The Bernwood Population of Bechstein's Bats

A Non-Technical Summary of the Evidence

June 2024

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Finally, Natural England would also like to thank the authors, for distilling the detailed monitoring evidence so clearly and succinctly in this report.

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Foreword

Natural England is reviewing the SSSI designations at Bernwood, Buckinghamshire. Bernwood is a largely agricultural landscape of woodlands, pastures and ancient hedgerows situated between Bicester and Aylesbury. Natural England are looking to expand the existing SSSI designations to protect Bechstein's bat maternity colonies known to be present in the area and also to notify for habitat and invertebrate interest. As part of this work Natural England has collected detailed monitoring information over several years, recording how Bechstein's bats are using the landscape at Bernwood. Natural England commissioned this report to provide a non-technical summary of that evidence.

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Executive summary

A single male Bechstein's bat recorded in 2009 in south Buckinghamshire represented the first record for the county. Surveys in the Bernwood area during 2010 confirmed the county's first breeding population and led to significant research and field surveys that were completed between 2011 and 2022. This Non-Technical Summary simplifies and explains the subsequent data, particularly how Bechstein's bat use the Bernwood area, why the area is important for the species and why this Bechstein's bat population is important to the future of the species in the UK.

Bechstein's bat is one of the UK's rarest bats. The species' core range is in southern England from Gloucestershire to Sussex, although breeding individuals have been recorded as far north as Herefordshire and Worcestershire. It is highly reliant on old-growth deciduous, oak-dominated, semi-natural woodlands that are often greater than 25 ha in extent. Such woodland was once common across the UK but is now very uncommon. The current population of Bechstein's bat in England has been estimated at 21,600 individuals. However, it has also been estimated that given the extent of suitable habitat in England, the favourable population of Bechstein's bats should be 28,000. Bechstein's bats in England are, therefore, not in a favourable conservation status.

The Bernwood area comprises a cluster of 12 deciduous, oak-dominated woodlands and numerous associated copses in Buckinghamshire. The intervening farmland is dominated by pasture, with some arable and is well connected by hedgerows, tree lines and riparian habitats including watercourses and ponds. Four of the woodlands have previously been designated as Sites of Special Scientific Interest (SSSI) for ancient woodland and their invertebrate assemblages. The eight remaining woodlands are Local Wildlife Sites.

Bat trapping and radio-tracking surveys between 2011 and 2022 identified a single population of Bechstein's bats that comprised at least three breeding colonies. The three breeding colonies are centred on three woodlands currently designated as SSSI; Finemere Wood SSSI, Grendon and Doddershall Woods SSSI and Ham Home-cum-Ham Green Woods SSSI. Approximately 20% of the 57 maternity roosts recorded were, however, located outside the existing SSSIs and supported a greater average number of bats than the maternity roosts located within the SSSIs. Comparison between the bat numbers in maternity roosts within and outside of the existing SSSI woodlands demonstrates that the roosts outside the SSSI are extremely important for the healthy functioning of the Bernwood Bechstein's population.

Using the data collected over the 12 years of field surveys, it is estimated that the Bernwood population of Bechstein's bats is approximately 300 individuals, which represents 1.4% of the population in England. It is one of the largest known populations in England and is at the northern edge of its UK distribution, and its European range. The data confirms that the population is stable and viable. However, the reduced genetic diversity and higher levels of inbreeding confirmed through genetic research confirms that

the population is genetically and geographically isolated. The nearest known maternity population is approximately 50 kilometres to the south-east.

The data confirms that Bechstein's bat maternity colonies use multiple roosts throughout the breeding season. Bats from all three colonies regularly moved between different roosts and were frequently recorded foraging and roosting in the same habitat. The evidence illustrates that bats from each colony shared woodlands but that they never shared or swapped roosts. Each roost remained unique to each colony. This behaviour indicates the presence of one interacting population comprising three colonies rather than three separate populations.

