Definition of Favourable Conservation Status for greater horseshoe bat (*Rhinolophus ferrumequinum*)

Defining Favourable Conservation Status Project

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January 2023

www.gov.uk/natural-england

Acknowledgements

We wish to thank the following for help in the production of this definition:

Carol Williams of Bat Conservation Trust, Roger Ransome and Orly Razgour.

From Natural England, Pete Wells, members of the Technical Steering Group, in particular Ian Taylor and Andy Brown, and Sam Dixon and Susannah Haley in the Evidence Services team.

Executive summary

This document sets out Natural England's view on favourable conservation status for greater horseshoe bat in England.

Favourable conservation status is the situation when the species can be regarded as thriving in England and is expected to continue to thrive sustainably in the future. The definition is based on the available evidence on the ecology of greater horseshoe bat. Favourable conservation status is defined in terms of three parameters: natural range and distribution; population; extent and quality of habitat necessary for long-term maintenance of populations.

A summary definition of favourable conservation status in England follows. Section 1 of this document describes the species and its ecosystem context, Section 2 the units used to define favourable conservation status and Section 3 describes the evidence considered when defining favourable conservation status for each of the three parameters. Section 4 sets out the conclusions on favourable values for each of the three parameters.

This document does not include any action planning, or describe actions, to achieve or maintain favourable conservation status. These will be presented separately, for example within strategy documents.

The guidance document Defining Favourable Conservation Status in England describes the Natural England approach to defining favourable conservation status.

Summary definition of favourable conservation status

The greater horseshoe bat is one of the most-studied bats in England. It is of Least Concern globally, but its population is decreasing (Piraccini 2016). The species is Near Threatened in Europe and Wales and Least Concern in England and Great Britain (Mathews & Harrower 2020).

The greater horseshoe bat is at the northern edge of its range in Britain, limited by climate to south-west England and Wales. After its GB range shrank in the last century the population and range have recently expanded. The current range is estimated to embrace 213 hectads (10 km squares), slightly less than half of its estimated favourable range, which comprises 445 hectads.

The current population in England is considered to be 10,200 individuals with upper and lower 95% confidence intervals of 7,277 and 14,554 (Mathews and others 2018). In order to ensure the population is at a level which is resilient to future pressures and threats, and occupies the favourable range and distribution, the favourable level for the population in England is proposed as 62,000 individuals.

The current geographical range for greater horseshoe bats is estimated as 29,600 km^2 (Mathews and others 2018). The area of occupancy of greater horseshoe bats in England is 3,068 km^2 (Mathews & Harrower 2020) and this is taken as the current area of supporting habitat for the species. In order to be deemed as favourable, the area of habitat will need to increase to 6,500 km^2 to support the proposed increase in range and population outlined above.

Table 1 Confidence levels for favourable values

Favourable conservation status parameter	Favourable status	Confidence in the favourable value
Range and distribution	445 hectads	Low
Population	62,000 individuals	Low
Habitat	6,500 km^2	Low

As of March 2022, based on a comparison of the favourable values with the current values, greater horseshoe bat is not in favourable conservation status. Note, this conclusion is based solely on the information within this document and not on a formal assessment of status nor on focussed and/or comprehensive monitoring of status.

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About the Defining Favourable Conservation Status project

Natural England's Defining Favourable Conservation Status (DFCS) project is defining the minimum threshold at which habitats and species in England can be considered to be thriving. Our Favourable Conservation Status (FCS) definitions are based on ecological evidence and the expertise of specialists.

We are doing this so we can say what good looks like and to set our aspiration for species and habitats in England, which will inform decision making and actions to achieve and sustain thriving wildlife.

We are publishing FCS definitions so that you, our partners and decision-makers can do your bit for nature, better.

As we publish more of our work, the format of our definitions may evolve, however the content will remain largely the same.

This definition has been prepared using current data and evidence. It represents Natural England's view of favourable conservation status based on the best available information at the time of production.

1. Species definition and ecosystem context

1.1 Species definition

Greater horseshoe bat (*Rhinolophus ferrumequinum*) Schreber 1774

1.2 Species status

Red list status

An assessment of the risk of extinction.

Global: Least Concern (but population trend decreasing). Source: The IUCN Red List of Threatened Species.

European: Near Threatened. Source: Temple & Terry (Compilers) 2007

GB: Least Concern. Source: Mathews and others 2020

England: Least Concern. Source: Mathews and others 2020

Conservation status

Species of Principal Importance under Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006.

Listed as a protected species on Schedule 5 of the Wildlife and Countryside Act 1981.

Listed as a Species of Community Interest under Annex II of the Habitats Directive.

Listed as a Species of Community Interest in need of strict protection under Annex IV of the Habitats Directive.

The greater horseshoe bat has suffered severe declines in Northern Europe and is now considered extinct or very rare in the Netherlands, Belgium, Gibraltar and Germany. Its conservation status is regarded as unfavourable across all of Europe apart from in Britain and the Black Sea region[1]. In Britain however populations appear to be increasing,

[1] https://eunis.eea.europa.eu/species/1544#threat_status

suggesting a population recovery at its northern range margin. The South Hams of Devon is thought to contain the largest known maternity roost in Britain and possibly in Europe.

1.3 Life cycle

Greater horseshoe bats can hibernate from October to late May if climate and food supplies require extended torpor (Ransome 1968; Ransome 1971; Park, Jones & Ransome 2000). However, in most years adult females ovulate, conceive and start pregnancy in early April. They group together to form their largest and most concentrated aggregations from June to late August when related breeding females and their immature offspring congregate in a traditional maternity roost (Ransome 2008). In early summer, adult males (normally originally born in the roost), may also be present (Ransome 2008). Females may give birth from mid-June to early August. Each has a single pup which is weaned at around 45 days of age. Pups forage from 28-30 days old and complete skeletal linear growth at 60 days (Jones, Duverge & Ransome 1995). Mothers start to leave the summer colonies around 55 days post-partum. By late September most adult females have left the colony for mating roosts, leaving their pups behind with some sub-adults. In early October all bats store fat in preparation for prolonged hibernation torpor underground over winter.

1.4 Supporting habitat

The habitat required to maintain a population of greater horseshoe bats in England is a combination of the habitat required for roosting, successful foraging and commuting through the landscape (see summary by Ransome & Hutson 2000).

Roost requirements

Greater horseshoe bats have high roost fidelity and are highly selective in the type of roosts they use throughout the year.

A bat colony is the sum of bats that form a social group including males, females and immature bats. Colony members might utilise a number of roosts for a range of purposes throughout the annual cycle (Ransome 1991; Ransome 2008). In summer, females are philopatric, returning to their natal roosts to form maternity roosts, while adult males are predominantly solitary, roosting in cooler roosts, mostly underground. In winter bats enter torpor in hibernation roosts underground. There are at least five types of roost necessary to maintain a viable colony in a region. They are maternity roosts, night roosts, hibernacula, mating roosts and transitional roosts. Historically greater horseshoe bats would have been reliant on natural caves and large hollow trees for roosts, however due to historic changes in habitat in England, their reliance has predominantly shifted to human-created structures.

Maternity roosts

In most of Europe greater horseshoe bats are traditionally cave-dwellers all year round. In Great Britain most underground sites are too cold for successful pup growth so they primarily roost within the attics of large buildings, such as stately homes, churches and barns, which are warmed by the sun during summer. Maternity sites in caves are known in Britain but are rare. Only roosts with a large number of bats seem to be capable of rearing young successfully in caves. Such colonies usually occupy vertical blind domes near entrances which permit the accumulation of body heat losses and warming from external circulation. Such positions, although they do not reach high temperatures, do not cool down rapidly at night.

