Factors Potentially Affecting the Viability and Success of Biodiversity Offsetting to Compensate for Nightingale Habitat Loss

Report

Authors

Chris M. Hewson & Robert J. Fuller

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1. INTRODUCTION

1.1 Aims of this Report

This report aims to provide ornithological information to facilitate a Technical Workshop on 'Nightingale Habitat Offsetting' relating to the proposed Lodge Hill development. Principally, it addresses the issue of whether it is feasible to create habitat for Nightingales on a large scale in Britain, and specifically whether this can be done close to Lodge Hill – e.g. in Kent or an adjacent part of south-east England. This includes a review of our current understanding of habitat selection in the species, in terms of what constitutes suitable habitat, and the identification of the factors likely to affect the chances of colonisation and successful Nightingale *Luscinia megarhynchos* population establishment, should potentially suitable habitat be established. The amount of land needed to accommodate the number of birds currently present at Lodge Hill, in habitat of equivalent quality, is also considered, along with the factors that need to be considered in estimating the effect that the development will have on Nightingale numbers at the site.

1.2 Current National Status of Nightingale

The Nightingale population in Britain has undergone severe and on-going declines in the last 45 years. According to the BTO/RSPB/JNCC Breeding Bird Survey the species declined by 60% between 1995 & 2009, whilst the longer-term CBC/BBS index indicates a decline of more than 90% in the last 40 years (Holt, Hewson & Fuller 2012). The latter decline is sufficiently great that had those figures been available at the time of the last Birds of Conservation Concern assessment, the species would have been placed on the Red list, rather than the Amber list that it currently sits on. Whilst the rate of decline was greatest prior to 1978 (17% per annum), the species is still declining at a rate of approximately 3% p.a.

These population declines have gone hand in hand with a range contraction towards the south-east of the country – thus populations in Kent, Sussex and other south-eastern counties are becoming more important for the national status of the species. Preliminary results from the latest BTO Atlas, with breeding season fieldwork

conducted between 2008 and 2011, show that the species is being lost from some areas within even these core counties (Holt, Hewson & Fuller 2012).

At the national scale, population size estimates for breeding small territorial birds are likely to be very approximate. However, to provide some context in which to place the Lodge Hill population, it should be noted that the British population (which lies entirely within England) was estimated to lie between 5600 and 9350 territorial males by the 1999 BTO National Nightingale Survey (Wilson, Henderson & Fuller 2002). The latest National Nightingale Survey was organised by the BTO in 2012; the data from this survey are still being collated and prepared so it is not yet possible to produce a population estimate for 2012.

2. SUMMARY OF LODGE HILL POPULATION IN 2012

The survey undertaken in 2012 as part of the BTO National Nightingale Survey estimated 69 territorial males within the Lodge Hill site and a further 14 in the Chattenden Woods SSSI, giving a total of 83 territorial males. Although this represents a large apparent increase over estimates from surveys in 2009 (28 males) and 2010 (43 males), we believe this is largely due to methodological and coverage differences between surveys. Detectability of Nightingales varies greatly with time of day and season, meaning that survey design (including the number as well as timing of visits employed) and the subsequent interpretation of territory clusters, are critical to the numbers estimated.

The 2009 survey by Thompson Ecology employed territory mapping (CBC) methodology to survey all species, with 5 visits between 5 March and 15 July. Assuming that these were spread evenly at once per month, this would give only one effective visit for surveying Nightingales (in early May), with the two earlier ones occurring before Nightingales would be present, the June survey after the main song period and the July survey after they had become completely unobtrusive and were preparing for migration. Furthermore, no details of the time of day at which surveys were undertaken were shown, which is critical given that Nightingale song output drops off sharply around two hours after dawn, whilst survey efficiency for Nightingales will have been further reduced by the need to survey all species. This survey can therefore only really be used as an indication that a substantial population of Nightingales exists at Lodge Hill. The 2010 survey was carried out from outside the Lodge Hill boundary and the results map shows clearly that many territories recorded in both 2009 and 2012 were missed in the eastern arm of the site at least. This can therefore only be considered a partial survey.

In contrast, the 2012 survey was undertaken using methodology specifically devised to most accurately survey the Nightingale population of Lodge Hill and was carried out by an expert surveyor with experience of Nightingale territory mapping surveys who carried out 6 Nightingale–specific surveys between 28 April and 3 June (including 3 in the critical period up to 13 May). It is possible that habitat change during this period may have contributed in a minor way. However, whilst some

habitats, such as coppiced woodland, could improve in suitability for Nightingales markedly over a three year period following intensive and widespread management, it is extremely unlikely that a site consisting of scrub and woodland such as Lodge Hill could do so to an extent to account for approximately two-fold and three-fold increases in two and three years respectively, even when accounting for the potential accelerating effect of social attraction, which should already have been quite strong by 2009. We therefore believe the 2012 estimate most accurately reflects the current and, most probably, recent population at the site.

For reasons discussed below, it can reasonably be assumed that all of the birds within the Lodge Hill site will be lost as a consequence of the development, although a small number may persist. This will be caused by a combination of loss of habitat comprising territories, loss of habitat that is very likely to form parts of the wider home ranges of Nightingales, reduction in quality of small fragments of habitat remaining which are not likely to be functionally useful for Nightingales, reduction in probable social attraction and the probable effects of disturbance and cat predation. An unknown proportion of the birds in the Chattenden Woods SSSI may persist but due to effects of disturbance, cat predation and reduction in social attraction, it is not clear how great this proportion is likely to be and it could be quite small (see section 7.1).

3. ECOLOGICAL AND BEHAVIOURAL REQUIREMENTS OF NIGHTINGALES IN BRITAIN

3.1 Climatic Envelope within Britain – Current and Future

The Nightingale's British range is climatically restricted (Wilson, Henderson & Fuller 2002), the species being restricted to areas with warmer springs and lower winter evapotranspiration than unoccupied areas. This is in keeping with the fact that the main part of the range lies to the south, in continental Europe. During this century, the European range is predicted to extend northwards and increase in extent by 30% in response to predicted climate change (Huntley *et al*. 2007). Range extension within Britain, however, is predicted to be only modest with the core part of the range remaining more or less stable but with gains along the eastern side of the country as far north as southern Scotland (Huntley *et al*. 2007). It should be noted that the current contraction in the British range is contrary to the expectations of how the species should be responding to on-going changes in climate (Wilson, Henderson & Fuller 2002; Holt, Hewson & Fuller 2012) which reinforces the view that the British population is under pressure at the present time.

3.2 Altitude and Soil Type

The Nightingale is largely restricted to low altitudes within Britain, the mean altitude of singing males recorded in the 1999 survey being 31m above sea level and c.80% being below 60 m asl (Wilson, Henderson & Fuller 2002). Within south-eastern England, there is some evidence that birds have been lost from higher altitude sites (e.g. downland sites) at a greater rate than from lower, less well-drained sites (Wilson, Henderson & Fuller 2002), possibly suggesting that the higher altitude sites are sub-optimal.

