as 'ruderal'. They respond to the high levels of physical disturbance (by the very nature of being on an allotment) along with the varying levels of disturbance caused by location along the urban-rural gradient, by having relatively high species turnover and abundance of individual species (*sensu* Smith *et al*., 2006_a). These results suggest that allotment sites contain relatively high levels of epigeal invertebrate diversity, irrespective of management style, especially in urban areas, which can provide a range of beneficial ecosystem services (see Section 6.8 below).

Thompson's (2007) book '*No nettles required: the truth about wildlife gardening*' was based on the results of the first series of BUGS results. He noted that the factors that appear to be good for wildlife i.e. factors linked to gardens with an abundant and diverse invertebrate fauna, could have been guessed at with common sense. Helpfully, the BUGS work discussed in Chapter 1, Section 1.3 helped provide empirical evidence to back up this common sense. Basically, dull gardens were dull for wildlife. Good gardens had variety. Similar principles could be happening on allotments; therefore it may not be the management style *per se* that is important but the structure of the plot and the overall site. Those plots with trees, compost heaps and hedges linked to a variety of crops and flowers were likely to be more diverse that those without these features, regardless of management style. However, it is likely that those whom make a particular effort to be ‘wildlife-friendly’ were more likely to have a combination of these factors.

6.8 Synanthropic habitats

This research has shown just how important synanthropic habitats are for a range of generalist invertebrate species. Although most species found were generally common species and largely synanthropic, they have been shown to play valuable ecological roles e.g. nutrient recycling, organic matter decomposition, as also demonstrated by McIntyre *et al*. (2001). Their study also uncovered differences in trophic webs within the epigeal arthropods in relation to urban land use. Predators, herbivores and detritivores were most abundant in urban agricultural sites, whereas omnivores were equally abundant in all forms of land use, which suggested that there may be differences in nutrient cycling with land use. Allotment studies following the same methodology could explore this further.

As urban habitats are where most of us spend most of our time and are therefore most likely to encounter wildlife here, the bulk of that wildlife will be synanthropic. For example, Hedblom and Soderstrom (2010) found in their study of thirty-four Swedish cities that thirteen bird species were classified as synanthropic due to their higher abundance in urban areas. This was thought to be linked to the availability of remnant woodland patches and the ability to adjust to constantly changing environments. Part of the birds’ success would of course depend on suitable food supplies; a need which could be partly filled by invertebrates on allotments. Perhaps this aspect could be explored in the UK.

6.9 Planning and urban greenspace implications

Biodiversity is seen as an important indicator of sustainable development (DEFRA, 2007) and so the current findings have implications for planners with respect to both the urban greenspace designation process and subsequent management of the green space so designated (Millard, 2008). The trend for loss of allotment sites since 1996, despite the increase in demand for plots and a government acknowledgement for the many benefits they bring (Crouch, 2011), is rather worrying. The current research has shown they are valuable spaces for both people and wildlife, that if resourced and managed with more care, could bring about many more human and biodiversity gains. Hopefully, this work will stimulate further research.

CHAPTER 7: CONCLUSIONS

7.0 INTRODUCTION

7.1 Plot-holder use and perceptions of the value of allotments

The current research has provided further evidence to existing studies that allotments are valuable habitats for both humans and wildlife. Whether they are located in rural, suburban or urban areas, the plot-holders enjoy the many benefits they bring, as shown by a questionnaire with 538 responses. It showed that whilst older men are still the majority users, managing their plots in a traditional way, the demographics are changing. Younger people and community groups are also using allotments, but tend to be more likely to manage them in a wildlife-friendly way. However, regardless of age or gender, the vast majority appear to value the wildlife on their sites, although opinions as to what is perceived as wildlife varies. Most respondents (85%) were also willing to participate in further research.

Among the many benefits of allotments, they help retain a 'little bit of green space' and nature in our urban areas for future generations to enjoy (Stokes, 2009). However, as noted by Gilbert (1991), the fostering of wildlife areas in cities is too complex an operation to be left in the hands of ecologists. Therefore in order to assess the wildlife value of these habitats requires an interdisciplinary approach between plot-holders, site managers and researchers.

7.2 Urban-rural gradients use in allotment ecological studies

Urban-rural gradients have been widely used to explore similarities and differences for many species as the gradients are characteristic of many cities around the world (e.g. Niemela *et al*., 2002; Ishitani *et al*., 2003; Sadler *et al*., 2006). The current research has also shown how useful gradients can be for exploring habitat patches with similar use but within a differing wider landscape. As allotments are easily identifiable distinct habitats spread across the urban-rural gradient, they offer ideal opportunities for further gradient-species interactions research. In particular, urban environments are where most universities are situated therefore urban allotments could be exploited much more for ecological and social science research.

Urban environments can be particularly harsh environments for wildlife due to a wide range of pressures not usually found in more 'natural' habitats. For example, increased traffic, noise, impenetrable surfaces and habitat fragmentation can cause decreased species diversity. Ecological disturbance and its effects include a range of complex and often interacting factors e.g. habitat fragmentation, changes in species composition and turnover, to name just a few (Grime, 1977; Donald and Evans, 2006; Gaines and Gratton, 2010). Allotments, regardless of their geographic position, can however offer a refuge for some species, despite the regularly disturbed nature of the individual plots, in comparison to the surrounding habitats.

7.3 Allotment invertebrates

The invertebrate wildlife of allotments appears to be a particularly neglected area of research. This thesis therefore then focused on the epigeal invertebrates in order to assess what communities were present in relation to a range of environmental factors and if they were generally pest species or beneficial. The abiotic data suggests that distinct urban-suburban-rural gradients can be determined from a relatively small number of factors (e.g. amount of hard surface, site area, human population size, number of trees on site/surrounding the allotment site). These factors in turn affect to some degree the species diversity and abundance.

Pitfall traps on forty-two allotment plots determined that the eight taxa examined (spiders, opilione, woodlice, millipedes, centipedes, beetles, slugs, snails) were similar to those found in the *Biodiversity in Urban Gardens of Sheffield* (BUGS) project conducted by Sheffield University which sampled the species richness and diversity and wildlife value of sixty-one gardens around the city (Thompson *et al*., 2004; Gaston *et al*., 2005; Smith *et al*., 2006_{ab}). Beetles (38%), woodlice (24%) and spiders (17%) dominated the catch, with a clear trend to increasing abundance from the rural to the urban sites. Thus, contrary to what may have been expected, the urban sites contained the highest abundance of invertebrates.

In relation to management style, half the plots sampled were managed in a traditional way, which usually meant use of a range of pesticides, whilst the other half were managed in a wildlife-friendly way. This had a significant effect for the woodlice, which were found in much higher abundance on the wildlife-friendly managed plots, as were the slugs and snails. In contrast, the beetles were more abundant on the traditionally-managed plots, whist the spiders, opilione and myriapods showed no significant effect.

When the individual species of spiders, woodlice and beetles were determined from three allotment sites representing the urban-rural gradient in relation to the opportunistic species hypothesis, it was found that the species do conform i.e. they were all ‘generalist’, mainly synanthropic species as opposed to specialist/rare species, probably largely due to the high levels of disturbance found on an allotment site. However, in relation to the intermediate disturbance hypothesis, only the spiders conformed, with the highest diversity on the suburban site. The highest beetle diversity was found on the urban site whilst the woodlice had similar diversity across the gradient.

Three species (*Pardosa amentata*, *Xysticus cristatus*, *Linyphiidae*), which composed 94% of the total spider catch, were generalists. They feed on a range of prey such as Collembola, as well as pests such as aphids, but have little or no known harmful effects on allotment crops. Two synanthropic species, *Porcellio scaber* and *Oniscus asellus* dominated the woodlice catch (93%). All five woodlice species found on the allotments play a beneficial role by decomposing leaf litter and recycling nutrients (Zimmer, 2002; Bigler *et al*., 2011) so would not harm crops.

Of the nineteen species of beetle identified, including the *Bembidion* species which compromised 61% of the catch, they were either neutral or beneficial on allotments. Thus, of all the species of spiders, woodlice and beetles identified, none could be reasonably classed as harmful. This information may come as a surprise to some allotment holders and could therefore be used to provide them information on the benefits of encouraging a diverse epigeal fauna on their plots, perhaps with the notable exception of slugs and snails, which are unlikely to ever be popular with the majority of plot-holders.

By sampling and identifying the invertebrates, useful baseline data are provided which may underpin further research involving the extant epigeal communities of UK allotments. As most of the species found play a useful role in pest control or soil conditioning, the empirical evidence could be used to inform allotment holders that the bulk of the species present are actually beneficial for a range of ecological services e.g. nutrient recycling, soil conditioning, weed control and pest management. Studies on beetle banks as part of agri-environment schemes (see Chapter 1, Section 1.9,) have also shown the banks provide beneficial impacts for bio-control. These benefits are not only from the significant increases in beetles species and abundance they support, but also spider abundance and diversity (Macleod *et al*., 2004 and refs therein) thereby providing further evidence of the value of such management measures that could be adopted, on a smaller scale level, on allotments.

7.4 Recommendations for further work and management of allotments

This thesis has highlighted that allotments are rich environments that could be used to undertake a range of both social and biological/ecological research. It has shown that allotments offer a refuge for both people and wildlife, regardless of geographic location. However, the pressures on urban land for development make urban allotment sites particularly vulnerable. In order to resist this pressure, evidence of the current value of allotments should show that they are ideal habitats to support a number of health and sustainability agendas and should therefore be protected. If the evidence of many social benefits of allotments could be presented to urban planners to help them plan development in a more sustainable way (a key part of their remit e.g. see Hull City Councils' '*Hull Core Strategy*', 2011) and retain them as valuable greenspaces, it would benefit the wider community. Thus, further work on the benefits that plot-holders gain from having their allotment directly in relation to health, social and interaction with wildlife would provide additional useful data.

This thesis has also shown that allotment management styles *per se* may not be vital for some epigeal species, whilst is has a bearing on others. However, the mix of management styles (i.e. traditional and wildlife-friendly) on individuals' plots existing cheek-by-jowl, along with the relatively complex habitat structure of whole allotment sites, suggests that if sites were more actively managed as a whole, it could help enhance their biodiversity value. In addition, if the biodiversity value of allotments was recognised and enhanced, this could only strengthen the case to retain them. For example, informing and encouraging plot-holders to use boundary hedging, open style compost bins (usually made from old pallets), consider having a community pond or some trees on site or build dead hedges could enhance their biodiversity value, as has been done on the Newland site (pers. obs.).

7.5 Final conclusions

This thesis has provided some novel research uniting both social and ecological sciences approaches. Firstly, a social science approach determined the social science aspects of plot-holder demographics, allotment use and attitudes to the wildlife found on the allotment site, using a questionnaire approach. The results showed that whilst older men who had had their plot for eight years or more were more likely to mange their plot in a traditional way using a range of chemicals, younger people, especially women, were more likely to manage their plots in a wildlife-friendly way and had had their plots for less than eight years.

Regardless of age or gender, the majority of plot-holders valued the wildlife on their sites, but may have differing views to what the term wildlife means. Most were also willing to allowing sampling on their plots to determine the epigeal invertebrate communities present.

Secondly, two rather neglected areas of ecological research were combined to determine the epigeal communities present on Yorkshire allotments in relation to urban-rural gradient effects and to management style of individual allotment plot. The results have shown, as noted above, that beetles (38%), woodlice (24%) and spiders (17%) dominated the catch, myriapods, molluscs and opilione constituted the remaining 21%. There was a clear trend of increasing abundance from the rural to the urban sites. The species found were mainly common, synanthropic generalists rather than rare habitat specialists. They performed a range of largely beneficial roles on the allotments i.e. pest control and nutrient recycling. Management effects were only pronounced for the woodlice, being significantly more abundant on wildlife-friendly plots and the beetles, which were significantly more abundant on traditionally-managed plots. Whilst, ecological disturbance and its effects include a range of complex and often interacting factors, these results suggest that both gradient and management do play a part in determining the epigeal communities present on a regularly disturbed habitat i.e. allotments.

This thesis has used a socio-ecological approach to demonstrate that allotments are vibrant, vital places for both plot-holders and the wildlife they support. Allotments have the capacity to provide a wide range of health, social and economic benefits for humans and a refuge for a range of epigeal species across the urban-rural gradient. Whether plots are managed traditionally or in a wildlife-friendly way, they offer food and shelter to a range of generalist species that, given the chance, can act as a means of biocontrol for unwanted pests. As Gilbert (1991) concluded in his book '*The Ecology of Urban Habitats'* "*it is our destiny to live side by side in mutual tolerance with synanthropic animals and plants*". The final words however come from three of the many plot-holders who made this research possible. They stated of their value of their allotment was "[the] *importance of preserving green spaces in Hull and learning the ways of the land*"; "*Enjoy the wildlife found there*" and "*While at your plot you are in your own world, with peace and quiet*."

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Urban Biodiversity: Successes and Challenges: Epigeal invertebrate abundance and diversity on Yorkshire allotments

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ALLOTMENTS: FASCINATING HABITATS

After more than half a century of neglect and decline, allotments are on the brink of a great revival (Foley, 2004). Recent decades in particular have witnessed a growing demand for allotments, partly linked to the demand for healthy, pesticide-free food and an escape from the pressures of modern, busy urban lives. The image of traditional plot-holders e.g. retired men, may be slowly changing. Allotment plots are increasingly managed by young women and professional couples keen to grow organic crops or seek an escape from the daily grind (Buckingham, 2005; pers obs). In parallel to the increased interest in the socio-economic, health and recreational benefits of allotments, there is a growing interest in the biodiversity value of these unique mosaics of intensively managed habitat (Gilbert, 1991). However, to date there has been little published research which concentrates on them.

Marshall (2009) used a questionnaire-based survey to assess garden and allotment biodiversity and attitudes to it. He found that, among other things, having direct contact with plants and wild animals in a garden or allotment helped foster a wider interest in nature. Thus, allotments, because they typically involve a cross-section of a community, can offer an ideal opportunity to engage people on an individual or community level and allow them to take a greater interest in their local wildlife.

The aims of our research were to test any variation in epigeal (ground-dwelling) invertebrate abundance and diversity along an urban-rural gradient, in relation to any effects of allotment plot management styles i.e. traditional or wildlife-friendly.

GENERAL APPROACH

A questionnaire-based survey was used to determine plot-holder attitudes to allotment management styles and the importance of wildlife on the sites. From these data, individual plots across allotment sites in east Yorkshire were identified to sample the epigeal invertebrates. In addition, plots were assigned as being either 'traditional' or 'wildlife-friendly' based on self-declaration. A range of environmental data were collected to determine the urban-rural gradient e.g. rural sites were likely to have a high percentage of surrounding farmland whilst urban sites were likely to have a high percentage of surrounding hard cover. These data were informed by the results of the Biodiversity in Urban Gardens in Sheffield (BUGS) project which examined, among other things, garden invertebrate biodiversity (Smith *et al*., 2006 a,b). Three pitfall traps, pooled per plot, were used to sample invertebrate abundance and diversity in May and September 2006 on six plots from each of seven sampling sites chosen ($N = 6 \times 7 \times 2 - 10$ plots compromised/vandalized = 74) . These sites represented an urban-rural gradient and each site contained three 'traditionally' managed plots and three organic, wildlife-friendly plots, as identified from the questionnaires.

BIOLOGICAL DATA

Pitfall trapping resulted in the collection of 11,718 individual organisms; eight taxa were subject to further analysis. There was a significant difference in the mean number of individuals per allotment site (Figure 1). The rural Driffield allotment site contained significantly lower overall invertebrate abundance compared to the Newland site in Hull city centre, which had the highest abundance. Although none of the other sites were statistically different from each other, there was a trend towards an increase in mean abundance moving towards the city centre.

Beetles (Coleoptera) constituted 37.95%, woodlice (Isopoda) 24.03% and spiders (Araneae), 16.93% of the catch respectively. Urban sites tended to be dominated by woodlice whilst beetles tended to be more common on some suburban and rural sites. The results for spiders and the other five taxa, whose abundance ranged between 0.73% - 8.96% of the total catch, showed mixed abundance across the urban-rural gradient (Figure 2).

With regard to overall invertebrate abundance in relation to management styles, the urban wildlife-friendly managed plots contained significantly higher abundance compared to all other plots, except the urban traditional plots. The latter, whilst not statistically significant, did not contain such high abundance as the urban wildlife plots. This therefore highlighted a trend towards increased abundance along the rural, suburban, urban gradient, especially on those plots managed in a wildlife-friendly way.

The effects of management style on individual taxa gave mixed results; different taxa dominated over differing management styles. Beetles were significantly more abundant on traditionally managed plots. In contrast, the woodlice, slugs and snails (Mollusca) were significantly more abundant on wildlife-friendly managed plots.

Spiders, opilione, millipedes and centipedes (Myriapoda) showed little difference in abundance in relation to management style. The most biologically diverse plots were managed in a wildlife-friendly way, with the highest diversity found on a rural site at Driffield. Interestingly, this site also contained the lowest diversity on the traditionally managed plots.

DISCUSSION

This study has shown that there is considerable interest from allotment plot-holders in projects that recognize the value of "their" allotments. Whilst older men still dominate, there are an increasing number of community groups, younger families and especially women, taking on allotments. The latter are also more likely to place a higher value on the wildlife on their plots and sites, as shown by their commitment to manage their plots in an organic, wildlife-friendly way.

The epigeal invertebrate taxa on the seven allotment sites studied showed a significant variation in both abundance and diversity along an urban-rural gradient. In contrast to what may have been expected, the urban sites contained the highest abundance whilst the rural sites contained the lowest. Whist urban sites are likely to be subject to a higher range of anthropogenic pressures, each allotment site may be a small-scale biodiversity oasis, due partly to the lack of other suitable surrounding habitat patches compared to rural areas.

The composition of the taxa found in the current study was similar to that of the BUGS studies mentioned above, but the actual proportions of some of the taxa were quite different. For example, Smith *et al.* (2006_b) found that the three most abundant taxa of the pitfall traps were woodlice (45%), beetles (25%) and slugs (19%) respectively, whilst in the current study they constituted 24%, 38% and 9% respectively. The most abundant taxa, the beetles, dominated the rural, and to lesser extent suburban, sites. The woodlice, however, dominated the urban sites, suggesting that they prefer synanthropic environments. In addition, spiders contributed 17% of the total catch, compared to less than 5% in the BUGS study.

The reasons for these differences are likely to be many and require further exploration. However, in the case of the slugs, it is likely that this group would be very actively discouraged from allotments, due to their primary *raison d'être* as a means of growing food crops. Slug pellets were the most common pesticide used, as evidenced in the questionnaires, supporting this conclusion.

Whilst management style suggests no *overall* difference in total invertebrate abundance, the differences at geographic scale do appear to show some effect. The higher abundance found on the wildlife-friendly allotment plots in the city centre may be due to a skewed effect of the high number of woodlice on these plots, as discussed above.

