Wild Thing: the effect of re-wilding on the densities of a group of Bird of Conservation Concern species.

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Project declaration

All transect data was collected by myself. However assistance was provided by volunteers for the collection of the nightingale and hedge data.

All analyses were developed by myself with some help from Dr David Orme.

ABSTRACT

The ecological impacts of land use change have been observed across the globe. In the UK in the past 50 years agricultural intensification has lead to loss of habitat heterogeneity and ecosystem biodiversity. Re-wilding aims to re-establish land to its previous state of wilderness and regenerate the biodiversity of simplified ecosystems.

This study was conducted at the re-wilded Knepp estate, which prior to 2001 was a mixed arable farm. Heterospecific attraction is a process by which migrant bird species use resident species for cues to high quality breeding habitats. Here is presented observational data of the effect of re-wilding on the densities of red and amber listed bird species, as well as an investigation into heterospecific attraction at the site and a continuing investigation into nightingales.

Surveys were carried out at the Knepp Estate and at Priors Byne, a working mixed arable farm nearby. These showed that densities were much higher at Knepp than previously found in good quality European breeding habitats. Two of the study species present at Knepp were not seen on Priors Byne farm. Heterospecific attraction was not seen to play a part in augmenting densities at Knepp. Nightingales were seen to have significantly increased from 2012. Strong positive effects on biodiversity have been observed after only nine years of the scheme being in place. These positive results advocate for the expansion of the re-wilding scheme seen at Knepp and further trials at sites around the UK.

INTRODUCTION

Re-wilding is the concept of re-establishing land to its previous state of wilderness, regulated by large predators or grazers. These megafauna encourage the development of an ecosystem which may otherwise undergo biotic simplification (Mills, Soulé & Doak, 1993). Re-wilding is a vital step in re-establishing simplified ecosystems (Soulé. M. & Noss, R., 1998) and can have far reaching benefits across an ecosystem (Noss, 1987).

Farming and conservation are conventionally viewed as incompatible (Tscharntke et al., 2005) however it is believed that traditional low intensity farming practices can encourage biodiversity (Bignal & McCracken, 1996). Organic farming and the use of agri-environmental schemes have shown increased biodiversity compared to conventional farming methods (Peach et al., 2001). Chamberlain et al. (1999) found that on organic farms hedges tended to be larger, field boundaries contained more trees and field sizes were smaller. Chamberlain suggested that these factors of habitat structure, as well as farming method could be important for breeding birds. Organic farms inherently have a more diverse and therefore heterogeneous landscape which consequently increases biodiversity (Norton et al., 2009), (Browne, Vickery & Chamberlain, 2000).

In the last 70 years a series of technical developments have lead to a revolution in agricultural practices (Gardner, 1996). This agricultural intensification has led to huge declines in biodiversity, particularly in birds (Devictor & Jiguet, 2007). Farmland species exhibited an 83% decline from 1970 -1990 (Fuller et al., 1995). Benton et al. (2003) propose that loss of heterogeneity is a global problem caused by agricultural intensification and that restoring this landscape heterogeneity is the key to restoring biodiversity.

Agri-environmental schemes aim to improve farmland biodiversity and are applied at two levels: “broad and shallow and “deep and narrow”. “Deep and Narrow” projects target specific species, for instance: cirl bunting (*Emberiza cirus*), corncrake (*Crex crex*) and stone curlew (*Burhinus oedicnemus*) (Vickery et al., 2004). “Broad and shallow” schemes aim to make use of low cost, easy to apply techniques such as: grass field margins, field breaks, or over winter stubble. The main challenge when devising management practices is to ensure that diversity is enhanced without creating problems for the land owner (Atkinson et al., 2005). An asymmetry has been observed in “option" uptake, with the least useful, usually the “broad and shallow” options, being those most broadly applied across the UK (Davey et al., 2010).

Bird species are widely used in studies of habitat selection and social information use, especially migrants arriving at breeding grounds, as they must annually re-establish territories (Betts, Nocera &

Hadley, 2010). These migrants only have information on habitat conditions from the previous year and are limited by the short period in which they have to breed (Betts, Nocera & Hadley, 2010). A migrating bird would not choose to nest directly next to a conspecific or a heterospecific individual due to perceived competition. The signal of birds nesting in a habitat, especially resident species that are privy to habitat clues for the duration of the year, may infer a successful breeding habitat (Seppänen et al., 2007). This process has been observed in European Rollers (*Coracias garrulus)* and Kestrels (*Falco tinnunculus)* who use the number of successful fledglings of heterospecifics as a proxy for habitat quality (Parejo, Danchin & Avilés, 2005). Whether or not a breeding attempt is successful it will always convey information (Chalfoun & Schmidt, 2012).

Social information is exchanged throughout the animal kingdom and used to improve decision making (Seppänen et al., 2007). The process of nesting near others of the same species has been observed for example in *Anolis aeneus* lizards (Stamps, 1991) where the probability of an individual choosing to settle in a habitat increased up to the point of saturation. These decisions allow individuals of any species to obtain a more adaptive response to their local environment (Danchin et al., 2005).

First defined by Mönkkönen (1990), heterospecific attraction (HA), is a form of inter-specific interaction between migrant and resident bird species which share a common niche. HA may act as an evolutionary stable strategy which occurs when a behaviour, in response to the environment, increases the fitness of the individual (Bertness & Callaway, 1994). Habitats often vary vastly in quality annually and seasonally. This seasonal variation in habitat has been seen to effect skylarks (*Alauda arvensis)* that nest in spring sown cereals. Breeding skylarks are forced to nest closer to tramlines due to the dense vegetation at the centre of these fields preventing chicks from feeding; nesting close to tramlines has been seen to increase nest predation as tramlines are used to by mammalian predators (Donald & Vickery, 2000). Over heterogeneous landscapes HA and conspecific attraction (CA) acts to create aggregations of species (Timonen, Mönkkönen & Orell, 1994).

