The biodiversity of short rotation willow coppice in Wales, with particular reference to birds.

Danielle Ann Fry BSc (Hons)

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Cardiff School of Biosciences
Llysdinam Field Centre
Cardiff University
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Summary

Changes in agricultural management have caused massive declines across many taxa associated with the farmed landscape including many of conservation value. Population declines of farmland birds have been particularly rapid, massive and widespread. Although currently under-utilised, particularly in Wales, short rotation willow coppice (SRC) could provide a sustainable fuel that offers a significant reduction in net carbon emissions compared with fossil fuels. This anticipated change to the Welsh agricultural landscape warrants investigation in terms of the impact it is likely to have on biodiversity. This study aimed to investigate the biodiversity of SRC in the Welsh agricultural landscape, concentrating on likely effects to bird populations. Weed floral diversity and species richness was found to increase significantly when SRC was planted compared to the previous landuse. This in turn provided substantial amounts of weed seeds in young SRC easily utilised by many bird species during the winter. As the crop matured the bird community changed but mainly, provided valuable habitat for diverse bird communities during the breeding season. SRC was found to be a highly beneficial breeding bird habitat chiefly for migrant warblers. The increased production of SRC in Wales could significantly increase the productivity of the Willow Warbler in particularly. Planting SRC in Wales could be of significant benefit to biodiversity including those bird species contributing to the UK government's Wild Bird Index. By making it financially beneficial for farmers to be less aggressive in their control of weeds, for instance through Tir Gofal or equivalent agri-environment scheme, SRC could realize its biodiversity potential. This could enable the government to reach both its carbon emissions and biodiversity targets.

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Chapter 1

General Introduction

The biodiversity of short rotation willow coppice in Wales with particular reference to birds

1.1 Biodiversity

Biodiversity, which 20 years ago was barely considered by most ecosystem ecologists, has now been shown to impact significantly upon many aspects of ecosystem functioning. Greater diversity leads to greater productivity in plant communities, greater nutrient retention in ecosystems and greater ecosystem stability (Tilman 2000). Some of the major functions ecosystems perform are; recycling waste, creating pure drinking water, driving global biogeochemical cycles that created and maintain an aerobic atmosphere, regulating global climate change through effects on greenhouse gasses and local climate through effects on evapotranspiration, generating soil fertility, and providing other ecosystem goods and services (Daily 1997). The myriad of organisms on earth are the catalysts that capture and transform energy and materials, producing, among other things, food, fuel, fibre and medicine. By eliminating species and destroying diversity, humans are harming the very ecosystems that ultimately are our life support systems.

Today, agriculture dominates around half of the earth's exploitable surface (Clay 2004). In Europe, the proportion is often even higher, with many countries having around two-thirds of their total surface in agricultural utilization, e.g. Denmark (64%), Ireland (63%) and the UK (70%) (Schafer 2007). Farmland consequently supports a substantial fraction of British biodiversity. During the second half of the 20^{th} century, UK agricultural management underwent an unprecedented revolution, which has resulted in rapid agricultural intensification over the last few decades (for a full review of changes see Shrub 2000). Accounting for such a large proportion of land coverage, farming is by far the single biggest influence on the British countryside, any changes within this industry affects the biodiversity that it supports.

The changes in agricultural management have caused massive declines across many taxa associated with the farmed landscape including many of conservation value (Krebs *et al.* 1999, Chamberlain *et al.* 2000, Robinson and Sutherland 2002). Twenty eight percent of native plant species have decreased in Britain over the past 40 years (Thomas *et al.* 2004) with particularly massive diversity declines amongst arable flora species being documented (Sutcliffe and Kay 2000, Wilson 1992, Rich and Woodruff 1996). The extinction rates of UK invertebrates have matched, and probably exceeded, those of vascular plants in the present century (Thomas *et al.* 1994). For common British macro-moths, 21% of the species studied, declined by more than 30%, a decline at least as great as those recently reported for British butterflies (Thomas *et al.* 2004) and exceeding those of British vascular plants (Conrad *et al.* 2006). There have also been declines reported in essential pollinator species such as bees (Biesmeijer *et al.* 2006).

1.2 Birds as biodiversity indicators

Population declines of farmland birds have been particularly rapid, massive and widespread, with some species in the UK experiencing more than 80% reductions in numbers and range in less than 20 years (Tucker and Heath 1994, Fuller *et al.* 1995). There is compelling and extensive evidence that the declines among farmland birds have been driven by agricultural intensification (Tucker and Heath 1994, Krebs *et al.* 1999, Aebischer *et al.* 2000, Chamberlain *et al.* 2000, Donald *et al.* 2001, Benton *et al.* 2002). By the turn of the millennium, the need to conserve farmland birds had become one of Britain's most pressing environmental issues and had emerged as a key driver of rural land management policies (Ormerod and Watkinson 2000, Grice *et al.* 2004).

Birds are major indicators of the changes occurring within the landscape and underlying biodiversity. Their patterns of behavior, distribution and demography track closely the spatial and temporal scales of agricultural change (Ormerod and Watkinson 2000). Their declines are indicative, or even the direct result of, severe declines in the other components of farmland biodiversity, including insects and wild plants (Holland 2006, Wilson 1992, Rich and Woodruff 1996, Donald 1998, Sotherton and Self 2000, Preston *et al.* 2002, Gregory *et al.* 2003). Foraging, nest-site selection and or breeding performance reflect features within the mosaic of agricultural habitat (Bradbury *et al.* 2000, Brickle *et al.* 2000). The multivariate and interacting factors of farming practices and some of the routes by which they affect farmland birds are summarized in Figure 1.1.

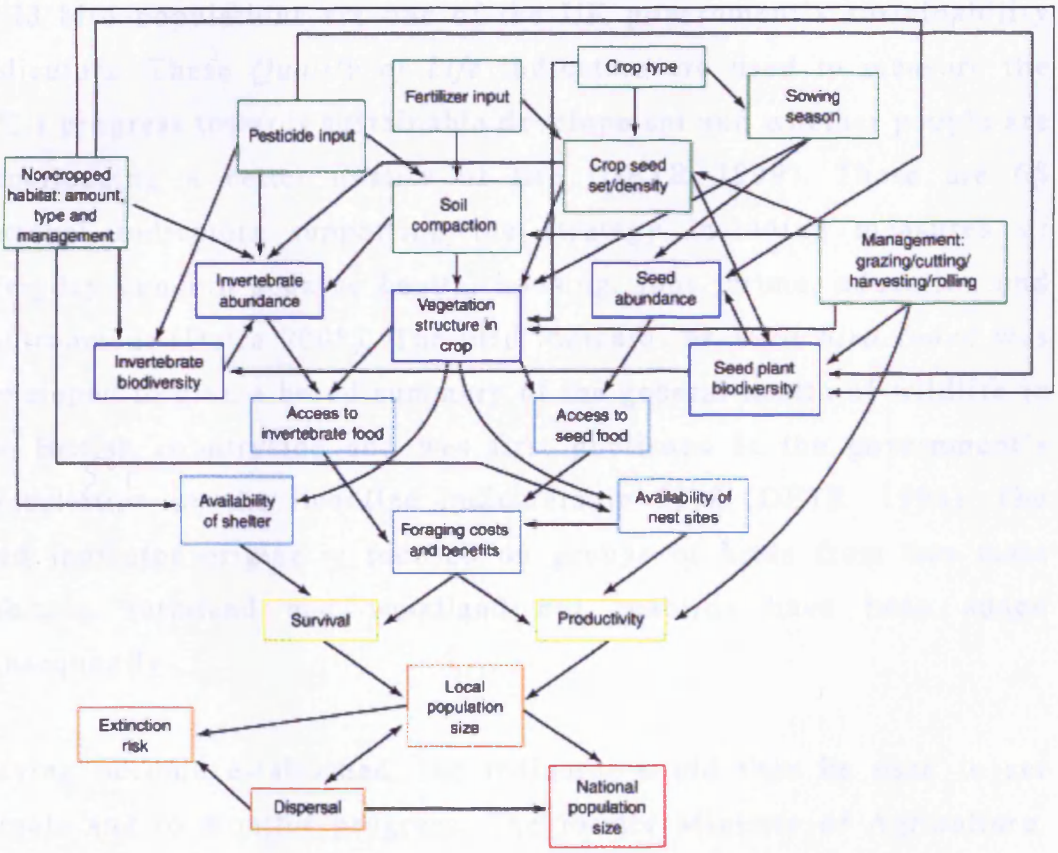

Figure 1.1 The multivariate and interacting nature of farming practices and some of the routes by which farming practice impacts on farmland birds. Arrows indicate known routes by which farming practices (green boxes) indirectly (dark-blue boxes) or directly (light-blue boxes) affect farmland bird demography (yellow boxes), and therefore local population dynamics (orange boxes) and finally total population size (red box). Taken from Benton *et al.* (2003).

Birds have widespread popular appeal and – by virtue of their conspicuous nature – are easily monitored. They therefore make excellent flagship species for mobilising volunteer-based monitoring networks and in Britain we have geographically and temporally extensive datasets available for analysis. Birds are also the best-known and documented major taxonomic group, especially in terms of the sizes and trends of populations and distributions, and the number of species is manageable, thereby permitting comprehensive and rigorous analyses (Birdlife International 2007). For these reasons, it has become common practice to use birds as indicators of the general state of nature.

Wild bird populations are one of the UK government's sustainability indicators. These *Quality of Life* indicators are used to measure the UK's progress towards sustainable development and whether people are experiencing a better quality of life (DETR 1999). There are 68 national indicators supporting the strategy including measures of everyday concern such as health, housing, jobs, crime, education and environment (Defra 2008). The bird indicator or *Wild Bird Index* was developed to give a broad summary of the general health of wildlife in the British countryside and was first published in the government's consultation on the Headline indicators in 1998 (DETR. 1998). The bird indicator originally focused on groups of birds from two main habitats, farmland and woodland but seabirds have been added subsequently.

Having become established, the indicator could then be used to set targets and to monitor progress. The former Ministry of Agriculture, Fisheries and Food (now Department for Environment, Food and Rural Affairs – Defra) and the forestry Commission developed key targets to reverse the long-term decline in farmland and woodland birds by 2020. Specifically, Defra adopted a Public Service Agreement (PSA) to 'Care for our living heritage and preserve natural diversity by reversing the long-term decline in the number of farmland birds by 2020, as measured annually against underlying trends'. Reversing the decline in farmland birds is viewed by government, as a measurable surrogate for the success of its policies that seek to conserve biodiversity in general.

1.3 Energy crops in the UK

Biomass currently accounts for just 0.43% of the UK's energy (Supergen 2007). Both the Biomass Task Force (MacLeod *et al.* 2005) and the subsequent UK Biomass Strategy (Defra. 2007a) concluded that biomass is a highly under-utilised resource. Increasing biomass production is one of the ways the UK government hopes to reach it's targets to reduce carbon dioxide emissions by 20% below 1990 levels by 2010 and by 60% by 2050 (Defra. (2007a). Correctly managed, biomass crops provide a sustainable fuel that offers a significant reduction in net carbon emissions compared with fossil fuels.

As well as helping to reduce carbon emissions there are other ancillary benefits to growing biomass crops. Other atmospheric pollutants, such as sulphur, are also reduced and there are opportunities for their use in phytoremediation and improving water quality (Thornton *et al.* 1997, Mirck *et al.* 2005). They are, in contrast to fossil fuels such as coal, oil and natural gas (currently our main sources of energy), a secure supply, being grown and sourced locally on an indefinite basis. Growing biomass crops can minimize financial and environmental costs of transport because local networks of production and usage are established. The development of biomass crops offers new local business opportunities and support to the rural economy (Perttu 1998). Despite the obvious benefits, the biomass industry has been slow to develop, with fossil fuels continuing to dominate energy production.

To increase the amount of energy crops grown in England, the Energy Crop Scheme, was introduced in 2001. The scheme offers a one off payment to help farmers with the establishment costs of growing two types of energy crops; the perennial grass *Miscanthus* (typically *Miscanthus x gigantus*) and short rotation willow (typically *Salix viminalis* hybrids) coppice (SRC). The scheme ran until 2006 under the England Rural Development Programme and a new but similar Energy Crops Scheme opened to new applications from 1st October 2007 under the Rural Development Programme for England. The uptake of these schemes has been good and has increased steadily since its introduction (Figure 1.2). The majority of farmers entering the scheme have been investing in *Miscanthus* rather than SRC (Figure 1.2). The scheme has only been available to land owners in England.

The Energy Aid Payment Scheme, coordinated by the Rural Payments Agency (RPA), introduced in 2004 is available across the UK. Farmers qualify for aid if they have a contract with the processing industry for their crops. This is the basic feature of the scheme that guarantees the crops grown will be processed into energy. The RPA have contracts in Scotland and Wales as well as England, evidence that the demand for energy crops does not occur in England only. Establishment grants made available to the rest of the UK would encourage the growth of this industry and help the government to reach its own targets.

Defra has produced regional yield maps across England for *Miscanthus* and SRC (Defra 2007b). The aim of these maps is to model potential yields of these crops and identify where they would be most productive. Local environmental conditions dictate which crop is better suited to a given area and therefore will produce greater yields. Although a greater amount of *Miscanthus* has been established under the grant schemes there are areas where SRC would be a more profitable crop. Although a similar map has not been published for Wales, previous research suggests that SRC would be better suited to much of the Welsh environment (Hodson 1995, Heaton 2000, Lowthe-Thomas 2003). *Miscanthus* is a genus of about 15 species of perennial grasses native to subtropical and tropical regions of Africa and southern Asia, with one species (*M. sinensis*) extending north into temperate eastern Asia (El Bassam 1998). Willow in contrast has a global range (Newsholme 1992), is native to the UK and is consequently better adapted to the generally harsher conditions experienced in areas of Wales.

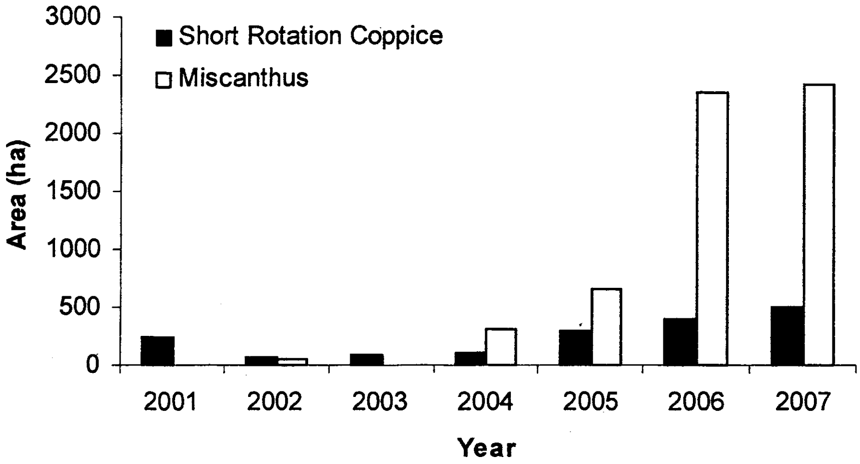

Figure 1.2 Area (ha) of newly planted short rotation coppice (willow) and *Miscanthus* under the Energy Crop Scheme (available in England only).

1.4 Willow for Wales

The project, 'the development of sustainable heat and power fuelled by biomass from short rotation coppice in Wales' (Helyg i Gymru – Willow for Wales) began in 2004 and will run until December 2008. The main objective of the project is to evaluate and demonstrate the potential of short rotation willow coppice as a biomass crop in Wales. An important aspect of the project is that it engages farmers as partners in establishing crop test sites and as potential commercial producers. One important impetus for the creation of the project was the fact that the biomass industry in Wales does not have a fully developed supply chain. The Welsh landscape and environment presents particular challenges to this burgeoning industry that have not been encountered elsewhere in Europe, even in neighbouring England. It is perceived that the Willow for Wales project will assist in the development of supply chains feeding into a range of markets.

The Willow for Wales project is funded by the European Regional Development Fund (ERDF) Objective 1 priority/measure 2.5 through the Welsh European Funding Office on behalf of the Welsh Assembly Government, by the Welsh Development Agency and by Industry. It is co-ordinated by the Institute of Grassland and Environmental Research (IGER) and not only involves Cardiff University, but also Forest Research, EGNI, Mid-Wales Energy Agency, RWE npower, Renewable Fuels Ltd, SW Seed Ltd and Agrobransle, ADAS and the West Wales Machinery Ring. In the words of the Project Co-ordinator Dr. John Valentine: "Helyg i Gymru – Willow for Wales is taking a stepwise approach to the development of heat and power from short rotation coppice in Wales. It will help bring about change through education and by allowing farmers to 'see with their own eyes.'"

The Willow for Wales project planted seven sites across Wales. All were located on farms that consisted predominantly of improved grassland habitat but at a range of altitudes and soil types representing a cross section of the Welsh environment. Due to this variation, ground preparation and planting varied between the sites according to the cropping history and site-specific practicalities. The main difference in management practice between sites was in herbicide application (Table 1.1). The area planted at each site ranged from 3 to 10 ha with a mean of 5.1 ha. Planting material was a mixture of five willow varieties: Tora, Tordis, Sven, Ashton Stott and Resolution. All of these varieties are *Salix viminalis* hybrids and therefore have similar characteristics. In addition, the varieties were planted as an intimate mixture rather than discrete blocks giving each site the same overall structure.

Table 1.1 Details concerning the SRC sites

Site	Grid Reference	Location	Soil type	History	Altitude (metres above sea level)	Field size (hectare)	Planting date	Herbicide treatment at time of planting	Additional management
1	SH383685	Bodorgan Estate, Anglesey	silty clay loam	Long term set aside for past 10 years – cereals previously	50	4.77	25th May 2004	5th May: Sprayed with Roundup and Touchdown @ 5l/ha. 19th May: Excess vegetation burnt off. 20th May: Plouhed and Dursban @1.25l/ha applied. 30th May: Residual herbicides applied; Stomp @5l/ha and Flexidor @2l/ha.	19th July: DowShield @ 1l/ha 31st January 2005: Sprayed with Harvest and Simazine 3l of each /ha in 400l water. Cut back in Feb 2006. Following cutback, Weedazol (amitrole) was applied at 10l/ha in March.
2	SH464557	Glynllifon College, Caernarvon	silty clay loam	Maize in recent years	50	4.36	May 2005	After planting the site was sprayed with Stomp @5l/ha.	Following cutback in Feb 2006 the site was sprayed with Weedazol (10l/ha). Spraying occurred in a cold mid Feb when plants were probably not actively growing – so control, particularly of grass weeds, was not that effective.
3	SJ033579	Ceryfed Farm, Denbighshire	brown earth over shale	Long term permanent pasture – sheep grazing	300	3	June 2005	Received 5l/ha of Stomp 3 days after planting and 10l Weedazol in early April.	

Table 1.1 continued

4	SJ061510	Cilgoed, Denbighshire	silty clay loam but stony below 15cm	Grassland – ploughed and reseeded in 2001	300	4.2	June 2005	5l/ha of Stomp 3 days after planting and sprayed with 10l Weedazol in early April.	
5	SM904255	Hayscastle Farm, Pembrokeshire	peaty loam (15-20cm) above semi permeable clay.	Reseeded as permanent pasture within the last 20yrs	110	5.86	18th May 2004	Soils limed prior to planting @ 2t/acre. 7th May: Sprayed with Touchdown @ 5l/ha. 29th May: Residual herbicides applied; Stomp @ 5l/ha and Dursban @ 1.25l/ha.	Early February 2005: Sprayed with Harvest and Simazine 3l of each /ha in 400l water. Following cut back in March 2006 the site was sprayed with Weedazol at 10l/ha.
6	SN072126	Oakwood, New House Farm, Pembrokeshire	silty clay loam	Permanent pasture – reseeded within the last 15 years	100	10	16th May 2004	7th May: Sprayed with Round up @ 5l/ha. 14th May: Dursban applied @ 1.25l/ha. Sewage sludge applied. 20th May: Residual herbicides applied; Stomp @ 5l/ha and Flexidor @ 1l/ha.	Following harvest in 2006 site sprayed in April with Laser to control grass weeds.
7	SS997799	Brigam Farm, Rhondda Cynon Taff,	silty clay loam		65	3.3	Planting in June 2005 failed and had to be re-planted in April 2006	Residuals (Stomp) sprayed after planting in Jun 05 resulted in massive crop damage due to leaf scorch. Replanting (April 06) was carried out using zero spray system (stale seedbed+ mechanical weed control post planting).	

1.5 Growing SRC

The main features of planting procedures are summarised below, for full best practice guidelines for growing short rotation willow coppice see Defra (2004).

1.5.1 Land preparation

Uncontrolled weed growth can impede the initial growth of SRC (Parfitt *et al.* 1992, Clay and Parfitt 1994, Sage 1999) and weed control is therefore considered essential when planting SRC (Clay and Dixon 1997, Britt 2000, Defra 2004). As SRC is a long-term, perennial crop (a plantation could be viable for up to 30 years before re-planting becomes necessary), ensuring ideal conditions at establishment will reap benefits for first and subsequent harvests (Defra 2004). One or two applications of a glyphosate-based herbicide should be carried out in the summer/autumn prior to spring planting. An additional application just before planting may be necessary on some sites. When planting a site previously classed as improved grassland, compaction is likely so the site should be sub-soiled to a depth of 40cm to remove this. It should then be ploughed to a depth of at least 25cm and left over winter. Power harrowing should be carried out immediately before planting. Organic manure with low nitrogen content can be incorporated into the soils prior to planting but this is unlikely to be necessary on areas of high nitrogen content such as previously improved sites.

1.5.2 Planting

Ideally, a mix of willow varieties will be planted to prevent or impede the spread of diseases such as rust and pests such as willow beetles (Chrysomelidae) through the crop later (Christian *et al.* 1994, Sage and Tucker 1998, Perttu 1999, McCracken and Dawson 2003). The Game Conservancy Trust has produced a booklet describing integrated pest management techniques for SRC (Tucker and Sage 1999). Planting should take place after the last frosts but as early as February if soil conditions allow as the longer the first growing season the better.

Willows should be planted in twin rows 0.75 metres apart and with 1.5 metres between rows. This spacing allows standard agricultural machinery to work across the crop. A spacing of 0.59 metres along the rows will give a planting density of 15,000/ha, the commercial standard. The site should be rolled immediately after planting and pre-emergence residual herbicide should be applied within 3-5 days of planting.

1.5.3 Cutback and harvesting

During the winter following planting the willow is cut back to almost ground level to encourage the development of multi-stemmed coppice. This should be carried out as late as possible in the winter but before bud-break, generally late February. 5-20 shoots will emerge from each cutback stool depending on the variety. Within 3 months of cutback, canopy closure will have occurred providing natural weed control and making further herbicide applications unnecessary (Sage 1998, Britt 2000, Defra 2004). Harvesting is then generally carried out on a three-year cycle. The harvests are carried out during the winter, after leaf fall and before bud-break, usually mid-October to early March.

1.5.3 General management

Browsing animals such as rabbits, hares and deer can cause damage to SRC but mainly during establishment and must be kept out of the site during this time. Headlands and rides need to be quite large (at least 8 metres in width) to allow for vehicle turning. These areas can be cut for silage but management is minimal. No fertiliser should be applied during the establishment year to allow the herbicide applications to be effective and because nitrate leaching has been recorded at this time (Defra 2004). Due to the structure of SRC, fertiliser application can be difficult in year 2 of the harvest cycle and impossible in year 3. Opportunities to work over the crop have to be taken during cutback and harvest making SRC an extensively managed crop.

1.6 SRC and biodiversity

SRC, by virtue of its nature and structure, requires far fewer herbicide, pesticide and fertiliser applications than other current farming practices, both arable and pastoral (Ranney and Mann 1994, Ledin 1998, Perttu 1998). Non-cropped areas are larger and less intensively managed, soil compaction should be reduced and overall, completely different farming practices are introduced, all of which will impact on biodiversity (Figure 1.1). It is well documented that tillage is detrimental to soil quality and decreases soil organic matter (Reicosky *et al.* 1995, Kladivko 2001). SRC production only disturbs the soil during the planting process and the planting of SRC has been reported to be of benefit to soil properties, both physical condition and biological activity (Makeschin 1994, Paine *et al.* 1995, Perttu 1995, Thornton 1997, Abrahamson *et al.* 1998, Ledin 1998, Perttu 1998, Perttu 1999, Borjesson 1999, Kahle *et al.* 2007, Rowe *et al.* 2007).

SRC consistently contains high richness and abundance of plant species (Sage *et al.* 1994, Coates and Say 1999, Cunningham *et al.* 2004, Cunningham *et al.* 2006). The plant composition in SRC is highly variable and depends largely on previous land use and management practices (Sage *et al.* 1994, Sage 1995, 1998, Ledin 1998). Sage (1995) suggested that SRC established on westerly sites, typically on former grassland sites and contained a more diverse ground flora with a higher proportion of long-lived perennials than on sites in the eastern part of the country that were frequently established on former arable land. A general pattern of succession has been identified (Gustafasson 1986, Coates and Say 1999, Cunningham *et al.* 2004, Cunningham *et al.* 2006), annuals germinating from the seed bank just after planting initially dominate, but then significantly decrease as the SRC becomes established and higher proportions of both invasive and long-lived perennials take over.

Work done on ground invertebrates in SRC indicated a predatory invertebrate community that changes from species characteristic of ruderal habitats to species of undisturbed habitats (Coates and Say 1999, Lowthe-Thomas 2003) reflecting the ground flora compositions within the crop. Native willows in Britain are known to be particularly rich in insect fauna. Kennedy and Southward (1984) found 450 insect (or mites) species on five willow species (*Salix* spp) in Britain, more than any other tree or genus. In surveys of SRC plantations in England, insect species from over 50 groups were found to be occupying the canopy alone (Sage and Tucker 1997). In addition to foliar insects the catkins produced in SRC may constitute an important resource for flower visiting insects particularly bee populations (Reddersen 2001) which are currently in decline (Williams 1995, Roubik 2001, Biesmeijer 2006).

In traditional coppiced woodland, small mammal populations respond quickly to changing habitats (Gurnell *et al.* 1992). Although some species disappear after initial felling, populations quickly recover so that at 3 years they reach peak numbers (Gurnell *et al.* 1992). Similar abundances of small mammals have been recorded for SRC (poplar) and row crops in the USA (Christian *et al.* 1994, Tolbert and Wright 1998). In these studies, ground cover was determined to be the single most important factor in small mammal populations using plantations compared with hay/pasture and grain crops (Christian *et al.* 1994, Tolbert and Wright 1998). Both rabbits and deer have been recorded to browse on new willow shoots (Kopp *et al.* 1996, Bergstrom and Guillet 2002, Guillet and Bergstrom 2006). Detrimental affects of herbivore browsing can me minimised by altering planting density and harvest cycles (Kopp *et al.* 1996). SRC has the potential to be an excellent habitat for declining British hare populations (Vaughan 1993, Smith *et al.* 2004).

1.7 SRC and birds

High bird diversity and density have been recorded in SRC in Sweden (Goransson 1990, 1994, Berg 2002), the USA (Christian *et al.* 1994, Dhont *et al.* 2004) and the UK (Kavanagh 1990, Sage and Robertson 1996, Sage and Tucker 1998, Coates and Say 1999). Several studies (Kavanagh 1990, Goransson 1994, Sage and Robertson 1996, Sage and Tucker 1998, Coates and Say 1999) have recorded densities comparable to traditional British coppice habitat between 3 and 10 years old (Fuller and Henderson 1992). Consistently greater bird diversity has been recorded in SRC compared to existing farmland habitat (Goransson 1990, 1994, Berg 2002, Sage *et al.* 2006). In sites managed commercially, more individuals and species were recorded in and around SRC than equivalent arable or grassland both in summer and winter (Sage *et al.* 2006). Goransson (1990) and Berg (2002) both concluded that *Salix* plantations increased bird diversity generally and were particularly positive for warblers and Pheasants. Berg (2002) also concluded that SRC might even be the preferred habitat for some rare or threatened species.

In the spring, birds are thought to be predominantly attracted to SRC by the substantial insect abundance (Sage and Tucker 1997). Because biomass crops in the UK are thought to lack nesting opportunities (Sage *et al.* 2006), boundary habitats are particularly important to the bird populations (Londo 2005, Sage *et al.* 2006). Indeed the interior of large SRC plots contained fewer birds than the edge zone (<50m) (Sage *et al.* 2006). In Sweden, Whitethroat and Chaffinch were found to avoid the interior of willow coppice (Berg 2002) and larger bird densities have been recorded in pre-commercial sites that were essentially all edge zone (Sage *et al.* 2006). Dhont *et al.* (2004), in the USA also found that a high proportion of the birds recorded regularly using SRC were actually breeding within the plots (at least 21 of 39). Again, the plots in this study were quite small and were therefore essentially all edge zone.

Age classes and growth stages of SRC affect which birds are recorded (Goransson 1994, Sage and Robinson 1996, Sage *et al.* 2006, Dhont *et al.* 2007). In Sweden, Whitethroats and Whinchat preferred the sprouts of the recently harvested areas while Willow Warbler and Garden Warbler preferred the fully grown bushes preceding the harvest (Goransson 1994). Berg (2002) found that taller plantations were preferred by most species but it is not clear if crop height was linked to crop age i.e. if the older crops are the tallest. The clones used for SRC can vary quite markedly in terms of structure. Dhont *et al.* (2004), in the USA, found that birds constructed nests non-randomly in respect to willow clone. Clones vary in terms of growth structure and this may have been what drove the preferences.

SRC has been found to provide excellent winter cover for game birds (Baxter *et al.* 1996, Sage and Robertson 1994). Particularly Pheasant, Partridge (Goransson 1990, Sage and Robinson 1994, Baxter *et al.* 1996, Berg 2002) and Snipe (Sage *et al.* 2006). Sage *et al.* (2006) concluded that there is a need for some autoecological bird studiesto be conducted within energy crops. This would help establish what characteristics of the SRC are important for those species. This could be particularly useful for game birds or species of conservation concern. In addition, although large numbers of songbirds have also been recorded using SRC during the winter (Sage *et al.* 2006) there has been little work done to establish what resources are attracting them at this time.

The benefits of SRC are strongly influenced by the landscape into which it is introduced and the land use it replaces (Christian *et al.* 1994, Perttu 1995, Tolbert and Wright 1998, Coates and Say 1999, Starback and Becht 2005, Anderson and Fergusson 2006, Rowe *et al.* 2007). For highly mobile animals, particularly birds, landscape composition plays a central role in determining occupancy of plantations (Christian *et al.* 1998) and adjacent habitats have a strong influence on the bird community composition in the SRCs (Berg 2002).

Of the 41 papers on SRC referenced in the last 2 sections of this review (6.1 SRC and biodiversity and 6.2 SRC and birds), 17 (41%) of the studies took place on sites replacing arable production or compare SRC directly to arable habitats, while only 1 (Cunningham *et al.* 2006) is based on SRC sites previously grassland. Two studies are conducted on SRC replacing peat land, 8 do not use other habitat controls or say what land use the plots have replaced and the remainder (32%) are review/discussion style papers.

In the Cunningham *et al.* (2006) study, although the SRC was replacing grassland fields, not all were in areas predominated by grassland. Grasslands sites were less commonly used to plant SRC on in the area (the ones used in the study were the only available) and it was difficult to find control sites (one was over 1km from its paired SRC plot (Sage 2006). This study was undertaken in England, which has a very different agricultural landscape to the rest of the UK (Figure 1.3). Consequently, relatively little is known of the likely effect of SRC on diversity in the grassland-dominated landscape that is currently found in other areas of the UK.

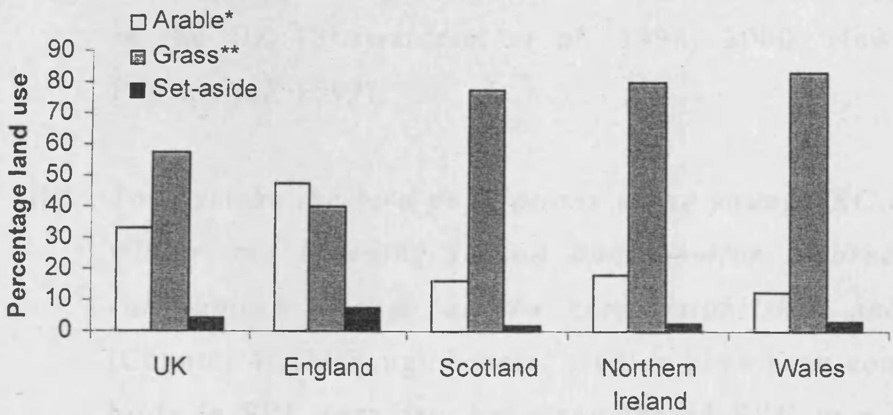

Figure 1.3 Percentage land use on agricultural holdings, June 2001 (Defra. 2008).
* crops, bare fallow and all grass under five years old.
** five years old and over (including sole right rough grazing).