Surveys of Nightingales in Kent in 1985, 1994 and 1999 show that the population in this county has become more associated with lower altitude land during this period (see Figs. 3 & 4 in Henderson 2002). The percentage of the Kent population occurring on land below 60 m has increased, whereas it has decreased above this altitude. The greatest relative increase has occurred on land below 20m. Henderson (2002) gives four possible explanations for this altitude shift. First, the

higher altitudes tend to be on chalk which has probably become drier and less suitable. Second, higher altitudes may be cooler and less suitable (though this does not fit with the recent pattern of increasing temperatures). Third, the shift to lower altitude could reflect a contraction into preferred habitats, such as low-lying damp scrub, at a time when overall populations are declining. Fourth, the shifts are a consequence of coincidental changes in habitat including (a) decline in coppicing at higher altitude and (b) an increase in availability of low-lying damp / wet scrub (as opposed to drier scrub) which may be strongly preferred by Nightingales.

In general, habitats occupied within Britain tend to be wetter than elsewhere in the range (Cramp 1988), suggesting preferential occupation of areas near to streams, ditches, ponds and other water bodies. In the Cambridgeshire / Suffolk / Norfolk Fens, the highest densities of Nightingales are found on humus-rich soils, especially earthy peats and humic sandy-gleys along river valleys (Wilson *et al*. 2005) but the causes of this correlation have not been determined although they may relate to food availability. It is also known, though, that the drainage and irrigation systems of areas with the earthy peat soils differs from other areas and the presence of partially water-filled ditches along the field boundaries occupied by the Nightingales in these areas may be significant, either directly (through providing foraging opportunities or food resources) or indirectly (through effects on vegetation and habitat structure). Nevertheless, it seems that Nightingales are associated with areas of damp nutrient-rich soils in these areas.

Some sites that are occupied by Nightingales, typically abandoned gravel and other workings, have poorer, drier less productive soils, often initially comprised of sub-soil, sand and gravel. These soils may retard vegetation growth in such a way as to prolong the period of time that structures suitable for Nightingales are present, although they may also prolong the period it takes to develop suitable structures. It is not clear what effect these soils have on food availability but as they are usually close to remaining water bodies, it is possible that these aquatic habitats enhance food availability in some way.

3.3 Broad Habitat Types Occupied

The Nightingale's ecological requirements are provided in a range of habitat types within Britain. These include: various types of scrub, including those found on heathland and chalk downland; coniferous, mixed and broad-leaf woodland, including active coppice (especially with a low to medium density of standard trees) and woodland edges, glades and rides; carr; new & young plantations; thick hedgerows with and without trees. Cramp (1988) noted that in England the species often occupies wetter habitats than elsewhere in the range, resembling those occupied by the Thrush Nightingale (*Lucinia luscinia*) of northern and eastern Europe. There is some evidence (e.g. section 3.2) above, that this tendency may have increased recently, with higher altitude, better drained sites being abandoned as the population has declined.

There has been a recent shift in the habitat distribution of British Nightingales, with a greater proportion being found in scrub and relatively fewer in mixed and coniferous woodland and coppice (although use of broad-leaf woodland has apparently remained stable) (Wilson, Henderson & Fuller 2002). This has not simply been a result of a reduction in the availability of coppice as Fuller (1992) and Fuller & Rothery (submitted) have demonstrated the presence of much apparently suitable coppice that is not occupied by Nightingales. It seems likely that coppiced woodland generally offers less suitable habitat for Nightingales than some types of scrub (see below).

3.4 Vegetation Structure

In areas of England where the species is relatively abundant a broader range of vegetation structures may characterise occupied territories than in areas on the margins of the range (Hewson, Fuller & Day 2005). However, most Nightingale habitats in England tend to share several common features, especially the presence of dense woody understorey vegetation, often enclosing, or in close proximity to, bare ground which forms foraging habitat. Dense vegetation appears to be important for singing and concealment. Nests are placed on or close to the ground, often within rank or ruderal vegetation immediately adjacent to woody thickets.

The dependence on areas with a dense understorey has been illustrated by two studies. First, in the East Anglian Fens, on the Cambridgeshire / Suffolk / Norfolk border, differences between scrub/shrub patches that were occupied by Nightingales and those that were not suggested that a dense and continuous canopy forming a shell over bare ground, but with dense low foliage at thicket edges provided ideal conditions for the species (Wilson *et al.* 2005) (see figure 3.4.1 below). The second study showed that Nightingale territories were strongly centred on areas from which deer had been excluded in Bradfield Woods, Suffolk, with the birds also spending the majority of their time in these areas (Holt, Fuller & Dolman 2010, 2011). In mature woodland, these types of structures are usually confined to external or internal edges and gaps, and patches of young regeneration, including coppice. Blackthorn *Prunus spinosa* thicket that is regenerating via suckering at the edges can produce ideal structures, as the advancing dense edge envelopes the open areas under the adjacent taller scrub (Fuller, Henderson & Wilson 1999).

Locally, a somewhat different vegetation structure can be occupied. For instance, in the parts of the Fens with earthy peat soils (mentioned in section 3.2), the vegetation in many occupied areas comprises a fairly open elder *Sambucus nigra* dominated understorey with dense beds of nettles *Urtica dioica* below and open-canopy trees (often poplars) above. This is reminiscent of the habitat occupied in parts of France, e.g. in the Petit Camargue Alsacinne near Basle (personal observation). The dampness of these habitats and the presence of water is a consistent feature. This combination of features is rather scarce in England which may explain why it appears to have been seldom recorded as prime Nightingale habitat.

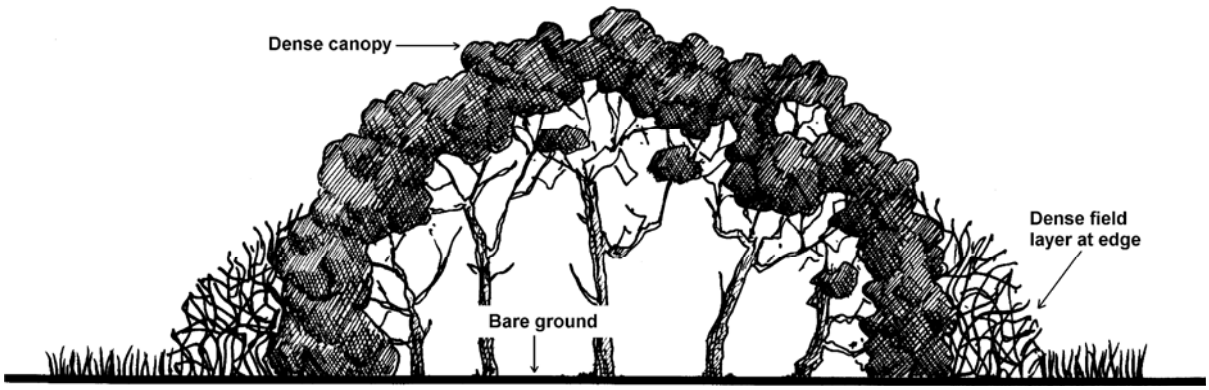

Figure 3.4.1 Cross section of typical thicket occupied by Nightingales on the eastern edge of the Cambridgeshire / Suffolk / Norfolk Fens (from Wilson *et al*. 2005). Note that permission to reproduce this figure is being sought from the publisher.

The 'classic' domed vegetation structures tend to be found in vegetation at intermediate successional stages, with younger vegetation first lacking shrub density and lacking bare ground under the canopy, but with older vegetation becoming 'leggy', presenting an open structure at low levels and lacking the concealed spaces for foraging. Sites where vegetation growth is fast may, therefore, become suitable sooner than other sites but may quickly become unsuitable as vegetation growth progresses.