Greater horseshoe bats require large openings to fly through to enter and exit their roosts as they are unable to land and crawl. They are specialised for manoeuvrable flight in fairly confined situations by having broad wings, with a large surface area. Climatic temperatures below 6 ^{o}C often occur in spring and prevent the flight of their insect prey (Ransome 1973). This, in conjunction with a drop in temperature inside the roost causes them to abandon their building roost in favour of more stable underground roosts for torpor and survival in poor weather. Warmer roost conditions are linked with improved breeding success (Ransome 1998), and roost modifications to improve thermal conditions to 26 ^{o}C has resulted in substantial increases in some key maternity roosts in south-west England. In unheated roosts, clusters form and disperse largely in relation to ambient temperature and the need to conserve energy for reproduction.

Night roosts

These can be any structure providing shelter, such as the chimneys of derelict buildings, garages, stables, porches, caves and even the branches of large trees. They are only used at night for the digestion of prey and consequently can be open structures which are brightly lit in daytime. Such roosts need to be located within close proximity of foraging grounds and offer shelter from wind, rain and cold temperatures while digestion occurs (Ransome & Hutson 2000).

Hibernation roosts

These can be located underground, for example in undisturbed caves, disused mines, ice houses or unheated cellars with high humidity and stable, cool temperatures. As greater horseshoe bats are known to forage during the hibernation period, if external temperatures are suitable, such sites need to be surrounded by good quality habitat (Ransome 1968).

Greater horseshoe hibernacula requirements vary throughout the winter (Ransome 2008):

- Early winter. Most fat deposition for hibernation occurs rapidly in mild weather in mid to late October. At this time bats choose hibernacula which have good ventilation, are relatively warm (about 9-11 ^{o}C), with temperatures that fluctuate with local weather conditions. It is possible that the air flow permits synchronization of their arousals with dusk. Bats arouse every 1-2 days at this time. They are particularly sensitive to provoked arousals at this time of year, especially torchlight or unusual sounds. Mating can also take place at this time.

- Mid-winter. As the weather becomes colder from December to February, the autumn hibernacula often become too cold, and bats are forced into more temperature-stable hibernacula where temperatures lie between 6 ^{o}C and 8 ^{o}C. At these temperatures, in mid-winter, bats normally arouse every 8-12 days. Foraging at this time of winter is much less frequent but can occur at dusk during mild winter spells. All bats are less sensitive to disturbance at these lower temperatures, but are still aroused by lights, especially at dusk.

- Late winter. From February to May. As the weather warms again, bats return to well-ventilated hibernacula, and arouse more often, possibly in synchrony with warmer days when insect availability is likely to permit feeding. At ambient temperatures of 8-9 ^{o}C they arouse each day but can reduce their arousal frequency by moving to colder regions (5-7 ^{o}C) if adverse weather persists.

It should be noted that some individual hibernacula provide all the bats' requirements.

Hibernacula can be classified into three types on the basis of the sex and age of the occupants (Ransome 1991; Ransome 2008):

- Type 1 hibernacula contain first-year bats and older immature bats of both sexes. Adult males and females may join them in mid-winter. In favourable habitat circumstances large clusters may develop.

- Type 2 hibernacula contain few first-year bats, but many second and third-year immature bats with some adult males. Clusters are also formed by these bats. Adult females, if present are usually solitary and are widely scattered in the deeper regions of larger hibernacula.

- Type 3 hibernacula are smaller, often isolated sites, occupied by the same adult male bat over many years and often also used as a mating roost. Up to eight mature females may be present with the male bat in September and October and they may return again in April and May during pregnancy.

Adult female bats are mostly found in type 1 and 2 sites and these are classed as major hibernacula. In a region where bats from several colonies hibernate in the same group of hibernacula, only one or two type 1 and 2 hibernacula serve the population and are usually less than 15 km from the maternity roost. Many type 3 hibernacula are required and these are not always distinct. They are usually in small isolated underground sites widely scattered usually up to 40 km from the maternity roost of origin (Ransome 2008).

Mating roosts

These are often located in underground sites such as cellars, tunnels and small caves, defended by solitary males and can form type 3 hibernacula. The males may be present from spring until autumn and may also stay throughout the winter. In late summer and autumn, groups of related females visit these sites to mate (Rossiter and others 2000b; Rossiter and others 2005) and up to eight females have been observed to visit a single male (Ransome 2008). Genetic analysis has shown that females are likely to mate with the same male in a series of years (Rossiter and others 2005). Usually fewer than seven bats are present at once, therefore the importance of these roosts may not be fully realised. Mating sites are where gene flow in the population occurs as colonies are virtually closed due to the philopatric nature of females (Rossiter and others 2000b). As males are solitary at these roosts, many mating sites will be required by the population, but very few are known.

Transitional roosts

Transitional roosts may also be used in the spring and autumn and are where bats congregate in smaller numbers either before the summer maternity or after the winter hibernation periods. Greater horseshoe bats do not swarm, and often occupy transitional roosts at the time of year when swarming is noted in some vespertilionid bats. Transitional roosts are also important for individuals moving between maternity roosts and hibernacula and individual bats using these show a high degree of roost fidelity to each site. These roosts may link different colonies and facilitate gene flow between them and may also be used as mating roosts or early winter hibernation roosts (Flanders & Jones 2009).

Foraging habitat requirements

Greater horseshoe bats are specialists in foraging at low levels above ground in, and close to, dense vegetation (Jones & Rayner 1989). Their specialised echolocation and flight morphology allows them to forage successfully in every month of the year (Ransome 1996; Ransome 2002).

The topography and habitat surrounding a roost and how it is managed are important in determining the availability of certain prey groups. Appropriate management is highly important for colony size through growth and survival effects (Duvergé & Jones 2003; Ransome 1996; Ransome 2000). Colonies are therefore dependent on a well-connected and diverse range of habitats close to suitable roosting sites that support prey throughout the year. Such areas are termed core sustenance zones and for greater horseshoe bats these are considered to extend 3 km from a communal roost[2].

Greater horseshoe bats require foraging habitat that provides plentiful insect prey, shelter and opportunities for perch-hunting. Duvergé & Jones (1994) found that greater horseshoe

[2] https://cdn.bats.org.uk/uploads/pdf/Resources/Core_Sustenance_Zones_Explained_04.02.16.pdf?v=1550597495

bats preferred the following habitats (in descending order of importance): pastures with cattle (either single/mixed stock), ancient semi-natural woodland, pastures with non-cattle stock. Woodlands and pasture close to woodland were used to a greater extent in spring and early summer while pasture was predominantly used in summer. Rides, footpaths, hedges and treelines were used by greater horseshoe bats when flying in these feeding areas and the bats flew low to the ground and generally within 2 m of these habitat structures. Given that greater horseshoe bats' sensory range is only 5-10 m, as their echolocation call attenuates rapidly in air due to its relatively high frequency, such habitat structures are important for bats to maintain their orientation when foraging or commuting. This reliance on linear habitat features makes this species vulnerable to habitat fragmentation. However, Finch and others (2020a) found that greater horseshoe bat activity was significantly higher close to linear features within an agricultural landscape, but almost a third of activity by this species was also recorded in the centre of fields. Further work is needed to understand how bats may use landscapes throughout the year.