1.8 Project aims

This study aimed to investigate the ecological consequences of introducing short rotation willow coppice into the Welsh agricultural landscape, concentrating on issues of biodiversity. Specifically, five main aims were identified:

(i) *To determine how short rotation willow coppice and conventional Welsh farmland differ in terms of ground vegetation species richness, abundance and general composition* (Chapter 2). In their position at the base of the food chain, plants must be a priority not only in their own right but because of the key role they play in maintaining the diversity and viability of all other taxa. Ground flora responses to planting SRC in Wales has thus far received limited attention, and will provide important insights into the likely responses of other taxa.

(ii) *To quantify the seed resource produced by young SRC fields in Wales and determine whether it is utilised by winter bird populations* (Chapter 3). Winter birds utilising SRC is another neglected issue despite high numbers being recorded in this habitat (Sage *et al.* 2006) and the fact that over winter survival is limiting several farmland bird species populations in the UK (Siriwardena *et al.* 1998, 2000, Newton 2004, Peach *et al.* 1999).

(iii) *To describe the bird populations using young SRC during the winter and breeding season and monitor if breeding bird community's change as the crop establishes and matures* (Chapter 4). Although several studies have been conducted on birds in SRC very few have considered SRC in a grassland-dominated landscape. For highly mobile animals such as birds, landscape composition plays a central role in determining occupancy of SRC plantations (Christian *et al.* 1997) and adjacent habitats can have a strong influence on the bird community composition found in SRC (Berg 2002).

(iv) *To establish how SRC compares to the scrub, or ffridd, habitat in terms of bird species, abundance and condition* (Chapter 5). Vegetation changes have been evident in the marginal uplands of Wales (the 'ffridd') in recent decades. These areas are typically mixtures of bracken, grass, scrub (usually willow) and scattered trees (Fuller *et al.* 2006). Scrub habitat is gaining recognition as an important and threatened habitat type and in 2007 upland willow scrub was added to the priority habitats in the UK Biodiversity Action Plan (Biodiversity Reporting and Information Group, 2007).

(v) *To compare habitat quality indicators from SRC and alternative ffridd habitat using the Willow Warbler, one of the commonest breeding bird species found using SRC in Wales, as a case study* (Chapter 5). Willow Warblers are Amber listed in Wales but a greater density of Willow Warblers have been recorded in SRC compared to both arable land (Cunningham *et al.* 2004) and grassland (Cunningham *et al.* 2006). They have been found to prefer the fully-grown SRC than recently harvested areas (Goransson 1994).

In common with modern thesis styles, the work has been prepared so that each chapter is self-contained with its own reference list. Species are referred to by their common names throughout the text but full species lists with scientific names can be found in the Appendices.

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Chapter 2

The effects on plant community composition of planting SRC in Wales

2.0 Abstract

Increasing demand for biomass crops in Wales could lead to a substantial increase in the land area devoted to short-rotation willow coppice (SRC) but little is known of the effect on biodiversity of planting SRC in a grassland-dominated landscape. This study used seven SRC fields, distributed throughout north and west Wales, on farms consisting predominantly of improved grassland. Plant abundance data collected over 3 years for grassland controls and 0-2 year old SRC were used to calculate species richness (number of species), diversity (Simpson's 1/D), evenness (rank-abundance plots) and in multivariate analysis (detrended correspondence analysis) of plant communities. Proportions of annuals, short and long-lived perennials and weed species thought to be of particular importance for phytophagous insects or in terms of seed for farmland birds were also investigated. Diversity was significantly greater in the SRC in the year it was planted (P=0.027) and the following year (P=0.017) than in the controls. Species richness followed the same pattern (39 species were recorded in the control plots and 87 in the SRC). Evenness was also greatest in the young SRC. These data support the idea that planting SRC in Wales will have a positive effect on the floral diversity, which may have knock-on effects for associated farmland biodiversity. There is now a need to understand the full impact of the replacement of grassland with SRC on other aspects of biodiversity, winter birds in particular. Further research is needed to develop management guidelines for SRC in grassland landscapes that can be incorporated into agri-environment schemes.

2.1 Introduction

Increasing demand for energy or 'biomass' crops in Wales could lead to a substantial increase in the area devoted to these crops, short rotation willow coppice (SRC) in particular (Chapter 1). SRC has been reported to significantly benefit several aspects of the environment, including soil properties (Makeschin 1994, Reieosky *et al.* 1995, Abrahamson *et al.* 1998, Borjesson 1999), biodiversity (Sage *et al.* 1994, Sage and Tucker 1998, Coates and Say 1999, Cunningham *et al.* 2004), and energy balances (Rowe *et al.* 2007) when compared to arable crops. However, the benefits of SRC are strongly influenced by the landscape into which it is introduced and the land use it replaces (Anderson and Fergusson 2006, Rowe *et al.* 2007). Little is known of the likely effect of SRC on diversity in the grassland-dominated landscape that is currently dominant in Wales (Chapter 1). The dominance of grassland systems in Wales and the fall in arable production has markedly reduced farm habitat diversity (Benton *et al.* 2003, Shrubb 2003). The proportion of arable land in Wales fell by more than 40% between 1970 and 1997 (National Statistics and Defra 2007) and a recent Habitat Survey recorded only 2.8% of the total area of Wales as arable habitat (Blackstock *et al.* 2007).

Arable weeds are the most threatened group of plants in Britain today (Still and Byfield, 2007) with massive declines in species diversity being documented across the UK (Wilson 1992, Rich and Woodruff 1996, Sutcliffe and Kay 2000) and elsewhere in Europe (Andreasen *et al.* 1996). The UK Biodiversity Steering Group Report (Anon. 1995) identified cereal field margins as a priority habitat for conservation action in the UK. In England, agri-environment schemes offer an effective means to conserve these plants (Walker *et al.* 2007). The Arable Field Margin Habitat Action Plan (HAP) seeks to expand the area of cultivated, unsprayed field margin. Meanwhile the new Entry Level Stewardship (ELS) scheme offers a range of management options that aim to provide a sustainable future for plant communities. ELS uptake has generally been good but because a choice of options is available, most applicants opt for boundary management options whilst uptake for key in field options has been low (Still and Byfield 2007).

In Wales there are no grant schemes specifically aimed at conserving farmland plant communities. However, because of The Convention on Biological Diversity the Welsh Assembly government are committed to halting the loss of biodiversity and for recovery to be underway by 2026. In the Environment Strategy for Wales (WAG 2006) the Welsh Assembly Government recognises the need for the wider environment to be more supportive of biodiversity. Of the total land area of Wales 77% is in agricultural production (CEH 2000) and it must therefore be a priority to improve the biodiversity of this habitat.

Farmland birds have been chosen by the UK government as a biodiversity indicator for the health of the farmland environment but the widespread and popular use of sown bird seed and pollen and nectar mixes often utilise non-native species. This has favoured bird populations without necessarily improving the native plant communities in the farmland landscape (Still and Byfield 2007). New developments within the agricultural industry should, from the outset, aim to incorporate maximisation of diversity into the management guidelines. In their position at the base of the food chain, plants must be a priority not only in their own right but because of the key role they play in maintaining the diversity and viability of all other taxa. Research in this area has focused on the link between plant and insect diversity (Seimann *et al.* 1998, Knops *et al.* 1999, Koricheva *et al.* 2000, Haddad *et al.* 2001, Asteraki *et al.* 2003, Gibson *et al.* 2006) and plants in terms of food for birds providing both seed and insect resources (Green 1990, Campbell *et al.* 1997, Donald 1998, Wilson *et al.* 1999, Vickery *et al.* 1999, Vickery *et al.* 2001, Robinson and Sutherland 2002, Marshal *et al.* 2003, Newton 2004, Storkey 2006).

SRC has been reported to consistently contain a higher species richness and abundance of plant species in comparison to arable controls (Sage *et al.* 1994, Sage and Tucker 1998, Coates and Say 1999, Cunningham *et al.* 2004). This is particularly true in the first year after planting and uncontrolled weed growth can impede the growth of the crop (Sage 1999). Weed control is therefore considered essential when planting SRC (Defra 2004). SRC growth has been shown to be unaffected by weeds in the second year, making weed control after establishment unnecessary and uneconomical (Sage 1999). A more stable ground flora with less competitive plants can colonise after just one year's growth (Rich *et al.* 2001) or it can take much longer to stabilize if the SRC is replacing highly dissimilar habitat such as peat bogs and fens (Gustafsson 1986). The plant composition in SRC is highly variable depending largely on previous land use and management practices (Sage *et al.* 1994, Sage 1995).

The plant composition of SRC that has replaced grassland has received little attention despite grassland accounting for 60% of all agricultural land in the UK (National Statistics and Defra 2007). It is likely that introducing any form of cultivation to Welsh farmland will have a positive effect on floral diversity (Critchley *et al.* 2006, Pywell *et al.* 2007) and associated taxa. For birds, the addition of weedy habitat in pastoral landscapes where it is particularly scarce might be of even greater importance than improving the quality of existing arable habitat (Henderson *et al.* 2004, Robinson *et al.* 2004). Recent studies suggest that in grassland dominated areas like Wales, if even a single field (typically 5-10 ha) on each farm was used for arable crops, farmland bird numbers could be increased (Robinson *et al.* 2001, Robinson *et al.* 2004, Siriwardena *et al.* 2006).

The main objective of this chapter is to provide an insight into the likely impact of commercial cropping of SRC in Wales on ground flora. The associations of invertebrates and birds with the flora recorded are also examined.

2.2 Study sites

Seven SRC field sites across Wales were used in this study (Figure 2.1). The sites are those (sites 1-7) described in Chapter 1 (see Chapter 1, Table 1.1 for full description of the sites).

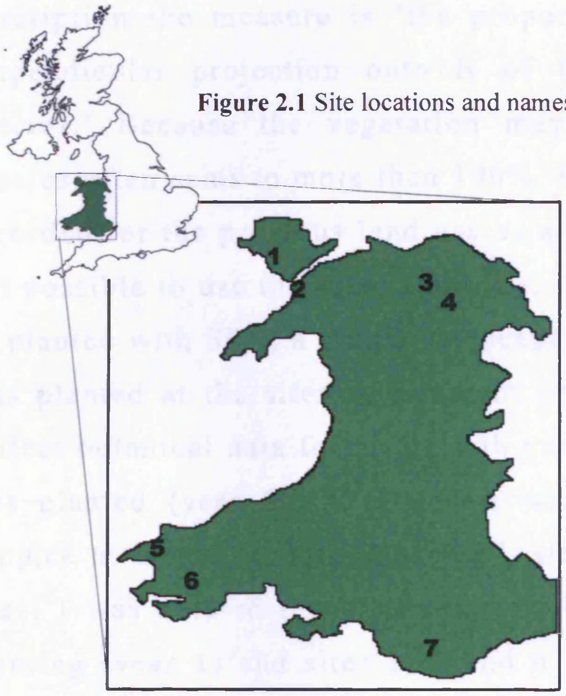


Figure 2.1 Site locations and names.

1. Bodorgan
2. Glynllifon
3. Ceryfed
4. Cilgoed
5. Hayscastle
6. Oakwood
7. Brigam Farm

2.3 Methods

2.3.1 Data collection

Botanical data were collected from quadrats (each 0.5 m x 0.5 m) randomly positioned in the central areas of each plot (at least 3m away from plot edges) to avoid bias and edge effects. The percentage cover of each plant species rooted in the quadrat was visually estimated to the nearest 5%. According to Greig-Smith's (1983) commonly used description the measure is 'the proportion of ground occupied by a perpendicular projection onto it of the aerial parts of individual species.' Because the vegetation may be layered the cover of all species often sums to more than 100%. For all 7 sites, 50 quadrats were recorded for the previous land use as a control (year -1). Where it was not possible to use the same field, i.e. it had already been ploughed up or planted with SRC, a similar adjacent one was used in its place. SRC was planted at the sites in different years and it was not possible to collect botanical data for all growth years at all sites. In the year SRC was planted (year 0), 80 quadrats were recorded within the willow coppice at the larger site (Oakwood, site 6) and 50 in the remaining 6 sites. I was able to repeat the survey for sites 1-6 for the year after planting (year 1) and sites 1, 5 and 6 in the following year (year 2). The surveys were conducted at the end of September in 2004, 2005 and 2006.

2.3.2 Data analysis

Because the sites were so varied to begin with, the underlying plant community patterns of the SRC are likely to reveal more. The computer package Estimates 5.0.1 (Colwell 2000) was used to compute the reciprocal form of the Simpson's index of diversity (Simpson's 1/D). This diversity index is particularly sensitive to changes in the more abundant species of a community (Krebs 1989) and has minimal bias when sample sizes are small (Lande 1996). It was calculated for all sites for every available year. Differences in both Simpson's 1/D and in species richness (the number of species recorded) between previous land use (-1) and the willow coppice in the year of planting (0), the following year (1) and the year after that (2) were tested by paired t-tests performed with MINITAB 14.

Evenness can be a good index of community structure because is is able to find patterns among communities that differ in species composition (Bulla 1994). The sites were combined into groups, the control, and the SRC at each age in order to explore the evenness patterns of the plant communities in each group. Rank abundance plots can be used to visualize species abundance distributions. In these plots, the species are sorted in descending order of abundance, and the proportion of the total number of individuals for each species is then plotted on the log scale against the species rank. The shape of the rank abundance plot can provide an indication of dominance or evenness, for example, steep plots signify assemblages with high dominance and shallower slopes indicate higher evenness. Rank abundance plots were constructed for each group.

Species composition of the sites was investigated. Plant species were divided into classes according to their establishment strategy (after Grime *et al.* 1988). The three categories were 1) annual species or those able to propagate from buried fragments 2) short-lived perennials (invasive perennials characteristic of disturbed habitat) and 3) long-lived perennial species characteristic of stable habitats. The proportion of total species belonging to each category was calculated and the difference between the controls and SRC of different ages explored.

Ordination of the weed communities was conducted using detrended correspondence analysis (DCA) performed with CANOCO 4.5. The Bray-Curtis index (Bray and Curtis 1957), sometimes called the Sorensen index, is a quantitative similarity index widely used and recommended (Clarke and Warwick 2001, Magurran 2004). The Bray-Curtis coefficient was calculated with Estimates 5.0.1 (Colwell 2000) and the biotic distinctness of the assemblages evaluated with the Mann Whitney U test performed with MINITAB 14.

Sixteen weed species thought to be of particular importance for phytophagous insects were identified and put in one of 4 groups according to their importance, group 1 being most important and 4 being least important (Table 2.3). Importance was recognised according to the number of associated insects with that particular weed species (adapted from Marshal *et al.* 2003). The same was done for arable weed genera potentially important in terms of seed for farmland birds (Wilson *et al.* 1996, Buxton *et al.* 1999, Marshal 2003, Holland *et al.* 2006). Importance was determined by the presence of the genus in the diet. Twenty-four species from 17 genera were included on this list (Table 2.4). There were 13 species that occurred on both lists but only 5 had the same importance ranking so the lists were quite different for each taxonomic group. Box plots were created to compare the changes in these species and genera at each site. Mann Whitney U was used to test for differences in the abundance of these plant groups between the control group and the SRC of different ages and was performed with MINITAB 14.

2.4 Results

There were no significant differences between the number of species recorded per quadrat in the controls or the SRC. The same was true of the percentage plant cover (Figure 2.2).

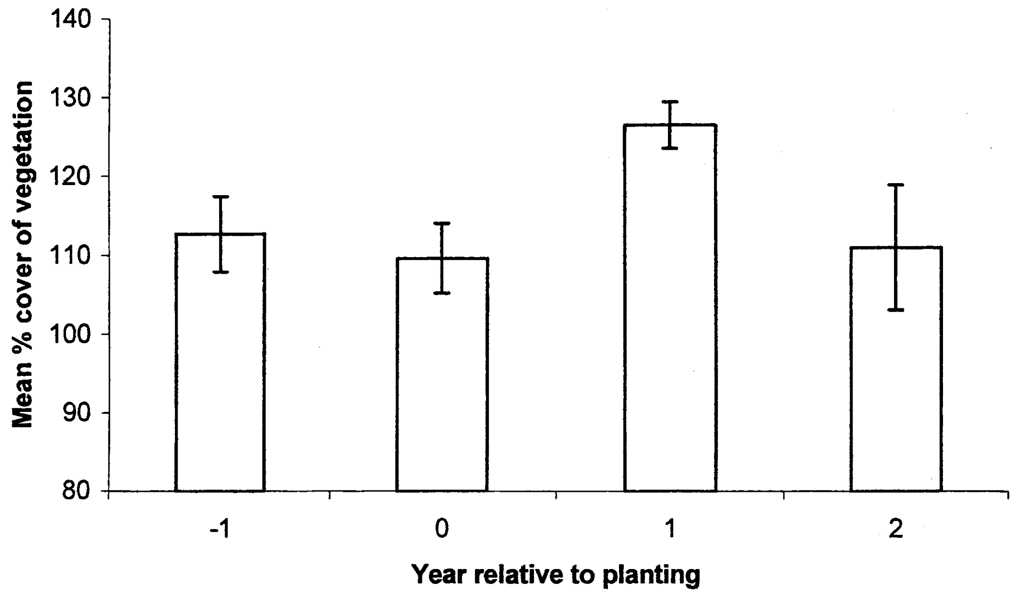


Figure 2.2 Mean percentage cover of ground vegetation for the sites at different ages (with 95% confidence intervals).

2.4.1 Diversity measures

A total of 93 species from 29 families were recorded (Appendix I). There were a total of 39 species recorded in the control plots and 87 in the SRC over the 3 years (58 in year 0, 70 in year 1 and 34 in year 2). There were 9 species that were recorded in the controls but were not recorded in the years after SRC was planted. However, there were 55 species which were recorded in the SRC plots which were not in the control plots.

Overall diversity was significantly greater in the SRC in year 0 (P=0.027) and year 1 (P=0.017) than in the controls (Table 2.2, illustrated in Figure 2.2). Although the average diversity score in year

2 remained higher than in the controls the difference was not significant (P=0.129). Species richness followed the same pattern and the difference between the controls and year 0 was statistically even greater (P=0.006) (Table 2.2). Rank abundance plots can be used to visualize species abundance distributions. The shape of rank abundance plots can provide an indication of dominance or evenness, for example, steep plots signify assemblages with high dominance and shallower slopes indicate higher evenness. The overall pattern in the control groups was for a few species to have a very high abundance, while the majority were less abundant than in the SRC (Figure 2.3). Years 0 and 1 demonstrate a more even rank abundance distribution but year 2 returns to the pattern exhibited by the control groups.

The composition of the plant community within SRC plots was different from that of the control plots. The controls were dominated by long-lived perennial species (90% of species recorded) but in year 0 when SRC was planted there was a more even proportion of each of the classes, annuals (34%), short-lived perennials (39%) and long-lived perennials (35%)(Figure 2.4). The proportion of annuals was significantly higher in the SRC in year 0 (P=0.001) and year 1 (P=0.0232) but by year 2 were back to the low levels found in the control plots (Table 2.2 and Figure 2.4). The short-lived perennials increased steadily from control proportions after SRC was planted until year 2 when levels remained the same as year 1.

Community ordination of the weed species abundance did not reveal any clear differentiation along the axes. It did suggest that the sites became much more similar in terms of species composition 2 years after SRC was planted. This was supported by the Bray-Curtis similarity values (Table 2.2 and Figure 2.5). The DCA also suggested that the sites, which previously had been improved grassland, were becoming increasingly similar to the set-aside site.

Table 2.2 Table of P-values for t-tests and where appropriate Mann-Whitney U tests for differences in diversity measures and flora classes between the control group (-1) and the SRC at different ages (0,1 and 2).

	-1 x 0	0 x 1	1 X x 2	-1 x 1	-1 x 2	0 x 2
Diversity measures						
Species richness	0.006**	0.82	0.497	0.012*	0.383	0.398
Simpson's diversity index	0.027*	0.787	0.824	0.017*	0.129	0.822
Bray-Curtis similarity index	0.5294	0.7974	0.9528	0.6189	0.7934	0.8959
Class						
1. Annuals	*0.0010***	*0.2581*	*0.0101**	*0.0232**	*0.6414*	*0.0005****
2. Short-lived perennials	0.2452	0.1786	0.0096**	0.0056**	0.9854	0.2762
3. Long-lived perennials	0.8415	0.1234	0.2541	0.1108	0.8669	0.9354

P***<0.001, P**<0.01, P*<0.05

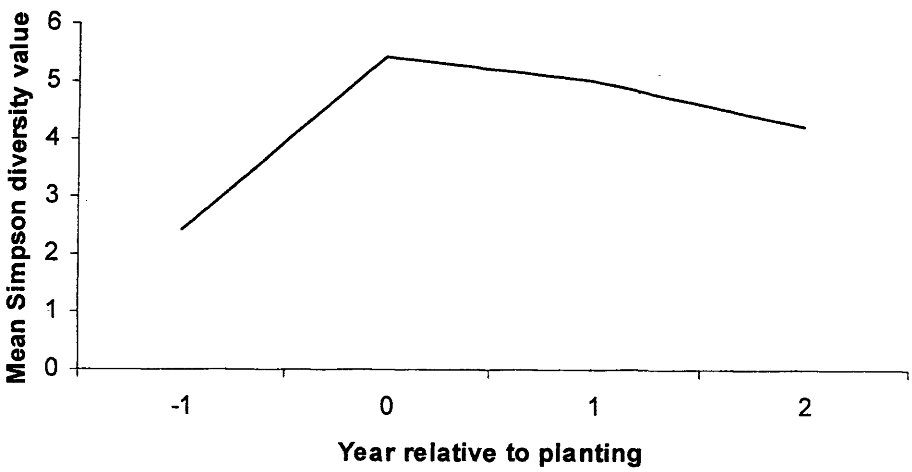


Figure 2.3 The trend in diversity scores showing the ground floral diversity increasing when SRC was planted (-1 = the control group; 0 = year of planting; 1 = second year SRC and 2 = third year SRC).

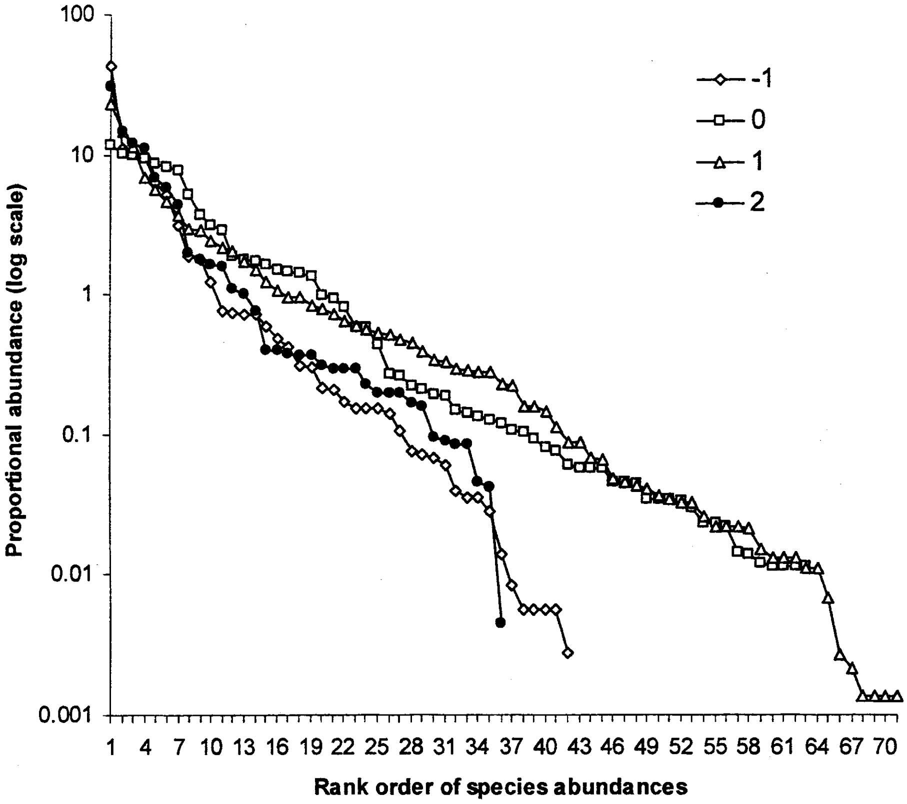


Figure 2.4 Rank abundance distributions of weed communities in conventional welsh farmland and in short rotation willow coppice (age codes as in Figure 2.2).

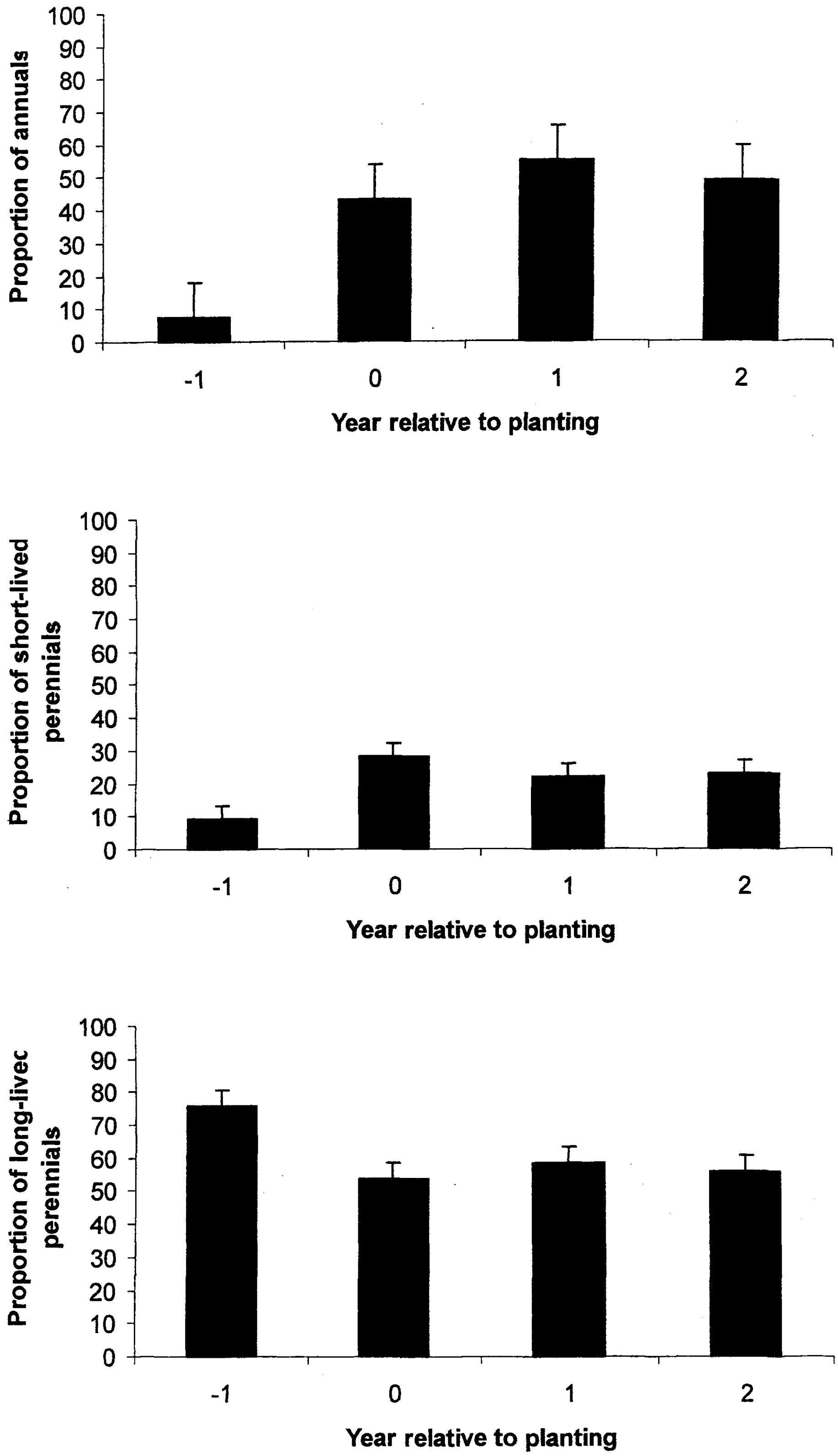
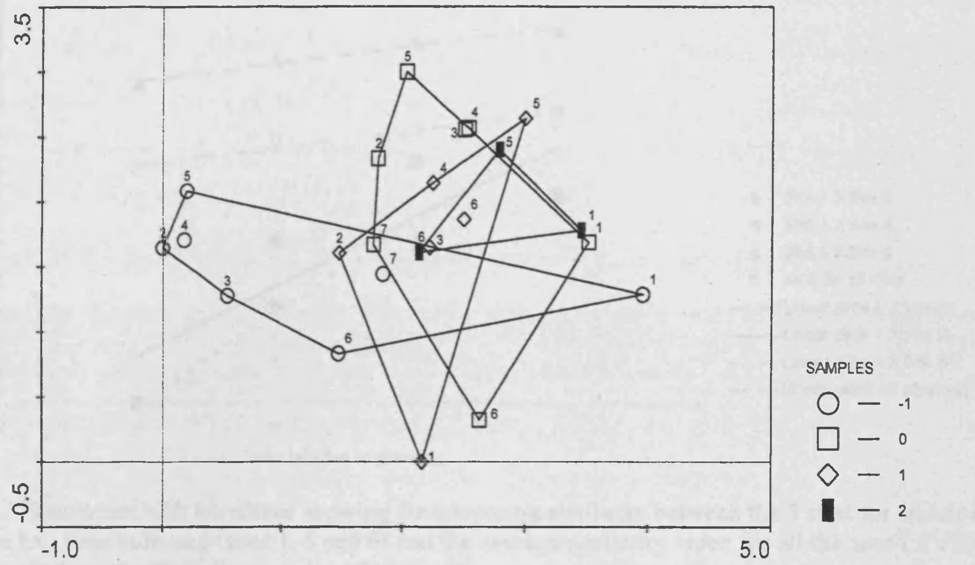


Figure 2.5 Proportion of annual, short-lived and long-lived perennial species (+1 SE) within the controls, and SRC of different ages (age codes as in Figure 2.2).

a)



b)

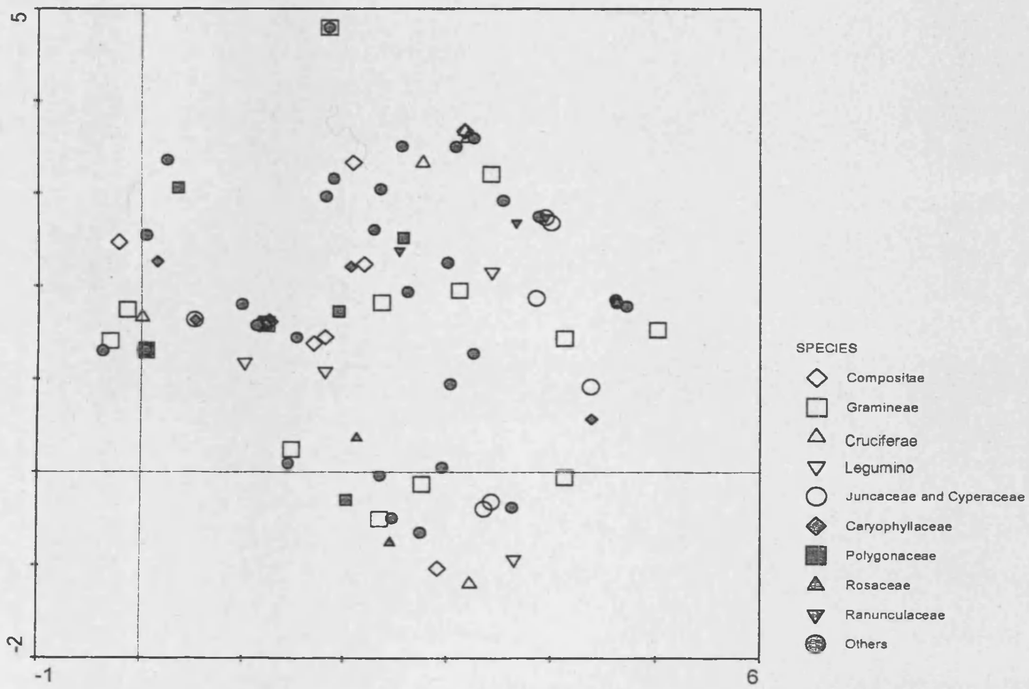


Figure 2.6 a) DCA ordination showing the increasing similarity between the sites (age codes as in Figure 2.2) b) DCA ordination of the weed families showing no taxonomic pattern.

