Using Citizen Science to Survey the Invertebrate Communities on Reclaimed Collieries

Kevin James Rich

A thesis submitted for the Degree of MSc by Research in Environmental Science

The University of York

Environment

September 2011

ABSTRACT

Public participation in scientific research, or ‘citizen science’, is becoming more widely used, as the benefits of this research model are realised. This study recruited and trained volunteers to survey invertebrates using a modified citizen science model. Participants were recruited from deprived communities local to two ex-collieries in West Yorkshire, UK. The sites had been reclaimed as Country Parks approximately 16 years prior to this study. Participatory mapping or ‘PGIS’ as it is commonly known, was undertaken with the local residents to discover the life history of the sites. It was found that the two sites are unusual in having a mixture of naturally re-vegetated and technically reclaimed habitats within each site. Survey design focused on finding differences between the invertebrate communities observed in habitats of either reclamation method. Participants successfully undertook a number of butterfly, bumblebee and grasshopper surveys. A multi-taxa invertebrate survey was carried out to assess the quality of invertebrate assemblage and determine the conservation value of the sites.

The results suggest that bumblebee community structure is significantly different, depending on the reclamation method used. Bumblebees did respond strongly to reclamation type, in particular *Bombus lapidarius* and *Bombus pascuorum*. As a group, butterflies did not respond to reclamation method, however some differences were found at the species level. Proposed factors responsible for the observed differences were the presence of flowers used for forage and the soil structure in the naturally regenerated habitat. Eleven habitat specific invertebrate assemblages were generated from the invertebrates records generated by this study, and from historical records. A number of locally uncommon species were discovered. It is concluded that when reclaiming brownfield land, it is desirable to retain an area of naturally regenerated habitat to maintain landscape biodiversity.

Keywords: Citizen Science; Participatory Mapping; Brownfield; Invertebrate; Bumblebee; Butterfly

TABLE OF CONTENTS

List of Figures

List of Tables

Acknowledgements

I would like to thank the following people and institutions for all their kind and enthusiastic help on this project. OPAL (Open Air Laboratories) and the Big Lottery Fund for funded this study, and together they have made a considerable contribution to environmental education in Yorkshire. I would like to thank my supervisors Professor Mike Ashmore and Dr Sarah West for all their encouragement, support and guidance throughout the MSc. I'd also like to thank Steve Cinderby for his contribution with the participatory mapping workshops and GIS. Wakefield council, and their biodiversity officer Paul Andrews deserve a special mention as they were instrumental in finding the right study sites and helped the team to network with key members of the communities.

This study would not have been possible without the time and energy that was generously given to the project by the volunteers. Some individuals require a special mention for their dedication shown throughout the year, Paul Raikes, Brian Hodge, and Lorna Harris for their work at Upton Country Park and for their inspired work with the youth at Fitzwilliam, Margaret Hall, Ann Westmoreland and Tony Healey. Members of the Yorkshire Naturalists' Union were most helpful with providing me with their expert knowledge of invertebrates, these were, Dr Terry Crawford, Roy Crossley, Dr Michael Archer, Jim Flanagan and Bill Ely.

Finally, but certainly not least, I would like to thank my wonderful family and friends who gave me the support and confidence needed to complete this piece of research, and also for lending me an empathetic ear when I encountered difficulties.

Author’s Declaration

I hereby declare that the research work contained within this thesis is my own, and where the work of others has been used; they were fully acknowledged and cited.

Signed: ____________________

Kevin Rich

1. INTRODUCTION

At present there is an increasing public awareness of the need to conserve threatened species; and as such they are generous with donations to wildlife conservation charities. In 2009/2010 the environment sector attracted approximately £6 million in public donations (National Council for Voluntary Organisations, 2010). This demonstrates that the general public is concerned about biodiversity and the wider countryside. The UK government is now acutely aware of the importance of landscape scale biodiversity; and as such, has recently set targets to improve and maintain the land that is important for the survival of native wildlife (Lawton et al., 2010). Therefore, an understanding of which landscapes provide real value to biodiversity is essential for effective species conservation. An increasing human population has led to an increased pressure on the amount of suitable land available for urban development. In the UK, the amount of available land for development is an acute problem, because of a relatively high population density (Home, 2009). Over the last two centuries, industries and commerce have utilised land, and in some cases left it derelict, after businesses became unviable or bankrupt. This land which is known as brownfield is now under an increasing threat of re-development. However, as will be explored in this study, brownfield or previously developed land can act as reservoirs for threatened and uncommon invertebrate species (English Nature, 1998).

Effective invertebrate surveying can determine if any given piece of land is valuable as an invertebrate habitat. However this activity is time consuming and requires a high level of entomological expertise. It has been shown in a recent study, that using volunteers to undertake invertebrate surveys can produce comparative results to that of a trained researcher (Lovell et al., 2009). The citizen science research model offers a framework whereby volunteers and researchers work together to circumvent the cost and time disadvantages of a traditional scientific research model. The novelty of this study is the use of a hybrid citizen science model, focused on a narrow geographical scope to undertake a multi-taxa invertebrate survey of an uncommon landscape type. The benefits and disadvantages of using this approach to invertebrate surveying will be highlighted throughout the course of this thesis.

1.1 RESEARCH FRAMEWORK

This study was funded and supported by Open Air Laboratories (OPAL), a Big Lottery funded initiative that aimed to educate and inspire the general public who, under normal circumstances, would not participate in environmental citizen science projects. A total of fifteen partner organisations, including governmental and environmental bodies, universities and the Natural History Museum delivered these objectives through the development of national surveys of air, soil, water, biodiversity and climate. On a local scale, a number of projects were developed, that targeted specific geographic and demographic areas, which would particularly benefit from environmental education activities. The framework for this particular piece of research was to encompass the objectives of the OPAL project, whilst producing a scientific study that highlights some of the ecological differences within a post mining landscape. Studies that rely on public participation for data collection usually make compromises in study design, to ensure that inexperienced volunteers collect reliable data. This study did make compromises with study design, but the mentoring provided to the volunteers by the primary researcher avoided some of the known disadvantages of this research model.

1.2 DEFINING BROWNFIELD AND ITS IMPORTANCE FOR INVERTEBRATES

In the UK there is no legal definition of what brownfield land constitutes, and the term most often used in documentation by governmental bodies to describe this land type is ‘previously developed land’ (Department for Communities and Local Government, 2008). This research studied the ecological patterns on brownfield sites; therefore a well defined criterion for identifying this land type was needed. The US Environmental Protection Agency has defined brownfield in the quote:

> *“The term "brownfield site" means real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant” (USEPA, 2002)*

Brownfield land can be created through the extraction of coal, either by the dumping of spoil or the stripping of surface soil. In some cases these activities can lead to environmental degradation such as the leaching of heavy metals or acid water discharge in watercourses (McGuinness, 1999). Despite this, brownfield land of this type can be a valuable habitat resource for invertebrates, by the creation of bare ground and changing competition in vegetation communities allowing ruderal vegetation to flourish (Key, 2000). The typical succession communities and timescale on colliery spoil is shown in Figure 1, where the woodland stages are the pinnacle of succession. The factors that lead to these communities are the shallow soil depth, poor soil nutrient status and soil contamination on brownfield; however these factors ultimately lead to a more diverse flora as it is a more competitive environment (Prach & Pysek, 2001).

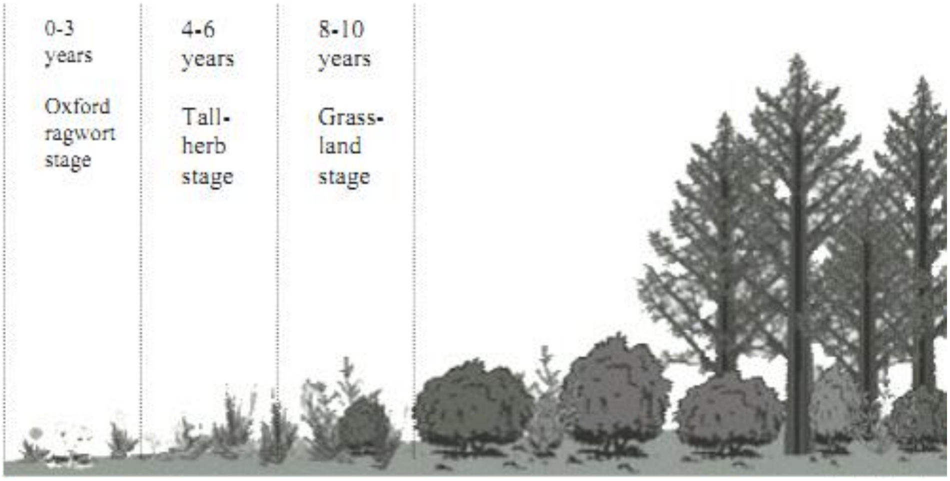


Figure 1: Typical plant succession communities observed on brownfield land over time. (Gilbert, 1989)

Brownfield land has been found to accommodate a rich variety of invertebrate species, including many rarities. The natural re-vegetation on nutrient poor substrate typical of brownfield land, can lead to very unusual invertebrate communities assembling on the site (Massini et al., 2006). In the past, brownfield land has been compared to ancient woodland in terms of the rich invertebrate assemblages present in these habitats (Barker, 2000). The importance of such sites has been the subject of many invertebrate studies, which include ants (Holeca & Frouza, 2005), arachnids (Wheater et al., 2000), isopoda (Wheater & Cullen, 1997), acari and collembola (Hutson, 1980) and lepidoptera (Holl, 1996). These studies all appear to suggest that naturally re-vegetated brownfield sites support a diverse set of species, and that the time since site abandonment is an important factor in attracting uncommon and rare species to a site. These studies are all based upon single taxa, which begin to describe the habitats and niches, however they do not look at multiple habitat layers within a site. This study will undertake a multi-taxa invertebrate survey to assess the invertebrate assemblages in a number of habitats, and determine the species richness and rarity of each assemblage.

A habitat corridor is an uninterrupted feature of a landscape which permits species to move along it, a good example of this is a hedgerow. Habitat corridors can be important for biodiversity as they should reduce genetic inbreeding within fragmented populations and may aid species migration routes, as seen in the case of the Ringlet butterfly (*Aphantopus hyperantus*) (Sutcliffe & Thomas, 1996). Habitat corridors are still a contentious issue for ecologists, with some studies indicating that invertebrate species do utilise the corridors, including butterflies (Haddad et al., 2003) and plant hoppers (Baum et al., 2004). However it appears that not all orders of invertebrates utilise the corridors, as it has been shown that ground beetle assemblages do not differ between connected and unconnected habitats (Small et al., 2006). Many ex-colliery sites have disused railways running through or alongside them which may act as a habitat corridor. If evidence emerges that a greater number of invertebrate groups are found to use habitat corridors, then ex-colliery sites are likely to be good candidates for carrying out this landscape function. It is outside of the scope of this study to add more evidence to this discussion, but it does highlight the role that ex-collieries map play in maintaining and improving biodiversity in the wider countryside.

A number of invertebrate site assessment techniques have been proposed over the years. Many of these are based around a mathematical index in which restricted and rare species within an assemblage give the index a higher weighting than an assemblage without these. These are typically called Species Quality Indices (SQI) or Species Quality Systems (SQS). Many individual taxonomic groups have had species quality indexes proposed by expert entomologists in that sector; these include flies (Pollet, 2001); (Crossley, 1996), saproxylic beetles (Fowles & Alexander, 1999), spiders (Oxford & Scott, 2003) and hymenoptera (Archer, 1993). These indices aim to place the community of invertebrates present on a site in perspective in terms of its rarity. It has been found that there are weaknesses with this approach to assessing a site because (a) total habitat coverage is not possible by assessing single invertebrate groups and (b) the frequency with which a species is found within a habitat is not accounted for. Taking these shortcomings into account, it is likely that site assessments using existing SQI techniques will draw inadequate conclusions on the importance of a site for invertebrates. To counter these issues a computer programme has been developed by Natural England called the Invertebrate Species-habitat Information System (ISIS). This program aims to combine the existing knowledge of species distribution and habitat preferences, in order to more accurately assess the quality of invertebrate assemblage of a site (Webb & Lott, 2006). The output produces typical taxa assemblages of each habitat and is similar to the programme TABLEFIT (Hill, 1996) used by botanists for determining the National Vegetation Classification. ISIS will be used in this study to assess the quality of invertebrate assemblages present on brownfield sites.

1.3 Reclaiming ex-colliery brownfield land

Brownfield land can occur in urban and rural locations, and in some case it has considerable economic value. Where the land type occurs in city centres or economically active areas, the land value may be sufficiently high enough to warrant a quick redevelopment. However in economically deprived geographical areas, this land may lie redundant for many years until land scarcity makes it economically viable to reclaim and re-develop. Many UK collieries are examples of brownfield land which did not see instantaneous redevelopment after closure, because they often exist in rurally deprived locations.

Brownfield and ex-colliery land is thought of as a public ‘eyesore’ that should be tidied up (Davidson, 1997). This eyesore factor places significant pressure on the local authorities to bring this land back into commercial, housing or recreational use. Whilst this style of reclamation is good for local economies, it adds to the ever increasing urban sprawl and in some cases a loss of a unique habitat for wildlife. The redevelopment of the Thames corridor is a good example of the conflict that can occur between developers and conservationists when brownfield land is allowed to naturally regenerate and assemble threatened invertebrate species on it (Harvey, 2000). The reclamation of disused collieries in the UK posed significant socio/economic and engineering challenges to land use planners in the 1980s and 1990s. Planners are required to balance the potential economic benefits of land regeneration, public health and to protect habitats for threatened flora and fauna of previously developed land (Office of the Deputy Prime Minister, 2005). In the case of the study sites in this project, Wakefield council redeveloped the naturally re-vegetating ex-coalfield landscapes into public green spaces as Country Parks.

The vegetation communities that had developed on the West Yorkshire derelict colliery sites were surveyed around the time of a wider coalfield reclamation scheme (Lunn et al., 2005). It is likely that some of these pioneering vegetation communities may have been lost during the reclamation process, as it is known that nutrient rich top soil was spread on the exposed spoil, and then seeded with fast growing and hardy plant and tree species (Pipkin, pers com). The change in substrate and flora will have undoubtedly impacted the invertebrate communities present on these sites. However, with no similar county-wide invertebrate surveys being carried out on the ex-colliery land, the change in community composition will be difficult to determine. The unique opportunity presented by the two sites surveyed here, are that pockets of naturally regenerated habitats remain within site. These may have acted as refugia for the invertebrates present before reclamation took place. To the author’s knowledge this study is the first to compare multiple taxa invertebrate communities of pre and post reclamation habitats within a single site.

1.4 THE STUDY SITES

The two sites selected for this study are located in the West Yorkshire coalfield between Doncaster and Wakefield, as shown in Figure 2.

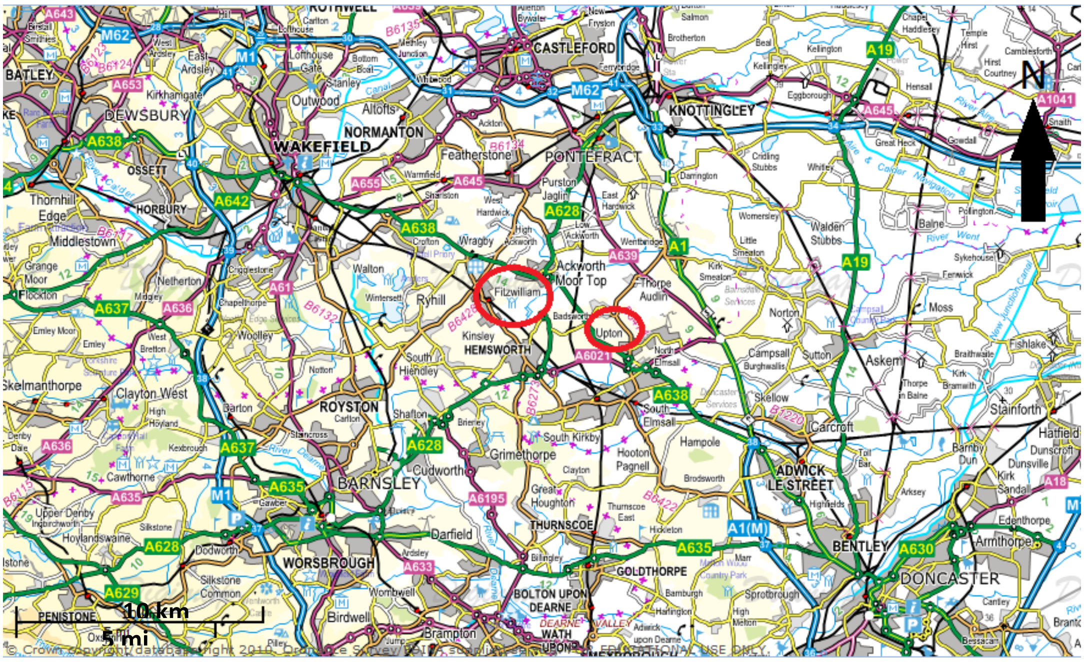


Figure 2: Regional map showing the location of Upton and Fitzwilliam Country Parks. (Courtesy of Digimap)

UPTON

Upton Country Park is a longitudinal site orientated east to west (SE 481 132), covering a spatial area of approximately 26 hectares. Upton Colliery Company opened in 1923; by 1933 it was recorded that 1099 employees worked underground and 296 above ground (Durham Mining Museum, 2010), indicating this was an economically important mine. The other uses of the site came in the form of brickworks and many examples of Upton bricks and other industrial archaeology from the railway are still visible around the site in 2011. Upton Colliery was finally closed in 1964 after a series of explosions and fires in the shafts (Wakefield District Council, n.d.). Whilst the UK Coal Board decided what should become of the site, natural vegetative regeneration was occurring. The site in the 1980 natural regenerative state is shown in Appendix A which clearly shows areas of established heathland scrub vegetation 16 years after the site was abandoned. A significant amount of un-extracted coal is estimated to be left under the site, approximately 200 000 tonnes according to geological surveys carried out in the 1970s (Wakefield District Council, n.d.). The site also has an easily accessible and valuable outcrop of magnesian limestone. Various plans and proposals were put forward to extract the remaining mineral wealth through open cast methods.

A series of botanical surveys of old coalmines in West Yorkshire were undertaken in the 1990s in their pre-reclamation state and noted that they (including Upton) had developed an interesting and sometimes rare flora (Lunn et al., 1995). This led to the railway cutting of Upton being assigned Site of Scientific Interest (SSI) status; however this was lost again in future years due to habitat destruction and vandalism. It would be fair to assume on this basis that the unusual flora communities on this site would have attracted and supported an uncommon invertebrate species community. At the time of reclamation Upton had lain derelict for three decades, which would have provided sufficient time for invertebrates to recolonise from the surrounding countryside, as it has been shown that within 9 years, brownfield sites can attract a diverse and abundant invertebrate community (Kadas, 2006). In 2007 a phase 1 habitat survey was carried out by an ecological consultancy for Wakefield Council to assess the botanical interest of the site. The outcome of this survey resulted in the Country Park being recognised as a Local Nature Reserve in 2008.

FITZWILLIAM

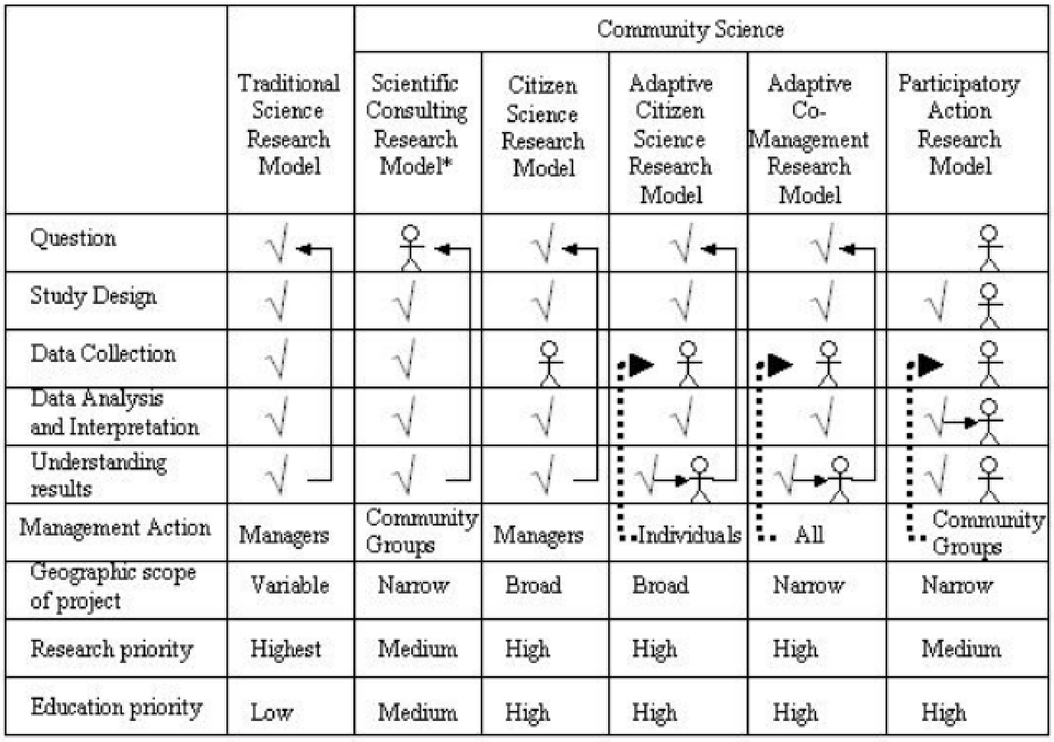
Fitzwilliam Country Park is a large site covering an area of approximately 58.5 hectares (SE 417 132) on the site of the Hemsworth Colliery, which was opened as a coal mine in 1876. By 1952 around 400,000 tonnes of coal was extracted per year from this pit (Ward, 2009). The shaft colliery closed in 1967 with pit head gear and buildings being removed by 1972. A drift mine was opened at the site to extract the remaining commercially viable coal from 1977 and continued to operate through to 1987 (Wakefield District Council, n.d.). A coke works is known to have existed in the north of the site, which undoubtedly polluted air, soil and water around the site. After closure the site laid derelict for approximately a decade. Reclamation was initially started in the form of a golf course, grass seeding and tree planting which was undertaken and is visible in the site structure today. After a change of management the golf course construction was dropped in favour of a country park. A phase 1 habitat survey was carried out in 2007 for the Wakefield Council to determine the flora interest on the site; a year later in 2008 the Country Park was recognised as a Local Nature Reserve.

1.5 WHAT IS CITIZEN SCIENCE?

Citizen science, as the term is understood today has been defined in numerous ways. It is a method of data collection using non-specialists (Trumbull et al., 2000) or using volunteers from the wider public to participate in data gathering and analysis (Silvertown, 2009). Scientific data collection on a national scale is usually impractical for scientists because of budget and time constraints. Therefore, the contribution of data from non-scientists across a greater spatial area expands the possibilities for the advancement of knowledge; in particular within the natural sciences (Cornell, 2007). The benefits available to participants in such interactions have been highlighted before, suggesting that the knowledge transfer from scientist to participant is the most valuable aspect of this type of project (Roetman & Daniels, 2010).

Citizen science is just one of a family of community science models that have been proposed and used by scientists as can be seen in Table 1. The model used in this study is a hybrid of the citizen science research model and participatory action research model. The study objectives, design, data analysis and interpretation were carried out by the primary researcher, with data collection being undertaken by members of the community; all features of the citizen science research model. However, the geographic scope was narrow; as it only focused on 2 sites and the education of participants was a high priority; which are all elements of the participatory action research model. To the author's knowledge, this is the first time this approach to a community science project has ever been undertaken.

Table 1: Forms of community science, ticks represent work undertaken by researchers, stick man represents community involvement, small arrow represents knowledge transfer, dashed lines represent the feedback from participant to action (Cooper et al., 2007).