It should be noted that because Nightingales are difficult to observe in most circumstances, their distribution and habitat use is usually determined by plotting the song territory. Whilst these territories tend to be centred on the vegetation structures described, it is probably normal for individual Nightingales to use a home range encompassing a wider range of habitats whilst breeding. Several studies (both in England and elsewhere within the range) have demonstrated the use of a home range incorporating a wider range of habitats than the song territory (Holt, Fuller & Dolman 2010; Holt *et al.* in press), possibly because of mating or foraging opportunities available there. Although detailed information is scarce, there is evidence that Nightingales also use more open areas away from their territories for foraging. A radio-tracking study at Paxton Pits found that whilst Nightingale territories tended to be centred on areas of scrub 3-5m high, home ranges were much larger and also usually included areas with mature trees and that these areas were used more than expected based on their availability (Holt *et al*. in press) (fig. 3.4.2). This

suggests that at the scale of the home range, a wider-scale habitat mosaic, including some areas without low dense vegetation may be ideal for Nightingales, possibly including open areas at edges and in gaps as well as under trees.

Figure 3.4.2 Home ranges (solid black lines) and song territories (dashed lines) of three Nightingales at Paxton Pits. Habitat patches shaded as: Black – woodland; grey – scrub; white – open habitats. Cross hatched areas are water bodies (from Holt *et al.* in press). Note that permission to reproduce this figure is being sought from the publisher.

3.5 Food Availability

Nightingales feed mostly on invertebrates taken from the ground, especially beetles and ants (Cramp 1988). There is little direct information on factors affecting the abundance of these food sources across the range of habitats occupied by Nightingales, although it is likely to be correlated with many of the factors discussed above. In particular, soil type may directly influence the abundance of ground invertebrates, as well as indirectly influencing it via its effects on vegetation and also influencing availability (the extent to which Nightingales can access the prey that is present) via its moisture content. This may be part of the reason why, in Britain more than in other parts of its range, the Nightingale may be associated with damp and waterside habitats.

3.6 Social Factors

Through a variety of mechanisms, it is possible that Nightingale settlement patterns within available habitat are influenced by 'conspecific attraction' – i.e. the presence of other Nightingales already occupying the area, which could act as an indicator of suitable habitat (Holt, Hewson & Fuller 2012). Such processes are more likely to operate in migratory species, such as the Nightingale, than resident species partly because they have a shorter period for territory establishment prior to the onset of breeding. The often transient nature of habitats occupied by Nightingales means that efficient methods of colonisation must have evolved and it is likely that social attraction provides one means of maximising the efficiency of dispersal, especially if reproductive output (e.g. pairing success of males) is higher where more birds are present. This seems likely as many European populations of Nightingales, including in England, are known to include more males than females with the result that up to 50% of males are not paired (Amrhein *et al.* 2007). It is thought that females search for males to pair with at night, and that the nocturnal advertising song of the males could serve as a settlement cue for other arriving males, whilst the song of multiple males could provide a stronger stimulus for females. The importance of this process would be amplified if females preferred to pair with males on territories close to other males in order to maximise the chances of extra pair copulations with high quality neighbours (the 'hidden lek' concept, Wagner 1997).

Although the precise potential mechanisms are varied, the result of social processes operating may be that initial stages of colonisation are more difficult and proceed more slowly, until a small population becomes resident. At that point, the existing birds may form as a nucleus for the settlement of further males and over time, colonisation may accelerate providing that suitable habitat conditions persist.

4. DOES HIGH DENSITY MEAN HIGH QUALITY?

It is frequently assumed that a locally high density of a species indicates high habitat quality (i.e. high reproductive output and / or high survival) in that location. There have been no specific studies of relationships between density and habitat quality in the Nightingale. More generally, however, a high density of breeding birds is usually found to correlate with habitat quality, but in habitats that have been strongly modified by humans this relationship can be reversed (Bock and Jones 2004). Similarly in habitat creation, 'ecological traps' could be created if settlement is stimulated by the creation of settlement cues but the habitat does not contain the critical resources required, for example in terms of food, safe nesting and foraging sites. Uncertainty over the precise determinants of habitat quality for Nightingales means that it should not necessarily be considered desirable to pack as many Nightingales into as small a piece of land as possible, whilst the provision of social settlement cues should be undertaken with caution.

The Nightingale population at the Lodge Hill development site is dispersed within an area of 325 ha, with the Chattenden Woods SSSI population dispersed within a further 133ha, although only a subset of the area supports Nightingale territories and it is not known what proportion of these areas falls within the home ranges of breeding Nightingales (i.e. in areas that are not lie within song territories). Packing the same number of Nightingales into habitat created on a smaller area of land may not necessarily result in equivalent numbers of Nightingales *in territories of the same quality* (i.e. territories which provide conditions for equivalent reproductive output and survival of both offspring and breeding adults).

5. VEGETATION DYNAMICS AND CURRENT HABITAT MANAGEMENT PRACTICES

As noted above, the vegetation structures typically included within Nightingale territories tend to occur at the early to middle stages of successions and as such are usually transient to some degree. Under natural conditions, circumstances where vegetation development is slow (due to poor soils, for instance) allow the habitat to remain at the required stages for longer and consequently a bigger population of Nightingales may build up. Habitat management will usually be required to maintain populations in the long-term; exceptions are rare and may include unstable riparian vegetation that is periodically removed or modified by floods.

Coppiced woodland is sometimes regarded as an iconic Nightingale habitat and is widely quoted as a 'traditional' English habitat. When coppice is occupied, the highest densities usually occur after 3-7 full summers of re-growth on richer soils and 5-10 years of re-growth on poorer soils (Fuller, Henderson & Wilson 1999). Although there is a popular association between the species and this habitat, we do not consider coppice to be a generally optimal habitat. The proportion of British Nightingales found in coppice decreased from 13.6% to 8.6% between 1976 and 1999 (Wilson *et al*. 2002). This does not simply reflect a reduction in the availability of coppice as Fuller & Rothery (in press) report that the species severely declined in Bradfield Woods, Suffolk, and has recently disappeared from this site despite the maintenance of high quality coppice management there. Similarly, Fuller (1992) found that many sites with apparently suitable coppice habitat (compartments of 3-8 years age in general) were not occupied, with only two of 17 such woods containing Nightingales, albeit with apparently high densities within the coppice available at these two locations. There are several reasons for thinking that much coppice may not represent the highest quality habitat for Nightingales. Coppice appears to be especially vulnerable to deer browsing which, by reducing the structural complexity of low vegetation, may reduce habitat quality for Nightingales (Holt, Fuller & Dolman 2010, 2011). Furthermore, coppice probably does not offer such complex spatial vegetation mosaics as some scrub. The period of habitat suitability in coppice is often relatively short for Nightingales, being as little as five years (Fuller & Henderson 1992, Fuller & Rothery submitted) whereas it can be considerably longer in many scrub environments (Fuller 2012). Furthermore,

apparently high occupancy of coppice by Nightingales in the past may have been evident during periods of relatively high Nightingale populations when sub-optimal as well as optimal habitats were more likely to be occupied.