Hunting bouts last 1-2.5 hours, with the bats resting at other periods during the night when rapid digestion and egestion of faeces allows the consumption of more food. Individual foraging areas average 6-7 ha, but greater horseshoe bats will use core zones within these areas of approximately 0.35 ha. Greater horseshoe bats do not spend the whole of a night foraging in a single foraging area, but frequently switch to other areas. Adult bats normally use between 2 and 11 different foraging areas in a single night. There is currently no evidence of foraging areas being treated as territories belonging to a specific individual or group of bats. Foraging areas are usually 3-4 km from a roost but may be up to 14 km away (Duvergé 1996). High quality feeding areas around maternity roosts are vitally important for the bats - providing food during the spring and summer months for pregnant and lactating females, as well as their young. Both young bats and breeding females cannot fly as far as non-breeding females so the availability of good quality foraging habitat within 3 km of maternity roosts is critical for the long-term survival of the population.

Greater horseshoe bats hunt by hawking along the edge of linear habitat features or perching on a twig and scanning for passing prey (more common during the second part of the night (Dietz & Kiefer 2016; Duvergé 1996). Selected twigs are bare, and in the range 5-10 mm diameter and may be selected for their safety from predators, as well as their size and position relative to good prey-capture opportunities. An overhead cover such as a leafy canopy, shaped like an umbrella, is preferred. Such a cover, besides protecting the bat from predator attacks, may also shelter it during rainfall and high wind. Tall hedgerows, or woodland edge, around pastures grazed by cattle, tend to be favoured core foraging areas. Cattle graze the lower hedge levels, creating an umbrella shape and bare twigs at about 2 m height, which the bats find attractive for perching. Cattle also generate high concentrations of dung close to hedges when they rest to ruminate in the shelter provided. The dung attracts concentrations of nocturnal *Aphodius sp.* dung beetles as potential prey (Ransome 1996). Large insects are consumed at feeding perches, such as the twigs used for perching, or within night roosts, and the less digestible parts discarded (Duvergé 1996; Jones 1990).

Greater horseshoe bats are highly selective in choosing their prey, conforming to optimal foraging models and only selecting lower quality prey (for example, Diptera and Ichneumonidae) when higher quality items (for example, *Melolontha melolontha* and Lepidoptera) are scarce (Jones 1990; Ransome 1996; Ransome 1997; Ransome 2000). They switch foraging strategies throughout the year in order to select those habitats with the greatest availability of suitable insect prey in any given season (Duvergé & Jones 1994; Flanders & Jones 2009). Juvenile greater horseshoe bats feed almost exclusively on the small dung beetle *Aphodius sp*. when they begin to feed at 28-30 days of age, thus they are an important food source during the development of flight and hunting skills (Jones, Duverge & Ransome 1995). They are also important for lactating mothers when moths are scarce (Duvergé & Jones 2003; Ransome 1996). Loss of cattle during the foot and mouth outbreak in 2001 and 2002 surrounding a large maternity roost in the Forest of Dean led to a reduction in consumption of *Aphodius sp.* by 31.5% with a subsequent rise in juvenile mortality, indicating the importance of this prey availability at this time (Ransome & Priddis 2005).

Winter feeding in this species was first shown by Ransome (1968). Park, Jones & Ransome (2000) showed that greater horseshoe bats are often active in hibernacula towards dusk in warm weather, when feeding is more likely to be successful. Dusk arousals from torpor are most synchronised in bats with low body fat reserves. In winter the foraging range from hibernacula is likely to be reduced compared to summer foraging ranges. In areas where conditions allow, the presence of grazing animals, such as cattle, deer or sheep is important (Ransome 2002); as well as the presence of good quality habitats such as woodland which are often slightly warmer than other habitat types and therefore provide a good feeding resource (Jones, Duverge & Ransome 1995).

Greater horseshoe bats are photophobic and avoid lighted areas whilst foraging or commuting (Stone 2013). Froidevaux and others (2017) found the size of greater horseshoe bat colonies was better predicted by the amount of artificial light at night than the proportion of urban area. This indicates the importance of dark flyways within colony core sustenance zones.

1.5 Ecosystem context

The range of greater horseshoe bats extends from north-west Africa throughout southern and central Europe eastwards towards the Pacific. The sub-species found between Afghanistan and the Pacific is, in Japan, recognised as a separate species *R. nippon,* whilst the endemic sub-species *R. f. creticus* is recognised on Crete (Iliopoulou-Georgudaki & Ondrias 1986). The core of the species' distribution is in the Mediterranean region. In Britain, the greater horseshoe bat is at the north-western edge of its range where it is limited by climate to south-west England and Wales, with the northern-most occurrence in Wales. During the Ice Ages the species retreated to refuge areas in the southern Iberian Peninsula and Asia Minor (Rossiter and others 2007).

Greater horseshoe bats mainly occupy the lowlands, usually below 800 m, which relates to the critical temperature ranges they require. Several studies show that severe, prolonged, cold winters reduce survival rates, especially of adult males and young of the year. Ransome (1989), and Ransome & McOwat (1994) showed that spring climate in April and May synchronised the timing of annual births over a wide region embracing three maternity sites in Britain. The time of birth affects the growth and survival of individuals and sex-ratios within cohorts. Froidevaux and others (2017) found the annual growth rate of colonies was strongly correlated with spring temperatures and precipitation. The single greatest cause of death seems to be starvation in late cold springs which delays birth timing. The later young are born, the less likely they are able to grow properly and survive their first winter. The critical temperature limit for the greater horseshoe bat is a mean temperature of 9.4 ^{o}C for the combined months of April and May. If the mean temperature sinks below this by as little as 2 ^{o}C the mean birth date increases by 18 days (Ransome & McOwat 1994). Viable populations can only exist where spring temperatures are favourable.

No cross-Channel movements have been recorded despite extensive ringing studies and no indication of gene flow has been found between English and European mainland colonies (Ransome 1991; Rossiter and others 2000a; Ransome 2008; Tournayre and others 2019).

This species is the primary qualifying feature of eight Special Areas of Conservation (SAC) in England and Wales and three where it is a qualifying feature. The majority of major maternity roosts and hibernacula are notified as Sites of Special Scientific Interest (SSSI).

2. Units

2.1 Natural range and distribution

Occupied hectads (10 km national grid squares) is the recommended metric for defining the favourable distribution of the greater horseshoe bat within its natural range in England, where ‘occupied’ excludes those hectads with records only of lone males or isolated records considered to represent unviable populations (although these records can be important in terms of tracing range expansion under climate change).

2.2 Population

The number of adult individuals.

2.3 Habitat for the species

Square kilometres (km^2). This metric has been used in red lists, Article 17 reporting and for range estimations.

3. Evidence

3.1 Current situation

Natural range and distribution

The current range of the greater horseshoe bat embraces 213 hectads.

The species' range is increasing in Britain (JNCC 2019a), with the recent discovery of bats breeding in areas of Herefordshire and the Tanat Valley in Powys, indicating a slight range extension to the north (Mathews and others 2018).

An increase in range may be due in part to climate change as the greater horseshoe is on the north-eastern edges of its British range around Herefordshire. Climatic conditions are a critical factor in survival and the annual growth rate of colonies has been found to be strongly correlated with spring temperatures and precipitation (see above) (Ransome & McOwat 1994; Ransome 1989; Froidevaux and others 2017). Increases in spring temperatures in past decades are likely to have facilitated northern range expansion. An increase may also be due to more effective protection and management of roost sites which, although aimed primarily at the more widespread lesser horseshoe bat (*Rhinolophus hipposideros*), may have also benefitted the greater horseshoe bat as it has similar roost requirements. Increased breeding success will also promote dispersal of young further afield.