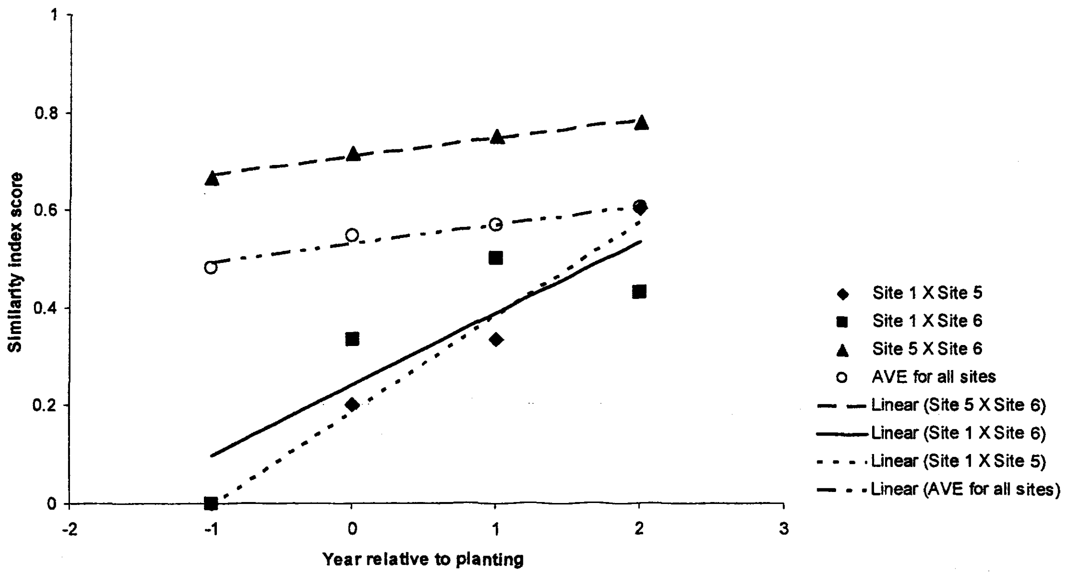


Figure 2.7 Scatterplot with trendlines showing the increasing similarity between the 3 sites for which 4 years data had been collected (sites 1, 5 and 6) and the average similarity index for all the sites (AVE). The index used was the Bray-Curtis index of similarity.

2.4.2 Weeds in relation to other taxa

Of the 16 species highlighted as important for insects 14 exhibited a positive response to the planting of SRC (Table 2.4). Of the 17 genera highlighted as important for birds in terms of seed, 13 responded positively (Table 2.5 and Figure 2.8). The following year (1) saw a much more mixed response and by year 2 most had disappeared completely (10/16 for the insect species and 12/17 for the bird seed resource). These abundance changes are illustrated for each site in Figure 2.6. Whether in year 0 or 1, every site did experience a dramatic increase in abundance of these important weed species. For the majority the increase is in year 0 but for sites 1, 4 and the insect weed species at site 2, the increases occurred in year 1 instead.

Table 2.3 Importance of selected plant species for phytophagous insects (adapted from Marshall *et al.* 2003) and their abundance. The groups are based on the number of associated insects with a particular weed species (60+ species = Group 1, 40-59 = Group 2, 20-39 = Group 3, 0-19 species = Group 4).

Group	Weed species	Number of associated insect species	Average % per quadrat (% change)						
			-1	0		1		2	
1	*Polygonum aviculare*	61	0.00	0.80	(+0.80)	6.66	(+5.86)	1.31	(-5.35)
	Rumex obtusifolius	79	1.60	2.12	(+0.52)	0.02	(-2.10)	0.19	(+0.17)
	Stellaria media	71	1.20	66.85	(+65.65)	7.68	(-59.17)	0.00	(-7.68)
2	*Cirsium arvense*	53	1.69	15.19	(+13.50)	8.66	(-6.53)	4.53	(-4.13)
	Poa annua	46	13.22	88.03	(+74.81)	26.43	(-61.60)	1.82	(-24.61)
	Senecio vulgaris	50	0.00	0.54	(+0.54)	22.08	(+21.54)	0.00	(-22.08)
3	*Cerastium fontanum*	22	6.76	1.68	(-5.08)	2.09	(+0.41)	0.00	(-2.09)
	Chenopodium album	31	0.00	8.52	(+8.52)	0.20	(-8.32)	1.69	(+1.49)
	Persicaria maculosa	20	0.00	24.88	(+24.88)	33.44	(+8.56)	2.10	(-31.35)
	Sinapsis arvensis	37	0.00	2.02	(+2.02)	0.00	(-2.02)	0.00	(0.00)
4	*Anagallis arvensis*	3	0.37	0.12	(-0.25)	0.01	(-0.11)	0.00	(-0.01)
	Capsella bursa-pastoris	13	0.00	16.40	(+16.40)	0.00	(-16.4)	0.00	(0.00)
	Fumaria officinaliis	3	0.00	4.98	(+4.98)	15.62	(+10.64)	0.00	(-15.62)
	Galeopsis tetrahit	13	0.00	0.70	(+0.70)	0.00	(-0.7)	0.00	(0.00)
	Solanum nigrum	7	0.00	11.68	(+11.68)	0.20	(-11.49)	0.00	(-0.20)
	Viola arvensis	2	0.00	0.26	(+0.26)	1.42	(+1.16)	0.00	(-1.42)

Table 2.4 Selected weed genera and their importance in farmland bird diet (adapted from Marshall *et al.* 2003).

Group	Importance	Weed Genera	Average % per quadrat (% change)						
			-1	0		1		2	
1	Very important	*Chenopodium*	0.00	8.52	(+8.52)	0.20	(-8.32)	1.69	(-1.49)
		Polygonum	22.10	0.80	(-21.30)	11.74	(+10.94)	1.71	(-10.03)
		Stellaria	1.20	66.85	(+65.65)	7.68	(-59.17)	0.00	(-7.68)
2	Important	*Cerastium*	6.96	1.68	(-5.28)	2.31	(+0.63)	0.70	(-1.61)
		Poa	13.22	88.03	(+74.81)	26.43	(-61.60)	0.00	(-26.43)
		Rumex	7.07	13.69	(+6.62)	10.28	(-3.41)	0.19	(-10.09)
		Senecio	0.00	1.76	(+1.76)	22.09	(+20.34)	0.00	(-22.09)
		Sinapsis	0.00	2.02	(+2.02)	0.00	(-2.02)	0.00	(0.00)
		Viola	0.00	0.26	(+0.26)	1.42	(+1.16)	0.00	(-1.42)
3	Present	*Capsella*	0.00	16.40	(+16.40)	0.00	(-16.40)	0.00	(0.00)
		Cirsium	3.91	94.27	(+90.36)	36.11	(-58.16)	5.42	(-30.69)
		Fumaria	0.00	4.98	(+4.98)	15.62	(+10.64)	0.00	(-15.62)
		Sonchus	0.00	1.54	(+1.54)	1.95	(+0.41)	0.00	(-1.95)
4	Nominally present	*Galeopsis*	0.00	0.70	(+0.70)	0.00	(-0.70)	0.00	(0.00)
		Galium	0.00	0.00	(0.00)	7.20	(+7.20)	0.00	(-7.20)
		Geranium	0.75	0.00	(-0.75)	0.02	(+0.02)	0.00	(-0.02)
		Matricaria	0.00	12.46	(+12.46)	0.00	(-12.46)	0.00	(0.00)

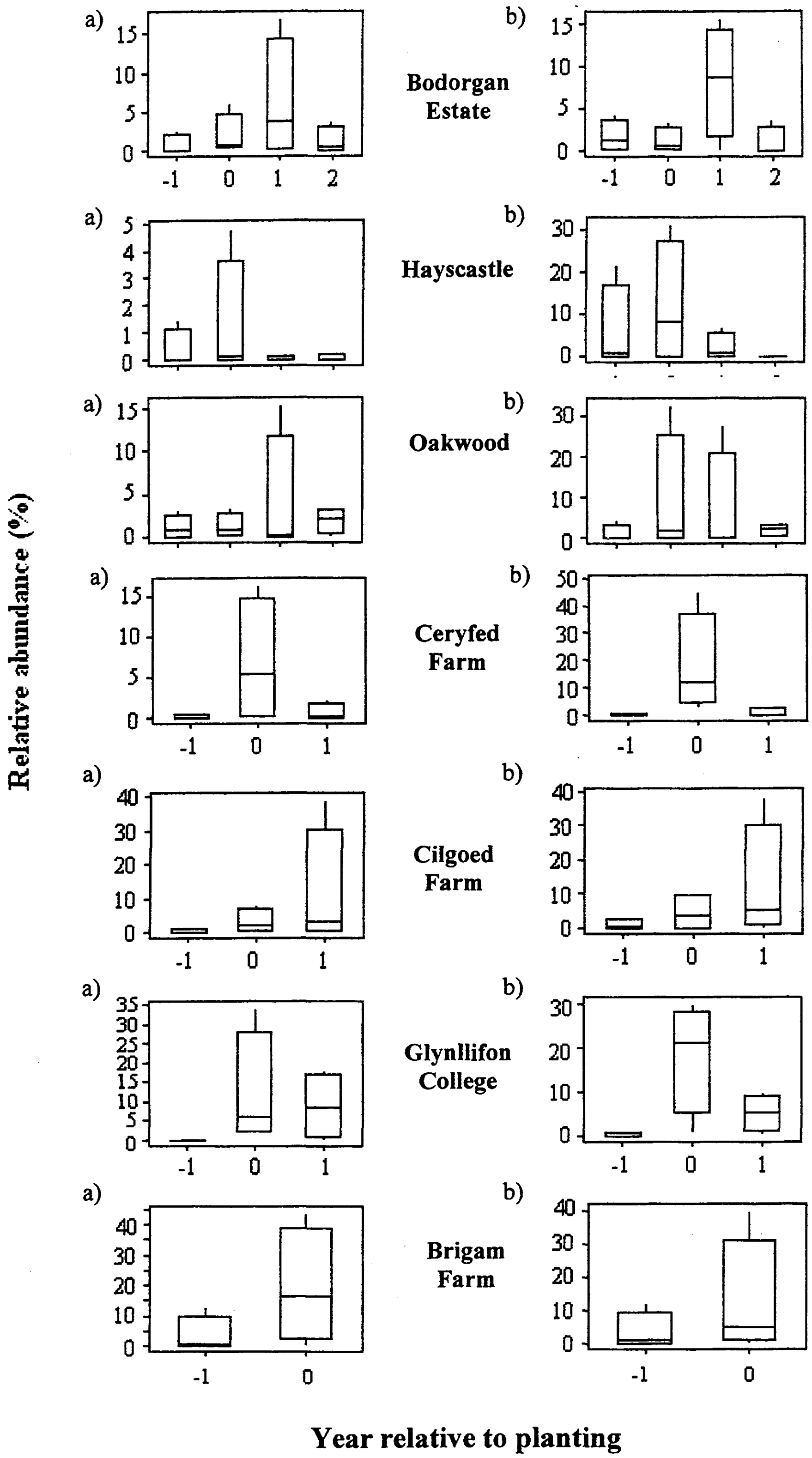
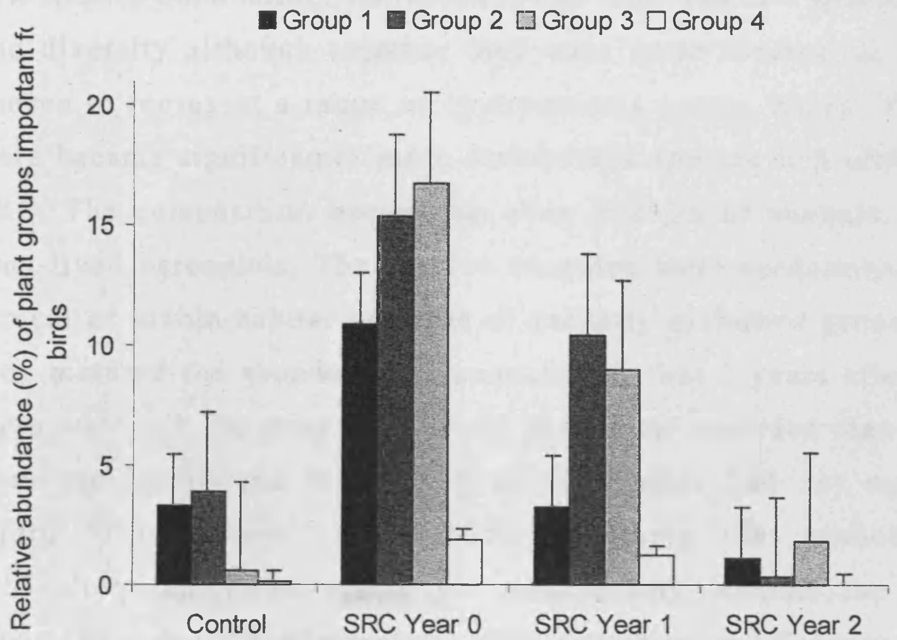


Figure 2.8 Box plots illustrating the changes in weed species important for a) insects and b) birds at each of the sites. Boxes represent the interquartile range, whiskers the 1st and 4th quartiles and the median is indicated by a solid line. Note the different abundance scales on the Y axis.

Table 2.5 Table of P-values of t-tests for differences between the abundance of each weed species listed as important between the control group and the SRC at different ages.

	-1 x 0	0 x 1	1 x 2	-1 x 1	-1 x 2	0 x 2
Bird genus	0.0159*	0.7048	0.0072**	0.0421*	0.4695	0.0014**
Insect species	0.0007***	0.2828	0.0302*	0.018*	0.8951	0.0016**

P***<0.001, P**<0.01, P*<0.0



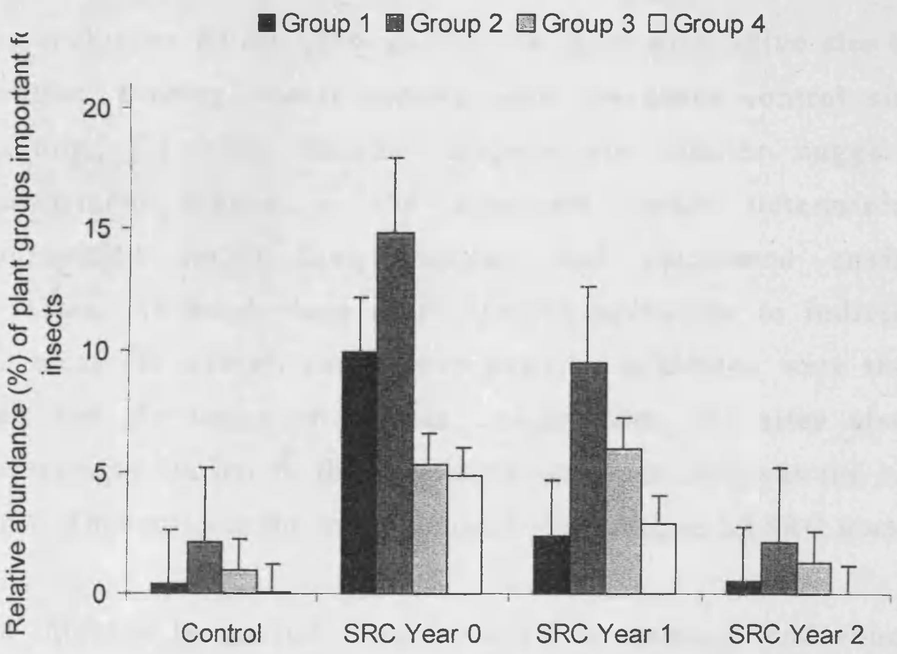


Figure 2.9 Trends in the abundance of weed genera a) important to birds and b) species important for phytophagous insects (for groups see Tables 2.3 and 2.4) in the control group and the SRC of different ages (+1 SE).

2.5 Discussion

The data support the idea that planting SRC in Wales will have a positive effect on weed flora and suggest that knock on effects are likely to be experienced by associated farmland biodiversity.

Long-lived perennials typified the vegetation of the controls with just a few species dominating. Individually the sites had low species richness and diversity although together they were quite diverse, as they were chosen to represent a range of environments across Wales. The ground flora became significantly more diverse and species rich after planting SRC. The composition became an even mixture of annuals, short and long-lived perennials. The species recorded were predominantly those typical of arable habitat or areas of recently disturbed ground. As the crop matured the abundance of annuals fell, but 2 years after planting there were still far more short-lived perennials recorded than there had been previously and the long-lived perennials had not managed to return to dominance. It is, however, likely that without further cultivation long-lived perennials will rapidly become the dominant group (Bazzaz 1979, Klein *et al.* 1998, Critchley and Fowbert 2000).

The Bodorgan Estate (Site 1) was the most distinctive site before the planting, sharing fewest species with the other control sites. After planting, the sites became increasingly similar suggesting that management regime is the dominant factor determining floral composition rather than location and associated environmental variables. Although there were species particular to individual sites and areas the overall community patterns exhibited were the same at each site. In terms of species composition, the sites also became increasingly similar to the long-term set-aside that was the control for site 1. This reflects the low chemical input nature of SRC management.

The increase in ground flora diversity in general, and abundance of certain species in particular, will initially benefit a wide range of insects. This positive response can be seen for a limited time because of herbicide applications and as the maturing coppice shades out the ground flora. However, the SRC itself is known to be very rich in insect life (Sage and Tucker 1997) and the presence of insects as a substantial food resource for birds will be an ongoing benefit. Some benefits will be more short-lived. The rapid increase in plant species of benefit to winter birds are almost as quickly reduced again. Unlike the insect resource, seeds cannot be maintained by the maturing SRC. It remains to be seen if these plant species increase again after harvest as has been reported in other studies of SRC on arable land (Cunningham *et al.* 2004) or if a positive input is needed to stimulate their return.

Floral species richness was lower than that recorded by Cunningham *et al.* (2004) in a similar study of arable habitat. Improved grassland is widely acknowledged to be generally less diverse that arable habitat (Buckingham *et al.* 2004, Woodhouse *et al.* 2005, Pywell *et al.* 2007). The lower number of species recorded after SRC was introduced could represent the depleted soil seed bank experienced in grassland systems. However, it could simply be that the Cunningham study included a greater number of sites in a different area of Britain and continued for a year longer than this study. The arable controls (Cunningham *et al.* 2004) showed almost the exact opposite to the grassland controls used in this study. Annual plants dominated the arable controls and their abundance fell when SRC was planted while the perennials increased. Short-lived perennials were at around the same abundance levels in the controls of both studies, and recorded in increasingly greater abundance in the years following planting SRC.

Critical assessment

Five percent steps in the plant abundance classes are quite small but I feel confident that it was possible to distinguish between these classes. I was able to look down on the vegetation in almost all cases making visual estimates easier and the subjective nature of the estimates was minimal as the same observer always conducted the surveys. The surveys were conducted a little late in the season considering main weed competition within SRC in England has been found to occur between April and June (Sage 1999). The timing was constrained by planting and spraying dates that were relatively late and it was thought more important to be consistent across the years of the study.

Implications and areas for further study

This study has shown the potential of SRC to provide a crop of enhanced biodiversity and so help the government reach targets agreed by The Convention on Biological Diversity. Incorporating SRC into the Welsh landscape would help the wider environment support an increased level of biodiversity, a main theme in the Environment Strategy for Wales (WAG 2006). Although the sites in this study were intended to be treated as a commercial crop the planters and growers had little or no previous experience of this crop. Even at sites where particularly aggressive chemical spaying occurred there was still an increase in weed abundance. In the future, weed control will probably be refined and become increasingly effective, rendering SRC less valuable for enhancing biodiversity unless contrary guidance is given.

Including SRC in Welsh agri-environment schemes such as Tir Gofal could significantly increase the floral diversity of Welsh farmland and positively effect associated taxa. Making it beneficial for farmers to be less aggressive in their control of weeds within this crop would allow it to realize its biodiversity potential and help the government to reach its biodiversity targets. With the EU Agriculture Council's decision to set a 0% rate of set-aside for 2008, farming will loose valuable areas of nil or low chemical input. SRC could be of particular importance, as it will inevitably reduce the chemical input into farming systems. Although the loss of set-aside will not be particularly felt in Wales any new farming system that reduces the level of intensity would be beneficial anywhere in the UK. The headlands associated with SRC might in themselves become a valuable biodiversity resource.

This study suggests that plant species introduced with SRC would benefit winter birds in terms of a winter seed resource. As a quality of life indicator birds are a particularly important group. The interaction between birds and changing food resources is an area that merits further investigation. The most obvious question raised is whether birds will utilize the resource available in SRC. Even if levels of weed seed resources rise significantly it does not necessarily follow that birds will utilize them. Birds select foraging sites based on a trade off between energy gain and predation risk (Lima and Dill, 1990). The change from grassland to SRC will alter the structure of the habitat, thus altering perceived predation risk (Bro *et al.* 2004, Atkinson *et al.* 2005, Wilson *et al.* 2005). The resource must also be detectable and accessible (Whittingham and Markland 2002, McCracken and Tallowin 2004, Whittingham *et al.* 2006). Further research is necessary to establish whether this resource is accessible to winter bird populations.

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Chapter 3

Seeds produced in SRC fields in Wales and their use by granivorous birds

3.0 Abstract

Passerines that eat seed in winter form an important guild of farmland birds and many are of conservation concern. The commercial cropping of SRC in Wales may provide a useful habitat for these declining granivorous species both in terms of winter food and by increasing the structural heterogeneity of the habitat. This study used six young (<2 year old) SRC fields distributed across Wales and through a variety of seed sampling methods and winter bird surveys set out to determine whether this crop is utilised by winter bird populations. The young SRC fields produced substantial amounts of seed and all the seeds of the weed species tested had high calorific values. Young SRC sites in Wales can be expected to produce an average of 4.2 MJ of energy per m^2 each winter in terms of seed production. Birds rapidly deplete these weed seeds as they ripen on the plant and then fall to the ground. Twenty-one of the 35 bird species recorded were granivorous and ground surface sampling showed significantly more seed in areas where birds had been excluded (P=0.021). *Cirsium* species were associated with the presence of Chaffinches and *Cerastium* and *Rumex* species with Redpoll. In addition, the strong negative correlation between seed abundance and bird condition scores (r2=-0.900 P=0.037) suggests that the birds in this study were relying directly on the seed provided within the SRC. Planting SRC could significantly raise the amount of winter seed in the Welsh landscape. The resource would be utilised by a range of bird species, several of which are of conservation concern. Sympathetic management of SRC should aim to maximise the diversity of weed species to extend the period of seed shed.

3.1 Introduction

Passerines that eat seed in winter form an important guild of farmland birds and many are of conservation concern (Gibbons *et al.* 2006). The decline of these birds has in part, been driven by changes in adult survival (Peach *et al.* 1999, Siriwardena *et al.* 1998, 2000, Newton 2004). As these species rely heavily on weed seeds for food, particularly outside the breeding season (Moorcroft *et al.* 2002, Robinson and Sutherland 2002), the estimated 2% per year decline in the arable seed bank since the 1940's (Robinson and Sutherland 2002) has had a profound affect on them.

Introducing SRC into the Welsh landscape will substantially increase weed abundance including many species that produce seed eaten by winter birds (Chapter 2). Although the SRC sites studied in Chapter 2 became increasingly similar in terms of weed composition over time, in the first few years they were highly varied. This diversity of weed species will affect the extent and quality of seed production. Seed production is also determined by growth and maturation, as affected by environmental conditions such as weather, soil fertility and time of year (Kendeigh and West 1965). In addition, weeds and seed production will be affected by management regime; each site in this study was managed slightly differently according to the individual farmers and site conditions (Chapter 1, Table 1.1).

The timing of seed shed (when seeds ripen and drop from the vegetation to the ground) is another highly variable factor, being species, crop and climate specific as documented for a number of weed species (Rauber and Koch 1975, Leguizamon and Roberts 1982). It is usually at the time of seed shed that the seeds are most available to predators, although some seed predators will consume ripe unshed seeds direct from the plant (Kjellsson 1985). Just prior to shedding, ripe seeds are abundant but not necessarily available to all of the birds, illustrating an important difference between abundance and availability (Hutto 1990). However, in many other agro ecosystems, weed seeds are readily available to a range of predators and high consumption rates of weed seeds have been recorded (Burst and House 1988, Smith and Watt 1993, Cardina *et al.* 1996, Anderson 1998, Tooley *et al.* 1999, Manalled *et al.* 2000, Povey *et al.* 2003, Westerman *et al.* 2003).

Environmental and crop management factors that affect which weed species grow and how much seed they produce may also affect the nutritional or energy value of the seeds. Differing calorific value of food has direct effects on growth (O'Sullivan *et al.* 1991) and egg production (Pallister 2004) in birds. These effects have been studied primarily in poultry but probably also exist in wild birds. Maintenance of condition is crucial to survival, particularly in the winter when food is scarce, although seed chemistry is less important than the effects of seed size and structure (Diaz 1996). Birds choose seeds based on their size and structure, which relates to seed processing speed and energy demands. For example, sparrows consume seeds that are an order of magnitude smaller than the seeds consumed by finches of similar body mass (Benkman and Pulliam 1988). For some species such as Linnets and Reed Buntings, the density of seed is important in order for them to meet their energy demands (Moorcroft *et al.* 2002).

Birds select foraging sites based on a trade off between this energy gain and predation risk (Dill 1987, Lima and Dill 1990). The degree of vegetation cover will alter an individual's perceived predation risk and affects most bird species (Bro *et al.* 2004, Atkinson *et al.* 2005, Wilson *et al.* 2005, Whittingham *et al.* 2006). It has been shown that the selection of stubble fields by wintering granivorous birds reflects both food abundance and vegetation cover (Moorcroft *et al.* 2002). Studies in other habitats have also shown that bird populations are limited by interacting predation and food supply factors (Sih 1980, 1982, Lima 1985, 1986, Rogers and Smith 1993).

The winter fat reserve in birds is a useful trait for investigating cost-benefit trade-offs and their implications for population regulation and limitation (Dill 1987). The hypothesis of optimal fattening predicts that a certain fat reserve maximises the probability of winter survivorship by representing the best possible trade-off between costs and benefits of winter fat (Lima 1986, Houston *et al.* 1988, Ekman and Hake 1990). Costs include costs of flight (Freed 1981), loss of agility at high fat levels (Blem 1975), and exposure to predators that increases with the high foraging rates associated with high fat reserves (Lima 1986). The major benefit of fat is that it insures against starvation and it has been demonstrated that fat reserves increase with foraging uncertainty or as the predictability of food supplies decrease (Ekman and Hake 1990, Ekman and Lilliendahl 1995, Rogers and Smith 1993, Bednekoff *et al.* 1994, Witter and Swaddle 1995, Gosler 1996).

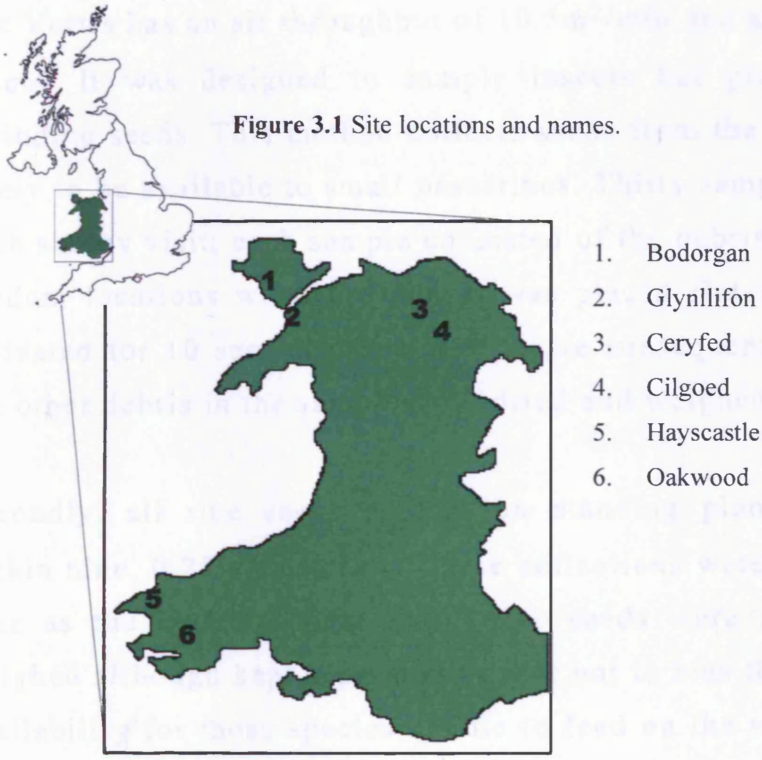
The addition of weeds to pastoral landscapes where they are particularly scarce might be of even greater importance for birds than improving the quality of existing weedy habitat such as arable areas (Henderson *et al.* 2004, Robinson *et al.* 2004, Parish and Sotherton 2008). Recent studies suggest that in grassland-dominated areas like Wales, if even a single field (typically 5-10 ha) on each farm was used for weedy crops, farmland bird numbers could be increased (Robinson *et al.* 2001, Robinson *et al.* 2004, Gillings *et al.* 2005, Siriwardena *et al.* 2006). These seeds must be both detectable and accessible, in order for birds to utilize them (Whittingham and Markland 2002, McCracken and Tallowin 2004, Whittingham *et al.* 2006). For example, some species require a certain amount of bare ground to enable efficient foraging (Whittingham *et al.* 2006). Agricultural intensification has encouraged uniform dense swards, thus reducing habitat diversity and any land use change that provides heterogeneous sward structure could facilitate bird conservation (Whittingham and Evans 2004, Whittingham *et al.* 2006).

The commercial cropping of SRC in Wales may provide a useful habitat for these declining granivorous species both in terms of winter food i.e. seed abundance, and by increasing the structural heterogeneity of the habitat. The objectives of this study were to quantify the seed resource produced by young SRC fields in Wales and with a number of methods, determine whether it is utilised by bird populations.

3.2 Study sites

Six SRC field sites across Wales were used in this study (Figure 3.1). The sites are those (sites 1-6) described in Chapter 1. The seventh site, Brigham Farm, was not used as it had not been successfully planted at the time of this study. For details of the sites see Chapter 1 Table 1.1.

Figure 3.1 Site locations and names.



3.3 Methods

3.3.1 Seed production

The abundance of seed resources was quantified in two ways, at 4 of the SRC sites (Glynllifon College, Cilgoed, Hayscastle and Oakwood), every 2 weeks from late September 2005 to early January 2006.

Firstly, seeds were collected using a 'Vortis' suction sampling system. The Vortis has an air throughput of $10.5m^2$/min and a collection area of $0.2m^2$. It was designed to sample insects but picks up all debris including seeds. This method collects seeds from the soil surface, most likely to be available to small passerines. Thirty samples were taken on each survey visit; each sample consisted of the debris collected at three random locations when the Vortis was placed flat to the ground and activated for 10 seconds. The seeds were subsequently separated from the other debris in the samples, air-dried and weighed.

Secondly, all ripe seeds present on standing plants were collected within nine, $0.25m^2$ quadrats. These collections were made at the same time as the Vortis collections. These seeds were also air-dried and weighed although kept separate in order not to bias the measure of seed availability for those species unable to feed on the standing crop. This sampling regime represented a compromise between adequate sampling per field and logistical constraints of seed analysis while providing a standardised measure of seed abundance (Benoit, Kenkel and Cavers 1989).

After weighing, 10x1g of seed from six of the most prolific species or groups of species were separated (*Cirsium* spp, *Chenopodium album, Rumex* spp, *Alopecurus geniculatus, Persicaria hydropiper* and *Persicaria maculosa*). These samples were used to determine calorific content for each species or group. Analysis was carried out by bomb calorimetry at the Institute of Grassland and Environmental Research

(IGER) laboratory at Aberystwyth, which specialises in this analytical technique.

3.3.2 Exclusion nets

In August 2005, exclusion nets were put up at three sites Glynllifon, Cilgoed, and Hayscastle. The netting used was a strong nylon 1.5cm gap mesh designed specifically to keep birds off particular areas and is widely used in horticulture (Figure 3.2). Although the effects of other seed predators in the UK (e.g. insects and mammals) are negligible (Robinson 1997), this mesh allowed other seed predators access so that only birds were excluded. Three nets were constructed at each site and the protected area under each net measured 25x1.5m. At the end of January 2006, the areas beneath the exclusion nets were sampled. From under each net, three Vortex samples, 3x 0.25m^2 quadrats of vegetation and 3x soil samples (the top 1cm of soil from an area 20cm^2) were taken. The same samples were taken from a nearby strip within the coppice with a similar vegetation composition from which birds had not been excluded. All seeds were separated from the samples, air-dried and weighed. Data were transformed where appropriate and comparisons made using t-tests.

Figure 3.2 Exclusion net at Glynllifon College (site 2).