		Community Science				
	Traditional Science Research Model	Scientific Consulting Research Model*	Citizen Science Research Model	Adaptive Citizen Science Research Model	Adaptive Co-Management Research Model	Participatory Action Research Model
Question	√		√	√	√	
Study Design	√	√	√	√	√	√
Data Collection	√	√				
Data Analysis and Interpretation	√	√	√	√	√	√
Understanding results	√	√	√	√	√	√
Management Action	Managers	Community Groups	Managers	Individuals	All	Community Groups
Geographic scope of project	Variable	Narrow	Broad	Broad	Narrow	Narrow
Research priority	Highest	Medium	High	High	High	Medium
Education priority	Low	Medium	High	High	High	High

*often called Science Shops

1.6 UTILISING CITIZEN SCIENCE

The ecological data collection by volunteers in a citizen science model is now seen as an essential way of measuring biodiversity on a landscape scale (Dickinson et al., 2010). There have been a number of ecological citizen science projects created in the last century with the Christmas Bird Count being one of the first and longest running studies. This successful study started in 1900 in a number of US states and in Canada with the aim to encourage the public to count rather than hunt wild birds (Audubon, 2011). One of the first citizen science projects in the UK dates back to the 1930's when the British Trust for Ornithology was inaugurated. This organisation was formed with the objective of monitoring wild bird populations and discovering more about their ecology through structured surveying methods (BTO, 2009). Volunteers would make species lists with dates and location information, which is the basis of all modern biological recording. Scientists at the British Trust for Ornithology analyse the data gathered from all over the UK to determine the health of bird populations and disseminate the results via a journal.

In the UK, the citizen science methodology has been used on a national scale to survey invertebrates. Some of the most recent invertebrate studies are the Moths

Count project which is documenting the nationwide distribution of moths in the UK (Fox et al., 2011) and Leaf Watch which is monitoring the spread of the Horse-Chestnut Leaf-miner (*Cameraria ohridella)* (Pocock et al., 2011). On a local scale a highly successful BBC Radio 4 citizen science project ‘Snail Swap’ was carried out in 2010, with the aim to discover if the garden snail *Helix aspersa* has homing instincts (Ghosh, 2010). Some invertebrate citizen science projects are now advanced enough to be considered good indicators of ecological change within habitats, such as the Butterfly Monitoring Scheme (BMS) organised by Butterfly Conservation (Nelson, 2007). The data collected for the BMS has been used to uncover and track species movements within the landscape, and some of these movements are thought to be in response to climate change (Fox et al., 2007). Current research suggests that ecological citizen science projects are geared towards mapping species distributions, which are used to determine the effects that climate change and the effects of invasive species (Silvertown, 2009). The community-mapping of species theme has been explored in numerous ways over the years, with one novel use of it being the participants reporting of the arrival of seasonal change indicator species such as the first flowering of specific flowers (Woodland Trust, 2011). Thus, with the successful use of citizen science to survey invertebrates on a national scale, it was expected that the learning of species identification and survey techniques would be in the grasp of the participants taking part in this survey.

It is recognised that a level of complexity exists when designing citizen science projects because the knowledge gap between specialists and non-specialists that needs to be addressed in the methodology (Lyon, 2009). The challenge here is to provide usable methods for volunteers with little training, but still provide data which are reliable. It has been shown that volunteers taking part in citizen science projects can produce robust data and is exemplified by a greater than 80% correlation between researcher and citizen collected data in a recent plant study (Lepczyk, 2009). The data collected by volunteers in this study will be compared with researcher collected data to ascertain if it is robust enough to be used in the analysis.

1.7 Working with Deprived Communities

One of OPAL’s objectives for this study was to undertake research with a deprived community, as they do not usually participate in ecological citizen science projects (Hobbs, pers com.).

To focus this study on the desired demographic group, it was necessary to determine what makes a community deprived and how to find them within the landscape. A recent government report suggests that a deprived community is one without access to employment, essential amenities and good transport links (Camina, 2004). The UK government assesses deprivation on seven tiers; income, employment, health, education, housing, crime and the local environment. These factors are combined to produce an overall indicator index, the Index of Multiple Deprivation (IMD), which can be accessed by a website (DirectGov, 2010). This tool was used to target the deprived communities which would benefit the most from OPAL's environmental education activities in the Yorkshire region.

Using the IMD database it was found that the communities surrounding the study sites have a high level of deprivation, as shown in Table 2. Fitzwilliam appears to be most severely deprived, in terms of the access to quality education, health and employment. A similar pattern is seen at Upton, but overall this community is less deprived than Fitzwilliam, and benefits from less crime and access to better housing stock. Both sites appear to have a good living environment, and this may be in part due to the presence of the country park itself within the vicinity of their homes.

Table 2: 2010 Upton and Fitzwilliam Index of Multiple Deprivation (IMD) domain percentage scores. The greater the IMD percentage score, the less deprived the community is on the specific tier. (DirectGov, 2010)

	Index of Multiple Deprivation Percentile Score	
Factor of Deprivation	**Fitzwilliam**	**Upton**
Income	31 %	39 %
Employment	11 %	24 %
Health & Disability	13 %	27 %
Education & Skills	10 %	35 %
Housing & Services	58 %	86 %
Crime	33 %	49 %
Living Environment	63 %	78 %
Combined Index	**29 %**	**40 %**

The major factor causing deprivation within the communities that this study engaged with was the sudden closure of UK coal mines in the 1980s and 1990s. It has been estimated that approximately 360,000 jobs were lost in the UK coal mining sector between 1984 and 2004, and Yorkshire is one of the worst affected counties with around 70,000 jobs lost during this period (Dept for Communities and Local Government, 2007). The result of this mass redundancy is a legacy of unemployment and socio-economic woes in the areas affected by the closures.

Unemployment is still an intractable issue in these areas, because they are typically in rural locations, known to have few employment opportunities available to residents. Over recent years under the Labour government, increased investment from regional development agencies such as Yorkshire Forward have had positive impacts on these communities, and the IMD scores presented in Table 2 were significantly improved over the last decade.

1.8 Recruiting Volunteers and Study Species Selection

Recruiting volunteers to take part in projects such as these can be challenging. The public are thought to have many preconceptions about the time required and level of previous experience to take part in volunteering schemes (Volunteering England, 2008). To effectively recruit individuals for citizen science projects these barriers must be overcome by effective recruitment which gives the participants confidence. One way to engage the public in citizen science projects such as these is to select interesting and stimulating topics for research that inspire participation.

An assortment of volunteer recruitment methods have been proposed in the past, all of which have positive and negative aspects in terms of targeted audience and the motivation level of participants (Gaskin & Simth, 1995). This study used three methods at local and county scales to reach into the local community and inspire dedicated volunteers to participate in the research. The outcome of the recruitment methods should provide an indicator into the effectiveness of each method for future citizen science projects.

Observing animal behaviour has long been an academic and recreational past-time and is known as ethology (Huntingford, 2003). Therefore, selecting study species that demonstrate interesting behaviour should make it less problematic to recruit volunteers to survey them. Butterflies and bumblebees forage for nectar and pollen on flowers, and because of this behaviour they belong to some of the few insect orders that are easily observed, thus making them attractive groups of species to research. These invertebrates should also provide a good proxy for assessing the quality of foraging resources in each habitat, based on how many individuals are seen and the butterfly/bumblebee species richness in each habitat.

Butterflies are an obvious choice for citizen science projects, with a recent study undertaken by the National Trust finding that the public harbour strong affection for butterflies. The fascination is reported to start between the ages of 5 and 11 years, with many of the contributors finding that observing butterflies reminded them of their childhood (Oates, 2011). It was hoped that childhood memories of butterflies would act as a stimulus for recruiting volunteers for monitoring on the sites. Butterflies make an ideal study species for a novice as there only 46 species to learn, and an observer at the latitude of this study is only likely to see just over half of these species depending on the location and habitat. Butterflies are brightly coloured, large, eye-catching, charismatic and relatively easy to differentiate to species level by sight in the field. Study methods already exist for the voluntary monitoring of butterflies. The UK Butterfly Monitoring Scheme has been acting as the national repository for butterfly population data collected by volunteers for a number of decades. A standardised method of setting up a walking transect through a site, which is repeatedly sampled, often weekly has been used to measure the long-term trends of butterfly species richness and diversity (Pollard & Yates, 1993). It has been tested and improved over the years and provides a simple but robust method of sampling butterfly populations (Gross et al., 2007) which is now used as an indicator of the state of the environment (JNCC, 2011). It was hoped that long term monitoring of butterflies on the study sites would be inspired by the selection of this invertebrate group for research.

Bee populations have been declining over recent years, with reports suggesting the use of neonictinoid pesticides (Buglife, 2011), Verroa mite (Tentcheva et al., 2004) and a reduction in the abundance of appropriate flowers for forage (Edwards & Williams, 2004) as possible causes of this decline. This is in part thought to be due to the loss in late flowering wildflowers, a direct result of conversion from growing silage instead of hay for animal feed (Fitzpatrick et al., 2007). These factors have left a large proportion of the UK native bumblebee species endangered, with 7 of the total 24 species currently included in the UK Biodiversity Action Plan (Buglife, 2011), which acts as a nationwide species recovery plan. This alarming decline has attracted a great deal of media attention and therefore stimulated a great deal of public interest in bee populations. To exploit this recent surge of public interest in bees, this study will use bumblebees as a study group to recruit volunteers. Bumblebees are ideal study subjects for novices as the common species can easily be identified by colour banding and they are relatively still for observation when feeding on flowers. Thus as the majority of bumblebee observations will be made whilst they feed on flowers, the number of observations should indicate the quality of forage in each surveyed habitat.

Grasshoppers are charismatic insects that are relatively easy to catch and are a low bite risk when handled. Thus it may be that they are suitable species for an invertebrate based citizen science project. The sites investigated have good grasshopper habitat that are large expanses of long and short sward grasslands.

Grasshopper nymphs were observed alighting on the survey materials when placed on the ground. There are a number of hypothesis that may explain this animal behaviour, e.g. the animal maybe using the platform as a proxy 'bare ground' for warming up their bodies. Grasshoppers that mounted survey materials were noted to stridulate, which may also imply they were using the platform as a podium for increased mate attraction. These hypotheses require laboratory experiments that are beyond the scope of this study and unsuitable for public engagement. However a much simpler study that is citizen science friendly could determine if grasshoppers have a preference for substrate/platform colour. It is known that *Circotettex* genus of grasshoppers exhibit a preference for substrate colour dependant on its body colour (Gillis, 1982). This led to the development of a hypothesis to determine which species of UK native grasshoppers respond in the field to patches of colour placed in their natural environment. If successful, this would be a novel and inexpensive Orthopteran survey method for entomologists undertaking site investigations.

1.9 Study Objectives

The focus of this investigation was centred on the key objectives outlined below.

Objective 1: Discover reclaimed colliery site history using participatory mapping methodologies with local residents.

The loss of the reclamation documentation meant that other sources had to be explored, in order to discover how the sites had changed over the last 50 years. The focus was to determine where natural re-vegetation had taken place, and where the patches of this habitat still exist today. This was achieved using participatory mapping workshops and rapid appraisal techniques with local residents who have knowledge of the site history and the reclamation events that took place on the sites.

Objective 2: Design and implement citizen science based invertebrate monitoring surveys, and compare species assemblages in naturally regenerated and reclaimed habitats.

A hybrid citizen science butterfly and bumblebee survey was created to sample the habitats now present on the sites. Volunteers were recruited through the engagement with local communities and through the media with press releases. Volunteers were provided with species identification and survey methodology training so they could undertake weekly monitoring and their records were validated. The monitoring transects were used to determine if the bumblebee and butterfly community structure differs significantly between naturally regenerated and reclaimed habitat. A multi taxa study of the ground layer dwelling invertebrates were sampled and compared by reclamation method. A novel grasshopper survey methodology was undertaken with the help of volunteers, to assess its effectiveness at sampling wild populations.

Objective 3: Describe the invertebrate assemblages that occur on reclaimed colliery sites and assess the quality of assemblage and habitat.

Inventories of invertebrate species were created using a combination of volunteer observations, researcher investigations and historical records. Using existing site assessment tools, species assemblages will be used to determine if the sites contain important species that require conservation. Habitat management recommendations were made in response to the results of the invertebrate assemblage assessment.

2. METHODS

2.1 SITE CHARACTERISATION

HABITAT CLASSIFICATION

Aerial photographs were sourced from Wakefield Council, and historical Ordinance Survey charts from the online mapping service Digimap. Aerial photos are provided in Appendices A and B. This gave a broad view of the vegetative structure at the sites, over twenty year intervals from the 1960's through to the present day. The main habitats were classified according to the vegetative structure and the reclamation history.

Long sward grassland, shown in Figure 3, is the typical habitat encountered in areas which were capped with top soil, seeded and fertilised. The original seed mix was *Poa compressa, Festuca ovina, Agrostis capilliaris, Festuca rubra trichophylla, Lolium perenne, Trifolium repens* and *Lotus corniculatus* (Pipkin, pers com). Average sward height measured during the summer of 2010 was approximately 1 metre. The area of reclamation can be easily delineated and thus is identified as a reclaimed grassland habitat for the purposes of this study. It covered an approximate area of 18.8 acres at Upton and 100 acres at Fitzwilliam. This habitat was sampled by transect in the bumblebee and butterfly monitoring survey; surveyed for grasshoppers using a novel paper method and finally pitfall trapped and sweep netted for the invertebrate site assessment.

Figure 3: Long Sward grassland at Fitzwilliam (Photo credit: K Rich 2010)

Short sward grassland shown in Figure 4, was observed in areas of thin soil capping, often with spoil reaching the surface layer. For the purposes of this study this habitat is classified as an example of natural regenerated grassland. Typical grass species recorded here in 2010 were *Festuca rubra*, *Holcus lanatus*, *Cynosurus cristatus* and *Arrhenatherum elatius* with an average sward height of 20 cm. The area of land this vegetation type covered was 9.4 acres at Upton and 15.5 acres at Fitzwilliam. This habitat was sampled by transect in the bumblebee and butterfly monitoring survey, surveyed for grasshoppers using a novel paper method and finally pitfall trapped and sweep netted for the invertebrate site assessment.

Figure 4: Short sward grassland with herb rich layer encountered at Upton Country Park, note pit wheel in foreground (Photo credit: K Rich 2010)

The **naturally regenerated woodland,** shown in Figure 5, self seeded themselves in the railway sidings and cuttings after the sites became derelict. It is clear from the structure of these trees that large scale coppicing had taken place in this habitat. Typical tree species found here are *Quercus robur, Crataegus laevigata* and *Betula pendula*. The approximate coverage of this habitat type is 5.4 acres at Upton and 5.2 acres at Fitzwilliam. This habitat was sampled by transect in the bumblebee and butterfly monitoring survey and pitfall trapped for the invertebrate site assessment.

Figure 5: Natural regeneration woodland ride at Upton Country Park, note the grass and herb rich margins (Photo credit: K Rich 2011)

Reclaimed/plantation woodland shown in Figure 6, is present at both sites, as a result of tree planting programmes initiated during the reclamation works. Large quantities of the non-native *Alnus cordata* and the native *Betula pendula* have been planted, interspersed with *Quercus robur*. In some cases the woodland had already started to naturally re-vegetate before the reclamation, however a large number of seedlings were placed in these habitats and existing trees were fed with nutrients to encourage growth (Pipkin, pers com.). The area covered by this woodland type was approximately 9.2 acres at Upton and 7 acres at Fitzwilliam. The high density of *Betula pendula* shown in Figure 6 implies that there was high seedling success rate. This habitat was sampled by transect in the bumblebee and butterfly monitoring survey and pitfall trapped for the invertebrate site assessment.

Figure 6: Reclaimed/Plantation woodland at Upton Country Park in spring, planting was carried out within the naturally regenerating woodland in the 1990s. (Photo credit: K Rich 2011)

Scrub shown in Figure 7, is developing on both sites in isolated pockets within the grassland mosaic. Some woody scrub species may have been intentionally planted to create a heterogeneous habitat structure. However it is clear that many have self-seeded and threaten the species rich wildflower grassland mosaic. The species of woody plant predominant in this habitat type are *Crataegus laevigata, Prunus sp.* and *Rubus sp.* are on average between 0.5 m – 2 m tall. The total area of scrub is difficult to define, as it is interspersed within the long and short sward grasslands at both of the sites. This habitat was sampled by pitfall trapping and sweep netting for the invertebrate site assessment.

Figure 7: Scrub grassland matrix at Upton Country Park, note the abundant wildflower community including a large diversity of Orchids (Photo credit K Rich 2011)

Freshwater lakes, shown in Figure 8, have been created intentionally during the land reclamation process. Marginal vegetation is likely to have been planted during the initial stages of reclamation. Habitat management appears to have taken place to keep the fishing platforms accessible. Typical vegetative species are mainly *Phragmites australis*, *Iris pseudacorus* and *Glyceria maxima.* Figure 8 shows the marginal vegetation structure and fishing platforms typical of both sites fishing lakes. The approximate area that the lakes cover at the sites is 3 acres at Upton and 0.8 acres at Fitzwilliam.

Figure 8: Main lake at Fitzwilliam, note marginal vegetation (Photo credit: K Rich 2010)

2.2 PARTICIPATORY GIS (PGIS)

Community members were recruited through press releases and by talking with park users. The PGIS workshops were conducted in a building used for community events. Rapid GIS (RAP-GIS) appraisal was utilised on the two sites for a day at each site. The methods for PGIS and RAP-GIS are fully described in the work by (Cinderby, 2010). The Rapid GIS appraisal approach was used to interact with stakeholders who may not have taken part in a formal PGIS workshop, but have views and information that were important for this study nonetheless.

A series of size A0 aerial photographs and ordnance survey charts dating back over the last 40 years were provided at the workshop. Aerial photography showing pre and post reclamation phases of the sites are provided for Upton in Appendix A and Fitzwilliam in Appendix B. The imagery was laid in the centre of the room, giving equal access to all participants to scribe onto the imagery, as shown in Figure 9. Participants brought a selection of photographic and historical documentation material to the workshop to aid the recollection of events.

Figure 9: A PGIS workshop taking place at Fitzwilliam with community members. Note the photographic material brought to workshop by participants in the foreground (Photo credit; K Rich 2011)

A series of pre-determined questions were asked regarding what had happened to the site in terms of where and when, and which areas of the site had provided good habitat for flora and fauna. The set questions provided a reproducible framework for each workshop, and efforts were made to avoid influencing the participants' answer. The participants were given a selection of coloured markers to outline areas of reclamation on the imagery, and their speech was recorded on a dictaphone for later transcription. A timeline showing the different phases of reclamation and notable changes in wildlife was compiled during the event, with agreement being sought from all participants about the dates when events took place.

2.3 Volunteer Recruitment

A number of methods were used to recruit volunteers, to increase the chances of contact with community members. Initially a press release appealing for volunteers to monitor wildlife on the sites and provide historical information was released to the local newspapers. Rapid GIS and the PGIS workshop participants were approached to take part in the invertebrate monitoring surveys. The researcher often had questions asked whilst undertaking fieldwork; these interested individuals were asked if they would wish to participate in further surveys.

2.4 Bumblebee & Butterfly Transects

The sites were walked over in June 2010 to assess the location of habitats and their accessibility for surveying. To avoid excessive trampling of vegetation and accommodate volunteers with low mobility, the existing pathways were used as the monitoring transects walks. This had an effect of improving the reliability and reproducibility of the results, because volunteers can easily navigate the monitoring walk each time they undertake the survey. The monitoring route at each site was divided into nine sectors (non-linear transects) and was delineated according to which habitat was most predominant within the sector, and by the ease at which a volunteer could recognise where each sector starts and ends. The length of each transect sector was also considered, so to ensure that the sector lengths could be reliably compared in the data analysis. Woodland and grassland habitats which were either reclaimed or allowed to naturally re-vegetate were sampled by the transect walks. The final monitoring route and sectors are shown in Figure 10 for Fitzwilliam and in Figure 11 for Upton.

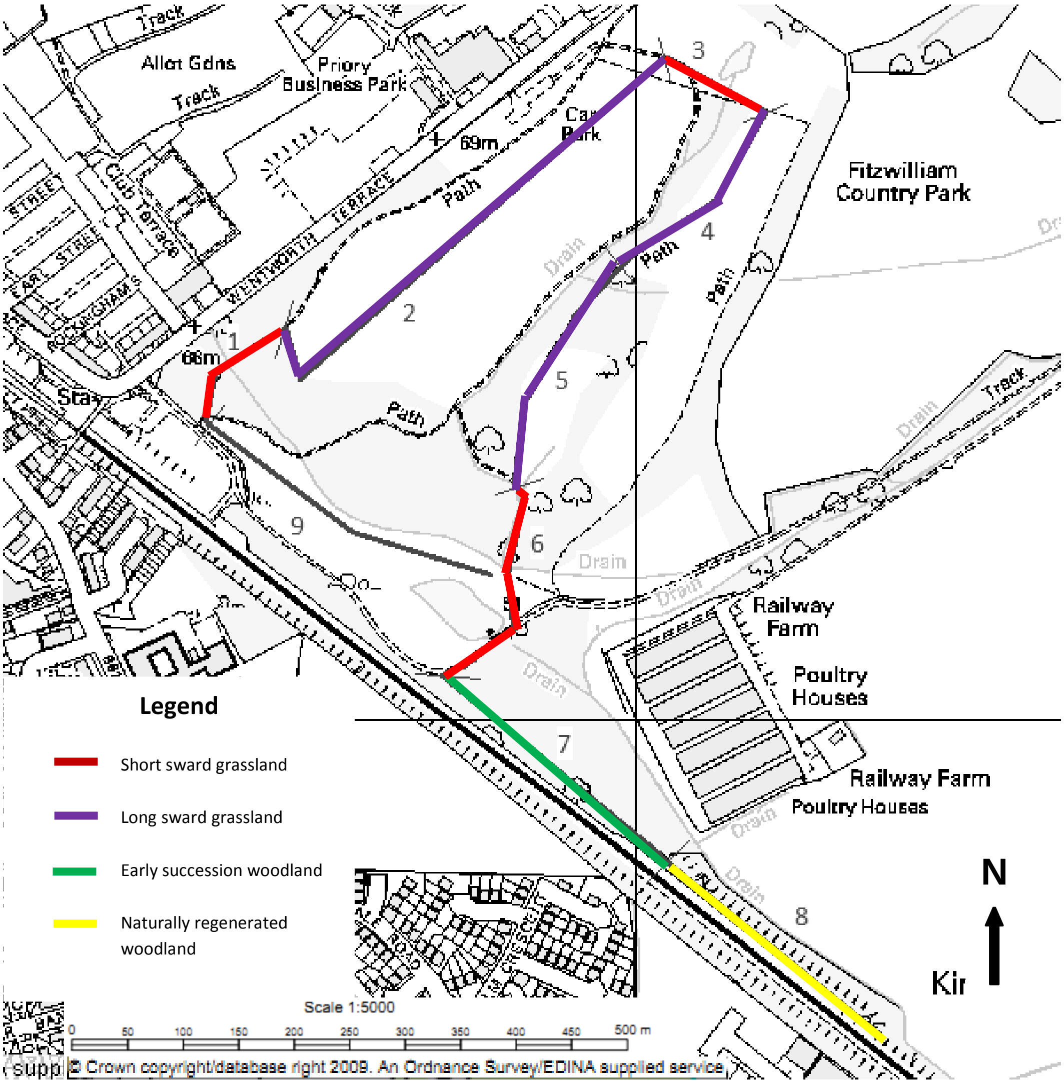


Figure 10: Fitzwilliam bumblebee and butterfly monitoring route, sampling a total of 4 habitat types. Sectors 1, 3, 6 = Short sward grassland, Sectors 2,4,5,9 = Long sward grassland, Sector 7 = Early succession woodland, Sector 8 = Natural regeneration woodland.