Mönkkönen considered two hypotheses that may lead to HA. His first hypothesis is that a co-operative predator defence/alert mechanism may be in place to alert not only conspecifics but heterospecifics. Sebastián-González et al. (2010) noted that the black winged stilt (*Himantopus himantopus*) exhibits noisy alarm calls in the presence of predators that may act as a warning for other species. Positive heterospecific communication has also been observed in primates, where predatory alarm calls between Diana monkey (*Cercopithecus diana*) and Campbell's monkey (*Cercopithecus campbelli*) are shared (Zuberbühler, 2000). Mönkkönen's second hypothesis is that the number of individuals at a site may convey information about the quality of the habitat and its breeding success (Hilden, 1965).

An initial study into heterospecific attraction by Dobson (1990) suggested that the majority of individuals that use heterospecific attraction are first year males. Assuming that adult bird survival is ~60%, the male breeding population consists of ~30-50% young males. Consistent with this Thomson et al. (2003) found that migrant Chaffinch (*Fringilla coelebs)* densities increased by 30-60% with increased resident tit densities, indicating that a good proportion of young males are suspected to be using HA. HA has been seen to occur more extensively when residents and migrants are of the same foraging guild (Mönkkönen et al., 1997). Using a continuum of resident densities Thomson et al. (2003) found that any addition of residents lead to an increase in total migrant densities. Thomson also found that migrants and residents of the same foraging guild were more likely to aggregate together, which implies that HA, is used.

Forsman et al. (2002) found that at both a landscape and nest site scale, using HA was beneficial to migrants; migrant flycatcher broods hatched 1.7 days earlier and had 0.6 more nestlings where residents and migrants nested closer together. It is thought that at very high resident densities competition becomes too high and prevents HA from occurring (Forsman, Seppänen & Mönkkönen, 2002). Habitats with intermediate resident densities are often preferred by migrants (Forsman et al., 2008). Densities of birds are likely to be lower in seasonal environments where HA is often observed (Bertness & Callaway, 1994), such as northern boreal communities (Herrera, 1978). In seasonal communities there is an annual "boom" of insect biomass which is an important resource for both residents and migrants (Dodds, 1988).

All of the studies previously mentioned are using structured and augmented communities, this in itself may change the behaviour of birds in the communities studied. Few observational studies on HA have been conducted. Generally, the same bird species (flycatchers and tits) are used for the majority of studies on HA, many of which are woodland based and willing to use nest boxes.

In some cases CA has been suggested as a conservation tool to increase densities of a target species. This method had previously only been used on non territorial species such as gulls. Aggregations of territorial species are often observed (Pöysä et al., 1998). Taking this into account Ward & Schlossberg (2004) aimed to experimentally introduce populations of black-capped vireo (*Vireo atricapilla)* a territorial species to previously un-colonised sites. Ward & Schlossberg (2004) found that black capped vireo were attracted to previously un-colonised sites through the use of playback of conspecific calls and specifically to high quality habitats. Forsman et al. (2009) took Ward &

Schlossberg's (2004) study into account and proposed that a similar method could be used with heterospecific attraction. If a keystone or target species could be identified, then a selection of species may be drawn to a previously un-colonised habitat. In a later study Ward et al. (2010) identified that some species be focal in social information exchange. In an observational study of water birds Sebastián-González et al. (2010) found that HA did occur in their study system, and that the presence of a focal species could act as a proxy for habitat quality. It is thought that both CA and HA are often used in habitat selection. The relationship between the focal species and their associates can be variable (Forsman, Hjernquist & Gustafsson, 2009), it appears that heterospecific and conspecific attraction is governed by similarities in species ecology, resource sharing and the degree of competition between species.

The Knepp Castle Estate consists of 1,400 hectares (ha) of land which was largely removed from mixed agriculture in 2001 when a re-wilding project was established. The scheme was initially prompted by the ideas of Frans Vera and the interest shown by the scientific community in his grazing ecology hypothesis (Vera, 2000). The Knepp re-wilding project is interested in examining the consequences of Vera's theory on the estate and aims to re-establish the land to its pre-industrial farming condition. The part of the estate in the re-wilding project is split into three different blocks with different treatments applied to each block (See appendix 1.1 for treatment of blocks). In the Southern Block (450ha) where research was carried out, hedgerows have changed very little, and fields are ~ 4 ha. In the southern block a highly heterogeneous landscape has developed which is required for maintaining high levels of biodiversity. The "wood-pasture" hypothesis (Vera, 2000), suggests that post glacial Europe was dominated by large grazers and browsers, which maintained a heterogeneous habitat mosaic, consisting of: grasslands, woodlands, scrub and large closed canopy trees. It is the application and consequences of these processes that the Knepp project hopes to explore, through the use of grazers and browsers in a near naturalist grazing scheme.

In 2005 a baseline survey at the Knepp estate was conducted recording 14 amber listed species and eight red listed breeding bird species (Greenaway, 2006). Ten red listed bird species and 12 amber listed bird species (James, 2011), were recorded on the estate in 2011. Taking this increase into account, a study to investigate the densities of some of these red and amber listed Birds of Conservation Concern (BoCC) species was proposed. This also provided an opportunity to investigate other processes that might be acting to increase species at the Knepp estate. Four resident BoCC species were chosen for this study: yellowhammer (*Emberiza citronella)*, linnet (*Carduelis cannabina),* green woodpecker (*Picus viridis)*, song thrush (*Turdus philomelos)* and three migrant BoCC: cuckoo (*Cuculus canorus*), whitethroat (*Sylvia communis*) and nightingale (*Luscinia* *megarhynchos)* (See Table 1 for information on each species). Due to the already known presence of these species on the Knepp Estate, it was decided that it would be interesting to study the response of these species to re-wilding as they either are, or have recently been, in severe decline in the UK. If HA is seen to be augmenting densities of these species, the implications for conservation management would be huge.