3.3.3 Bird condition

At the Hayscastle site, birds were caught by mist-net during the seed-sampling period (early September until mid January). Three 18m 4 shelf mist nets were erected within the SRC. All birds caught were identified and marked with aluminium (BTO) rings. Each individual was given a tracheal pit score (TPS) and pectoral muscle score (PMS) recorded for consistency by a single recorder (D. Fry). These scores reflect levels of fat and muscle protein reserves. These have a bearing on a bird's future survival prospects and can provide information about the health or 'condition' of a population. TPS is a measure of the amount of fat deposited in the tracheal pit. This reserve is directly proportional to the total body fat carried by the bird (Redfern and Clark 2001). Fat, as the primary energy reserve fluctuates and typically increases throughout the day in non-migrating diurnal birds and may determine the bird's chances of survival. The scoring system was a modified version of the Biometrics Working Group of the BTO Ringing Committee (BWG) system (Redfern and Clark 2001). Pectoral muscle may also be used as a fuel under certain conditions and is therefore another valuable indicator of body condition. Score classes were those used in the BTO Ringer's Manual (Redfern and Clark 2001). Because of the intensive nature of mist netting, it is very time consuming, and the distance of travel required to the site, just one site was chosen to collect this data from.

3.4 Results

3.4.1 Seed production

From late September to early January, Hayscastle produced an average of 0.28kg of seed per m^2. The standing seed, on vegetation, peaked in October while the ground seed (from the Vortis sampling) peaked in November (Figure 3.3). For the same period, Glynllifon produced 0.39kg/m^2, the unshed seed peaking again in October while the ground seed peaked in November (Figure 3.3). Oakwood produced 0.02kg/m^2. Both seed surveys at this site showed that peaks were occurring as sampling began in September or had already finished (Figure 3.4). Calorific values are given in Table 4.1. Based on these figures, in terms of seed, Glynllifon produced an average 7.15 MJ/m^2 (min: 5.94, max: 8.12) of energy, Hayscastle 5.13 (min: 4.26, max: 5.82) and Oakwood 0.37 (min: 0.3, max: 0.39). Young SRC sites in Wales might therefore be expected to produce an average of 4.21 MJ of energy per m^2 in terms of seed production.

Table 3.1 Calorific values of seeds collected from four SRC fields across Wales.

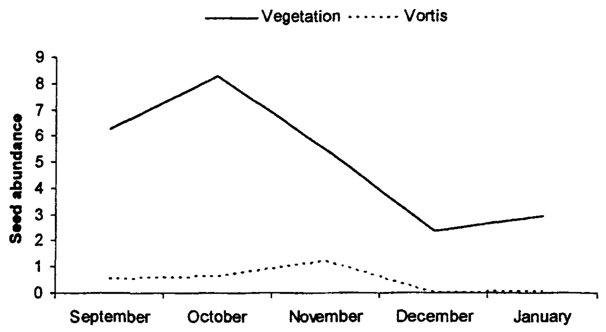
Species	Mean energy content (MJ/kg) of seed	Range of energy content (MJ/kg) of seed
Cirsium spp	19.82	19.73-20.79
Chenopodium album	18.85	18.33-19.31
Rumex spp	17.50	16.99-18.03
Alopecurus geniculatus	17.23	16.94-17.58
Persicaria hydropiper	16.72	15.01-18.06
Persicaria maculosa	16.60	15.21-17.56

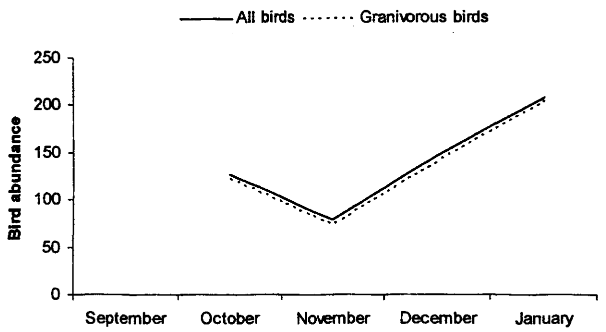
3.4.2 Bird and seed abundance

There is a big discrepancy in the total volume of seed collected by the two sample techniques (Figure 3.3), with collection from the plant revealing a greater quantity of seed. The Vortis sampling revealed a peak in seed abundance shortly after the peak shown by vegetation sampling. This reflects the time of seed shed when the majority become available to the birds. Bird abundance appeared either to peak, or begin to increase around this time. As the resource was depleted, the bird numbers declined at Glynllifon and Cilgoed (Figure 3.3).

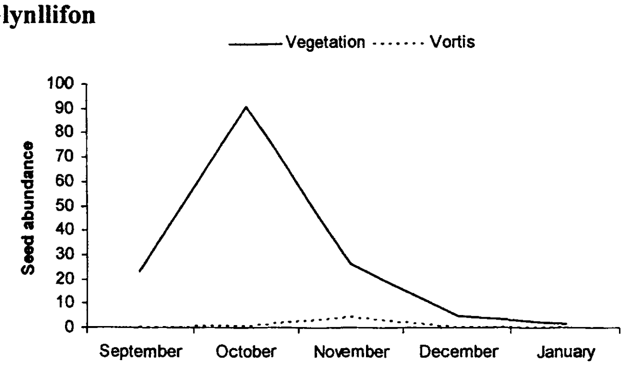
Twenty-one of the 35 bird species recorded were granivorous (60%) but at the majority of sites, it was a greater proportion than this (Table 3.3). The two lowland Pembrokeshire sites (Hayscastle and Oakwood) had the highest species counts (22 at each) while the upland site at the greatest elevation (Ceryfed) had the lowest (13).

Hayscastle





Glynllifon



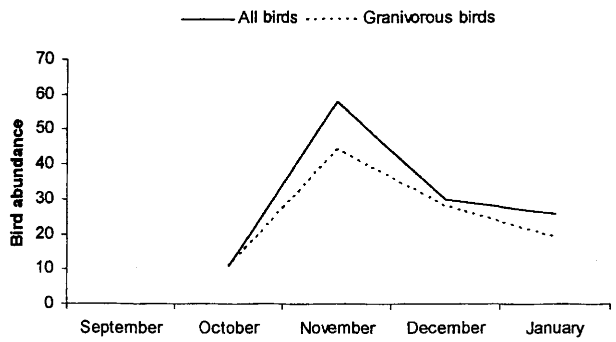
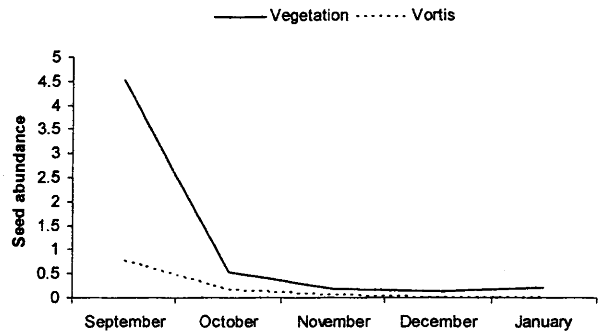
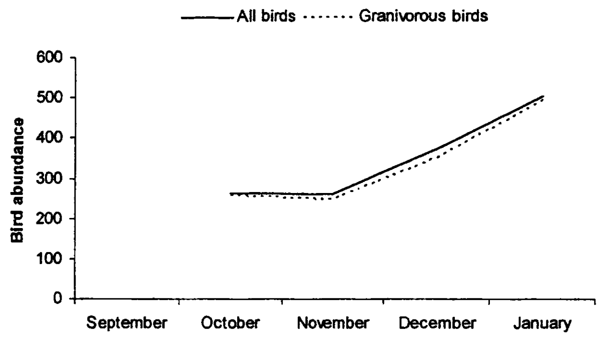


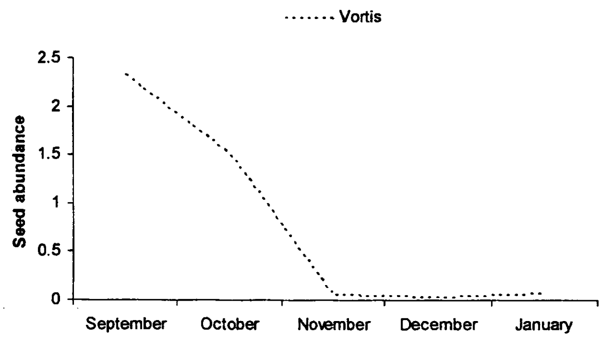
Figure 3.3 Comparing peak seed abundance (kg/ha) with the bird abundance (mean no per visit) at 4 of the sites. Note different scales on the y-axis and that vegetation sample data are not available for Cilgoed.

Oakwood





Cilgoed



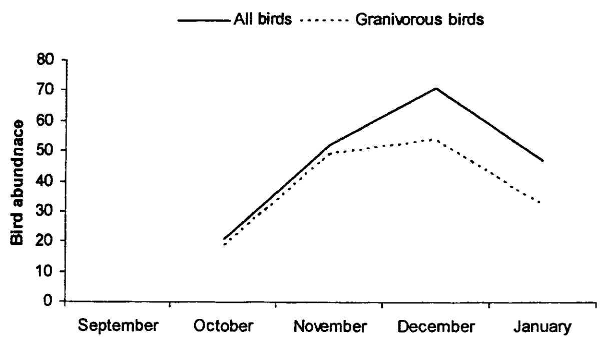


Table 3.2 List of winter bird species recorded at the six sites.

	Bodorgan	Hayscastle	Oakwood	Glynllifon	Ceryfed	Cilgoed
Granivorous species						
Blackbird	*	*	*	*	*	*
Blue Tit	*	*	*	*	*	*
Bullfinch		*		*	*	
Chaffinch	*	*	*	*	*	*
Coal Tit						*
Dunnock	*	*	*	*	*	*
Fieldfare		*		*		*
Goldfinch		*	*			
Great Tit	*	*	*		*	*
Greenfinch	*	*	*		*	*
Linnet		*	*			
Pheasant	*		*			*
Redpoll				*	*	*
Redwing		*	*			
Reed Bunting	*	*	*	*		*
Robin	*	*	*	*	*	*
Song Thrush	*	*		*		
Starling	*	*	*			
Willow Tit			*			
Woodpigeon	*		*	*	*	*
Yellowhammer						*
Other species						
Buzzard		*		*	*	
Crow			*		*	*
Goldcrest	*	*		*		
Great Spotted Woodpecker				*		
Jay			*	*		*
Lesser spotted Woodpecker				*		
Long-tailed Tit			*	*		*
Magpie						*
Rook		*	*			
Snipe	*	*				
Sparrowhawk	*	*		*		
Stonechat		*	*			
Woodcock			*			
Wren	*	*	*	*	*	*
No of species	16	22	22	19	13	19
No of granivorous species	13	15	15	11	10	14
Percentage of granivorous species	81%	68%	68%	58%	77%	74%

3.4.3 Exclusion nets

At all three sites where exclusion nets were used, less seed was found outside the nets than inside the nets (Figure 4.4). This was significant for the Vortis sampling and in the soil at Glynllifon (Table 4.2). There were no significant differences found at the other sites when tested individually, but when all sites were combined, the Vortis sampling showed significantly less seed outside the nets (t=2.38, P=0.021, DF=43). The large confidence intervals (Figure 4.4) are due to the patchy nature of the seeds. For the Vortis sampling, the confidence limits were much smaller outside the net.

Table 3.3 Results (P-values) from 2-sample t-tests comparing inside and outside the exclusion nets.

	Soil	Vegetation	Vortis
Glynliffon	**0.003****	0.319	**0.012***
Oakwood	0.762	0.456	0.617
Hayscastle	0.866	0.068	0.329

* Significantly different
** Highly significantly different

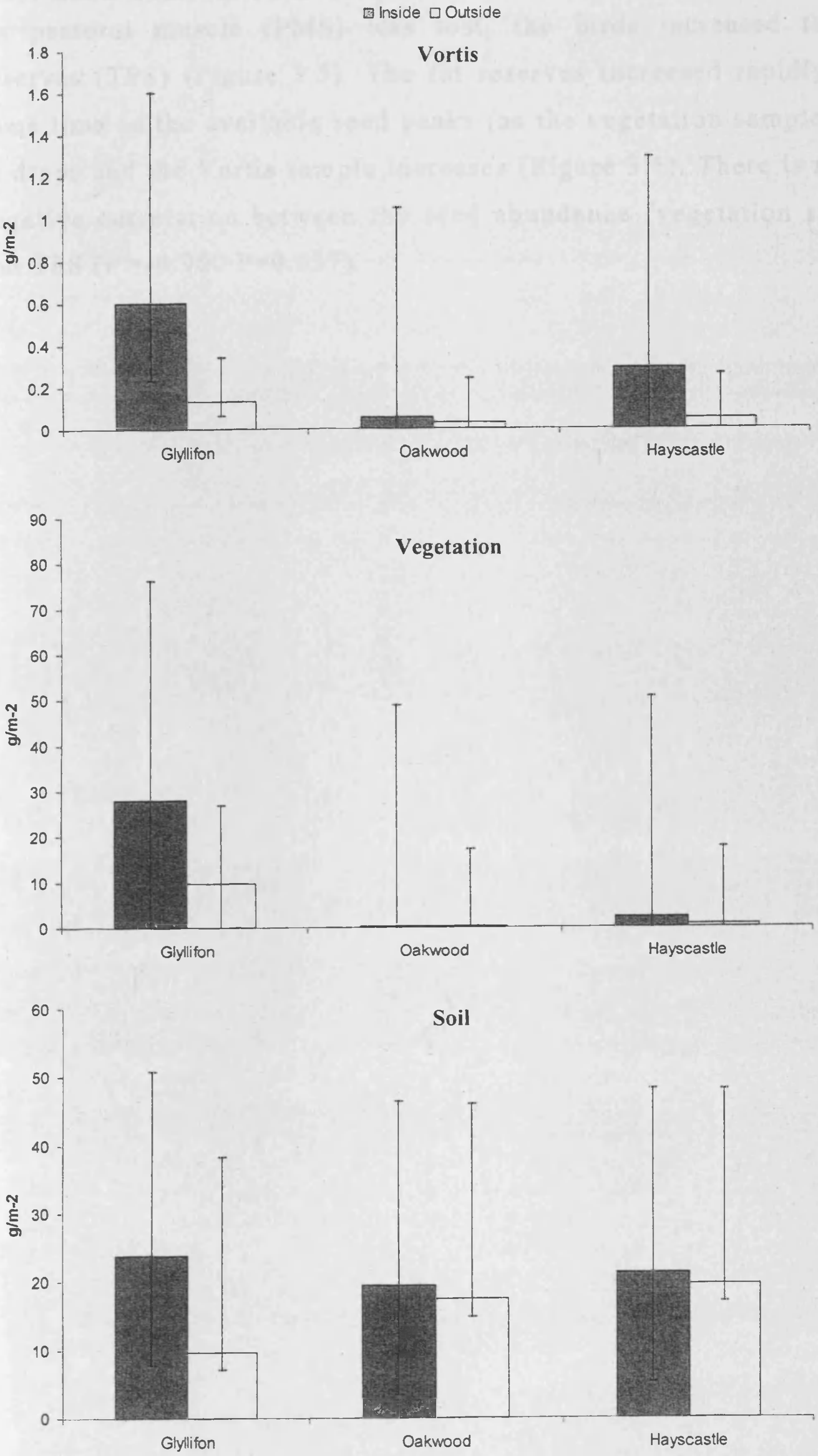
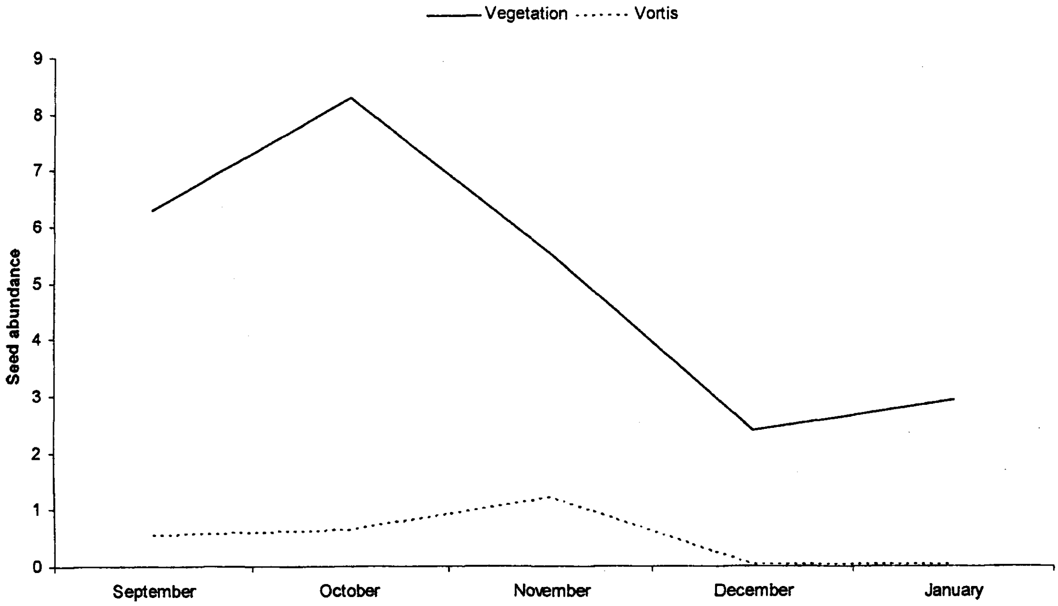


Figure 3.4 Average weights (g/m^2) for Vortis, vegetation and soil samples (with 95% confidence intervals).

3.4.4 Seed abundance and bird condition

As pectoral muscle (PMS) was lost, the birds increased their fat reserves (TPS) (Figure 3.5). The fat reserves increased rapidly at the same time as the available seed peaks (as the vegetation sample begins to drops and the Vortis sample increases (Figure 3.5). There is a strong negative correlation between the seed abundance (vegetation samples) and TPS (r^2=-0.900 P=0.037).



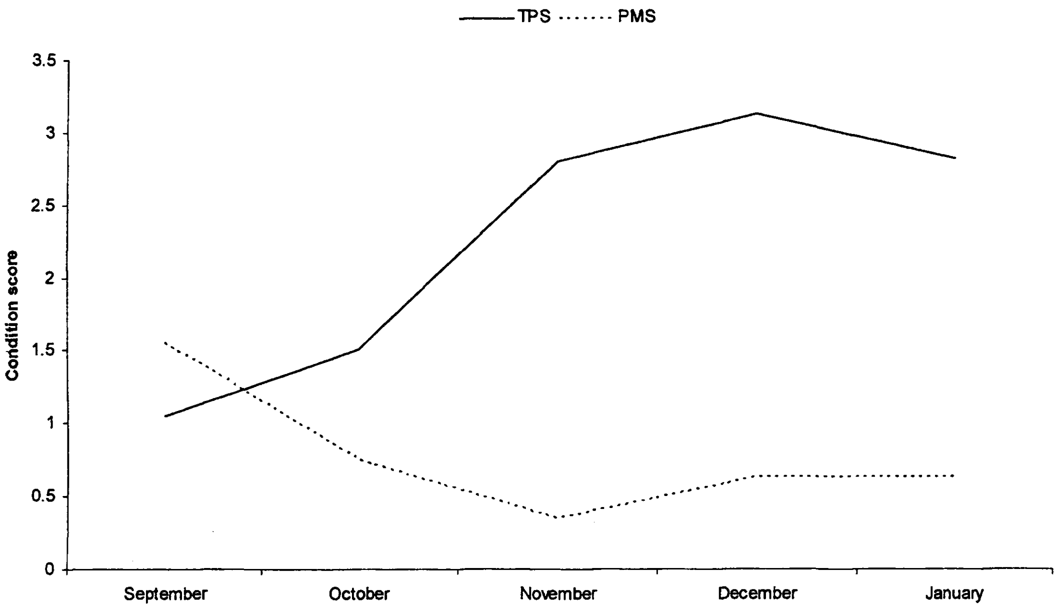


Figure 3.5 Trends in the seed abundance (kg/ha) and the condition scores (TPS = Tracheal Pit Score and PMS = Pectoral Muscle Score) of birds caught at Hayscastle.

3.5 Discussion

This study shows that young SRC fields in Wales have the potential to produce substantial amounts of weed seeds that can be utilised by many bird species. The seeds are generally high in energy value, detectable and accessible to a range of species. The perceived predator risk is low enough to enable foraging and is likely to decline for many species as the weeds provide shelter (Whittington and Evans 2004) and the willow itself provides watch posts and additional shelter that is not generally available in managed grassland.

Substantial amounts of seed were produced by the young SRC fields and all the seeds of the weed species tested had high calorific values. Winter seed is a resource that has been reduced across the UK during the last 3-4 decades, particularly in grassland-dominated areas like Wales (Vickery *et al.* 2001). Grazed grass fields are generally avoided by granivorous species (Wilson *et al.* 1996) because they no longer provide any seed resources for this guild (Vickery *et al.* 2001). The timing of peak seed production and the total seed production was highly variable between sites and this is consistent with other studies (Westerman *et al.* 2003). The lowland sites on the west coast (Glynllifon and Hayscastle, Figure 3.1) shed seed slightly earlier than the upland site (Cilgoed), although, the period of seed shed seemed to last slightly longer at the later site. The Oakwood site produced the smallest amounts of seed and the data show that the majority had been shed by October. This site received the most aggressive management regime towards weed species which may be the cause of this effect.

There was a big discrepancy between the volume of seed collected by the two sample techniques suggesting a rapid depletion of seeds as they ripen on the plant and then fall to the ground. In other agro ecosystems, high consumption rates by a variety of seed-eating animals over short periods have been recorded (Burst and House 1988, Povey *et al.* 1993, Cardina *et al.* 1996, Anderson 1998, Tooley *et al.* 1999, Manalled *et al.* 2000, Westerman *et al.* 2003,). This study showed that in this habitat, it is the birds that are the biggest seed predators. The majority of the birds recorded were granivorous and their numbers increased shortly after the time of seed shed at every site. In addition, at the end of the winter, there was significantly more seed remaining in areas from which birds were excluded i.e. under the nets. This pattern showed up particularly well at Glynllifon, which produced the greatest volume of seed. At this site, there was also significantly less seed in the soil where birds had been feeding so the birds had significantly reduced the seed being recruited back into the soil seed bank.

It has been shown previously in non-agricultural ecosystems that seed predation is an important factor limiting the population expansion of plants (Reichman 1979, Marone *et al.* 1998, Alignier *et al.* 2008). The results of the exclusion net experiment had large confidence intervals and ideally, greater numbers of samples need to be taken to reduce these. Seed sampling is an intensive activity and this sampling regime provides a standardised measure of seed abundance (Benoit *et al.* 1989). The amount of seed collected was always much less variable outside the nets suggesting that the patchiness is reduced by feeding, lending further weight to the idea that birds act as a very efficient weed control in this crop.

In the field, it was observed that goldfinches were particularly associated with standing *Cirsium* species, feeding on the seeds directly from the plant. Once the plants started to die back and collapse, ground foragers such as Blackbird, Redwing and other thrushes seemed to move in. These associations merit further investigation as there may be many such interactions between other species.

At Hayscastle, the birds tracheal pit score (TPS or 'fat score') increased steadily over the recorded period of seed shed. As seed shed begins the greatest abundance of seed is available but as time goes on seed abundance depletes. As abundance decreases so too do foraging certainty and the predictability of food supply. As the food abundance steadily falls, the birds just as steadily increase their fat deposits. The birds are adjusting their fat reserves in direct response to the changing food supply. There are no other sources of seed in the landscape around this site other than perhaps some garden feeders. This would suggest that the birds are relying directly on the seed provided within the SRC.

If agricultural practices can advance weed morphology and cause early seed shed (Westerman *et al.* 2003) the opposite should also be true. Management that leads to later seed shed could extend the availability of seeds further into the winter and have a significant impact on granivorous bird populations. Because weed species vary so much in the times at which they set seed, a greater diversity of weed species may increase the longevity of this resource.

Implications and suggestions for further research

This study has shown that young SRC sites can significantly increase the amount of winter seed in the Welsh landscape and provides compelling evidence that the resource is available to a range of bird species. This resource is non-renewable however, as most plants only set seed prior to the onset of winter (Grime *et al.* 1989). Sympathetic management should aim to maximise the diversity of weed species and extend the period of seed shed. Associations between specific bird species and the availability of seeds to them merits further investigation. This would allow targeted management to maximise the benefit to local bird populations and conserve those species most at risk.

Chapter 2 showed the sites becoming increasingly similar over time in terms of weed composition and the annuals (the most important group for the granivorous guild of birds), becoming scarce. The benefits of these weed species to birds is therefore likely to be short-lived. This chapter and Chapter 2 raise the question what happens to bird populations as the SRC establishes and the seeding weed species disappear? Further investigation should be done to establish if birds utilise SRC out of the winter season and older more weed free coppice.

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Chapter 4

Bird diversity and abundance in SRC in Wales

4.0 Abstract

The use of agricultural chemicals has negatively affected bird populations indirectly by reducing insect availability and abundance. SRC, by virtue of its nature and structure, requires far fewer chemical applications than other current farming practices in Wales and could help increase non-cropped areas important for insect populations. This study set out to describe the bird populations of SRC in Wales during the winter but particularly the breeding season in a range of coppice ages. This was achieved by using eight SRC fields distributed across Wales and a mixture of breeding and winter bird surveys and mist netting studies. In the young plots, 35 species were recorded during the winter surveys and 46 during the breeding surveys. Young SRC in the winter was characterised by large flocks of mixed finches, but also included Reed Buntings and thrushes such as Redwing and Song Thrush. Finches were still a diverse group during the breeding season in young coppice but far less abundant. Other groups characteristic of the SRC at this time were warblers, tits, thrushes and starlings, all of which were present in reasonable numbers. As the SRC matured, breeding bird numbers increased particularly warbler species. Five species were confirmed to be nesting within the older SRC; Blackbird, Song Thrush, Redpoll, Goldfinch and Willow Warbler (only Skylark nested in the young crop). The increase in nesting birds was accompanied with an increase in corvid numbers. A total of fifty-one species were recorded overall from the SRC plots in both young and established SRC during the breeding bird surveys. Willow Warblers were the most abundant species in mature SRC. Young SRC provides winter forage for large numbers of finches but also for Reedbuntings and thrushes. As it matures, SRC becomes valuable habitat for nesting, feeding and post breeding juvenile dispersal for warblers, finches and thrushes in particular. Maintaining a mix of coppice age will maximise the benefits to the widest range of bird species.

4.1 Introduction

Many farmland birds in Western Europe have suffered severe population declines since the 1970s (Tucker and Heath 1994, Fuller *et al.* 1995, Siriwardena *et al.* 1998, Donald *et al.* 2001), probably caused by agricultural intensification (Krebs *et al.* 1999, Aebischer *et al.* 2000, Chamberlain *et al.* 2000, Chamberlain and Fuller 2000, Benton *et al.* 2002, Donald *et al.* 2006). The use of agricultural chemicals affects bird populations both directly, causing bird mortality (Carson 1962, Mineau 2002) and indirectly, reducing bird food resources (both seed (Chapter 3) and insects). Insect abundance is reduced by both herbicide (Freemark and Boutin 1995, Taylor *et al.* 2006) and pesticide (Pimentel *et al.* 1992, McLaughlin and Mineau 1995, Cambell *et al.* 1997, Wilson and Tisdell 2001, Boatman 2004) application and impacts on bird populations, many of which feed largely on insects during the breeding season. The cost of reduced insect abundance can be immediate (through chick starvation or smaller clutches) or delayed (slower growth, reduced over winter survival of both juveniles and adults, reduced fecundity the following year) (Homes 1995, Peach *et al.* 1999, Siriwardena *et al.* 2000).

Reduced availability of invertebrate prey for chicks has been implicated in the declines of Grey Partridge (Southwood and Cross 1969, Green 1984, Potts 1986), Skylark (Poulsen *et al.* 1998), Corn bunting (Brickle *et al.* 2000), a number of hirundines (Byrant 1973, 1975, Turner 1980, Johnston 1990) Lapwing (Johansson and Blomqvist 1996, Blomqvist and Johansson 1995), Linnet (Moorcroft *et al.* 2006) and Yellowhammer (Hinsley 2000, Morris *et al.* 2001, Hart *et al.* 2006). On a farm scale, comparison of organically (no chemical input) or extensively (reduced chemical input) managed farms and conventional farms (high chemical input) often indicates an increased bird diversity or greater productivity in the organic and lower input systems (Wilson *et al.* 1997, Christensen *et al.* 1996, Freemark and

Kirk 2001, Stoate *et al.* 2001, Beecher *et al.* 2002, Wolff *et al.* 2001, Barnett *et al.* 2004, Bradbury *et al.* 2008).

SRC, by virtue of its nature and structure, requires far fewer chemical applications than other current farming practices, both arable and pastoral (Ledin 1998, Perttu 1998, Ranney and Mann 1994). In addition, non-cropped areas, known to be important for both insects (Meek *et al.* 2002) and birds (Fuller *et al.* 2004) are larger and less intensively managed than most current farmland. High bird diversity and density have been recorded in SRC in the UK (Kavanagh 1990, Sage and Robertson 1996, Sage and Tucker 1998a, Coates and Say 1999). Consistently greater bird diversity has been recorded in SRC compared to existing farmland habitat (Sage *et al.* 2006, Goransson 1990, 1994, Berg 2002) both in summer and winter (Sage, Cunningham and Boatman 2006). In the spring they are thought to be predominantly attracted by the substantial insect abundance (Sage and Tucker 1997).

Biomass crops in the UK are thought to lack nesting opportunities for song-birds (Sage *et al.* 2006). Large densities of nesting birds have been recorded in pre-commercial sites however (Sage *et al.* 2006). Dhont *et al.* (2004), in the USA also found that a high proportion of the birds recorded regularly using SRC were actually breeding within the plots (at least 21 of 39). In larger, commercially managed plots the interior contained fewer birds than the edge zone (<50m) (Sage *et al.* 2006). Age classes and growth stages of SRC affect which nesting birds are recorded (Goransson 1994, Sage and Robinson 1996, Sage *et al.* 2006, Dhont *et al.* 2007). In Sweden, Whitethroats and Whinchat preferred the sprouts of the recently harvested areas while Willow Warbler and Garden Warblers preferred the fully-grown bushes preceding the harvest (Goransson 1994). Dhont *et al.* (2004) found that birds constructed nests highly non-randomly in respect to willow clone. The clones used for SRC can vary quite markedly in terms of structure and this may have been what drove the preferences.

SRC has been found to provide excellent winter cover for game birds (Baxter *et al.* 1996, Sage and Robertson 1994), particularly Pheasant, Partridge (Goransson 1990, Sage and Robinson 1994, Baxter *et al.* 1996, Berg 2002) and Snipe (Sage *et al.* 2006). Habitats managed for game birds have been shown to greatly benefit songbirds including several threatened species (Parish and Sotherton 2004). SRC could provide suitable cover for holding game birds during the winter shooting season and at the same time benefit threatened song-bird populations.

The benefits of SRC are strongly influenced by the landscape into which it is introduced and the land use it replaces (Christian *et al.* 1994, Perttu 1995, Tolbert and Wright 1998, Coates and Say 1999, Starback and Becht 2005, Anderson and Fergusson 2006, Rowe *et al.* 2007). For highly mobile animals such as birds, landscape composition plays a central role in determining occupancy of plantations (Christian *et al.* 1998) and adjacent habitats have a strong influence on the bird community composition in SRC (Berg 2002). Most studies relating agricultural intensification with population declines of farmland birds are from the UK (Ormerod and Watkinson 2000) and many suggested strategies for the conservation of farmland biodiversity are based on the situation in the UK (Aebischer *et al.* 2000, Vickery *et al.* 2004). However, the agricultural landscape across the UK varies greatly. The late 1940s saw the agricultural landscape become increasingly polarized, and arable systems now predominate in the east of Britain and pasture-based farming in the west (Stoate 1995, Robinson and Sutherland 2002, Shrubb 2003 and see Chapter 1 Figure 1.3).

An overview of agricultural research papers published in the UK reveals a geographical bias. The majority of studies (70%) conducted within the UK are in England or the UK (Figure 4.1). Most studies conducted under the UK umbrella are predominantly conducted in England. The geographical bias of the UK literature reflects a bias in the agricultural habitat being studied. The majority of recent, relevant, research has focused on arable farming systems (Aebischer *et al.* 2000, Vickery *et al.* 2001) even though grassland accounts for almost 60% of agricultural land in Britain (National Statistics and Defra 2007). Increased research activity into SRC in grassland farming systems seems warranted.

This study first describes the bird populations using young SRC during the winter and breeding season, then secondly compares breeding bird communities of young and established SRC. A mist netting study of a mature SRC site over a full year is also described.