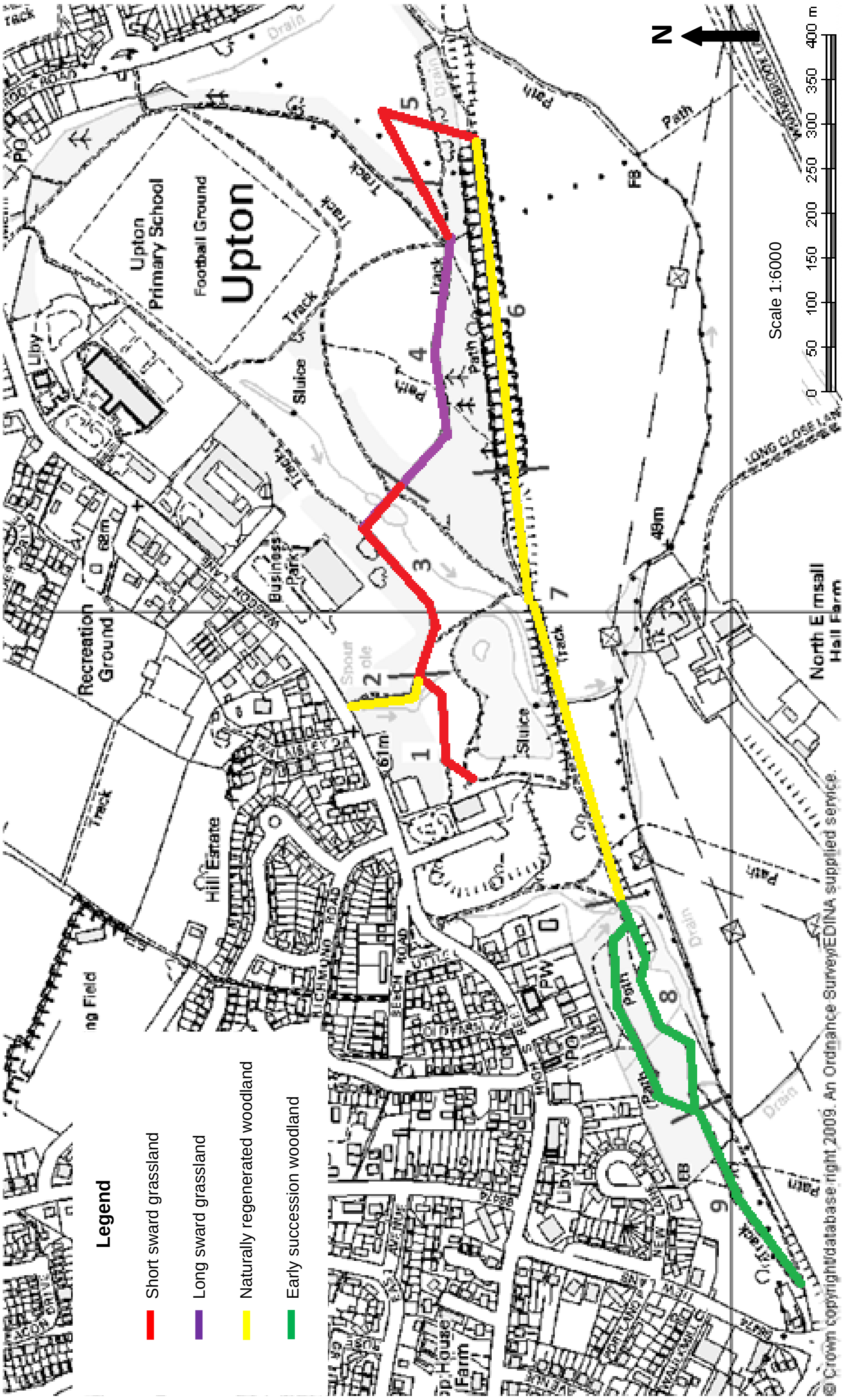


Figure 11: Upton bumblebee and butterfly monitoring transect which samples 4 habitats. Sector 1, 2, 5 = Short sward grassland, Sectors 3, 4 = Long sward grassland, Sectors 6, 7 = Natural regeneration woodland, Sectors 8, 9 = Plantation woodland.

Weekly transect data were recorded onto a customised A4 survey form as shown in Figure 12. This recording sheet took elements from the Butterfly Monitoring Scheme (Pollard & Yates, 1993) and the Bumblebee Conservation Trust Beewalk methodology, combining them into a single recording sheet. The form enabled the volunteer to record the species and abundance of bumblebee and butterfly species observed whilst undertaking the transect walk. Before each survey was carried out, the temperature, wind speed, and percentage sunshine were estimated. Temperature was either estimated from vehicle temperature sensors or local weather forecast data, and a survey requirement of a minimum 15 °C was set. Wind speed was estimated by the level of tree movement and was categorised into no wind, calm, light wind, moderate wind and gusts. The percentage of sunshine was estimated on a subjective basis by the amount of blue sky visible to the observer. Transect start and end times were recorded, as it has been shown that time of day can strongly influence the observed abundance of butterflies (Pollard et al., 1986). For data quality purposes, surveys undertaken outside the 10:00 to 16:00 time period were screened out of data analysis.

Volunteers were trained in the methodology and species identification on an individual basis, whilst undertaking a survey. Each volunteer was provided with a folder containing survey materials which included a Bumblebee Conservation Trust identification guide, a Field Studies Council Butterflies of Britain identification guide, a transect map, survey sheets and an instruction letter outlining the methodology. This pack enabled the volunteer to carry out the survey without additional researcher support or equipment. The volunteers undertook the surveys in August and September 2010 and May 2011.

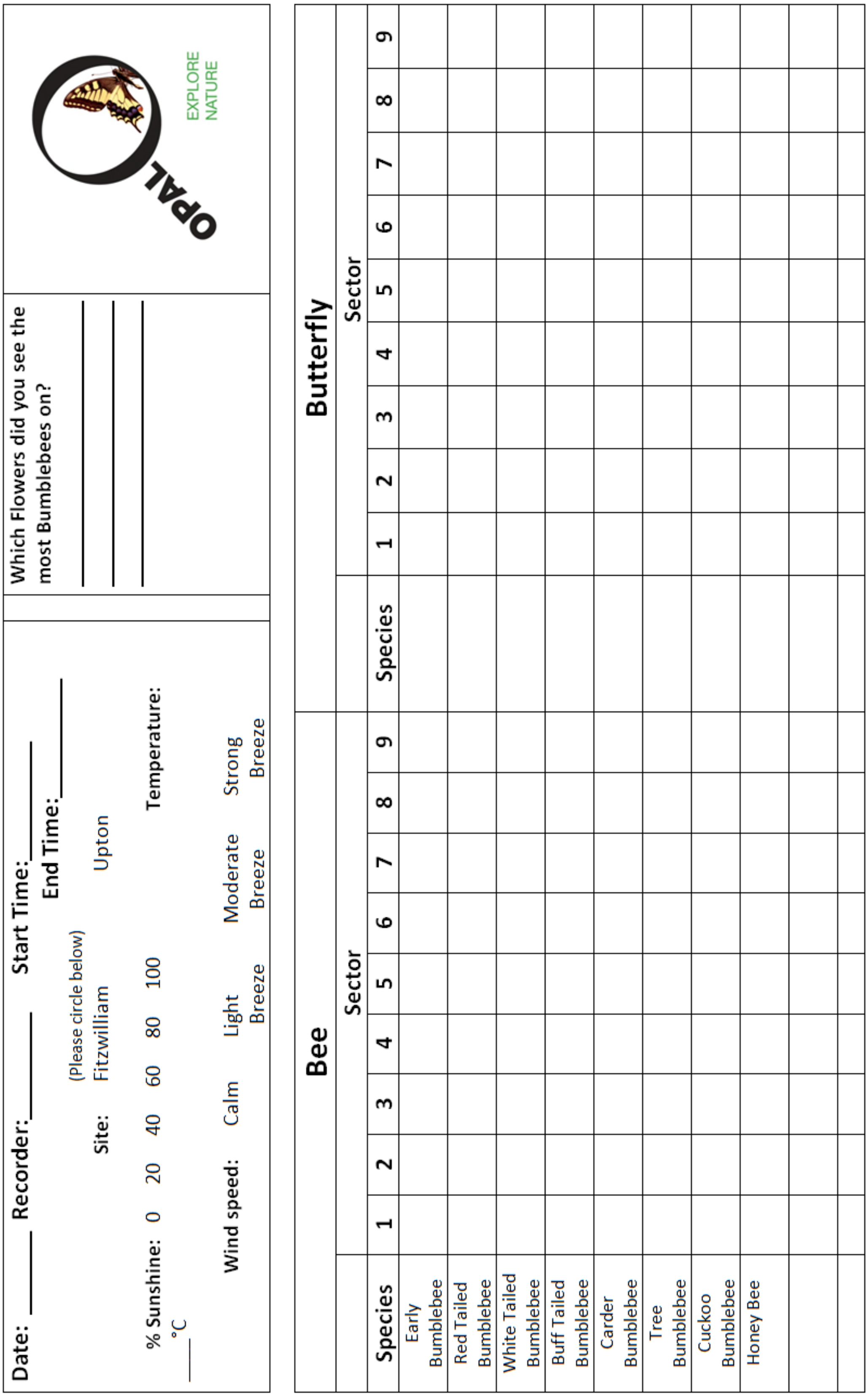


Figure 12: The hybrid bumblebee and butterfly transect recording form developed for this study

2.5 GRASSHOPPER SURVEY

A 3 m^2 square was marked out in the long sward grassland habitats at Upton and Fitzwilliam during July 2010 using canes and tape. Coloured paper was attached to nine clipboards and placed into the marked grid, spaced a metre apart as shown in Figure 12. The paper colour spectrum was tested for its attractiveness to grasshoppers according to the colours blue, brown, white, green and black. Environmental variables recorded were % sunshine, wind speed, temperature, dominant grass species and average sward height. Numbers of grasshoppers alighting on the paper were recorded over a 15 min period. Validation was carried out using a wooden box quadrat measuring 1 m^2, which was placed over each grid square to verify how many grasshoppers, and of what species, were present in the grid square. Grasshoppers were flushed to a corner of the box quadrat using a clipboard. Grasshoppers were then counted and identified to species level; unknown specimens were photographed for later identification and verification.

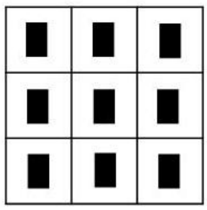


Figure 12: 3m x 3m Grasshopper survey quadrat with A4 clipboards placed in each 1m x 1m square

2.6 PITFALL TRAPPING

The traps were constructed from a clear plastic cup 10 cm in diameter and 13.5 cm in depth. The traps used had an additional component that had been designed to reduce by-catch of small mammals and amphibians. A plastic disc, with circular holes drilled through it was placed on a shelf within the plastic trap at a height of 8.5 cm; this allowed the non-targeted fauna to escape the trap. However it did not preclude insects from falling through the drilled holes and into the killing fluid below. To reduce the likelihood of a trap flooding, and to inhibit organic material migrating into the trap fluid, a steel lid measuring 10.5 cm^2 was placed over the trap, leaving a height gap of 2 cm for invertebrates to manoeuvre under. Standard pitfall trap methods use ethylene glycol as a trap fluid. However this fluid poses a significant risk to dogs using the site. After consultation with the Wakefield Biodiversity Group a decision was made to use a fully saturated salt solution to avoid the risk of unintended damage to dogs using the site. Fully saturated salt solution quickly disables and kills invertebrates entering pitfall traps, providing an effective storage solution for fortnightly trap emptying, and has been used successfully in similar studies (Brandle et al., 2000).

Soil was extracted to a depth of 13.5 cm using a bespoke soil corer designed to accommodate the dimensions of each pitfall trap. Where the soil organic layer was too shallow to accommodate the depth of a pitfall trap, soil was placed around the lip of the trap to create a gradient for invertebrates to travel up and into the trap. Traps were placed in triplicate within scrub, reclaimed and naturally regenerated grassland and naturally regenerated woodland at both sites. In the reclaimed woodland only 2 traps were placed, due to complications caused by a minority of local residents. Trap visibility to the public was a concern as it was felt that there was an inherent risk of vandalism, therefore traps were placed inconspicuously. GPS waypoints were recorded for each trap to ease later re-discovery by the researcher.

The pitfall traps were in the field between the 2nd and 28th August 2010. Traps were drained on the 12th and the 28th of August 2010. The trap fluid was emptied through a funnel and child's nappy liner in order to filter the deceased invertebrates. The specimens were then transferred from the liner by tweezers into 10 ml glass vials. The glass vials contained 10 ml of 70% ethanol; 30 % distilled water. The 70% ethanol mix acts a good preservative for these types of specimens (Upton, 1991). The vials containing the invertebrates were stored in the dark at room temperature. Species identification was carried out using a high powered binocular microscope. A diverse range of invertebrates inhabit the surface layer and enter pitfall traps and therefore a number of keys were required to identify them. These were for woodlice (Hopkin, 1991), spiders (Jones-Walters, 1994) (Roberts, 1996), ground beetles (Luff, 2007) and ants (Skinner & Allen, 1996).

2.7 SWEEP & POND NETTING

In order to sample above ground dwelling invertebrates within the vegetation, two consecutive five minute linear sweeps of comparable habitats on each site were performed on two days in August 2010 and April 2011. A pooter was used to collect specimens not found by the other survey methods. The specimens were killed using ethyl acetate and stored in glass vials and returned to the lab for identification. Specimens were identified to species level using microscopy techniques. Where lack of researcher experience or restricted access to suitable species keys prevented accurate species identification, specimens were forwarded onto the relevant entomological experts from the Yorkshire Naturalists' Union.

Pond netting was carried out using a 1 mm mesh hand net for the standardised 3 min sweep around emergent vegetation and banking (ISO, 1985). The contents of the net were turned out into a white tray containing water. Invertebrates were identified to species level where possible using field guides.

2.8 Invertebrate Species Information System (ISIS)

All terrestrial and freshwater invertebrate species that had been recorded by the researcher were combined into site inventories. Post reclamation dated invertebrate records were also sourced from the local ecological records centre for Fitzwilliam (West Yorkshire Ecology, 2010a) and Upton (West Yorkshire Ecology, 2010b). Volunteers were encouraged to take photographs of invertebrates at the sites and upload onto the online species identification tool iSpot (Open University, 2010). Volunteer data were later extracted from the iSpot website database. Invertebrate records were combined from the three sources to create a master species list for each site. Master inventories were individually entered into the ISIS package. Quality control of the species list was performed by removing species that did not appear in the package dictionary and by checking for synonymised names.

The results produced from the ISIS package were assessed by a number of methods. Broad and specific assemblage type codes produced by ISIS output were examined for accuracy by inspecting the grid reference and the related habitat the record was taken from. This information was used to assess if ISIS could produce sufficiently detailed reports from a novice entomological surveyor. Habitat assessment was performed using ISIS values pertaining to each habitat code. Rarity scores are based upon the UK national invertebrate species rarity values provided by the RECORDER 3 database, and are averaged per habitat code. The richness score here uses published species range and distribution data to calculate a species quality index (SQI) score for each invertebrate assemblage code. SQI is calculated from a ranking procedure whereby the most restricted and rare species on a 10 km square basis are weighted higher than more common and abundant species, an assemblage SQI is calculated by adding the total SQI weights of each species (Williams, 2000). The calculated BAT representation score characterised the relative importance of each assemblage.

2.9 Data Analysis

A paired transect experiment was devised to determine if volunteers were collecting reliable bumblebee and butterfly species data in terms of identification and abundance. In April 2011 at Upton Country Park a group of three previously trained volunteers by the researcher were given the transect sheet shown in Figure 12, and allowed to perform the survey unaided. The researcher concurrently carried out an identical survey, with no advice being given to the participants as to which species they were observing. Differences between volunteer and researcher collected data were assessed using a chi square analysis.

The effect of habitat and reclamation on the assemblage of species was analysed using the software Species Diversity & Richness 4 (Seaby & Henderson, 2006). Total butterfly and bumblebee observations in each sector were used to determine which habitat and reclamation type was most diverse. The limited number of resident species at this latitude meant that a small proportion of the species were likely to dominate the observations. Therefore Simpson’s diversity index (D) was thought most appropriate for calculation as it is the most suitable index for dominance weighted data (Magurran, 2004). The equation used to calculate D is presented in Equation 1.

$$D = \qquad (\frac{\mathrm{n}}{\mathrm{N}})^2$$

Equation 1: Simpson's diversity index D. N represents the cumulative total of all species recorded, n represents the total number of individuals recorded for an individual species

Evenness is used by ecologists to describe a community structure in terms of the dominance individual species. Figure 13 illustrates high and low community evenness for two communities comprising the same number of species. Communities with a high evenness index such as community 1 in Figure 13 are thought to use the natural resources in a uniform manner (Schowalter, 2001). In contrast to this, community 2 is dominated by a smaller proportion of the total number of species, and is typical of a community that has been disturbed in some way. A suggested reason for this uneven species distribution is that species that are well adapted and tolerant of the environmental change are likely to be more abundant than the less tolerant species (Grześ, 2009).

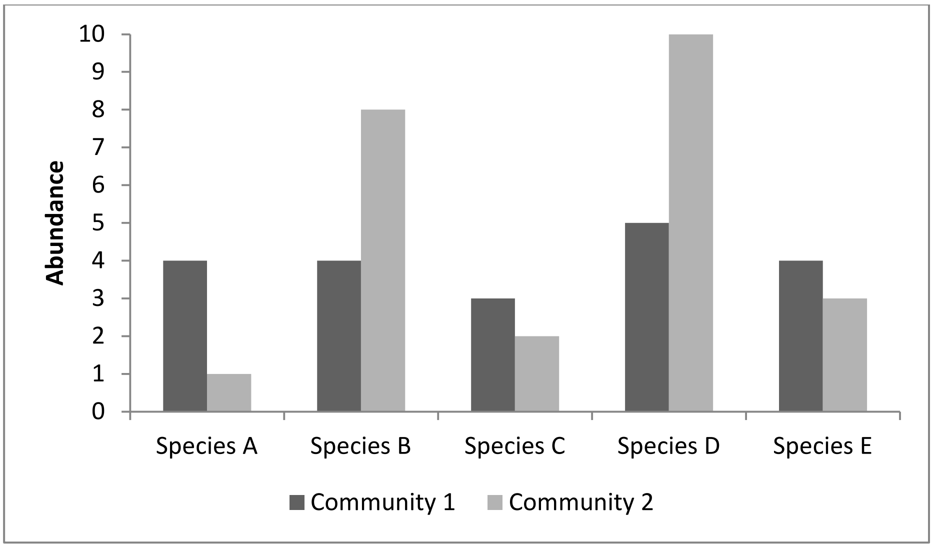


Figure 13: A hypothetical representation of two communities with different evenness. Community 1 is a typical assemblage of an undisturbed habitat; niches are well distributed between species and therefore have a high evenness index value. Community 2 is a typical disturbed community where niche apportionment has changed and few species dominate, thus giving a low evenness index value.

A number of evenness indices exist and are used by ecologists to assess the abundance of species classes. The Simpsons E evenness index is thought to be a good estimate of community structural equitability (Magurran, 1988). This index requires the Simpsons D diversity to be pre-calculated and modified by dividing the reciprocal of Simpsons D by the number of species in the sample. Simpson's evenness was calculated using Equation 2 (Simpson, 1949). This was calculated for butterfly, bumblebee and pitfall trapped invertebrate data in this study.

$$E = \frac{(\frac{1}{D})}{S}$$

Equation 2: Simpson's E evenness index. Simpsons Diversity is represented by D and S represents the number of species per sample

Contingency chi square analysis was performed on the total observations in each habitat and reclamation method to ascertain if invertebrate communities differed between reclamation types. The equation used for the contingency chi square analysis is shown in Equation 3.

$$x^2 = \sum_{n=1}^{n} \frac{(O-E)^2}{E}$$

Equation 3: Contingency chi square x^2 calculation. O is the observed species count, E is the expected count derived from ((total of individual species / total observation in habitat) / total observations).

The invertebrate species sampled by pitfall trapping were simplified to taxonomic groups due to the difficulties encountered during species identification. This enabled analysis of community structure and the functional feeding groups in each habitat. The mean number of trapped specimens and the standard error was calculated from the replicate samples per habitat. Simpson's diversity and evenness were calculated and chi square analysis of each taxonomic group was used to determine if the differences can be attributed to the reclamation method used.

3. RESULTS

3.1 VOLUNTEER RECRUITMENT

A total of thirteen volunteers were recruited by the three methods as shown in Table 3. The press release proved the most effective tool for recruiting the largest number of volunteers, three of whom went on to undertake multiple surveys. This reflects the motivation of the individuals to take part and demonstrates the effectiveness of this recruitment tool.

Table 3: Total number of people recruited by each recruitment method, and the number of participants that carried out more than one survey

Recruitment Type	No. of people showing interest	No. of people who undertook training and survey	No. of volunteers that undertook > one survey
Participatory GIS	5	4	1
Press Release	8	6	3
Site Presence	6	3	3

Volunteer recruitment on the site and during the organised Participatory GIS workshops had an excellent conversion rate from participants that showed an initial interest in volunteering, to participants that actually received training. However more of the volunteers recruited by this method failed to repeat the surveys on more than one occasion. Recruitment of volunteers by site presence appeared to be a very effective recruitment method. Members of the public using the site were curious about the research being carried out, and this appeared to break down the initial barriers to communication with a stranger. A sense of enthusiasm for wildlife was generally observed in most members of the community. Individuals that had the predisposition for learning more about wildlife were most successfully recruited to take part in surveys. The volunteers recruited by this method also undertook multiple surveys, which indicate a high level of motivation within this recruited group.

3.2 PARTICIPATORY GIS HISTORY MAPPING

UPTON

A timeline was constructed from the data collected during the workshop, shown in Table 4, and the locations reclamation impacts on vegetation are presented in Figure 15. Workshop participants included 2 ex-coal miners who had previously worked at the pit. They proved a valuable source of information regarding the condition of the site during its operational years, such as outlining areas grazed by the pit ponies. The participants were aware of a variety of orchids establishing themselves on the derelict site by the 1980s, the areas of which were delineated on the map. Natural regeneration of the spoil vegetation to heath and scrub matrix was observed by local residents within the first two decades of site abandonment, which was noted as providing an excellent bird habitat. Participants highlighted the fact that some coal still remains un-extracted and moves were made to open cast mine it in the 1980s. However a successful public relations campaign by the local community stopped this action; archival evidence is still in existence to support this assertion. Within the original open-cast planning proposal, the site was to be returned to use as a local ecology park after mining activities had ceased. Local community members took a key role in determining the fate of the site as a Country Park and the open cast mining proposal was dropped in favour of the reclamation scheme.

The PGIS workshop at Upton did successfully uncover a variety of spatial and temporal reclamation measures undertaken at this site. Participants recalled remaining coalmine buildings being demolished and crushed for hardcore. The resulting aggregates were spread over the west of the site along with a quantity of topsoil originating from the last operational Pontefract liquorice farms. Members of the community who were keen wildlife observers were well aware of important habitats on the site and had protected them from what they perceived as destructive reclamation techniques. The participants described an orchid transplantation scheme that took them from areas of the site due for reclamation, to areas of the site that were naturally regenerated and would be protected. Subsequent site visits with the workshop participants have led to a rediscovery of the orchids. Since the reclamation was completed, members of a local community group ‘Upton Anglers Club’ have acted as wardens assisting in the management of the site and provided the workshop with valuable information relating to post reclamation activities. This included information relating to the drainage channels and ponds constructed to ease flood issues downstream of the site in 2007.