Table 1. Information on study species with reasons for recent demographic change.

Species	**Red/Amber Listed**	**% change in last 25 years**	**Speculated reasons for demographic change**	**Literature**
Nightingale	Amber	-49	- Migration pressure & conditions at overwintering grounds coupled with loss of suitable habitat in the UK. - Deer browsing reducing habitat quality.	Wilson et al. (2002); Fuller et al. (2005); Gill & Fuller (2007)
Cuckoo	Red	-73	- Shift in host range. - Reduced prey availability in the breeding season. - Habitat degradation at wintering grounds.	Newson et al. (2009); Douglas & Newson (2010)
Whitethroat	Amber	+ 117	- Population crashed by 70% in the late 1960's and has still not recovered. -Population is limited by resources and habitat availability.	Winstanley et al. (1974); Stevens et al (2010)
Yellowhammer	Red	-54	- Agricultural intensification: loss of winter food & winter stubbles. - Loss of foraging habitats in the breeding season.	Siriwardena et al. (2007); Kyrkos (1997); Douglas et al. (2010)
Linnet	Red	-34	- High egg failure & fewer fledglings. - Agricultural intensification: reduced availability of breeding season food.	Siriwardena et al. (2000b)
Green Woodpecker	Amber	+103	- Amber listed but increasing. - Cold weather sensitive, but mild winters have increased the availability of food resources.	Smith (2007)
Song Thrush	Red	-2	- Low post fledging survival. - Agricultural intensification: loss of breeding season & winter foraging habitat.	Siriwardena et al. (1998); Peach et al. (2004)

AIMS

1) To discover the densities of bird species surveyed at both Knepp and Priors Byne.
2) To establish if densities of birds surveyed are being augmented by HA (Table 2).
3) To discover whether nightingale territories are re-occupied in subsequent years.

Table 2. Predictions made for associations between migrant species and a resident that they could potentially associate with.

Migrant Species	Association Species	Niche-Overlap	Literature
Whitethroat	Yellowhammer	- Feed on similar invertebrate taxa: Lepidoptera, Gastropoda and Hemiptera. - Have similar nesting habitat: scrub & hedgerows.	Moreby & Stoate (2001); Fuller (2001); Green, Osborne & Sears (1994)
	Linnet	- Similar breeding habitat preferences: farmland breeders.	van Strien , Pannekoek & Gibbons (2001); Newson et al. (2005); Fuller (2001); Berg & Part (1994)
	Song Thrush	- Similar habitat preferences: autumn sown cereals.	Boddy (1983); Green, Osborne & Sears (1994)
Cuckoo	Green Woodpecker	- Similar habitat preferences: mixed deciduous woodland.	Charles Elton (1935); Lack & Venables (1939)
	Song Thrush	- Similar habitat: mixed deciduous woodland.	Williamson (1964)
Nightingale	Yellowhammer	- Similar nesting preferences: nest in scrub or hedges.	Fuller (1992)
	Song Thrush	- Similar habitat requirements: woodland of greater than 5ha.	Mason (2001)

METHODS

Study site

The majority of the data collection was carried out on the Knepp Castle Estate in West Sussex (TQ 15589 21738) and comparative surveys were carried out at Priors Byne Farm in Partridges Green, West Sussex (TQ 18985 18228). Priors Byne Farm is a mixed agricultural farm of 250 ha and is approximately four miles from the Knepp Castle Estate. Priors Byne runs on an eight year rotational system of: wheat, rape seed, wheat, barley, oats, beans, wheat, and rape seed. Priors Byne has a single suckling heard of Sussex Cattle. Priors Byne was part of the Countryside Stewardship scheme from 1993 and since 2007 has held a Higher Level Stewardship grant.

The Knepp Castle Estate consists of 1,400 ha of which 968 ha are in the re-wilding project, which is extensively managed land grazed by Tamworth pigs, English longhorn cattle, red deer, fallow deer, roe deer and Exmoor ponies. The project land is split into three sections (see appendix 1.1) which have been subject to different regeneration treatments since the land was taken out of agriculture between 2000 and 2006. The surveys were carried out in the southern block (470 ha) previously an arable farm, which has not been subjected to any additional vegetative sowing. The southern block has had grazers and browsers present since 2009 and has 0.26 grazing livestock units/ha (see appendix 1.4 for breakdown of stocking densities). The southern block is composed of woodland, scrub, wetland and water meadows broken by outgrowing hedges and hedge-row oaks.