Overall, the diversity of the taxa found suggests that allotments are valuable habitats for epigeal invertebrates. The highest invertebrate diversity, found at the rural Driffield wildlife-friendly plots, corresponds with their low abundance and requires further study to try and explain the reasons. The environmental data gathered suggests that the high proportion of farmland surrounding the allotment site may account for some of the variation. Species are likely to be able to disperse readily into the surrounding habitat, unlike the more constrained urban habitat patches.

FUTURE WORK

Further work is ongoing to identify the three most abundant taxa to species level from a rural, suburban and urban allotment site respectively. Additional analysis of the questionnaire data, environmental and biological data will be published separately in due course. This work will therefore provide some much-needed empirical data on the epigeal invertebrate communities present on Yorkshire allotments. This baseline information could then be used to explore further issues such as biological control methods or effects of climate change on crop growing on allotments.

CONCLUSIONS

The increase in popularity of allotments offers a great opportunity to study the wildlife benefits of such sites, particularly in urban areas where greenspace is at a premium. In order to advance these studies, it is important to engage with individual plot-holders.

The epigeal invertebrate taxa found on these allotments are similar to those found in garden studies, but the proportions of dominating taxa vary across the urban-rural gradient and with management styles. Abundance was higher on urban plots, especially wildlife-friendly managed ones, compared to both traditionally and wildlife-friendly managed plots on rural or suburban sites. Invertebrate diversity was highest on some wildlife-friendly rural plots, which also had low abundance. Future work will help identify the specific species present and provide further clues to their ecological role on allotment sites.

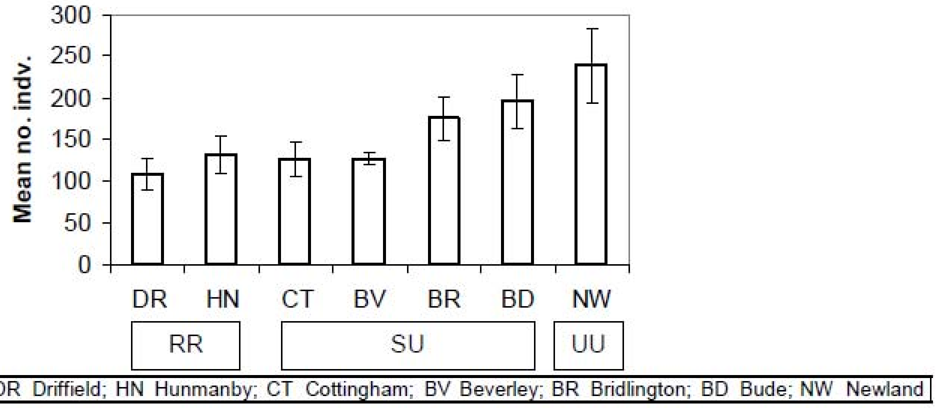

Fig. 1. Mean number of invertebrates per Yorkshire allotment site (+ SE), based on individual plot totals (N=74), grouped per urban-rural gradient. (RR=rural; SU=suburban; UU=urban.)

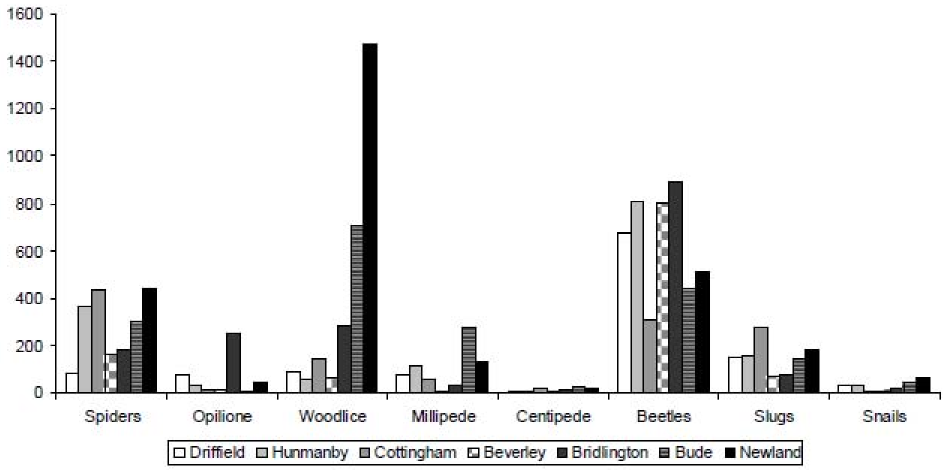

Fig. 2. Total number of each invertebrate taxon from pitfall-traps on seven Yorkshire allotment sites.

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Table A2.1: Breakdown of 557 responses to the question "Are you male or female?" (N/R = no reply to site name; HU = Hull city sites; DR = Driffield; CT = Cottingham; HN = Hunmanby; BV = Beverley; BR = Bridlington; WN = Withernsea.)

QC		Gender					
Site Name	Site Code	Male		Female		Total per Site	
		No.	%	No.	%	No.	%
N/R	N/R	31	79.49	8	20.51	39	100
Albert Cottage	HU	28	68.29	13	31.71	41	100
Allotment Lane	DR	26	83.87	5	16.13	31	100
Bacon Garth	CT	4	100.00	0	0.00	4	100
Bilton Grove	HU	6	100.00	0	0.00	6	100
Bude Rd.	HU	22	70.97	9	29.03	31	100
Calvert Rd.	HU	13	72.22	5	27.78	18	100
Clough Rd.	HU	8	80.00	2	20.00	10	100
County Rd.	HU	14	70.00	6	30.00	20	100
Field St.	HU	0	0.00	0	0.00	0	100
Gipsyville	HU	18	78.26	5	21.74	23	100
Hunmanby	HN	3	50.00	3	50.00	6	100
Keldgate	BV	10	90.91	1	9.09	11	100
Lamorna Ave.	HU	24	72.73	9	27.27	33	100
Leads Rd.	HU	26	83.87	5	16.13	31	100
Mappleton Grove	HU	14	100.00	0	0.00	14	100
Marfleet Lane	HU	2	100.00	0	0.00	2	100
National Ave.	HU	16	80.00	4	20.00	20	100
Newland	HU	32	54.24	27	45.76	59	100
Noddle Hill	HU	1	33.33	2	66.67	3	100
North Bar Without	BV	1	25.00	3	75.00	4	100
Oak Rd.	HU	13	72.22	5	27.78	18	100
Perth St.	HU	25	75.76	8	24.24	33	100
Pickering Rd.	HU	22	68.75	10	31.25	32	100
Portabello St.	HU	1	33.33	2	66.67	3	100
Queensgate	BR	10	90.91	1	9.09	11	100
Richmond St.	HU	10	55.56	8	44.44	18	100
Wansbeck Rd.	HU	2	50.00	2	50.00	4	100
Withernsea	WN	26	81.25	6	18.75	32	100
TOTAL PER RESPONSE OPTION		408	73.25	149	26.75	557	100

Table A2.2: Breakdown of 528 responses to the question "What age group are you in?" (N/R = no reply to site name.)

QB		Age													
Site Name	Site Code	Under 21		21-30		31-40		41-50		51-60		Over 60		Total per Site	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
N/R	100	1	2.50	1	2.50	3	7.50	5	12.50	11	27.50	19	47.50	40	100
Albert Cottage	1	0	0.00	1	2.38	1	2.38	10	23.81	7	16.67	23	54.76	39	100
Allotment Lane	2	0	0.00	0	0.00	1	3.45	4	13.79	10	34.48	14	48.28	29	100
Bacon Garth	3	0	0.00	0	0.00	0	0.00	0	0.00	1	25.00	3	75.00	4	100
Bilton Grove	4	0	0.00	0	0.00	0	0.00	0	0.00	1	16.67	5	83.33	6	100
Bude Rd.	5	0	0.00	1	3.57	5	17.86	1	3.57	10	35.71	11	39.29	28	100
Calvert Rd.	6	0	0.00	1	5.56	0	0.00	1	5.56	4	22.22	12	66.67	18	100
Clough Rd.	7	0	0.00	1	9.09	1	9.09	2	18.18	4	36.36	3	27.27	10	100
County Rd.	8	0	0.00	1	5.00	3	15.00	4	20.00	3	15.00	9	45.00	20	100
Field St.	9	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	100
Gipsyville	10	0	0.00	1	4.76	2	9.52	4	19.05	5	23.81	9	42.86	21	100
Hunmanby	11	0	0.00	0	0.00	1	25.00	1	25.00	0	0.00	2	50.00	4	100
Keldgate	12	0	0.00	0	0.00	1	9.09	1	9.09	4	36.36	5	45.45	11	100
Lamorna Ave.	13	0	0.00	0	0.00	0	0.00	5	16.13	4	12.90	22	70.97	30	100
Leads Rd.	14	0	0.00	1	3.33	0	0.00	2	6.67	7	23.33	20	66.67	30	100
Mappleton Grove	15	0	0.00	0	0.00	3	21.43	1	7.14	1	7.14	9	64.29	14	100
Marfleet Lane	16	0	0.00	0	0.00	0	0.00	0	0.00	2	100.00	0	0.00	2	100
National Ave.	17	0	0.00	1	5.00	2	10.00	2	10.00	1	5.00	14	70.00	20	100
Newland	18	1	1.79	5	8.93	7	12.50	9	16.07	10	17.86	24	42.86	54	100
Noddle Hill	19	0	0.00	0	0.00	2	100.00	0	0.00	0	0.00	0	0.00	2	100
North Bar Without	20	0	0.00	0	0.00	0	0.00	0	0.00	3	75.00	1	25.00	4	100
Oak Rd.	21	0	0.00	0	0.00	1	6.25	4	25.00	7	43.75	4	25.00	16	100
Perth St.	22	0	0.00	0	0.00	8	24.24	6	18.18	6	18.18	13	39.39	33	100
Pickering Rd.	23	1	3.33	2	6.67	3	10.00	4	13.33	4	13.33	16	53.33	28	100
Portabello St.	24	0	0.00	0	0.00	2	66.67	0	0.00	0	0.00	1	33.33	3	100
Queensgate	25	0	0.00	0	0.00	0	0.00	3	27.27	0	0.00	8	72.73	11	100
Richmond St.	26	0	0.00	1	5.56	3	16.67	5	27.78	8	44.44	1	5.56	17	100
Wansbeck Rd.	27	0	0.00	0	0.00	1	25.00	1	25.00	1	25.00	1	25.00	4	100
Withernsea	28	0	0.00	0	0.00	0	0.00	3	9.68	8	25.81	20	64.52	30	100
TOTAL PER RESPONSE OPTION		3	0.57	17	3.22	50	8.59	78	14.77	122	23.11	269	50.95	528	100

Table A2.3: Breakdown of 528 responses to the question "How far do you have to go from home to get to your plot?" split per site. (N/R = no reply to site name.)

QA		Distance to site											
Site Name	Site Code	<1/4 mile		<1/2 mile		<1mile		1-3 miles		>3 miles		Total per Site	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
N/R	100	11	27.50	6	15.00	6	15.00	14	35.00	3	7.50	40	100
Albert Cottage	1	10	25.64	10	25.64	4	10.26	13	33.33	2	5.13	39	100
Allotment Lane	2	5	17.24	6	20.69	11	37.93	6	20.69	1	3.45	29	100
Bacon Garth	3	3	75.00	0	0.00	1	25.00	0	0.00	0	0.00	4	100
Bilton Grove	4	3	50.00	1	16.67	1	16.67	1	16.67	0	0.00	6	100
Bude Rd.	5	10	35.71	4	14.29	8	28.57	6	21.43	0	0.00	28	100
Calvert Rd.	6	6	33.33	4	22.22	2	11.11	6	33.33	0	0.00	18	100
Clough Rd.	7	3	30.00	0	0.00	1	10.00	3	30.00	3	30.00	10	100
County Rd.	8	8	40.00	4	20.00	5	25.00	3	15.00	0	0.00	20	100
Field St.	9	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	100
Gipsyville	10	11	52.38	5	23.81	1	4.76	3	14.29	1	4.76	21	100
Hunmanby	11	1	25.00	0	0.00	1	25.00	2	50.00	0	0.00	4	100
Keldgate	12	3	27.27	2	18.18	4	36.36	2	18.18	0	0.00	11	100
Lamorna Ave.	13	7	23.33	6	20.00	9	30.00	8	26.67	0	0.00	30	100
Leads Rd.	14	5	16.67	1	3.33	13	43.33	11	36.67	0	0.00	30	100
Mappleton Grove	15	1	7.14	2	14.29	6	42.86	5	35.71	0	0.00	14	100
Marfleet Lane	16	0	0.00	1	50.00	1	50.00	0	0.00	0	0.00	2	100
National Ave.	17	5	25.00	3	15.00	4	20.00	8	40.00	0	0.00	20	100
Newland	18	16	29.63	3	5.56	12	22.22	16	29.63	7	12.96	54	100
Noddle Hill	19	2	100.00	0	0.00	0	0.00	0	0.00	0	0.00	2	100
North Bar Without	20	2	50.00	0	0.00	2	50.00	0	0.00	0	0.00	4	100
Oak Rd.	21	3	18.75	0	0.00	5	31.25	7	43.75	1	6.25	16	100
Perth St.	22	8	24.24	5	15.15	12	36.36	5	15.15	3	9.09	33	100
Pickering Rd.	23	5	17.86	4	14.29	10	35.71	8	28.57	1	3.57	28	100
Portabello St.	24	1	33.33	0	0.00	0	0.00	2	66.67	0	0.00	3	100
Queensgate	25	4	36.36	2	18.18	2	18.18	1	9.09	2	18.18	11	100
Richmond St.	26	8	47.06	6	35.29	2	11.76	0	0.00	1	5.88	17	100
Wansbeck Rd.	27	0	0.00	1	25.00	2	50.00	1	25.00	0	0.00	4	100
Withernsea	28	5	16.67	8	26.67	11	36.67	4	13.33	2	6.67	30	100
TOTAL PER RESPONSE OPTION		146	27.65	84	15.91	136	25.76	135	25.57	27	5.11	528	100

Table A2.4: Breakdown of 532 responses to the question “How long have you had your plot(s)?” split per site. (N/R = no reply to site name.)

Q2		Time owned									
Site Name	Site Code	> 1yr		1-3yr		3-8yr		>8yr		Total per Site	
		No.	%	No.	%	No.	%	No.	%	No.	%
N/R	100	8	20.51	7	17.95	9	23.08	15	38.46	39	100
Albert Cottage	1	5	13.16	9	23.68	8	21.05	16	42.11	38	100
Allotment Lane	2	4	13.33	7	23.33	6	20.00	13	43.33	30	100
Bacon Garth	3	1	25.00	0	0.00	1	25.00	2	50.00	4	100
Bilton Grove	4	0	0.00	0	0.00	1	16.67	5	83.33	6	100
Bude Rd.	5	2	7.41	9	33.33	9	33.33	7	25.93	27	100
Calvert Rd.	6	3	16.67	3	16.67	2	11.11	10	55.56	18	100
Clough Rd.	7	6	54.55	1	9.09	2	18.18	2	18.18	11	100
County Rd.	8	5	27.78	5	27.78	3	16.67	5	27.78	18	100
Field St.	9	1	100.00	0	0.00	0	0.00	0	0.00	1	100
Gipsyville	10	6	28.57	2	9.52	4	19.05	9	42.86	21	100
Hunmanby	11	1	25.00	1	25.00	2	50.00	0	0.00	4	100
Keldgate	12	2	20.00	1	10.00	1	10.00	6	60.00	10	100
Lamorna Ave.	13	6	19.35	5	16.13	8	25.81	12	38.71	31	100
Leads Rd.	14	4	13.33	2	6.67	13	43.33	11	36.67	30	100
Mappleton Grove	15	0	0.00	5	35.71	4	28.57	5	35.71	14	100
Marfleet Lane	16	0	0.00	0	0.00	1	50.00	1	50.00	2	100
National Ave.	17	3	14.29	3	14.29	7	33.33	8	38.10	21	100
Newland	18	8	14.04	13	22.81	11	19.30	25	43.86	57	100
Noddle Hill	19	2	100.00	0	0.00	0	0.00	0	0.00	2	100
North Bar Without	20	1	25.00	1	25.00	1	25.00	1	25.00	4	100
Oak Rd.	21	7	41.18	5	29.41	2	11.76	3	17.65	17	100
Perth St.	22	4	12.12	9	27.27	7	21.21	13	39.39	33	100
Pickering Rd.	23	8	28.57	1	3.57	4	14.29	15	53.57	28	100
Portabello St.	24	1	33.33	2	66.67	0	0.00	0	0.00	3	100
Queensgate	25	3	27.27	2	18.18	3	27.27	3	27.27	11	100
Richmond St.	26	3	16.67	4	22.22	4	22.22	7	38.89	18	100
Wansbeck Rd.	27	1	25.00	0	0.00	1	25.00	2	50.00	4	100
Withernsea	28	1	3.33	7	23.33	4	13.33	18	60.00	30	100
TOTAL PER RESPONSE OPTION		96	18.04	104	19.55	118	22.18	214	40.23	532	100

Table A2.5: Breakdown of 536 responses to the question “How much of your plot is actively used?” split per site. (N/R = no reply to site name.)

Q4		Area Used									
Site Name	Site Code	All		2/3rd		c.1/2		<1/2		Total per Site	
		No.	%	No.	%	No.	%	No.	%	No.	%
N/R	100	29	72.50	5	12.50	3	7.50	3	7.50	40	100
Albert Cottage	1	33	84.62	5	12.82	1	2.56	0	0.00	39	100
Allotment Lane	2	22	73.33	6	20.00	2	6.67	0	0.00	30	100
Bacon Garth	3	4	100.00	0	0.00	0	0.00	0	0.00	4	100
Bilton Grove	4	5	83.33	1	16.67	0	0.00	0	0.00	6	100
Bude Rd.	5	22	78.57	5	17.86	1	3.57	0	0.00	28	100
Calvert Rd.	6	15	88.24	2	11.76	0	0.00	0	0.00	17	100
Clough Rd.	7	6	54.55	1	9.09	2	18.18	2	18.18	11	100
County Rd.	8	17	85.00	1	5.00	1	5.00	1	5.00	20	100
Field St.	9	0	0.00	1	100.00	0	0.00	0	0.00	1	100
Gipsyville	10	17	80.95	2	9.52	1	4.76	1	4.76	21	100
Hunmanby	11	0	0.00	2	50.00	1	25.00	1	25.00	4	100
Keldgate	12	8	72.73	2	18.18	1	9.09	0	0.00	11	100
Lamorna Ave.	13	29	90.63	1	3.13	2	6.25	0	0.00	32	100
Leads Rd.	14	24	80.00	5	16.67	1	3.33	0	0.00	30	100
Mappleton Grove	15	11	78.57	2	14.29	0	0.00	1	7.14	14	100
Marfleet Lane	16	2	100.00	0	0.00	0	0.00	0	0.00	2	100
National Ave.	17	13	65.00	5	25.00	1	5.00	1	5.00	20	100
Newland	18	40	70.18	10	17.54	5	8.77	2	3.51	57	100
Noddle Hill	19	1	50.00	0	0.00	0	0.00	1	50.00	2	100
North Bar Without	20	4	100.00	0	0.00	0	0.00	0	0.00	4	100
Oak Rd.	21	9	52.94	5	29.41	1	5.88	2	11.76	17	100
Perth St.	22	25	75.76	5	15.15	3	9.09	0	0.00	33	100
Pickering Rd.	23	20	71.43	5	17.86	1	3.57	2	7.14	28	100
Portabello St.	24	1	33.33	1	33.33	0	0.00	1	33.33	3	100
Queensgate	25	10	90.91	1	9.09	0	0.00	0	0.00	11	100
Richmond St.	26	15	83.33	1	5.56	0	0.00	2	11.11	18	100
Wansbeck Rd.	27	3	75.00	0	0.00	0	0.00	1	25.00	4	100
Withernsea	28	24	82.76	5	17.24	0	0.00	0	0.00	29	100
TOTAL PER RESPONSE OPTION		409	76.30	79	14.74	27	5.04	21	3.92	536	100

Table A2.6: Breakdown of 546 responses to the question “How often do you visit your plot?” split per site. (N/R = no reply to site name.)