Various types of management can create the low dense vegetation that characterises Nightingale habitat. Rotational cutting of blocks of scrub is one such method, which allows Nightingale habitat within a suitable habitat mosaic to persist within a site over long periods. Small scale mosaics can also be formed by processes such as creating scallops within scrub, or rides within woodlands along the edges of which scrub can develop. The features of suckering blackthorn scrub that can make it such good Nightingale habitat (see section 3.4) can be reproduced via management, in particular by cutting at the edge of the thicket to produce a low regenerating thicket there (Figure 5.1). Layering of blackthorn scrub also produces suitable structures, such as at Castor Hanglands, Cambridgeshire (Fuller, Henderson & Wilson 1999). This involves partially cutting the stems 30cm above the ground, laying them over to a height of some 1.5m. New growth suckers rapidly, creating suitable dense thicket habitat very quickly which deer can find difficult to penetrate.

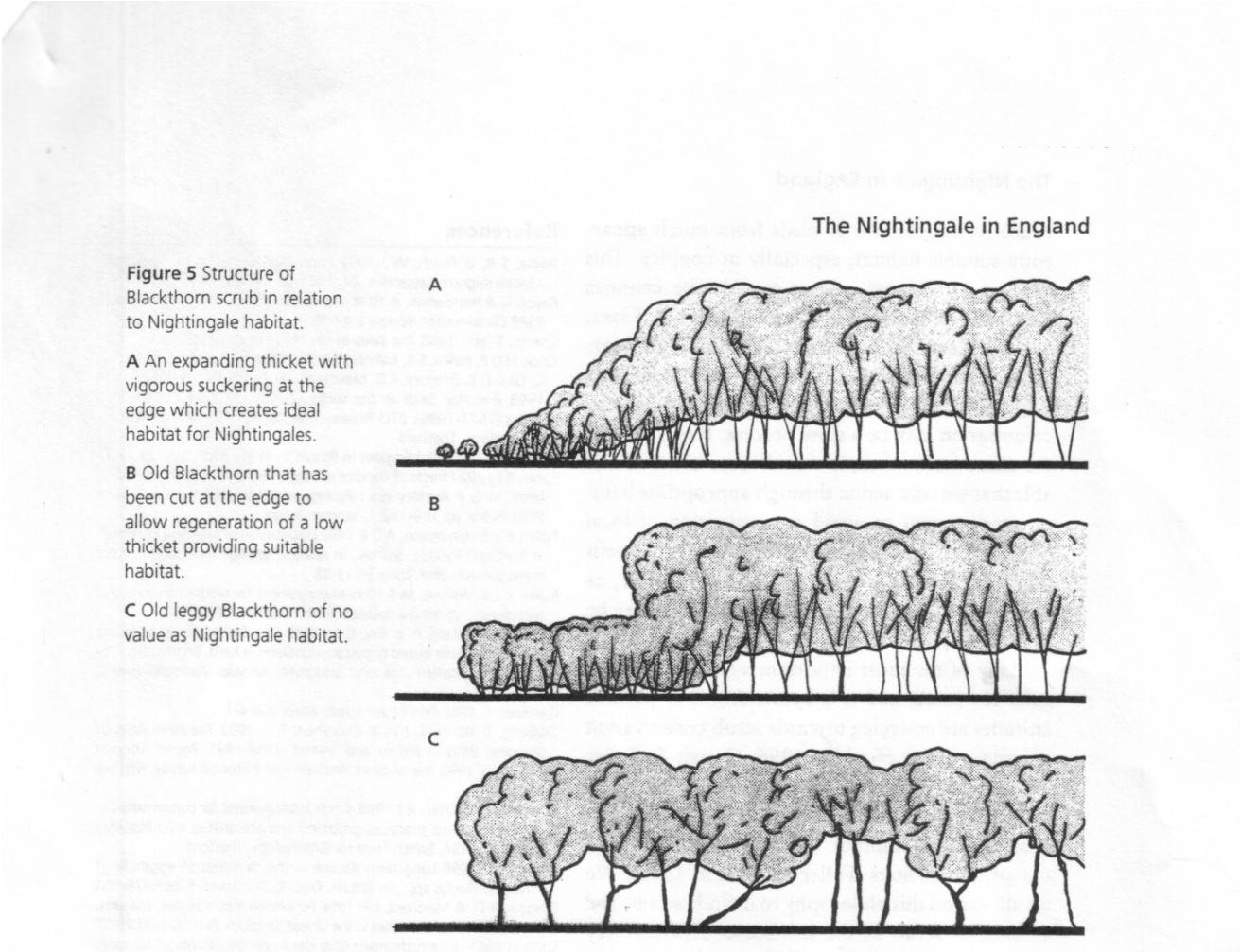

Figure 5.1 Structure of blackthorn scrub in relation to Nightingale habitat (from Fuller, Henderson & Wilson 1999). Note that permission to reproduce this figure is being sought from the publisher.

Excessive deer grazing can cause a reduction in the density of understorey vegetation and therefore in habitat quality for Nightingales (Gill & Fuller 2007). A study in Bradfield Woods demonstrated that male Nightingales showed a strong preference for centering their song territories on coppice stands that were protected from grazing, compared to similar unprotected stands (Holt, Fuller & Dolman 2010). At the national scale, Newson *et al.* (2011) found a strong likelihood of a causal relationship between local increases in roe deer numbers and declines in Nightingales. In Kent, deer numbers have yet to increase in numbers sufficiently to be a problem for Nightingale habitat quality but they may do in the future and so it should be remembered that deer management may be required if Nightingale numbers are to be maintained at any habitat created for them.

6. CASE STUDIES

In this section we summarise several case studies of locations supporting concentrations of nightingales to explore the historical establishment of the population and site-specific factors that have influenced the establishment of local populations and the apparent effects of specific management practices. Taken together with knowledge about the critical habitat requirements (section 3), this information is relevant to the assessment of whether habitat creation is feasible for Nightingales and to assessing what factors need to be considered in maximising the probability that potential habitat will be colonised and a population become established. We present these case studies in two categories: (1) locations that lie within the core of the British range where populations are relatively high and it is assumed that there is a greater chance that birds will be available to colonise potential habitat (Kent, Essex and Sussex), (2) locations lying outside the range core, either at the periphery of the core region or at the fringes of the current range, where we assume that there will be fewer potential colonists. This information has been compiled through a mixture of personal experience and interviews with individuals who are familiar with the locations and their history of Nightingales. We do not claim that this is a comprehensive list of relevant and potentially informative locations.

We are unaware of any detailed published account that explicitly describes the establishment of a Nightingale population in relation to habitat creation and vegetation development on a formerly unoccupied site. Indeed, we are unaware of any instance where habitat creation for Nightingales has been attempted on any large scale. In this section we describe instances where, fortuitously, habitat has become recently available and has been colonised by the species. We have focused on scrub or shrubland environments because we think these offer the best opportunity for creation of high quality Nightingale habitat. We have excluded the Cambridgeshire / Suffolk / Norfolk fen-edge populations because we know nothing about their history. Also, it is well known that Nightingales colonised many areas of treefall following the severe gale that hit south-east England in 1987 (Henderson, 1996) but this phenomenon is not considered here.