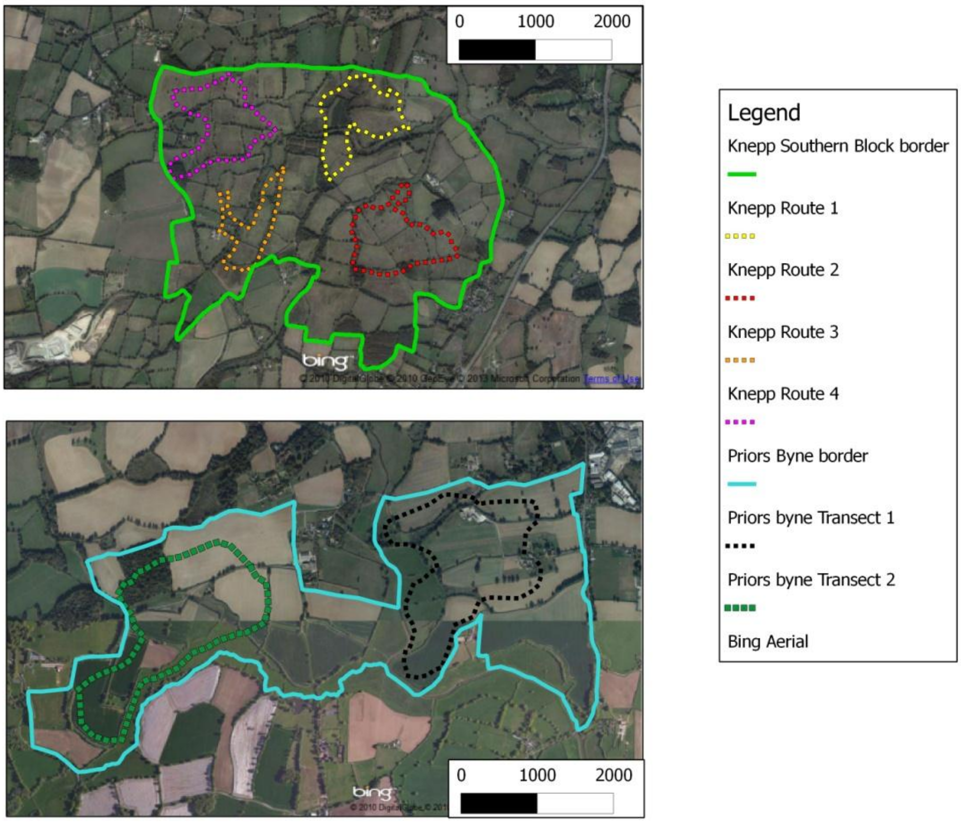

Figure 1. The study sites, Knepp above and Priors Byne below, with transects walked indicated.

Species Densities and Heterospecific Attraction

Transects were chosen to encompass the variety of habitats that occur within the southern block. The area through which transects passed was surveyed. Each transect was walked on six separate occasions between dawn and 1000 when birds are most active. Transects were not carried out in unfavourable weather conditions such as heavy rain, fog or high winds. All transects were carried out between 22nd April – 29th May 2013, as this is when birds are establishing territories. All transects were walked in both a clockwise and anti-clockwise direction to account for temporal variation. Displaying birds were identified aurally and visually, but preferably by both methods. Once the displaying individual had been identified, their location was marked with GPS (Garmin E-Trex, Vista HCX).

Nightingale territories

Previous work by Hicks (2012) on the southern block recognised the high numbers of nightingales, only a couple of other sites in the UK exhibit such high densities, for example Lodge Hill on the Medway Hook peninsula. A survey was carried out to determine if the Knepp population of nightingales is increasing. On the 22nd of May 2013, helped by a group of ecologists, the northern and southern blocks (including the Shipley block) were surveyed. All hedgerows were walked between 0600 and 1000 at a steady pace and where a singing nightingale was heard a waypoint was marked using a GPS (Garmin E-Trex, Vista HCX). Male nightingales were not heard in the north block or Shipley. All territories that were identified were revisited between 2330 22nd May – 0130 23rd May 2013, to identify whether males were paired or unpaired. At each of the territories identified, the width (of the woody vegetation) at the base of the hedge was measured and recorded.

Analysis

Species Densities

Data on territory sizes was obtained from the Common Bird Census (CBC), a volunteer led surveying project which ran from 1962-2000. Analysed CBC species territory maps from two woodland, farmland and scrubland sites and one national nature reserve were chosen to be used for territory analysis (see appendix 1.2 for list of sites and average territory sizes of the species found at each site). The size of the sites varied from 16ha - 70ha. When the original CBC maps were analysed, territories for each bird or group of bird species were marked. These were then measured and an average territory size gleaned from this information (see appendix 1.3 for table of territory sizes used in cluster analysis), which allowed the removal of birds that may have been recorded more than once when carrying out transects on subsequent days.

Using a cluster analysis in R (R Core Development Team, 2011) birds nearer together than the radius of their territory were removed. This is probably an excessively stringent method of removing overly represented birds, however it was deemed to be the most appropriate method when individuals cannot be recognised. The coordinates of the birds that were clustered were averaged and replaced with an average of the coordinates from the cluster.

The densities of birds within the area surveyed were calculated for both Priors Byne and Knepp. Estimates of the area surveyed were calculated at both 30m and 50m surrounding transects. This gives both a conservative and speculative estimate of the densities of the species within the survey areas.

Heterospecific attraction

Using the spatstat package (Baddeley & Turner, 2005) minimum distances were calculated between individuals of each species and their nearest conspecific. Heterospecific minimum distances were calculated from each individual of the three migrant species to each of the four resident species these minimum distances and were then compared to the minimum conspecific distances using a one tailed Wilcoxon's test.

Nightingales

Statistical analysis was carried out using R software (R Core Development Team, 2011). Territories that were not counted on the same day during the 2013 survey period, but were closer than 50m were averaged to remove this duplication; this was done using a cluster analysis as previously described. It was decided that comparing the collected data to a point pattern of complete spatial randomness was not appropriate, as habitat effects the positioning of the territories. All territories recorded in 2012 and 2013 were then randomly reassigned a year (2012 or 2013) in the proportions of: 20 territories in 2012 and 42 in 2013, this was simulated 10,000 times. The distance between the numbers of 2012 territories within 50m of a 2013 territory was calculated. The number of nightingale territories that were effectively "re-occupied" from 2012 to 2013 was calculated against this null. A chi-squared test was then carried out to determine whether the increase seen in the number of nightingale territories between 2012- 2013 was significant.