Q10		How often you visit													
Site Name	Site Code	Daily		4-5 times		2-3 times		Once a week		Once a fortnight		Less often		Total per Site	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
N/R	100	12	30.77	9	23.08	11	28.21	3	7.69	3	7.69	1	2.56	39	100
Albert Cottage	1	6	12.50	14	29.17	23	47.92	3	6.25	1	2.08	1	2.08	48	100
Allotment Lane	2	10	33.33	5	16.67	10	33.33	4	13.33	1	3.33	0	0.00	30	100
Bacon Garth	3	2	50.00	1	25.00	0	0.00	1	25.00	0	0.00	0	0.00	4	100
Bilton Grove	4	1	20.00	1	20.00	3	60.00	0	0.00	0	0.00	0	0.00	5	100
Bude Rd.	5	5	17.86	9	32.14	14	50.00	0	0.00	0	0.00	0	0.00	28	100
Calvert Rd.	6	6	37.50	2	12.50	8	50.00	0	0.00	0	0.00	0	0.00	16	100
Clough Rd.	7	1	9.09	3	27.27	5	45.45	2	18.18	0	0.00	0	0.00	11	100
County Rd.	8	4	21.05	2	10.53	12	63.16	1	5.26	0	0.00	0	0.00	19	100
Field St.	9	0	0.00	0	0.00	0	0.00	1	100.00	0	0.00	0	0.00	1	100
Gipsyville	10	10	47.62	5	23.81	6	28.57	0	0.00	0	0.00	0	0.00	21	100
Hunmanby	11	0	0.00	0	0.00	3	75.00	0	0.00	1	25.00	0	0.00	4	100
Keldgate	12	1	9.09	1	9.09	7	63.64	2	18.18	0	0.00	0	0.00	11	100
Lamorna Ave.	13	4	12.90	12	38.71	12	38.71	2	6.45	1	3.23	0	0.00	31	100
Leads Rd.	14	5	16.67	11	36.67	11	36.67	2	6.67	1	3.33	0	0.00	30	100
Mappleton Grove	15	3	17.65	7	41.18	4	23.53	2	11.76	1	5.88	0	0.00	17	100
Marfleet Lane	16	2	100.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	100
National Ave.	17	5	25.00	5	25.00	4	20.00	4	20.00	2	10.00	0	0.00	20	100
Newland	18	9	15.52	17	29.31	21	36.21	10	17.24	1	1.72	0	0.00	58	100
Noddle Hill	19	0	0.00	0	0.00	1	50.00	0	0.00	0	0.00	1	50.00	2	100
North Bar Without	20	0	0.00	0	0.00	2	50.00	2	50.00	0	0.00	0	0.00	4	100
Oak Rd.	21	3	17.65	6	35.29	5	29.41	2	11.76	1	5.88	0	0.00	17	100
Perth St.	22	8	24.24	9	27.27	10	30.30	3	9.09	1	3.03	2	6.06	33	100
Pickering Rd.	23	5	17.24	7	24.14	16	55.17	1	3.45	0	0.00	0	0.00	29	100
Portabello St.	24	1	33.33	0	0.00	1	33.33	1	33.33	0	0.00	0	0.00	3	100
Queensgate	25	2	18.18	3	27.27	5	45.45	0	0.00	0	0.00	1	9.09	11	100
Richmond St.	26	2	11.11	3	16.67	9	50.00	2	11.11	0	0.00	2	11.11	18	100
Wansbeck Rd.	27	0	0.00	2	50.00	2	50.00	0	0.00	0	0.00	0	0.00	4	100
Withernsea	28	11	36.67	4	13.33	12	40.00	3	10.00	0	0.00	0	0.00	30	100
TOTAL PER RESPONSE OPTION		118	21.61	138	25.27	217	39.74	51	9.34	14	2.56	8	1.47	546	100

Table A2.7: Breakdown of 813 responses to the question “How did you learn the techniques needed to manage an allotment?” split per site. (N/R = no reply to site name.)

Q11		How skills learned									
Site Name	Site Code	Family		Friends		plot-holders		self taught		Total per Site	
		No.	%	No.	%	No.	%	No.	%	No.	%
N/R	100	10	17.54	4	7.02	19	33.33	24	42.11	57	100
Albert Cottage	1	15	24.19	6	9.68	18	29.03	23	37.10	62	100
Allotment Lane	2	14	34.15	2	4.88	3	7.32	22	53.66	41	100
Bacon Garth	3	1	25.00	0	0.00	0	0.00	3	75.00	4	100
Bilton Grove	4	0	0.00	1	14.29	2	28.57	4	57.14	7	100
Bude Rd.	5	9	21.43	4	9.52	10	23.81	19	45.24	42	100
Calvert Rd.	6	4	13.33	4	13.33	9	30.00	13	43.33	30	100
Clough Rd.	7	1	7.14	2	14.29	6	42.86	5	35.71	14	100
County Rd.	8	7	23.33	1	3.33	7	23.33	15	50.00	30	100
Field St.	9	0	0.00	0	0.00	1	50.00	1	50.00	2	100
Gipsyville	10	7	25.93	1	3.70	6	22.22	13	48.15	27	100
Hunmanby	11	1	16.67	1	16.67	1	16.67	3	50.00	6	100
Keldgate	12	5	31.25	1	6.25	2	12.50	8	50.00	16	100
Lamorna Ave.	13	7	14.00	7	14.00	15	30.00	21	42.00	50	100
Leads Rd.	14	12	27.91	3	6.98	8	18.60	20	46.51	43	100
Mappleton Grove	15	6	30.00	2	10.00	6	30.00	6	30.00	20	100
Marfleet Lane	16	0	0.00	1	33.33	1	33.33	1	33.33	3	100
National Ave.	17	6	24.00	0	0.00	7	28.00	12	48.00	25	100
Newland	18	21	19.81	15	14.15	27	25.47	43	40.57	106	100
Noddle Hill	19	0	0.00	1	33.33	0	0.00	2	66.67	3	100
North Bar Without	20	1	20.00	1	20.00	1	20.00	2	40.00	5	100
Oak Rd.	21	7	26.92	3	11.54	8	30.77	8	30.77	26	100
Perth St.	22	10	19.61	4	7.84	14	27.45	23	45.10	51	100
Pickering Rd.	23	14	29.17	2	4.17	14	29.17	18	37.50	48	100
Portabello St.	24	0	0.00	0	0.00	0	0.00	3	100.00	3	100
Queensgate	25	2	14.29	1	7.14	2	14.29	9	64.29	14	100
Richmond St.	26	6	18.18	4	12.12	9	27.27	14	42.42	33	100
Wansbeck Rd.	27	0	0.00	0	0.00	3	50.00	3	50.00	6	100
Withernsea	28	12	30.77	3	7.69	6	15.38	18	46.15	39	100
TOTAL PER RESPONSE OPTION		178	21.89	74	9.10	205	25.22	356	43.79	813	100

Table A2.8: Breakdown of 796 responses to the question "What is the main use of your plot(s)?" split per site. (N/R = no reply to site name.)

Q3		**Main use**											
Site Name	Site Code	Veg		Veg/Flowers		Flowers		WLG		Other		Total per Site	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
N/R	100	29	52.73	12	21.82	4	7.27	3	5.45	7	12.73	55	100
Albert Cottage	1	20	33.33	19	31.67	2	3.33	5	8.33	14	23.33	60	100
Allotment Lane	2	21	37.50	12	21.43	1	1.79	3	5.36	19	33.93	56	100
Bacon Garth	3	2	22.22	2	22.22	0	0.00	0	0.00	5	55.56	9	100
Bilton Grove	4	2	28.57	3	42.86	0	0.00	1	14.29	1	14.29	7	100
Bude Rd.	5	12	35.29	16	47.06	2	5.88	1	2.94	3	8.82	34	100
Calvert Rd.	6	11	45.83	9	37.50	2	8.33	0	0.00	2	8.33	24	100
Clough Rd.	7	8	57.14	3	21.43	1	7.14	1	7.14	1	7.14	14	100
County Rd.	8	12	41.38	8	27.59	0	0.00	1	3.45	8	27.59	29	100
Field St.	9	1	50.00	0	0.00	0	0.00	0	0.00	1	50.00	2	100
Gipsyville	10	13	43.33	9	30.00	3	10.00	1	3.33	4	13.33	30	100
Hunmanby	11	3	60.00	0	0.00	0	0.00	1	20.00	1	20.00	5	100
Keldgate	12	6	22.22	5	18.52	1	3.70	0	0.00	15	55.56	27	100
Lamorna Ave.	13	17	41.46	17	41.46	2	4.88	0	0.00	5	12.20	41	100
Leads Rd.	14	18	45.00	12	30.00	1	2.50	1	2.50	8	20.00	40	100
Mappleton Grove	15	10	62.50	4	25.00	0	0.00	0	0.00	2	12.50	16	100
Marfleet Lane	16	1	33.33	1	33.33	0	0.00	0	0.00	1	33.33	3	100
National Ave.	17	14	53.85	5	19.23	1	3.85	1	3.85	5	19.23	26	100
Newland	18	32	36.36	29	32.95	1	1.14	10	11.36	16	18.18	88	100
Noddle Hill	19	1	33.33	1	33.33	0	0.00	1	33.33	0	0.00	3	100
North Bar Without	20	2	50.00	2	50.00	0	0.00	0	0.00	0	0.00	4	100
Oak Rd.	21	9	31.03	7	24.14	3	10.34	3	10.34	7	24.14	29	100
Perth St.	22	19	38.78	14	28.57	1	2.04	4	8.16	11	22.45	49	100
Pickering Rd.	23	19	47.50	13	32.50	1	2.50	2	5.00	5	12.50	40	100
Portabello St.	24	1	20.00	1	20.00	0	0.00	1	20.00	2	40.00	5	100
Queensgate	25	5	33.33	5	33.33	0	0.00	1	6.67	4	26.67	15	100
Richmond St.	26	13	41.94	7	22.58	1	3.23	2	6.45	8	25.81	31	100
Wansbeck Rd.	27	3	50.00	1	16.67	0	0.00	0	0.00	2	33.33	6	100
Withernsea	28	16	33.33	15	31.25	0	0.00	6	12.50	11	22.92	48	100
TOTAL PER RESPONSE OPTION		320	40.20	232	29.15	27	3.39	49	6.16	168	21.10	796	100

Table A2.9: Breakdown of responses to the ranked question *"What are the main reasons for having your plot(s)?" split per site.* *(Ranks were 1-7; 1= most important*, 7=least important) (N/R = no reply to site name.)

Q9		Main Reasons						
Site Name	Site Code	Enjoy grow No.	Better Food No.	Social No.	Economic No.	Outdoors No.	Peace No.	Other No.
N/R	100	59	63	118	116	67	93	28
Albert Cottage	1	75	85	138	139	97	130	27
Allotment Lane	2	48	71	131	114	79	121	42
Bacon Garth	3	4	7	12	8	10	17	0
Bilton Grove	4	5	6	5	7	5	5	1
Bude Rd.	5	35	60	87	97	58	74	22
Calvert Rd.	6	22	25	51	47	38	53	3
Clough Rd.	7	16	20	32	28	21	21	1
County Rd.	8	34	43	65	65	43	59	8
Field St.	9	2	1	3	5	4	6	0
Gipsyville	10	27	34	63	54	43	49	4
Hunmanby	11	9	9	18	18	10	9	1
Keldgate	12	14	23	30	35	21	27	7
Lamorna Ave.	13	47	60	83	100	82	84	26
Leads Rd.	14	34	56	94	107	60	91	10
Mappleton Grove	15	19	22	32	40	24	32	2
Marfleet Lane	16	2	2	6	1	2	2	0
National Ave.	17	45	51	87	78	54	77	21
Newland	18	123	123	178	213	133	147	69
Noddle Hill	19	4	4	11	9	6	8	0
North Bar Without	20	5	11	21	21	11	16	7
Oak Rd.	21	18	41	61	54	40	41	2
Perth St.	22	46	65	104	126	78	103	26
Pickering Rd.	23	43	48	90	98	64	83	11
Portabello St.	24	9	3	12	11	8	9	6
Queensgate	25	13	21	27	28	23	27	6
Richmond St.	26	34	50	72	60	42	59	10
Wansbeck Rd.	27	7	7	15	15	15	15	1
Withernsea	28	46	58	108	103	69	93	19
TOTAL PER RESPONSE OPTION		845	1069	1754	1797	1207	1551	360

Table A2.10: Breakdown of 524 responses to the question "How important is the wildlife on site to you?" split per site. (N/R = no reply to site name.)

Q12		Importance of Wildlife									
Site Name	Site Code	very		important		neutral		not important		Total per Site	
		No.	%	No.	%	No.	%	No.	%	No.	%
N/R	100	17	44.74	16	42.11	4	10.53	1	2.63	38	100
Albert Cottage	1	23	58.97	8	20.51	6	15.38	2	5.13	39	100
Allotment Lane	2	11	37.93	13	44.83	3	10.34	2	6.90	29	100
Bacon Garth	3	3	100.00	0	0.00	0	0.00	0	0.00	3	100
Bilton Grove	4	2	50.00	1	25.00	1	25.00	0	0.00	4	100
Bude Rd.	5	14	51.85	8	29.63	5	18.52	0	0.00	27	100
Calvert Rd.	6	5	26.32	7	36.84	6	31.58	1	5.26	19	100
Clough Rd.	7	4	40.00	4	40.00	1	10.00	1	10.00	10	100
County Rd.	8	9	45.00	5	25.00	5	25.00	1	5.00	20	100
Field St.	9	1	100.00	0	0.00	0	0.00	0	0.00	1	100
Gipsyville	10	8	40.00	7	35.00	3	15.00	2	10.00	20	100
Hunmanby	11	1	25.00	2	50.00	1	25.00	0	0.00	4	100
Keldgate	12	4	36.36	5	45.45	2	18.18	0	0.00	11	100
Lamorna Ave.	13	15	48.39	9	29.03	7	22.58	0	0.00	31	100
Leads Rd.	14	12	40.00	14	46.67	4	13.33	0	0.00	30	100
Mappleton Grove	15	7	50.00	4	28.57	3	21.43	0	0.00	14	100
Marfleet Lane	16	1	50.00	1	50.00	0	0.00	0	0.00	2	100
National Ave.	17	9	47.37	6	31.58	2	10.53	2	10.53	19	100
Newland	18	41	73.21	14	25.00	1	1.79	0	0.00	56	100
Noddle Hill	19	2	100.00	0	0.00	0	0.00	0	0.00	2	100
North Bar Without	20	1	25.00	3	75.00	0	0.00	0	0.00	4	100
Oak Rd.	21	12	75.00	1	6.25	2	12.50	1	6.25	16	100
Perth St.	22	10	31.25	16	50.00	5	15.63	1	3.13	32	100
Pickering Rd.	23	15	53.57	5	17.86	7	25.00	1	3.57	28	100
Portabello St.	24	1	33.33	1	33.33	1	33.33	0	0.00	3	100
Queensgate	25	4	40.00	6	60.00	0	0.00	0	0.00	10	100
Richmond St.	26	14	77.78	2	11.11	2	11.11	0	0.00	18	100
Wansbeck Rd.	27	1	25.00	2	50.00	1	25.00	0	0.00	4	100
Withernsea	28	20	66.67	6	20.00	4	13.33	0	0.00	30	100
TOTAL PER RESPONSE OPTION		267	50.95	166	31.68	76	14.50	15	2.86	524	100

Table A2.11: Breakdown of 632 responses to the question "How do you manage your plot?" split per site. (N/R = no reply to site name.)

Q5		Management Style									
Site Name	Site Code	Traditional		Organic		WLF		O/WLF		Total per Site	
		No.	%	No.	%	No.	%	No.	%	No.	%
N/R	100	26	53.06	10	20.41	3	6.12	10	20.41	49	100.00
Albert Cottage	1	29	64.44	3	6.67	3	6.67	10	22.22	45	100.00
Allotment Lane	2	19	61.29	3	9.68	2	6.45	7	22.58	31	100.00
Bacon Garth	3	3	75.00	0	0.00	0	0.00	1	25.00	4	100.00
Bilton Grove	4	4	66.67	2	33.33	0	0.00	0	0.00	6	100.00
Bude Rd.	5	16	53.33	5	16.67	3	10.00	6	20.00	30	100.00
Calvert Rd.	6	16	69.57	2	8.70	3	13.04	2	8.70	23	100.00
Clough Rd.	7	7	50.00	1	7.14	1	7.14	5	35.71	14	100.00
County Rd.	8	11	44.00	5	20.00	2	8.00	7	28.00	25	100.00
Field St.	9	0	0.00	0	0.00	0	0.00	1	100.00	1	100.00
Gipsyville	10	12	52.17	7	30.43	1	4.35	3	13.04	23	100.00
Hunmanby	11	3	75.00	0	0.00	0	0.00	1	25.00	4	100.00
Keldgate	12	9	64.29	2	14.29	1	7.14	2	14.29	14	100.00
Lamorna Ave.	13	24	68.57	2	5.71	3	8.57	6	17.14	35	100.00
Leads Rd.	14	24	64.86	6	16.22	4	10.81	3	8.11	37	100.00
Mappleton Grove	15	10	71.43	1	7.14	1	7.14	2	14.29	14	100.00
Marfleet Lane	16	2	66.67	0	0.00	0	0.00	1	33.33	3	100.00
National Ave.	17	9	39.13	8	34.78	2	8.70	4	17.39	23	100.00
Newland	18	22	30.56	15	20.83	8	11.11	27	37.50	72	100.00
Noddle Hill	19	0	0.00	1	50.00	0	0.00	1	50.00	2	100.00
North Bar Without	20	3	60.00	1	20.00	1	20.00	0	0.00	5	100.00
Oak Rd.	21	9	47.37	3	15.79	2	10.53	5	26.32	19	100.00
Perth St.	22	20	55.56	4	11.11	6	16.67	6	16.67	36	100.00
Pickering Rd.	23	18	51.43	7	20.00	4	11.43	6	17.14	35	100.00
Portabello St.	24	1	33.33	0	0.00	1	33.33	1	33.33	3	100.00
Queensgate	25	7	50.00	2	14.29	1	7.14	4	28.57	14	100.00
Richmond St.	26	8	34.78	6	26.09	3	13.04	6	26.09	23	100.00
Wansbeck Rd.	27	1	20.00	2	40.00	0	0.00	2	40.00	5	100.00
Withernsea	28	23	62.16	3	8.11	6	16.22	5	13.51	37	100.00
TOTAL PER RESPONSE OPTION		336	53.17	101	15.98	61	9.65	134	21.20	632	100.00

Table A2.12: Breakdown of 534 responses to the question "Do you use any pesticides on your plot?" split per site. (N/R = no reply to site name.)