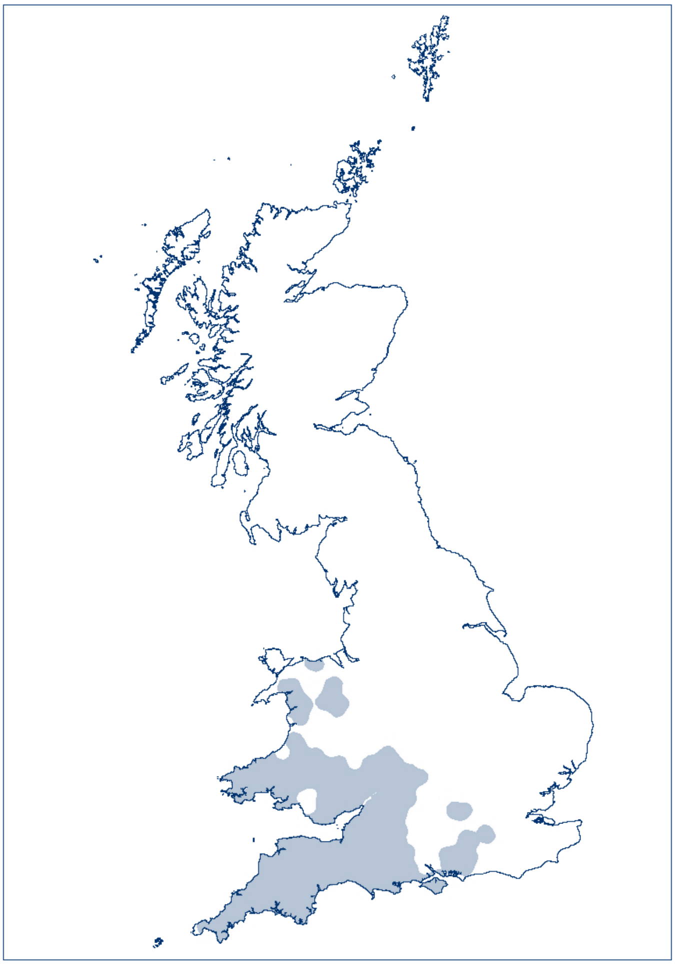

Figure 1 Current range (1995-2016) of the greater horseshoe bat in Britain. Areas that contain very isolated records 'may not' have been included in the area of distribution. Source: Mathews and others 2018.

Confidence: Moderate

Population

The current population of greater horseshoe bats in England is estimated to be 10,200 individuals with upper and lower 95% confidence intervals of 7,280 and 14,600. The population in Wales and Britain overall is 2,751 and 12,951 respectively (JNCC 2019b). These population estimates are based on colony size rather than inferences drawn from habitat associations. It is assumed that a high proportion of colonies are known as this species is well-studied and most maternity roosts are in buildings.

The population estimates above are slightly higher than those reported in the previous Article 17 report of 4746-7120 (JNCC 2013b) for England and 6226-9340 for Britain (JNCC 2013a) due to changes in methodology used and increased understanding of the species.

Other sources: Mathews and others 2018

Confidence: High

Habitat for the species

The current geographical range for greater horseshoe bats is estimated as 29,600 km^2 (Mathews and others 2018). The area of occupancy of greater horseshoe bats in England is 3,068 km^2 (Mathews & Harrower 2020) and this is taken as the area of supporting habitat.

However, the total area of *suitable* habitat is unknown, as the species depends on a matrix of habitats within a much wider landscape. Because of this uncertainty these estimates assume that suitable habitat is equivalent to the area of occupancy.

To obtain a more reliable estimate of suitable habitat used by the species, it would be necessary to first identify all of the foraging and roosting habitat located within the species' range and determine whether or not each of these features were being used; and subsequently calculate the combined area of all currently used habitats. This process would require very detailed habitat information at a fine scale across the UK. We do not currently have this level of information.

The 2019 Article 17 report states that as the population is increasing and the range is stable, the habitat can also be considered to be stable. There is thought to be a sufficient area and quality of occupied habitat for long-term survival of the greater horseshoe bat in Britain (JNCC 2019a, 2019b).

Confidence: Low

3.2 Historical variation in the above parameters

During the 20th century populations of greater horseshoe bats declined significantly in Britain. A decline of over 90% was suggested by Stebbings (1988), associated with a significant contraction in range, Although Stebbings's estimate of the scale of the decline is disputed (Ransome 1989) a marked decline has occurred throughout northern Europe over the last 100 years (Stebbings 1988).

The decline is likely to have been due to a number of factors:

Disturbance and loss of maternity roosts. The greater horseshoe bat is reliant on buildings with large open roof spaces for breeding. Such buildings are often derelict or semi derelict and may deteriorate further or be restored to the detriment of resident bats. A colony is very faithful to its roosts, which may be occupied for long historical periods. Female bats which gather in maternity roosts represent almost all of a breeding population for a considerable area. Loss of these roosts and the individuals within them through, for instance, persecution, development or fire will therefore have had a major impact on the local population.

Disturbance and loss of hibernacula. Greater horseshoe bats hibernate during winter in order to minimise energy expenditure when there is little or no food available. A large proportion of the population can concentrate into just a few underground hibernacula which can be subject to disturbance through recreation, change in use or destruction. Repeated unscheduled arousals may impact upon energy resources of individuals. Hibernacula, especially mines, may also be lost through infilling or capping, reducing roost resources.

Foraging habitat loss. Agricultural intensification has resulted in a decline in habitat heterogeneity through the conversion of many small, grazed pastures bounded by substantial hedgerows, into extensive arable fields, either without hedgerows or with small ones. These habitats are unsuitable for foraging bats or their movement through the landscape (Jones, Duverge & Ransome 1995). The conversion of broadleaved woodland to other less used habitats listed by Duverge (1996), such as conifer plantation, has also led to a loss of optimal foraging habitat, thus reducing the carrying capacity of the landscape. Froidevaux and others (2017) found that colony size was positively related to a range of landscape features (for example, amount of broadleaf woodland and grassland, and density of linear features) surrounding the roost, while the amount of artificial light at night had a significant negative effect. Greater horseshoe bats require a good supply of a specific range of insects throughout their reproductive season (Jones 1990; Ransome 1996; Ransome 1997), but especially in mid-summer when females suckle their young and late summer when young are first flying. Consequently, the loss of foraging areas, mainly due to agricultural intensification, has led to a drastic decline in western populations during the twentieth century (Stebbings 1988; Hutson and others 2001).

Increased use of pesticides. This has resulted in the loss of insect prey both directly by targeting the larvae of melolonthid beetles, noctuid moths and craneflies and also indirectly by use of anti-parasitic drugs (Avermectins) on livestock which drastically reduces the availability of dung feeding insects upon which this species depends. This in turn reduces the quality of foraging habitat. The application of pesticides, specifically lindane, used for the remedial treatment of timbers in bat roosts also resulted in the direct death of many large bat colonies, including the largest known colony of greater horseshoe bats in Dorset, due to its high toxicity to mammals and long-persistence on timbers in roosts (Mitchell-Jones and others 1989; Stebbings & Arnold 1987).