RESULTS

Species Densities

Table 3. Estimates of densities of species breeding pairs/10 ha at Knepp & Priors Byne, compared to densities found in good habitat (May, 1998).

Species	Densities in good habitats	Knepp density estimates	Priors Byne density estimates
Linnet	8	5.5-9.2	1.3-2.2
Yellowhammer	4.7	4.5-7.5	3.6-6.1
Song Thrush	15	3.5-5.8	None observed
Green Woodpecker	0.3	3.8-6.38	1-1.6
Whitethroat	10	8.5-14.2	2.6-4.4
Cuckoo	0.3	3-5	None observed
Nightingale	2	7-11	1.3-2.2

A range of density estimates at 30m and 50m around transects at Knepp and Priors Byne can be seen in table three. Estimated densities of the birds surveyed at Knepp are higher than estimates of bird densities in high quality European habitat and are higher than density estimates at Priors Byne. Two species that had high densities at the Knepp estate were not recorded at Priors Byne.

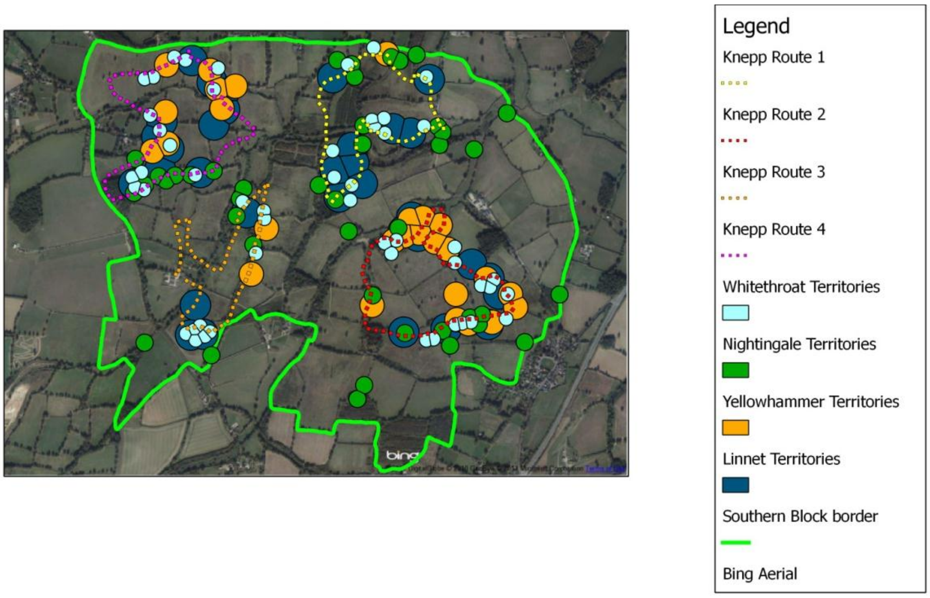

Figure 2. The distribution of whitethroat, nightingale, yellowhammer and linnet territories at Knepp.

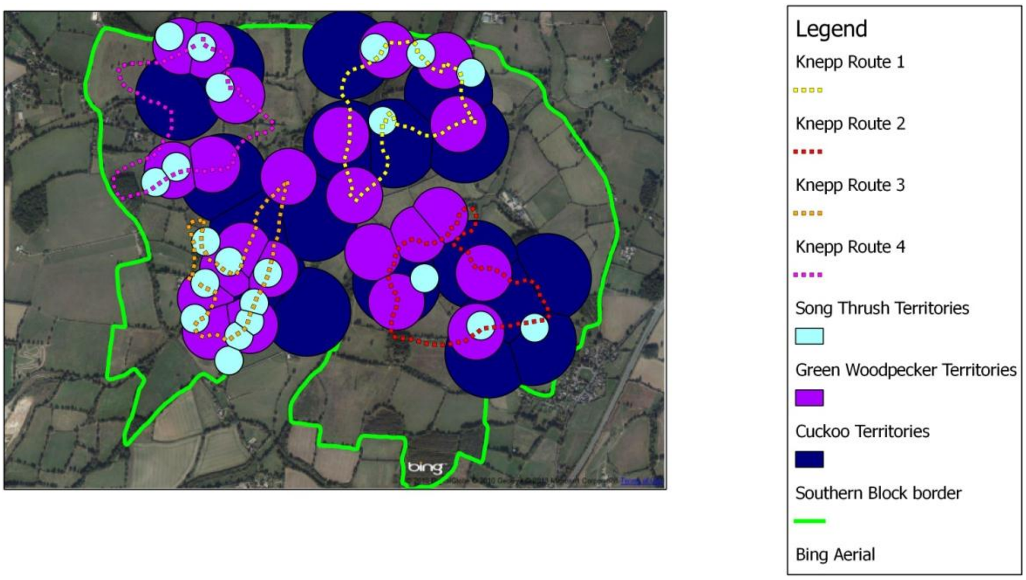

Figure 3. The distribution of cuckoo, green woodpecker and song thrush territories

Distributon of the species recorded at Knepp can be observed in figures two and three. Cuckoos appear to be highly saturated within the environment. For distribution of species at Priors Byne, see appendix 1.5.

Heterospecific attraction

Table 4. Shows the mean minium distance from any specified migrant territory to any associated resident territory and the Wilcoxon's test to compare the conspecific distance to the mean minimum distance between a migrant and a resident.