The home range and Core Sustenance Zone (as detailed on page 26) for the Bernwood population extends far beyond these discrete woodland blocks and currently existing SSSI boundaries. Bechstein's bats were recorded commuting, foraging and roosting several kilometres away. The 12 woodlands comprise a small percentage of the total area of the Bernwood population home range (5.8%) and Core Sustenance Zone (4.5%).

The survey data demonstrated that all 12 woodlands in the Bernwood area are important core foraging habitat. While the bats generally preferred to forage in and around the woodlands close to their maternity roosts, they frequently fed throughout the Bernwood area. For example, both the Finemere Wood SSSI colony and the Grendon and Doddershall SSSI colony foraged regularly and together within Sheephouse Wood, Decoypond Wood, Romer Wood and Greatsea Wood.

Bechstein's bats also foraged regularly along natural, vegetated linear features. The linear features provide connectivity for bats to move between their roosts and their core foraging habitat. The hedgerows, tree lines, watercourses and intervening agricultural land are therefore important foraging resources in their own right, and vital in supporting the resilience of the Bernwood population.

The faecal DNA analysis of Bechstein's bats at Bernwood confirms that approximately two-thirds to three-quarters of their diet comprises invertebrate prey associated with woodland. The remaining quarter to a third comprise species associated with open habitats or wetland habitats. The research illustrated that every woodland within the Bernwood area, including those not currently designated as SSSI, and the intervening pasture and arable habitats are integrally important to the vitality and reproductive success of the Bernwood population.

Bechstein's bats are rare in the UK and while the population in the Bernwood area is large, it is genetically and geographically very isolated. The population is therefore vulnerable to continual expansion of built developments, habitat fragmentation and loss, uncoordinated land management and the effects of climate change. The Aylesbury Link Railway Line passes through the Bernwood area, and the Calvert Landfill Site and Energy from Waste facility are immediately south of the railway. HS2 Phase 1 is being constructed parallel to the Aylesbury Link Railway and other developments are proposed. The population is vulnerable and the effects of local land use change, differing land management techniques

and climate change are being felt already. In order for the Bernwood population to develop resilience to these pressures, it will be important to ensure that the habitat requirements of Bechstein's bats are put to the forefront in the future planning and management of the various woodland blocks and connecting commuting corridors within the Bernwood area.

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Overview

Natural England is considering the notification of a Site of Special Scientific Interest (SSSI) for a population of Bechstein's bat in Buckinghamshire. The population inhabits areas of ancient woodland and surrounding habitat in the Bernwood area, approximately five miles east of Bicester.

A proportion of the area is already notified as four separate SSSIs, and will, with additional habitats used by the Bechstein's bat population for roosting, foraging and commuting, form part of a single new, larger SSSI. The existing SSSIs are notified for ancient woodland and invertebrates. The new SSSI will be notified for its Bechstein's bat maternity colonies as well as the ancient woodland, semi-natural deciduous woodland, lowland wet meadow grassland, the Black Hairstreak butterfly and other invertebrate interest.

The population of Bechstein's bats in the Bernwood area is at or very close to the northern edge of the species' current UK distribution, and its European range. It is one of the largest known populations of Bechstein's bats in the UK and is located at least 50 kilometres to the north-west and at least 60km to the north from the nearest known breeding population. The population is genetically isolated (Wright *et al.* 2018), although stable. However, the landscape is changing, largely as a result of local development but also different land management regimes and potentially climate change.

A single male Bechstein's bat was recorded in 2009 in south Buckinghamshire and represented the first record for the county. Surveys in 2010 confirmed a breeding population in the Bernwood Forest and justified a significant increase in research and surveys from 2011. A large amount of the data is now available and continues to be collected but given its volume it can be difficult to understand and interpret. The research and data collection was not systematically planned for any one reason. The purpose of the surveys changed each year, the methods utilised, and the survey locations varied, and the data was collated in multiple formats, including written reports, geo-spatial data, thermal imaging files and audio recordings.