Table 4: PGIS timeline of events post reclamation and the resulting perceived effects on wildlife at Upton

Year	Activity	Site Impacts
1964	Pit closure	
1968	Railway line becomes disused, Clay extraction continues for the brick works	Salvaging materials would have disturbed the site
1971	Railway lines completely removed	
1976	Proposed open cast coal mine for the site	
1978	Proposed limestone quarry	
1980	BMX park built	Disturbance of soil to build BMX track and jumps; Bee orchids noticed for first time
1984	National Miners Strike	Tree coppicing for wood fuel, surface coal digging created the first pond (since in-filled during development of the big pond)
1985	Proposed golf course	
1988	Wildlife Trust recognises the wildlife value of the site	
1990	Doctor's surgery built encroaching onto the site, planning application approved for open casting of coal and relocation of the clothing factory	Disturbance around surgery during building
1991	January - Phase 1 planting plan (tree planting on site) (not clear if undertaken)	
1992	May - Planning enquiry about the site. After use plan version 2 produced February	
1994	Major landscaping - Phase II planting	Sluices built on marshy land, brick rubble and flues crushed with rubble spread around site, air raid shelter demolished, new topsoil brought in from Green Lane area for the sport field, rest of site covered in rubble
1996	School built	Disturbance of site around school building; Seskew environment group undertake tree planting onsite
2005	Major floods; Factory Built; Walkways to the Spout Hole installed	Floods around the 'coffin' ponds; trees planted to screen the factory site from park
2007	Play area installed. Phase I Habitat Survey undertaken	Top soil skimmed off, protective covering added
2008	Spout Hole tree clearance	Willow trees removed from Spot Hole - leaving trunks;
2009	Settling ponds built; Scrapes and hollows built	Buffer ponds created to reduce storm flow. Soil and spoil exposed

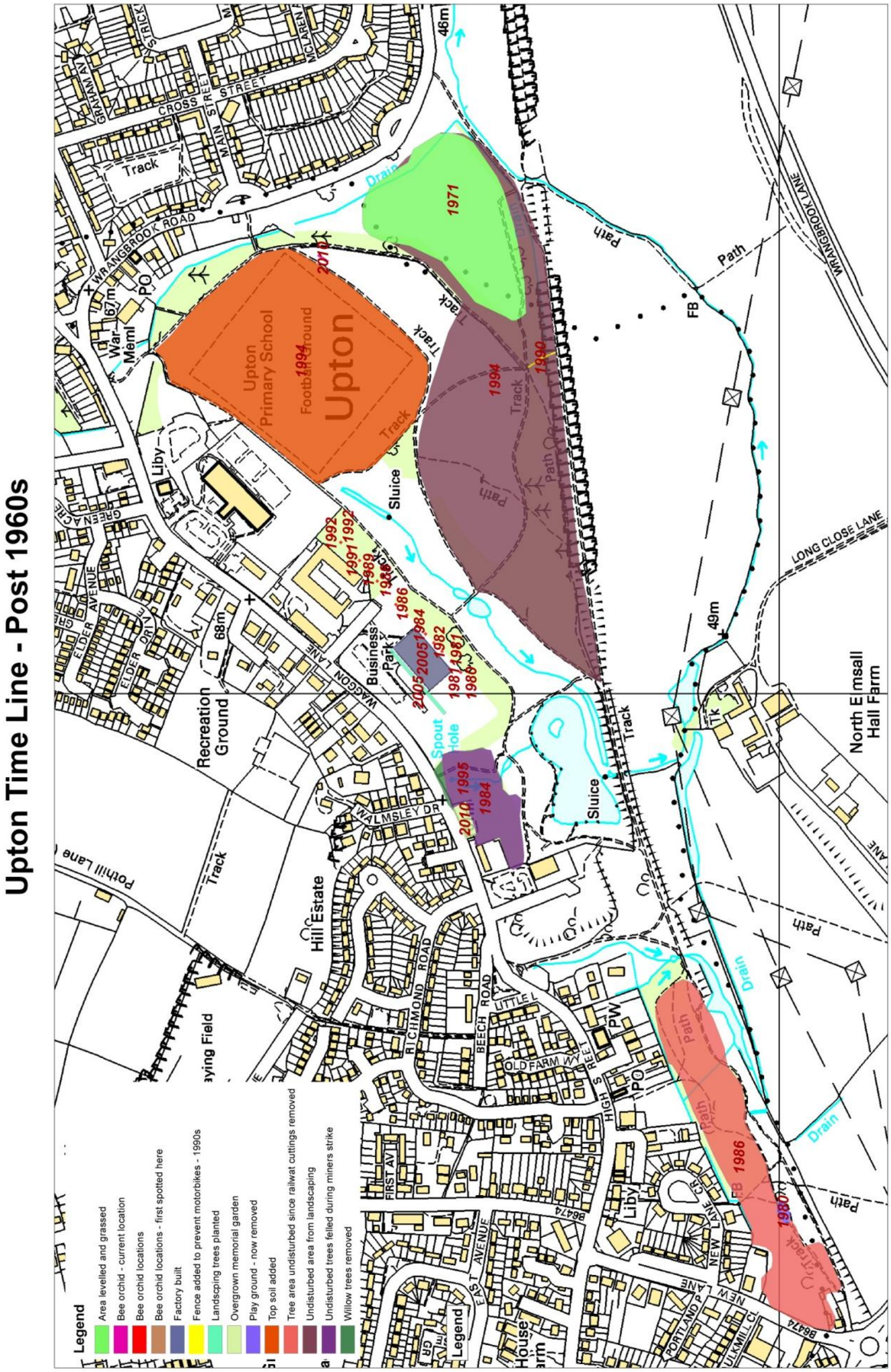


Figure 14: PGIS workshop generated spatial timeline of reclamation events at Upton. Areas delineated by colour outline areas of the site which had its vegetation impacted by reclamation. Dates provided relate to when the impact occurred. The map was assembled from data collected in the workshop by S Cinderby.

Fitzwilliam

The PGIS workshop was attended by members of the Fitzwilliam Country Park group, and included an ex-miner who had previously worked at the colliery. Data gathered during this workshop are presented as a timeline in Table 5, and outlines the sequence of reclamation events at this site. The scribed maps were used to construct the map presented in Figure 16.

It appears that colliery spoil from the Nostell and South Kirby mines was being discarded at the site from 1972 through to 1987. A one-off significant tree coppicing event took place across the disused Hemsworth colliery site during the national coal miners' strikes of 1984/85. Workshop participants provided reclamation dates that had previously been lost with other archived material. Site reclamation began in 1990 with the setting out of a golf course, and landscaping included grass and tree planting. A large scale tree planting scheme was initiated during this early phase of the reclamation. Due to changes in council project management, the reclamation was halted and the golf course plan scrapped. By 1993 the site was being used for recreation by the local residents, and it was noted that fly tipping and discarding of stolen vehicles was becoming prevalent at the site. The Fitzwilliam Country Park group was set up in 1998 with the aim to finish the reclamation of the site off as a nature park and to reduce habitat vandalism. Paths were laid through the park and by 2004 many new species were noted to be recolonising the sites. The workshop participants suggested that a reduction in butterfly diversity and abundance had taken place after reclamation.

Table 5: PGIS Timeline of post reclamation events and their perceived wildlife impact at Fitzwilliam

Year	Activity	Site impacts
1967	Pit closed	
1972	Mine buildings demolished, railway lines removed	
1973	Pit waste is being dumped on site	
1977	Drift mine opens on site	
1978	Pit waste continues to be dumped onsite	
1984	Miners Strike - Coppicing trees for wood fuel and coal collected form pit stack	Trees coppiced towards the south east of site
1987	Drift Mine Closes	
1990	Topsoil added to site – probably for a local source; Council start to feed the trees. Site is now being landscaped as a golf course	Tree and Grass planting
1993	Site being used in various ways	
1995	Abandoned cars removed from the site	
1996	BMX track built within the park	
1998	Country park group setup	
1999	Paths built through the sites, seats erected around the pound and fences built on the edges to deter vehicles entering the park.	Disturbance to vegetation
2004	Improvements in wildlife and plant life; Range of different species seen. Not equal improvements across all wildlife groups	Probable decline in butterflies diversity and abundance
2005	Stolen digger damages park - demolishing seats and felling trees	Trees knocked down
2006	Major wildlife survey undertaken and water voles were found onsite	
2008	Nature reserve status given to the site	
2010	Some trees removed in the isolated woodland	Trees cut down

Figure 15: PGIS spatial timeline of reclamation events at Fitzwilliam. Areas delineated by colour outline areas of the site which had its vegetation impacted by reclamation. Dates provided relate to when the impact occurred. The map was assembled from data collected in the workshop by S Cinderby

3.3 Bumblebee and Butterfly Transect Results

The results presented here for bumblebee and butterfly data are exclusively taken from Upton Country Park. The transect data from Fitzwilliam were not used due to lack of continuous surveys being undertaken by volunteers.

Volunteer data validation

A total of three participants performed the validation experiment at Upton Country Park with the results presented in Table 6. Confusion was noted between the various white butterflies observed whilst undertaking the survey. However, in many cases the initial identifications were correct and it was likely that they were seeking reassurance of correct identification. A total of four species of bumblebee and six species of butterfly were observed during the validation survey. Bumblebee observations by volunteers were well aligned with the researcher's observations; overall totals were within a 10% margin of error. Butterflies were generally well recorded by the volunteers, with the largest difference being found in the number of recorded Orange Tip butterflies. A chi square test showed no significant difference (X^2 = 3.472, dF = 27, P>0.05) between the volunteer and researcher collected data. This indicates that community members can collect ecological data which is as robust as data collected by a trained ecologist.

Table 6: Total bumblebee and butterfly species abundance observed during the Upton data validation transect in April 2011.

Species	Observation Counts			
Bumblebee	Researcher	Volunteer 1	Volunteer 2	Volunteer 3
Bombus pratorum	1	1	1	1
Bombus lapidarius	4	3	4	4
Bombus terrestris/lucorum	4	5	4	4
Bombus pascourum	1	0	0	1
Total	**10**	**9**	**9**	**10**
Butterfly				
Orange Tip	18	16	21	18
Holly Blue	3	3	3	3
Brimstone	3	2	2	3
Speckled Wood	20	18	19	19
Peacock	3	3	3	3
Comma	2	1	2	2
Total	**49**	**43**	**50**	**48**

Effects of Environmental Parameters

Butterflies and bumblebees were observed on the transect walks throughout July, August and September 2010; and in April and May 2011. Week number, wind, temperature and % sun was tested for correlation with the average number of observed bumblebees and butterflies per transect in any given week in PASW 18 software. The results of this are presented in Table 7. Bumblebee numbers observed on site were significantly negatively correlated with week throughout 2010 ($r = -0.88$, $p<0.01$). This is shown graphically in Figure 17 with a significant regression trend line. The surveys undertaken in spring 2011 appear to be forming a positive trend in the numbers of bumblebees observed; however, the small sample size does not allow statistical analysis of these results. The number of observed butterflies was not significantly correlated with any of the environmental parameters. The direction of the correlation coefficients suggest that increasing wind speed and % sunshine may reduce the numbers of butterflies and bumblebees observed on a given day. Temperature appears to have a positive effect on the numbers of butterflies and bumblebees observed, but the effect is not statistically significant.

Table 7: Pearson's bi-variate correlation coefficients of the number of observed butterflies and bumblebees under different environmental conditions. ** indicates statistical significance at 0.01 level

Group	Week	Wind	Temperature	Sun
Butterfly	0.25	-0.403	0.277	-0.223
Bumblebee	-0.88**	-0.352	0.113	-0.417

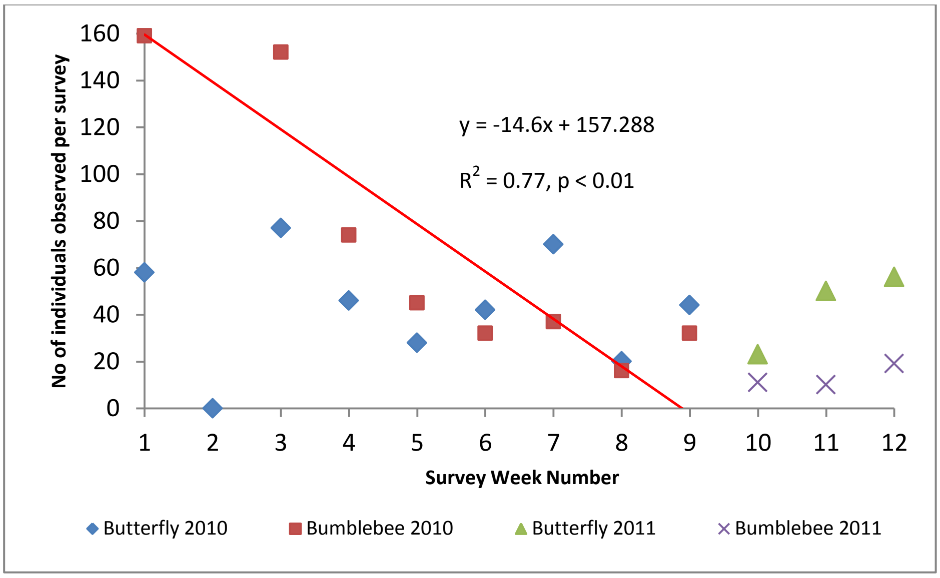


Figure 16: Seasonality effects on weekly number of butterfly and bumblebee individuals counted per survey at Upton. Weeks 1 – 8 are July to September 2010, Weeks 9 – 12 are April and May 2011.

Effects of Reclamation

In the woodland and grassland, two transect sectors sampled the naturally regenerated and two sectors sampled the reclaimed habitat. The total number of observations per reclamation method and habitat were combined to reduce the imbalance in total sector length. The total numbers of butterfly and bumblebee species observations per habitat and reclamation method are presented in Table 8. The total numbers of bumblebee and butterfly observations were higher in the woodland rides than in the grassland. Bumblebees and butterflies appear to be slightly more abundant in the naturally regenerated habitats. Many species of bumblebee appear to be strongly associated with the woodland habitat, e.g. *Bombus pratorum, Bombus hypnorum* and the *Bombus terrestris/lucorum* complex. The cuckoo bumblebees *Bombus bohemicus* and *Bombus vestalis* were observed almost exclusively in the woodland habitat, where their hosts *Bombus terrestris/lucorum* are also mainly found. *Bombus pascuorum* appears to be less restricted to woodland and was observed in greater numbers in the naturally regenerated areas of the habitats sampled.

Butterflies were observed less frequently than the bumblebees in all the habitats sampled. The most abundant butterfly sampled was the orange tip butterfly (*Anthocharis cardamines*), which was seen in equal abundance in reclaimed and natural regenerated woodland and was observed patrolling along the rides. Other members of the white family (*Pieridae*), small white (*Pieris rapae)* and large white (*Pieris brassicae*), appear to show a similar preference for the woodland habitat. However the green veined white (*Pieris napi*) did not appear to show the same association, as it was only observed in the grassland. The peacock butterfly (*Inachis io*) and comma (*Polygonia c-album*) were restricted to woodland habitats where they were almost exclusively observed. The common blue butterfly (*Polyommatus icarus*) was observed in significant numbers within naturally regenerated habitats and in the woodland habitat. The discovery of a foraging population in the woodland is notable, as this species is thought to be restricted to flower rich grassland habitats. The speckled wood butterfly (*Pararge aegeria*), a known woodland specialist, was often observed in grassland habitat; this maybe due to the presence of hedgerow and woodland edge in some grassland transects.

Table 8: Combined sector bumblebee and butterfly species observations at Upton Country Park during summer, autumn 2010 and spring 2011. Transect sectors were combined according to the reclamation method and habitat type.

		Number of Species Observed in Habitat			
Bumblebee	**Number Observed**	**Reclaimed Grassland 420 m**	**Naturally Regenerated Grassland 360 m**	**Reclaimed Woodland Ride 700 m**	**Naturally Regenerated Woodland Ride 960 m**
Bombus pratorum	177	4	7	85	81
Bombus lapidarius	117	30	19	52	16
Bombus terrestris/lucorum	67	5	7	25	30
Bombus pascuorum	218	14	34	62	108
Bombus hypnorum	8	1	0	3	4
Bombus bohemicus	43	0	0	12	31
Bombus vestalis	19	1	0	13	5
Total	649	55	67	252	275
Butterfly	**Number Observed**	**Reclaimed Grassland 420 m**	**Naturally Regenerated Grassland 360 m**	**Reclaimed Woodland Ride 700 m**	**Naturally Regenerated Woodland Ride 960 m**
Gonepteryx rhamni	6	2	0	0	4
Polygonia c-album	13	0	0	4	7
Polyommatus icarus	32	6	11	3	12
Pyronia tithonus	27	2	14	3	8
Pieris napi	9	4	4	0	1
Pieris brassicae	22	1	3	9	9
Maniola jurtina	20	4	7	5	4
Inachis io	34	5	1	19	9
Anthocharis cardamines	68	4	1	34	34
Lycaena phlaeas	2	0	0	1	1
Thymelicus sylvestris	6	3	1	2	0
Aglais urticae	1	0	0	1	0
Pieris rapae	14	2	0	11	1
Pararge aegeria	90	4	13	29	44
Lasiommata megera	4	2	2	0	0
Total	351	39	57	121	134

Contingency Chi Square Analysis

To test if the communities of bumblebees and butterflies were indeed different from each other areas that were reclaimed and naturally regenerated were compared in a contingency chi square test, that was performed on the data presented in Table 8. The small number of butterfly observations of many butterfly species meant that data had to be grouped by family (*Pieridae, Lycaenidae, Nymphalidae* and *Hespiridae*) to perform chi square analysis as shown in Table 10. There was no significant difference observed between butterfly communities of reclaimed and naturally regenerated areas of either grassland and woodland ride.

Table 9: The total number of butterfly observations in each habitat, grouped by reclamation method and taxonomic family.

Butterfly Family	Reclaimed Woodland Ride	Naturally Regenerated Woodland Ride	Reclaimed Grassland	Naturally Regenerated Grassland	Taxa Group Total
Pieridae	54	49	13	8	**124**
Lycaenidae	4	13	6	11	**34**
Nymphalidae	61	72	17	37	**187**
Hesperiidae	2	0	3	1	**6**
Habitat Total	**121**	**134**	**39**	**57**	**351**

Bumblebee communities sampled in grassland and woodland that had been naturally regenerated and reclaimed were statistically significantly different from each other. The results of the chi square analysis are presented in Table 10. A highly significant difference was found between naturally regenerated and reclaimed woodland bumblebee community structure. A statistical difference was also noted between grassland bumblebee communities; however, it was not as significant as in the woodlands. Less species were found within the grassland, thus a reduced degrees of freedom is noted within the chi square analysis. It was noted that the significant differences found here were mainly attributed to two species, which is considered in the discussion.

Table 10: Bumblebee and butterfly contingency chi square results for naturally regenerated versus reclaimed habitats. Significance values given by * $p<0.05$ and *** $p<0.001$

Species	Habitat	X^2	Degrees of freedom
Bumblebee	Grassland	10.46*	3
Bumblebee	Woodland	43.20***	5
Butterfly	Grassland	6.68	3
Butterfly	Woodland	6.38	3

Diversity and Evenness

Simpson's diversity and evenness indices calculated for each habitat and reclamation method are presented for bumblebees in Table 11 and butterflies in Table 12.

Table 11: Simpson's diversity and evenness indices calculated for bumblebees per habitat and reclamation method.

Habitat	Simpsons D	Simpsons E
Reclaimed Grassland	2.74	0.46
Natural Regenerated Grassland	2.86	0.71
Reclaimed Woodland Ride	4.37	0.62
Natural Regenerated Woodland Ride	3.75	0.54

The grassland reclamation methods appear to have little effect on the observed diversity of bumblebees; however, the evenness is strikingly different. The species responsible for the differences in evenness appear to be *Bombus pascuorum* and *Bombus lapidarius*. The potential factors responsible for the imbalance in number of observations are examined in the discussion. The bumblebee species diversity and evenness was found to be marginally different in the woodland rides. The reclaimed woodland ride appears to support a marginally more diverse and even bumblebee community; however, there were less observations in this habitat overall, as can be seen in Table 8.

Table 12: Simpson's diversity and evenness indices calculated for butterflies per habitat and reclamation method.

Habitat	Simpsons D	Simpsons E
Reclaimed Grassland	13.23	1.10
Natural Regenerated Grassland	6.26	0.63
Reclaimed Woodland Ride	5.80	0.48
Natural Regenerated Woodland Ride	5.22	0.44

Grassland butterfly diversity and evenness differed greatly between reclamation types, with the reclaimed habitat producing a more diverse and even community. However the total number of species observed within the areas of different reclamation did not differ greatly. The differences in diversity are due to a few species being abundant in either reclamation type as can be seen in Table 8. Woodland reclamation method appears to have had little effect on the butterfly diversity and evenness, with only marginally greater calculated indices being calculated in the reclaimed woodland. Again the overall total number of observations is not greatly different according to which reclamation type has been used. Similarly there are a number of species which are more abundant in one reclamation type than the other. These differences will be discussed later in the thesis.

3.4 Grasshopper Survey

Three volunteers assisted with the grasshopper survey over three afternoons in late August 2010. The paper and box quadrat methods sampled a range of grasshopper species, as shown in Table 13. The box quadrat survey that took place immediately after the paper survey discovered a greater number of grasshopper individuals. It also appears that not all species were responding in the same way towards the paper being placed into the habitat. The field grasshopper (*Chorthippus brunneus)* was encountered most frequently during the surveys, accounting for more than 90% of all records using the paper method. The relatively uncommon lesser marsh grasshopper (*Chorthippus albomarginatus*) was also recorded using the paper methodology. However the paper survey failed to attract common green (*Omocestus viridulus*) and meadow grasshoppers (*Chorthippus parallelus*), which were present in the subsequent box quadrat samples.

Table 13: Grasshopper species surveyed using paper and quadrat methodologies

Survey Method	Species Observed	Number Observed
Paper	Chorthippus brunneus	12
	Chorthippus albomarginatus	1
Box Quadrat	Chorthippus brunneus	13
	Chorthippus parallelus	5
	Omocestus viridulus	3

The colour analysis focuses on the *C. brunneus* records because enough records were made of this species to enable a comparison. The blue paper appeared to attract a larger proportion of *C. brunneus* than other colours tested, as shown in Figure 18. The dark colours black and brown did not attract a single grasshopper; suggesting that reflected light is responsible for attracting the grasshoppers to the paper. The sample size was too small to demonstrate a statistical difference between abundances on different paper colours.

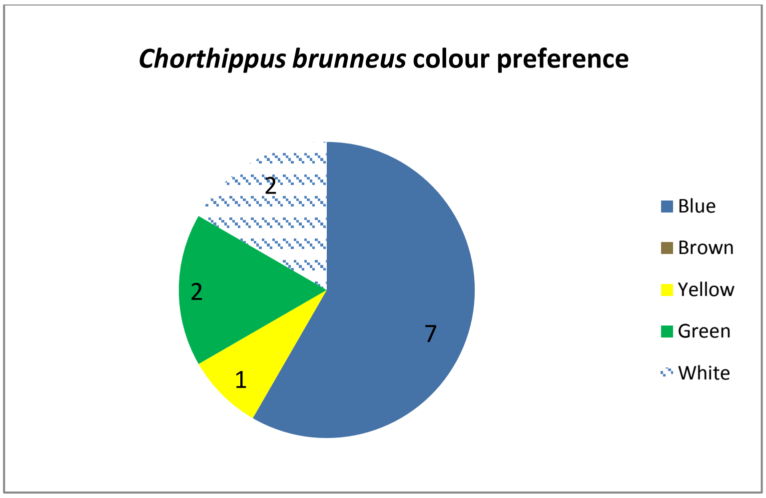


Figure 17: Field grasshopper (*Chorthippus brunneus*) paper colour preference. Numbers indicate the total number of grasshoppers alighting on each paper colour.