Prevailing weather conditions. Populations have dramatically declined over at least two periods in the UK since the 1950s, the first between 1962 and 1965 and the second between 1984 and 1986. On each occasion study populations fell by 50% or more. At two sites in the UK the number of young born annually fell from about 45 to 20 after 1986. Both crashes followed a series of severe winters, with abnormally prolonged cold periods, which continued well into spring. This delayed mean birth dates until late in July and led to poor growth of the young. There was high mortality of both mothers, who had little time to recover from lactation stress, and the young which had stunted growth. Both were also faced with cold September and October conditions which affected fat storage for hibernation. Recovery from such crashes can take 10 to 15 years given the slow reproductive rate and long period of immaturity of sub-adults. (Ransome & Hutson 2000).

Greater horseshoe bats have been the subject of a long-term conservation programme and are now considered to be increasing, with statistically significant increases indicated by the National Bat Monitoring Programme Roost Counts and Hibernation Surveys. The trend since the 1999 base year is a 220.1% increase at 110 hibernation roosts and 116.4% increase at 31 summer roosts in England and increases have been consistent throughout the monitoring period. This is equivalent to an annual increase of 6.3% for hibernation roosts and 4.2% for summer roost counts in England (Bat Conservation Trust 2019). However, a small number of sites where colony sizes have increased dramatically contribute a high proportion of the total monitored population (notably those in South Devon, which includes probably the largest known roost in Europe).

Natural range and distribution

In 1900, the limit of the range of the greater horseshoe bat was described as the line drawn from Aberystwyth in mid Wales to North London (Stebbings & Arnold 1987) and bats were found in and around London including Hampstead Heath and Regents Park (Mickleburgh 1988; Stebbings 1989). There are more recent records to the north of this line (Figure 2), but these are of lone males and, therefore, are considered unlikely to indicate the presence of viable populations. The species disappeared from Kent by about 1900, but a hibernating individual was located in the county in 2020, for the first time in over 100 years[3]. At the beginning of the twentieth century greater horseshoe bats were considered to be fairly numerous on the Isle of Wight (Millais, Rothschild & Wheler 1904-1906). They were also abundant in some parts of the south-west (Barrett-Hamilton & Hinton 1910-1921). The relative scarcity of fossil and sub-fossil remains in caves suggests the greater horseshoe was never more widely distributed or more abundant than the extent shown in Figure 2 (Yalden 1992).

Available records suggest that there has been a decline in range since historic times of approximately 20% (JNCC 2007), largely from eastern and central England and possibly North Wales. However, there are doubts about the quality of records from south-east England, which may not represent historic breeding populations.

[3] https://www.kentonline.co.uk/dover/news/rare-sighting-of-greater-horseshoe-bat-at-castle-is-first-in-a-century-240659/?cmpredirect

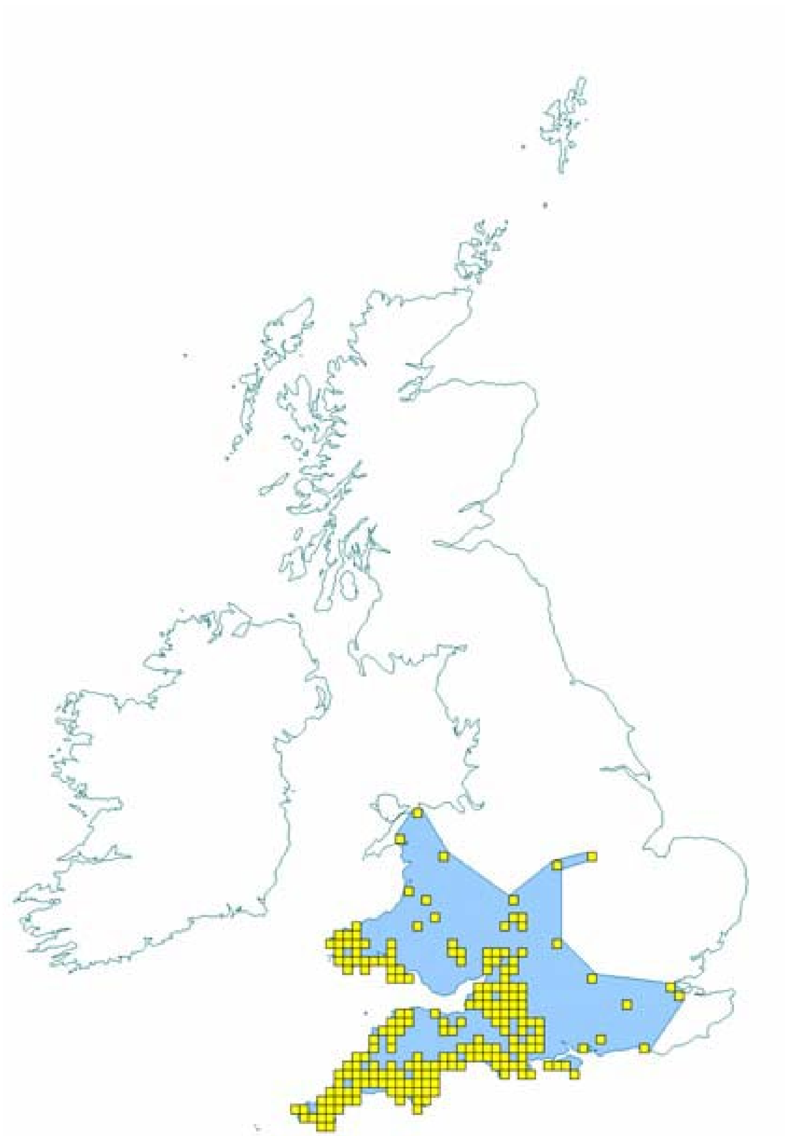

Figure 2 Historic extent of occurrence and occupied hectads (1900-2006). Source: JNCC 2007.

Population

In 1900 it is estimated there were 300,000 individuals in Britain (Stebbings & Arnold 1987), this estimate was based on an estimated earlier distribution of about 6,000,000 ha and a known bat density for one particular colony of 0.05 per ha. This estimate is based on a number of assumptions, many of which cannot be tested. In particular, the density at one colony may not be typical for the entire range. In optimum habitat the population density may have been considerably higher but there would also have been areas that were sparsely occupied (Harris and others 1995), therefore it is unlikely to be wholly accurate.

There were believed to be about 2,200 greater horseshoe bats in Britain in 1983 (Stebbings & Griffith 1986), 4,000 in 1993 (Hutson 1993) and a total pre-breeding population of at least 4,000, and possibly nearer 6,600 in 1995; in England 3,650 and in Wales 350 (Harris and others 1995).

The latter figures are likely to be an underestimate as some maternity roosts, each containing several hundred individuals, unknown at the time of the 1995 report, have since been discovered. Also, the sex ratios in the roosts were not considered which influences the final predicted population numbers.

Within England, there was a recorded loss of colonies and a large decline in populations between 1950 and the1980s to around 3,500–3,800 individuals.

A reduction in greater horseshoe bats in Dorset from 15,000 to 1,500 between 1953 and 1957 and then to 90 bats in 1986 was documented by Stebbings & Arnold (1987) after lindane poisoning of a major roost. However, in South Devon, Hooper & Hooper (1956) and Hooper (1983) studied 80 sites encompassing an area of approximately 3,000 km^2. The mean number of bats captured in hibernacula per year from 1948/9 to 1954/5 averaged 390 and no consistent trend in population size was evident over this period. In 1979 a coordinated search of 80 hibernacula in Devon found 304 bats, only three more than a count of 301 made in 1948 in the same area. In the Stroud area of Gloucestershire the estimated minimum total number of adult greater horseshoe bats was 162 over 1968/9, 129 in 1982/3 before falling to 65 in 1987/8 (Ransome 1989).