This Non-Technical Summary summarises the evidence enabling the technical data and the subsequent analysis and conclusions to be readily accessible. This Non-Technical Summary explains how Bechstein's bat use the Bernwood area, why the area is important for the species and why this Bechstein's bat population is important to the future of the species in the UK.

Bechstein's Bat Ecology

Bechstein's bat *Myotis bechsteinii* is a medium-sized European bat species belonging to the Vespertilionidae family. The species' is long-lived with some individuals exceeding 20

years of age. Its range includes much of Europe, from the United Kingdom and Spain in the west to Greece and Poland in the east.

Bechstein's bats prefer old-growth woodland, which has been subject to significant decline in the recent past. Suitable woodland, including ancient woodland, is today limited in extent, isolated and fragmented. Despite the species natural range across Europe, the species is often restricted to isolated woodlands. There is very little information on the population trends of Bechstein's bat, but it is understood that the species is declining, largely because of the loss, degradation and severance of suitable woodland. Human disturbance and potentially climate change may compound these affects.

During the summer, female Bechstein's bats form maternity colonies within natural cavities in old deciduous trees, usually oak trees. Maternity colonies are groups of females that roost together to give birth and raise their young. Female Bechstein's bats have one pup per year but they don't necessarily breed every year. Colonies tend to move roosts every few nights and can use up to 60 different tree roosts throughout the breeding period (Natural England, 2023). Bechstein's bat maternity roosts usually number between 15 to 50 individuals, although roosts comprising up to 90 bats have been recorded. There is increasing evidence that females frequently select mature oak trees situated in hedgerows or isolated in arable fields during the summer, outside but close to woodlands. It is believed that Bechstein's bats may preferentially select exposed trees over sheltered trees in woodlands, as the internal micro-climate will be warmer, ideal for raising young. Male Bechstein's bats tend to roost alone or in small groups and frequently stay in the same roost for two weeks or more. Unlike the females, males often roost in younger trees or small woodlands.

Bechstein's bats forage for insects during the night and usually along woodland edges. Bechstein's bats rarely fly more than 1.5km to feed and in good habitat, such as the Bernwood area, they tend to forage within 300m of their roost. Foraging is primarily associated with the same woodland habitats within which they roost. Bechstein's bats also forage while flying between locations and therefore also depend on hedgerows, tree lines, watercourses, ponds and open habitat when searching for prey.

During the winter Bechstein's bats hibernate in hollow trees and in underground shelters, but little is known about their hibernating ecology.

Bechstein's Bat – Conservation Status and UK Context

The International Union for the Conservation of Nature (IUCN) predicts that the species' population at a global level has declined approximately 30% during the past 15 years. Consequently, the IUCN categorises the Bechstein's bats as Near Threatened. Near Threatened describes species that are close to qualifying for or likely to qualify as Vulnerable, Endangered or Critically Endangered in the near future.

Bechstein's bat is included on the list of habitats and species of principal importance in England. The list enables public bodies to be aware of biodiversity conservation in their

policy or decision making and supports nature recovery. Publishing the list is a legal duty under Section 41 of the Natural Environment and Rural Communities (NERC) Act.

Bechstein's bat is one of the UK's rarest bats. It is highly reliant on deciduous, oak-dominated, semi-natural woodlands that are often greater than 25 ha in extent, comprise a diversity of tree ages, a well-developed understorey and a diversity of vegetative structure (Natural England, 2023).

In the UK, the Bechstein's bat's core range is in southern England from Gloucestershire to Sussex, although breeding individuals have been recorded as far north as Herefordshire and Worcestershire (Natural England, 2023), see **Figure 1**. The current population of Bechstein's bat in England has been estimated at 21,600 individuals, with a confidence interval of 10,200 - 55,000, (Natural England, 2023). This figure is entirely derived from expert opinion and informed by data from 75 roosts using parameters such as roost size, sex ratios and roost density to estimate population size within the perceived species range (Natural England, 2023). The population size is therefore an estimate only.