Migrant Species	Resident Association	Mean min. Distance(m) M-> R	Wilcoxon 1 tailed test
Whitethroat	Yellowhammer	207.23	W= 834, p=0.9991
	Linnet	87.52	W=1328, p=0.4283
	Song Thrush	126.83	W=610, p=1
Cuckoo	Green Woodpecker	179.51	W=250, p=0.9809
	Song Thrush	206.77	W=243, p=0.005419
Nightingale	Yellowhammer	281.03	W=446, p=1
	Song Thrush	219.53	W=647,p=0.9824

The results displayed in table four indicate that HA between this set of residents and migrants is not playing a part in augmenting densities of these birds in the southern block. The only case where this may be occuring is in that of the cuckoo to song thrush, where the predicted relationship is observed. However there is doubt over this result as the cuckoo appears to be saturated in the habitat (Figure 3) which may give us a false positive result.

Nightingales

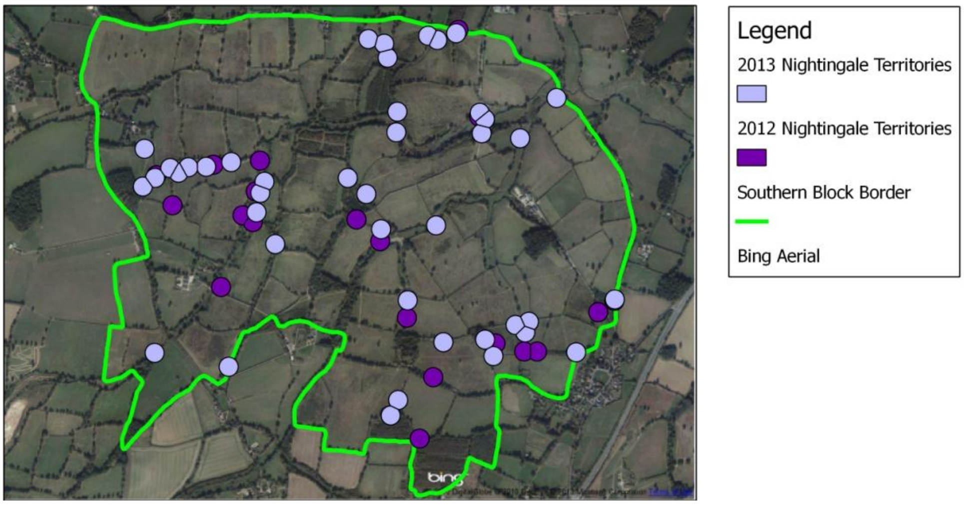

Figure 4. Nightingale territories recorded in 2012 and 2013.

Of the nightingales recorded in 2013, 12 clusters were identified with individuals being closer than 50 meters. Their locations averaged, which lead to 42 nightingale territories being identified in the southern block. A chi squared test was carried out on the number of individuals found in the Southern Block in 2012 (20) and 2013 (42). It was found that in 2013, significantly more (χ^2=7.8, p=0.00526) nightingales were observed.

The number of territories identified in 2012 (Hicks, 2012), within 50m of a territory identified in 2013 was not significant (test statistic p=0.1002), and therefore we cannot assume that nightingale territories are re-occupied in subsequent years. However Boano et al.(2004) estimates nightingale survival rate to be 44%± 4 taking this into account, of the 20 male nightingale territories identified in 2012, ~8 nightingales are expected to return. There is no significant difference between the number of nightingales assumed to be re-occupying territories and the number expected to be re-occupying territories, (χ^2= 1, p=0.317).

Four un-paired male nightingales were detected on the evening when the night survey was carried out. This indicates that 90.5% of nightingales found on the southern block were paired compared to 80% in 2012 (Hicks, 2012). This is a 10.5% increase from 2012.

36 of the territories recorded were in hedges, the remaining six were located in a wood or copse. Of the territories that were located in hedges, only two occurred in a habitat that was less than eight meters wide at ~6.5 meters. Hedge measurements were consistent and not significantly different from measurements taken by Hicks (2012).

DISCUSSION

Species Densities

Estimates of densities of the red and amber species studied at Knepp are equal to or higher than estimates of densities in pristine European habitats, apart from song thrush. The increases in birds measured in this study may indicate that the other components of the ecosystem have significantly increased in biodiversity as well, however tests would have to be carried out to confirm this

Neither song thrush nor cuckoo were observed on Priors Byne Farm, both of which are red listed species BoCC. The song thrush has declined more that 50% in the last 25 years (Gregory et al., 2002). It is postulated that the compaction of soil by farmland machinery, extensive soil drainage and conversion to arable land may have reduced the ease of foraging for song thrushes (Peach, Robinson & Murray, 2004), and would limit access to earth worms in particular. This lack of available food may deter song thrushes from creating nest sites, as juvenile survival would be significantly decreased and hence, propensity for re-nesting in arable sites has declined (Peach, Robinson & Murray, 2004). Song thrushes have been negatively associated with arable crops (Peach, Robinson & Murray, 2004) and they are rarely used by them as foraging habitat. The lack of these agricultural processes occurring at Knepp may have helped promote key prey items on which song thrushes depend.

Cuckoo abundances are generally thought to be related to their breeding success which can be determined by the number of successful breeding attempts made by host species (Newson et al., 2009). It can be postulated that Priors Byne has low densities of host species and consequently no cuckoos, although this would have to be confirmed in a further study. It is also thought that the structure of the habitat may affect the presence of cuckoos. Cuckoos rely on vantage points in order to survey for host nests (Moskát & Honza, 2002). On Knepp and especially in the southern block, large hedge-row oaks are present in almost all fields. Roskaft et al. (2002) suggests that vantage points for cuckoos should be >3-4 m high, and prime habitat for cuckoos is an open forest area or scattered trees which can be used as vantage points; this type of habitat is similar to the "wood-pasture" that Knepp provides. The densities of cuckoos in the southern block appear to be extremely high (Table 4) and the habitat appears to be saturated with them (Figure 3).