Q6		**Pesticides Used**					
Site Name	Site Code	Yes		No		Total per Site	
		No.	%	No.	%	No.	%
N/R	100	26	65.00	14	35.00	40	100
Albert Cottage	1	32	82.05	7	17.95	39	100
Allotment Lane	2	22	73.33	8	26.67	30	100
Bacon Garth	3	4	100.00	0	0.00	4	100
Bilton Grove	4	6	100.00	0	0.00	6	100
Bude Rd.	5	18	66.67	9	33.33	27	100
Calvert Rd.	6	15	83.33	3	16.67	18	100
Clough Rd.	7	7	63.64	4	36.36	11	100
County Rd.	8	10	50.00	10	50.00	20	100
Field St.	9	0	0.00	1	100.00	1	100
Gipsyville	10	14	70.00	6	30.00	20	100
Hunmanby	11	3	75.00	1	25.00	4	100
Keldgate	12	8	72.73	3	27.27	11	100
Lamorna Ave.	13	28	87.50	4	12.50	32	100
Leads Rd.	14	26	86.67	4	13.33	30	100
Mappleton Grove	15	11	78.57	3	21.43	14	100
Marfleet Lane	16	2	100.00	0	0.00	2	100
National Ave.	17	12	60.00	8	40.00	20	100
Newland	18	28	50.00	28	50.00	56	100
Noddle Hill	19	0	0.00	2	100.00	2	100
North Bar Without	20	3	75.00	1	25.00	4	100
Oak Rd.	21	8	47.06	9	52.94	17	100
Perth St.	22	24	72.73	9	27.27	33	100
Pickering Rd.	23	19	67.86	9	32.14	28	100
Portabello St.	24	2	66.67	1	33.33	3	100
Queensgate	25	7	63.64	4	36.36	11	100
Richmond St.	26	7	38.89	11	61.11	18	100
Wansbeck Rd.	27	1	25.00	3	75.00	4	100
Withernsea	28	17	58.62	12	41.38	29	100
TOTAL PER RESPONSE OPTION		360	67.42	174	32.58	534	100

Table A2.13: Breakdown of 727 responses to the question "Which types of pesticide do you use?" split per site. (N/R = no reply to site name.)

Q7 Site Name	Site Code	Types of Pesticide Used: Slug Pellets No.	%	Pesticide No.	%	Weedkiller No.	%	Fungicide No.	%	Other No.	%	Total per Site No.	%
N/R	100	22	46.81	5	10.64	12	25.53	4	8.51	4	8.51	47	100
Albert Cottage	1	23	36.51	10	15.87	19	30.16	7	11.11	4	6.35	63	100
Allotment Lane	2	18	39.13	8	17.39	12	26.09	4	8.70	4	8.70	46	100
Bacon Garth	3	4	66.67	0	0.00	2	33.33	0	0.00	0	0.00	6	100
Bilton Grove	4	6	75.00	1	12.50	1	12.50	0	0.00	0	0.00	8	100
Bude Rd.	5	17	48.57	3	8.57	10	28.57	2	5.71	3	8.57	35	100
Calvert Rd.	6	14	51.85	5	18.52	5	18.52	2	7.41	1	3.70	27	100
Clough Rd.	7	3	30.00	0	0.00	5	50.00	0	0.00	2	20.00	10	100
County Rd.	8	8	57.14	3	21.43	2	14.29	0	0.00	1	7.14	14	100
Field St.	9	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	100
Gipsyville	10	13	44.83	3	10.34	9	31.03	2	6.90	2	6.90	29	100
Hunmanby	11	3	42.86	1	14.29	2	28.57	1	14.29	0	0.00	7	100
Keldgate	12	6	54.55	1	9.09	3	27.27	0	0.00	1	9.09	11	100
Lamorna Ave.	13	26	38.81	15	22.39	17	25.37	6	8.96	3	4.48	67	100
Leads Rd.	14	23	40.35	9	15.79	18	31.58	7	12.28	0	0.00	57	100
Mappleton Grove	15	10	45.45	0	0.00	8	36.36	1	4.55	3	13.64	22	100
Marfleet Lane	16	2	28.57	2	28.57	2	28.57	1	14.29	0	0.00	7	100
National Ave.	17	10	37.04	6	22.22	8	29.63	3	11.11	0	0.00	27	100
Newland	18	20	34.48	9	15.52	18	31.03	4	6.90	7	12.07	58	100
Noddle Hill	19	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	100
North Bar Without	20	3	37.50	1	12.50	2	25.00	1	12.50	1	12.50	8	100
Oak Rd.	21	6	37.50	4	25.00	4	25.00	1	6.25	1	6.25	16	100
Perth St.	22	16	31.37	12	23.53	13	25.49	5	9.80	5	9.80	51	100
Pickering Rd.	23	16	43.24	6	16.22	9	24.32	4	10.81	2	5.41	37	100
Portabello St.	24	0	0.00	0	0.00	0	0.00	0	0.00	2	100.00	2	100
Queensgate	25	7	41.18	3	17.65	3	17.65	2	11.76	2	11.76	17	100
Richmond St.	26	6	54.55	1	9.09	2	18.18	0	0.00	2	18.18	11	100
Wansbeck Rd.	27	1	33.33	1	33.33	1	33.33	0	0.00	0	0.00	3	100
Withernsea	28	13	31.71	7	17.07	11	26.83	5	12.20	5	12.20	41	100
TOTAL PER RESPONSE OPTION		296	40.72	116	15.96	198	27.23	62	8.53	55	7.56	727	100

Table A2.14: Breakdown of 350 responses to the question "How often do you usually use pesticides?" split per site. (N/R = no reply to site name.)

Q8 Site Name	Site Code	Frequency of Pesticide Use: > monthly No.	%	4x a year No.	%	2x a year No.	%	c. Once a year No.	%	Total per Site No.	%
N/R	100	4	16.00	5	20.00	12	48.00	4	16.00	25	100
Albert Cottage	1	1	3.13	9	28.13	14	43.75	8	25.00	32	100
Allotment Lane	2	2	10.00	4	20.00	10	50.00	4	20.00	20	100
Bacon Garth	3	0	0.00	2	50.00	1	25.00	1	25.00	4	100
Bilton Grove	4	1	20.00	0	0.00	3	60.00	1	20.00	5	100
Bude Rd.	5	2	10.53	2	10.53	7	36.84	8	42.11	19	100
Calvert Rd.	6	3	18.75	3	18.75	8	50.00	2	12.50	16	100
Clough Rd.	7	0	0.00	1	14.29	4	57.14	2	28.57	7	100
County Rd.	8	0	0.00	3	33.33	2	22.22	4	44.44	9	100
Field St.	9	0	0.00	0	0.00	0	0.00	0	0.00	0	100
Gipsyville	10	2	15.38	3	23.08	6	46.15	2	15.38	13	100
Hunmanby	11	0	0.00	2	66.67	1	33.33	0	0.00	3	100
Keldgate	12	1	12.50	0	0.00	3	37.50	4	50.00	8	100
Lamorna Ave.	13	2	7.69	11	42.31	12	46.15	1	3.85	26	100
Leads Rd.	14	3	11.54	7	26.92	12	46.15	4	15.38	26	100
Mappleton Grove	15	1	9.09	5	45.45	1	9.09	4	36.36	11	100
Marfleet Lane	16	1	50.00	0	0.00	1	50.00	0	0.00	2	100
National Ave.	17	1	8.33	4	33.33	6	50.00	1	8.33	12	100
Newland	18	4	12.50	6	18.75	11	34.38	11	34.38	32	100
Noddle Hill	19	0	0.00	0	0.00	0	0.00	0	0.00	0	100
North Bar Without	20	0	0.00	1	33.33	2	66.67	0	0.00	3	100
Oak Rd.	21	1	12.50	1	12.50	4	50.00	2	25.00	8	100
Perth St.	22	2	9.52	6	28.57	6	28.57	7	33.33	21	100
Pickering Rd.	23	2	11.11	6	33.33	9	50.00	1	5.56	18	100
Portabello St.	24	0	0.00	0	0.00	0	0.00	0	0.00	0	100
Queensgate	25	1	14.29	1	14.29	4	57.14	1	14.29	7	100
Richmond St.	26	1	14.29	2	28.57	1	14.29	3	42.86	7	100
Wansbeck Rd.	27	0	0.00	0	0.00	1	100.00	0	0.00	1	100
Withernsea	28	0	0.00	1	6.67	10	66.67	4	26.67	15	100
TOTAL PER RESPONSE OPTION		35	10.00	85	24.29	151	43.14	79	22.57	350	100

Table A2.15: Breakdown of 522 responses to the question "Would you be willing to participate in some small-scale surveying on your plot? (This would not involve any invasive sampling or damage to crops.)" split per site. (N/R = no reply to site name.)

Q13		**Allow further survey**					
Site Name	Site Code	Yes		No		Total per Site	
		No.	**%**	No.	**%**	No.	**%**
N/R	100	30	78.95	8	21.05	38	100
Albert Cottage	1	30	85.71	5	14.29	35	100
Allotment Lane	2	24	80.00	6	20.00	30	100
Bacon Garth	3	4	100.00	0	0.00	4	100
Bilton Grove	4	5	100.00	0	0.00	5	100
Bude Rd.	5	24	88.89	3	11.11	27	100
Calvert Rd.	6	15	83.33	3	16.67	18	100
Clough Rd.	7	10	90.91	1	9.09	11	100
County Rd.	8	17	85.00	3	15.00	20	100
Field St.	9	1	100.00	0	0.00	1	100
Gipsyville	10	17	80.95	4	19.05	21	100
Hunmanby	11	4	100.00	0	0.00	4	100
Keldgate	12	7	70.00	3	30.00	10	100
Lamorna Ave.	13	26	86.67	4	13.33	30	100
Leads Rd.	14	24	80.00	6	20.00	30	100
Mappleton Grove	15	11	78.57	3	21.43	14	100
Marfleet Lane	16	2	100.00	0	0.00	2	100
National Ave.	17	15	78.95	4	21.05	19	100
Newland	18	49	87.50	7	12.50	56	100
Noddle Hill	19	2	100.00	0	0.00	2	100
North Bar Without	20	4	100.00	0	0.00	4	100
Oak Rd.	21	15	93.75	1	6.25	16	100
Perth St.	22	29	87.88	4	12.12	33	100
Pickering Rd.	23	24	88.89	3	11.11	27	100
Portabello St.	24	3	100.00	0	0.00	3	100
Queensgate	25	8	72.73	3	27.27	11	100
Richmond St.	26	17	94.44	1	5.56	18	100
Wansbeck Rd.	27	4	100.00	0	0.00	4	100
Withernsea	28	23	79.31	6	20.69	29	100
TOTAL PER RESPONSE OPTION		444	85.06	78	14.94	522	100

A2.16 Cross-product (correlation) matrix for PCA (Figure 2.15) on allotment questionnaire responses.

	< 1yr	1-3yr	3-8yr	>8yr	Veg	Veg/Flower	Flowers	WLG	Other	All	2/3rd	c1/2	<1/2	Trad	Organic	WLF
< 1yr	1.000	0.502	0.540	0.525	0.704	0.650	0.719	0.494	0.534	0.603	0.524	0.717	0.365	0.578	0.660	0.630
1-3yr	0.502	1.000	0.767	0.696	0.820	0.807	0.525	0.652	0.678	0.774	0.754	0.576	0.054	0.790	0.606	0.844
3-8yr	0.540	0.767	1.000	0.832	0.904	0.839	0.569	0.509	0.650	0.861	0.738	0.652	-0.016	0.886	0.750	0.777
>8yr	0.525	0.696	0.832	1.000	0.912	0.940	0.585	0.532	0.765	0.955	0.714	0.528	-0.076	0.920	0.806	0.822
Veg	0.704	0.820	0.904	0.912	1.000	0.911	0.666	0.593	0.761	0.920	0.801	0.684	0.148	0.933	0.822	0.875
Veg/Flower	0.650	0.807	0.839	0.940	0.911	1.000	0.664	0.596	0.746	0.978	0.723	0.588	-0.042	0.928	0.807	0.893
Flowers	0.719	0.525	0.569	0.585	0.666	0.664	1.000	0.289	0.455	0.621	0.570	0.566	0.120	0.644	0.571	0.550
WLG	0.494	0.652	0.509	0.532	0.593	0.596	0.289	1.000	0.601	0.512	0.726	0.529	0.269	0.507	0.579	0.660
Other	0.534	0.678	0.650	0.765	0.761	0.746	0.455	0.601	1.000	0.737	0.693	0.555	-0.038	0.735	0.609	0.689
All	0.603	0.774	0.861	0.955	0.920	0.978	0.621	0.512	0.737	1.000	0.658	0.537	-0.042	0.934	0.815	0.853
2/3rd	0.524	0.754	0.738	0.714	0.801	0.723	0.570	0.726	0.693	0.658	1.000	0.654	0.100	0.751	0.671	0.773
c1/2	0.717	0.576	0.652	0.528	0.684	0.588	0.566	0.529	0.555	0.537	0.654	1.000	0.213	0.600	0.548	0.571
<1/2	0.365	0.054	-0.016	-0.076	0.148	-0.042	0.120	0.269	-0.038	-0.042	0.100	0.213	1.000	-0.081	0.284	0.072
Trad	0.578	0.790	0.886	0.920	0.933	0.928	0.644	0.507	0.735	0.934	0.751	0.600	-0.081	1.000	0.699	0.844
Organic	0.660	0.606	0.750	0.806	0.822	0.807	0.571	0.579	0.609	0.815	0.671	0.548	0.284	0.699	1.000	0.747
WLF	0.630	0.844	0.777	0.822	0.875	0.893	0.550	0.660	0.689	0.853	0.773	0.571	0.072	0.844	0.747	1.000
O/WLF	0.760	0.789	0.751	0.715	0.850	0.792	0.551	0.702	0.754	0.761	0.701	0.721	0.304	0.716	0.721	0.780
Pesticide Yes	0.568	0.785	0.897	0.918	0.919	0.925	0.645	0.508	0.726	0.929	0.760	0.632	-0.085	0.988	0.698	0.829
PesticideNo	0.732	0.806	0.708	0.712	0.864	0.782	0.548	0.710	0.686	0.759	0.739	0.611	0.379	0.692	0.844	0.833
Slug Pellets	0.511	0.717	0.909	0.921	0.896	0.902	0.620	0.424	0.677	0.918	0.705	0.565	-0.161	0.969	0.704	0.760
Pesticide	0.588	0.666	0.797	0.801	0.783	0.811	0.571	0.535	0.658	0.783	0.688	0.595	-0.205	0.807	0.666	0.771
Weedkiller	0.542	0.731	0.928	0.866	0.898	0.859	0.636	0.481	0.646	0.868	0.749	0.667	-0.097	0.928	0.645	0.774
Fungicide	0.452	0.632	0.809	0.720	0.728	0.729	0.487	0.496	0.514	0.701	0.706	0.506	-0.257	0.770	0.516	0.724
Other	0.445	0.825	0.555	0.630	0.681	0.732	0.397	0.620	0.562	0.686	0.569	0.501	0.064	0.672	0.445	0.744
>monthly	0.457	0.508	0.704	0.734	0.676	0.727	0.679	0.290	0.485	0.703	0.628	0.515	-0.088	0.697	0.647	0.613
4x a year	0.586	0.672	0.855	0.714	0.823	0.726	0.530	0.361	0.532	0.745	0.595	0.603	0.033	0.798	0.557	0.688
2x a year	0.614	0.635	0.830	0.880	0.846	0.878	0.670	0.500	0.623	0.862	0.731	0.613	-0.183	0.911	0.687	0.762
c. Once a year	0.453	0.811	0.753	0.796	0.815	0.838	0.520	0.599	0.762	0.826	0.731	0.584	-0.038	0.814	0.666	0.754
Daily	0.506	0.754	0.776	0.869	0.839	0.873	0.579	0.571	0.730	0.866	0.738	0.501	-0.075	0.859	0.676	0.785
4-5 times	0.630	0.757	0.904	0.857	0.907	0.884	0.665	0.540	0.679	0.892	0.743	0.640	0.102	0.857	0.759	0.780
2-3 times	0.670	0.794	0.813	0.846	0.914	0.893	0.606	0.613	0.678	0.868	0.745	0.621	0.108	0.894	0.795	0.848
Once a week	0.404	0.597	0.498	0.516	0.588	0.511	0.241	0.551	0.633	0.511	0.575	0.573	0.147	0.496	0.423	0.635
Once a fortnight	0.288	0.518	0.610	0.355	0.509	0.328	0.340	0.353	0.404	0.340	0.595	0.571	0.079	0.440	0.301	0.368
Less often	0.162	0.206	0.120	0.086	0.116	0.145	0.052	0.333	0.169	0.149	-0.013	-0.009	0.000	0.047	0.149	0.194
family	0.652	0.838	0.868	0.881	0.954	0.911	0.635	0.608	0.810	0.896	0.835	0.631	0.067	0.921	0.781	0.877
friends	0.516	0.733	0.695	0.686	0.724	0.785	0.573	0.574	0.471	0.715	0.582	0.575	0.045	0.738	0.543	0.764
plot-holders	0.655	0.744	0.832	0.840	0.906	0.846	0.686	0.519	0.582	0.847	0.706	0.631	0.206	0.838	0.791	0.826
self taught	0.699	0.840	0.881	0.917	0.958	0.954	0.639	0.643	0.802	0.933	0.796	0.664	0.049	0.921	0.837	0.898
very imp	0.670	0.827	0.848	0.881	0.928	0.934	0.631	0.692	0.776	0.907	0.785	0.604	0.157	0.870	0.806	0.876
important	0.544	0.742	0.858	0.808	0.858	0.811	0.525	0.429	0.619	0.828	0.692	0.669	-0.134	0.869	0.690	0.787
neutral	0.490	0.663	0.674	0.748	0.796	0.750	0.623	0.312	0.556	0.741	0.629	0.440	0.002	0.807	0.574	0.711
not imp	0.580	0.350	0.341	0.407	0.507	0.388	0.574	0.331	0.358	0.416	0.439	0.424	0.173	0.433	0.409	0.297
Survey Yes	0.694	0.854	0.909	0.919	0.979	0.957	0.674	0.640	0.751	0.949	0.794	0.679	0.114	0.950	0.826	0.904
Survey No	0.597	0.785	0.847	0.883	0.919	0.888	0.566	0.511	0.765	0.893	0.782	0.593	-0.081	0.900	0.745	0.825
<1/4 mile	0.703	0.722	0.741	0.788	0.804	0.878	0.647	0.590	0.630	0.845	0.610	0.587	0.051	0.801	0.789	0.769
<1/2 mile	0.382	0.684	0.704	0.849	0.780	0.798	0.465	0.431	0.671	0.819	0.531	0.329	-0.159	0.772	0.656	0.685
<1mile	0.447	0.727	0.838	0.828	0.847	0.827	0.413	0.484	0.716	0.832	0.736	0.599	-0.079	0.852	0.676	0.811
1-3 miles	0.604	0.735	0.779	0.734	0.831	0.764	0.638	0.522	0.596	0.729	0.854	0.695	0.124	0.812	0.630	0.746
>3 miles	0.555	0.524	0.439	0.493	0.552	0.537	0.302	0.801	0.496	0.496	0.521	0.559	0.277	0.471	0.468	0.576
Under 21	0.412	0.163	0.268	0.376	0.360	0.363	0.123	0.431	0.240	0.295	0.412	0.419	0.440	0.261	0.465	0.418
21-30	0.612	0.400	0.549	0.540	0.607	0.561	0.455	0.450	0.333	0.538	0.510	0.506	0.450	0.485	0.722	0.577
31-40	0.357	0.505	0.348	0.266	0.425	0.341	0.253	0.467	0.300	0.313	0.434	0.516	0.544	0.235	0.515	0.414
41-50	0.784	0.766	0.773	0.761	0.885	0.797	0.606	0.698	0.764	0.790	0.672	0.684	0.263	0.787	0.735	0.762
51-60	0.545	0.674	0.693	0.784	0.782	0.829	0.688	0.522	0.655	0.808	0.611	0.554	-0.005	0.794	0.668	0.764
Over 60	0.534	0.726	0.847	0.891	0.876	0.877	0.527	0.485	0.690	0.877	0.769	0.580	-0.126	0.925	0.683	0.772
M	0.601	0.780	0.897	0.930	0.948	0.932	0.644	0.564	0.768	0.940	0.780	0.625	0.018	0.967	0.771	0.810
F	0.767	0.744	0.697	0.650	0.781	0.761	0.621	0.679	0.549	0.692	0.653	0.652	0.266	0.677	0.747	0.829