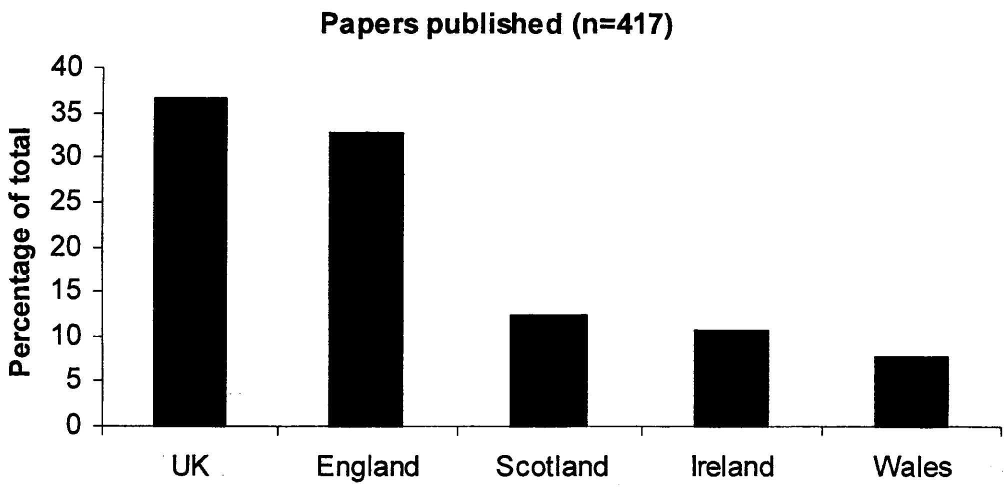
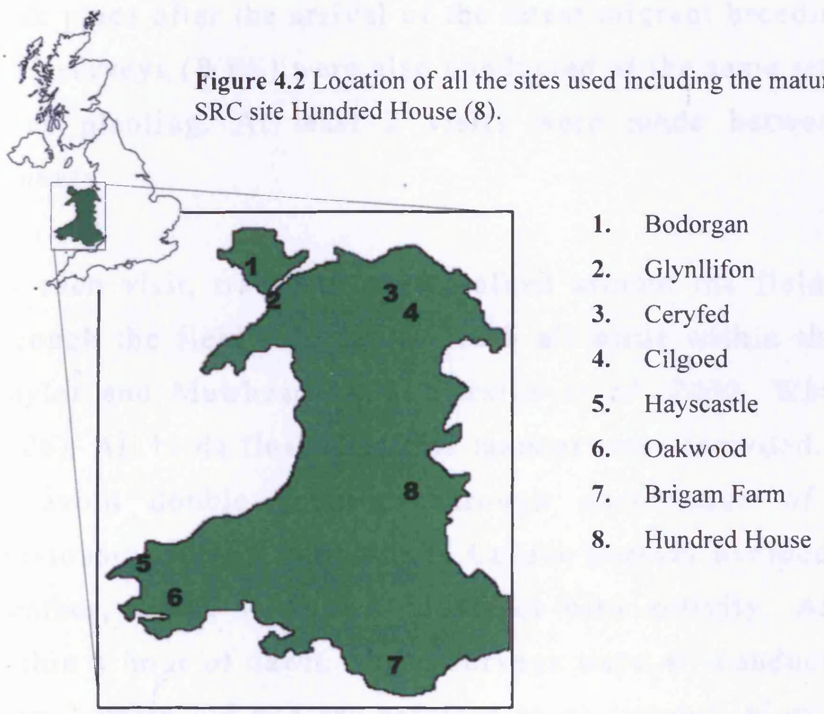


Figure 4.1 The percentage of published papers referring to the UK and constituent countries (Ireland and Northern Ireland are combined) within European agricultural research (defined as any paper containing the word 'Europe' and 'farmland' or 'agriculture' and related synonyms in the title, keywords or abstract) listed by the ISI database, 1997-2006.

4.2 Study sites

The seven SRC field sites used in this study are those described in Chapter 1. For details, see Chapter 1 Table 1.1. In addition, an eighth site, in mid-Wales known as Hundred House (HH) was used (Figure 4.1). HH is a small area (1.1ha) of mature SRC planted in 1999 and harvested once in 2003. For more details of this site and the surrounding area, see Chapter 5 Figure 5.3.

Figure 4.2 Location of all the sites used including the mature SRC site Hundred House (8).



4.2 Methods

4.2.1 Birds of young SRC

Breeding bird surveys (BBS) were conducted at seven sites (1-7) in year 1 and six sites (1-6) in year 2 of planting SRC. Each BBS consisted of two visits, one 'early' transect count (early April – mid May) and one 'late' transect count (mid May – late June). The visits were made at least 4 weeks apart. The first visit coincided with the main activity period of the resident breeding birds, while the second took place after the arrival of the latest migrant breeding birds. Winter bird surveys (WBS) were also conducted at the same sites in year 1 and 2 of planting. At least 2 visits were made between October and January.

At each visit, transects were walked around the fields perimeter and through the field in order to flush all birds within the crop (Wilson, Taylor and Muirhead 1996, Perkins *et al.* 2000, Whittingham *et al.* 2006). All birds flushed in this manner were recorded. Care was taken to avoid double counting through observation of movements of previously flushed individuals. Census periods avoided wet and windy weather, which is known to affect bird activity. All counts began within 1 hour of dawn. These surveys were all conducted on sites less than 2 years old and are referred to as 'young' plots throughout this Chapter. The bird communities using the young plots in the winter and breeding season are compared.

4.2.2 Breeding birds

The BBS were repeated at three of the sites, Bogorgan Estate, Hayscastle and Oakwood (sites 1, 5 and 6), once they reached 3 years old. These plots are referred to as 'established' plots throughout this Chapter. Breeding birds of young and established coppice are compared for these three sites. The recorded birds at the 3 sites were grouped as follows: corvids, finches, thrushes, tits, warblers and other (Robins, Wrens and Dunnocks). Chi-Squared tests were then performed on each of these groups for young and established plots. In addition, the

Shannon Index of diversity (H) is calculated for each site for young and established coppice. The variance of H is calculated and using this method, t can be calculated to test for significant differences between the samples (Hutchinson 1970).

4.2.3 Birds of mature SRC

HH is a small area (1.1ha) of SRC planted in 1999. It is in its 2nd year of the second rotation (harvested once in 2003). It will be referred to as a 'mature' plot throughout this Chapter. This site was operated as a constant effort mist-netting site (CE site). Three 18m 4 shelf mist nets were erected within the SRC. They were opened for 2 hours, 1 hour within sunrise, once a week from March 2005 to April 2006. All caught birds were identified and marked with the relevant (BTO) rings.

Additional small netting studies have been taking place in some of the sites over the years and the species caught in these were added to the overall species lists.

4.3 Results

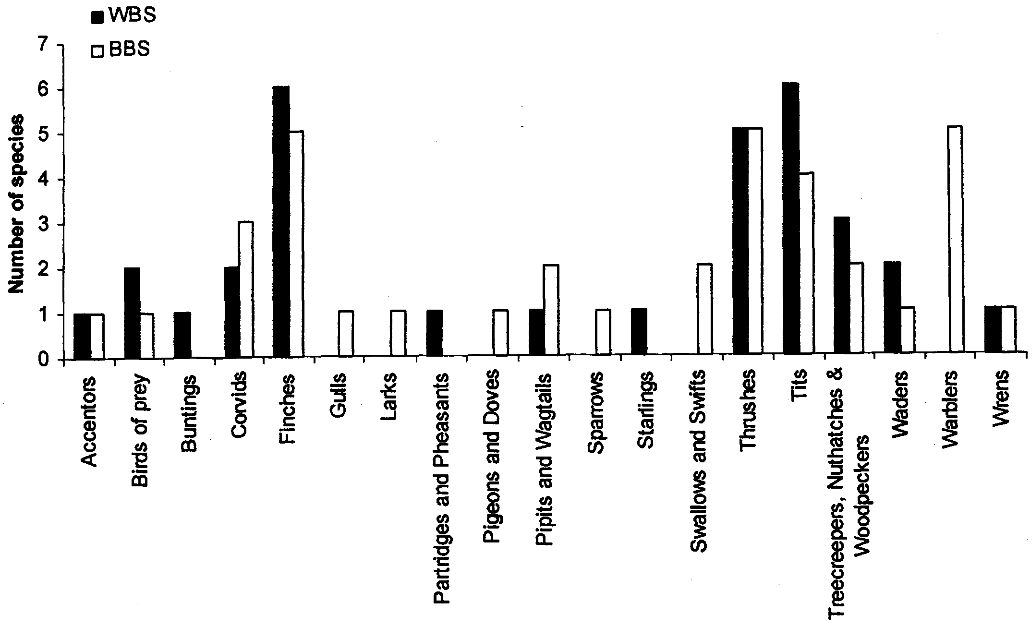
A total of 61 species were recorded in the SRC plots all together (Table 4.1). In the young plots, 35 species were recorded during the winter surveys (Chapter 4, Appendix II). Three species were recorded in the SRC during the WBS only, Reed Buntings, Starlings and Pheasants. The most diverse groups were the finches (6 species), thrushes (5 species) and tits (6 species) (Figure 4.2a). The most abundant group were the finches, which were present in large flocks (Figure 4.2b). Other groups more abundant during the WBS were accentors, birds of prey, pigeons and doves, thrushes, tits, waders and wrens (Figure 4.2b). The waders were predominantly made up of Snipe but also included Woodcock.

A total of 46 species were recorded in the young SRC during the breeding bird surveys. Six groups recorded in the SRC were only present in the BBS; these were the gulls, larks, pigeons and doves, sparrows, Swallows and Swifts and warblers (Figure 4.2). The most diverse groups were the finches (5 species), thrushes (5 species), tits (4 species) and warblers (5 species). These were also the most abundant groups along with Starlings (Figure 4.2b). The only species found to be nesting in the young coppice was Skylark.

Table 4.1 Bird species caught or recorded in the surveys during the breeding season (April-Sept), winter (Oct-March) and both periods.
* Species confirmed to be nesting in the SRC.

Breeding season only (20 species)	**Winter season only (15 species)**	**Caught in both seasons (25 species)**
Barn Owl	Fieldfare	Blackbird*
Blackcap	Goldcrest	Blue Tit
Chiffchaff	Greenfinch	Bullfinch
Curlew	Herring Gull	Buzzard
Garden Warbler	Lesser Spotted Woodpecker	Chaffinch
Grasshopper Warbler	Linnet	Coal Tit
House Sparrow	Meadow Pipit	Crow
Jackdaw	Redwing	Dunnock
Kestrel	Reedbunting	Goldfinch*
Mistle Thrush	Siberian Chiffchaff	Great Tit
Pied Wagtail	Snipe	Great Spotted Woodpecker
Redstart	Starling	Jay
Sedge Warbler	Stonechat	Long-tailed Tit
Siskin	Willow Tit	Magpie
Skylark*	Woodcock	Marsh Tit
Swallow		Nuthatch
Swift		Pheasant
Treecreeper		Redpoll*
Tree Pipit		Robin
Whitethroat		Rook
Willow Warbler*		Song Thrush*
		Sparrowhawk
		Woodpigoen
		Wren
		Yellowhammer

a)



b)

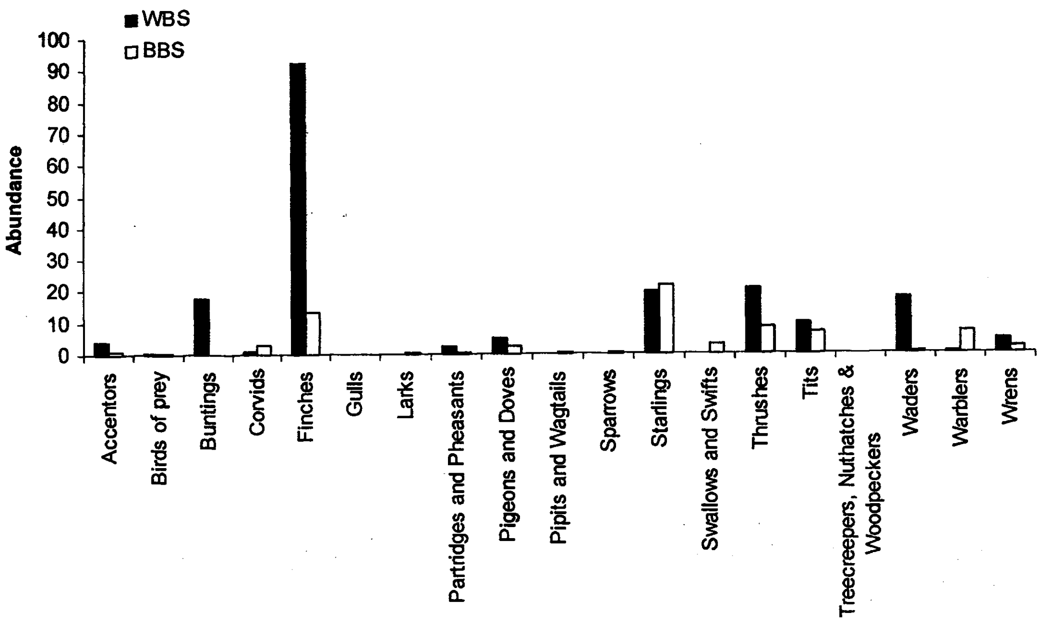
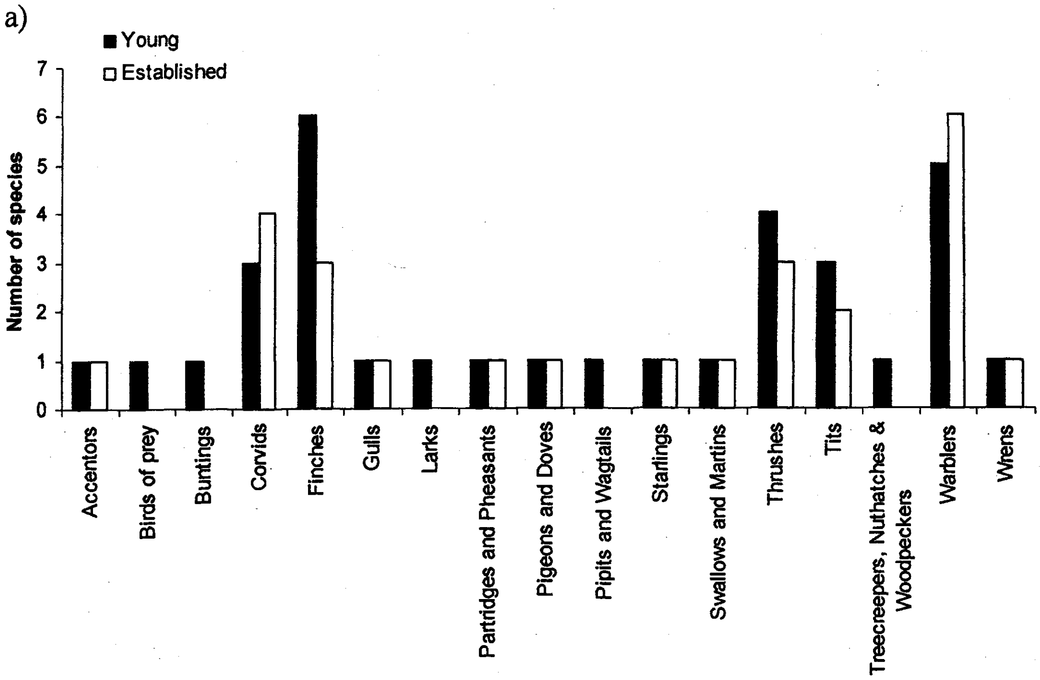


Figure 4.3 Comparison of winter bird survey (WBS) and breeding bird surveys (BBS). Comparisons are made in the bird groups for a) species diversity and b) abundance (mean individuals/visit)

Fifty-one species were recorded overall from the SRC plots in both young and established SRC during the BBS (Appendix III). However, only the warblers and the corvids showed a greater diversity in the established SRC (Figure 4.4a). The abundance of the accentors, finches, warblers and corvids was greatest in the established SRC (Figure 4.4b) but only the warblers were significantly greater (36%, Chi-sq=7.28, P=<0.05). The abundance of all the other groups stayed approximately the same or fell (Figure 4.4b) but again, only thrushes decreased significantly (35% Chi-sq=6.03, P=<0.05). Several species were only recorded in the young SRC (Barn owl, Reedbunting, Skylark, Tree Pipit and Treecreeper). At the site level, only Hayscastle showed a significantly more diverse bird community in the established crop than had been recorded in the young coppice (t=2.097, P=<0.05, DF=139). Bodorgan (t=0.097, P=>0.20, DF=88) and Oakwood (t=0.686, P>0.20, DF=348) showed no such difference.

Blackbird, Song Thrush, Redpoll, Goldfinch and Willow Warbler were confirmed to be nesting in the older coppice (established or mature).

a)



b)

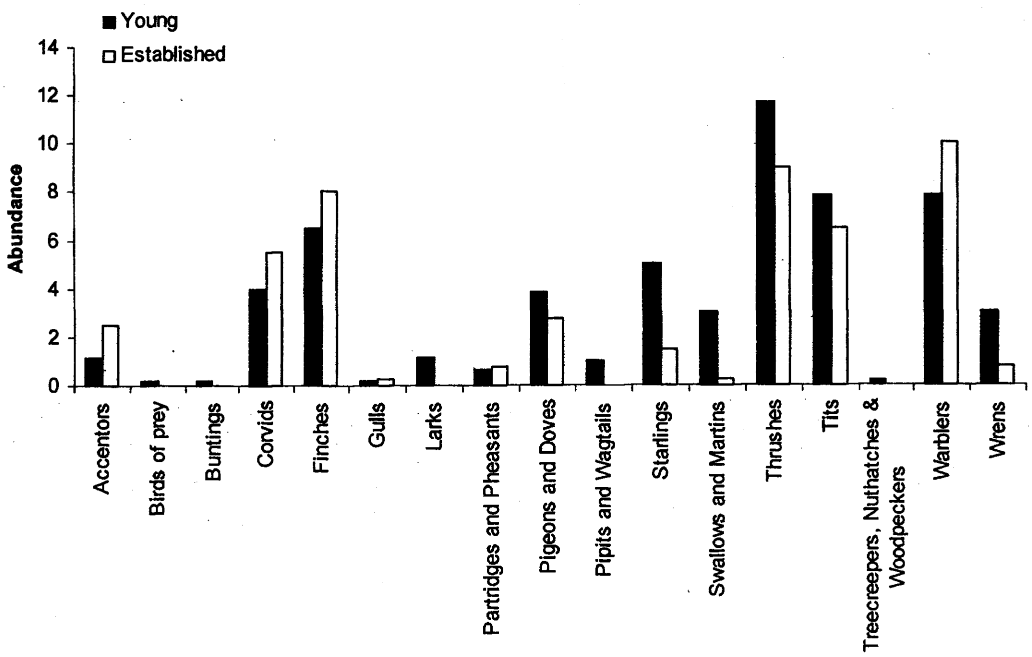


Figure 4.4 Comparison of breeding bird survey conducted in young SRC and established SRC. Comparisons are made in the bird groups for a) species diversity and b) abundance (mean individuals/visit)

4.3.1 Birds of mature SRC

There were 2 peaks in bird abundance within the mature crop at Hundred House (Figure 4.5). One peak occurred at the end of March into April and then dropped off again in August. The second peak occurred in winter, October to December. From Figure 4.6 it is apparent that very different groups of birds caused the peaks in abundance. The peak during the breeding season was caused predominantly by migrant *Phylloscopus* species but also by resident *Parus* species (Figure 4.6). The winter peak was caused by a further increase in *Parus* species but mainly the *Aegithalos* or Long-tailed Tits.

Willow Warblers were the most commonly occurring species in the mature SRC. Of the warblers, Garden Warbler numbers peaked just after the Willow Warblers (Figure 4.7a). Small numbers of Chiffchaffs were recorded as late as October and Goldcrests continued to be caught throughout the winter, usually with the Long-tailed Tit flocks. The Long-tailed Tits were the most abundant species in late winter when little else was being caught (Figure 4.7b). Blue Tits were also common in the winter but more so in the early winter. Blue Tits and Great Tits were the most abundant *Parus* species throughout the breeding season. Finches were very sparse (Figure 4.7c) particularly in consideration of how numerous they were in both the young and established SRC (Figure 4.3 and 4.4). Thrushes were present in low numbers throughout the year (Figure 4.7d). Small numbers of Wrens were caught from June to January (Figure 4.7e).

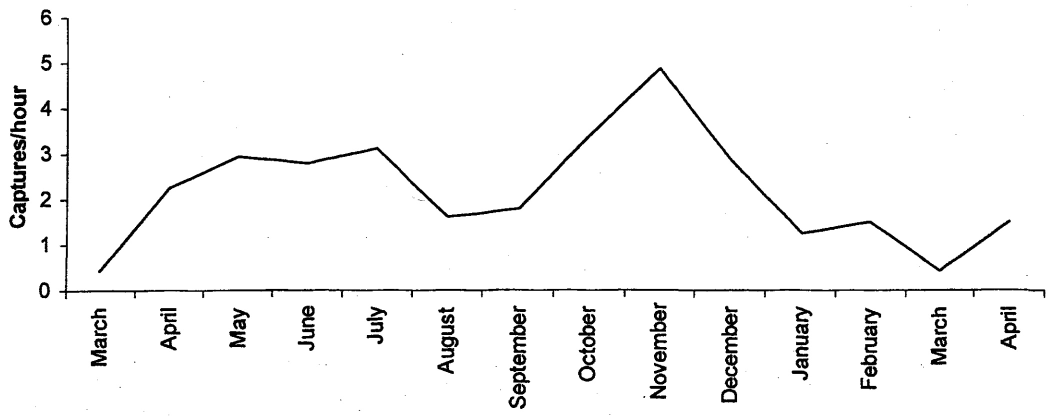


Figure 4.5 Mean bird abundance recorded in the mature SRC at Hundred House (March 2005 to April 2006)

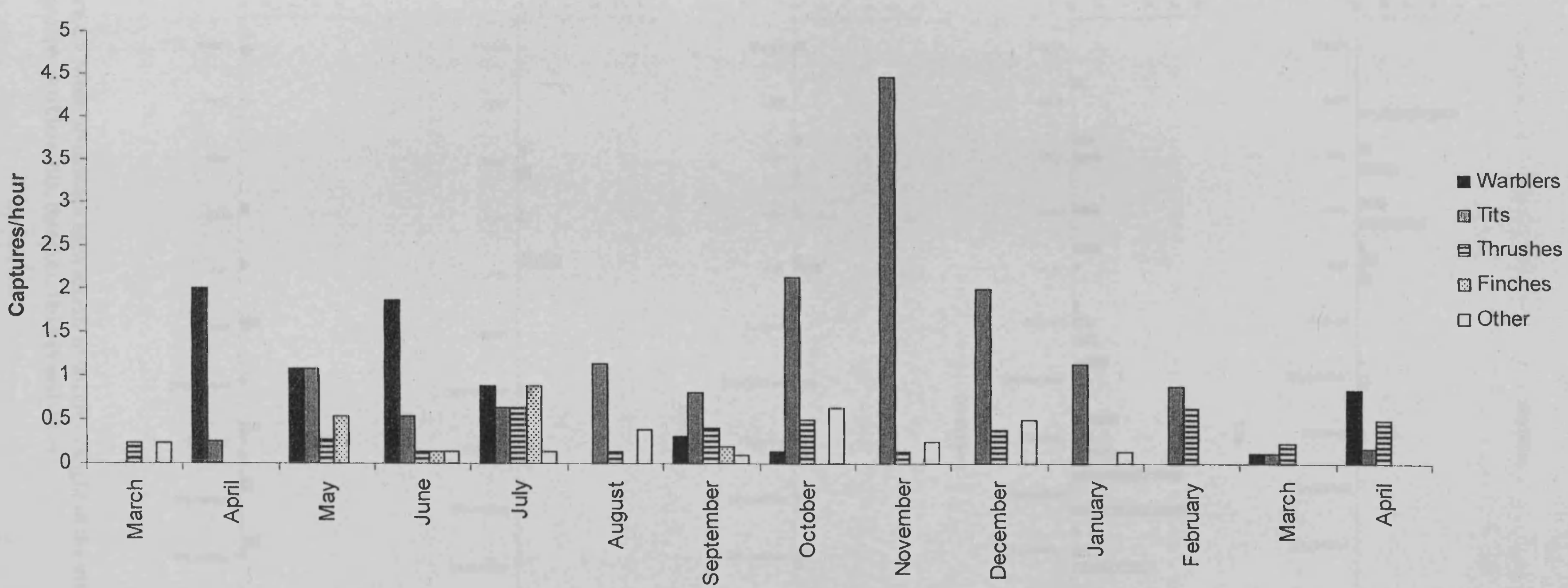


Figure 4.6 Abundance of bird groups caught in the mature SRC at Hundred House.

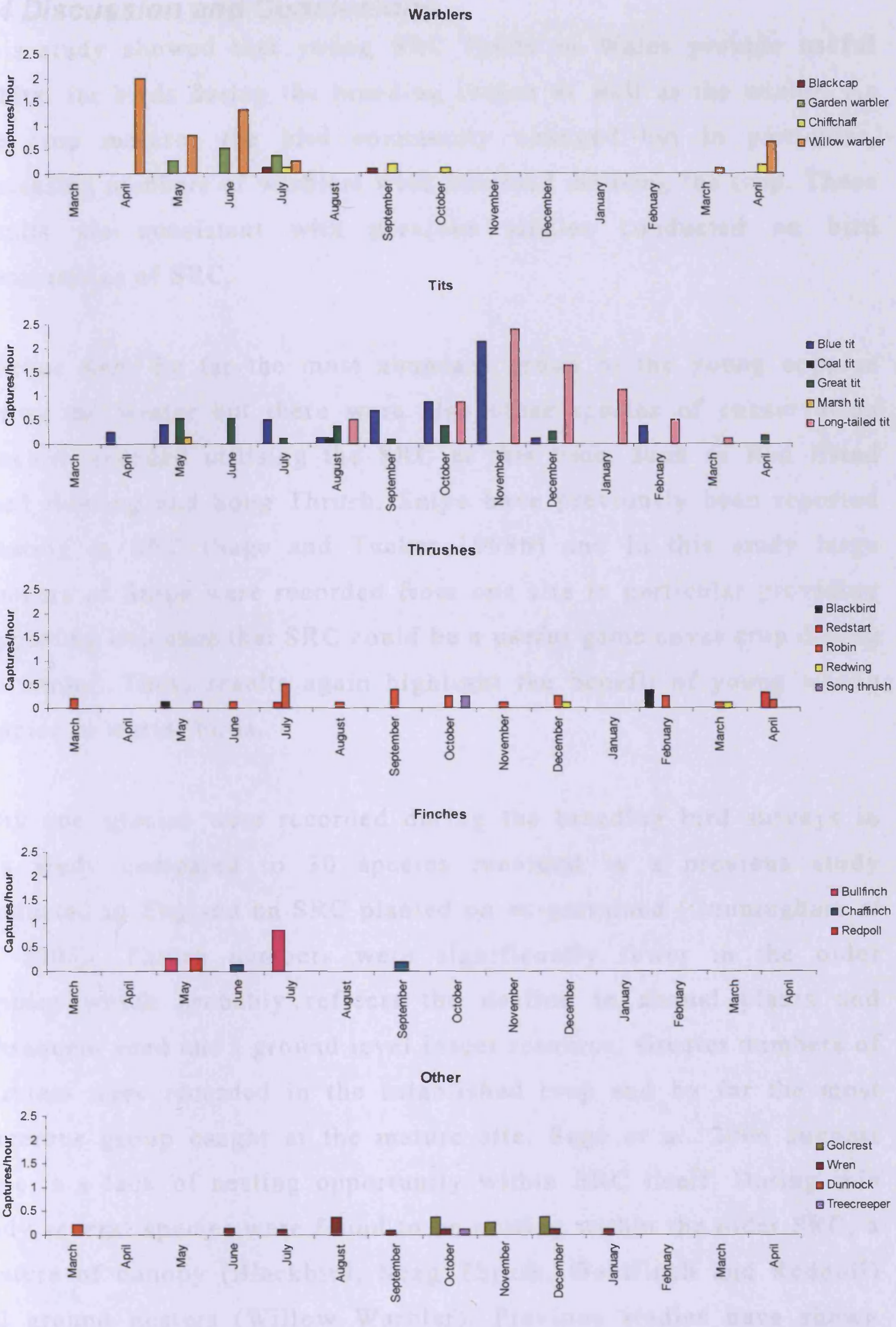


Figure 4.7 Mean abundance each month of species caught in the mature SRC at Hundred House in the bird groups; warblers, tits, thrushes, finches and other.

4.4 Discussion and Conclusions

This study showed that young SRC fields in Wales provide useful habitat for birds during the breeding season as well as the winter. As the crop matures the bird community changed but in particular, increasing numbers of warblers were recorded utilising the crop. These results are consistent with previous studies conducted on bird communities of SRC.

Finches were by far the most abundant group in the young coppice during the winter but there were also other species of conservation concern recorded utilising the SRC at this time, such as Red listed Reed Bunting and Song Thrush. Snipe have previously been reported roosting in SRC (Sage and Tucker 1998b) and in this study large numbers of Snipe were recorded from one site in particular providing supporting evidence that SRC could be a useful game cover crop during the winter. These results again highlight the benefit of young weedy coppice to winter birds.

Fifty one species were recorded during the breeding bird surveys in this study compared to 30 species recorded in a previous study conducted in England on SRC planted on ex-grassland (Cunningham *et al.* 2006). Thrush numbers were significantly fewer in the older coppice which probably reflects the decline in annual plants and subsequent seed and I ground level insect resource. Greater numbers of warblers were recorded in the established crop and by far the most numerous group caught at the mature site. Sage *et al.* 2006 suggest there is a lack of nesting opportunity within SRC itself. During this study several species were found to be nesting within the older SRC, a mixture of canopy (Blackbird, Song Thrush, Goldfinch and Redpoll) and ground nesters (Willow Warbler). Previous studies have shown birds nesting within SRC show preference for the edge of the coppice and weedy plots (Sage *et al.* 2006). The mature site (Hundred House) is small and could be regarded as being all edge. However it is not very weedy within the SRC at this site, the old coppice having shaded out much of the ground flora. There were undoubtedly more individuals nesting in surrounding habitats, hedgerows, gorse patches and old trees and then feeding within the SRC. But this plot showed great potential as a breeding habitat for a wide range of species.

The increase in corvid abundance in established SRC, although not significant, is probably a response to the number of breeding birds. Corvids can be major predators of breeding passerine nests, particularly Magpies and Jays (Groom 1993, Roos 2002, Barkow 2005, Stevens *et al.* 2008), which were regularly recorded within the SRC. SRC may also be valuable as a post breeding dispersal habitat for juveniles. Many juveniles move into scrubby habitats after fledging as it offers, as well as abundant insects, structural heterogeneity and cover from potential predators (Gillings *et al.* 1998, Gillings and Fuller 1998).

As the crop became established at Hayscastle, the bird community became more diverse. This was not the case at the other two sites (Bodorgan and Oakwood). Both of these sites are surrounded by diverse hedgerows containing numerous mature trees and have areas of broadleaved woodland nearby. There are also more areas of scrub and rough grassland around these sites. In short, these two SRC fields were located in areas of higher habitat diversity than that found at Hayscastle. The Hayscastle site has a much greater degree of grassland in the surrounding landscape and the nearest woodland is much further away. The field boundaries are more often fences but what hedgerows there are, are much lower and more heavily managed. The SRC at Hayscastle increased the landscape diversity and this was reflected in the bird community.

The mist netting studies only added a few extra species but it did add a British rarity to the list (Siberian Chiffchaff). We also caught several woodland bird species which were not expected to be present in SRC.

Species such as Nuthatch and Treecreeper were caught on several occasions and Great and Lesser Spotted Woodpecker were also recorded actually within the coppice. Bird surveys are perhaps not as good at picking these species up, particularly in the winter when they are not singing and not as obvious as the flocking species. In addition, these species are not generally expected to be in SRC (Berg 2002) and this could bias some observers. Fuller and Henderson (1992) suggested that a mix of woodland ages would benefit woodland birds and SRC provides a mix of young and old coppice which could compliment older woodlands. I tentatively suggest that SRC may be better for bird species associated with older woodland than previously thought.

Implications and suggestions for further research

Many of the findings support those of previous studies. SRC provides a relatively semi-natural habitat that benefits many bird species. Maintaining a mix of coppice age will maximise the benefits to the widest range of bird species.

Willow Warblers were the most numerous species recorded during the breeding season (April-June 2005) in the mature SRC. Other studies have demonstrated a greater density of Willow Warblers in SRC compared to both arable land (Cunningham *et al.* 2004) and grassland (Cunningham *et al.* 2006). The commercial cropping of SRC in Wales may provide a useful habitat for this declining species. Further investigation is needed to establish exactly how this species utilises this crop compared to other alternatives in the landscape.