The large difference in counts between Devon and Dorset over a similar time period have caused Stebbings & Arnold’s (1987) estimate of 300,000 individuals in 1900 to be questioned (Ransome 1989).

Habitat for the species

There is considerable potential for the historical habitat area to have been greater than it is now given habitat changes through loss of woodland and agricultural intensification in the past 100 years. However, detailed information about the habitat area used historically by greater horseshoe bats is not available.

Other sources: Haines-Young and others 2000; Ransome & Hutson 2000; Robinson & Sutherland 2002; Stebbings & Griffith 1986.

Confidence: Moderate

3.3 Future maintenance of biological diversity and variation of the species

Climatic conditions are a critical factor in greater horseshoe bat survival and climate change is likely to have a significant impact on greater horseshoe bat populations in the next 50-100 years, as it may result in changes in the vegetation communities and insect populations the bats depend on. Preliminary predictive models generated for greater horseshoe bats based on climate and land use change projections, show increased suitability areas in the north of England and Scotland, but the south-east and east of England remain unsuitable (Razgour unpublished data). Other models also indicate conditions further north may become more favourable for greater horseshoe bats (Rebelo and others 2010), although this may be coupled with a loss in range from southern Europe as conditions become unsuitable. Warmer springs are expected to benefit populations (Froidevaux and others 2017; Ransome & McOwat 1994), but as this species is at the northern limit of its distribution, it remains vulnerable to extreme climatic events. An increase in spring temperatures since 1987 is likely to be a significant factor in the increases in British populations. However, summer droughts can delay the emergence of *Aphodius rufipes* and this dung beetle species is a critical dietary item for juvenile greater horseshoe bats when they first begin to forage (Ransome 1996). Body condition of juvenile greater horseshoe bats fell during the foot and mouth disease outbreak, which was likely linked to a reduced availability of *Aphodius* sp. due to livestock slaughter (Ransome & Priddis 1995). Elsewhere there is concern for smaller colonies, which appear particularly vulnerable to the impact of adverse weather conditions on reproductive output.

Greater horseshoe bats remain vulnerable to disturbance and loss of maternity roosts and hibernacula. However, protection through legislation has helped mitigate against the adverse impacts to roost structures. If the population increases to recover some of its losses a limiting factor could be the availability of new suitable roosting opportunities, given their exacting requirements, and availability of optimal foraging habitat.

The use of pesticides in roosts is now limited and any resulting adverse effects on populations should have ceased. However, the use of antiparasitic drugs in cattle and sheep, the residues of which have harmful effects upon insects that breed in dung, does have conservation implications for greater horseshoe bats and needs to be carefully monitored (Ransome 1996).

Greater horseshoe bats are extremely light shy and artificial lighting potentially severs commuting routes and delays emergence time from roosts (Boldogh, Dobrosi, & Samu 2007; Stone, Jones & Harris. 2009). Roads also pose a risk both through causing a barrier to dispersal through light, noise or fragmentation of habitat (Finch and others 2020b) or direct mortality through collision with vehicles (Fensome & Mathews 2016). The interruption of a flyway by light disturbance, as with physical removal or obstruction, forces them to find an alternative route which is likely to incur an additional energetic burden and could therefore be a threat to the viability of the bat colony. In some circumstances, an alternative route is not available and can lead to isolation of the bat population from key foraging areas and/or roosts.

The British population of greater horseshoe bats is now very fragmented. Analysis by Rossiter and others (2000a) showed that Welsh populations of greater horseshoe bats are genetically isolated and have relatively low genetic variation. Tournayre and others (2019) found that there is no genetic exchange between continental and British greater horseshoe bats and those greater horseshoe bats in Britain (and the very north of France) are more inbred and potentially at higher extinction risk, because of genetic drift, low gene flow, and small effective population size. These colonies located at the edge of the species range are also genetically divergent and may harbour some genetic and phenotypic variability that could be important for adaptation to climate change (Lesica & Allendorf 1995). However, Razgour and others (2018) found that populations of the grey long eared bat (*Plecotus austriacus*) at the northern (colder) edge of its range were already adapted to cooler conditions, and therefore maladapted to future changes, which may also be the case for greater horseshoe bats. Thus, the English colonies and others at the edge of the species range are more vulnerable to extinction and need particular management effort.

Previous work has shown there is limited gene flow among colonies within Britain and provided evidence of inbreeding depression (Rossiter and others 2000a, Rossiter and others 2007). As such, these colonies have reduced genetic diversity which may limit their evolutionary potential, in particular in relation to environmental changes. This highlights the importance of facilitating gene flow between colonies to maintain population health. Colonies should be linked by suitable habitat to address the problem of populations becoming fragmented and at risk of genetic drift, as has occurred in Wales (Rossiter and others 2000a). If the distance between two maternity roosts exceeds about 150 km, and there are no other colonies between, it is unlikely that adult males from one colony would be able to meet females from the other, so gene-flow between them would cease (Ransome & Hutson 2000). In England the distance between all known individual maternity roosts is less than 150 km, although there may be unknown barriers to dispersal between some roosts. The risk of inbreeding through loss of mating roosts is also of particular concern, especially as so few mating roosts are known (Rossiter and others 2001). Colony size is attributable to landscape features such as broadleaf woodland, grassland and linear features such as hedgerows (Froidevaux and others 2017), therefore changes in land use resulting in the loss or modification of these features or changes in vegetation cover and composition under climate change could also be expected to impact on population size.

Natural range and distribution

In order to increase resilience in the population to changing ecological circumstances, such as climate change, the current range and distribution should be maintained and increased.

An exercise was undertaken by Natural England to determine the likely maximum potential range for greater horseshoe bats based on climatic and habitat requirements. Geographic

Information for the following criteria were overlain and hectads where all the criteria were met were identified as the potential range. A full method is attached at Appendix 1.

Climate – Meteorological Office climate districts with temperature averages of at least 9.4°C in April and May from 1970 to 2019. East, north-east and north-west England and north Wales did not meet this threshold.

Natural England's Landscape Description Units with likely suitable habitat present. Two Description Units - Urban areas and Open/unenclosed land - were excluded as unsuitable habitat for greater horseshoe bats.

British Geological Survey solid geology data with either limestone or mineral veins present, which may indicate the likelihood of underground features.

The resulting map (Figure 3 below) indicates a maximum potential range of 445 hectads across England. Historic and current records from the Institute of Terrestrial Ecology and the National Bat Monitoring Survey have been added to indicate current range.

This analysis is relatively rudimentary and may over-state the species' potential range. The climate data is for whole climate districts and the Landscape Description Units do not necessarily indicate habitat suitable for greater horseshoe bats. Also, areas that are discrete, indicating isolated pockets of suitability, may not be accessible. However, there are also some areas, such as central Devon and Somerset, where greater horseshoe bats are present but are not indicated as suitable on the map. Despite these limitations, there is clearly scope for range expansion, particularly to areas that formed part of the species' historic range.