6.1 Within the Core Range

Fingringhoe Wick, Essex (50 hectares) – At this site, gravel extraction took place from the 1920s through to 1959. In 1961 the site was taken over by Essex Wildlife Trust. At that time 'a few' singing Nightingales were present, presumably in bramble *Rubus fruticosus* thickets which were present in meadow areas, as scrub was yet to be established. In 1969 there were 7 males, increasing to 16 the following year and to 26 males by 1979 and 1982. Numbers remained stable until 1993 then rose slowly to a peak of 42 males in 1999, before falling sharply in the early years of the 21st century. This gradual increase from the early 1960s through to the late 1970s reflects the development of scrub on the abandoned gravel workings, suggesting that peak conditions were reached after about 20 years. Some early increases in settling Nightingales are thought to have occurred on the richer soil of the spoil heaps, with subsequent increases due to the later maturation of scrub on the sand and gravel dominated areas.

The reason for the increase in the late 1990s is not clear, but it appears some tree removal by ring barking was undertaken prior to this. The pattern of increase is consistent with an episode of management having been undertaken in the early 1990s and the subsequent decrease in the early 2000s likely reflects the scrub becoming too mature to support suitable habitat following its cessation. Numbers have increased since 2005, due to the re-instatement of scrub management, with between 40 and 50 pairs being present this year. The success of this habitat management contrasts with the limited success at Paxton Pits (see below) – this is likely a consequence of the relative positions of these sites within the species range, with a greater pool of birds being present at Fingringhoe to occupy habitat created whilst conspecific attraction may be relatively more important in maintaining numbers at Paxton. We are not certain from the information we have available whether this level of population is sustainable by rotational coppicing / scrub cutting, or whether it is the result of a short-term peak of habitat availability.

The scrub at the site comprises blackthorn, sallow *Salix* spp., hawthorn *Crataegus monogyna*, rose *Rosa* spp. and oak *Quercus* spp., centred around small pits and ponds left over from the gravel workings. Most Nightingale territories are in this,

although a few are in areas with less complex structure, including areas of nettle beds and brambles and areas dominated by gorse *Ulex europaeus* – this likely reflects the broader habitat occupancy in the core of the species range in England (Hewson, Fuller & Day 2005). Current scrub management at the site involves coppicing the scrub to ground level, with some brash placed over the stools to protect against deer browsing and a dead hedge being erected to provide further protection in the early years. Scrub is being cut on a 10-15 year rotation (10 years for areas dominated by sallow, 15 years for oak). Wood (2005) suggests that the enlarging of rabbit-grazed glades at the site may have been beneficial for Nightingales through providing feeding areas in the glades but it is also likely that they will have benefitted from an increase in heterogeneity, including scrub edge density, through this process.

Orlestone Forest, Kent (331 hectares) – Establishment of forestry at Orlestone Forest after the Second World War resulted in the existing native woodland being largely replaced with Norway Spruce *Picea abies* and Scots Pine *Pinus sylvestris*, with the native woodland surviving as fire breaks along rides etc. The storm of October 1987 resulted in the destruction of large areas of mature conifer trees, which were replaced by regeneration of native broadleaves (primarily birch *Betula* spp., oak, hornbeam *Carpinus betulus*, aspen *Populus tremula*, willow, field maple *Acer campestre* and wild service *Sorbus torminalis*). This increase in dense, low scrubby habitat resulted in a large increase in the Nightingale population through the 1990s (to about 60 pairs) but this was in decline by the end of the decade as the scrubby habitats that had been created matured.

Since 2000, 1 hectare blocks spread throughout of the forest have been mulched to provide continuity of habitat for Nightingales and other migratory birds such as Garden *Sylvia borin* and Willow Warblers *Phylloscopus trochilus*. These blocks are embedded within a matrix of more mature woodland and are mulched every 6-10 years (limited by resources available for management operations), resulting in a window of suitability for Nightingales between 2-3 years until 6-8 years post-management. This has resulted in a recovery and maintenance of the Nightingale population from about 2003 to and at its current level of around 50-55 singing males.

This management method is used primarily because traditional coppicing is prohibitively expensive. Apart from mulching, no detailed management of the habitat is undertaken to enhance suitability for Nightingales. However, the habitat is suitable for Nightingales sooner after management when the mulching machine's head is not allowed to touch the ground, as this retains the stumps and roots of the woody vegetation *in situ* and re-growth begins immediately. Areas dominated by birch become suitable more quickly than those dominated by for example hornbeam, due to the higher growth rate of birch.

This demonstrates that suitable habitat for Nightingales can be colonised very quickly within Kent and that the required habitat structures can develop naturally with even relatively crude management techniques applied to existing woodland. It should be noted that as the mulched blocks are set within a matrix of more mature woodland, they form part of a wider mosaic of habitats that may be important as Nightingales, at least in some circumstances, use a larger home range within which they may use such habitats (see above). It should also be noted that Orlestone Forest is very wet and contains several marshy areas and pools which may contribute to the favourability of the site for Nightingales.

Burham, Eccles and New Hythe, Kent ('the Medway Gap') – The lower Medway valley has held one of the main concentrations of Nightingales in Kent in recent decades (Henderson 1996, 2002). This area downstream of Maidstone, sometimes known as the 'Medway Gap' where the river cuts through the North Downs, is extremely complicated in terms of the habitats it offers Nightingales. The downland and its woodland has become less populated by the species which has redistributed in recent years into the valley (Henderson 2002). The valley contains different types of scrub habitat in various contexts including gravel, chalk and clay pits, sewage works and other industrial land. Within this complex of scrub and shrubland there have been major shifts in local distribution and numbers of Nightingales with birds apparently rapidly colonising suitable vegetation as it has become available. A detailed account is provided by Woodcock (1992) who documents that approximately 30 pairs were present in some 100 hectares of scrub (exact areas are not given but a map is provided) on the east bank of the Medway in 1991. Particularly interesting is the rapid build up of an extremely dense population (11 to 15 pairs in a small area of approximately 4 hectares) where waste paper pulp was

dumped in the 1960s. By 1979 a high density of Nightingales was present. Woodcock (1992) states that the 'most sought after territories are in willow carr, followed by bramble and then buddleia, nearly all of which have an undergrowth of nettles'. This demonstrates that under ideal conditions (i.e. highly suitable vegetation structures combined with a high local Nightingale population providing colonists and social stimulation), a population can become rapidly established. This population persisted at high density from the late 1980s until sometime in the 2000s when the vegetation lost its suitability due to natural growth, although some birds continue to use the site (A. Henderson pers comm.).

Alton Water, Suffolk (60 hectares of scrub surrounding a 180ha reservoir). This area supports a current Nightingale population of in excess of 30 pairs, giving a density almost comparable with that at Fingringhoe Wick, albeit in linear fringing habitat rather than a more discrete habitat block. The reservoir was dammed in the mid-1970s and scrub development has taken place since then, together with growth of single-species blocks of broad-leafed trees (including some non-natives such as Norwegian maple *Acer platanoides*) that were planted around the time of damming. The soils of the area are sandy and somewhat acidic, hence there are patches of gorse in addition to the mixed species scrub and coppice currently present. There is little information immediately available about the build-up of Nightingales at the site (from the warden, Simon Walters), other than that some were present 15 years ago (i.e. c.20 years after the reservoir was created) but that numbers were smaller than they are now. The subsequent increase is attributed to the management that has been undertaken over the last 10-15 years, particularly the removal of larger trees (especially sycamore *Acer pseudoplatanus*) from the scrub and very small-scale coppicing, both designed to restrict the development and area of woodland on the site.