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Chapter 5

*Bird communities in SRC and upland ffridd habitat with particular reference to Willow Warblers (*Phylloscopus trochilus*).*

5.0 Abstract

In Britain, a rapid decline of the breeding Willow Warbler population occurred during the 1980's and early 1990's after 20 years of relative stability. The decline is associated mainly with increased failure rates at the egg stage. Habitat choice and territory location determine the acquisition of critical resources that in turn influences fitness and demography. The commercial cropping of short rotation willow coppice (SRC) in Wales may provide a useful habitat for this declining species. This study compares a mature SRC site (> 5 years old) to the scrub of ffridd habitat in terms of bird species composition, abundance and condition (measurable energy reserves). Willow Warbler populations in particular are investigated in the two habitats using radio-telemetry. The bird communities of SRC scrub and ffridd are distinct and both habitats provide valuable habitat for diverse bird communities. Average home range sizes of Willow Warblers were significantly smaller at the SRC site than the ffridd ($P<0.001$). The larger the proportion of SRC in the territory, the smaller the overall home range was. The opposite was true for the ffridd scrub habitats. Improved grassland was strongly avoided by all individuals. For Willow Warblers, SRC is a highly beneficial addition to the Welsh landscape. It could significantly increase the productivity of this currently declining species. When planting SRC, it is important for Willow Warblers that the integrity of landscape features, such as hedgerows and old trees are maintained.

5.1 Introduction

The Willow Warbler is a small, insectivorous, migratory passerine that winters over a large area of western and southern Africa (Mead and Clark 1993) and breeds throughout much of northern Europe and Asia. In Britain, the Willow Warbler is one of our commonest migratory bird species with an estimated 2,125,000 breeding pairs holding territories in 2000 (Bird Life International 2004). However, the population has suffered a 30% fall in numbers between 1982 and 2005 across Europe (EBCC 2007) and in Britain, a rapid decline occurred during the 1980's and early 1990's after 20 years of relative stability. This decline occurred mainly in the south of the UK and was accompanied by a fall in survival rates (Peach *et al.* 1995). The British Trust for Ornithology (BTO) Breeding Bird Survey (BBS) figures since 1994 indicate a stark contrast between a population increase in Scotland and Northern Ireland, and further severe decreases in England and in Wales (Figure 5.1). The recent population decline is associated with a moderate decline in productivity as measured by BTO Constant Effort Sites (CES) and a substantial increase in failure rates at the egg stage (Figure 5.2).

Female Willow Warblers choose males with a greater song rate and repertoire size (Arvidsson and Neergaard 1991, Gill and Slater 2000). Male song rate has been found to correlate positively with territory quality (e.g., food abundance) (Arvidsson and Neergaard 1991) and clutch size (Gill and Slater 2000). Increased repertoire can be beneficial in territorial disputes in some species (Krebs *et al.* 1978, Yasukawa 1981) and the highest song rate and repertoire occurs in older birds (Gill *et al.* 2001). In many migratory bird species, individuals of higher phenotypic quality are commonly observed to arrive and mate first (Flood 1984, Francis and Crooke 1986, Hill 1988, Moller 1990, 1994, Enstom 1992, Lindberg and Alatalo 1992, Lozano, Perreault and Lemon 1996, Kokko 1999). In Willow Warbler populations, older birds are first to arrive and establish territories (Jakobsson 1988, Pratt and Peach 1991) and are generally in better

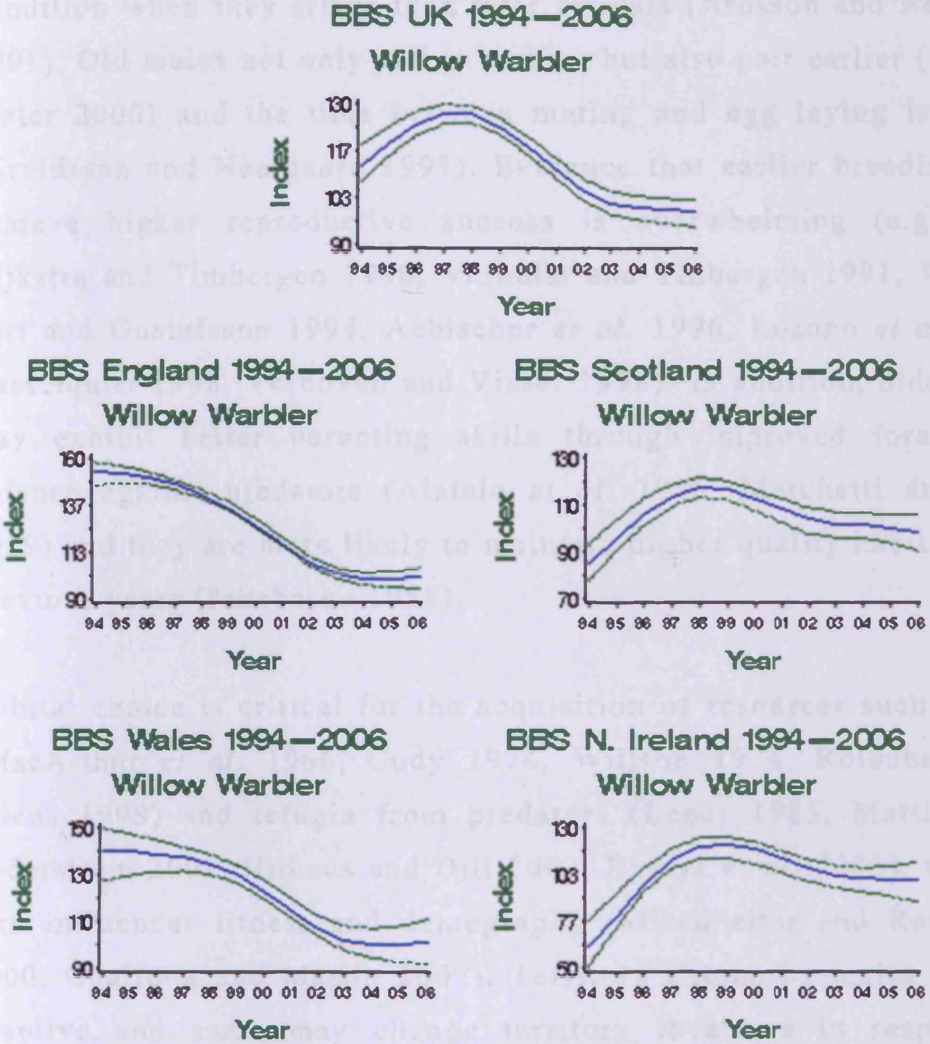


Figure 6.1 Smoothed population trends for the Willow Warbler (taken Baillie *et al.* (2007). Annual estimates of the abundance of adults and young are separately assessed through application of log–linear Poisson regression models, from which fitted year-effects are taken as annual relative abundances, compared to an arbitrary value of 100 in a recent year in the sequence, the abundance index used here.

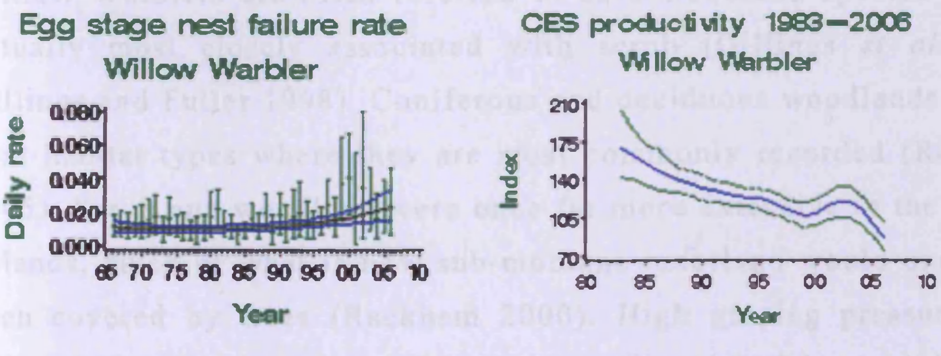


Figure 5.2 Productivity declines in the Willow Warbler (Baillie *et al.* (2007). Annual indices of productivity (young per adult) are estimated from logistic regression models applied to the proportions of juvenile birds in the catch, the year-effects then being transformed to measures of productivity relative to an arbitrary value of 100 in a recent year.

condition when they arrive than later arrivals (Ardsson and Neergaard 1991). Old males not only arrive earlier, but also pair earlier (Gill and Slater 2000) and the time between mating and egg laying is shorter (Arvidsson and Neergaard 1991). Evidence that earlier breeding birds achieve higher reproductive success is overwhelming (e.g. Daan, Dijkstra and Timbergen 1990, Verhulst and Tinbergen 1991, Wiggins, Part and Gustafsson 1994, Aebischer *et al.* 1996, Lozano *et al.* 1996, Hasselquist 1998, Verboven and Visser 1998). In addition, older males may exhibit better parenting skills through improved foraging or defence against predators (Alatalo *et al.* 1986, Marchetti and Price 1989) and they are more likely to maintain higher quality habitats from previous years (Jakobsson 1988).

Habitat choice is critical for the acquisition of resources such as food (MacArthur *et al.* 1966, Cody 1974, Willson 1974, Rotenberry and Wiens 1998) and refugia from predators (Leber 1985, Martin 1988, Soderstrom 2001, Hithaus and Dill 2002, Eggers *et al.* 2005), which in turn influences fitness and demography (Misenhelter and Rotenberry 2000, Chalfoun and Martin 2007). Territory choice by males must be adaptive and some may change territory locations in response to reduced breeding success in the preceding year (Jakobsson 1988, Lawn 1994).

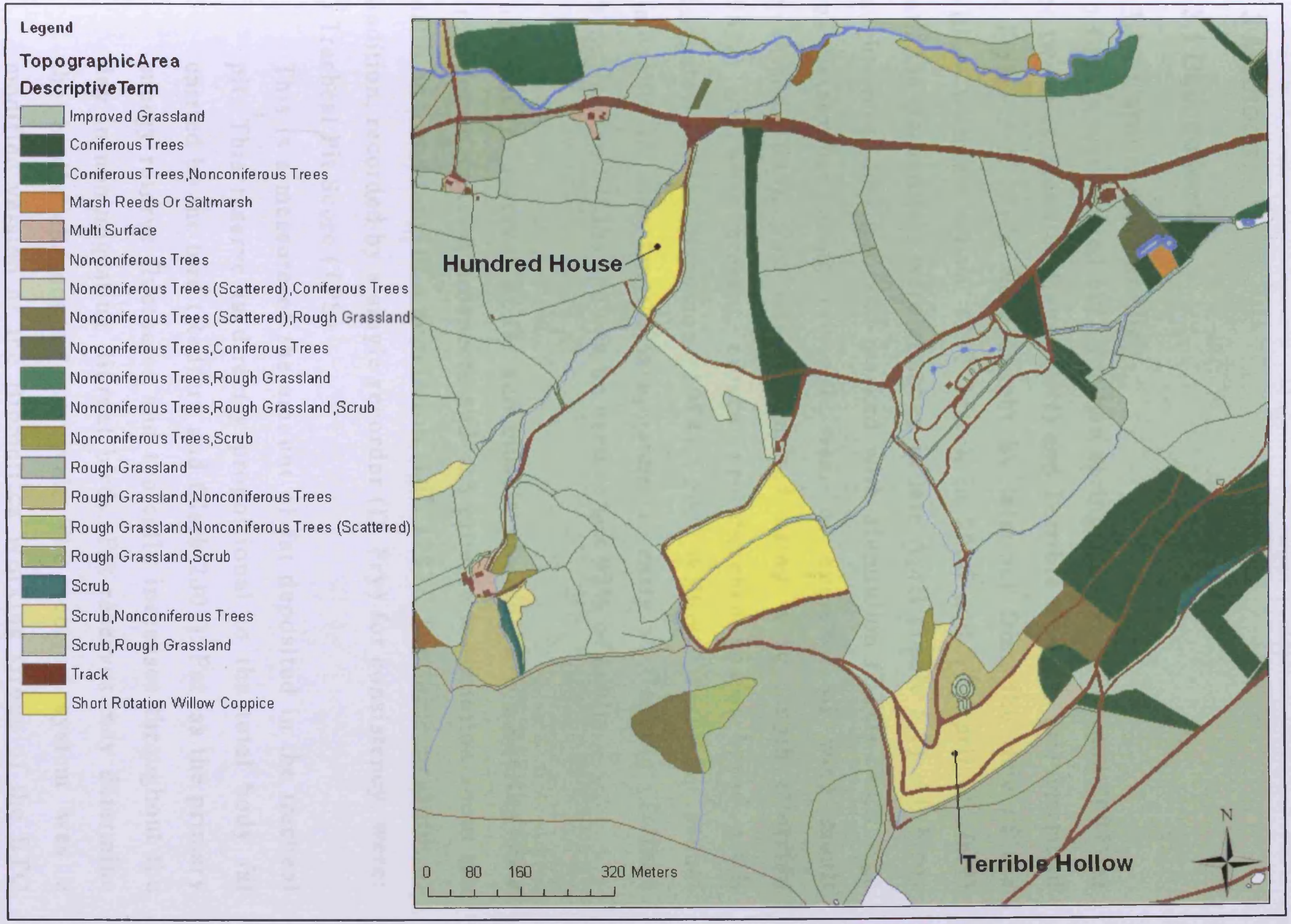
Willow Warblers are often referred to as a woodland species but are actually most closely associated with scrub (Gillings *et al.* 1998, Gillings and Fuller 1998). Coniferous and deciduous woodlands are the next habitat types where they are most commonly recorded (Robinson 2005). Scrub and woodland were once far more extensive in the British uplands, much of what is now sub-montane moorland would once have been covered by trees (Rackham 2000). High grazing pressure from deer and sheep, coupled with burning, now widely inhibits tree regeneration (Fuller *et al.* 2005, Amar *et al.* 2006). Vegetation changes have also been evident in the marginal uplands of Wales (the 'ffridd') in recent decades, but here the trend has been towards intensified grazing by sheep (Fuller and Gough 1999). These areas, which occur on hillside slopes below the open moorland, are typically mixtures of bracken, grass, scrub and scattered trees and Willow Warblers are a species typically found in them (Fuller *et al.* 2006). Scrub habitat is gaining recognition as an important and threatened habitat type and in 2007 upland willow scrub was added to the priority habitats in the UK Biodiversity Action Plan (Biodiversity Reporting and Information Group, 2007).

In a mist-netting study of a small field of short rotation willow coppice (SRC) in Powys, Willow Warblers were the most numerous species recorded during April-June 2005 (Chapter 4). Other studies have demonstrated a greater density of Willow Warblers in SRC compared to both arable land (Cunningham *et al.* 2004) and grassland (Cunningham *et al.* 2006). Willow Warblers have been found to prefer the fully-grown bushes found in SRC than recently harvested areas (Goransson 1994) which is consistent with my findings in Chapter 4. The commercial cropping of SRC in Wales may provide a useful habitat for this declining species. The objective of this study is to see how SRC compares to the scrub of ffridd habitat in terms of bird species composition, abundance and condition (measurable energy reserves). Willow Warbler populations in particular were investigated in the two habitat types using radio-telemetry.

5.2 Study sites

The study was carried out at two sites, Hundred House (HH) and Terrible Hollow (TH) in Powys Mid Wales (grid references SO 100 528 and SO 095 536, see Chapter 4 Figure 4.2). Figure 5.3 shows a map of the study sites and the surrounding area. HH is a small area (1.1ha) of mature SRC planted in 1999 and harvested once in 2003. TH is an area more than four times larger (4.8ha) of traditional marginal upland known as ffridd habitat in Wales. Ffridd habitat is quite variable but in this case consists of a mosaic of scrub with lots of bracken, non-coniferous and coniferous trees and some rough grassland. The sites are less than 1 km apart and therefore have similar surrounding land types, are subject to similar climatic factors and both have streams running through them. One of the main differences between the sites is the topography. TH has a marked gradient while HH is relatively flat with the surrounding hills sloping gently upwards. However, in a study of bird communities of ffridd habitat, Fuller *et al.* (2006) found that topographical and geographical variables were relatively unimportant in explaining variation in the bird communities of ffridd habitat. Skylark density was found to have a strong negative relationship with steep slopes in this habitat, but no topographical relationship was found for Willow Warblers.

Figure 5.3 Site locations and surrounding land use.



5.3 Methods

5.3.1 Data collection

5.3.1.1 Capture and handling

This study was carried out over two spring seasons (2006 and 2007) at the two sites, Hundred House (HH) and Terrible Hollow (TH) described in Figure 5.2. Birds were caught by mist-net from the time of the Willow Warblers arrival (29^{th} March in 2006 and 4^{th} April in 2007) until the transmitters were attached in late April (Table 5.1). All birds caught were identified and marked with aluminium (BTO) rings. Age was determined using plumage wear or evidence of wing moult (Svensson 1984). Sex was determined using wing length (Norman 1983a) and when present, cloacal protuberence and/or brood patch (Langslow 1971, Svensson 1984). For Willow Warblers, sexual bimodality in wing lengths is apparent as early as fledging (Tiainen 1978, Norman 1983b) and can be used to sex 95% of adults.

The levels of reserves of fat and muscle protein have a bearing on a bird's future survival prospects and can provide information about the health or 'condition' of a population (Dill 1987). The three measures of condition, recorded by a single recorder (D. Fry) for consistency, were:

1) Tracheal Pit Score (TPS)

    This is a measure of the amount of fat deposited in the tracheal pit. This reserve is directly proportional to the total body fat carried by the bird (Redfern and Clark 2001). Fat, as the primary energy reserve fluctuates and typically increases throughout the day in non-migrating diurnal birds. Fat reserves may determine the bird's chances of survival. The scoring system was a modified version of the Biometrics Working Group of the BTO Ringing Committee (BWG) system (Redfern and Clark 2001).

2) Pectoral Muscle Score (PMS)

    Pectoral muscle may also be used as a fuel under certain conditions and is therefore another valuable indicator of body condition. Score classes were those used in the BTO Ringer's Manual (Redfern and Clark 2001).

3) Body Mass Index (BMI).

This was calculated by dividing weight by wing length to allow for comparison across species.

Each individual was weighed, with an electronic balance with an accuracy of 0.1g, and tracheal pit scores (TPS) and pectoral muscle scores (PMS) given.

Table 5.1 The frequency of sampling and capture events of Willow Warblers at the study sites Hundred House (HH) and Terrible Hollow (TH), spring 2006 and 2007.

	Site	
	HH	TH
Netting sampling period		
2006	29th March – 12th May	04th April-16th May
2007	12th April – 21st May	20th April– 29th April
No of sampling events		
2006	10	8
2007	9	5
No of sampling hours		
2006	44	37
2007	36	33
Transmitter attachment		
2006	21st and 22nd April	21st and 22nd April
2007	20th – 23rd April	20th – 23rd April
Tracking period		
2006	24th – 30th April	24th – 30th April
2007	25th April-1st May	25th April-1st May
No of capture events		
2006	28	24
2007	16	7
No of transmitters attached		
2006	8	7
2007	6	6

In late April, adult male Willow Warblers were fitted with Biotrak PIP transmitters (Biotrak Ltd, Wareham, UK), weighing approximately 0.5g. Transmitters were attached to the two central tail feathers (Figure 5.4). Each animal was also fitted with coloured rings with an individual colour combination to facilitate direct identification by observation. One or 2 further netting sessions were conducted after the radio-tracking period in an attempt to recapture tagged individuals to check on the birds physical health (Godfrey and Bryant 2003) and to retrieve any transmitters that were still attached. Only males were used in this study for several reasons. Males tend to arrive before the females to establish territories (Lawn 1994a 1994b). They engage in activities of territory announcement and defence and lend themselves to easier tracking and territory mapping. The females spend more time lower to the ground constructing nests and sitting on eggs, which could muffle the signal (Norman 1994). It has been suggested that females are more difficult to catch than males (Lawn 1982, Tiainan 1983) and previous studies had established that far more males than females tend to be caught at the HH site.

5.3.1.2 Radio-tracking

Tagged individuals were tracked using hand-held collapsible three-element Yagi antennae and 'Sika' receivers (Biotrak Ltd, Wareham, UK). Five pairs of fixed locations were used at each site to search for signals and the locations of tagged birds were determined through triangulation (Figure 5.5). Bearings were recorded from a hand held compass directly onto a map. Searches were conducted during three sessions a day (06:00-10:00, 10:00-14:00 and 14:00-18:00) from each pair of fixed locations, at each site, for seven consecutive days. The first site to be visited (either TH or HH) was alternated each day. Data were collected from 24th to 30th April in 2006 and from 25th April to 1st May in 2007. Error in location estimates was quantified by taking repeated bearings (n=30) on 5 transmitters placed at known locations within each study site. Mean errors associated with triangulation were:

Figure 5.4 Attaching the radio transmitters. The transmitters are attached to the 2 central tail feathers using elastic, waxed floss and fast drying glue.

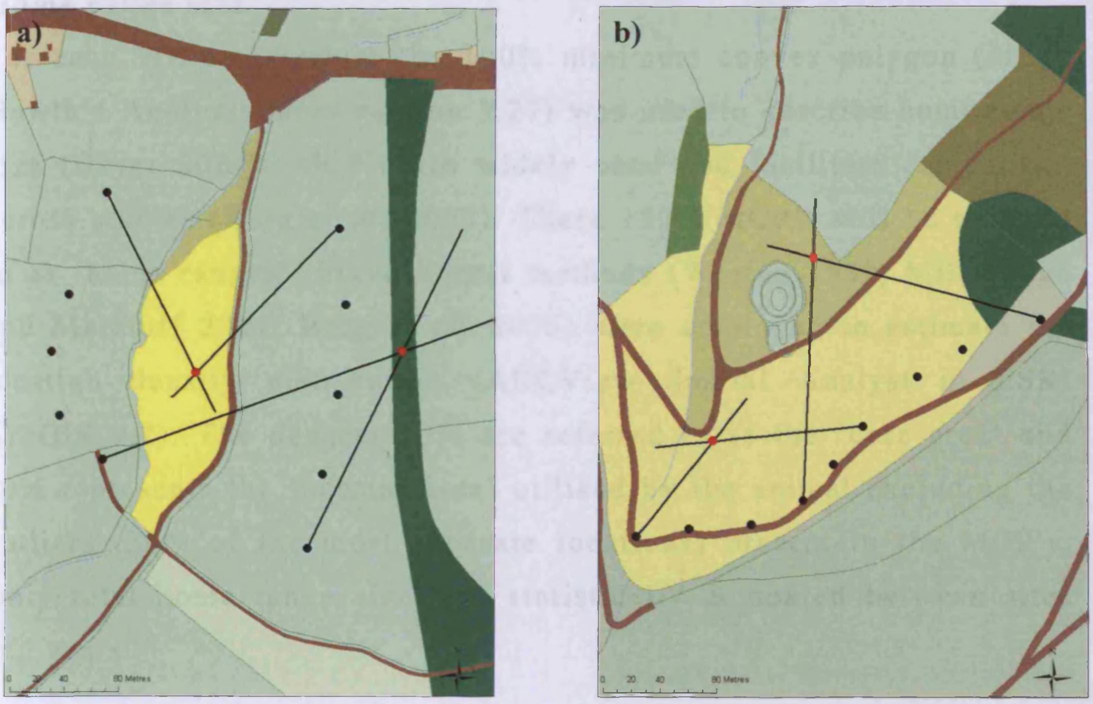


Figure 5.5 Examples of how locations were estimated using triangulation methods at a) HH and b) TH. Black dots represent the post locations from where the bearings were taken, lines are the directional bearings and the red dots the subsequent estimated bird location.

HH, 4.3m (range 10.2m): TH, 6.9m (range 16.1m). When fewer than 30 fixes were recorded for an individual they were excluded from the data analysis. These exclusions left available for analysis; 273 fix locations from 4 individuals at TH in 2006 (median 75.5 per bird, range 34-88), 542 locations from 7 individuals at HH in 2006 (median 77.43, range 37-92), 233 locations from 3 individuals at HH in 2007 (median 91, range 44-98) and locations from 4 individuals at TH in 2007 (median 69.25, range 47-84).

5.3.2 Data analysis

Species communities were compared at the 2 sites by species caught, relative abundance (number of individuals caught/hour) and condition measures. Comparisons of condition measures were also conducted for the Willow Warblers caught at both sites in both years.

Home range size

For each Willow Warbler the 100% minimum convex polygon (MCP; Hawth's Analysis tools version 3.27) was used to describe home range size (Beyer 2004). MCP's are widely used and facilitate comparison across studies (Barg *et al.* 2005). These 100% MCP's will be referred to as 'home ranges'. Fixed kernel methods (Worton 1989, Millspaugh and Marzluff 2001, Barg *et al.* 2005) were employed to estimate the location density distribution (ARCView Spatial Analyst in ESRI ArcGIS 9.2). The densest 20% are referred to as the 'core area' and 70% represents the 'normal area' utilised by the animal excluding the outliers (30% of the most separate locations) present in the MCP's. Only total home range size was statistically compared between sites and years.

Habitat utilisation

The habitat types shown in Figure 5.3 were collated into categories (Table 5.2) and the number of locations within each habitat category for each individual counted. Locations which had linear features within their error distances were put into the linear feature category. This was decided on because observations from the field showed birds were far more likely to be there than in an open field. Habitat types were collated to achieve large enough expected values to enable Chi-squared tests to be performed. Chi-squared tests were employed to analyse the differences between observed and expected numbers of locations in the different habitat types. Bonferroni confidence intervals were fitted to show whether use of each habitat by individuals was greater or less than the proportion of that habitat in the home range (Neu *et al.* 1974, Marcun and Loftsgaarden 1980, Byers *et al.* 1984, Alldredge and Ratti 1986, 1992). There are problems with this technique. The data are vulnerable to disproportionate effects of one individual if the data are pooled. I first carried out the test for individuals to see how different individual's habitat choices were before pooling the data. Another problem is that the procedure uses the locations not the animal as the sample unit for analysis and the same problem affects other more complex analyses (Heisey 1985, Kenwood 2001). However, the technique is easy to use and interpret and so was used, but, to provide further evidence of habitat importance, linear regression was also employed. This would find any significant correlations between habitat content and home range size indicating the importance of the habitat to the species (Kenwood 1982).

Table 5.2 Habitat types collated into groups for analysis.

Total habitat types shown in Figure 6.3	**Categories used in analysis**
Improved Grassland	Improved Grassland
Coniferous Trees Coniferous Trees, Nonconiferous Trees	Mainly Coniferous Trees
Tracks Water features Field boundaries, Hedgerows	Linear Features
Nonconiferous Trees Nonconiferous Trees (Scattered), Coniferous Trees Nonconiferous Trees (Scattered), Rough Grassland Nonconiferous Trees, Coniferous Trees Nonconiferous Trees, Rough Grassland Nonconiferous Trees, Rough Grassland, Scrub Nonconiferous Trees, Scrub	Mainly Nonconiferous Trees
Rough Grassland Rough Grassland, Nonconiferous Trees, (Scattered) Rough Grassland, Scrub	Mainly Rough Grassland
Rough Grassland, Nonconiferous Trees	Rough Grassland, Nonconiferous Trees
Scrub Scrub, Nonconiferous Trees Scrub, Rough Grassland	Mainly Scrub
Short Rotation Willow Coppice	Short Rotation Willow Coppice

5.4 Results

5.4.1 Species communities at the sites

A total of 28 bird species were caught. Nineteen species were recorded at HH and 18 at TH. The birds caught at TH tended to be species more closely associated with older woods and trees like Treecreeper, Pied flycatcher and Great Spotted Woodpecker and/or the patches of coniferous trees found at TH e.g. Coal Tit and Siskin. The species caught at HH prefer younger trees and dense undergrowth such as Blackcap and Garden Warbler. The species that were caught at both sites were more generalist species found in a wider range of habitats e.g. Blackbirds and Blue Tits (Table 5.3). Twenty-seven species were recorded in 2006 and 15 in 2007. The species not caught in 2007 are all from the "more specialist" lists of species found at only one of the sites (Table 5.3).

Table 5.3 Lists of species, where they were caught and when.

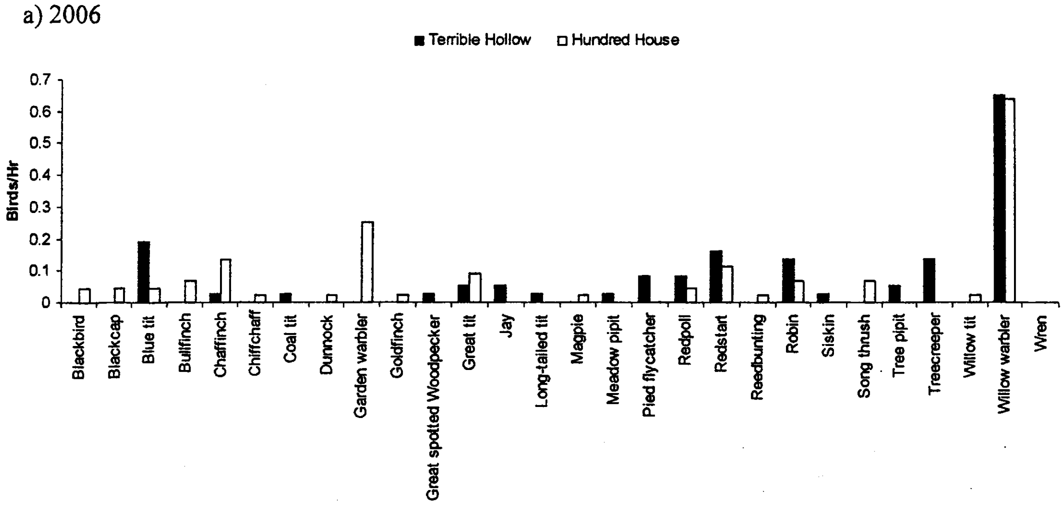
	Caught only at TH	Caught only at HH	Caught at both sites
Caught in 2006 only	Coal Tit Great Spotted Woodpecker Jay Long-tailed Tit Meadow Pipit Siskin Tree Pipit	Blackcap Chiffchaff Dunnock Garden Warbler Goldfinch Magpie Reedbunting Song Thrush Willow Tit	
Caught in 2007 only		Wren	
Caught in both years	Pied flycatcher Treecreeper		Blackbird Blue Tit Bullfinch Chaffinch Great Tit Redpoll Redstart Robin Willow Warbler Blackbird

In terms of abundance (capture events/hour) all recorded species fell in abundance at TH between years while the species at HH showed a mixed response (Figure 5.6). Some increased markedly (Chaffinch, Redpoll, Robin and Wren) and others only slightly (Blackbird, Blue Tit, Reed Bunting, Great Tit and Goldfinch). The remaining species declined in abundance with the most striking being the Garden Warbler, with 11 capture events (9 individual birds) in 2006 and 0 in 2007. Of the 12 species more abundant at TH than HH in 2006, 5 were not recorded in 2007 and 4 reversed the trend and were more abundant at HH that TH (Blue Tit, Redpoll, Robin and Willow Warbler). Willow Warbler abundance for example was approximately equal at the 2 sites in 2006 (TH=0.649 and HH 0.636) but in 2007 the abundance at HH was double that of TH (TH=0.212 and HH=0.444).

Condition

Of the 9 species caught at both sites one species (Blackbird) was left out of this comparison due to lack of condition data. Numbers of birds caught at TH were too few to allow statistical analysis of the individual species or between years. TPS was generally higher at HH than TH except for Blue Tits and Robins (Figure 5.7a). PMS was also generally higher at HH except for Blue Tits and Great Tits (Figure 5.7b). All species had slightly higher BMI at HH (Figure 6.7c). No significant differences were found when species were pooled between the sites for the condition indices PMS ($t=-1.79$, $P=0.097$, $DF=12$) TPS ($t=-1.54$, $P=0.149$, $DF=12$) or BMI ($t=-1.31$, $P=0.231$, $DF=12$).

a) 2006



b) 2007

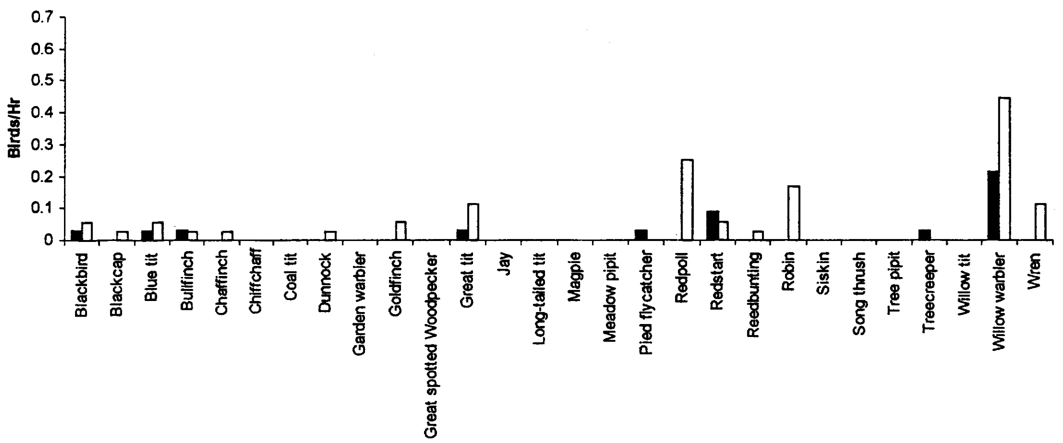


Figure 5.6 Abundance of bird species caught at the sites Terrible Hollow and Hundred House in a) 2006 and b) 2007. Abundance is adjusted for effort (number of birds caught /hour).