3.5 Invertebrate Pitfall Trapping

A total of 154 invertebrates were identified from 30 pitfall traps in 5 habitats. Difficulties encountered with some invertebrate group identifications meant that analysis had to be simplified to taxonomic orders. Invertebrates are known to respond to perturbations, such as reclamation of habitat, at a taxonomic community level (Tropek et al., 2010). Therefore the analysis based taxonomic groups should provide useful information on invertebrate community structure. Woodlice (*Isopoda*), spiders (*Araneae*) and ants (*Hymenoptera*) were the best represented taxonomic orders by volume of catch. The results of the pitfall trapping are presented in Table 14. The results for the reclaimed woodland were multiplied by 1.5 and rounded to the nearest whole number to allow comparison between reclamation methods in the woodland

Table 14: Total pitfall trapped invertebrates in grassland and woodland habitats at Upton and Fitzwilliam over 4 weeks in August 2010.

Order	Reclaimed Woodland	Naturally Regenerated Woodland	Reclaimed Grassland	Naturally Regenerated Grassland	Scrub	Total
Araneae	5	12	12	7	5	**41**
Chilopoda	2	0	0	0	0	**2**
Coleoptera	5	8	7	2	2	**24**
Dermaptera	0	2	0	0	0	**2**
Hymenoptera	6	7	5	3	5	**26**
Isopoda	2	23	5	3	2	**35**
Mollusca	0	1	3	2	0	**6**
Opiliones	3	10	0	3	1	**17**
Orthoptera	0	0	0	1	0	**1**
Total	**23**	**63**	**32**	**21**	**15**	**154**

The numbers of spiders (*Araneae*) differed according to the habitat and reclamation method employed in the areas sampled. The naturally regenerated woodland appears to support the most abundant community of spiders, and it also supports the most abundant ground beetle (Coleoptera), harvestmen (Opiliones) and woodlice (Isopoda) communities. These results suggest that the naturally regenerated woodland supports a much greater abundance of both predators and prey species than in the reclaimed woodland. The differences observed in the grassland invertebrate communities are more subtle when compared to the results in the woodland. Fewer invertebrates were trapped in the naturally regenerated grassland, however there were more groups sampled than the reclaimed grassland. There were more predators in the reclaimed grassland as seen by the elevated number of spiders and ground beetles. No statistical analysis could be used to find significant differences between reclamation methods because of the small sample sizes.

The diversity and evenness results presented in Table 15 suggest that the majority of invertebrate communities sampled by this study have greater evenness taxonomic group abundance with the exception of naturally regenerated woodland. Little difference in terms of taxonomic group evenness and diversity was observed between the grassland invertebrates. The scrub that is developing within the reclaimed grassland has a reduced taxonomic diversity, but still retains an even community structure.

Table 15: Diversity and Evenness scores for total number of pitfall trapped invertebrates at Fitzwilliam and Upton

Habitat	Simpsons D	Simpsons E
Reclaimed Woodland	6.33	1.05
Naturally Regenerated Woodland	4.72	0.67
Reclaimed Grassland	5.27	0.88
Naturally Regenerated Grassland	6.56	0.94
Scrub	4.77	0.95

3.6 INVERTEBRATE SPECIES-HABITAT INFORMATION SYSTEM

The local record centre invertebrate records were input into the ISIS package to create the assemblages known before this study. The records gained during this study were then added to create a more complete assemblage. The researcher collected invertebrate records were made from the pitfall trapping, sweep netting, grasshopper survey and butterfly and bumblebee monitoring surveys. The web based invertebrate records were made by local residents and downloaded from the iSpot website. Additional records were provided by a local entomologist specialising in Heteroptera added to the site inventories. The number of additional invertebrate records per recoding source at each of the sites is shown in Table 16. The web based recording in iSpot proved useful, as it was done remotely by a local amateur photographer, and provided 10% of the total records at Upton. The researcher collected records account for between 60 – 70% of all invertebrate records.

Table 16: A table showing the number of additional invertebrate species added to the inventory from each record source at each site.

Record Source	Upton	Fitzwilliam
Record Centre (Baseline)	27	19
Local Entomologist	0	8
iSpot	13	4
Researcher	62	50
Total	**102**	**81**

The invertebrate species habitat information system (ISIS) was used to generate a number of invertebrate assemblage codes using the inventories. The assemblage codes are based upon the specialist habitat requirements of invertebrates recorded at the sites. The greatest diversity of invertebrate species was found at Upton Country Park, with a total of 102 species being described and evaluated by the ISIS package. A total of 81 species were recorded at Fitzwilliam Country Park and recognised by ISIS. At both sites sampled, a sufficient number of invertebrates with specific habitat requirements were described to calculate a range of specific and broad assemblage codes. The assemblage codes generated by ISIS are supported by the investigators observations of the habitats present on the sites. The results of the combined records analysis are presented for Upton in Table 16 and Fitzwilliam in Table 18. Site inventories using the existing historical records were input into the ISIS to allow comparison between what was known about the invertebrate assemblages previous to this study, these results are presented for Upton in Table 17 and Fitzwilliam in Table 19.

Table 17: ISIS invertebrate assemblage analysis based on the combined invertebrate records at Upton Country Park. Assemblage types are coded by species habitat specialisation. Representation is the sampled % of species in each assemblage code, Richness and Rarity scores are based upon known national distribution and rarity of species

Number of species	**102**				
Specific Assemblage Types (SAT)					
SAT code	**SAT name**	**No. spp.**	**Condition**	**% of national species pool**	**Related BAT rarity score**
F002	rich flower resource	11	-----	5	-----
F001	scrub edge	3	-----	1.7	-----
F112	open short sward	3	-----	1.5	100
F003	scrub-heath & moorland	1	-----	0.3	-----

Broad Assemblage Types (BAT)					
BAT code	**BAT name**	**Representation (1-100)**	**Rarity score**	**Condition**	**BAT species richness**
F2	grassland & scrub matrix	29.4	107	-----	30
W2	mineral marsh & open water	15.7	118.8	-----	16
F1	unshaded early successional mosaic	14.7	100.0	-----	15
A1	arboreal canopy	4.9	-----	-----	5
F3	shaded field & ground layer	1.0	-----	-----	1
W1	flowing water	1.0	-----	-----	1
W3	permanent wet mire	1.0	-----	-----	1

Table 18: ISIS invertebrate assemblages using existing Upton Country Park invertebrate records prior to this study

Number of species	**27**				
Specific Assemblage Types (SAT)					
SAT code	**SAT name**	**No. spp.**	**Condition**	**% of national species pool**	**Related BAT rarity score**
F001	scrub edge	2	-----	1.1	-----
F112	open short sward	2	-----	1	-----

Broad Assemblage Types (BAT)					
BAT code	**BAT name**	**Representation (1-100)**	**Rarity score**	**Condition**	**BAT species richness**
F2	grassland & scrub matrix	37	-----	-----	10
W2	mineral marsh & open water	37	-----	-----	10
F1	unshaded early successional mosaic	11.1	-----	-----	3
A1	arboreal canopy	3.7	-----	-----	1
W3	permanent wet mire	3.7	-----	-----	1

Table 19: ISIS invertebrate assemblage analysis based on the combined invertebrate records at Fitzwilliam Country Park. Assemblage types are coded by species habitat specialisation. Representation is the sampled % of species in each assemblage code, Richness and Rarity scores are based upon known national distribution and rarity of species.

Number of species	**81**				
Specific Assemblage Types (SAT)					
SAT code	**SAT name**	**No. spp.**	**Condition**	**% of national species pool**	**Related BAT rarity score**
F002	rich flower resource	8	----	3.3	----
F001	scrub edge	2	----	1.1	----
F112	open short sward	1	----	0.5	107.1
Broad Assemblage Types (BAT)					
BAT code	**BAT name**	**Representation (1-100)**	**Rarity score**	**Condition**	**BAT species richness**
F2	grassland & scrub matrix	36.5	107	----	31
F1	unshaded early successional mosaic	16.5	107	----	14
W2	mineral marsh & open water	15.3	138.5	----	13
A1	arboreal canopy	9.4	----	----	8
W3	permanent wet mire	3.5	----	----	3
F3	shaded field & ground layer	2.4	----	----	2

Table 20: ISIS invertebrate assemblages using existing Fitzwilliam Country Park invertebrate records prior to this study

Number of species	**19**				
Specific Assemblage Types (SAT)					
SAT code	**SAT name**	**No. spp.**	**Condition**	**% of national species pool**	**Related BAT rarity score**
F112	open short sward	1	----	0.5	----
Broad Assemblage Types (BAT)					
BAT code	**BAT name**	**Representation (1-100)**	**Rarity score**	**Condition**	**BAT species richness**
W2	mineral marsh & open water	52.6	----	----	10
F2	grassland & scrub matrix	21.1	----	----	4
F1	unshaded early successional mosaic	10.5	----	----	2
W3	permanent wet mire	5.3	----	----	1

A specific assemblage type, *rich flower resource* is well represented by the invertebrate fauna at both sites. Further analyses within the ISIS package shows that the lepidopteran and hymenopteran insect orders contribute the most towards this specific assemblage code. This code reflects and confirms that these sites have excellent wildflower foraging resources. A total of 5% of the national invertebrate species pool associated with rich flower resource was discovered at Upton and 3.3% at Fitzwilliam. This assemblage type was not accounted for by historical records at both sites prior to this study.

The hymenopterans *Trypoxylon attenuatum* and *Andrena clarkella* were discovered on flowers in the natural regenerative scrub zones of Upton site. Scrub and moorland also appears as a specific assemblage code at the Upton site and is coded by one species, the Garden Chafer beetle (*Phyllopertha horticola*). This specialised invertebrate assemblage was not coded for by previous records, and as such highlights these species as important records for Upton.

The open short sward assemblage was coded by few species at both sites, Upton being the richest with three species of the site inventory belonging to this assemblage. Only one new record was added to this assemblage by this study, the yellow meadow ant (*Lasius flavus*). This additional record generated a rarity score as it is an insect of conservation interest. Whilst the relative importance of this specific assemblage is lower than other assemblages, it is the only assemblage to generate a rarity value at both sites. This hints at the importance of this habitat and will be discussed later in the thesis.

In the broad assemblages the invertebrate species assemblage best represented is the *grassland and scrub matrix* with approximately a third of the UK native invertebrate species classified in the ISIS dictionary associated with this habitat type being found on both sites. This habitat type is also recognised by ISIS to be the most species rich and contain a number of rarities. This result is unsurprising as the greatest proportion of land on the two sites is a grassland scrub matrix. The relative importance of this assemblage improved greatly with the additional species added to this list.

Unshaded early successional mosaic was reasonably well accounted for in the ISIS package and contains a couple of rarities. The majority of species recorded for this particular habitat code were in areas that had most recently been disturbed, for example on the drainage works at Upton and around the BMX track at Fitzwilliam. With the additional species added to the site inventories by this study, the rarity, richness and representation scores in ISIS all increased. This may suggest this habitat type is of conservation interest.

The broad assemblage type *arboreal canopy* was coded for at both sites, with Fitzwilliam being best represented. Hemiptera featured prominently in this assemblage type, although all these records were of common species. The sampling effort in the woodland canopy was restricted, and thus may have negatively influenced the relative importance of this assemblage type.

Open water and mineral marsh was well represented by the invertebrate fauna at Fitzwilliam and Upton. The site inventories generated the greatest rarity value for this assemblage type out of all tested. The historical records of dragonflies contributed towards the richness score in ISIS. However it was the additional records taken by this study which generated a broad assemblage type rarity score. It appears that invertebrates that have specialised habitat requirements around the edges of water and in marginal vegetation are responsible for this result. These species are examined in the discussion and are shown in Appendix C.

4. DISCUSSION

4.1 VOLUNTEER RECRUITMENT

The successful recruitment of thirteen volunteers from the communities surrounding the study sites shows that local residents can be motivated to participate in scientific research if given the opportunity and provided with the relevant training. A number of different advertising and recruitment methods were used by this study; and depending on which method was used, they may have attracted volunteers with different levels of motivation. A total of five individuals were recruited for the invertebrate surveys from the participatory mapping workshop, and four of these participants went onto receive species identification training and returned at least one completed survey. The conversion from an interested individual into a reliable volunteer may be attributed to the trust gained between participant and researcher whilst undertaking the participatory mapping. It is already known that a level of trust between the participant and researcher is an important factor in the success of PGIS projects (Harvey, 2003). Therefore this method may work well for recruiting volunteers in similar citizen science based studies. This interaction could be investigated in further detail through the use of structured interviews and surveys. Members of the public who were initially interested in participating in the study, but did not take part cited not being able to commit enough free time on a weekly basis as the most restricting factor. This factor appeared to preclude many of the interested individuals in the working age range between 20 - 60 years old from undertaking the surveys.

The site presence of the researcher proved effective at recruiting highly motivated volunteers. This set of volunteers included residents recruited by talking to them on-site, and through word of mouth between local residents. This result appears to support the suggestion that one to one contact with volunteers is the key to successful volunteer recruitment (Smith, 1994). All three volunteers recruited using this method undertook the training and were dedicated to the project, which can be seen in the number of volunteers undertaking multiple surveys. This method benefits from being a targeted approach to recruitment, and the author tailored the volunteering opportunity to the skills and interests of the individual where possible. The author speculates that the extended time used to build up a personal working relationship with the participant was fundamental to achieving a lasting and productive collaboration. This observation appears to support the results of other studies requiring volunteer participation in the research (Laidler et al., 2004), (Stewart et al., 2008).

The press release proved an effective tool for recruitment, and resulted in a team of dedicated volunteers taking part in the weekly transect surveys. This recruitment method has the greatest spatial advertising coverage of the three methods utilised, which may explain the increased number of interested individuals getting in contact with the project. Approximately 25% of those who contacted the project failed to undertake any training and surveys, this failure rate appears to be consistent with advice given to volunteering organisations undertaking recruitment (Scott, 2006). All the individuals who were recruited by the press release undertook multiple surveys for the project, which indicates a high level of motivation. It may be that individuals recruited by the press release have a higher level of volunteering motivation compared to the other methods, as they had taken the time to track down the opportunity and been pro-active by contacting the researcher directly. This could be an indication that it is more desirable to use a press release to recruit members of the public for citizen science projects, as they are highly motivated. However care must be taken when interpreting these results because only a relatively small number of volunteers were recruited overall, and there is a chance that this may not be representative of the wider community.

The data appears to support the expected 50% volunteer drop-out rate for the press release and site presence recruitment methods (ATC Citizen Science Working Group, 2006). The drop-out rate was measured in the number of individuals who had shown an interest but failed to commit to training. If a similar study were to be carried out in the future, a survey to discover the reasons behind volunteer drop out may provide useful information for voluntary organisations on volunteer retention. These results offer a glimpse into the effectiveness of volunteer recruitment methods, but the low numbers of volunteers recruited for this locally based citizen project precluded any statistical analysis needed to make solid conclusions.

4.2 PARTICIPATORY MAPPING

The results of this study suggest that participatory mapping is a powerful tool for documenting local history. The PGIS workshops and Rapid GIS appraisal sessions reconstructed the life histories of the sites and recorded the perceived impacts on the resident flora and fauna. The information collected during this phase of the study was essential in survey design and the interpretation of the results in terms of a comparison between the two reclamation methods.

Some community members appeared to be particularly inspired by the natural emergence of orchids on the naturally re-vegetating sites, and were keen to conserve them during the reclamation landscaping. The conservation activism demonstrated by the residents appears to support the notion that the general public are fond of wild orchids (Heath, 1999). This pre-disposition towards protecting wild orchids could be exploited and utilised in other landscape or habitat conservation schemes requiring an input from community stakeholders. The decline perceived by participants in the abundance and diversity of butterflies at Fitzwilliam is noteworthy as this may be associated with reclamation events; however, this could also be attributed to the nationwide decline in butterfly richness (Wilson et al., 2004). The lack of a pre-reclamation butterfly inventory for Fitzwilliam prevents the corroboration of these observations, but it does suggest changes in richness and abundance has occurred here.

Some discrepancies were noted between the perceived and the archived published timeline of reclamation events. The uncertainty may lie with inaccurate archives, or be attributed to the participants inability to recall the timing of events accurately. Typical errors were no more than two years difference and in most cases of a trivial nature. This highlights the problems associated with gathering historical data many years after the original event took place.

4.3 Validation of Community Collected Data

The validation of the transect data suggests there is little difference between volunteer and researcher-collected data. This supports the findings of a volunteer based invertebrate study carried out in Africa, where the data collected by the participants were at least as reliable and robust as the researcher's (Lovell et al., 2009). Only a few studies have researched the validity of records from specialist and non-specialist recorders. An assessment of volunteer collected bird data found a bias towards recording rare species (Snäll et al., 2011). This factor was noted in a small proportion of volunteer collected butterfly data by this study. The identifications were checked with the recorder and screened out on the basis of phenology and known distribution. Therefore it is essential that volunteer recorders are given this information in a complete field guide, to ensure misidentifications are kept to a minimum.

The skill level of a recorder has been shown to significantly affect results in butterfly studies (Dennis et al., 1999). Ascertaining the level of identification skill of each volunteer could be achieved through formal tests. However, setting tests for volunteers may alienate them and discourage them if they are not confident. This did not fit with the inclusive objective of this study; therefore recorder skill level was not estimated. The lack of clarity on the volunteer skill level is an area of weakness for the butterfly and bumblebee research undertaken here. Whether this skewed the results is uncertain, however screening of the data removed obvious species mis-identifications and therefore circumvented one problem associated with volunteer skill level.

4.4 Bumblebee Survey

Upton Country Park appeared to be providing a good habitat for bumblebee, supporting eight species of bumblebee, a third of the total resident UK species.

Environmental Parameters

The numbers of bumblebees observed at Upton did not show statistically significant correlations with environmental variables such as wind speed, temperature and percentage sunshine. Most invertebrates need to reach a minimum temperature to function, and are reliant on the ambient air temperature to rise to reach their operating temperature. Bumblebees have developed a way to circumvent this limitation by disengaging their flight muscles from their wings and using them to shiver in order to raise their internal body temperature (Benton, 2006). As a result bumblebees can forage in lower temperatures than other hymenopterans such as honeybees (McKenney, 2010). The lack of correlation between temperature and number of observed bumblebees in the data collected here could be a result of assigning a minimum survey temperature of 15 °C to accommodate butterfly flight conditions; thus the survey does not cover the range of temperatures needed to uncover the statistical differences. Bumblebees can forage at temperatures as low as 10 °C (Goulson, 2010); therefore repeating surveys at this temperature as well as higher temperatures may uncover a statistically significant correlation between numbers of bees observed and temperature.

The lack of a significant correlation with wind speed, percentage sunshine and the observed number of bumblebees may also be the result of the restricted range of environmental parameters set for the surveys. Volunteers were encouraged to survey in optimum butterfly flying conditions, and thus only survey on days where wind speed was low, temperatures were elevated and there was little cloud cover. Therefore it is likely that the range of weather conditions is too narrow to observe significant correlations here.

The number of bumblebee observations declined with increasing week number in 2010. This observation can be explained by the nesting lifecycle of bumblebees.

The workers begin to die off in the late summer and autumn, and the queen bumblebee stops producing workers due to the lack of fertilized eggs in the late summer (Benton, 2006). This will have the effect of a reduction in observations of bumblebees towards the end of summer and into autumn. The transect results collected in the spring of 2011 appear to show an increasing bumblebee population, however without additional results, this trend could not be subjected to statistical tests. This population would be made up of emerging queen bumblebees and the first workers produced by early emerging bumblebees.

EFFECTS OF RECLAMATION ON THE BUMBLEBEE COMMUNITY

The data presented in this study appear to show that bumblebee community structure is sensitive to the landscaping events on a reclaimed colliery site. The significant difference between bumblebee community structure in the reclaimed and naturally regenerated woodland and grassland habitats may suggest that these habitats are offering different niches to the bumblebees. The reasons for the potential niche differentiation will be discussed here, but due to the limitations of this type of study, the conclusions are tentative.

Grassland

It appears that the grassland bumblebee community structure differs in terms of species dominance and evenness between reclamation methods. Simpson's diversity indices differ little between the habitats, although the reclaimed grassland supported two additional but rarer species than the naturally regenerated equivalent. The shared dominance of *Bombus lapidarius* and *Bombus pascuorum* in both grassland habitats may be explained by their foraging preference for birds-foot trefoil (*Lotus corniculatus*). A recent study of foraging bumblebee flower choice constancy showed that birdsfoot trefoil was visited far more than other suitable inflorescences (Raine & Chittka, 2007). Birdsfoot trefoil was observed in large patches alongside the transect paths in the grassland; thus the presence of this plant may explain the dominance of these species associated with it, such as *Bombus pascuorum* (Edwards & Jenner, 2009). The abundance of both *Bombus lapidarius* and *Bombus pascuorum* were not constant between reclamation methods, and are the key species responsible for the highly significant chi square results. It is unclear exactly why this difference was observed, but it could be because of the distance from nests to foraging patch. *Bombus pascuorum* nests in a bundle of grass, that rests on the soil surface, whereas *Bombus lapidarius* is known to nest in small mammal burrow in the soil (Benton, 2006). *Bombus lapidarius* was observed more often in the reclaimed grassland, which should better support the nesting preferences of this species. Soil factors such as compactness and permeability will differ between the clay capped reclaimed habitats and the spoil rich naturally regenerated grassland. The difficulty a small mammal must have when attempting to burrow into spoil may reduce the small mammal population in the naturally regenerated grassland, and therefore is likely to have an effect on the number of potential bumblebee nests. Further research into the number of nests and small mammal burrows per m^2 in each reclamation method habitat may highlight the importance of soil conditions for *Bombus lapidarius* to colonise an area. *Bombus pascuorum* nests on the soil surface, and therefore would be unaffected by changes in the soil character, but this bumblebee species is likely to benefit from a denser grass sward as it combs the dead grass for its nest. This was not shown in the data, as it was observed more often in the short sward grassland where the favoured food plant existed.

Woodland

The woodland rides at Upton support a more diverse and abundant bumblebee population than in the grasslands. This population also included the cuckoo bumblebees *Bombus vestalis* and *Bombus bohemicus*, which were strongly associated with the woodland rides.

The reclamation method appeared to exert a highly significant effect on the bumblebee community structure. However the reclamation method did not greatly affect the total bumblebee abundance. The diversity and evenness indices show only subtle differences between each reclamation method, with the reclaimed habitat appearing to have a greater diversity. However, all the species that occurred in the planted woodland ride also appeared in the naturally regenerated ride. As with the grassland *Bombus lapidarius* and *Bombus pascuorum* are mainly responsible for a significant chi square result and as such it may be the flora and the soil structure in these habitats that are responsible for the observed differences in abundance. The natural regeneration of woodland tends to be patchy in the distribution and frequency of the establishing flora (Clarke, 2002). This patchiness tends to result in a comparatively more open woodland canopy and allows ground flora to proliferate more effectively, as has been demonstrated in a study of bryophyte communities under natural regeneration of woodland (Ross-Davis & Frego, 2002). It was noted that a key bumblebee forage plant growing in the reclaimed woodland rides was rosebay willowherb (*Epilobium angustifolium)*. This species did also occur in the naturally regenerated woodland, but in much lower densities, the presence of *E. angustifolium* has previously been reported as a key factor in predicting bumblebee species richness and diversity (Bäckman & Tiainen, 2002). Added to this, the medium tongued *B. lapidarius* has been shown to prefer stands of tall flowers (Brodie, 1996). Thus it is likely that the elevated number of observations of *B. lapidarius* in the reclaimed woodland is attributable to the increased abundance of *E. angustifolium.*

The difference in total numbers of bumblebees observed between habitats and reclamation method may also be due to the distance between the foraging patches and nests. Bumblebees are known to travel 400 metres from the nest to find good patches of forage (Osbourne et al., 1999), and recently it has been shown that the most common bumblebee species have different foraging ranges (Knight et al., 2005). *B. lapidarius* and *B. pascuorum* were found by Knight et al. (2005) to have the smallest range of the six most commonly observed UK species of bumblebee. It was noted that a considerable number of nest searching queens were observed in both years in the naturally regenerated woodland ride within the railway cutting. The fractured and fissured Permian limestone here provide an ideal bumblebee nesting feature for terrestrial nesting species such as *B. lapidarius, B. lucorum and B. terrestris*, and were all noted as abundant in this area. Therefore the cutting should be viewed as an important area of the site for hymenoptera.