6.2. Outside the Core Range

Paxton Pits LNR, Cambridgeshire (core area of 110ha, though we are unclear how much water is included in this area) – This site is an area from which gravel was extracted between the 1940s and the early 1960s. The first three territorial Nightingales were recorded in 1974 but further territorial birds were only recorded in

two further years prior to 1987. Since then breeding has been annual, with 5-9 birds each year up to 1992, 15 in 1993 and between 21 and 29 birds each year since. Ray Matthews, the warden of the LNR since its establishment in 1989, says that scrub that develops on the bare mixture of subsoil, shingle and sand remaining after gravel activities takes between 15 and 20 years to reach a stage where Nightingales could become established. This is borne out by the time-scale outlined above, with the first singing Nightingale present 12 years after workings ceased and annual breeding not occurring until after 25 years. According to Ray Matthews, habitat management at this site (comprising layering and coppicing, combined with leaving deadwood *in situ* and also the erection of some rabbit and muntjac exclosures) does not appear to have had a positive effect on Nightingale numbers, but it may have prevented the population decreasing in line with regional declines. Specifically, management has never successfully brought Nightingales back into areas that they had abandoned. In one instance, removal of invasive Turkey Oaks *Quercus cerris* over a period of 15 years, combined with leaving the dead wood *in situ*, successfully led to Nightingales expanding into a hitherto unused part of the reserve following natural regeneration of ash *Fraxinus excelsior*, hawthorn, rose and bramble. In 2012 that area was inhabited by 4 singing birds.

There is much apparently suitable, more or less identical habitat in the area (both very locally and along nearby river valleys with similar histories of gravel extraction) that is not occupied by Nightingales. Ray Matthews considers this to be evidence of the importance of conspecific attraction in determining habitat occupancy. Conspecific attraction may be especially important at sites such as this at the edge of the range, where the pool of birds available for colonisation is smaller, and this process may have been responsible for maintaining the numbers at this site in the face of regional decline. If so, this could explain the limited success of habitat management on Nightingale numbers at this site. In this regard, it is notable that annual breeding was only established up to 25 years after gravel extraction ceased and 13 years after the presence of the first territorial bird. It is possible that this is due to the difficulties of establishing a breeding population in a new area at the edge of the range without social stimuli, although it should be noted that the national, and probably the regional, breeding population was declining throughout the establishment period.

Bainton, near Helpston, SE Lincolnshire – An area, approximately 20 hectares, of former gravel workings filled with rubble and topped off with fly ash some 40 years ago. Scrub, consisting mainly of hawthorn with vigorous rose and bramble, has colonised in a patchy way, creating a complex mosaic of impenetrable vegetation interspersed with sparsely vegetated openings. The structure is very close to that shown in Figure 3.4.1 with many scrub patches fringed by dense bramble. The rate of woody vegetation expansion appears to be slow, probably partly a consequence of poor soils and partly due to suppression of new growth by rabbits and deer. In recent years, the site has supported several pairs of Nightingales (probably less than 10 territories in any one year). It is likely that development of a suitable vegetation structure for the species at this site took more than 20 years but it is also likely, given the 'suppressed vegetation dynamic' described above, that, in the absence of any intervention, the scrub would remain in a suitable condition for many years to come. Immediately to the north of the scrub occupied by singing nightingales, and within some 300 m of the birds, there is an area of mixed woodland sloping down to a river. This may enhance the quality of the site by providing additional foraging areas (see discussion in section 3.4 about the potential value of trees to nightingales). These notes are based on a site visit in June 2011 by the authors with Chris Hughes who operates a ringing site there.

Cotswold Water Park – This site is a huge wetland complex where 20 Nightingale territories were located in 2012. Of these, 19 were in the western complex, scattered through an area of approximately 1200 hectares. The highest density within this area is 5 territories in approximately 14 hectares. According to Gareth Harris (Cotswold Water Park Biodiversity Manager) the birds are located within very mature hedgerows and blackthorn / sallow scrub. This is not new habitat that has recently developed on gravel workings but rather very old habitat remaining from the previous farmland landscape, albeit having become much more mature. All territories are close to water, either adjacent to one of the numerous gravel pits or over a ditch. The gravel workings may be important in that (a) they have meant that some of these woody features have been preserved in the areas between the pits and (b) that they provide proximity to water. Within the complex, Gareth Harris believes that management has negligible effect because Nightingale numbers are

limited and they always settle in the areas that are currently most suitable, with the vast area of habitat constantly offering suitable habitat somewhere due to natural habitat dynamics, management or habitat creation through planting.

7. WHAT FACTORS NEED TO BE CONSIDERED IN CREATING NEW HABITAT?

7.1 Key Uncertainties

The **speed at which new habitat will become suitable** for Nightingales is unclear. Some of the examples given in section 6 suggest that 15-20 years may be required under natural regeneration, although these times are usually at sites with soil characteristics likely to retard vegetation development. Planting, rather than natural regeneration, may result in more rapid establishment of suitable habitat. Even in cases where the vegetation reaches an apparently suitable stage sooner, there is uncertainty over whether the entire requirements, including food sources, would become sufficiently established in that time. As the development at Lodge Hill is due to commence in 2014 and continue over the next few years, the only conceivable way that offsetting habitat could be in place relatively soon (but not immediately) after the start of habitat loss (it is clearly not possible for it to be in place in advance of the current start date) would be for management to be instated through some form of rotational cutting at a woodland site currently unsuitable for Nightingales. If management was carried out over winter 2012-13 (i.e. as soon as is possible), managed areas would begin to become suitable from 2016 (i.e. after three complete summers re-growth) and would not reach a peak until a few years later, so even in this instance there would be a time lag between management and the creation of suitable conditions. Furthermore, the conditions created – akin to some form of coppicing – would not necessarily be as satisfactory as a scrub mosaic.

The **degree to which social attraction plays a role** in settlement decisions by Nightingales is unclear, although this may be less important in the core of the range, as in Kent, where there is a greater pool of potential colonisers.

The extent to which **effects of existing development close to the site** of habitat creation will negatively impact on habitat quality (i.e. the probability of occupancy and breeding success of occupants) is unknown. It is quite likely that nearby housing developments could negatively impact Nightingales through recreational disturbance, predation by cats and by reducing the local Nightingale population

and hence social attraction, but the strength of these effects and how far from the development they would have an effect are not known.

7.2 Major Limiting Factors Concerning Site Choice that Affect Likelihood of Success Given Above Uncertainties

The **geographical location** of receptor sites within the English range of Nightingales is likely to be important. Colonisation of suitable habitat is very likely in the core of the range, as in Kent, where the pool of potential colonisers is great, but such habitat may well not be colonised towards the range periphery. This emphasises the importance of any habitat being created in Kent or possibly an adjacent county such as Essex or Sussex.

On a smaller spatial scale, **proximity to an existing concentration of Nightingales** could be important because of the possibility of conspecific attraction. It is not clear how important a factor this might be within the core range, although it is likely to be very important towards the periphery. It is also not clear over what spatial scale this process would operate. For example, are birds likely to be influenced to settle within the same hectare or one kilometre square as existing birds or could the number present over the adjacent landscape be important, with other factors determining the precise settlement location?