A.2.16 Cross product (correlation) matrix for Figure 2.15 (cont)

	O/WLF	Pesticide Y	PesticideN	Slug Pellet	Pesticide	Weedkiller	Fungicide	Other	>monthly	4x a year	2x a year	c. Once a y	Daily	4-5 times	2-3 times	Once a we
	0.760	0.568	0.732	0.511	0.588	0.542	0.452	0.445	0.457	0.586	0.614	0.453	0.506	0.630	0.670	0.404
< 1yr	0.789	0.785	0.806	0.717	0.666	0.731	0.632	0.825	0.508	0.672	0.635	0.811	0.754	0.757	0.794	0.597
1-3yr	0.751	0.897	0.708	0.909	0.797	0.928	0.809	0.555	0.704	0.855	0.830	0.753	0.776	0.904	0.813	0.498
3-8yr	0.715	0.918	0.712	0.921	0.801	0.866	0.720	0.630	0.734	0.714	0.880	0.796	0.869	0.857	0.846	0.516
>8yr	0.850	0.919	0.864	0.896	0.783	0.898	0.728	0.681	0.676	0.823	0.846	0.815	0.839	0.907	0.914	0.588
Veg	0.792	0.925	0.782	0.902	0.811	0.859	0.729	0.732	0.727	0.726	0.878	0.838	0.873	0.884	0.893	0.511
Veg/Flower	0.551	0.645	0.548	0.620	0.571	0.636	0.487	0.397	0.679	0.530	0.670	0.520	0.579	0.665	0.606	0.241
Flowers	0.702	0.508	0.710	0.424	0.535	0.481	0.496	0.620	0.290	0.361	0.500	0.599	0.571	0.540	0.613	0.551
WLG	0.754	0.726	0.686	0.677	0.658	0.646	0.514	0.562	0.485	0.532	0.623	0.762	0.730	0.679	0.678	0.633
Other	0.761	0.929	0.759	0.918	0.783	0.868	0.701	0.686	0.703	0.745	0.862	0.826	0.866	0.892	0.868	0.511
All	0.701	0.760	0.739	0.705	0.688	0.749	0.706	0.569	0.628	0.595	0.731	0.731	0.738	0.743	0.745	0.575
2/3rd	0.721	0.632	0.611	0.565	0.595	0.667	0.506	0.501	0.515	0.603	0.613	0.584	0.501	0.640	0.621	0.573
c1/2	0.304	-0.085	0.379	-0.161	-0.205	-0.097	-0.257	0.064	-0.088	0.033	-0.183	-0.038	-0.075	0.102	0.108	0.147
<1/2	0.716	0.988	0.692	0.969	0.807	0.928	0.770	0.672	0.697	0.798	0.911	0.814	0.859	0.857	0.894	0.496
Trad	0.721	0.698	0.844	0.704	0.666	0.645	0.516	0.445	0.647	0.557	0.687	0.666	0.676	0.759	0.795	0.423
Organic	0.780	0.829	0.833	0.760	0.771	0.774	0.724	0.744	0.613	0.688	0.762	0.754	0.785	0.780	0.848	0.635
WLF	1.000	0.702	0.902	0.643	0.657	0.703	0.554	0.711	0.508	0.639	0.648	0.749	0.701	0.813	0.786	0.589
O/WLF	0.702	1.000	0.657	0.970	0.805	0.932	0.779	0.670	0.730	0.823	0.910	0.806	0.868	0.871	0.871	0.507
Pesticide Yes	0.902	0.657	1.000	0.610	0.625	0.643	0.517	0.688	0.458	0.556	0.612	0.720	0.671	0.760	0.827	0.565
PesticideNo	0.643	0.970	0.610	1.000	0.818	0.929	0.790	0.571	0.758	0.830	0.909	0.766	0.839	0.854	0.838	0.415
Slug Pellets	0.657	0.805	0.625	0.818	1.000	0.809	0.891	0.479	0.690	0.707	0.876	0.541	0.771	0.737	0.742	0.416
Pesticide	0.703	0.932	0.643	0.929	0.809	1.000	0.874	0.629	0.707	0.842	0.910	0.743	0.825	0.897	0.786	0.539
Weedkiller	0.554	0.779	0.517	0.790	0.891	0.874	1.000	0.519	0.655	0.768	0.845	0.489	0.740	0.736	0.652	0.424
Fungicide	0.711	0.670	0.688	0.571	0.479	0.629	0.519	1.000	0.405	0.503	0.546	0.695	0.648	0.640	0.698	0.536
Other	0.508	0.730	0.458	0.758	0.690	0.707	0.655	0.405	1.000	0.609	0.705	0.576	0.690	0.702	0.604	0.241
>monthly	0.639	0.823	0.556	0.830	0.707	0.842	0.768	0.503	0.609	1.000	0.707	0.586	0.693	0.801	0.697	0.492
4x a year	0.648	0.910	0.612	0.909	0.876	0.910	0.845	0.546	0.705	0.707	1.000	0.661	0.792	0.814	0.821	0.426
2x a year	0.749	0.806	0.720	0.766	0.541	0.743	0.489	0.695	0.576	0.586	0.661	1.000	0.747	0.782	0.793	0.547
c. Once a year	0.701	0.868	0.671	0.839	0.771	0.825	0.740	0.648	0.690	0.693	0.792	0.747	1.000	0.775	0.695	0.439
Daily	0.813	0.871	0.760	0.854	0.737	0.897	0.736	0.640	0.702	0.801	0.814	0.782	0.775	1.000	0.812	0.523
4-5 times	0.786	0.871	0.827	0.838	0.742	0.786	0.652	0.698	0.604	0.697	0.821	0.793	0.695	0.812	1.000	0.443
2-3 times	0.589	0.507	0.565	0.415	0.416	0.539	0.424	0.536	0.241	0.492	0.426	0.547	0.439	0.523	0.443	1.000
Once a week	0.403	0.483	0.350	0.472	0.531	0.581	0.592	0.190	0.397	0.643	0.419	0.334	0.368	0.551	0.343	0.583
Once a fortnight	0.216	0.032	0.227	0.027	0.108	-0.001	0.077	0.243	0.062	0.119	-0.057	0.201	0.031	0.128	0.166	0.054
Less often	0.806	0.902	0.836	0.888	0.771	0.877	0.745	0.683	0.661	0.800	0.808	0.835	0.848	0.857	0.880	0.610
family	0.698	0.716	0.624	0.703	0.643	0.716	0.616	0.694	0.660	0.623	0.677	0.712	0.580	0.716	0.770	0.450
friends	0.808	0.823	0.801	0.809	0.743	0.812	0.651	0.612	0.675	0.747	0.778	0.736	0.705	0.891	0.863	0.478
plot-holders	0.847	0.922	0.847	0.889	0.818	0.845	0.726	0.707	0.707	0.776	0.849	0.833	0.852	0.882	0.934	0.529
self taught	0.878	0.858	0.860	0.834	0.736	0.831	0.684	0.698	0.629	0.749	0.782	0.835	0.835	0.900	0.861	0.616
very imp	0.669	0.873	0.681	0.843	0.791	0.866	0.775	0.653	0.689	0.722	0.842	0.715	0.739	0.767	0.839	0.455
important	0.554	0.794	0.601	0.760	0.670	0.699	0.592	0.510	0.534	0.693	0.690	0.623	0.698	0.705	0.809	0.247
neutral	0.403	0.446	0.421	0.399	0.431	0.417	0.350	0.239	0.267	0.439	0.470	0.302	0.531	0.384	0.382	0.233
not imp	0.843	0.947	0.845	0.913	0.807	0.896	0.738	0.721	0.692	0.812	0.868	0.836	0.859	0.919	0.931	0.558
Survey Yes	0.769	0.888	0.780	0.867	0.779	0.876	0.771	0.668	0.681	0.735	0.841	0.802	0.867	0.836	0.844	0.536
Survey No	0.707	0.812	0.718	0.790	0.654	0.693	0.546	0.616	0.601	0.678	0.742	0.764	0.753	0.718	0.819	0.400
<1/4 mile	0.651	0.754	0.656	0.770	0.720	0.688	0.626	0.641	0.561	0.608	0.684	0.661	0.783	0.671	0.765	0.296
<1/2 mile	0.681	0.835	0.701	0.841	0.786	0.845	0.743	0.581	0.609	0.701	0.779	0.728	0.721	0.812	0.786	0.585
<1mile	0.704	0.835	0.671	0.768	0.740	0.829	0.745	0.541	0.645	0.741	0.809	0.666	0.725	0.836	0.790	0.504
1-3 miles	0.711	0.462	0.637	0.378	0.406	0.491	0.406	0.706	0.300	0.324	0.479	0.548	0.483	0.536	0.515	0.528
>3 miles	0.465	0.283	0.412	0.264	0.277	0.290	0.283	0.320	0.398	0.315	0.304	0.208	0.266	0.344	0.361	0.329
Under 21	0.652	0.500	0.617	0.467	0.370	0.471	0.320	0.324	0.515	0.502	0.485	0.508	0.475	0.538	0.586	0.335
21-30	0.540	0.267	0.608	0.189	0.122	0.232	0.070	0.467	0.260	0.306	0.055	0.487	0.298	0.395	0.411	0.289
31-40	0.900	0.766	0.856	0.728	0.746	0.743	0.632	0.690	0.516	0.721	0.708	0.691	0.697	0.819	0.840	0.546
41-50	0.660	0.759	0.677	0.737	0.645	0.743	0.537	0.608	0.588	0.517	0.742	0.770	0.711	0.693	0.743	0.509
51-60	0.665	0.942	0.638	0.926	0.796	0.888	0.790	0.596	0.652	0.795	0.901	0.740	0.835	0.851	0.836	0.464
Over 60	0.773	0.963	0.752	0.948	0.785	0.909	0.730	0.645	0.710	0.772	0.880	0.838	0.884	0.902	0.887	0.470
M	0.784	0.667	0.830	0.617	0.733	0.643	0.629	0.614	0.491	0.650	0.674	0.570	0.594	0.672	0.826	0.460

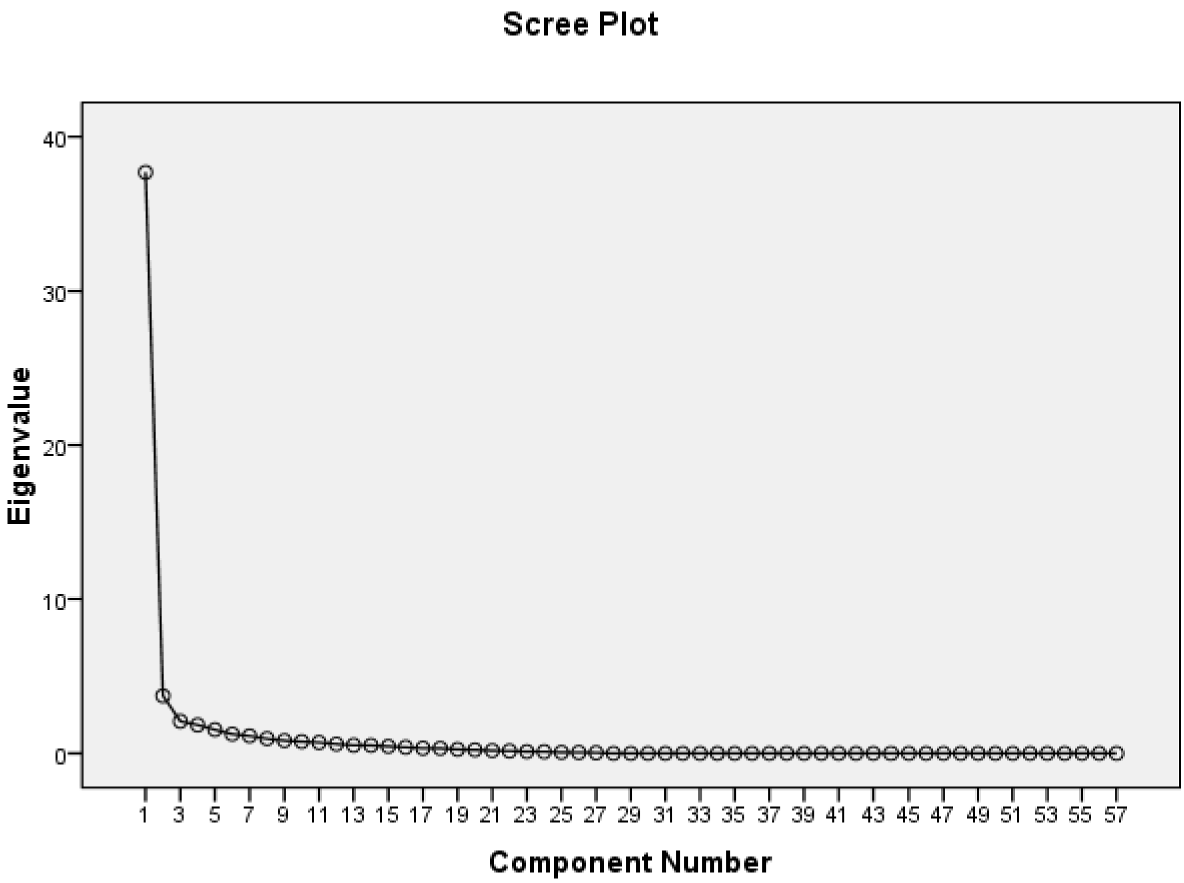
A.2.16 Cross product (correlation) matrix for Figure 2.15 (cont)