A separate assessment (Natural England, 2023) estimated what the favourable population of Bechstein's bats in England should be given the extent and condition of suitable habitat. Habitat suitability modelling assessed the species' natural range and distribution, the estimated population and the extent and quality of habitat necessary for the long-term maintenance of the species. The assessment concluded that the favourable population size in England would be 28,000 individuals. This estimate is approximately 6,400 individuals greater than the current estimated population. Based on a comparison between the current population estimate and the favourable population size, Bechstein's bat is not in a favourable conservation status. Favourable conservation status is the situation when the species can be regarded as thriving in England and can be expected to thrive sustainably in the future.

The population in England is currently assessed as Least Concern (Mathews & Harrower 2020). This is largely because there is no evidence of recent declines in population and no evidence of a contraction in range. Rather, there has been a consistent increase in the number of records, which is likely due to increased survey effort and the growing use of tools such as acoustic lures. Therefore, the Least Concern assessment should be treated with caution.

Data Validity

The data used to inform this Non-Technical Summary was collected over a twelve-year period between 2011 and 2022. From 2012, most of the data was collected on behalf of HS2 Limited and as such, the objective, or objectives, for the surveys evolved annually. The data requirements were very different in the earlier years for HS2 when the project was being designed, compared with the requirements in later years when construction was commencing. The technical teams however, including the Bechstein's bat specialists leading the surveys remained consistent between 2012 and 2020. Professional and

independent consultant bat workers were always employed and worked closely with Natural England. All work was completed within Natural England's licencing requirements for bat field work.

Field surveys comprised radio tracking surveys, emergence surveys, bat filming emergence surveys, static surveys, crossing point surveys, thermal imaging surveys, infra-red surveys, tree climbing surveys, the ringing of bats, and faecal DNA analysis. Not all survey types were used every year and some years comprised very little field work. Surveys during 2012 and 2013 sought to identify important roosts, map core foraging areas and commuting routes, and understand the likely population size. Access was not always possible to the SSSI woodlands in these years and where breeding female Bechstein's bats were captured outside these woodlands and roosting within, a precautionary approach was adopted, where the presence of breeding roosts were assumed present. These roosts have been included within this summary. Access was made available to all woodlands from 2014 onwards. Fewer surveys were completed between 2015 and 2017 when the HS2 Act was being passed through Parliament. Surveys during 2017 and 2018 were used to define a baseline against which all future surveys could be compared. The purpose of the surveys in 2018 and 2022 were largely informed by and aligned with the construction programme and its locations.

Survey success was occasionally affected by inclement weather, access permissions, unplanned activities such as nearby shooting events, and equipment failure. The survey methodologies, including the frequency of the surveys and the number of surveyors or surveyor devices were often designed to compensated for unexpected failures or survey abortions. No surveys were planned or completed during the winter months so data on hibernation or potential hibernation roosts is not available.

Despite the varying survey objectives and difficulties with survey consistency across a twelve-year period, the data used to inform this Non-Technical Summary is valid. Data validity is partially ensured through the number of repeat surveys. Twelve years of surveys are more than sufficient to identify broad trends and compensate for the occasional inaccuracy or error. The data was also routinely reviewed and analysed by Bechstein's bat experts, consultant bat workers and Natural England. It is evident therefore that the broad conclusions drawn in 2012, 2013, 2014, 2015 and 2016 are consistent with the surveys completed between 2017 and 2018 and subsequently with the 2022 surveys.

The Bernwood Area

The Bernwood area is part of the former Royal Hunting Forest of Bernwood, which during the 12th century comprised 400km^2 of woodland across Buckinghamshire and Oxfordshire. The remaining areas of woodland 'the former Bernwood Forest' consists of areas of Ancient and Semi-Natural and Planted Ancient Woodland Sites that extend for approximately 21km from the northeast of Oxford to approximately 7km southwest of Wilmslow, south of the village of Calvert.