Because the annual survival rate of Nightingales probably does not exceed 50%, the chances of luring many of the actual birds whose habitat had been lost by the development would probably not be high, so **proximity to Lodge Hill itself would not necessarily be important**, especially given that timescales suggest that new habitat would not be ready for at least a decade, whereas the development is projected to begin within 2-3 years. Nonetheless, proximity to an existing population could be beneficial though.

Whilst towards the periphery of the range, conspecific attraction may be especially important in determining occupancy patterns and much suitable habitat remains unoccupied, in the core of the English range **intrinsic characteristics of sites** are likely to be relatively more important as follows.

Altitude: low altitude sites are preferred (section 3.2)

Soil type: soils with high moisture content may be preferred but poorer soils, such as at gravel pits, may inhibit vegetation development and thus extend the period over which habitat remains suitable in the absence of management (section 3.2);

Drainage: wetter habitats appear to be preferred and the presence of water bodies, such as ponds and marshy areas, and drainage features such as streams and ditches may be beneficial

Adjacent habitats: nearby habitats harbouring predators such as cats may be highly detrimental whilst establishment of habitat next to existing habitat that could form part of home ranges, such as mature woodland, may be beneficial to habitat quality

Existing and past habitat features: the presence dense hedges, trees or tree patches or other woody vegetation that takes a long time to develop may increase the speed with which good quality habitat develops, by acting both as receptor habitat features and sources of seeds for future natural regeneration.

If the Kent Nightingale population is to be maintained through offsetting without suffering at least a temporary decline due to the development, it will be necessary to use sites where good quality habitat can be brought into condition as soon as possible. This also means that, without habitat management, these sites could become unsuitable more quickly but the availability of relatively cheap, simple techniques for maintaining Nightingale habitat, such as the rotational mulching used at Orlestone Forest, means that this may not be a problem. These sorts of techniques may be easier to apply within larger sites. Larger sites may also be more likely to develop valuable mosaics and, because they could hold more Nightingales within a single location, they could produce stronger benefits via conspecific attraction.

7.3 Management Considerations

Methods of vegetation and habitat development need to be carefully chosen, partly to reduce the time it takes for an area to become 'mature' as Nightingale habitat and partly to maximise the quality of the habitat and its attractiveness to Nightingales (not necessarily the same thing – see section 4).

Numerous examples suggest that natural regeneration of scrub and woody vegetation can produce structures that are attractive to Nightingales. At sites such as Paxton Pits, Fingringhoe Wick and numerous other gravel pit sites, high density populations of Nightingales have resulted from such processes. It is less clear whether high Nightingale habitats can be easily created through deliberate and direct habitat creation, although there is some evidence that planted habitats can be colonised by Nightingales, possibly more rapidly than sites which have become suitable through natural regeneration. For example, at Strensham Water treatment Works, Worcestershire, Nightingales colonised an area in which young trees had been planted to screen a plant but rapidly declined from around 7 birds in 1998 to 2 in 2006, the last year they were recorded there – this could reflect the rapid maturation of the habitat beyond the successional stages suitable to Nightingales but it could also partly reflect the declines that were happening at that time in the area, which is now well outside the species core range. There are also many reports of young conifer plantations being occupied for some years after planting (Fuller, Henderson & Wilson 1999) which would suggest that planting can produce Nightingale habitat. Appropriate management could prolong and even maintain the habitat, provided a sufficiently large area was created to allow rotational management, which may also provide a useful mosaic of habitats. Similarly, there are many examples of natural processes producing Nightingale habitat within existing scrub and woodland, through wind throw of mature trees creating gaps for vegetation regeneration, for instance.

Natural regeneration (combined with subsequent management) may produce the required habitat structures, including heterogeneity on an appropriate scale, more readily than planting or seeding. Artificial habitat creation will require that heterogeneity is built into planting or seeding regimes and subsequent management

plans in order to provide the mosaics that characterise the best Nightingale habitat. Incorporation of numerous gaps and edges will help to provide this form an early stage, as will inclusion of mature trees and bushes where available. This is returned to in section 9.

8. HOW MUCH LAND MIGHT BE NEEDED?

The Lodge Hill site is 325 hectares and Chattenden SSSI is 133 hectares. The amount of land required for offsetting will depend on the actual reduction in the numbers Nightingales at the site but this is difficult to predict precisely and will depend partly on whether appropriate avoidance and mitigation measures are taken during the development. Because of these unknowns it is, however, unrealistic to firmly predict the persistence of any Nightingales within the Lodge Hill development itself whilst serious reductions could also occur in Chattenden Woods SSSI. The reduction in the number of Nightingales will therefore theoretically be between 69 and 83 so we will take a hypothetical mid-point of 75.

The area required to contain this number of Nightingales will depend on a number of factors, in particular the territory and home range sizes of Nightingales and, importantly, their dispersion within any habitat created. There is minimal information available on these factors and none on how they might vary with habitat characteristics. Song territories may be as small as 0.25 hectares but are usually >0.5 hectares (Fuller, Henderson & Wilson 1999 and inferred from Holt *et al.* in press). At Paxton Pits, home range size estimates were between 0.4 and 2.3 hectares (Holt *et al.* in press). The extent of overlap in home ranges, the number of birds that can overlap and the relation between home ranges and song territories will all influence the area of habitat required in a way that makes it difficult to estimate a 'Nightingale unit' metric. The best way of estimating the areas that might be required is probably to look at areas of habitat that contains similar numbers of Nightingales in the types of habitats most likely to be created as offset habitat for Lodge Hill, which could lead to estimation of a 'Nightingale unit' via division of the area by the number of birds. These habitats are scrub and scrub / woodland mosaics, depending on the receptor site or sites chosen. We would stress that even within apparently suitable habitat, birds are unevenly distributed; typically not all apparently suitable habitat is occupied. This may be because there are insufficient potential colonists or because there is variation in habitat suitability that is evident to Nightingales but not to humans.

Excluding populations on small sites from which densities cannot be extrapolated to larger areas (e.g. the area where waste paper pulp was dumped in the Medway Gap described above), the densest Nightingale population that we are aware of is at Fingringhoe Wick, Essex, where at least 42 males were present in 2012 within the core 50 hectares of the reserve, although as this is dependent on management it is not clear how sustainable this population level is in the medium term. To be sustainable, rotational management systems require that only a subset of the vegetation is in prime Nightingale condition at any one time, which will increase the total area required. This site is likely to provide optimal conditions as a result of recent management of the scrub / grassland mosaic that lies around numerous small water bodies remaining from the period of gravel extraction (see section 6). Additionally, its position within the core of the species range and on the entry route for many Nightingales returning to England is likely to have facilitated the build-up of these numbers. The same geographical context applies to the region within which Lodge Hill is situated. It should be mentioned that although the population is high at this site, the habitat quality for Nightingales cannot be properly assessed because no information is currently available on pairing success of males (which is predicted to be high) or breeding success of pairs (for which predictions are unclear). Nonetheless, the Fingringhoe experience suggests that, under absolutely ideal conditions and circumstances, an area of around 100 hectares in Kent could conceivably hold the required 75 territorial males. However, the habitat at Fingringhoe had developed naturally over a period of 20-25 years up to the point of management intervention which was necessary to reach the current densities – such timescales may be prohibitive in the current context. We do not think this scenario (100 hectares) is appropriate in the situation currently under review; a considerably larger area of land would be needed to realistically offer compensatory habitat for 75 Nightingale territories. We suggest that an area of at least 300 hectares is more realistic as the following would suggest.