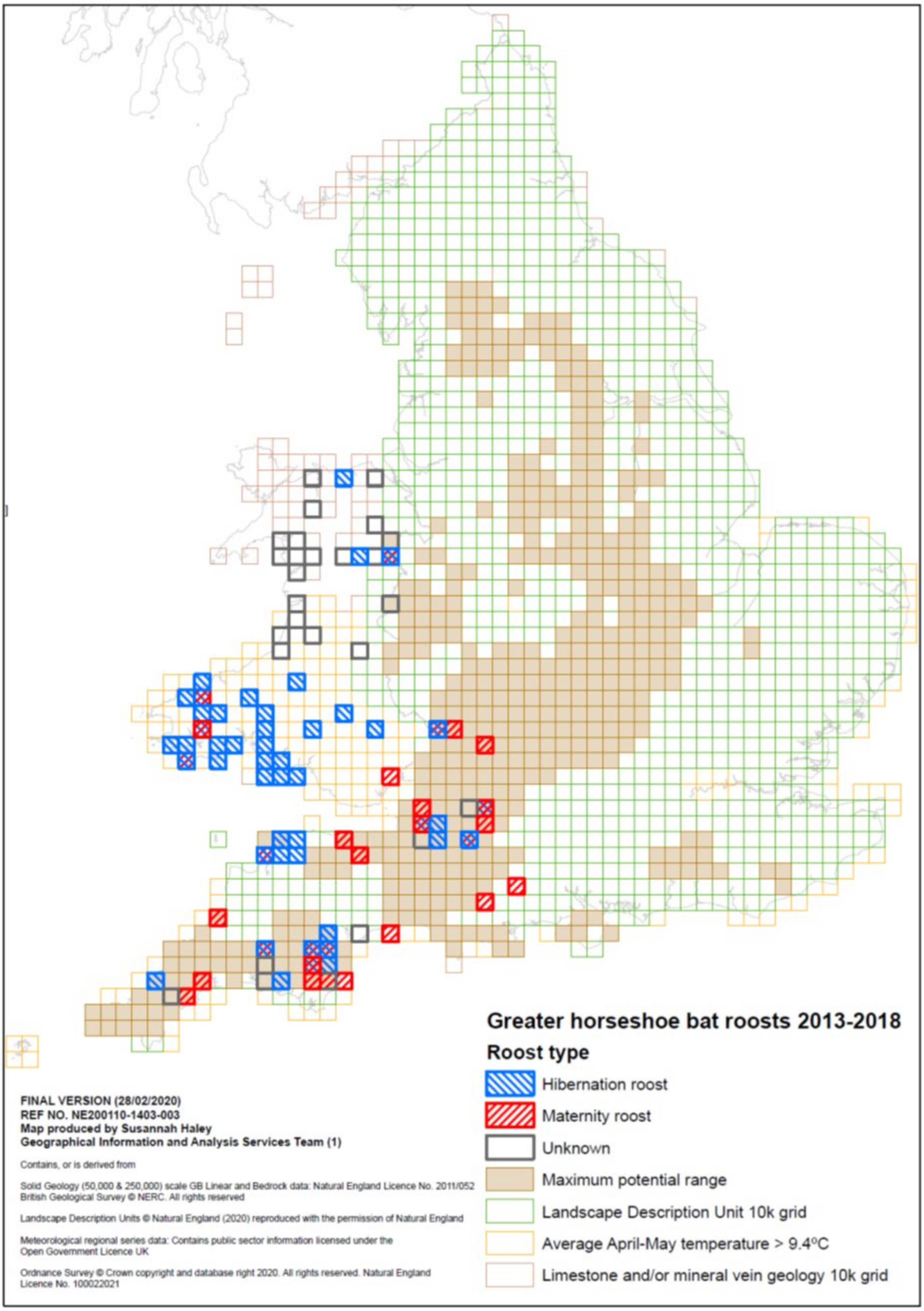

Figure 3 Maximum potential range of greater horseshoe bat. Greater horseshoe bat roosts 2013-2018. © Natural England, 2020.

Population

The current population of 10,200 individuals in England is considered to be large enough for the population to be viable, but it is not necessarily favourable, given the scale of historical losses. The current population is also increasing, suggesting that it has not yet recovered from historical losses and reached carrying capacity. Given the contraction in range and the pressures and threats that may impact upon greater horseshoe bats in the future, a favourable population should be at a level which will be resilient to future changes and reverses historical losses of the species.

However, caution must be taken in using the historical population estimate (300,000 as stated above) as a base to set the current favourable level given the considerable uncertainties surrounding these figures.

Therefore, two different methods have been considered to derive a favourable population level.

Assuming one viable colony present within each hectad of the favourable range and distribution.

A viable colony is one that is capable of resisting a future climate-induced population crash, after which only 50% of the bats may be alive. Colonies represent breeding females, their immature offspring and adult males which may be distributed across several roosts in an area. Ransome & Hutson (2000) concluded that a colony of about 200 bats, producing 45 to 60 births per year appears to be viable in the long term, and should be the target level for each colony. Alongside this there needs to be landscape scale connectivity between colonies to ensure sustained dispersal and gene flow.

Density of colonies varies across the landscape in relation to favourable habitat and roosting opportunities. Although the core sustenance zone surrounding a greater horseshoe bat roost is 3 km, as mentioned above, greater horseshoe bats need a myriad of roosting and foraging opportunities at a landscape scale. Therefore, one viable colony per hectad is deemed a proportionate density.

The range map above (Figure 3) shows 445 potentially suitable hectads across England. A viable colony is 200 bats so multiplying 200 by 445 gives a favourable population estimate of 89,000 individuals including juveniles. As our unit is for adult individuals, removing juveniles from the colony figure presents a total of 62,300 adult bats (200-60*445).

Using the matrix developed by Natural England’s Defining Favourable Conservation Status project (Mousley & Van Vliet 2021).

The matrix has been applied to provide a figure for the favourable population based on restoration of a set proportion of the historical population loss.

The following assumptions were applied to the calculation:

The population declined by approximately 296,500 from about 300,000 individuals to approximately 3,500 individuals.

The species is Least Concern in England but is not common and widespread.

The species has high biodiversity importance in a UK and international context.

There is good potential to reverse the historical loss.

Applying the above assumptions to the matrix results in a figure of restoration of 30% of the population loss. That is 0.30 x 296,500 = 88,950 individuals. Increasing the population nadir of 3,500 individuals by 88,950 results in a favourable population of approximately 93,000 individuals for England. The figure is rounded to reflect the uncertainties in the data.

Given the uncertainties over the historical population estimates, and the arbitrary nature of the matrix approach, it is proposed that the first method is used to provide a favourable population level of 62,000 adult bats. The figure is rounded to reflect the uncertainties in the data.

Other sources*:* JNCC 2013b; Mathews and others 2018.

Confidence: Low

Habitat for the species

The area of suitable habitat will need to increase to support the proposed increase in range and population and ensure colonies do not become isolated. To give a figure for the favourable area it is proposed to increase the current area (3,068 km^2) in line with the increase proposed for favourable range. The favourable range is 109% greater than the current range. Therefore, the favourable area of supporting habitat is proposed as 6,500 km^2 (figure rounded).

3.4 Constraints to expansion or restoration

The greater horseshoe bat is one of the best studied species in England and has been the subject of a long-term conservation programme, which has ensured that roosts are in good condition and that foraging areas are improving. There are strong indications of a population increase suggesting that these measures have had a positive impact, although the species remains vulnerable to adverse weather conditions and lowered genetic diversity.