Two species of parasitic cuckoo bumblebees were found at Upton, *Bombus vestalis and Bombus bohemicus,* and were almost exclusively observed in the woodlands and in particular around areas of known social bumblebee nests. The implications of this finding adds weight to the conclusion that Upton is providing good nesting and foraging resources for bumblebees, as the efficiency of successful parasitism is as low as 40% in *Bombus vestalis* (Erler & Lattorff, 2010) and the proximity of good forage increases the likelihood of successful nest parasitism (Goulson, 2010). This may suggest that a healthy population of social bumblebees is present on site, as a large number of nests will be required to sustain the number of cuckoo bumblebees observed in this study

4.5 Butterfly Survey

A total of fifteen species of butterfly were recorded at Upton Country Park over the twelve week survey period, which account for a quarter of the UK resident butterfly species.

Environmental Parameters

No significant correlation was found between week and observed butterfly abundance. This may be explained by the sampling of different species' flight periods (phenology). The common blue butterfly (*Polyommatus icarus*) reaches its peak flying abundance in July, with a few laggard individuals emerging throughout August; however the overall population is declining from late July onwards (Eeles, 2010). In contrast to this, the peacock butterfly (*Inachis io*) is reaching its peak population flying abundance in August (Eeles, 2010b). The limitation of measuring combined total observed butterfly abundance and plotting it against the time variable is that the overlapping phenology of individual species will mask an overall decline in butterfly abundance. If this study had sampled the population for a longer period of time into the late autumn, a declining population trend may have been detected. In the spring of 2011 it appears that the combined population of butterflies increasing rapidly in the three weeks that were sampled. The weather conditions during early spring in 2011 was unseasonably warm which resulted in the early emergence of many butterfly species (Hickman, 2011), including the orange tip butterfly (*Anthocharis cardamines)* that was recorded in abundance at Upton during this time period.

With the exception of temperature, all the environmental parameters were estimated by the observer, as there was no provision for providing weather parameter instruments. This may have led to inaccurate environmental variables being recorded, and thus is an area of uncertainty. To improve the data quality of the environmental parameter estimation in future studies of this type, volunteers should be provided with light intensity, wind speed and temperature instrumentation.

EFFECTS OF RECLAMATION ON THE BUTTERFLY COMMUNITY

The results suggest that taxonomic butterfly family composition in the naturally regenerated and reclaimed habitats are not significantly different from each other. Very few butterflies were observed, which meant that data simplification and reduction from species level data to family level was required to ensure the assumptions made by the chi square analysis method were met. This data transformation may mask real differences between butterfly species abundances in the reclamation methods. In some cases butterfly species are different according to the reclamation method used. The reason why such low numbers of butterflies were observed in such a flower rich habitat is uncertain; as the grassland contains a good diversity of grasses and flowers that many species of caterpillar and butterfly are known to feed on. Thus, interpreting these results will be focused on the differences in abundance of individual butterfly species in the reclaimed and naturally regenerated habitats.

Grassland

The most striking difference between butterfly communities and reclamation methods is seen in the grassland habitat. The reclaimed grassland contained two additional species of butterfly not seen in the naturally regenerated grassland; these were the brimstone (*Gonepteryx rhamni*) and small white (*Pieris rapae*). The small white butterfly is a gregarious species and it is more likely chance that it was not observed in the naturally regenerated habitat. However the sighting of two brimstone butterflies in the reclaimed grassland may be more significant, because the caterpillar is dependent on buckthorn (*Rhamnus cathartica*) as a food plant, which is typically found in a calcareous habitat (Butterfly Conservation, 2011); a habitat found at Upton. Another difference noted between the reclamation methods used in the grassland is the dominance of certain species. The Gatekeeper (*Pyronia tithonus*), common blue (*Polyommatus icarus*) and speckled wood (*Pararge aegeria*) butterflies were all present in greater numbers in the naturally regenerated habitat and when totals were combined, they account for the increased total butterfly abundance in this habitat over the compared reclaimed grassland. This has resulted in a lower evenness and diversity index despite the greater overall total number of observations. It may be that the presence of scrub and hedgerow alongside the transect paths in the naturally regenerated areas have elevated the numbers of gatekeeper and speckled wood butterflies here as they are known to favour this habitat (Butterfly Conservation, n.d.). The increased number of observations of the common blue butterfly in the naturally regenerated grassland is most likely associated with the greater presence of the caterpillar's main food plant, birdsfoot trefoil (*Lotus corniculatus*) along the sides of the pathways. These results hint at the importance of having abundant birdsfoot trefoil on reclaimed sites such as these. It also appears to promote the view that having a mosaic of habitats with hedgerow and scrub is beneficial for a site's butterfly diversity.

Woodland

The woodland rides were found to support a greater abundance of butterflies than in the grassland; however this may in part be an artefact of the greater transect length. The diversity and community evenness were very similar between reclamation methods; however on a species level the communities are different. The most abundant species in both reclamation methods were the woodland specialists, speckled wood (*Pararge aegeria*), orange tip (*Anthocharis cardamines*) and peacock (*Inachis io*) butterflies. The peacock butterfly was observed twice as many times in the reclaimed woodland, and this may be the result of this habitat having large patches of nettles, which are the main caterpillar food plant of this species (Lewington, 2003). The small white butterfly (*Pieris rapae*) was significantly more abundant in the reclaimed woodland, which may relate to the proximity of the planted woodland to urban gardens at this end of the site. In a recent study it has been shown that small white butterflies occurred very frequently in urban grasslands (Blair & Launer, 1997), therefore it may be that the small white butterflies observed here are overspill from local gardens. As with the grassland habitat the common blue butterfly (*Polyommatus icarus*) abundance differed between reclamation methods, with naturally regenerated habitat being favoured which was noted to support patches of the food plant birdsfoot trefoil (*Lotus corniculatus*). A number of brimstone butterflies were recorded in the naturally regenerated woodland ride. This may be attributed to the presence of buckthorn which will favour the soils that benefit from calcareous runoff water originating from the exposed Permian limestone in the railway cutting.

4.6 GRASSHOPPER SURVEY

Estimating animal population by placing artificial platforms into the environment has been used for the study of many different species in the past, including shrews (Eadie, 1948) and water voles (Miller, 1957), but not for invertebrates. Grasshoppers did respond in a similar fashion to artificial platforms being placed into their environment; however the use of the platform differs from mammal use, in the fact that it is not used for defecation. In mammals it appears that the use of the platform is restricted to territorial marking. However the field observations of grasshopper behaviour once alighted on the paper may suggest the insect is looking to gain a sexual advantage by an increased visibility to potential mates. The reason for this particular behaviour needs further exploration.

The attractiveness of paper colour to grasshoppers was explored in this study. It is known that grasshopper eyes are tuned for background colour frequencies (Gillis, 1982), presumably to aid its ability to camouflage itself from predators. Therefore the grasshopper should alight on a paper colour similar to its own body colour. However in this study, grasshoppers with a green, pink and brown body colour were observed alighting on a blue platform. The grasshopper is extremely conspicuous to its predators under these circumstances, which suggests they are not trying to camouflage themselves when using the platform. Therefore the platform colour selection could be linked to the more extrovert stridulation that was observed by the researcher. There is evidence emerging that blue is attractive to many hymenopterans and dipterans when comparing coloured water pan traps (Campbell & Hanula, 2007). It is well known that flower-visiting insects have eyes tuned for the reflected blue UV to aid flower detection (Kevan, 1972). Evidence is also emerging that orthoptera act as a pollinator for orchids (Micheneau et al., 2010) and tropical flowers (Schuster, 1974), but it is not clear if it is plant volatiles or flower colour that is driving this pollination behaviour. It is a possibility that UK native grasshoppers are acting as pollinators, but this has yet to be observed. Filming blue or purple flowers in areas of high orthoptera activity may support these observations of flower pollination. Interestingly, there are high densities of grasshoppers and orchids at Upton; whether these are correlated or due to chance pose interesting research questions.

As a tool for entomological survey, the paper grasshopper population monitoring method is unreliable. Some grasshopper species responded more readily to the method and validation showed it to severely underestimate grasshopper populations. Nevertheless the insight shown here by the grasshopper behaviour may provide further opportunities to develop pesticide free population control of these species during their mating season.

4.7 Invertebrate Pitfall Traps

This element of the study combined the results from both Fitzwilliam and Upton and therefore should enable a broader interpretation of the effects of brownfield and site reclamation on invertebrate communities. The species were combined into taxonomic orders for the assessment of habitats. Each invertebrate order can be thought of as a functional group, as they tend to specialise in terms of food source consumed and are commonly referred to as functional feeding groups (Cummins et al., 2005).

Woodland

The diversity index result suggests that invertebrate diversity increases in planted trees when compared with the naturally regenerated woodland. This result is driven by a high evenness and low abundance of each taxonomic group. It is thought that communities with a high evenness perform better when under environmental stress and pressures (Wittebolle et al., 2009), and in a recent study of ecological community evenness on organic farms, results suggest that greater predator evenness promotes pest control down the trophic layers (Crowder et al., 2010). It is therefore intuitive that a community with a greater evenness and diversity index should be in a better ecological condition than one with lower index values. The reclaimed woodland is probably in a less favourable condition than that of the naturally regenerated woodland because of the fewer overall numbers of invertebrates caught there. In terms of functional feeding groups, it is clear that there is a greater population of decomposer and detritus feeders, represented by woodlice and isopoda, within the naturally regenerated woodland. In a study of soil dwelling invertebrates on post-mining landscapes, it was found that the development of a humus rich vegetation layer was a key factor in determining the community diversity and abundance (Frouza et al., 2008). A rich humus layer was encountered when setting the pitfall traps in the naturally regenerated woodland, which may explain the elevated abundance of the decomposer groups such as the isopoda.

Viewing the invertebrate communities in terms of predator and prey abundance, the elevated abundance of invertebrate top predators such as spiders, harvestmen and carabid beetles, and their prey isopoda and dermaptera, in the naturally regenerated woodland may be significant. It has been suggested in trophic predator-resource modelling that the abundance and diversity of lower trophic orders directly impacts the abundance and diversity of predators (Liebold, 1996). Thus the striking increase in isopoda prey in the naturally regenerated woodland compared to the reclaimed may be partly responsible for the increase in predator diversity and abundance here too.

GRASSLAND

Grassland invertebrate communities did appear to differ in terms of reclamation method and successional stage. However some of these differences are subtle and without formal statistical comparison only tentative conclusions can be drawn from the results. The naturally regenerated grassland appears to have the most diverse invertebrate community, in part due to the capture of a grasshopper (*orthoptera*) and harvestmen (*opiliones*). However the overall number of invertebrates is less than in the reclaimed grassland. A possible factor driving this observation is increased bird predation in short sward naturally regenerated grassland. In a study of starling (*Vanellus vanellus*) invertebrate feeding behaviour, it was found that the birds were much more effective at finding invertebrates in short sward grass as opposed to longer sward habitats (Devereux et al., 2004). Conservation advice asserts that sward height is critical for some invertebrate species living in lowland grassland, and the habitat management should reflect this (Buglife, 2011). Whether sward height is a critical variable controlling invertebrate abundance at these sites is unknown, but it could be the focus of further investigation, and one that may be undertaken by local citizen scientists.

The developing scrub within the reclaimed grassland has a negative effect on the abundance and species richness of the invertebrate fauna. The invertebrate orders recorded in the scrub are similar to the reclaimed grassland, but with reduced abundances in each class and the notable absence of mollusc records. The lack of molluscs in the scrub habitat is surprising, as scrub was found to support a diverse range of mollusc species in previous studies (Chatfield, 1972). However the pitfall trap method has been shown to be a poor method of estimating mollusc species richness and diversity (Uys et al., 2010). Therefore the results of this study are likely to be an underestimation of the true number and diversity of terrestrial molluscs at both sites. The overall reduced invertebrate diversity and abundance found in the scrub suggests that scrub encroachment is reducing the grassland invertebrate diversity. However when looking at the individual species using the scrub habitat, it is clear that it is adding to the overall site diversity; this will be addressed in section 4.8.

A number of different sampling approaches would be advised if repeating this study. Increasing the number of pitfall traps from three to five would provide a better estimate of invertebrate richness and diversity according to a study by (Brandle et al., 2000). Difficulties were found when setting the pitfall traps due to the shallow soil profile, which at times meant that the pitfall trap was set in a less than ideal position. Therefore if setting pitfall traps in these conditions again, a mattock would be beneficial for breaking up base rock and spoil substrate. Carabid beetles are unlikely to be properly represented in these results because the trapping was carried out in August, a poor month for trapping this taxa because the majority of species are in larva form during that time (Godfrey, A, pers com). If a similar study were to be undertaken in the future, hand sorting through soil cores would better estimate soil and ground dwelling invertebrate diversity and richness (Smith et al., 2008)

Areas of uncertainty exist in this element of the study because no invertebrate records exist for the site in its pre-reclamation state. Ideally a Before/After Control Impact 'BACI' would have increased the explanatory power of this study, but due to circumstances this was not possible. It is therefore recommended that in the future an invertebrate site survey is carried out before colliery reclamation, to enable a multi taxa BACI study to be undertaken in the future.

4.8 Site Evaluation for Invertebrates

This element of the study aimed to determine if Fitzwilliam and Upton have retained and defined habitats that are of interest for invertebrate conservation. The ISIS reports from the inventories were used to determine if the sites support rich and specialised invertebrate assemblages.

The number of invertebrate records obtained through the different sources showed that web-based photographic recording by amateurs can effectively complement a survey carried out by a trained ecologist. The benefits of this approach to recording are that it costs little in terms of time and support, but it generates valuable data. Therefore iSpot or other web based photographic recording schemes should be promoted in areas where natural history records are lacking.

The ISIS results found no invertebrate assemblage in a favourable condition for common standards monitoring, however with greater sampling effort some of these assemblages may become favourable. Common standards monitoring is the protocol used by Natural England for assessing and monitoring protected sites such as SSSIs (Rose, 2006). ISIS requires between 3% and 19% of the national species pool to be present within a habitat on a site to generate a favourable index (Drake et al., 2007). It is worth noting therefore that the rich flower resource at Upton may become suitable for CSM with additional sampling, as 5% of the national invertebrate species pool associated with this habitat was identified there.

UPTON

In addition to existing invertebrate records at Upton, a further 75 invertebrate species were added to the site inventory by this study. In total 102 invertebrate species have now been recorded at Upton. Using ISIS to create assemblages from the existing and new records generated by this study has enabled a comparison of what was known about the site before and after this survey. The additional species recorded by this study have added two specific assemblage types and two broad assemblage types to the site assemblage list, whilst increasing the rarity and richness of assemblages already coded for in the existing inventory. The representation scores of the broad assemblage types have changed little in the order of significance after the more extensive survey. This suggests that the grassland and scrub matrix and open water are the most important habitat types for invertebrates on this site.

Grasslands and Scrub

This rich flower resource specific assemblage type was generated by the 11 species of hymenoptera at Upton. The invertebrate assemblage was mainly constituted of bumblebees and mining bees. This implies that Upton is already providing good foraging and nesting opportunities in order to support a diverse group of bees. Parallels can be drawn between the hymenoptera of other ex colliery sites reclaimed in a similar way to Upton, particularly Bishops Hill in Warwickshire where the site is known to have been extensively landscaped in the 1980s and is now an example of flower rich limestone grassland (Falk, 2006). Falk (2006) found over 100 species of hymenoptera, including nationally and regionally rare species, at this site. Only a limited range of bee species could be focused on by this study, due to the scope of the multi-taxa research. However in light of the hymenoptera records generated by this study and the findings of the Bishops Hill survey, it is recommended that further survey of bees should be carried out at Upton by a qualified hymenopterist.

There were a number of invertebrates captured in the short open sward grasslands upon the calcareous and spoil rich substrate. The open short sward specific assemblage code was designated by the yellow meadow ant (*Lasius flavus*) and wall brown butterfly (*Lasiommata megera*). The wall brown butterfly population is currently in decline in the UK, and its continued presence at Upton should be encouraged with habitat management sensitive to their needs. The yellow meadow ant has fairly specific habitat requirements, such as a low vegetation sward height to allow sunlight to warm their nests and low disturbance by livestock and farm machinery (DSTI, 2010).

Sampling in the open short sward at Upton also resulted in finding invertebrates typical of unshaded early successional mosaic and scrub heath habitats. Important species found in this habitat are the locally uncommon mottled grasshopper (*Myrmeleotettix maculatus)* and the adonis ladybird (*Adonia variegata)* which is shown in Appendix C. The impeded vegetation succession due to the substrate and the grazing by rabbits has provided ideal conditions for bare-ground loving invertebrates. This should be capitalised upon in any conservation management. The scrub that is growing in this area is a concern because if left unmanaged and left to proliferate, will begin shading and changing the flora and invertebrate communities. However this does not imply that all scrub should be cleared from the site, as the discovery of the locally distributed garden chafer beetle, a SAT coded scrub heath and moorland species, implies it is a habitat of intrinsic conservation interest. Added to this observation, some species, such as the gatekeeper butterfly (*Pyronia tithonus)* and the solitary mining bee (*Andrena clarkella),* are also suggested to be important indicators of this habitat in ISIS. Therefore to maintain the current level of diversity in the early successional mosaic, selective coppicing should take place and low intensity grazing by rabbits should be encouraged.

It appears that many of the locally important invertebrate species found at Upton require patches of bare-ground. Whilst this habitat is currently well represented at the site, management plans should make provisions for creating and maintaining it. The motorcycle activity on site is seen as anti-social behaviour by other park users. However in some areas of the park the bikes are creating useful bare-ground habitats which are enjoyed by the invertebrates. Habitat management guidelines suggest that a controlled disturbance by vehicles should be encouraged in most terrestrial habitats (Kirby, 2001). Therefore it may be beneficial for conservation of ruderal plants and bare-ground loving invertebrates if some areas of the site were assigned as suitable for motorcycles. This action may alleviate unwanted disturbance to areas of the site, such as the limestone grassland and the pathways which the public use.

Woodland

In the site inventory a number of invertebrates were considered woodland specialists by ISIS. These included the brimstone butterfly (*Gonepteryx rhamni)*, birch shield bug (*Elasmostethus interstinctus)*, forest shield bug (*Pentatoma rufipes)* and the green lacewing (*Chrysopa carnea)*. All of these species are widespread throughout the UK and in the county of West Yorkshire, and therefore are of little conservation concern. However, the brimstone butterfly is an asset to the site and its main food plant buckthorn should be encouraged to grow in the woodland rides. The poor representation of this invertebrate assemblage may be in part due to a reduced sampling effort which is attributed to the researcher's lack of expertise of sampling in this type of habitat.

Mineral marsh & Open water

These freshwater assemblage codes were generated primarily from records obtained from the local records centre, and a few additional discoveries from pond netting. It is already known that Upton supports an important assemblage of dragonflies. The small pond was found to be in the best condition for invertebrates at Upton, and the majority of the pond netted invertebrate records were obtained from here. In order to improve the freshwater invertebrate diversity in the main fishing pond, the banking needs to be planted with more marginal flora. Translocating some of the marginal plants from the other diverse and rich ponds of the site may prove effective at boosting the diversity of the fishing pond.

The parasitic wasp *Exephanes ischioxanthus*, a rare species in Yorkshire, was found in marginal vegetation at Upton and is shown in Appendix C. The species account suggests that food plants of the host caterpillar are *Deschampsia cesptiosa, Arrhenatherum elatius* and *Festuca arundinacea,* whilst adding that railway embankments and heath appear to be a favoured habitat of *Exephanes ischioxanthus* (Zoologischen Staatssammlung München, 1977). All three of these plant species have been recorded at Upton in 2010 (Ridealgh, pers com.). The host caterpillar the cloaked minor moth (*Mesoligia furuncula*) feeds on the inside stems of these plants (Flemish Entomological Society, 2011). It is likely to be presented at Upton due to the close proximity of a 1 km record to the site, but light trapping during the months of August and September will be required to confirm its presence at Upton. The behaviour of the *Exephanes ischioxanthus* specimen captured in this study suggests it was hunting for a host caterpillar within the marginal vegetation surrounding the recently disturbed drainage channels. Based on the match with habitat preferences and host food plants it may tentatively be concluded that *Exephanes ischioxanthus* is resident at Upton and is unlikely to be a passing vagrant. Therefore, because of the rarity of this species, it would be advisable to ensure *D. cesptiosa* and *A. elatius* continue to flourish in the areas of marginal vegetation to effectively conserve both host and parasite in this case. Management could be achieved by removing competitive plants around the species or by assisted seed dispersal.

Conclusions

To conclude, Upton Country Park is of local and county importance for invertebrate conservation. The combination of site life history and exposed Permian limestone geology makes this a very rich site in terms of available niches for invertebrates. Maintaining and improving management of the grasslands should be a priority if the invertebrate interest is to be retained at this site for years to come.

Further invertebrate survey is recommended at Upton, especially of the hymenoptera which could be used to ascertain if the grassland on the Permian magnesian limestone should be included in Common Standards Monitoring. This may lead to Upton Country Park being notified as a protected site in the future.

FITZWILLIAM

A total of three specific assemblage types were coded for at Fitzwilliam, which indicates there is an intrinsic invertebrate conservation interest at this site. ISIS also coded six broad assemblage types, with three of them generating rarity values. In comparison with Upton, fewer invertebrates were recorded, but they generated a comparable ISIS report.

Grassland & Scrub

The rich flower resource code was solely generated by the bumblebee species recorded, which account for 3.3% of the national species pool for this assemblage type. This assemblage is not diverse enough to warrant Common Standards Monitoring, however it may be suitable for other national monitoring such as the Bumblebee Conservation Trust's Beewalk, in which the survey methodology used in this thesis was adapted. The discovery of a locally distributed cuckoo bumblebee, *Bombus campestris,* at Fitzwilliam indicates that the site supports a good population of its host *Bombus lapidarius*. Therefore this habitat should have appropriate management applied to ensure that the wildflowers used for forage are not shaded out by faster growing long grasses such as *Festuca* species*.* The researcher recommends a two year rotational cutting at the end of autumn, to ensure that invertebrate assemblages are not impacted by this method, as described in (Kirby, 2001).

The broad invertebrate assemblage type Grassland & Scrub matrix was the most species rich type of all assemblages coded for. Butterflies and other day flying lepidoptera, all coded for in this BAT were found to be abundant and diverse at Fitzwilliam. One of the species the site supports, the small heath butterfly is one of the grassland specialist butterflies known to be in decline and appears on the UK Biodiversity Action Plan. Many of the grassland specialist butterflies are in decline, with a reported loss of 50% in abundance over the last fifteen years (van Swaay et al., 2008). The discovery of eleven species of grassland specialist lepidoptera suggests that Fitzwilliam is of specific interest to invertebrate conservation.

Orthoptera are well represented in the assemblages at Fitzwilliam, with five species all being found in abundance within the grassland and scrub matrix. The management of this habitat is unstructured and undertaken by the generosity of a local farmer. The early cutting of key grasslands could seriously impede the Orthopteran diversity and richness. Conservation evidence indicates that leaving grassland uncut till autumn improves orthoptera survival and proliferation (Gardiner et al., 2011). Therefore improved liaison between stakeholders, and those undertaking conservation work would be advisable to ensure that unintended damage to the invertebrate ecology is avoided.