At Paxton Pits, the majority of Nightingales (21-26 pairs annually) occurs in an area of 100-110 hectares, giving a density similar to that at Lodge Hill, implying an area of 330-380 hectares for offsetting. The Medway Gap area east of the River Medway held some 30 pairs in approximately 100 hectares of complex scrubland and this included one exceptional small hotspot. Orlestone Forest is a near optimal

woodland site in Kent that is now managed specifically with Nightingales in mind. At 331 hectares, this site is very similar in size to Lodge Hill yet it contains only 50-55 territories, about two-thirds of the estimated requirement. It is not clear to what extent other demands on the forest have been traded off against Nightingale habitat, or whether the current amount of habitat is the maximum that could be sustained in the long-term.

Because of the likelihood of social attraction being important and because they are more likely to contain the habitat mosaics and finer scale heterogeneity that Nightingales require, providing the required area of habitat in one or as few 'parcels' as possible is a better option than providing several smaller pieces of habitat. Whilst it could be argued that several smaller blocks might contain more initial diversity overall in site conditions, it is within-patch diversity (e.g. structural gradients and mosaics) that is likely to be beneficial for Nightingale numbers and we consider it more likely these would develop on an extensive site. Furthermore, in the longer-term it may be easier to manage the habitat on a small number of large sites than a large number of small sites. Insufficient is currently known about the precise scale at which social attraction occurs or how this varies with local density to give definitive estimates of the effects of having different patch sizes on this, but it is likely that adjacent Nightingale populations would be important, especially for attracting birds to smaller blocks. In general, the surrounding habitat is most likely to impact the quality of smaller patches. It is worth mentioning that in some limited parts of the East Anglian Fens, Nightingales persist at high density in tree belts and hedges around the margins of intensively farmed salad and vegetable fields. This situation appears, however, to be exceptional and is unlikely to be readily replicated.

9. SUMMARY AND CONCLUSIONS

This section draws out the main points from that are relevant to the issue of creating compensatory habitat.

We have provided several examples of sites where newly available habitat has been strongly colonised since the early 1970s. Therefore, it is theoretically feasible to create habitat that will be occupied by Nightingales in lowland England. We suggest that, **if the right conditions are satisfied**, there is a greater probability of achieving success in Kent than in most parts of the country. Kent, together with parts of Essex, Suffolk and Sussex now form the core of the species range in Britain and there are likely to be more potential colonists available here than elsewhere. We have focused on scrub or shrubland environments because we think these offer the best opportunity for creation of high quality Nightingale habitat. Most areas of scrub containing Nightingales appear to have taken 15 to 25 years of vegetation growth to reach a suitable structure for the species but in many instances this will have been constrained by poor soils. This is an obvious constraint on the timescales for creation of compensatory habitat. If a large area of mature woodland were available (i.e. that currently does not provide suitable habitat but is a suitable low-lying damp woodland), large-scale and severe intervention within this could produce a more rapid development of young growth vegetation. Orlestone indicates that this is possible, given appropriate site conditions, but it would be necessary to sacrifice the management of the woodland for mature trees and the total area required would be substantial. As noted in section 7.1, such habitat would not begin to become suitable until 2016, even if management were carried out immediately. This would be considerably sooner than is likely through the establishment of completely new habitat such as scrub but would still lead to a considerable lag between the development as currently scheduled and the provision of suitable alternative habitat. As such habitat is also possibly not of such good quality for Nightingales compared with scrub habitat created from scratch, a mixed strategy involving the provision of habitat through immediate management intervention at existing woodlands followed as soon as possible by the creation of good quality scrub habitats might work best.

To maximise the chance of success a number of key considerations must be taken into account, all of which are detailed in the main body of this report. It must be stressed that even if these are all incorporated into a habitat creation plan, the establishment and persistence of a large Nightingale population cannot be absolutely guaranteed. Meeting the requirements of the species as thoroughly as possible is especially important at a time when nationally the range of the species is contracting and the overall population is declining. There are still unknown factors affecting the local distributions of Nightingales so it is not possible to be definitive but, based on current knowledge, the following elements would seem to be critical to any habitat creation plan:

(1) Site choice is critically important. It must be low altitude, lower than 40 m and ideally below 20 m. The site should contain areas of damp ground, or have areas of open water or ditches adjacent to which woody vegetation should develop. An increasing proportion of the population occurs in such environments which appear to offer preferred resources for the birds.

(2) Sites should ideally be in the vicinity of existing populations which may provide a large social stimulus for settlement. Conspecific attraction is discussed further below.

(3) The area of land required to create a scrub mosaic supporting an equivalent Nightingale population to that currently at Lodge Hill is probably in the order of 300 to 400 hectares. This will increase the likelihood of diverse vegetation mosaics developing and patches of high quality habitat becoming established that could provide conditions for a population of equivalent size to that currently occupying Lodge Hill. Sites are rarely, if ever, uniformly occupied by Nightingales and apparently suitable patches are frequently not occupied. It is unknown exactly how much area a Nightingale needs due to their home ranges apparently being much bigger than song territories and overlapping to an unknown extent. In any case, this area is likely to be context-specific; ultimately, how much area will be needed will depend on the habitat quality and characteristics that develop. Furthermore, it is not necessarily the case that the very densest populations will be in the highest

quality habitat in terms of reproduction and survival (see section 4). There may also be density-dependent reduction of breeding output arising through competition at high densities. It would, we suggest, be wisest to attempt to establish a moderate density of birds over a larger area than a very high density over a smaller area.

(4) Careful consideration of existing habitat features is important. First, the existence of water / damp areas as outlined above. Second, the presence of some scrub or hedgerows which could form focal points for vegetative expansion of scrub or seed sources for scrub development. Third, patches of trees, or proximity to woodland edge, are highly desirable because these may improve habitat quality for foraging.

There are also important considerations about the management of appropriate habitat, both in terms of the speed of creation and the potential quality. Most of the large populations of Nightingales using scrub occur at locations where the scrub has developed through natural regeneration which generally tends to produce complex mosaics of bushes and open areas. These mosaics appear to be favourable to Nightingales because the fine-scale structural heterogeneity can provide optimum feeding, singing, nesting and sheltering conditions in close proximity. Where some trees are present within the mosaic the conditions may be even better. It may be possible to speed up the process of scrub development by preparation of the substrate to enhance seed germination (e.g. by rotovation) and the provision of perches for birds to encourage the dispersal of seeds (McClanahan & Wolfe 1993). It may be possible to use a combination of natural regeneration, seeding and planting to establish mosaics but we are not aware of any cases where such attempts have been made to establish young growth vegetation. Willow may give the greatest opportunity for rapid habitat development. The choice of site is important in that it may be possible to rapidly develop mixtures of dense young willow and nettles on damp soils. On damp sites, potential habitat quality might be enhanced by providing flooded ditches and allowing bushes to grow over these forming a tunnel effect; this structure appears to be favoured in the East Anglian fens (personal unpublished observation).

Even if the habitat conditions can be made as suitable as possible, this might not be enough due to social factors (Ahlering & Faaborg 2006). The use of conspecific attraction through tape luring would be a possible way of attracting some in but there are a number of potential issues with this. These include factors about how you would do it (what vocalisations to use and when) and whether it was ecologically and ethically correct (one would not wish to lure birds into an ecological trap).

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