Taking these results into account, it could be suggested that the cuckoo may be used as a focal species for creating a habitat management plan. It could also be suggested the nightingale and green woodpecker could be used in this manner, due to their high densities on the southern block of Knepp. Focal species modelling can be used to develop and manage ecological networks in order to re-establish ecological function and conserve biodiversity (Bennett & Wit, 2001). The use of focal species can help evaluate the potential effects of land use change, focal species may also be used as surrogates to encapsulate the needs of other species (Eycott, 2007). It appears that improving habitats for the song thrush and cuckoo may encapsulate the needs of other species that are important in increasing biodiversity on re-wilded agricultural land.

It looks as if the re-wilding project at Knepp is finding an appropriate median between the "broad and shallow" and "deep and narrow" agri-environmental schemes, aiming to use low cost techniques that have high impact. It is clear that this method is working, with the species investigated here clearly flourishing in this environment.

Heterospecific attraction

For six out of the seven predicted attractions (see table 2), only one was seen to be significant, between cuckoo and song thrush, however this result could be due to the high saturation of cuckoos in the southern block. The method used to eliminate records of the same individual may have led to the lack of results seen here and may have resulted in removing clustering that was actually present.

Looking at figures 2 & 3 there is obvious clustering of somes species in some habitats, for instance only one yellowhammer was observed on transect one, and two on transect three but large clusters observed on transect two. The majority of species can be seen to be clustered in at least one area of the southern block. Perhaps the niche overlap that was assumed in the predictions between resident and migrant species is not large enough for HA to occur or the species chosen are too specialised for a substantial niche overlapp. Danchin et al. (1991) suggests that as juveniles prior to summer migration, individuals may collect information about habitat and subsequently may not have to use HA as a cue to habitat quality. However it is impossible to tell whether the birds that were seen creating territories at Knepp were fledged juveniles from the site. This could only be determined if a ringing scheme was in place.

Habitat quality was not controlled for in this study and it has been observed that local aggregations can map closely onto resource densities (Davies & Houston, 1984). There is a huge variety of habitats at Knepp, so perhaps HA is not a necessary mechanism for birds to employ, when high quality habitat is avaliable.

Nightingales

In most cases territories that were occupied in 2012 were not seen to be re-occupied in 2013. Male nightingales are a highly philopatric species (Cramp, 1988). Six territories that were occupied in the southern block in 2012 were seen to be re-occupied in 2013. The number of nightingale territories that are being reoccupied appears to coincide with survival estimates from Boano et al. (2004). This may indicate that juveniles are important in occupying new areas, rather than adults who may already hold an established territory emigrating to a new habitat.

The number of nightingales has increased since 2012 and significantly more are paired than suggested by the literature Amrhein et al.(2007, 2002) which suggests that only 50% of nightingales pair. Once again this demonstrates that the quality of the habitat at Knepp is helping to provide nesting sites for nightingales and is supporting an increasing nightingale population.

The habitat in the southern block is obviously of high quality, nightingales tend to be found in shrubby habitats and lowland, broad leaved, woodland margins (Boano, Bonardi & Silvano, 2004). In the past 25 years the nightingale has undergone a 49% decline (Risely et al., 2010) and Fuller et al. (2005) suggests that this maybe due to worsening conditions at the species wintering grounds, compounded by habitat loss at its breeding sites in Europe and specifically the UK. Nightingales have undergone a range contraction, limiting its habitat to the south-eastern corner of the UK, which goes against predictions for its range expansion with climate change. If the nightingale continues to be contained in the south eastern corner of the UK, then increases in temperatures may dry soils and limit the amount of invertebrate prey available for nightingales to feed upon (Huin & Sparks, 2000). As male nightingales are highly philopatric, their tendency to disperse to new areas is low and range expansion expected to be slow (Fuller, Henderson & Wilson, 1999). The availability of suitable habitat may also play a part in limiting the population of nightingales; hedges appear to be highly important to breeding individuals and browsing height has been seen to negatively affect nightingale distribution. However Hicks' (2012) study in the southern block of Knepp found that browsing only explained 5% of the variation in nightingale distribution.

Of the 36 territories located in out grown hedges only two were seen to be less than eight meters wide and not significantly different from the results of Hicks (2012). One of the two territories which were less than eight meters in width was that of an unpaired male, potentially indicating that habitat quality effects ability of males to pair. Holt suggests that nightingales prefer a dense layer of shrub with areas of open ground in which to forage and 94% of the habitat where nightingales were recorded concurs with this description.

The results of this study must be interpreted with caution due to its observational nature. The study may be subject to observer bias, where by the observer may only see or hear what the observer expects to although hopefully carrying out repeats of transects will have eliminated some of this bias. Carrying out transect repeats also helped account for the temporal variation seen in the arrival of migrant species and their settling times. The collection of the data was time constrained and therefore late arriving individuals will not have been measured. The cold spring of 2013 delayed both the arrival of migrant birds and the breeding attempts of both resident and migrant species. It is therefore highly possible that estimates for bird densities are lower than would be expected had spring conditions had been more favourable. There is the possibility that not all territories occupied in the southern block were detected, therefore the estimates of territories surveyed may be conservative. It is also possible that some males were transients and may have remained at the site for only a short period of time before moving on.