	Once a fortnight	Less often	family	friends	plot-holders	self taught	very imp	important	neutral	not imp	Survey Yes	Survey No	<1/4 mile	<1/2 mile	<1mile	1-3 miles
< 1yr	0.288	0.162	0.652	0.516	0.655	0.699	0.670	0.544	0.490	0.580	0.694	0.597	0.703	0.382	0.447	0.604
1-3yr	0.518	0.206	0.838	0.733	0.744	0.840	0.827	0.742	0.663	0.350	0.854	0.785	0.722	0.684	0.727	0.735
3-8yr	0.610	0.120	0.868	0.695	0.832	0.881	0.848	0.858	0.674	0.341	0.909	0.847	0.741	0.704	0.838	0.779
>8yr	0.355	0.086	0.881	0.686	0.840	0.917	0.881	0.808	0.748	0.407	0.919	0.883	0.788	0.849	0.828	0.734
Veg	0.509	0.116	0.954	0.724	0.906	0.958	0.928	0.858	0.796	0.507	0.979	0.919	0.804	0.780	0.847	0.831
Veg/Flower	0.328	0.145	0.911	0.785	0.846	0.954	0.934	0.811	0.750	0.388	0.957	0.888	0.878	0.798	0.827	0.764
Flowers	0.340	0.052	0.635	0.573	0.686	0.639	0.631	0.525	0.623	0.574	0.674	0.566	0.647	0.465	0.413	0.638
WLG	0.353	0.333	0.608	0.574	0.519	0.643	0.692	0.429	0.312	0.331	0.640	0.511	0.590	0.431	0.484	0.522
Other	0.404	0.169	0.810	0.471	0.582	0.802	0.776	0.619	0.556	0.358	0.751	0.765	0.630	0.671	0.716	0.596
All	0.340	0.149	0.896	0.715	0.847	0.933	0.907	0.828	0.741	0.416	0.949	0.893	0.845	0.819	0.832	0.729
2/3rd	0.595	-0.013	0.835	0.582	0.706	0.796	0.785	0.692	0.629	0.439	0.794	0.782	0.610	0.531	0.736	0.854
c1/2	0.571	-0.009	0.631	0.575	0.631	0.664	0.604	0.669	0.440	0.424	0.679	0.593	0.587	0.329	0.599	0.695
<1/2	0.079	0.000	0.067	0.045	0.206	0.049	0.157	-0.134	0.002	0.173	0.114	-0.081	0.051	-0.159	-0.079	0.124
Trad	0.440	0.047	0.921	0.738	0.838	0.921	0.870	0.869	0.807	0.433	0.950	0.900	0.801	0.772	0.852	0.812
Organic	0.301	0.149	0.781	0.543	0.791	0.837	0.806	0.690	0.574	0.409	0.826	0.745	0.789	0.656	0.676	0.630
WLF	0.368	0.194	0.877	0.764	0.826	0.898	0.876	0.787	0.711	0.297	0.904	0.825	0.769	0.685	0.811	0.746
O/WLF	0.403	0.216	0.806	0.698	0.808	0.847	0.878	0.669	0.554	0.403	0.843	0.769	0.707	0.651	0.681	0.704
Pesticide Yes	0.483	0.032	0.902	0.716	0.823	0.922	0.858	0.873	0.794	0.446	0.947	0.888	0.812	0.754	0.835	0.835
PesticideNo	0.350	0.227	0.836	0.624	0.801	0.847	0.860	0.681	0.601	0.421	0.845	0.780	0.718	0.656	0.701	0.671
Slug Pellets	0.472	0.027	0.888	0.703	0.809	0.889	0.834	0.843	0.760	0.399	0.913	0.867	0.790	0.770	0.841	0.768
Pesticide	0.531	0.108	0.771	0.643	0.743	0.818	0.736	0.791	0.670	0.431	0.807	0.779	0.654	0.720	0.786	0.740
Weedkiller	0.581	-0.001	0.877	0.716	0.812	0.845	0.831	0.866	0.699	0.417	0.896	0.876	0.693	0.688	0.845	0.829
Fungicide	0.592	0.077	0.745	0.616	0.651	0.726	0.684	0.775	0.592	0.350	0.738	0.771	0.546	0.626	0.743	0.745
Other	0.190	0.243	0.683	0.694	0.612	0.707	0.698	0.653	0.510	0.239	0.721	0.668	0.616	0.641	0.581	0.541
>monthly	0.397	0.062	0.661	0.660	0.675	0.707	0.629	0.689	0.534	0.267	0.692	0.681	0.601	0.561	0.609	0.645
4x a year	0.643	0.119	0.800	0.623	0.747	0.776	0.749	0.722	0.693	0.439	0.812	0.735	0.678	0.608	0.701	0.741
2x a year	0.419	-0.057	0.808	0.677	0.778	0.849	0.782	0.842	0.690	0.470	0.868	0.841	0.742	0.684	0.779	0.809
c. Once a year	0.334	0.201	0.835	0.712	0.736	0.833	0.835	0.715	0.623	0.302	0.836	0.802	0.764	0.661	0.728	0.666
Daily	0.368	0.031	0.848	0.580	0.705	0.852	0.835	0.739	0.698	0.531	0.859	0.867	0.753	0.783	0.721	0.725
4-5 times	0.551	0.128	0.857	0.716	0.891	0.882	0.900	0.767	0.705	0.384	0.919	0.836	0.718	0.671	0.812	0.836
2-3 times	0.343	0.166	0.880	0.770	0.863	0.934	0.861	0.839	0.809	0.382	0.931	0.844	0.819	0.765	0.786	0.790
Once a week	0.583	0.054	0.610	0.450	0.478	0.529	0.616	0.455	0.247	0.233	0.558	0.536	0.400	0.296	0.585	0.504
Once a fortnight	1.000	0.036	0.496	0.351	0.439	0.432	0.443	0.451	0.328	0.338	0.471	0.457	0.241	0.208	0.514	0.648
Less often	0.036	1.000	0.099	0.242	0.136	0.180	0.170	0.068	0.006	0.054	0.135	0.065	0.263	0.275	-0.020	-0.168
family	0.496	0.099	1.000	0.703	0.822	0.933	0.938	0.803	0.763	0.449	0.944	0.916	0.797	0.754	0.871	0.798
friends	0.351	0.242	0.703	1.000	0.784	0.740	0.776	0.630	0.547	0.091	0.774	0.625	0.679	0.556	0.647	0.623
plot-holders	0.439	0.136	0.822	0.784	1.000	0.852	0.859	0.752	0.770	0.419	0.902	0.770	0.709	0.714	0.751	0.791
self taught	0.432	0.180	0.933	0.740	0.852	1.000	0.930	0.858	0.782	0.421	0.977	0.917	0.885	0.808	0.825	0.811
very imp	0.443	0.170	0.938	0.776	0.859	0.930	1.000	0.694	0.701	0.375	0.944	0.860	0.836	0.745	0.800	0.765
important	0.451	0.068	0.803	0.630	0.752	0.858	0.694	1.000	0.691	0.396	0.852	0.892	0.691	0.717	0.798	0.770
neutral	0.328	0.006	0.763	0.547	0.770	0.782	0.701	0.691	1.000	0.471	0.797	0.724	0.612	0.749	0.695	0.767
not imp	0.338	0.054	0.449	0.091	0.419	0.421	0.375	0.396	0.471	1.000	0.460	0.447	0.431	0.414	0.211	0.483
Survey Yes	0.471	0.135	0.944	0.774	0.902	0.977	0.944	0.852	0.797	0.460	1.000	0.893	0.863	0.773	0.851	0.836
Survey No	0.457	0.065	0.916	0.625	0.770	0.917	0.860	0.892	0.724	0.447	0.893	1.000	0.754	0.791	0.812	0.807
<1/4 mile	0.241	0.263	0.797	0.679	0.709	0.885	0.836	0.691	0.612	0.431	0.863	0.754	1.000	0.690	0.578	0.603
<1/2 mile	0.208	0.275	0.754	0.556	0.714	0.808	0.745	0.717	0.749	0.414	0.773	0.791	0.690	1.000	0.637	0.530
<1mile	0.514	-0.020	0.871	0.647	0.751	0.825	0.800	0.798	0.695	0.211	0.851	0.812	0.578	0.637	1.000	0.749
1-3 miles	0.648	-0.168	0.798	0.623	0.791	0.811	0.765	0.770	0.767	0.483	0.836	0.807	0.603	0.530	0.749	1.000
>3 miles	0.186	0.371	0.492	0.579	0.532	0.544	0.582	0.461	0.132	0.299	0.566	0.481	0.516	0.354	0.372	0.390
Under 21	0.065	-0.125	0.376	0.380	0.409	0.370	0.417	0.233	0.134	0.027	0.366	0.267	0.293	0.159	0.358	0.373
21-30	0.125	-0.035	0.550	0.510	0.663	0.600	0.617	0.466	0.362	0.313	0.607	0.496	0.635	0.373	0.344	0.537
31-40	0.235	0.312	0.418	0.300	0.430	0.432	0.423	0.317	0.325	0.245	0.434	0.300	0.410	0.289	0.311	0.348
41-50	0.473	0.337	0.831	0.691	0.840	0.862	0.851	0.717	0.634	0.518	0.871	0.776	0.737	0.720	0.674	0.690
51-60	0.205	0.045	0.790	0.737	0.737	0.753	0.779	0.661	0.628	0.356	0.811	0.665	0.693	0.622	0.729	0.567
Over 60	0.496	-0.065	0.858	0.603	0.763	0.897	0.820	0.843	0.766	0.422	0.893	0.907	0.761	0.718	0.816	0.871
M	0.470	0.088	0.923	0.700	0.838	0.943	0.909	0.835	0.789	0.460	0.960	0.918	0.818	0.781	0.846	0.823
F	0.354	0.208	0.758	0.721	0.763	0.818	0.774	0.674	0.641	0.385	0.818	0.638	0.769	0.601	0.620	0.680

A.2.16 Cross product matrix (correlation) for Figure 2.15 (cont)

	>3 miles	Under 21	21-30	31-40	41-50	51-60	Over 60	M	F
< 1yr	0.555	0.412	0.612	0.357	0.784	0.545	0.534	0.601	0.767
1-3yr	0.524	0.163	0.400	0.505	0.766	0.674	0.726	0.780	0.744
3-8yr	0.439	0.268	0.549	0.348	0.773	0.693	0.847	0.897	0.697
>8yr	0.493	0.376	0.540	0.266	0.761	0.784	0.891	0.930	0.650
Veg	0.552	0.360	0.607	0.425	0.885	0.782	0.876	0.948	0.781
Veg/Flower	0.537	0.363	0.561	0.341	0.797	0.829	0.877	0.932	0.761
Flowers	0.302	0.123	0.455	0.253	0.606	0.688	0.527	0.644	0.621
WLG	0.801	0.431	0.450	0.467	0.698	0.522	0.485	0.564	0.679
Other	0.496	0.240	0.333	0.300	0.764	0.655	0.690	0.768	0.549
All	0.496	0.295	0.538	0.313	0.790	0.808	0.877	0.940	0.692
2/3rd	0.521	0.412	0.510	0.434	0.672	0.611	0.769	0.780	0.653
c1/2	0.559	0.419	0.506	0.516	0.684	0.554	0.580	0.625	0.652
<1/2	0.277	0.440	0.450	0.544	0.263	-0.005	-0.126	0.018	0.266
Trad	0.471	0.261	0.485	0.235	0.787	0.794	0.925	0.967	0.677
Organic	0.468	0.465	0.722	0.515	0.735	0.668	0.683	0.771	0.747
WLF	0.576	0.418	0.577	0.414	0.762	0.764	0.772	0.810	0.829
O/WLF	0.711	0.465	0.652	0.540	0.900	0.660	0.665	0.773	0.784
Pesticide Yes	0.462	0.283	0.500	0.267	0.766	0.759	0.942	0.963	0.667
PesticideNo	0.637	0.412	0.617	0.608	0.856	0.677	0.638	0.752	0.830
Slug Pellets	0.378	0.264	0.467	0.189	0.728	0.737	0.926	0.948	0.617
Pesticide	0.406	0.277	0.370	0.122	0.746	0.645	0.796	0.785	0.733
Weedkiller	0.491	0.290	0.471	0.232	0.743	0.743	0.888	0.909	0.643
Fungicide	0.406	0.283	0.320	0.070	0.632	0.537	0.790	0.730	0.629
Other	0.706	0.320	0.324	0.467	0.690	0.608	0.596	0.645	0.614
>monthly	0.300	0.398	0.515	0.260	0.516	0.588	0.652	0.710	0.491
4x a year	0.324	0.315	0.502	0.306	0.721	0.517	0.795	0.772	0.650
2x a year	0.479	0.304	0.485	0.055	0.708	0.742	0.901	0.880	0.674
c. Once a year	0.548	0.208	0.508	0.487	0.691	0.770	0.740	0.838	0.570
Daily	0.483	0.266	0.475	0.298	0.697	0.711	0.835	0.884	0.594
4-5 times	0.536	0.344	0.538	0.395	0.819	0.693	0.851	0.902	0.672
2-3 times	0.515	0.361	0.586	0.411	0.840	0.743	0.836	0.887	0.826
Once a week	0.528	0.329	0.335	0.289	0.546	0.509	0.464	0.470	0.460
Once a fortnight	0.186	0.065	0.125	0.235	0.473	0.205	0.496	0.470	0.354
Less often	0.371	-0.125	-0.035	0.312	0.337	0.045	-0.065	0.088	0.208
family	0.492	0.376	0.550	0.418	0.831	0.790	0.858	0.923	0.758
friends	0.579	0.380	0.510	0.300	0.691	0.737	0.603	0.700	0.721
plot-holders	0.532	0.409	0.663	0.430	0.840	0.737	0.763	0.838	0.763
self taught	0.544	0.370	0.600	0.432	0.862	0.753	0.897	0.943	0.818
very imp	0.582	0.417	0.617	0.423	0.851	0.779	0.820	0.909	0.774
important	0.461	0.233	0.466	0.317	0.717	0.661	0.843	0.835	0.674
neutral	0.132	0.134	0.362	0.325	0.634	0.628	0.766	0.789	0.641
not imp	0.299	0.027	0.313	0.245	0.518	0.356	0.422	0.460	0.385
Survey Yes	0.566	0.366	0.607	0.434	0.871	0.811	0.893	0.960	0.818
Survey No	0.481	0.267	0.496	0.300	0.776	0.665	0.907	0.918	0.638
<1/4 mile	0.516	0.293	0.635	0.410	0.737	0.693	0.761	0.818	0.769
<1/2 mile	0.354	0.159	0.373	0.289	0.720	0.622	0.718	0.781	0.601
<1mile	0.372	0.358	0.344	0.311	0.674	0.729	0.816	0.846	0.620
1-3 miles	0.390	0.373	0.537	0.348	0.690	0.567	0.871	0.823	0.680
>3 miles	1.000	0.466	0.460	0.374	0.710	0.476	0.408	0.499	0.523
Under 21	0.466	1.000	0.684	0.407	0.349	0.233	0.311	0.283	0.448
21-30	0.460	0.684	1.000	0.479	0.526	0.484	0.467	0.505	0.656
31-40	0.374	0.407	0.479	1.000	0.431	0.272	0.207	0.340	0.500
41-50	0.710	0.349	0.526	0.431	1.000	0.656	0.709	0.814	0.791
51-60	0.476	0.233	0.484	0.272	0.656	1.000	0.591	0.751	0.692
Over 60	0.408	0.311	0.467	0.207	0.709	0.591	1.000	0.929	0.610
M	0.499	0.283	0.505	0.340	0.814	0.751	0.929	1.000	0.661
F	0.523	0.448	0.656	0.500	0.791	0.692	0.610	0.661	1.000

A.2.17 Scree plot for PCA on allotment questionnaire responses.



A2.18 Un-rotated loadings for PCA on allotment questionnaire responses.

Component Matrix a

	Component						
	1	2	3	4	5	6	7
Survey Yes	0.990						
Veg	0.979						
self taught	0.977						
Veg/Flower	0.958						
family	0.957						
Male	0.956						
Trad	0.947						
very imp	0.947						
Pesticide Yes	0.945						
All	0.941						
>8yr	0.925						
2-3 times	0.924						
Survey No	0.922						
4-5 times	0.920						
Weedkiller	0.915						
Slug Pellets	0.913	-0.333					
3-8yr	0.912						
WLF	0.907						
plot-holders	0.902						
Over 60	0.899						
2x a year	0.886						
41-50	0.882						
Daily	0.871						
important	0.870						
O/WLF	0.861	0.356					
<1mile	0.856						
1-3 miles	0.855		0.356				
1-3yr	0.854						
No pest	0.847	0.390					
<1/4 mile	0.847						
c. Once a year	0.842						
Pesticide	0.841						
2/3rd	0.831						
Organic	0.822						
Female	0.815	0.302					
4x a year	0.812						
51-60	0.803						
<1/2 mile	0.785		-0.321				
Fungicide	0.784	-0.326				0.305	
friends	0.781						
GrowOther	0.778						
neutral	0.777						
OtherPest	0.727		-0.385				
>monthly	0.726						
c1/2	0.711		0.312				
< 1yr	0.703	0.357					
Flowers	0.684			-0.307	0.321		
Grow WLG	0.657	0.449					
21-30	0.611	0.420	0.302	-0.333			
>3 miles	0.592	0.491				0.363	
Once a week	0.589			0.546			
<1/2		0.800	0.355				
31-40	0.427	0.622				-0.385	
Less often			-0.606		0.389		0.401
Once a fortnight	0.505		0.382	0.625			
not imp	0.477				0.626		-0.363
Under 21	0.395	0.461	0.309		-0.585		

Extraction Method: Principal Component Analysis.
a. 7 components extracted.

A2.19 Table of communalities as extracted by PCA for allotment questionnaire responses.

	Communalities	
	Initial	Extraction
< 1yr	1	0.868
1-3yr	1	0.870
3-8yr	1	0.907
>8yr	1	0.934
Veg	1	0.970
Veg/Flower	1	0.970
Flowers	1	0.750
Grow WLG	1	0.812
GrowOther	1	0.783
All	1	0.948
2/3rd	1	0.802
c1/2	1	0.732
<1/2	1	0.836
Trad	1	0.957
Organic	1	0.803
WLF	1	0.865
O/WLF	1	0.876
Pesticide Yes	1	0.952
No pest	1	0.900
Slug Pellets	1	0.954
Pesticide	1	0.860
Weedkiller	1	0.932
Fungicide	1	0.888
OtherPest	1	0.737
>monthly	1	0.724
4x a year	1	0.822
2x a year	1	0.967
c. Once a year	1	0.836
Daily	1	0.837
4-5 times	1	0.870
2-3 times	1	0.886
Once a week	1	0.744
Once a fortnight	1	0.934
Less often	1	0.861
family	1	0.936
friends	1	0.823
plot-holders	1	0.873
self taught	1	0.966
very imp	1	0.921
important	1	0.803
neutral	1	0.827
not imp	1	0.846
Survey Yes	1	0.985
Survey No	1	0.897
<1/4 mile	1	0.823
<1/2 mile	1	0.817
<1mile	1	0.874
1-3 miles	1	0.893
>3 miles	1	0.873
Under 21	1	0.832
21-30	1	0.828
31-40	1	0.812
41-50	1	0.901
51-60	1	0.718
Over 60	1	0.911
Male	1	0.948
Female	1	0.807

Table A2.20 Full Pattern and structure for coefficients from allotment questionnaire responses extracted by Direct Oblimin rotation for PCA.