Greater horseshoe bats require secure, suitable roosts and insect prey provided by surrounding pasture/deciduous woodland habitat that is managed favourably. Restoration and creation of such habitats is technically feasible. In order to increase the current populations in England there would need to be continued favourable improvements in habitat management to promote and protect dark areas for foraging and commuting and continued legislative protection to protect roosts alongside measures to enhance and create new roosts and ensure landscape connectivity to facilitate range expansion and link populations.

Climate change is predicted to result in an expansion of the suitable range to the north. Any northward range expansion would need to be facilitated by improving landscape connectivity and suitability for the species. It is however worth noting that matching phenology with future climatic conditions will constitute one of the main pressures for bat populations, especially for example if temperature-driven gestation times become out of synchrony with food abundance (Parmesan & Yohe 2003). Range overlap between species is another consideration as interspecific competition is likely to play an important role in limiting species' future ranges (Razgour and others 2019).

Greater horseshoe bats have quite specific roosting requirements, particularly for hibernation. Therefore, the distribution of the principal cave forming rock, limestone, in conjunction with mineral seams (and hence mines) will have a significant impact on where viable populations of greater horseshoe bats can survive. Although other underground features are used such as unheated cellars, icehouses and caves, it is unlikely such features would be numerous enough and offer the variety of conditions required over hibernation to support greater horseshoe bats in the absence of caves and mines. Therefore, parts of the country where features for hibernation are limited are unlikely to be successfully colonised by greater horseshoe bats.

The other member of the family *Rhinolophidae* occurring in Britain is the lesser horseshoe bat which has similar roost requirements, but habitat needs vary and they have different prey requirements. There is no published evidence that these two species compete directly for roosts, although anecdotal records do exist showing that lesser horseshoe bats will vacate a roost or move to another part of the building if greater horseshoe bats also start to roost in that building, whilst other anecdotal records show both species sharing without changes in behaviour and use. To protect lesser horseshoe bat roosts baffles have been placed over some roost entrances that prohibit entry by the larger greater horseshoe bat (Roger Ransome pers. comm.) but until evidence is available this should only be considered on a case-by-case basis.

The serotine bat (*Eptesicus serotinus)* has a considerable dietary overlap with the greater horseshoe bat and also utilises buildings for maternity roosts, although serotine will use crevices inaccessible to greater horseshoe bats. Therefore, it is possible there may be some ecological competition between the two species, but there is no evidence to suggest this currently.

Habitat measures undertaken to improve habitat for greater horseshoe bats would also be expected to benefit a wide range of other wildlife, including many other bat species (Ransome & Hutson 2000).

Confidence: Moderate

4. Conclusions

4.1 Favourable range and distribution

The natural range for the greater horseshoe bat when in Favourable Conservation Status is considered to be 445 hectads in England.

4.2 Favourable population

The favourable level for the population in England should be set at approximately 62,000 individuals in England. Colonies should contain at least 200 bats and maternity roosts should be no further than 150 km apart with no major barriers to dispersal between them.

Greater horseshoe bat roosts can be measured and monitored through the existing National Bat Monitoring Programme (Bat Conservation Trust 2019) which provides long term standardised monitoring for this species. Any newly discovered maternity or hibernation roosts which are not currently part of the scheme should be included.

4.3 Favourable supporting habitat

The area of supporting habitat for the greater horseshoe bat should be no less than 6,500 km^2 to ensure sufficient habitat is available to the species. This value has been increased in line with the favourable range.

It is recommended further study is undertaken to investigate the availability of suitable habitat within the range. Habitat should be measured by land cover data.

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Appendix 1 Methodology for determining maximum potential range for greater horseshoe bat

Parameters required for greater horseshoe bat:

Average temperature April-May to be above 9.4ºC

Favour caves for hibernation, so underlying geology to be limestone and mineral veins

Foraging: woodland, pasture, particularly cattle-grazed pasture.

Climate

The mean temperature for the combined months of April and May should not fall below 9.4ºC in order for greater horseshoe bats to breed successfully (Ransome & McOwat 1994).

Averages for districts were obtained for the past 10 years from Met Office open access data. East, North East and North West England and North Wales were ruled out as they were right on the limit of 9.4ºC. Given that the weather data were averages for districts, it was considered more appropriate to remove them from the analysis.

Mean Apr-May temperature above 9.4ºC

Data downloaded as text file for each MO climate district, from MetOffice data download site.

April and May temperatures extracted to spreadsheet.

Temperature data from pivot table mapped to MetOffice Climate districts shapefile (downloaded), then intersected with OS 10k grid to derive layer

1. MetOffice_climatedist_AprMay_94C_10k_grid_FINAL

Key habitats

Land use data for pastures with cattle (either single/mixed stock), ancient semi-natural woodland and pastures with non-cattle stock

Landscape Description Units data used

All land classes were used except Urban and Open/unenclosed land.

Land classes used were: Trees and woods – general cropping; Trees and woods – dairying; Trees and woods – mixed farming; Trees and woods – stock rearing; Trees – arable – general cropping; Trees – arable – mixed farming; Trees - arable – market gardening; Trees – pastoral – dairying; Trees – pastoral – mixed farming; Trees – pastoral – stock rearing; Secondary woodland – general cropping; Secondary woodland – dairying; Secondary woodland – mixed farming; Secondary woodland – stock rearing; Secondary woodland – rough grazing; Ancient woodland – general cropping; Ancient woodland – dairying; Ancient woodland – mixed farming; Ancient woodland – stock rearing; Ancient woodland – rough grazing;

These were then intersected with OS 10k grid to derive layer

2. LDU_LDU1_NE_exc_Ur_Or_CHowe_SMousley_10k_grid_FINAL

Geology

Potential to form caves (such as carboniferous limestone) or where mineral veins are present indicating the likelihood of mines.

Layers used M:\Geo-Data\Geology_Soils\Solid_Geology_BGS

Solid Geology (50,000 scale) GB - Linear © British Geological Survey selection

Field FEATURE_D = Mineral vein, inferred or Mineral vein, observed

Solid Geology (250,000 scale) GB - Bedrock © British Geological Survey selection

Field RCS_D = LIMESTONE, LIMESTONE and CONGLOMERATE, LIMESTONE and MUDSTONE (UNDIFFERENTIATED), LIMESTONE and SANDSTONE (UNDIFFERENTIATED), LIMESTONE and SILICICLASTIC ARGILLACEOUS-ROCK, LIMESTONE and SILICICLASTIC ARGILLACEOUS-ROCK with SANDSTONE (UNDIFFERENTIATED), LIMESTONE, DOLOMITIC and DOLOSTONE, SILICICLASTIC ARGILLACEOUS-ROCK and LIMESTONE

These were then intersected with OS 10k grid to derive layer

3. solid_geology_geology_BGS_10k_grid_FINAL

Historic and current records from NBN database and the National Bat Monitoring Survey were also used to indicate current range

NBN download 20191209

Bat roost data covers Wales so this is shown in Roost type layer

Maximum potential range derived from the three overlaps of each 10k grid

Count of the total number of squares (known and potential) in England = 445

About Natural England

Natural England is here to secure a healthy natural environment for people to enjoy, where wildlife is protected and England's traditional landscapes are safeguarded for future generations.

Further Information

This report can be downloaded from the Natural England Access to Evidence Catalogue. For information on Natural England publications or if you require an alternative format, please contact the Natural England Enquiry Service on 0300 060 3900 or email enquiries@naturalengland.org.uk.

Citation

Claire Howe. 2023. Definition of Favourable Conservation Status for Greater horseshoe bat (*Rhinolophus ferrumequinum*). RP2963. Natural England.

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Catalogue code: RP2963

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