The Next Step

The next step would be to further survey the site on all trophic levels. Manipulative field experiments would be the obvious next step in research, however this would be inappropriate at Knepp as carrying these out would disrupt the re-wilding process. For density experiments, continual monitoring of the birds at Knepp using a similar method to that described here would provide long term trends of densities of bird species. These methods of surveying are similar to that of the CBC (Common Bird Census) providing an un-intrusive and easily replicable method of surveying for bird densities. Another option would be to use a method similar to that of the Constant Efforts Sites Scheme (BTO) whereby ringers operate the same number of nets, at the same sites, over a set period of time, at regular intervals during the breeding season. If individuals could be colour ringed this would help to identify individual behaviour as well as how philopatric the nightingales are at Knepp. The ringing scheme may also allow the opportunity to ring juveniles which would allow for observation of natal philopatry and reveal whether juvenile males nest closer to their natal nest than expected by chance dispersal. It would also provide information on the mean shift in territory location for each returning male.

CONCLUSIONS

Currently agricultural land is not managed to increase ecosystem diversity or act as refuges for rare or declining species. The results of this study suggest that extensive agriculture and re-wilding can hugely benefit these species, especially severely declining species such as the nightingale. Re-wilding aims to increase biodiversity and this is being seen at Knepp here only nine years of the scheme being implicated. The positive results seen here advocate for the expansion of the re-wilding scheme seen at Knepp and further trails at sites around the UK.

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APPENDIX

1.1 Treatment of the four blocks that make up Knepp Estate

	North Block	Middle Block	Southern Block including Shipley
Before re-wilding	Arable Farmland	Estate gardens and polo fields	Arable and dairy farmland
Re-wilding Treatment	Re-seeded; grazed by cattle and deer	None	Naturally re-seeded; grazed by cattle, deer, pigs and ponies.

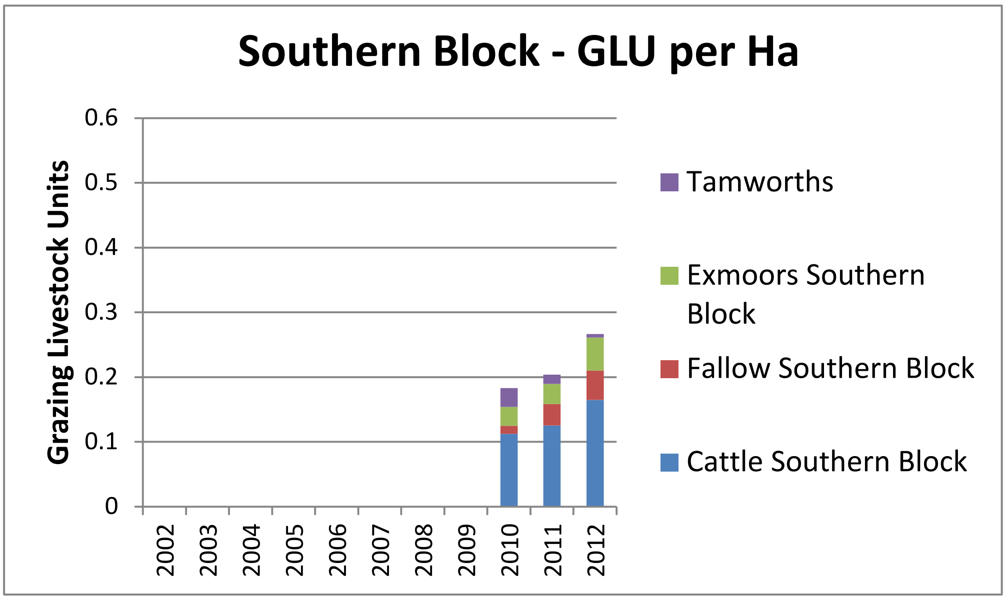
1.2 CBC plots used to calculate territories

CBC Plot Name	Grid Reference	Habitat	Size (ha)	Relevant species	Average territory size(m)
Steadham Common	SU 856218	Woodland	39.7	Yellowhammer	63.75
				Linnet	55.64
				Green Woodpecker	145.92
				Song Thrush	63.52
Barns Copse	SU 980070	Woodland	16.1	Song thrush	50.27
				Whitethroat	31.52
				Green Woodpecker	158.41
				Yellowhammer	36.18
Warblington Castle Farm	SU 731055	Farmland	70.9	Cuckoo	308.63
				Linnet	176.86
				Song thrush	84.55
				Whitethroat	92.49
Grantleys Farm	TQ 5881854	Farmland	45.3	Whitethroat	47.83
				Song thrush	136.86
				Linnet	48.66
				Green Woodpecker	184.81
				Yellowhammer	178.80
Culverlea Common	SU 292020	Scrub/Grassland	16.0	Green Woodpecker	55.28
				Song thrush	57.34
Broad Street Common	SU 969516	Scrub/Grassland	41.3	Whitethroat	26.97
				Song thrush	50.88
				Linnet	113.01
				Cuckoo	144.98
				Yellowhammer	70.69
				Green Woodpecker	134.55
Lullington Heath NNR	TQ 545017	Scrub/Grassland	64.4	Yellowhammer	66.15
				Green Woodpecker	206.18
				Song thrush	78.35
				Linnet	99.64
				Whitethroat	34.84
				Nightingale	58.29

1.3 Averaged territory sizes used in cluster analysis

Species	Average territory size (m)
Cuckoo	241.12
Green Woodpecker	154.61
Linnet	88.84
Nightingale	58.29
Song Thrush	78.19
Whitethroat	40.52
Yellowhammer	71.14

1.4 Break down of stocking densities on the southern block of the Knepp estate



1.5 Distribution of species recorded at Priors Byne Farm.