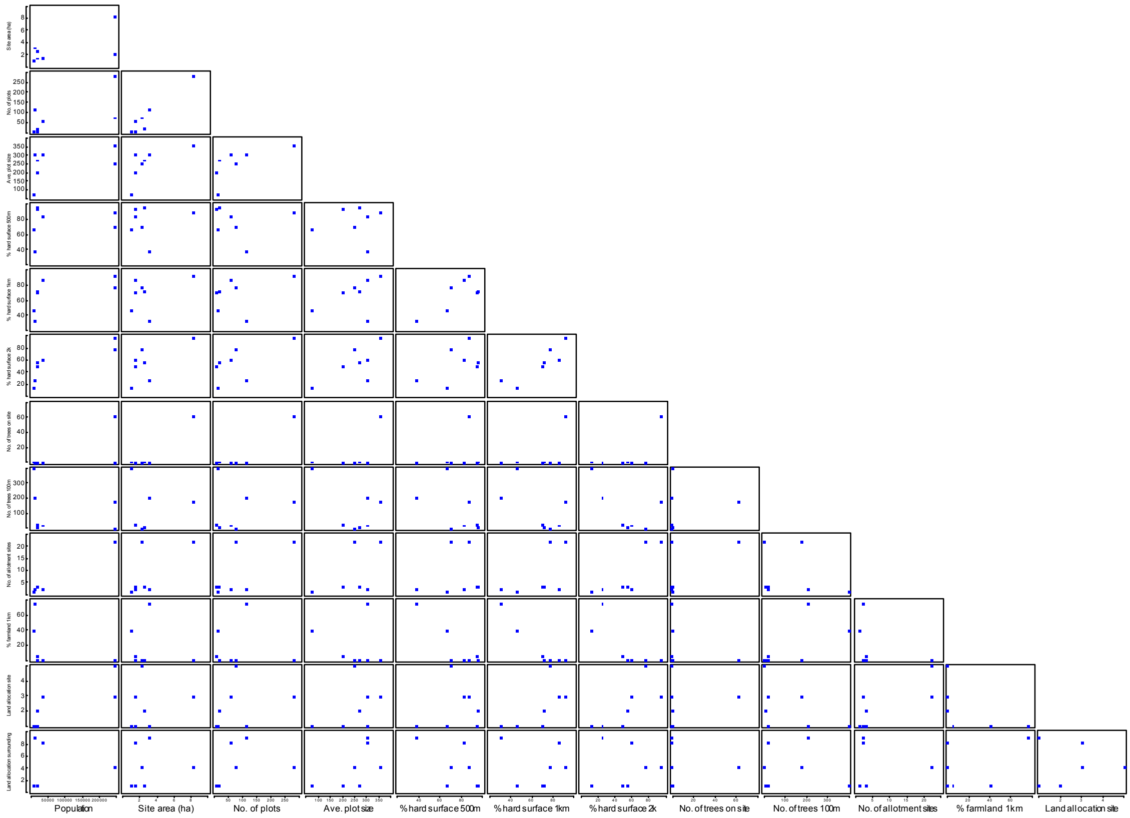
Structure Matrix		
	Component	
	1	2
Survey Yes	0.983	0.468
Veg	0.971	0.467
self taught	0.971	0.459
Trad	0.967	0.235
Male	0.966	0.315
Pesticide Ye:	0.966	0.230
Veg/Flower	0.960	0.380
family	0.954	0.427
All	0.950	0.321
Slug Pellets	0.944	0.131
>8yr	0.939	0.278
Weedkiller	0.937	0.207
Survey No	0.935	0.287
very imp	0.929	0.533
Over 60	0.925	0.170
3-8yr	0.923	0.292
4-5 times	0.918	0.401
2x a year	0.913	0.156
2-3 times	0.913	0.468
WLF	0.892	0.498
important	0.887	0.230
plot-holders	0.887	0.493
Daily	0.884	0.257
<1mile	0.872	0.232
Pesticide	0.864	0.174
1-3 miles	0.858	0.330
41-50	0.849	0.623
1-3yr	0.840	0.465
c. Once a ye	0.833	0.420
<1/4 mile	0.832	0.471
4x a year	0.823	0.250
2/3rd	0.819	0.442
Fungicide	0.816	0.076
O/WLF	0.815	0.716
<1/2 mile	0.800	0.203
51-60	0.800	0.361
No pest	0.798	0.740
neutral	0.798	0.161
Organic	0.793	0.570
Female	0.775	0.647
GrowOther	0.772	0.371
friends	0.767	0.437
>monthly	0.743	0.164
OtherPest	0.701	0.504
Flowers	0.681	0.308
c1/2	0.679	0.547
< 1yr	0.659	0.643
Once a week	0.560	0.468
Once a fortni	0.513	0.151
not imp	0.467	0.271
31-40	0.354	0.749
<1/2	-0.020	0.740
>3 miles	0.533	0.710
Grow WLG	0.603	0.703
21-30	0.560	0.656
Under 21	0.341	0.592
Less often	0.104	0.324

Appendix 3.0

A3.1a Photograph of an example allotment from Newland site, Hull

A3.1b Photograph of Beverley Allotment site with Beverley Minster in the background.

A 3.1c Photograph of an example allotment from Driffield.



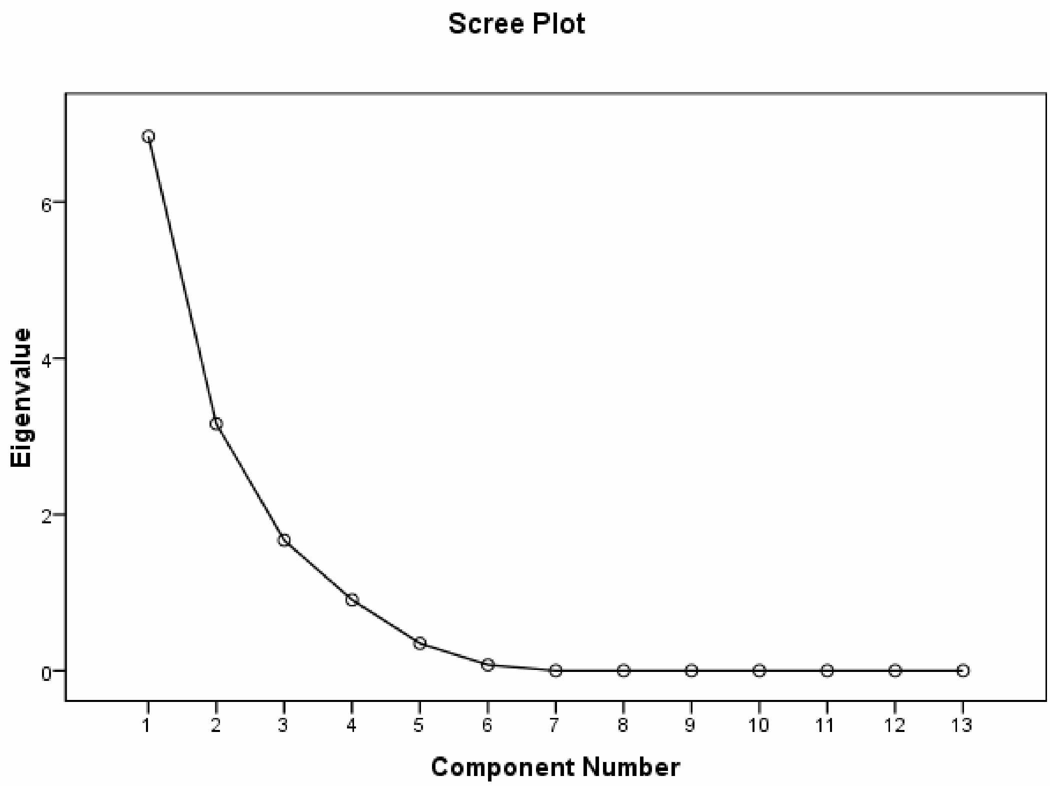
A3.2 Primer Draftsman Plot for run prior to PCA on environmental variables. (See Chapter 3, Section 3.12)

A3.3 Photograph of Pitfall trap *in situ*, with plot identification sheet. (See Chapter 3, Section 3.7.4)

A3.4 Correlation matrix for PCA on environmental variables. (See Chapter 3, Section 3.10)

	Population	Site allocation	Surrunding allocation	Site area	No. plots	Ave plot size	% Hard surface 500m	% Hard surface 1km	% Hard surface 2km	No. trees on site	No. trees 100m	No. of allotment sites	% Farmland 1km
Population	1	0.839	0.200	0.646	0.699	0.470	0.193	0.614	0.814	0.620	-0.255	0.986	-0.579
Site allocation	0.839	1	0.286	0.292	0.423	0.469	0.260	0.691	0.781	0.251	-0.546	0.775	-0.739
Surrunding allocation	0.200	0.286	1	0.235	0.592	0.614	-0.575	-0.107	0.165	0.055	0.012	0.110	0.160
Site area	0.646	0.292	0.235	1	0.905	0.621	0.077	0.329	0.598	0.938	0.200	0.668	-0.234
No. plots	0.699	0.423	0.592	0.905	1	0.687	-0.200	0.234	0.560	0.802	0.199	0.676	-0.124
Ave plot size	0.470	0.469	0.614	0.621	0.687	1	0.059	0.412	0.735	0.407	-0.440	0.450	-0.420
% Hard surface 500m	0.193	0.260	-0.575	0.077	-0.200	0.059	1	0.830	0.548	0.258	-0.501	0.189	-0.826
% Hard surface 1km	0.614	0.691	-0.107	0.329	0.234	0.412	0.830	1	0.868	0.443	-0.590	0.560	-0.965
% Hard surface 2km	0.814	0.781	0.165	0.598	0.560	0.735	0.548	0.868	1	0.557	-0.608	0.792	-0.856
No. trees on site	0.620	0.251	0.055	0.938	0.802	0.407	0.258	0.443	0.557	1	0.297	0.624	-0.299
No. trees 100m	-0.255	-0.546	0.012	0.200	0.199	-0.440	-0.501	-0.590	-0.608	0.297	1	-0.247	0.723
No. of allotment sites	0.986	0.775	0.110	0.668	0.676	0.450	0.189	0.560	0.792	0.624	-0.247	1	-0.539
% Farmland 1km	-0.579	-0.739	0.160	-0.234	-0.124	-0.420	-0.826	-0.965	-0.856	-0.299	0.723	-0.539	1

A3.5 SPSS Scree plot of principle components, showing a break after component 2. (See Chapter 3, Section 3.10)



A3.6 Pooled number of individual taxa found per allotment site.

	Rural		Suburban				Urban				
	DR	HN	CT	BV	BR	BD	NW	Total	Ave	SE	%Species
Spiders	84	369	438	166	182	304	441	1984	283.429	53.523	16.931
Opilione	77	29	14	14	253	6	46	439	62.714	33.019	3.746
Woodlice	89	57	148	62	282	705	1473	2816	402.286	198.228	24.031
Millipede	73	111	55	6	36	278	133	692	98.857	34.007	5.905
Centipede	3	5	16	5	12	25	20	86	12.286	3.190	0.734
Beetles	677	810	311	804	891	444	510	4447	635.286	82.168	37.950
Slugs	151	157	277	69	72	142	182	1050	150.000	26.687	8.961
Snails	30	36	3	7	19	45	64	204	29.143	8.152	1.741
Total	1184	1574	1262	1133	1747	1949	2869	**11718**	1674.000	438.973	100.000
Ave	148.000	196.750	157.750	141.625	218.375	243.625	358.625	1464.750			
SE	77.118	96.821	58.494	96.587	103.166	85.762	171.799	689.746			
%Site	10.104	13.432	10.770	9.669	14.909	16.633	24.484	100.000			

Appendix 4.0

Allotments Questionnaire 08 FEB 2006

Ref: HU 281

Name.[redacted] **Allotment site name** DEGGINGHAM **Plot No.** 153

Address.[redacted]**. Tel ……………………..**

Q1 What size is your allotment? (If you have more than one, please give dimensions of each one.)

| 300 m | X | m | or | ft | X | ft |

Q2 How long have you had your plot(s)?

< 1 year ☐ 1-3 years ☐ 3-8 years ☐ > 8 years ☑

Q3 What is the main use of your plot(s)?

Growing vegetables	☐	Mix of veg and flowers	☑
Growing flowers	☐	Wildlife garden	☐

Other (please specify) [ ]

Q4 How much of your plot is actively used?

All of it	☑	About 2/3rds	☐
About half	☐	less than half	☐

Q5 How do you manage your plot?

Traditional	☑	Organic	☐
Wildlife-friendly	☐	Organic & Wildlife-friendly	☐

Q6 Do you use any pesticides on your plot?

Yes ☑ Go to Q7 No ☐ Go to Q9

Q7 Which types of pesticide do you use? (Tick all that apply)

Slug pellets	☑	Pest killer	☑
Weed killer	☐	Fungicide	☐

Other (please specify) [ ]

Q8 How often do you usually use pesticides?

At least monthly	☐	About 4 times a year	☐
About twice a year	☑	Once a year	☐

A4.1a Example of a 'traditional' completed questionnaire: side 1

Q9 Please rank your main reasons for having an allotment (1 = most important, 7 = least important).

Enjoy growing veg/flowers	☑	Better tasting food	☑
Social contact	☑	Economic	☐
Enjoy being outdoors	☑	Peace and quiet	☑

Other (please specify) ☐

Q10 How often do you visit your plot?

At least daily	☐	4-5 times a week	☐
2-3 times a week	☑	Once a week	☐
Once a fortnight	☐	Less often (please specify)……………………	

Q11 How did you learn the techniques needed to manage an allotment?

From family	☐	From friends	☐
From other plot holders	☑	Self taught	☐

Q12 How important is the wildlife on the site to you?

Very important	☐	Important	☑
Neutral	☐	Not important	☐

Q13 Would you be willing to participate in some small-scale surveying on your plot? (This would not involve any invasive sampling or damage to crops.)

Yes	☑	No	☐

Q14 Please use this box to add any comments you think may be useful.

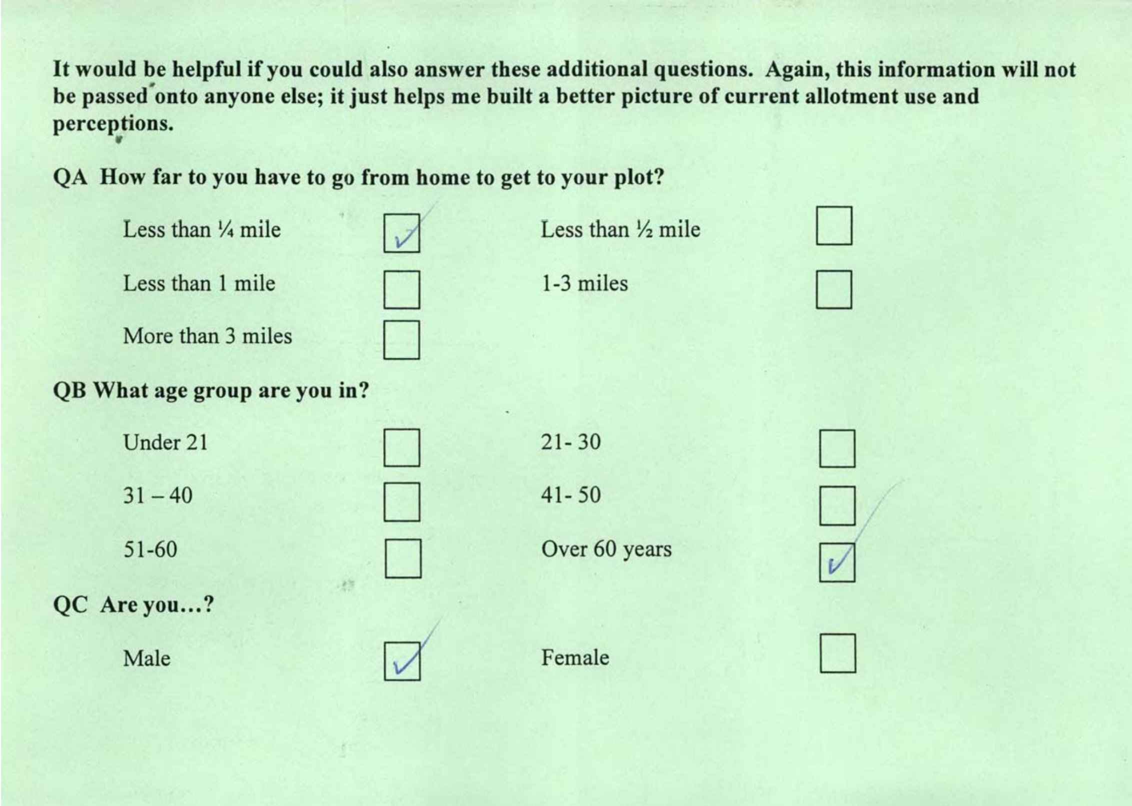
☐

Thank you very much for your help

This information will form part of my research at the University of Hull, looking at the wildlife value of allotment sites. It is hoped this data will help ensure the continued provision of allotment sites in Yorkshire and provide management guidelines to enhance their value.

Data Protection: the information you have provided will only be used to build up a better picture of allotment use. Your personal details will not be passed on to anyone else. <u>If you are willing to participate in further survey work, please ensure you have filled in your contact details at the top of the page overleaf.</u>

A4.1b Example of a 'traditional' completed questionnaire: side 2.



It would be helpful if you could also answer these additional questions. Again, this information will not be passed onto anyone else; it just helps me built a better picture of current allotment use and perceptions.

QA How far to you have to go from home to get to your plot?

Less than ¼ mile	☑	Less than ½ mile	☐
Less than 1 mile	☐	1-3 miles	☐
More than 3 miles	☐		

QB What age group are you in?

Under 21	☐	21- 30	☐
31 – 40	☐	41- 50	☐
51-60	☐	Over 60 years	☑

QC Are you…?

Male	☑	Female	☐

A4.1c Example of a ‘traditional’ completed questionnaire: A5 attachment.

Allotments Questionnaire

20 FEB 2006

Ref: HU 154 ✓

Name [redacted] .... **Allotment site name**..NEWLAND...**Plot No.**.96 S

Address.[redacted] **Tel** [redacted]

Q1 What size is your allotment? (If you have more than one, please give dimensions of each one.)

7 m X 50 m or ft X ft

350

Q2 How long have you had your plot(s)?

- < 1 year [x]
- 1-3 years [ ]
- 3-8 years [ ]
- > 8 years [ ]

Q3 What is the main use of your plot(s)?

- Growing vegetables [x]
- Mix of veg and flowers [ ]
- Growing flowers [ ]
- Wildlife garden [x]

Other (please specify) [ ]

Q4 How much of your plot is actively used?

- All of it [ ]
- About 2/3rds [ ]
- About half [x]
- less than half [ ]

Q5 How do you manage your plot?

- Traditional [ ]
- Organic [ ]
- Wildlife-friendly [ ]
- Organic & Wildlife-friendly [x]

Q6 Do you use any pesticides on your plot?

- Yes [ ] Go to Q7
- No [x] Go to Q9

Q7 Which types of pesticide do you use? (Tick all that apply)

- Slug pellets [ ]
- Pest killer [ ]
- Weed killer [ ]
- Fungicide [ ]

Other (please specify) [ ]

Q8 How often do you usually use pesticides?

- At least monthly [ ]
- About 4 times a year [ ]
- About twice a year [ ]
- Once a year [ ]

A4.2a Example of a 'wildlife-friendly' completed questionnaire: side 1.

Q9 Please rank your main reasons for having an allotment (1 = most important, 7 = least important).

Enjoy growing veg/flowers	5	Better tasting food	1
Social contact	6	Economic	4
Enjoy being outdoors	3	Peace and quiet	2
Other (please specify)			

Q10 How often do you visit your plot?

At least daily	☐	4-5 times a week	☑ SUMMER
2-3 times a week	☐	Once a week	☑ WINTER.
Once a fortnight	☐	Less often (please specify)……………………	

Q11 How did you learn the techniques needed to manage an allotment?

From family	☑	From friends	☑
From other plot holders	☑	Self taught	☑

Q12 How important is the wildlife on the site to you?

Very important	☑	Important	☐
Neutral	☐	Not important	☐

Q13 Would you be willing to participate in some small-scale surveying on your plot? (This would not involve any invasive sampling or damage to crops.)