The unshaded grassland mosaic produced a couple of locally restricted records such as the pill woodlouse (*Cylisticus convexus)* and the attractive iridescent beetle (*Poecilus versicolor).* There appears to be a good selection of ground dwelling invertebrates here, all of which require an unshaded habitat to either hunt or to warm up their bodies, such as the abundant orthoptera at the site. The orthoptera assemblage at Fitzwilliam is also an important coloniser of this habitat, as the locally restricted mottled grasshopper (*Myrmeleotettix maculatus)* was found in abundance on a spoil rich banking. However in some areas of the site there is risk of shading out of this habitat by the fast growing planted trees. This should be addressed with selective thinning and coppicing to ensure these important assemblages are not lost with increasing vegetation succession pressures. Encouraging grazing of the grassland by rabbits should maintain a patchy grassland mosaic and control the vegetation succession. It has been suggested that allowing scrub to persist where rabbit warrens are already situated is a good way of encouraging rabbit populations to grow (Kirby, 2001).

Woodland

The arboreal canopy assemblage code was determined solely by the heteroptera interest at the site. The species recorded here are widespread and have no particular rarity value. This may be because it is still a new habitat and needs additional time to assemble a more diverse and specialised fauna, or it could be due to the major coppicing event that took place in the 1980s. A lack of sampling effort and researcher knowledge of woodland invertebrate sampling techniques means this study cannot come to a conclusion on the current status of this habitat for invertebrates, but it is unlikely that the woodland is of intrinsic conservation interest.

Open water and mire

Fitzwilliam appears to contain a rich and diverse freshwater community, which is accounted for by the number of species of odonata on the site. Most of the odonata records were provided by the local records centre, and around half of these species were observed by the researcher during the survey in 2010. It may be that the odonata were present on the site before reclamation. The aerial photography in Appendix B shows that settling ponds were historically situated close to the location of the current fishing pond seen in Figure 8. Therefore it could be that the diverse species of odonata which initially populated these ponds before reclamation took place moved to the newly excavated fishing pond. Without records from this time period, this hypothesis cannot be tested. It is thought that flooded mineral workings provide a rich habitat for generalist and rare species of invertebrates (Kirby, 2001). The destruction of the existing settling ponds and creation of the fishing pond is likely to have reset the ecological succession in these habitats and is not desirable for invertebrate conservation. However at Fitzwilliam, this approach appears to have allowed interesting invertebrate assemblages to proliferate. A more stratified sampling approach should be adopted to determine if this habitat supports other rarities or interesting species assemblages.

Conclusions

Fitzwilliam has large expanses of flower rich grasslands, pockets of early successional vegetation and bare ground. These features are undoubtedly the most important elements of the site, and will require careful management if the specialised invertebrate communities that are currently resident in these habitats are to continue being a part of the site inventory. Vegetation cutting already occurs in the flower rich meadows, but this needs to be carried out on a schedule and in patterns that allow invertebrates to seek refuge from the disturbance. The freshwater lake is currently in good condition, with healthy marginal vegetation present that will only require monitoring at present.

Overall this site does not meet the invertebrate assemblage criteria for Common Standards Monitoring. However this site is of particular value to orthoptera and some species of grassland butterfly, and therefore sensitive habitat management should be carried out.

Further Recommendations

Using and interpreting the assemblage results given by the ISIS programme is a first step in indentifying potentially important habitats on a site. One area of programme improvement could be adding a layer of functionality specifically identifying potential Biodiversity Action Plan habitat when assemblages are diverse and rare enough. This would require existing BAP habitat invertebrate inventories to be created in order to generate the typical assemblages in each BAP habitat. This information may already exist in local record centres and amateur naturalist's field notebooks. Therefore it may just be a case of collating records, and using principle component analysis to discover the indicator invertebrate species needed to generate a BAP habitat code when they appear as a group. This would aid conservation groups and local records centres to highlight which habitats are in need of protection based upon the assemblages found there.

4.9 Participants Environmental Awareness

To end this discussion, it was felt that, besides the scientific results presented in this study, there was an important social impact on the participants. It is known that there are many perceived and hidden benefits available to volunteers who take part in citizen science projects; for example it has been shown that an increased level of personal contact with wildlife in green spaces alleviates mental health issues and generally improves personal wellbeing (Maller et al., 2006). Feedback from the participants in this study suggest that the knowledge transfer between researcher and volunteer has made a positive impact on their perceptions of wildlife and had sparked an increased interest in natural history as shown by the quote given by Paul Raikes. He has been inspired to setup a community photography group, which now meets on a regular basis to photograph wildlife on the park and in the local area around Upton.

"I've had a great day, the insect walk has given me a purpose to be outside and enjoy the park in other ways"

It may be that the legacy of this study is an expansion of the participants' environmental awareness and an increased appreciation for the invertebrates that had passed them by without notice, before taking part in this study. A recent study of a bird themed citizen science project showed no effect of the study on the environmental attitude of the participants (Brossard et al., 2005). Whilst this may be the case in a conventional citizen science project, it is the author's opinion, after the experience obtained during this study, working with local residents on a one-to-one basis does improve environmental awareness of the fauna inhabiting their local green space. The improved local knowledge and engagement is likely to support improved site management.

5. CONCLUSIONS

The aims and objectives of this study were satisfied by the results taken during this research. It has shown for the first time that citizen science methods can work on a local scale, and that volunteers from deprived communities can be inspired to undertake surveys of invertebrates. The participatory mapping has for the first time successfully reconstructed the reclamation history of brownfield sites The multi-taxa invertebrate assemblages recorded by this study has for the first time determined the conservation importance of a reclaimed colliery site based upon ISIS generated assemblages. Each study objective will be individually concluded below.

Objective 1: Discover reclaimed colliery site history using participatory mapping methodologies with local residents

The PGIS and RAP-GIS workshops proved very effective at elucidating the history of reclamation at both of the sites studied here. Historical information pertaining to the sites reclamations gathered during these events proved invaluable for study design. This information was particularly useful in determining which areas of the sites were allowed to re-vegetate naturally. The information gained by this research proved crucial in the design phases of this investigation.

Objective 2: Design and implement citizen science based invertebrate monitoring surveys. Species assemblages in naturally regenerated and reclaimed habitats are to be compared.

Volunteers were recruited, trained and successfully carried out the invertebrate monitoring surveys, adding a considerable amount of data to this study. The data collected suggests that bumblebee and butterfly community composition changes depending on the reclamation type used, and may be the result of a vegetation dominance of certain floral species. Grasshoppers appear to respond to coloured objects placed into their habitats and the data is tentatively interpreted that blue objects are favoured out of a range of primary colours.

Objective 3: Describe the invertebrate assemblages that occur on reclaimed colliery sites and assess the quality of assemblage and habitat they are found in.

Invertebrates were sampled from a total of 14 invertebrate orders, making this a multi taxa study. Invertebrate assemblages were generated from the inventories using the ISIS programme, and discussed in terms of their rarity and representation. The reclaimed colliery sites studied here have developed specialised invertebrate communities in the flower rich grasslands, open mosaic scrub matrix and lakes. The specialised and sometimes uncommon species found at these sites are likely to have taken refuge in the time when natural re-vegetation was allowed to take place. Sparing areas of the sites from landscaping may have allowed these specialised invertebrates to persist at these sites. Management will be required to maintain an early successional vegetation structure to accommodate these specialist assemblages into the future.

APPENDIX A: UPTON AERIAL PHOTOGRAPHS 1980 – 2011

Figure 18: Aerial photograph of Upton colliery in 1980. Natural regeneration is visible across the whole site. Areas of natural regeneration surviving today are highlighted in red. (Photo courtesy of Wakefield Town Council, 1980)

Figure 19: Aerial photograph of Upton Country Park in 2011. Note the natural regenerative habitats surviving are highlighted in red. (Photo courtesy of Google, 2011)

APPENDIX B: FITZWILLIAM AERIAL PHOTOGRAPHS, 1980 – 2011

Figure 20: 1980 aerial photo of Hemsworth Colliery. The red area is the woodland which naturally regenerated on the disused railway sidings. (Photo courtesy of Wakefield Town Council, 1980)

Figure 21: Aerial photo of Fitzwilliam Country Park in 2011. A stark contrast to the 1980's landscape, with natural regenerative woodland well developed in the red zone. (Photo courtesy of Google, 2011)

APPENDIX C: RECORDED NOTABLE INVERTEBRATE SPECIES

COLEOPTERA

The adonis ladybird *Adonia variegata* was found in a remnant of the original spoil heathland habitat at Upton. This ladybird is classified as *Nationally Scarce b* because it is locally distributed in the North of England and prefers a short sward with r-selected vegetation to inhabit (Hyman, 1992). It appears to be locally abundant within the small spatial area it currently inhabits, therefore management to maintain this habitat should be strongly considered. The ground beetle *Amara ovata* was found at Fitzwilliam in a pitfall trap, a search on the National Biological Network (NBN) gateway website suggests this beetle has a patchy distribution in Yorkshire, and is previously unrecorded in this 10 km square. However it has a widespread distribution throughout the rest of the UK (Luff, 2007).

ORTHOPTERA

A number of notable Orthopteran species were found at these sites, indicating their habitat importance for this invertebrate group. The lesser marsh grasshopper *Chorthippus albomarginatus* was found at Upton, a new 10 km record pushing the known UK distribution further northwest. It is thought that this species is now becoming more tolerant of drier grasslands (Evans & Edmondson, 2007), which may explain its presence at Upton Country Park. This specimen was identified by an invertebrate expert from the photograph that was initially posted on the iSpot community website; this is shown in Figure 22.

Figure 22: Lesser Marsh Grasshopper (*Chorthippus albomarginatus*) (Photo Credit: K. Rich 2010)

The mottled grasshopper *Myrmeleotettix maculatus* was present on both sites in short sward heath that have been untouched by reclamation and is shown in Figure 23. This small species is locally distributed throughout the UK, with a strong preference for short sward or bare ground (Evans & Edmondson, 2007). The Yorkshire distribution of this grasshopper suggests that more effective conservation of its habitat should be undertaken, with many heaths being threatened by development or successional scrub encroachment.

Figure 23: Mottled Grasshopper (*Myrmeleotettix maculatus*) found at Upton (Photo credit: J. Bowers 2010)

The slender groundhopper *Tetrix subulata* was discovered at Fitzwilliam and Upton Country Parks in April 2011. The habitat preference of this species is in the short grass and bare-ground surrounding ponds and damp patches. Surprisingly the specimen shown in Figure 24 was found in a dry area, quite a considerable distance from the main pond. The known distribution of this species is patchy and considered local. However with the discovery of these records means its distribution will need to be re-appraised. A recent study has suggested that a lack of Yorkshire records may be attributed to recorders overlooking potential habitat (Heads & Chesmore, 2008).

Figure 24: The locally distributed Slender Groundhopper (*Tetrix subulata*) found April 2011 at Fitzwilliam Country Park. Note the extended wings past the abdomen (Photo credit: K Rich 2011).

HYMENOPTERA

A small number of bees were caught at the sites, with Upton being the most fruitful for solitary bees. Upton provided better habitat opportunities for these species due to the exposed substrate and bare ground being available for the bees to nest in. One notable discovery was of *Lasioglossum morio* (Figure 25) which is uncommon in Yorkshire. After an interrogation of past records this species appears to have been in decline or at least been under-recorded in the years 1920s to the 1990s. A few records of this species are now appearing and this particular find is adding to the body of evidence that this species is in the process of recolonising. However due to the lack of disturbance to the naturally reclaimed habitat at Upton it is likely that the site acted as a refuge during this period and went un-recorded by the local Hymenopterist.

Figure 25: An uncommon solitary mining bee to Yorkshire (*Lasioglossum morio*) discovered in the Railway cutting at Upton (Photo credit: Tristan Bantock 2009)

A very uncommon Ichneumon wasp was discovered at Upton Country Park after sweeping vegetation around one of the recently excavated drainage ponds. This record of *Exephanes ischioxanthus* is only the fourth for Yorkshire, and has not been seen in the county for nearly 30 years. The markings on this wasp are very distinctive and are shown in Figure 26. Ichneumon wasps are an under recorded group of invertebrates in the UK, so the distribution of these invertebrates are unknown. However it is likely that this wasp is uncommon or locally distributed at best, which adds weight to the importance of this site for invertebrates.

Figure 26: A rare Ichneumon wasp (*Exephanes ischioxanthus*) in Yorkshire found at Upton Country Park (Photo credit: Y Engmann 2010)

APPENDIX D: SITE INVENTORIES OF INVERTEBRATE SPECIES

Upton

Order	Species
Araneae	*Araneus diadematus*
	Araneus quadratus
	Dysdera crocata
Chilopoda	*Lithobius forficatus*
Coleoptera	*Adonia variegata*
	Notiophilus biguttatus
	Oedemera nobilis
	Oulema rufocyanea
	Phyllopertha horticola
	Propylea quattuordecimpunctata
	Pterostichus madidus
	Pterostichus niger
Demaptera	*Forficula auricularia*
Diptera	*Bibio marci*
	Bombylius major
	Episyrphus balteatus
	Melanostoma mellinum
	Platycheirus scambus
	Sphaerophoria scripta
	Syrphus ribesii
	Volucella bombylans
	Volucella pellucens
Hemiptera	*Dolycoris baccarum*
	Elasmostethus interstinctus
	Hydrometra stagnorum
	Palomena prasina
	Pentatoma rufipes
Hymenoptera	*Andrena clarkella*
	Andrena fulva
	Apis mellifera
	Bombus hypnorum
	Bombus lapidarius
	Bombus lucorum
	Bombus pascuorum
	Bombus pratorum
	Bombus terrestris
	Exephanes ischioxanthus
	Halictus tumulorum
	Inachis io
	Lasioglossum morio
	Lasius flavus
	Lasius niger
	Myrmica rubra
	Myrmica ruginodis
	Pontania proxima
	Trypoxylon attenuatum
Isopoda	*Armadillidium nasatum*
	Armadillidium vulgare
	Asellus aquaticus
	Oniscus asellus
	Philoscia muscorum

Fitzwilliam

Order	Species
Araneae	*Araneus diadematus*
	Tibellus oblongus
Coleoptera	*Amara ovata*
	Poecilus versicolor
	Pterostichus madidus
	Pterostichus melanarius
	Pterostichus niger
	Sitona lineatus
Diptera	*Lucilia ampullacea*
	Eristalis arbustorum
	Melanostoma mellinum
	Scaeva pyrastri
	Sphaerophoria scripta
Hemiptera	*Acanthosoma haemorrhoidale*
	Chilacis typhae
	Elasmucha grisea
	Kleidocerys resedae
	Lygocoris contaminatus
	Malococoris chlorizans
	Megacoelum infusum
	Palomena prasina
	Pantilius tunicatus
	Pentatoma rufipes
	Philaenus spumarius
	Salicarus roseri
	Tritomegas bicolor
Hymenoptera	*Bombus campestris*
	Bombus hortorum
	Bombus lapidarius
	Bombus lucorum
	Bombus pascuorum
	Bombus pratorum
	Bombus sylvestris
	Bombus terrestris
	Lasius niger
	Myrmica rubra
	Myrmica ruginodis
Isopoda	*Cylisticus convexus*
	Oniscus asellus
	Philoscia muscorum
	Porcellio scaber
	Trichoniscus pygmaeus

Upton	
Order	**Species**
Lepidoptera	*Celastrina argiolus*
	Aglais urticae
	Anthocharis cardamines
	Aphantopus hyperantus
	Autographa gamma
	Coenonympha pamphilus
	Gonepteryx rhamni
	Lasiommata megera
	Maniola jurtina
	Pieris brassicae
	Pieris napi
	Polygonia c-album
	Polyommatus icarus
	Pyronia tithonus
	Rivula sericealis
	Zygaena filipendulae
	Zygaena lonicerae
Megaloptera	*Sialis lutaria*
Mollusca	*Arion distinctus*
	Arion intermedius
	Arion subfuscus
	Cochlicopa lubrica
	Deroceras panormitanum
	Discus rotundatus
	Limax maximus
	Lymnaea peregra
	Lymnaea stagnalis
	Monacha cantiana
Neuroptera	*Chrysopa carnea*
Odonata	*Aeshna cyanea*
	Aeshna grandis
	Aeshna mixta
	Anax imperator
	Coenagrion puella
	Enallagma cyathigerum
	Ischnura elegans
	Libellula depressa
	Libellula quadrimaculata
	Orthetrum cancellatum
	Pyrrhosoma nymphula
	Sympetrum striolatum
Orthoptera	*Chorthippus albomarginatus*
	Chorthippus brunneus
	Chorthippus parallelus
	Myrmeleotettix maculatus
	Tetrix subulata

Fitzwilliam	
Order	**Species**
Lepidoptera	*Aglais urticae*
	Anthocharis cardamines
	Aphantopus hyperantus
	Coenonympha pamphilus
	Inachis io
	Lycaena phlaeas
	Maniola jurtina
	Ochlodes venata
	Pararge aegeria
	Pieris brassicae
	Pieris napi
	Pieris rapae
	Polyommatus icarus
	Pyronia tithonus
	Rivula sericealis
	Scotopteryx chenopodiata
	Thymelicus sylvestris
	Zygaena filipendulae
Mollusca	*Aegopinella pura*
	Arion ater
	Monacha cantiana
Odonata	*Aeshna grandis*
	Aeshna mixta
	Anax imperator
	Coenagrion puella
	Enallagma cyathigerum
	Ischnura elegans
	Lestes sponsa
	Libellula quadrimaculata
	Pyrrhosoma nymphula
	Sympetrum sanguineum
	Sympetrum striolatum
Orthoptera	*Chorthippus brunneus*
	Chorthippus parallelus
	Myrmeleotettix maculatus
	Omocestus viridulus
	Tetrix subulata

References

Archer, M., 1993. Recorder's fourth report on the aculeate hymenoptera in Watsonian Yorkshire and the development of a quality scoring system. *Naturalist*, 118, pp.13-15.

ATC Citizen Science Working Group, 2006. *Citizen science: Overview of the basics*.

Audubon, 2011. *History of the Christmas Bird Count*. [Online] Available at: http://birds.audubon.org/history-christmas-bird-count [Accessed 2 March 2011].

Bäckman, J. & Tiainen, J., 2002. Habitat quality of field margins in a Finnish farmland area for bumblebees (Hymenoptera: Bombus and Psithyrus). *Agriculture, Ecosystems & Environment*, 89(1), pp.53-68.

Barker, G., 2000. Ecological recombinantion in urban areas: implications for nature conservation. In *Proceedings of a workshop held at the Centre for Ecology & Hydrology*. Monks Wood, 2000.

Baum, K., Haynes, K., Dillemuth, F. & Cronin, J., 2004. The Matrix Enhances the Effectiveness of Corridors and Stepping Stones. *Ecology*, 85(10), pp.2671-2676.

Benton, T., 2006. *Bumblebees*. London: HarperCollins.

Blair, R. & Launer, A., 1997. Butterfly diversity and human land use: Species assemblages along an urban gradient. *Biological Conservation*, 80, pp.113-25.

Brackertz, N., Zwart, I., Meredyth, D. & Ralston, L., 2005. *Community Consultation and the Hard to Reach. Concepts and Practiec in a Victorian Government*. [Online] Institute for Social Research Available at: http://www.sisr.net/cag/docs/HardtoReach_main.pdf [Accessed 22 June 2011].

Brandle, M., Durka, W. & Altmoos, M., 2000. Diversity of surface dwelling beetle assemblages in open-cast lignite mines in Central Germany. *Biodiversity and Conservation*, 9, p.1297–1311.

Brodie, L., 1996. *Bumblebee foraging preferences: Differences between species and individuals*. Aberdeen: University of Aberdeen.

Brossard, D., Lewenstein, B. & Bonney, R., 2005. Scientific knowledge and attitude change: The impact of a citizen science. *International Journal of Science Education*, 27(9), p.1099–1121.

BTO, 2009. *British Trust for Ornithology*. [Online] Available at: http://www.bto.org/aboutBTO/history.htm [Accessed 13 December 2010].

Buglife, 2011. *Buglife: Lowland Calcareous Grassland*. [Online] Available at: http://www.buglife.org.uk/conservation/adviceonmanagingbaphabitats/lowlandcalcareousgrassland [Accessed 28 August 2011].

Buglife, 2011. *Bumblebees in the UK*. [Online] Available at: http://www.buglife.org.uk/conservation/currentprojects/Species+Action/Big+bumblebee+hunt/Bumblebee+superfacts [Accessed 8 August 2011].

Buglife, 2011. *Neonicotinoid pesticides increasingly implicated in Honeybee mass poisoning incidents*. [Online] Available at: http://www.buglife.org.uk/News/newsarchive/News+Archive+2011/Neonicotinoid+pesticides+increasingly+implicated+in+Honeybee+mass+poisoning+incidents [Accessed 18 June 2011].

Butterfly Conservation, 2011. *Brimstone*. [Online] Available at: http://www.butterfly-conservation.org/butterfly/32/butterfly.html?butterflyid=6 [Accessed 20 May 2011].

Butterfly Conservation, 2011. *E Moth: Moths Count Update January 2011*. Circular. Butterfly Conservation.

Butterfly Conservation, n.d. *Woodland Butterflies: A brief guide*. Wareham: Butterfly Conservation.

Camina, M., 2004. *Understanding and engaging deprived communities*. London: The Home Office.

Campbell, J. & Hanula, J., 2007. Efficiency of Malaise traps and colored pan traps for collecting flower visiting insects from three forested ecosystems. *Journal of Insect Conservation*, 11, pp.399-408.

Chatfield, J., 1972. The natural history of Slapton ley nature reserve: V non-marine mollusca. *Field Studies*, 4, pp.579-88. [Accessed 27 Augustus 2011].

Cinderby, S., 2010. How to reach the 'hard-to-reach': the Development of Participatory Geographic Information Systems (P-GIS) for Inclusive Urban Design in UK Cities. *Area*, 42(2), p.239 – 251.

Clarke, P.J., 2002. Experiments on tree and shrub establishment in temperate grassy woodlands: Seedling survival. *Austral Ecology*, 27(6), pp.606-15.

Cook, D., 2002. 'Consultation for a change? Engaging users and communities in the policy process. *Social Policy & Administration*, 36(5), pp.516 - 531.

Cooper, C., Dickinson, J., Phillips, T. & Bonney, R., 2007. Citizen science as a tool for conservation in residential ecosystems. *Ecology and Society*, 12(2), p.11.

Cornell, 2007. *What is this, "Citizen Science"?* Ithaca: Cornell Lab of Ornithology.

Crossley, R., 1996. Using Diptera in assessing site quality, with particular reference to Empidoidea – a regional perspective. *Naturalist*, 122, p.155–7.

Crowder, D., Northfield, T., Strand, M. & Snyder, W., 2010. Organic agriculture promotes evenness and natural pest control. *Nature*, 466, p.109–112.

Cummins, K., Merritt, R. & Andrade, P., 2005. The use of functional feeding groups to characterize ecosystem attributes in selected streams and rivers in South Brazil. *Studies on Neotropical Fauna and Environment*, 40(1), pp.69-89.

Davidson, P., 1997. Reclamation of Watergate Colliery from public eyesore to public amenity. *Proceedings of the ICE - Municipal Engineer*, 121(3), p.122 –130.

Dennis, R., Sparks, T. & Hardy, P., 1999. Bias in Butterfly Distribution Maps: The Effects of Sampling Effort. *Journal of Insect Conservation*, 3(1), pp.33-42.

Department for Communities and Local Government, 2008. *Previously-developed land that may be available for Development: England 2007*. [Online] Available at: http://www.communities.gov.uk/publications/corporate/statistics/previouslydevelopedland2007 [Accessed 2 August 2011].

Dept for Communities and Local Government, 2007. *Regenerating the English coalfields - interm evaluation of the coalfield regeneration programmes*. Wetherby: Communities and Local Government Publications.