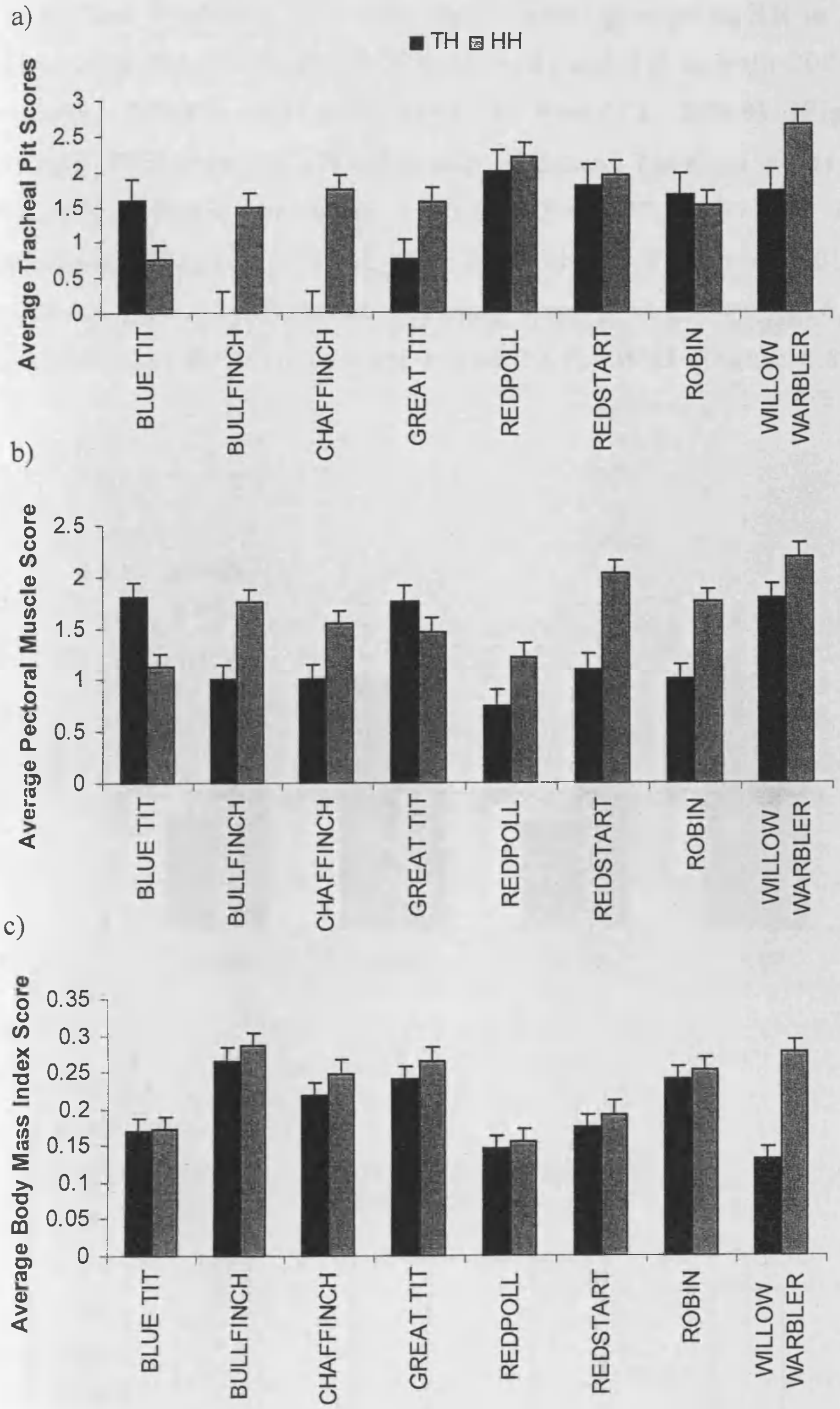


Figure 5.7 Average condition scores for a) tracheal pit b) pectoral muscle and c) body mass (+ 1 SE) at the sites TH (54 birds in total: 6 Blue Tits, 2 Bullfinch, 2 Chaffinch, 3 Great Tit, 2 Redpoll, 5 Redstart, 3 Robin, 31 Willow Warbler) and HH (89 birds in total: 4 Blue Tit, 4 Bullfinch, 7 Chaffinch, 7 Great Tit, 9 Redpoll, 7 Redstart, 8 Robin, 43 Willow Warbler). Data is pooled for 2006 and 2007.

5.4.2 Comparing Willow Warblers at the sites

For Willow Warblers, TPS was significantly greater at HH in 2007 than HH in 2006 (t=-10.77, P=<0.001, DF=48) and TH in both 2006 (t=2.22, P=0.033, DF=37) and 2007 (t=3.14, P=0.012, DF=9) (Figure 6.8). Overall, TPS was not significantly different between years (t=-1.74, P=0.089, DF=45) or sites (t=0.89, P=0.377, DF=54). PMS was significantly higher in 2007 than 2006 (t=-10.77, P= <0.001, DF=48) but there was no difference between sites (t=1.25, P=0.216, DF=68). No significant differences were found for the BMI (Figure 6.8).

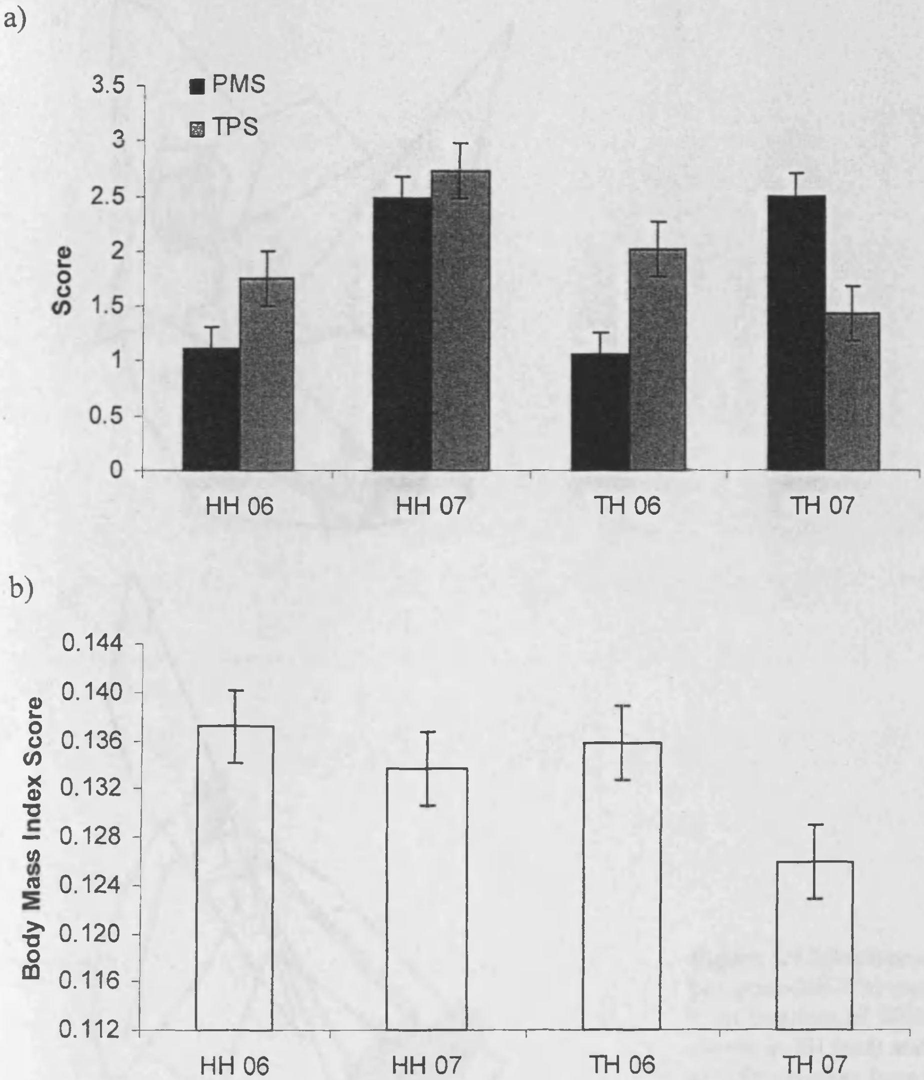


Figure 5.8 Average condition scores for a) tracheal pit and pectoral muscle and b) body mass (+ 1 SE) of Willow Warblers caught at TH in 2006 (n=24) and 2007 (n=7) and HH in 2006 (n=26) and 2007 (n=16).

Average territory sizes (measured by MCP's, Figure 6.9) varied significantly among sites (t=-4.55, DF=12, P<0.001) but not between years (t=-0.95, DF=14, P=0.358) (Figure 6.10). The territories displayed large overlaps, even in the core areas (Figure 6.11), in 2006 but in 2007 they were much more dispersed (Figures 6.12, 6.13 and 6.14). The occurrence of multiple core areas was also more prevalent in 2006. Three individuals appeared to have more than one completely separate core area within their territory in 2006 (1 at HH and 2 at TH) (Figure 6.12 and 6.13).

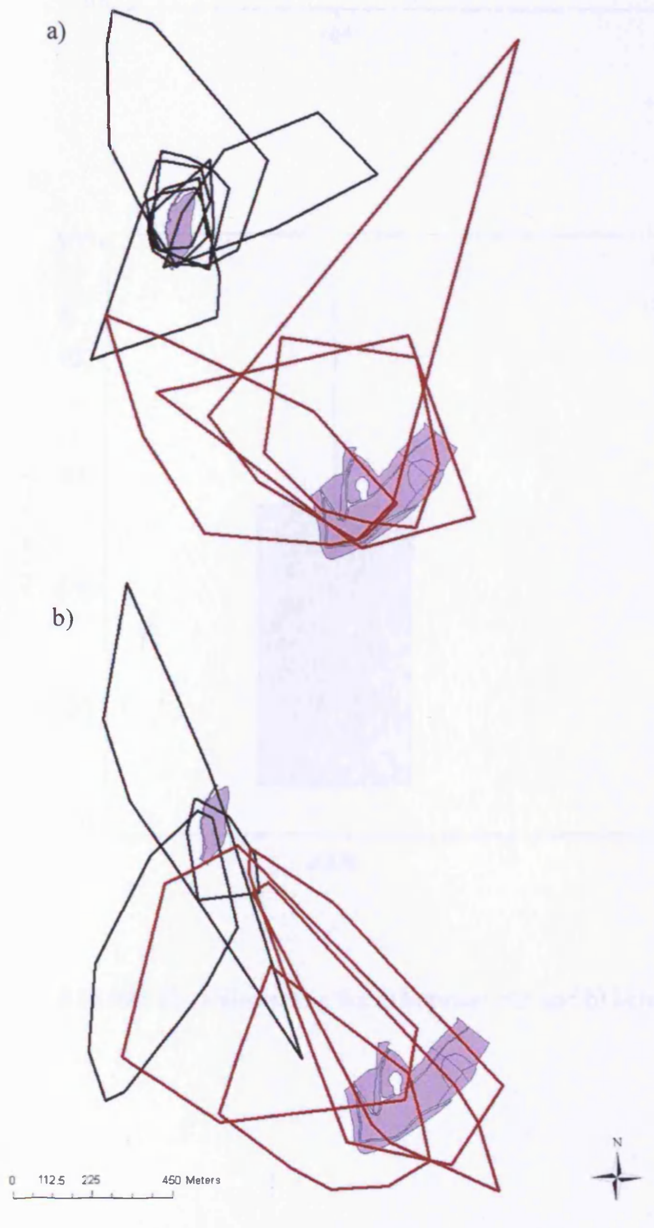
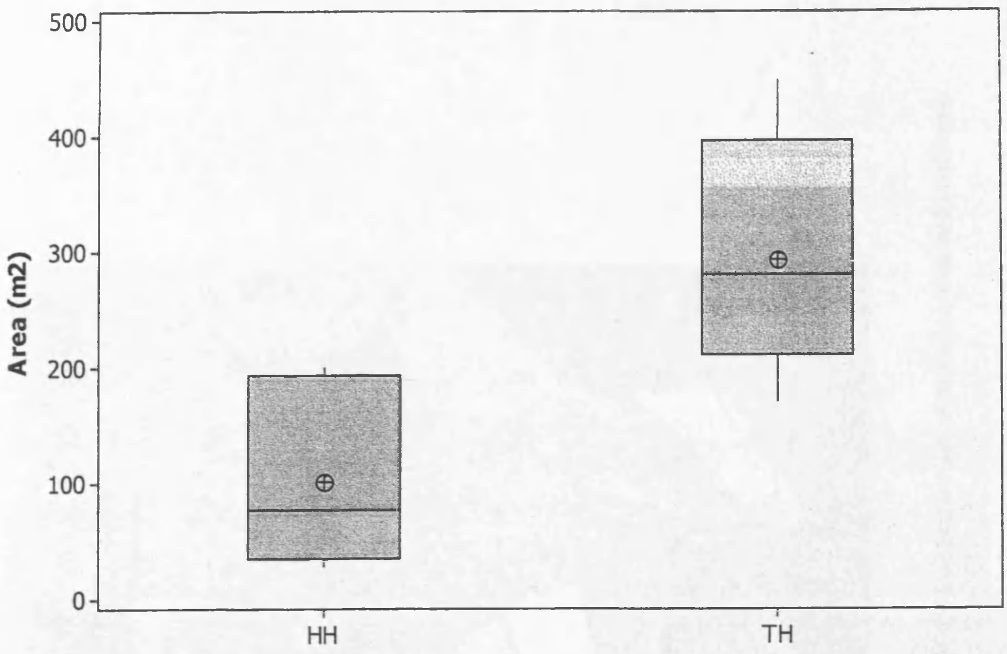


Figure 5.9 Minimum convex polygons (MCP's) around the outer most locations of Willow Warblers caught at TH (red) and HH (black) in a) 2006 (median fixes at HH=77.43 and TH=75.5) and b) 2007 (median fixes at HH=91 and TH=69.25).

a)



b)

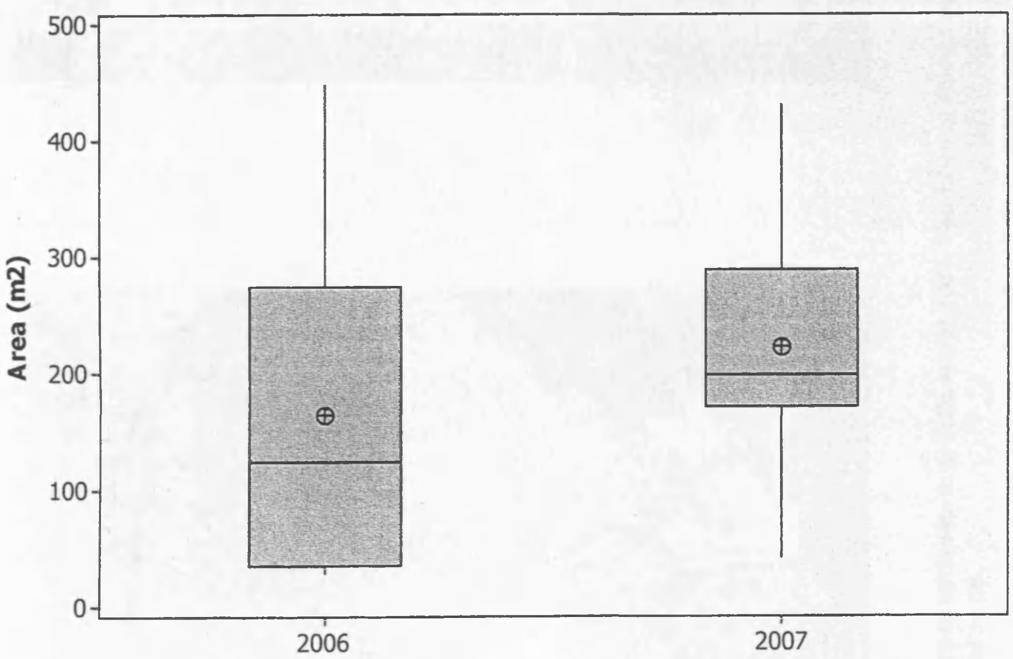


Figure 5.10 Box plots illustrating the a) between site and b) between year variation in territory sizes.

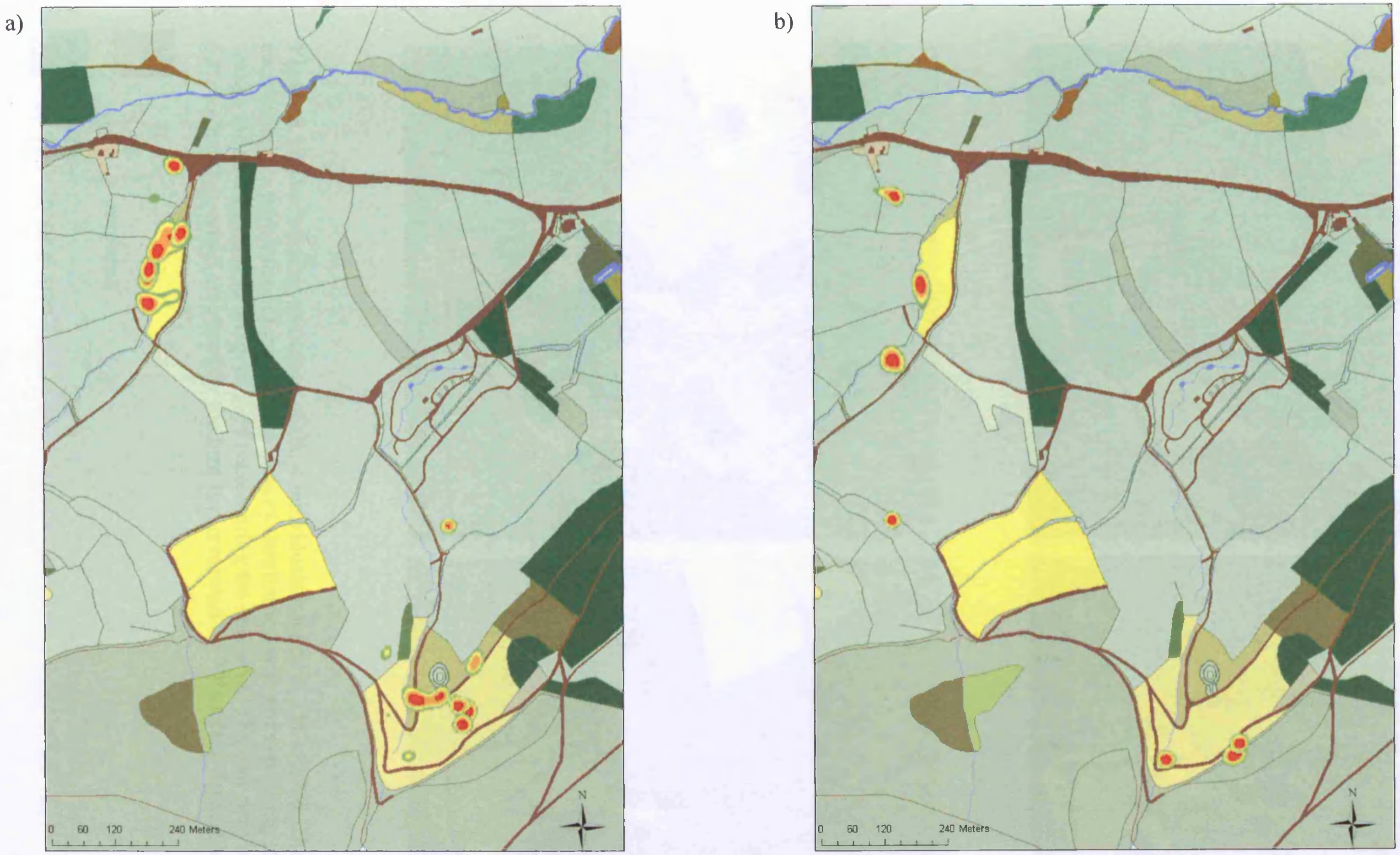


Figure 5.11 Core areas within the mapped territories in a) 2006 and b) 2007. The different colours each contain 5% of the location density distribution with red containing the densest 5%, orange the next 5% and so on.

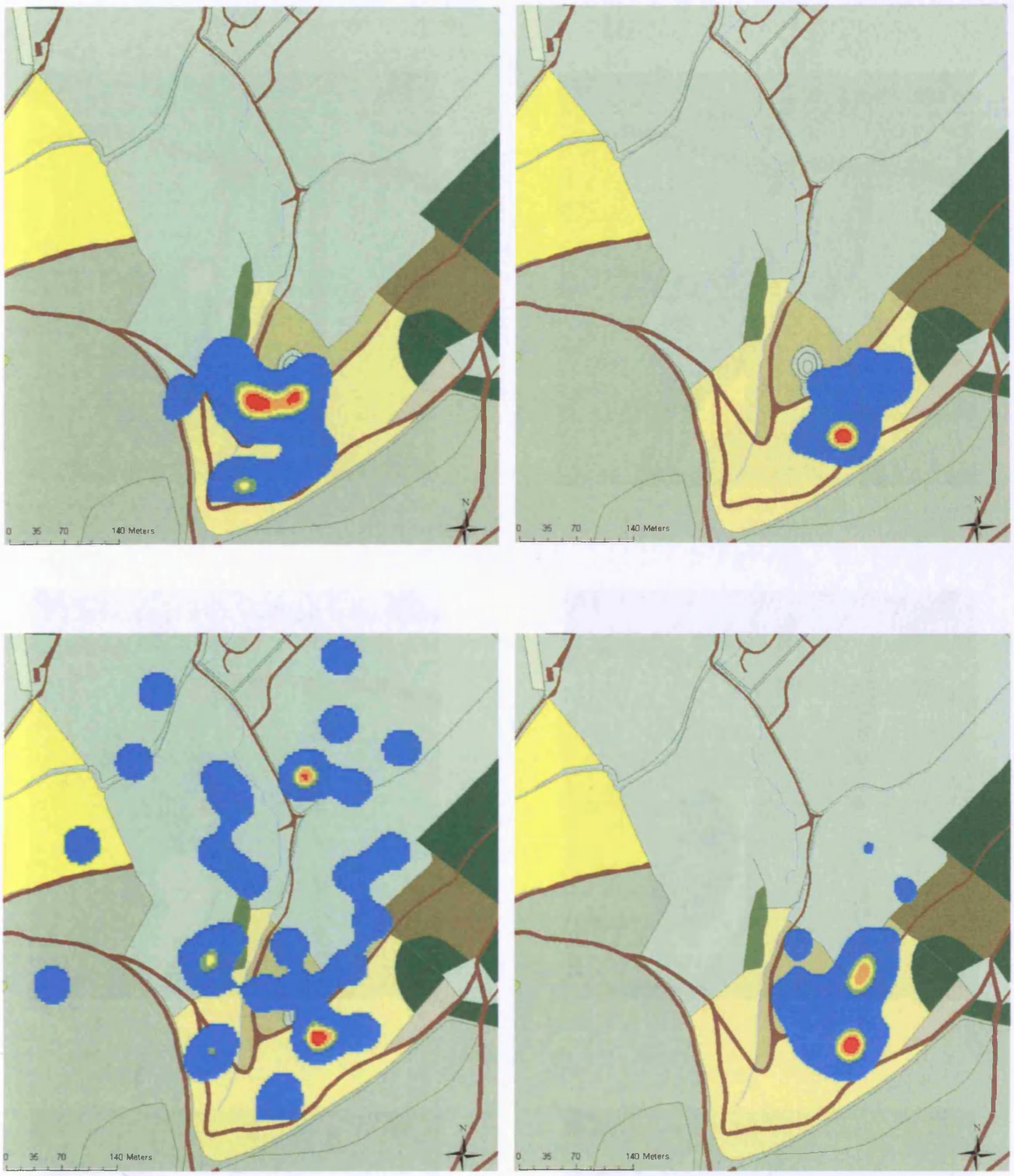
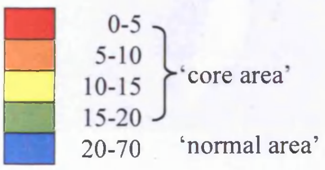


Figure 5.12 The breeding territories of the 4 individuals tracked at TH in 2006. The different colours each contain a percentage of the location density distribution with red containing the densest 5%, orange the next 5% and so on up to 20% representing the core area. The blue area contains a further 50% so that the normal area used by the bird is represented by 70% of the densest location points.



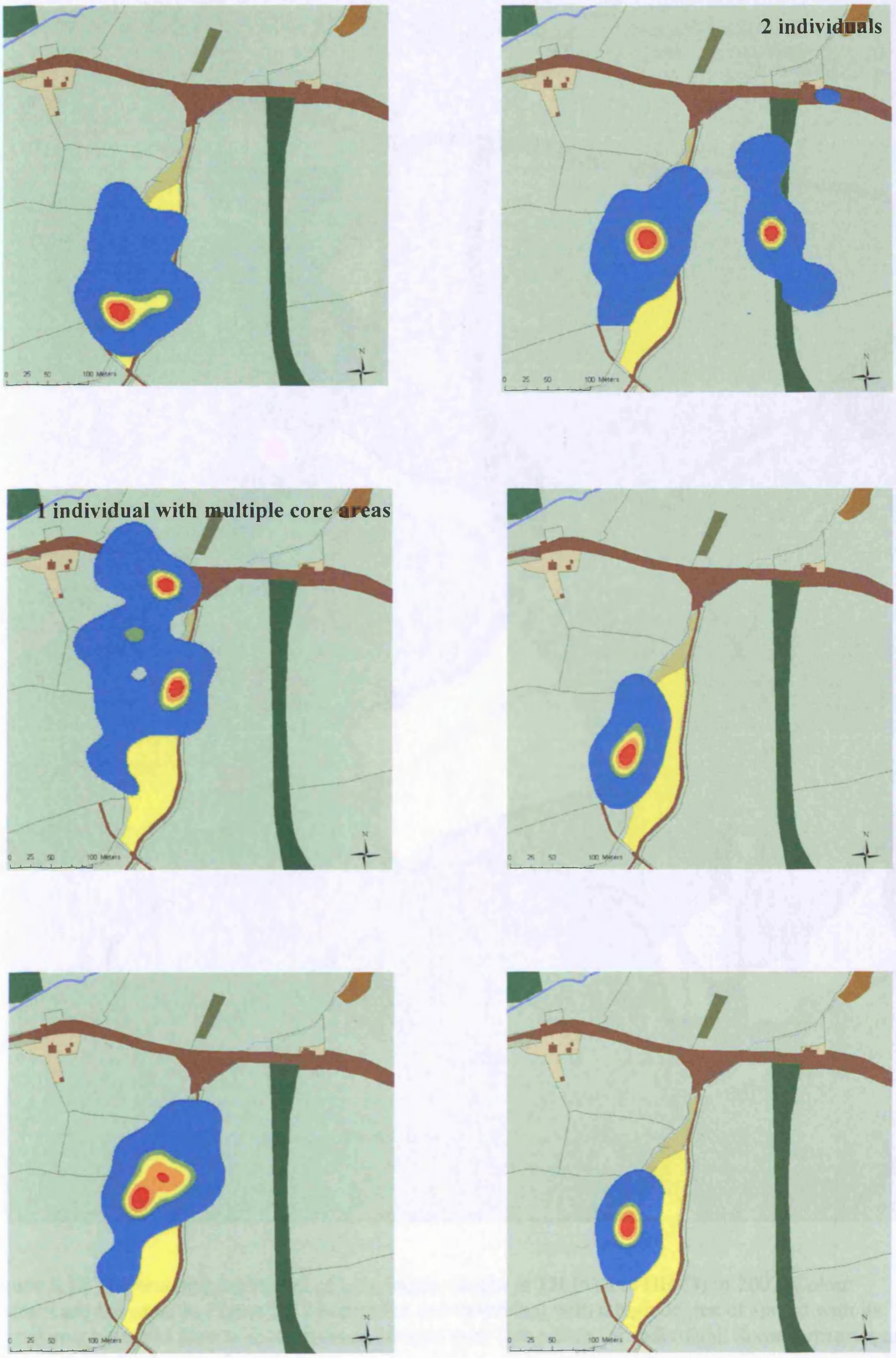


Figure 5.13 The breeding territories of the 7 individuals tracked at HH in 2006. Colour contours are the same as Figure 5.12.

Figure 5.14 The breeding territories of individuals caught at TH (4) and HH (3) in 2007. Colour contours are the same as Figure 5.12 except for one individual with a high degree of spread with its normal area coloured lilac to show areas associated with that particular individual. Some territories are faded to show the degree of overlap.

A significant correlation was found between home range size and two habitat types, scrub (2006 only) and SRC for 2006 and the overall trend for SRC was still significant despite variation because of year (Figure 5.15). The relationships suggest that the larger the proportion of SRC in the territory, the smaller the overall home range is. The opposite is true for the ffridd scrub habitats. Improved grassland was strongly avoided by all individuals and most showed preference for the linear features i.e. the hedgerows and tree lines (Table 5.4). The birds at HH tended to prefer SRC to other available habitats (6 out of 10 birds) while the ones at TH preferred scrub (7 out of 8). Habitat selection differed for the populations at the two sites. As expected from looking at the individual preferences, the birds at HH spent more time in the SRC than statistically expected while the TH population spent more time in the scrub habitats (Figure 5.16). The population at HH had a stronger association with linear features than those at TH.

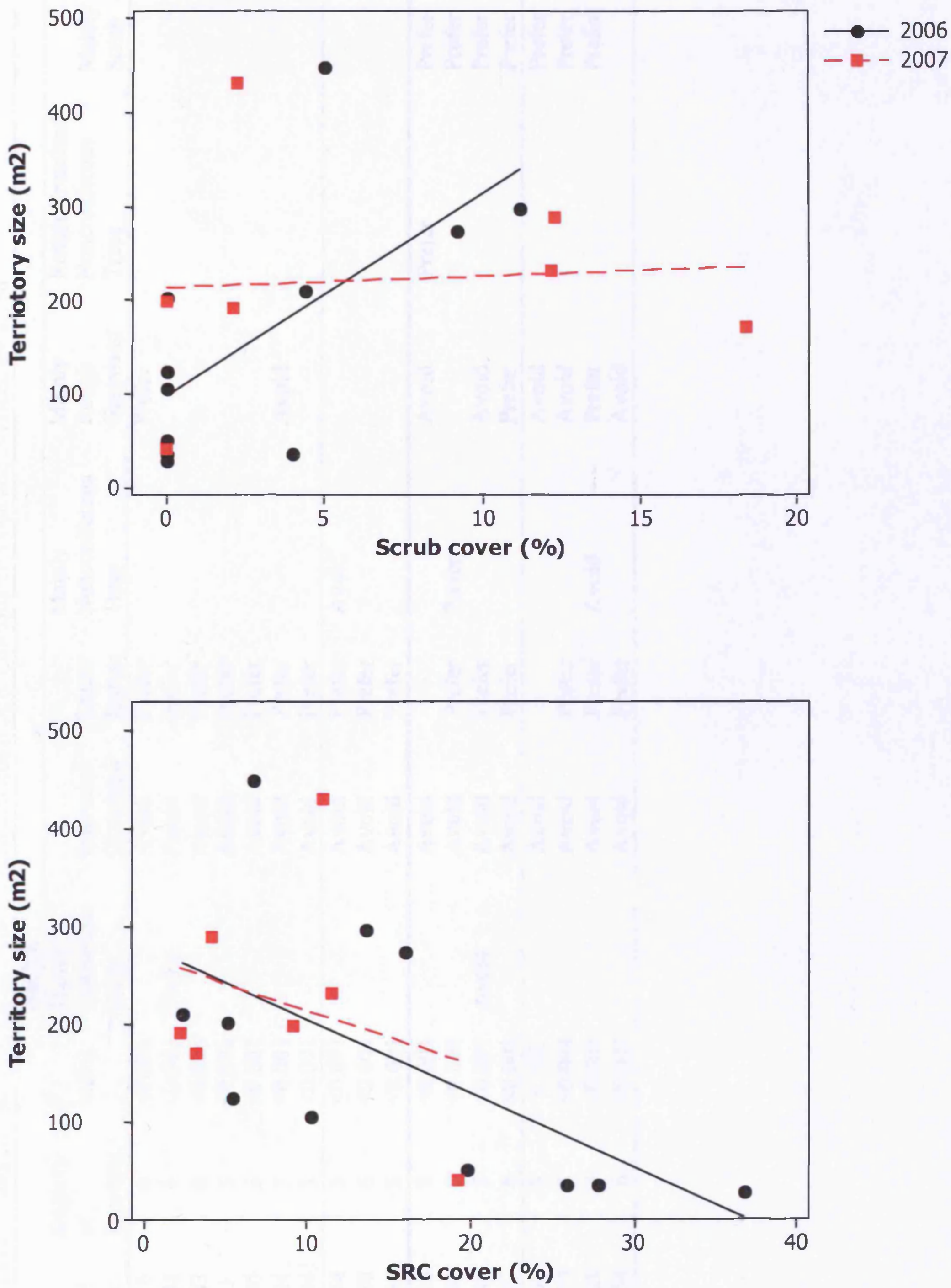


Figure 5.15 Regression lines showing scrub and SRC related to home range size. Scrub was significantly related to home range size in 2006 (F=6.53, P=0.031) and in SRC also 2006 (F=5.59, P=0.042). For SRC the trend was still significant despite variation because of year (F=7.48, P=0.015). No other habitat categories were significantly related.