Yes	☑	No	☐

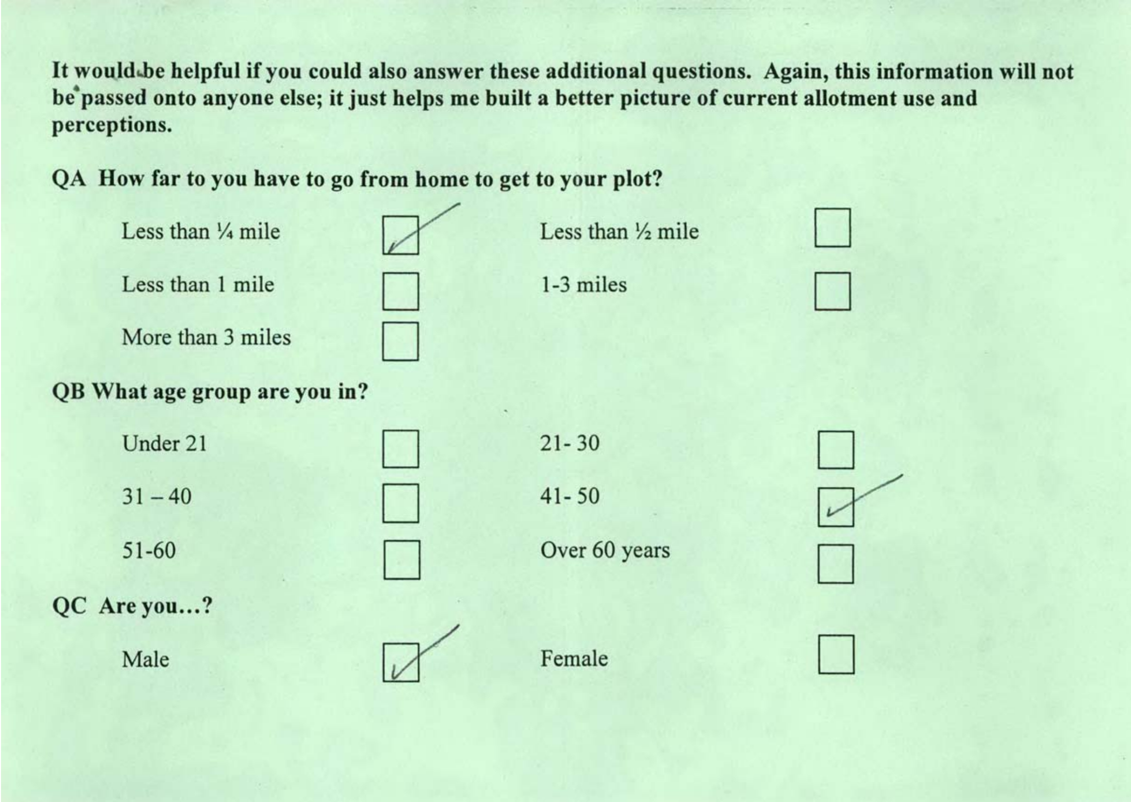
Q14 Please use this box to add any comments you think may be useful.

Thank you very much for your help

This information will form part of my research at the University of Hull, looking at the wildlife value of allotment sites. It is hoped this data will help ensure the continued provision of allotment sites in Yorkshire and provide management guidelines to enhance their value.

Data Protection: the information you have provided will only be used to build up a better picture of allotment use. Your personal details will not be passed on to anyone else. <u>If you are willing to participate in further survey work, please ensure you have filled in your contact details at the top of the page overleaf.</u>

A4.2b Example of a 'wildlife-friendly' completed questionnaire: side 2.



It would be helpful if you could also answer these additional questions. Again, this information will not be passed onto anyone else; it just helps me built a better picture of current allotment use and perceptions.

QA How far to you have to go from home to get to your plot?

Less than ¼ mile	☑	Less than ½ mile	☐
Less than 1 mile	☐	1-3 miles	☐
More than 3 miles	☐		

QB What age group are you in?

Under 21	☐	21- 30	☐
31 – 40	☐	41- 50	☑
51-60	☐	Over 60 years	☐

QC Are you…?

Male	☑	Female	☐

A4.2c Example of a 'wildlife-friendly' completed questionnaire: A5 attachment.

A4.3 Number and percentages of individual taxa at each allotment site split by management style: T = traditional; W = wildlife-friendly

	HNT	BRT	DRT	BVT	CTT	BDT	NWT	Total T	Ave per spp	%T	%Total catch
Spiders	188	56	49	84	220	224	262	1083	154.71	19.57	9.24
Opilione	11	1	9	4	3	2	21	51	7.29	0.92	0.44
Woodlice	39	92	8	11	84	375	210	819	117.00	14.80	6.99
Millipede	38	30	8	2	32	154	46	310	44.29	5.60	2.65
Centipede	2	9	0	4	8	21	10	54	7.71	0.98	0.46
Beetles	453	560	544	470	109	272	355	2763	394.71	49.94	23.58
Slugs	43	7	17	15	158	90	61	391	55.86	7.07	3.34
Snails	7	2	0	1	1	22	29	62	8.86	1.12	0.53
Totals	781	757	635	591	615	1160	994	5533	790.43	100.00	47.23
Ave No. per T plot	97.625	94.625	79.375	73.875	76.875	145	124.25	691.625	1580.86		
% abundance per T sites	14.11	13.68	11.48	10.68	11.12	20.97	17.96	100			
% abundance per total sites	6.66	6.46	5.42	5.04	5.25	9.9	8.48	47.21			

	HNW	BRW	DRW	BVW	CTW	BDW	NWW	Total W	Ave per spp	%W	%Total catch
Spiders	181	126	35	82	218	80	179	901	128.71	14.57	7.69
Opilione	18	252	68	10	11	4	25	388	55.43	6.27	3.31
Woodlice	18	190	81	51	64	330	1263	1997	285.29	32.29	17.04
Millipede	73	6	65	4	23	124	87	382	54.57	6.18	3.26
Centipede	3	3	3	1	8	4	10	32	4.57	0.52	0.27
Beetles	357	331	133	334	202	172	155	1684	240.57	27.23	14.37
Slugs	114	65	134	54	119	52	121	659	94.14	10.65	5.62
Snails	29	17	30	6	2	23	35	142	20.29	2.29	1.21
Totals	793	990	549	542	647	789	1875	6185	883.57	100.00	52.77
Ave No. per W plot	99.125	123.75	68.625	67.75	80.875	98.625	234.375	773.125	1767.14		
% abundance per W sites	12.82	16.01	8.88	8.76	10.46	12.76	30.31	100			
% abundance per total sites	6.77	8.45	4.69	4.63	5.52	6.73	16	52.79			
% abundance per total sites	6.77	8.45	4.69	4.63	5.52	6.73	16	52.79			

A4.4 Percentages of individual taxa split by management style: T = traditional; W = wildlife-friendly

	% Total T rural	% Total T suburban	% Total T urban	Total
Spiders	4.28	10.55	4.74	19.57
Opilione	0.36	0.18	0.38	0.92
Woodlice	0.85	10.16	3.80	14.81
Millipede	0.83	3.94	0.83	5.60
Centipede	0.04	0.76	0.18	0.98
Beetles	18.02	25.50	6.42	49.94
Slugs	1.08	4.88	1.10	7.06
Snails	0.13	0.47	0.52	1.12
Total	25.59	56.44	17.97	100.00

	% Total W rural	% Total W suburban	% Total W urban	Total
Spiders	3.49	8.18	2.89	14.56
Opilione	1.39	4.48	0.40	6.27
Woodlice	1.60	10.26	20.42	32.28
Millipede	2.23	2.54	1.41	6.18
Centipede	0.10	0.26	0.16	0.52
Beetles	7.92	16.80	2.51	27.23
Slugs	4.01	4.69	1.96	10.66
Snails	0.95	0.78	0.57	2.30
Total	21.69	47.99	30.32	100.00

A4.5 Shannon diversity values (H) and Pielou evenness values (J) for invertebrate abundance on individual allotment plots. (Site codes as per Figure 4.1; T = traditional, W = Wildlife-friendly, M= May sample, S= September sample.)

Plot	Diversity (H)	Evenness (J)	Plot	Diversity (H)	Evenness (J)
HN3 TM	1.425	0.732	BV4 TS	0.568	0.353
HN7 TM	0.805	0.500	BV5 WM	0.945	0.587
HN8 TM	1.412	0.788	BV8 WM	1.174	0.729
HN3 TS	1.078	0.602	BV8 WS	0.671	0.375
HN7 TS	0.395	0.221	BV14A WS	1.289	0.663
HN8 TS	0.650	0.938	BR 445 TM	0.811	0.417
HN9 WM	1.456	0.812	BR446 TM	0.971	0.603
HN10 WM	1.256	0.646	BR447 TM	0.476	0.344
HN11 WM	1.317	0.818	BR446 TS	0.922	0.474
HN9 WS	1.354	0.696	BR447 TS	0.902	0.503
HN10 WS	1.687	0.867	BR465 WM	1.391	0.864
HN11 WS	1.395	0.671	BR468 WM	1.166	0.651
DR49 TM	0.616	0.383	BR439 WS	1.199	0.616
DR87 TM	0.377	0.343	BR465 WS	1.150	0.715
DR93 TM	0.272	0.169	BR468 WS	1.344	0.750
DR49 TS	0.660	0.476	BD36 TM	1.685	0.866
DR87 TS	0.625	0.569	BD50 TM	1.480	0.761
DR93 TS	1.195	0.667	BD67 TM	1.289	0.662
DR29 WM	1.347	0.837	BD36 TS	1.595	0.767
DR109 WM	1.248	0.641	BD50 TS	1.345	0.691
DR29 WS	1.691	0.813	BD67 TS	1.346	0.836
DR55 WS	1.030	0.640	BD33 WM	1.304	0.670
DR109 WS	1.836	0.883	BD63 WM	1.567	0.805
CT1 TM	1.368	0.764	BD33 WS	1.262	0.704
CT5B TM	1.200	0.670	BD63 WS	0.823	0.593
CT6 TM	1.588	0.886	NW28 TM	1.296	0.723
CT1 TS	1.474	0.758	NW76 TM	1.391	0.715
CT6 TS	1.468	0.706	NW126 TM	1.439	0.740
CT4A WM	1.475	0.823	NW28 TS	1.557	0.749
CT4B WM	1.322	0.679	NW76 TS	1.491	0.766
CT5A WM	1.257	0.781	NW126 TS	1.129	0.580
CT4A WS	1.743	0.896	NW8 WM	0.892	0.459
CT5A WS	1.640	0.789	NW39 WM	1.393	0.778
BV10 TM	0.753	0.468	NW94 WM	1.026	0.527
BV4 TM	0.789	0.405	NW8 WS	0.761	0.366
BV11 TM	0.500	0.311	NW39 WS	1.188	0.663
BV10 TS	0.589	0.329	NW94 WS	1.239	0.596

Appendix 5.0

A5.1 Spider basic ecology summary

A5.2 Woodlice basic ecology summary

A5.3 Beetle basic ecology summary

A5.1 Spider basic ecology summary

Family	**Species**	**Type**	**Habitat preference**	**Beneficial/ Neutral/ Pest***	**Food preference**	**Sources**
Gnaphosidae	*Micaria pulicaria*	Common & Widespread; synanthropic	Sandy heaths, chalk, derelict land.	B?	N/K	Harvey *et al* (2002); Roberts (1996)
Thomisidae	*Xysticus cristatus*	Common & Widespread	Low vegetation, or ground level. Variety of habitats.	B	Extremely varied; bees, butterflies, spiders, ants, aphids	Harvey *et al* (2002); Nentwig (1988) Roberts (1996);
Lycosidae	*Pardosa amentata*	Common & Widespread: synanthropic	Wide variety of habitats, widespread, open, esp. damp areas. Usually the most common *Pardosa* spp. in gardens.	B	Diptera, Collembola	Harvey *et al* (2002); Kuusk & Ekbom, (2010)
	P. pullata	Common & Widespread	Ubiquitous, open habitats.	B	Diptera, Collembola	Harvey *et al* (2002); Roberts (1996)
	P. hortensis	Very local	Open situations, waste ground, mainly southern parts of UK	B	Diptera, Collembola	Harvey *et al* (2002); Roberts (1996)
	Alopecosa pulverunlenta	Common & Widespread	Cultivated land, grassland, open habitats.	B/N	Diptera	Harvey *et al* (2002); Roberts (1996)
Agelenidae	*Tegenaria sp.*	Widespread	Largely synanthropic.	B/N	Diptera?	Harvey *et al* (2002); Roberts (1996)
Tetragnathidae	*Pachynatha degeeri*	Very common & widespread	Among grass & low vegetation. Humid microhabitats.	B	Aphids, Collembola	Hardwood et al.(2004); Harvey *et al* (2002); Roberts (1996)
	P. clercki	Widespread; frequently in wet habiats	low vegetation, moss, leaf litter in damp habitats.	B	Aphids, Collembola	Roberts (1996)
Linyphidae	*Linynphiidae*	n/a	n/a	B	Diptera, aphids, Collembola	Nyffeler & sunderland, (2003)

* Value judgement based on the readily available literature

A5.2 Woodlice basic ecology summary

Family	Species	Type	Habitat preference	Beneficial/ Neutral/ Pest*	Food preference**	Sources
Trichoniscidae	*Trichoniscus pusillus*	Very common; synanthropic	Wide variety of synanthropic habitats including gardens, grasslands, woodlands.	B	N/K	Gregory (2009)
Oniscidae	*Oniscus asellus*	Very common; highly synanthropic	Ubiquitous	B	N/K	Faeth *et al.* (2011); Gregory (2009); Hopkin (1991); Wang & Schriber (1999); Zimmer & Topp (2000).
Philosciidae	*Philoscia muscorum*	Abundant in England and Wales; synanthropic	Grassy sites and gardens	B	N/K	Gregory (2009)
Armadillidiidae	*Armadillidium vulgare*	*Locally abundant in south-eastern England*	Railway lines, waste ground	B	N/K	Gregory (2009)
Porcellionidae	*Porcellio scaber*	Very common; highly synanthropic	Ubiquitous, especially gardens, churchyards and waste ground	B	N/K	Hopkin (1991); Richards (1995); Faeth *et al.* (2011); Zimmer & Topp (2000).

* Value judgement based on the readily available literature

** All feed on decaying material, fungi, lichen and algae to varying degrees (Gregory, 2009)

A5.3 Beetle basic ecology summary

Family	Species	Type	Habitat preference	Beneficial Neutral/ Pest*	Food preference	Sources
Carabidae	*Nebria brevicollis*	*Very common; synanthropic*	Woodland litter; gardens, agricultural grasslands	B	Collembola; spiders, beetles & larvae, mites; aphids.	Greenslade, 1964; Luff, 2007; Penney, 1966; Sunderland, 1975; Sunderland & Vickerman, 1980; Telfer & Butterfield, 2004.
	Nebria salina	*Widespread, except north-west Scotland*	Sandy or unproductive soils	B	Collembola; spiders, beetles, mites;	Luff, 2007.
	Notophilus biguttatus	*Ubiquitous; sysnanthropic*	Gardens, woodland, grassland, arable fields.	B/N	Collembola	Luff, 2007.
	Loricera pilicornis	*Widespread; synanthropic*	Grasslands, damp woodland, gardens	?	Collembola	Luff, 2007; Sunderland, 1975.
	Bembidion lampros	*Ubiquitous except northern Scotland; synanthropic*	All dry,sunny, habitats, especially gardens.	B	Collembola; arthropod larvae;mites; aphids.	Bilde *et al* , 2000; Langor & Larson, 1983; Lovei & Sunderland,1996; Luff 2007; Mitchell, 1963; Obadofin, 1976; Reigart & Roberts, 1999.
	Bembidion tetracolum	*Ubiquitous*	Open, not too dry soil, especially near water.	B	Collembola; arthropod larvae;mites	Bilde *et al* , 2000; Langor & Larson, 1983; Lovei & Sunderland, 1996; Luff 2007; Mitchell, 1963; Obadofin, 1976; Reigart & Roberts, 1999.
	Bembidion quadrimaculatum	*Widespread in eastern and sourthern England, , local in rest of England*	Fields and gardens	B	Collembola; arthropod larvae;mites	Bilde *et al* , 2000; Langor & Larson, 1983; Lovei & Sunderland, 1996; Luff 2007; Mitchell, 1963; Obadofin, 1976; Reigart & Roberts, 1999.
	Bembidion spp	*n/a*	n/a	B	Collembola; arthropod larvae;mites	Bilde *et al* , 2000; Langor & Larson, 1983; Lovei & Sunderland, 1996; Luff 2007; Mitchell, 1963; Obadofin, 1976; Reigart & Roberts, 1999.
	Pterostichus madidus	*Ubiquitous, often extremely abundant; synanthropic*	Woodlands, gardens.	N	Slugs	Chinery, 2005 & 2004; Luff, 2007 &1974; van Toor, 2006
	Pteristichus melanrius	*Widespread, very abundant; synanthropic*	Gardens, argricultural fields	N	Aphids, slugs	Bohan *et al.* , 2000; Luff, 2007; Sunderland & Vickerman, 1980; van Toor, 2006.
	Pterstichus minor	*Widespread in England, Wales and Ireland, often abundant*	wet grasslands	N	small zoophages	Bukejs & Balalaikins, 2008; Luff, 2007.
	Pterostichus spp.	*n/a*	n/a	N	n/a	Tuovinen *et al* , 2006;

(cont)

	Anchomenus dorsalis	*Widespread except northern Scotland*	Gardens, agricultural land.	?	Slugs, aphids.	Anon, 2011; Bonacci *et al* , 2011; Anderson *et al* , 2000; Luff, 2007.
	Agonum muelleri	*Widespread, abundant; synanthropic*	Damp grasslands, gardens	?	Weed seeds	Luff, 2007; Shearin *et al* ., 2007.
	Amara aenea	*Widespread, very abundant; synanthropic*	Gardens, dry grasslands, dunes and waste land.	B	Weed seeds	Honek *et al* ., 2005; Luff, 2007; Saska, 2008; White *et al* ., 2007.
	Amara spp	*n/a*	n/a	n/a	n/a	n/a
	Harpalus rufipes	*Widespread in England; synanthropic*	Open, dry habitats, esp. arable fields, waste ground and gardens.	N	Beetle larvae; weed seeds	Luff, 2007 & 1998; Mann & O'Toole, 2004; Shearin *et al* ., 2007; Sunderland, 1975.
	Harpalus affinus	*Widespread, very abundant; synanthropic*	Gardens, waste ground.	B	Weed seeds	Luff, 2007; Martinkova *et al* ., 2006.
	Harpalus spp.	*n/a*	n/a	n/a	n/a	n/a

* Value judgement based on the readily available literature