Dept for Communities and Local Government, 2008. *Previously-developed land that may be available for Development: England 2007*. London: HMSO.

Devereux, C., Mckeever, C., Benton, T. & Whittingham, M., 2004. The effect of sward height and drainage on Common Starlings Vanellus vanellus foraging in grassland habitats. *Ibis*, 146(2), p.115–122.

Dickinson, J., Zuckerberg, B. & Bonter, D., 2010. tizen Science as an Ecological Research Tool: Challenges and Benefits. *Annual Review of Ecology, Evolution, and Systematics*, 41, pp.49-172.

DirectGov, 2010. *The English Indices of Deprivation 2010*. [Online] Available at: http://www.imd.communities.gov.uk/ [Accessed 10 June 2010].

Drake, M., 2011. The Diptera of wet woodlands in Devon. *Diptersits Digest*, 19(1), pp.9 - 26.

Drake, C., Lott, D., Alexander, K. & Webb, J., 2007. *Surveying terrestrial and freshwater invertebrates for conservation evaluation: Natural England Research Report NERR005*. Sheffield: Natural England.

DSTI, 2010. *Defence Science & Technology Instiiute: Conservation*. [Online] Available at: http://www.dstl.gov.uk/pages/115 [Accessed 9 July 2011].

Durham Mining Museum, 2010. *1933 Colliery Year Book and Coal Trades Directory - Upton Colliery*. [Online] The Louis Cassier Co. Ltd Available at: http://www.dmm.org.uk/company/u1004.htm [Accessed 22 June 2011].

Eadie, R., 1948. Shrew-Mouse Predation during Low Mouse Abundance. *Journal of Mammology*, 29(1), pp.35 - 37.

Edwards, M. & Jenner, M., 2009. *Field Guide to the Bumblebees of Great Britian & Ireland*. Ocelli Ltd.

Edwards, M. & Williams, P., 2004. Where have all the bumblebees gone, and could they ever return? *British Wildlife*, June, pp.305-12.

Eeles, P., 2010b. *UK Butterflies*. [Online] Available at: http://www.ukbutterflies.co.uk/species.php?species=io [Accessed 27 August 2011].

Eeles, P., 2010. *UK Butterflies*. [Online] Available at: http://www.ukbutterflies.co.uk/species.php?species=icarus [Accessed 27 August 2011].

English Nature, 1998. *Brownfield Red Data: The values atrifical habitats have for uncommon invertebrates*. Oxford: English Nature.

Erler, S. & Lattorff, H.M.G., 2010. The degree of parasitism of the bumblebee (Bombus terrestris) by cuckoo bumblebees (Bombus (Psithyrus) vestalis). *Insectes Sociaux*, 57(4), pp.371-77.

Evans, M. & Edmondson, R., 2007. *A photographic guide to the Grasshoppers & Crickets of Britian & Ireland*. 1st ed. Kings Lynn: WildGuideUK.

Falk, S., 2006. The Modern Bee & Wasp Assemblages (Hymenoptera Aculeate) of Warwickshire's Calcareous Quarries and Spoilheaps, and the conservation issues facing them. *British Journal of Entomology and Natural History*, 19(1), pp.7-25.

Fitzpatrick, U. et al., 2007. Rarity and declines in bumblebess - A test of causes and correlates in the Irish fauna. *Biological Conservation*, 136, pp.185 -194.

Flemish Entomological Society, 2011. *Catalogue of the Lepidoptera of Belgium: Mesoligia furuncula ([Denis & Schiffermüller], 1775)*. [Online] Available at: http://webh01.ua.ac.be/vve/Checklists/Lepidoptera/Noctuidae/Mfuruncula.htm [Accessed 9 September 2011].

Fowles, A. & Alexander, K.K.R., 1999. The Saproxlic Quality Index: evaluating wooded habitats for the conservation of dead-wood Coleoptera. *Coleopterist*, 8(3), pp.121-41.

Fox, R. et al., 2011. Moths count: recording moths for conservation in the UK. *Journal of Insect Conservation*, 55, p.55–68.

Fox, R. et al., 2007. *The state of Britain's butterflies 2007*. Wareham, Dorser: Butterfly Conservation and the Centre for Ecology and Hydrology.

Freeman, S., 2009. *Towards a method for the estimation and use of averaged multispecies, as indicators of patterns of change in butterfly populations*. Wallingford: Centre for Ecology and Hydrology.

Frouza, J. et al., 2008. Interactions between soil development, vegetation and soil fauna during spontaneous succession in post mining sites. *European Journal of soil biology*, 44, p.109–121.

Gardiner, T., Gardiner, M. & Cooper, N., 2011. Grasshopper strips prove effective in enhancing grasshopper abundance in Rivenhall Churchyard, Essex, England. *Conservation Evidence*, (8), pp.31-37.

Gaskin, K. & Simth, J., 1995. *A new civic Europe? A study of the extent and role of volunteering*. London: The Volunteer Centre.

Ghosh, P., 2010. *BBC News*. [Online] Available at: http://www.bbc.co.uk/news/science-environment-10856523 [Accessed 2 March 2011].

Gilbert, O., 1989. *The Ecology of Urban Habitats*. London: Chapman & Hall.

Gillis, J., 1982. Substrate Colour-Matching Cues In The Cryptic Grasshopp Cirrcotettix Rabula rabula (REHN & HEBARD). *Animal Behaviour*, 30, pp.113-116.

Goulson, D., 2010. *Bumblebees: behaviour, ecology and conservation*. 2nd ed. Oxford: Oxford University Press.

Gross, K., Kalendra, E., Hudgens, B. & Haddad, N., 2007. Robustness and uncertainty in estimates of butterfly abundance from transect counts. *Population Ecology*, 49(3), pp.191-200.

Grześ, I., 2009. Ant species richness and evenness increase along a metal pollution gradient in the Bolesław zinc smelter area. *Pedobiologia*, 53, pp.65 - 73.

Haddad, N. et al., 2003. Corridor Use by Diverse Taxa. *Ecology*, 84(3), pp.609-615.

Harrison, A., 2004. *Monitoring and Re-use of Brownfield Land in England and Wales*. LandInform Ltd.

Harvey, P., 2000. The East Thames Corridor: a nationally important invertebrate fauna under threat. *British Wildlife*, (December), pp.91- 99.

Harvey, F., 2003. Developing geographic information inrafstructures for local government: the role of trust. *The Candian Geographer*, 47(1), pp.28-36.

Heads, S. & Chesmore, D., 2008. New Records of the Slender Ground-hopper Tetrix subulata from Yorkshire (Orthoptera: Tetrigidae). *British Journal of Entomology and Natural History*, 21, pp.243-46.

Heath, J., 1999. Why Save Orchids Under Threat? *Orchids Australia*, 11(6).

Hickman, C., 2011. *Woodland Trust: Natures Calender*. [Online] Available at: http://www.woodlandtrust.presscentre.com/News-Releases/Woodland-Trust-data-suggests-record-breaking-spring-for-Mother-Nature-85d.aspx [Accessed 26 August 2011].

Hill, M., 1996. *TABLEFIT version 1.0, for identification of vegetation types.* Huntingdon.

Hill, D., 2008. *Marketing Community Colleges: Reaching Hard to Reach Populations*. [Online] Available at: www.idea.gov.uk/idk/aio/398115 [Accessed 31 May 2011].

Holeca, M. & Frouza, J., 2005. Ant (Hymenoptera: Formicidae) communities in reclaimed and unreclaimed brown coal mining spoil dumps in the Czech Republic. *Pedobiologia*, 49, p.345—357.

Holl, K., 1996. The Effect of Coal Surface Mine Reclamation on Diurnal Lepidopteran Conservation. *Journal of Applied Ecology*, 33(2), pp.225-36.

Home, R., 2009. Land ownership in the United Kingdom: Trends, preferences and future challenges. *Land Use Policy*, 265, pp.103-08.

Hopkin, S., 1991. *A key to the Woodlice of Britian and Ireland*. Dorset: Field Studies Council.

Huntingford, F., 2003. A history of Animal Behaviour by a partial, ignorant and prejudiced ethologist. *Animal Behaviour*, (66), p.409–415.

Hutson, B., 1980. Colonization of Industrial Reclamation Sites by Acari, Collembola and Other Invertebrates. *Journal of Applied Ecology*, 17(2), pp.255-75.

Hyman, P., 1992. *A review of the scarce and threatened Coleoptera of Great Britain*. JNCC.

ISO, 1985. *Methods of biological sampling – Guidance on hand-net sampling of aquatic benthic macro-invertebrates. International Standard 7828*. Geneva: International Organisation for Standardization.

JNCC, 2011. *Trends in populations of selected species (butterflies)*. [Online] Available at: http://jncc.defra.gov.uk/page-4236 [Accessed 1 August 2011].

Jones-Walters, L., 1994. *Keys to the families of British Spiders*. Preston Montford: Field Studies Council.

Kadas, G., 2006. Rare invertebrates colonising green roofs in London. *Urban Habitats*, 4(1), pp.66-86.

Kevan, P., 1972. Floral colors in the high arctic with reference to insect–flower relations and pollination. *Canadian Journal of Botany*, 50, pp.2289-316.

Key, R., 2000. Bare ground and the conservation of invertebrates. *British Wildlife*, (February), pp.183 - 190.

Kindt, R., Van Damme, P. & Simons, A., 2006. Tree diversity in western Kenya: using profiles to characterise richness and evenness. *Biodiversity and Conservation*, 15, p.1253–1270.

Kirby, P., 2001. *Habitat Management for Invertebrates: A Handbook*. Sandy: Royal Society for the Protection of Birds.

Knight, M. et al., 2005. An interspecific comparison of foraging range and nest density of four bumblebee (Bombus) species. *Molecular Ecology*, 14(6), pp.1811-20.

Laidler, G., Shirley, J. & Nickels, S., 2004. Negotating Research Relationships - A draft guide for researchers. In *Proceedings 14th Inuit Studies Conference*. Cagary, 2004. University of Calgary.

Lawton, J.H. et al., 2010. *Making Space for Nature: A review of England's Wildlife Sites and Ecological Network*. Department for Environment, Food and Rural Affairs.

Lepczyk, C., 2009. Symposium 18: Citizen Science in Ecology: the Intersection of Research and Education. The Increasing Acceptance, Role, and Importance of Citizen Science in Ecology., 2009. Symposium reports from the 2008 ESA annual meeting.

Lewington, R., 2003. *Pocket Guide to the Butterflies of Great Britain and Ireland*. British Wildlife Publishing Ltd.

Liebold, M., 1996. A Graphical Model of Keystone Predators in Food Webs: Trophic Regulation of Abundance, Incidence, and Diversity Patterns in Communities. *The American Naturalist*, 147(5), pp.784-812.

Lovell, S., Hamer, M., Slotow, R. & Herbert, D., 2009. An assessment of the use of volunteers for terrestrial invertebrate biodiversity surveys. *Biodiversity Conservation*, 18, p.3295–3307.

Luff, M., 2007. *The Carabidae (ground beetles) of Britian and Ireland*. Shrewsbury: Field Studies Council.

Lunn, J., Wild, M. & Rotherham, I., 1995. Pioneer Vegetation Communities from the Coal Measures of South Yorkshire, England: 2 Vulpia bromoides-Arenaria serpyllifollia poineer community. In *Internation Urban Ecology Review*., 1995.

Lunn, J., Wild, M. & Rotherham, I., 2005. Pioneer Vegetation Communitieson from the Coal Measures of Yorshire, England: 1. Agrostis stolonifera-Holcus lanatus pioneer community. *International Urban Ecology Review*, 1, pp.38 -44.

Lyon, L., 2009. Open Science at Web-Scale: Optimising Participation and Predictive Potential: Consultative Report. p.2009.

Maddock, A, 2008. *UK Biodiversity Action Plan; Priority Habitat Descriptions*. [Online] Available at: http://www.ukbap.org.uk/library/UKBAPPriorityHabitatDescriptionsfinalAllhabitats20081022.pdf [Accessed 1 August 2011].

Magurran, A., 1988. *Ecological diversity and its measurement*. Princeton University Press.

Magurran, A., 2004. *Measuring Biological Diversity*. 2nd ed. Oxford: Blackwell Publishing.

Maller, C. et al., 2006. Healthy nature healthy people: ‘contact with nature’ as an upstream health promotion intervention for populations. *Health Promotion International*, 21(1), pp.45 - 54.

Massini, P., Roberts, J. & Hitchcock, G., 2006. *Planning for Inverterbrate Biodiversity*. Peterborough: Buglife: The Inverterbrate Conservation Trust.

McGuinness, S., 1999. *Treatment of Acid Mine Dischage*. Research Paper. London: House of Commons.

McKenney, M., 2010. *Native bees, honeybees and pollination in Oregon cranberries*. [Online] Available at: http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/20602/McKenney_Melissa.pdf?sequence=3 [Accessed 8 January 2011].

Meffe, G. & Carroll, C., 1996. *Principles of Conservation Biology*. 2nd ed. Sunderland: Sinauer Associates.

Micheneau, C. et al., 2010. Orthoptera, a new order of pollinator. *Annals of Botany*, 105(3), pp.355-64.

Midlothian Council, 2011. *The Bumblebee Conservation Trust's BeeWalk*. [Online] Available at: http://www.midlothian.gov.uk/info/200134/biodiversity/412/biodiversity_projects/3 [Accessed 10 March 2011].

Miller, L., 1957. Tracing Vole Movements by Radioactive Excretory Products. *Journal of Mammalogy*, 38(1), pp.132-36.

National Council for Voluntary Organisations, 2010. *UK Giving 2010: An overview of charitable giving in 2009/2010*. Financial Review. London: National Council for Voluntary Organisations Charities Aid Foundation.

Nelson, M., 2007. Butterflies (Papilionoidea and Hesperioidea) as potential ecological indicators of riparian quality in the semi-arid western United States. *Ecological Indicators*, 7(2), pp.469-480.

Oates, M., 2011. Summer Souls. *National Trust Magazine*, May. pp.48 - 51.

Office of the Deputy Prime Minister, 2005. *Planning Policy Statement 9: Biodiversity & Geological Conservation*. Norwich.

Open University, 2010. *iSpot*. [Online] Available at: http://www.ispot.org.uk/ [Accessed 7 September 2011].

Osbourne, J. et al., 1999. A landscape scale study of bumble bee foraging range and constancy, using harmonic radar. *Journal of Applied Biology*, 36, pp.519- 533.

Oxford, G. & Scott, A., 2003. The Spider fauna of Askham Bog, York, and the assessment of conservation value. *Naturalist*, 128, pp.157-70.

Pocock, M., Evans, D., Straw, N. & Polaszek, A., 2011. The Horse-Chesnut Leaf-miner and its parasitoids. *British Wildlife*, (June), pp.305 - 131.

Pollard, E., Hall, M. & T, B., 1986. *Monitoring the abundance of butterflies 1976–1985. Research and Survey in Nature Conservation Series*. Peterborough: Research and.

Pollard, E. & Moss, D., 1995. Historical records of the occurrence of butterflies in Britain: examples showing associations between annual number of records and weather. *Global Change Biology*, 1(2), pp.107 - 113.

Pollard, E. & Yates, T.J., 1993. *Monitoring butterflies for ecology and conservation*. London: Chapman & Hall.

Pollet, M., 2001. Dolichopodid biodiversity and site quality assessment of reed marshes and grasslands in Belgium (Diptera: Dolichopodidae). *Journal of Insect Conservation*, 4, p.99–116.

Prach, K. & Pysek, P., 2001. Using spontaneous succession for restoration of human-disturbed habitats: Experience from Central Europe. *Ecological Engineering*, 17(1), pp.55-62.

Raddick, M. et al., 2010. Galaxy Zoo: Exploring the Motivations of Citizen Science Volunteers. *Astronomy Education Review*, 9(1).

Raine, N. & Chittka, L., 2007. Flower Constancy and Memory Dynamics in Bumblebees (Hymenoptera: Apidae: Bombus). *Entomologia Generalis*, 29(2-4), p.179–199.

Roberts, M., 1996. *Field Guide to Spiders: Britian & Northern Europe*. London: HarperCollins Publishers Ltd.

Roetman, P. & Daniels, C., 2010. *Barbara Hardy Centre for Sustainable Urban Environments*. [Online] Available at: http://www.unisa.edu.au/barbarahardy/research/citizen-science.asp [Accessed 24 Augustus 2011].

Rose, P., 2006. *JNCC: Common Standards Monitoring (CSM)*. [Online] Available at: http://jncc.defra.gov.uk/page-2217 [Accessed 3 September 2011].

Ross-Davis, A. & Frego, K., 2002. Comparison of plantations and naturally regenerated clearcuts in the Acadian Forest: forest floor bryophyte community and habitat features. *Canadian Journal of Botany*, 80(1), pp.21-33.

Rotherham, I., Spode, F. & Fraser, D., 2003. *Post Coal Mining Lanscapes: an under appreciated resource for wildlife and people*. Lisse: Swets & Zeitlinger.

Saville, N., Dramstad, W., Fry, G. & Corbet, S., 1997. Bumblebee movement in a fragmented agricultural landscape. *Agriculture, Ecosystems and Environment*, (61), pp.145- 154.

Schowalter, T., 2001. *Insect Ecology: An Ecosystem Approach*. 2nd ed. Burlington: Academic Press.

Schuster, J., 1974. Saltatorial Orthoptera as Common Visitors to Tropical Flowers. *Biotropica*, 6(2), pp.138-140.

Scott, J., 2006. *World volunteering web: 16 tips in recruiting adult volunteers*. [Online] Available at: http://www.worldvolunteerweb.org/browse/volunteering-issues/senior-volunteers/doc/16-tips-in-recruiting.html [Accessed 11 August 2011].

Seaby, R. & Henderson, P., 2006. *Species Diversity and Richness*. 4th ed. Lymington.

Silvertown, J., 2009. A new dawn for citizen science. *Trends in Ecology and Evolution*, 24(9), pp.467 - 470.

Simpson, E., 1949. Measurement of diversity. (168), p.688.

Skinner, G. & Allen, G., 1996. *Ants*. Slough: The Richmond Publishing Co. Ltd.

Small, E., Sadler, J. & Telfer, M., 2006. Do landscape factors effect brownfield carabid assemblages? *Science of the Total Environment*, 360 (1), pp.205 - 222.

Smith, D., 1994. *Working with volunteers. Recruitment & Selection*. London: The volunteer centre UK.

Smith, J., Potts, S. & Eggleton, P., 2008. Evaluating the efficiency of sampling methods in assessing soil macrofauna communities in arable systems. *European Journal of Soil Biology*, 44(3), pp.271-276.

Smith, B. & Wilson, J., 1996. A consumer’s guide to evenness. *Oikos*, 76, p.70–82.

Snäll, T., Kindvall, O., Nilsson, J. & Pär, T., 2011. Evaluating citizen-based presence data for bird monitoring. *Biological Conservation*, (144), p.804–810.

Stefanescu, C., Herrando, S. & Pa´ramo, F., 2004. Butterfly species richness in the north-west Mediterranean Basin: the role of natural and human-induced factors. *Journal of Biogeography*, 31, p.905–915.

Stewart, E., Jacobson, D. & Draper, D., 2008. Public participation geographic information systems (PPGIS): challenges of implementation in CHurchill, Manitoba. *The Canadian Geographer*, 52(3), pp.351-66.

Sungusia, E., 2010. Community-Based Conservation in Tanzania: Getting the Incentives Right. *Tropical Resources*, 29, pp.54 - 58.

Sutcliffe, O. & Thomas, C., 1996. Open Corridors Appear to Facilitate Dispersal by Ringlet Butterflies (Aphantopus hyperantus) between Woodland Clearings. *Conservation Biology*, 10(5), p.1359–1365.

Tentcheva, D. et al., 2004. Prevalence and Seasonal Variations of Six Bee Viruses in Apis mellifera L. and Varroa destructor Mite Populations in France. *Applied and Environmental Microbiology*, 70(12), pp.7185-91.

Thomas, J., Simcox, D. & Clarke, R., 2009. Successful Conservation of a Threatened Maculinea Butterfly. *Science*, 325(5936), pp.80-83.

Tropek, R. et al., 2010. Spontaneous succession in limestone quarries as an effective restoration tool for endangered arthropods and plants. *Journal of Applied Ecology*, 47, p.139–147.

Trumbull, D., Bonney, R., Bascom, D. & Cabral, A., 2000. Thinking scientifically during participation in a citizen-science project. *Science Education*, 84, pp.265-75.

Upton, M., 1991. *Methods for Collecting, Preserving, and Studying Insects and allied forms*. 4th ed. Brisbane: The Australian Entomological Society.

USEPA, 2002. *Brownfields and Land Revitalization*. [Online] Available at: http://epa.gov/brownfields/overview/glossary.htm [Accessed 6 August 2011].

Uys, C., Hamer, M. & Slotow, R., 2010. Step Process for Selecting and Testing Surrogates and Indicators of Afrotemperate Forest Invertebrate Diversity. *PLoS ONE*, 5(2), pp.1-10.

van Swaay, C., Nowicki, P., Settele, J. & van Strien, A., 2008. Butterfly monitoring in Europe: methods, applications and perspectives. *Biodiversity and Conservation*, 17(14), p.3455–3469.

Volunteering England, 2008. [Online] Available at: http://www.volunteering.org.uk/NR/rdonlyres/0C0C5DBD-5917-49B2-89CB-9DF7C263E2B3/0/Overcomingstudentsbarrierstovolunteering.pdf [Accessed 18 June 2011].

Wakefield District Council, n.d. *Land Quality Ref Number: DJ/0710/MAS*.

Wakefield District Council, n.d. *Land Quality Reference: DJ/0900/MAS*.

Ward, R., 2009. *Hemsworth Archives*. [Online] Available at: http://www.hemsworthpast.org.uk/colliery.html [Accessed 22 June 2011].

Webb, J. & Lott, D., 2006. The development of ISIS: a habitat-based invertebrate assemblage classification system for assessing conservation interest in England. *Journal of Insect Conservation*, 10, p.179–188.

West Yorkshire Ecology, 2010a. *Ecological Records Search for Fitzwilliam Country Park; REF - 20100707 W152 EB*. Wakefield: West Yorkshire Ecology.

West Yorkshire Ecology, 2010b. *Ecological Records Search for Upton Colliery, Wakefield: REF 20100707 W153 EB*. Wakefield: West Yorkshire Ecology.

Wheater, P.C. & Cullen, R., 1997. The Flora and Invertebrate Fauna of Abandoned Limestone Quarries in Derbyshire, United Kingdom. *Restoration Ecology*, 5(1), p.77–84.

Wheater, P., Cullen, R. & Bell, J., 2000. Spider communities as tools in monitoring reclaimed limestone quarry landforms. *Landscape Ecology*, 15, p.401–406.

Williams, P., 2000. Some propoerties of rarity scores used in site quality assessment. *British Journal of Natural History*, 13, pp.73 - 86.

Wilson, R. et al., 2004. Spatial patterns in species distributions reveal biodiversity change. *Nature*, 432, pp.393-96.

Wittebolle, L. et al., 2009. Initial community evenness favours functionality under selective stress. *Nature*, (458), pp.623-626.

Woodland Trust, 2011. *Natures Calender*. [Online] Available at: http://www.naturescalendar.org.uk/ [Accessed 2 March 2011].

World Coal Institute, 2008. *The Coal Resource: A Comprehensive Overview of Coal*. London: World Coal Institute.

Yarnell, R., Scott, D., Chimimba, C. & Metcalfe, D., 2002. Untangling the roles of fire, grazing and rainfall on small mammal communities in grassland ecosystems. *Oecologia*, 154, pp.387-402.

Zoologischen Staatssammlung München, 1977. *Spixiana*. 32nd ed. Munich: Verlag Dr. Friedrich Pfeil.