Table 5.4 Preference and avoidance statements for each habitat type for each individual bird. Chi-squared value and P-values are given.

Site	Year	Bird ID	Chi-Squared Statistic	Degrees of Freedom	P-Value	Habitat: Mainly Coniferous Trees	Improved Grassland	Linear feature	Mainly Nonconiferous Trees	Mainly Rough Grassland	Rough Grassland, Nonconiferous Trees	Mainly Scrub	SRC
HH	06	1	202.016	4	<0.001		Avoid	Prefer		Prefer			Prefer
HH	06	2	175.381	4	<0.001	Prefer	Avoid	Prefer					
HH	06	3	283.483	6	<0.001		Avoid	Prefer					Prefer
HH	06	4	405.43	3	<0.001		Avoid	Prefer					Prefer
HH	06	5	430.495	3	<0.001		Avoid	Prefer					Prefer
HH	06	6	312.924	3	<0.001		Avoid	Prefer		Avoid			Prefer
HH	06	7	286.594	3	<0.001		Avoid	Prefer					
HH	07	1	318.174	3	<0.001		Avoid	Prefer	Avoid				Prefer
HH	07	2	531.776	6	<0.001		Avoid	Prefer					
HH	07	4	444.034	5	<0.001		Avoid	Prefer					
TH	06	11	161.915	7	<0.001		Avoid			Avoid	Prefer	Prefer	Avoid
TH	06	13	35.3061	6	<0.001		Avoid	Prefer	Prefer			Prefer	
TH	06	14	200.146	5	<0.001	Avoid	Avoid	Prefer		Avoid		Prefer	Avoid
TH	06	15	274.827	6	<0.001		Avoid	Prefer		Prefer		Prefer	
TH	07	101	20.2693	6	0.002		Avoid			Avoid		Prefer	
TH	07	102	170.135	5	<0.001		Avoid	Prefer		Avoid		Prefer	Avoid
TH	07	104	93.5628	7	<0.001		Avoid	Prefer	Avoid	Prefer		Prefer	
TH	07	105	158.754	6	<0.001		Avoid	Prefer		Avoid			

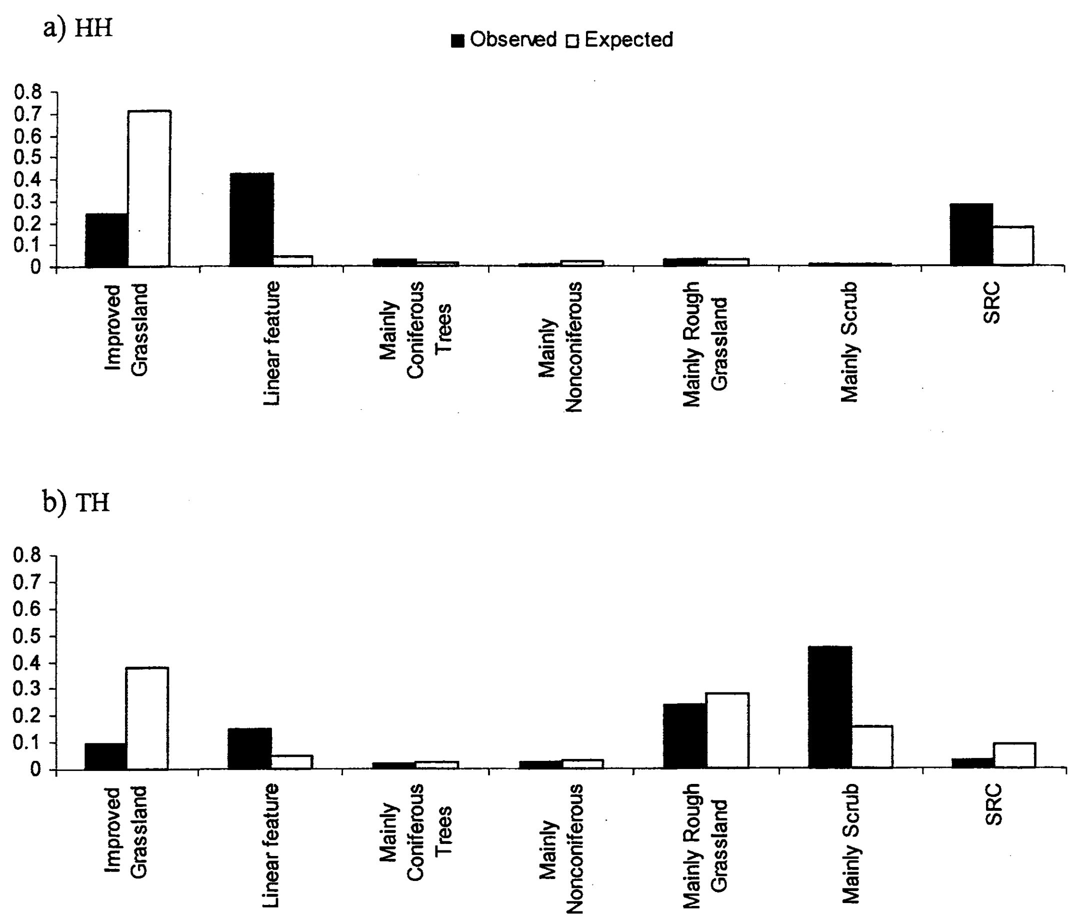


Figure 5.16 Observed habitat use compared with expected use based on the proportions of available habitat for the Willow Warblers caught at a) HH and b) TH.

5.5 Discussion

The main findings were that bird communities of SRC scrub and the scrub of ffridd habitat are distinct and both provide valuable habitat for diverse bird communities. For Willow Warblers SRC is a highly beneficial addition to the landscape. Increasing SRC production could significantly increase the productivity of this species. This study also shows the importance of maintaining the integrity of landscape features, such as hedgerows and old trees.

5.5.1 Species communities at the sites.

The year 2007 was generally a poor one for breeding birds with many species experiencing the worst breeding season since the BTO's Constant Effort Scheme (CES) began in 1983. May 2007 was the wettest since 1967 and the thundery weather continued through much of June leading to devastating flooding in many parts of the country. The adverse weather began in the study area during the study period in 2007. Nationally, early breeders such as Blackcap and Long-tailed Tit missed the worst of the weather but slightly late species such as Garden Warblers suffered. Ground nesters suffered particularly and the BTO' Bird Track received reports of warblers dying in the nest. This may have lead to the reduction of caught species in this study in 2007. The drop in species caught between years may also partially reflect slightly reduced effort (number of visits) (Table 5.1), indeed some of the species are ones that were caught in very low numbers in 2006 and would be most effected by reduced effort. However, the species not caught in 2007 are all from the "more specialist" lists of species found at only one site (Table 5.2) and most likely reflects the ability of more generalist species and/or early breeding species to cope better with the weather patterns. The bad weather explains the dramatic fall in Garden Warbler numbers caught between years in this study. The bird numbers at TH were particularly affected by the wet weather and some species may have made greater use of the SRC at HH in this "bad" year. This seems particularly true for Willow Warblers as their relative abundance at HH in 2007 was approximately double that of TH. There was no difference in the bird's condition at the 2 sites but the relative abundance numbers suggest that the resources provided by the SRC can maintain more individual birds at that condition than the habitats at TH overall and particularly when conditions are adverse.

5.5.2 Willow Warblers at the sites

PMS were higher in 2007 at both sites suggesting that the Willow Warblers arrived back in better condition than 2006 albeit at lower numbers at TH. Fat scores did differ reflecting more immediate conditions. The higher fat scores recorded at HH can be interpreted in several ways. It could mean that birds here were able to fatten up quicker. Because of the increased cover afforded by the SRC birds may feel less vulnerable to predation and able to carry more fat (Rogers 1987), although if this were the case the pattern would presumably have occurred in 2006 as well. It has been shown in birds with a dominance hierarchy that more dominant birds are more certain of feeding and can afford to carry less fat (Gosler 1996, Lima 1986). The resource at TH may have been more predictable in 2007 and the birds could carry less fat because they were more certain of being able to feed (Rogers and Reed 2003). As is often the case, adaptive fat regulation was difficult to interpret (Rogers and Heath-Coss, 2003) and it is unclear what the differences in fat scores reflect.

The only bird caught at both sites was an individual who was tracked in 2006 at TH and then was re-caught the following year at HH. He was re-caught in 2007 at HH on the 16th March and the 21st April suggesting that he had changed territory locations. Male Willow Warblers may change to a higher quality habitat in response to reduced breeding success in the preceding year (Jakobsson 1988, Lawn 1994). This would suggest that having held a territory at TH one year the individual chose a better quality one the following year in the SRC.

Home ranges were larger than has been previously reported but the core areas where more like those previously mapped or described (Enemar *et* *al.* 1979, Lawn 1982, Tiainen 1983). Home ranges were significantly smaller at HH and this did not alter between years despite the lower density of birds in 2007 as has been found to happen in Great Tit populations (Both and Visser 2000). Habitat type was a greater influence on territory size than the population density. The more SRC was available to an individual the smaller his home range needed to be to provide him with all the resources he would need to attract a mate and successfully fledge young. Conversely, when scrub in the ffridd habitat was utilized a greater home range size was required to provide the same resources. This indicates the resources provided by SRC are more concentrated than in the ffridd habitat (Tremblay *et al.* 2005). Additional support for this idea comes from the fact that SRC can support a greater number of individuals by allowing considerable overlap of territories consequently increasing productivity.

The long-term trend of a declining English and Welsh Willow Warbler population appears to be due to failure at the egg stage (BTO Bird Trends 2008). In a single study in Norway 68% of nests failed due to predation (Bjoernstad and Lifjeld 1996). Holding a smaller territory and having to travel smaller distances to feed would mean more time spent nest guarding and presumably lead to a greater breeding success than those individuals forced to spend longer away from the nest (Kerbiriou *et al.* 2006). These results suggest that growing more SRC in Wales could significantly increase Willow Warbler productivity.

The occurrence of multiple core areas was more prevalent in 2006 with three individuals having multiple core areas within their home range in 2006. Previous studies have found Willow Warblers to be highly polygynous with bigyny being the rule and some males even having three females (Neergaard and Arvidson 1995). This is more evidence that 2006 was a much better year for breeding birds than 2007 and enabled increased pairing and nesting attempts.

Analysis of habitat utilization by the Willow Warblers showed that SRC appeared to be used in complete substitution for the traditional ffridd habitat. Further evidence of the importance of this habitat was the significant correlation between SRC content and home range size. However, one thing the ffridd has but is lacking in the SRC is old trees. The population inhabiting the SRC made greater use of the trees present in the linear features i.e. in the hedgerows. Willow Warblers are especially associated with trees at the site scale (Fuller *et al.* 2006) and this study confirms the importance of maintaining trees within the landscape for this species. Although most closely associated with scrub habitats the presence of old trees in the habitat mosaic is clearly important for Willow Warblers. In this case, for males setting up territories, the trees are probably playing an important role as song posts. They are the highest available perches from which the males can perform their song repertoires in order to attract a mate and signal to other males that a territory has been established.

Bird density alone does not necessarily mean greater breeding success as some introduced non-native vegetation can become 'ecological traps' (Remes 2003). SRC provides good forage and apparently good nesting opportunities. Willow is not an exotic introduction and is probably returning to a more 'natural' or at least older habitat type. It is unlikely to act as an ecological trap in the UK (Dhont *et al.* 2007) and the assumption that SRC could increase Willow Warbler productivity based on these results seem justified.

Implications and suggestions for further research

Future studies need to address the lack of direct measures of productivity for birds in these habitats. It was originally envisaged that nests would be located and monitored as part of this study but this proved to be too labour intensive to do in addition to dealing with the radio tracking data. There is a need to understand and identify the preferred mosaics and structures of vegetation of other bird species and what role SRC can play in that mosaic. This will provide a better understanding of the implications of introducing SRC into the landscape and enable it to be managed with the surrounding area to the maximum benefit to birds and other wildlife. If SRC is to be managed to its full potential a more complete understanding of the habitat needs of birds and other wildlife is necessary.

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Chapter 6

General Discussion:

The consequences to biodiversity of growing short rotation willow coppice in Wales with particular reference to birds.

6.1 Main findings and Conclusions

This thesis found that planting SRC in Wales could be of significant benefit to biodiversity. Weed floral diversity and abundance would be increased and this would have significant knock on benefits for a wide range of bird species including those contributing to the government's Wild Bird Index. Specifically:

i) Weed floral diversity and species richness are significantly increased by planting SRC (Chapter 2)

ii) Young SRC fields produce substantial amounts of weed seeds easily utilised by many bird species during the winter (Chapter 3)

iii) SRC provides valuable habitat for diverse bird communities during the breeding season. As the crop matures the bird community changes but in particular, increasing numbers of migrant warblers are recorded utilising the crop (Chapter 4)

iv) SRC is a highly beneficial addition to the landscape for Willow Warblers and could significantly increase the productivity of this declining species (Chapter 5).

This thesis shows the potential of SRC to help the government reach targets agreed by The Convention on Biological Diversity. Incorporating SRC into the Welsh landscape would help the wider environment support an increased level of biodiversity, a main theme in the Environment Strategy for Wales (WAG 2006).

Although it was the intention that the sites in this study would be treated as a commercial crop, the planters and growers had little or no previous experience of this crop. They may therefore have been weedier than future commercially managed plots. However, even at sites where particularly aggressive chemical spaying occurred there was a relative abundance of weed species. In the future, weed control will probably be refined and become increasingly effective, rendering SRC less valuable for enhancing biodiversity unless discouraged by agri-environment schemes.

In the UK, each devolved country has its own agri-environment scheme, and in Wales this is Tir Gofal. Tir Gofal operates competitively, such that farmers must apply and obtain a certain number of points if they wish to join the scheme. Points are awarded for a range of habitats, environmental features and farm characteristics. Once approved, each agreement is for a minimum of 5 years, and there are currently over 3000 farms in Wales in Tir Gofal covering over 300,000 hectares of land.

Including SRC in Welsh agri-environment schemes could significantly increase the floral diversity of Welsh farmland and positively effect associated taxa. Making it beneficial for farmers to be less aggressive in their control of weeds within this crop would allow it to realize its biodiversity potential and help the government to reach its biodiversity targets. With the EU Agriculture Council's decision to set a 0% rate of set-aside for 2008, farming will loose valuable areas of nil or low chemical input. SRC could be of particular importance, as it will inevitably reduce the chemical input into farming systems. Although the loss of set-aside will not be particularly felt in Wales, any new farming system that reduces the level of intensity would be beneficial anywhere in the UK.

The importance of maintaining the integrity of landscape features, such as hedgerows and old trees has been highlighted (Chapter 4 and 5, Sage *et al.* 2006). If biomass crops become more widely grown it is likely that larger blocks will be planted. If biodiversity is to be encouraged measures must be implemented to preserve the integrity of landscape features. Smaller plantings could be encouraged or larger plots broken up with rides or hedges. Maintaining a mix of coppice age is also important to maximise the benefits to the widest range of bird species (Chapter 4).

Despite the benefits to birds, it is unlikely that SRC planted on unimproved farmland would lead to a conservation gain (Sage *et al.* 2006). However, Wales is currently dominated by improved grazing habitat that has become increasingly impoverished in terms of biodiversity (Vickery *et al.* 2002, Fuller and Gough 1999, Fuller *et al.* 2006). In this context, the addition of SRC into the landscape would lead to massive benefits to all aspects of biodiversity.

The landscape into which SRC is introduced will affect the species recorded with in it (Christian *et al.* 1994, Perttu 1995, Tolbert and Wright 1998, Coates and Say 1999, Starback and Becht 2005, Anderson and Fergusson 2006, Rowe *et al.* 2007). For highly mobile animals in particular such as birds, landscape composition plays a central role in determining occupancy of plantations (Christian *et al.* 1998) and adjacent habitats have a strong influence on the bird community composition in the SRCs (Berg 2002). This study was based on plots generally no more than 5ha set in conventional Welsh farmland. As demand for biomass grows and more of the Welsh landscape is planted with these crops this will inevitably have an effect on biodiversity and this should be taken into account when considering these results.

This thesis demonstrates that SRC could significantly contribute to enhancing biodiversity and meeting government targets. It highlights the importance of adapting agri-environment schemes to new agricultural developments.

Future studies need to address the lack of direct measures of productivity for birds in SRC. Studies which address breeding productivity issues such as nest survival, hatching and fledging rates from nests at SRC sites with other land uses need to be implemented.

It is unclear whether other biomass crops such as energy grasses will also provide habitat for birds. Work has been undertaken on a small number of sometimes weedy fields (Semere and Slater 2005). It has been suggested that they might provide good summer and winter foraging if they contain weeds and insects similar to SRC. However, willow's are native and known to be high in insect abundance (Kennedy and Southward 1984) in contrast to energy grasses which are foreign introductions and have been shown to provide less insect food than winter crop plants (Bellamy *et al.* 2008). Further investigation is warranted.

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Appendix I

Complete list of plant species recorded within the SRC and the control sites throughout the 3 year study. Shows the mean percentage of cover recorded for each species.

Class 1 = Annual species
Class 2 = Short-lived perennials
Class 3 = Long-lived perennials
(After Cunningham *et al.* 2004)

Species		Control -1	Year 0	Year 1	Year 2	Class
Achillea millefolium	Yarrow	0.006	0	0.237	0	3
Agrostis stolonifera	Creeping Bent	19.520	1.686	22.738	8.675	3
Alopecurus geniculatus	Marsh Foxtail	0	6.531	8.580	10.167	2
Anagallis arvensis	Scarlet Pimpernel	0.036	0.017	0.002	0	1
Anthoxanthum odoratum	Sweet Vernal-grass	0.006	0	0	0	3
Anthriscus sylvestris	Cow Parsley	0	0.043	0	0	2
Aphanes arvensis	Parsley-piert	0	0	0.423	0	1
Arctium lappa	Greater Burdock	0	0	0.017	0.463	2
Atriplex patula	Common Orache	0	1.134	0	0	1
Bellis perennis	Daisy	0.737	0.020	0	0	3
Capsella bursa-pastoris	Shepherd's-purse	0	2.329	0	0	1
Cardamine armara	Large Bitter-cress	0	0.186	0.493	0	3
Cardamine hirsuta	Hairy Bitter-cress	0.606	0	0	0	2
Carex diandra	Lesser Tussock-sedge	0	0	0	0.6	3
Carex nigra	Common Sedge	0.071	0.274	0.417	6.547	3
Carex ovalis	Oval Sedge	0	0.014	0.647	0	3
Cerastium fontanum	Common Mouse-ear	0.983	0.240	0.349	0.233	1
Cerastium glomeratum	Sticky Mouse-ear	0.029	0	0.037	0	1
Chamerion angustifolium	Rosebay Willowherb	0	0.012	1.285	0.292	2
Chenopodium album	Fat-hen	0	1.961	0.050	0.563	1
Cirsium arvense	Creeping Thistle	0.241	2.170	1.443	1.511	1
Cirsium palustre	Marsh Thistle	0	0	0.007	0	2
Cirsium vulgare	Spear Thistle	0.317	16.291	4.569	0.296	2
Dactylis glomerata	Cock's-foot	1.786	0.029	0.052	0.550	3
Deschampsia cespitosa	Tufted hair-grass	0	0.043	0.073	0	3
Elymus repens	Common Couch	0	0.331	1.645	0.067	1
Epilobium montanum	Broad-leaved Willowherb	0.056	0.523	1.333	2.429	2
Equisetum arvense	Field Horsetail	0.114	0.157	0	1.633	2
Euphorbia peplus	Petty Spurge	0	0.257	0.017	0	2
Fallopia convolvulus	Black-bindweed	0	0.014	0	0	1
Festuca gigantea	Giant Fescue	1.249	2.027	0	0	3
Festuca ovina	Sheep's Fescue	0	0	0	0	3
Festuca rubra	Red Fescue	0	0	0.223	0.125	3
Fumaria officinalis	Common Fumitory	0	0.711	2.603	0	1
Galeopsis tetrahit	Common Hemp-nettle	0	0.100	0	0	1

Galium palustre	Common Marsh-bedstraw	0	0	1.200	0	2
Geranium molle	Dove's-foot Crane's-bill	0.107	0	0.003	0	1
Glyceria fluitans	Floating Sweet-grass	0	1.141	0.700	2.963	3
Hedera helix	Common Ivy	0	0	0.002	0	3
Helictotrichon pubescens	Hairy Oat	0.507	0.723	0.790	0	3
Heracleum sphondylium	Hogweed	0.443	0	0.817	0	2
Holcus lanatus	Yorkshire-fog	12.963	10.070	7.159	18.037	3
Hypericum humifusum	Trailing St John's-wort	0	0	0.070	0	3
Juncus articulatus	Jointed Rush	0	0	0.039	0.007	3
Juncus bufonius	Toad Rush	0	0.055	0.103	0	1
Juncus conglomaratus	Compact Rush	0	0	0.050	0.140	3
Juncus effusus	Soft Rush	0.157	0	0	0.44	3
Kickxia elatine	Sharp-leaved Fluellen	0	0.041	0.333	0	1
Kickxia spuria	Round-leaved Fluellen	0	0	0.010	0	1
Lathyrus pratensis	Yellow Vetchling	0	0	0	0.333	3
Lolium perenne	Perennial Rye-grass	46.970	0.687	3.096	2.650	3
Lotus corniculatus	Common Bird's-foot-trefoil	0	0	0.020	0	2
Lotus pedunculatus	Greater Bird's-foot-trefoil	0.036	0.114	0.716	0	2
Luzula multiflora	Heath Wood-rush	0.069	0	0	0	3
Matricaria discoidia	Pineappleweed	0	1.780	0	0	1
Montia fontana	Blinks	0.157	0.076	2.320	0	2
Persicaria hydropiper	Water-pepper	3.157	2.189	0.847	0.132	1
Persicaria maculosa	Redshank	0.006	3.554	5.573	0.438	1
Phleum pratense	Timothey	0	0	0.037	0	3
Plantago lanceolata	Ribwort Plantain	0	0.015	0	0	3
Plantago major	Greater Plantain	0	0.186	0.004	0	2
Poa annua	Annual Meadow-grass	1.889	10.659	4.405	0.607	1
Polygonum aviculare	Knotgrass	0	0.071	1.110	0.438	1
Potentilla anserina	Silverweed	0	0	0	2.353	3
Potentilla reptans	Creeping Cinquefoil	0	12.932	0.897	0	2
Prunella vulgaris	Selfheal	0.003	0	0	0	3
Ranunculus acris	Meadow Buttercup	0.036	0	0.502	0.133	3
Ranunculus flammula	Lesser Spearwort	0	0	0.056	0	3
Ranunculus repens	Creeping Buttercup	7.009	0	35.573	46.167	2
Raphanus raphanistrum	Wild Radish	0	0.249	0	0	1
Rubus fruticosus	Bramble	0	0.027	0.066	0.292	3
Rumex acetosa	Common Sorrel	0.781	0.163	1.440	0	3
Rumex acetosella	Sheep's Sorrel	0	0	0.100	0	3
Rumex obtusifolius	Broad-leaved Dock	0.229	1.792	0.173	0.063	2
Sagina procumbens	Procumbent Pearlwort	0	0	0.023	0	2
Salix caprea	Goat Willow	0	0.057	0.020	0	3
Salix cinerea	Grey Willow	0	0	0.020	0	3
Senecio jacobaea	Common Ragwort	0	0.174	0.002	0	2
Senecio vulgaris	Groundsel	0	0.077	3.680	0	2
Silene dioica	Red Campion	0	0.014	0.003	0	2
Sinapsis arvensis	Charlock	0	0.057	0	0	1
Solanum nigrum	Black Nightshade	0	1.669	0.033	0	1

Solanun dulcamara	Bittersweet	0	0	0.065	0	2
Sonchus arvensis	Perennial Sowthistle	0	0.220	0.430	0	1
Stellaria media	Common Chickweed	0.171	3.787	1.280	0	1
Taraxecum (agg)	Dandelions	0.586	0.995	0.131	0.246	1
Trifolium pratense	Red Clover	0	0.134	0.002	0	3
Trifolium repens	White Clover	5.570	17.983	1.905	1.150	3
Urtica dioica	Common Nettle	0.286	0.149	0.996	0.546	2
Veronica agrestis	Field Speedwell	0.040	0	0	0	2
Veronica officilalis	Heath Speedwell	0.009	0	0	0	1
Vicia hirstua	Hairy Tare	0.207	0	0	0	1
Viola arvensis	Field Pansy	0	0.038	0.237	0	1

Appendix II

Complete list of bird species recorded within the young SRC (<2 years old) by the winter bird surveys (WBS).

Species		Sites N=6	Mean no per visit	UK conservation status
Blackbird	*Turdus merula*	6	8.85	
Blue Tit	*Parus caeruleus*	6	5.54	
(Eurasian) Bullfinch	*Pyrrhula pyrrhula*	2	0.15	Red
Common Buzzard	*Buteo buteo*	2	0.15	
Chaffinch	*Fringilla coelebs*	6	71.54	
Coal Tit	*Parus ater*	1	0.08	
Carrion Crow	*Corvus corone corone*	3	0.23	
Dunnock	*Prunella modularis*	3	4.15	Amber
Fieldfare	*Turdus pilaris*	3	0.23	Amber
Goldcrest	*Regulus regulus*	2	0.38	
(European) Goldfinch	*Carduelis carduelis*	3	6.15	
Great Tit	*Parus major*	5	0.69	
(European) Greenfinch	*Carduelis chloris*	5	3.23	
Herring Gull	*Larus argentatus*	1	0.08	Amber
Jay	*Garrulus glandarius*	3	0.31	
Lesser Spotted Woodpecker	*Dendrocopus minor*	1	0.08	Red
Linnet	*Carduelis cannabina*	1	0.08	Red
Long-tailed Tit	*Aegithalos caudatus*	3	3.38	
Magpie	*Pica pica*	1	0.08	
Willow Tit	*Parus montanus*	1	0.08	Red
(Common) Pheasant	*Phasianus colchicus*	3	2.31	
(Common) Redpoll	*Carduelis flammea*	3	10.31	
Redwing	*Turdus iliacus*	2	8.38	Amber
(Common) Reedbunting	*Emberiza schoeniclus*	5	17.85	Red
Robin	*Erithacus rubecula*	6	2.62	
Rook	*Corvus frugilegus*	2	0.23	
(Common) Snipe	*Gallinago gallinago*	2	17.46	Amber
Song Thrush	*Turdus philomelos*	3	0.38	Red
(Eurasian) Sparrowhawk	*Accipiter nisus*	2	0.15	
Starling	*Sturnus vulgaris*	2	19.77	Red
(Common) Stonechat	*Saxicola torquata*	2	0.08	Amber
(Common) Woodpigeon	*Columba palumbus*	4	4.85	
(Eurasian) Woodcock	*Scolopax rusticola*	1	0.08	Amber
Wren	*Troglodytes troglodytes*	3	4.23	
Yellowhammer	*Emberiza citrinella*	1	0.85	Red

Species caught in other winter mist netting occasions not used in this Chapter		
Great Spotted Woodpecker	*Dendrocopus major*	
Marsh Tit	*Parus palustris*	Red
Meadow Pipit	*Anthus pratensis*	
Nuthatch	*Sitta europaea*	
Siberian Chiffchaff	*Phylloscopus collybita tristis*	British rarity

Appendix III

Complete list of bird species recorded within the young (<2 years old) and established and mature SRC by the breeding bird surveys (BBS).

Species		Young SRC Sites N=7	Young SRC Mean no per visit	Older SRC Sites N=4	Older SRC Mean no per visit	UK conservation status
Barn owl	*Tyto alba*	1	0.2			Amber
Barn swallow	*Hirundo rustica*	6	2.38	2	1.2	Amber
Black bird	*Turdus merula*	7	6.67	4	5.5	
Blackcap	*Sylvia atricapilla*	4	0.46	2	0.6	
Blue Tit	*Parus caeruleus*	7	4.38	4	2.4	
(Eurasian) Bullfinch	*Pyrrhula pyrrhula*	3	0.31	1	0.4	Red
Buzzard	*Buteo buteo*	3	0.23			
Chaffinch	*Fringilla coelebs*	6	3.85	4	2.8	
Chiffchaff	*Phylloscopus collybita*	3	1.08	2	2	
Coal Tit	*Parus ater*	1	0.08			
Crow	*Corvus corone corone*	5	2.38	3	2	
Curlew	*Numenius arquata*	1	0.08			Amber
Dunnock	*Prunella modularis*	7	1.31	3	1.4	Amber
Fieldfare	*Turdus pilaris*	3	0.23	0	0	Amber
Garden Warbler	*Sylvia borin*	3	0.62	3	1	
(European) Goldfinch	*Carduelis carduelis*	7	2.69	4	2.2	
Grasshopper Warbler	*Locustella naevia*			1	0.2	Red
Great Tit	*Parus major*	6	2.62	3	3.6	
Greater spotted Woodpecker	*Dendrocopus major*	1	0.08			
(European) Greenfinch	*Carduelis chloris*	2	0.23			
House Sparrow	*Passer domesticus*	2	0.31			
Jackdaw	*Corvus monedula*	2	0.31	1	0.2	
Jay	*Garrulus glandarius*	1	0.23	1	0.6	
Lesser Black-backed Gull	*Larus fuscus*	2	0.15	1	0.2	Amber
Linnet	*Carduelis cannabina*	1	0.08			Red
Magpie	*Pica pica*	2	0.15			
Marsh Tit	*Parus palustris*	1	0.08			Red
Mistle Thrush	*Turdus viscivorus*	2	0.15			Amber
Nuthatch	*Sitta europaea*	1	0.08	1	0.2	
(Common) Pheasant	*Phasianus colchicus*	2	0.38	1	0.6	
Pied Wagtail	*Motacilla alba*	1	0.15			
(Common) Redpoll	*Carduelis flammea*	1	4.85			
Redstart	*Phoenicurus*	1	0.38	1	0.2	Amber

	phoenicurus					
(Common) Reedbunting	*Emberiza schoeniclus*	1	0.08			Red
Robin	*Erithacus rubecula*	7	2.54	4	1.6	
Rook	*Corvus frugilegus*			1	1	
Sedge Warbler	*Acrocephalus schoenobaenus*	1	0.77			
Siskin	*Carduelis spinus*	1	0.08			
Skylark	*Alauda arvensis*	3	0.54			Red
Song Thrush	*Turdus philomelos*	5	0.62	3	1	Red
(Eurasian) Sparrowhawk	*Accipter nisus*	1	0.08			
Starling	*Sturnus vulgaris*	2	21.54			Red
Swift	*Apus apus*	1	0.46			
Tree Pipit	*Anthus trivialis*	2	0.31			Amber
Treecreeper	*Certhia familiaris*	1	0.08	1	0.2	
Whitethroat	*Sylvia communis*			3	0.8	
Willow Tit	*Parus montanus*	1	0.08			Red
Willow Warbler	*Phylloscopus trochilus*	6	3.69	4	3.4	Amber
(Common) Woodpigeon	*Columba palumbus*	6	2.54	3	2.4	
Wren	*Troglodytes troglodytes*	6	1.77	3	1	
Yellowhammer	*Emberiza citrinella*	1	0.15			Red