The Bernwood area, which is the subject of this Non-Technical Summary, is immediately north of the A41 and is the most north-easterly part of the former Bernwood Forest. It is located between Quainton and Calvert, Buckinghamshire and includes 12 separate woodlands, of which four are SSSI, and are summarised below. The remaining eight woodlands that are not SSSI's are all designated as Local Wildlife Sites.

To the southwest, between the A41 and M4 are several comparatively widely spaced ancient woodlands including Rushbed Wood and Railway Cutting SSSI. The largest and most contiguous constituent woodlands are between Oxford and the M4. They include Shabbington Wood Complex SSSI (the largest relict of the former Bernwood Forest), Waterperry Wood SSSI, Holly Wood SSSI, Holton Wood SSSI and Stanton Great Wood SSSI.

The 12 woodland blocks in the Bernwood area, see **Figure 2**, have a combined extent of 348 ha. They consist of semi-natural and planted ancient woodland, all of which is Lowland Deciduous Woodland Priority Habitat[1] that is situated in a largely agricultural landscape. The Aylesbury Link Railway Line passes through this area, and the Calvert Landfill Site and Energy from Waste facility are immediately south of the railway. The topography of the Bernwood area is gently undulating with areas approximately 110-120m above sea level (ASL)) in the northeast of the area giving way to lower lying areas, approximately 70-20m ASL to the centre and southwest of the area.

Nine of the 12 woodland blocks comprising Finemere Wood, Runts Wood, Balmore Wood, Greatsea Wood, Romer Wood, Home Wood, Sheephouse Wood, Decoypond Wood and Shrubs Wood are to the north of the railway. The average minimum distance between these woodland blocks is approximately 350m. The three remaining areas of woodlands comprising Grendon and Doddershall, Ham Home-cum-Ham Green Woods and Hewins Wood are to the south of the railway. There is a greater average minimum distance of approximately 550m between these woodlands.

The available information on the 12 woodlands is summarised in the habitat descriptions in Appendix 1. The woodlands are predominantly deciduous, oak-dominated, semi-natural woodlands with areas of plantation and extensive rides and are variously designated as SSSI and non-statutory Local Wildlife Sites (LWS). They vary considerably in terms of their age and density of trees, extent of felling and restocking, and the diversity and structure of shrub layer and ground flora.

[1] Priority habitats and priority species refer to those identified in the former UK Biodiversity Action Plan that form the basis for the list of habitats and species of principal importance in England. This includes 56 habitats for which the Environment Act 2021 introduces a strengthened 'biodiversity duty' to conserve and enhance biodiversity in England.

Overall, conditions that provide the optimum roosting and foraging habitat for Bechstein's bat are well represented in the Bernwood area, including a well-developed understorey and trees of different stages of maturity. The diversity of tree ages within these woodlands is of particular importance as it includes abundant old deciduous trees with natural cavities that are suitable for the formation of maternity roost sites, and younger trees that will provide an ongoing supply of roost sites as they age. Eight of the 12 woodlands are greater than 25 ha in extent, which further enhances their suitability to support Bechstein's maternity colonies (Natural England, 2023). **Table 1** presents the extent of each woodland block within the Bernwood area (of note, Balmore Wood, Greatsea Wood and Romer Wood form a contiguous block of woodland).

Table 1: Areas of woodlands in the Bernwood area[2]

Woodland name	Area (hectares)	
Finemere Wood SSSI	46.2	
Grendon and Doddershall Woods SSSI	69.5	
Ham Home-cum-Ham Green Wood SSSI	23.0	
Sheephouse Wood SSSI	58.9	
Decoypond Wood	8.6	
Hewins Wood	1.9	
Home Wood	37.5	
Runts Wood	25.9	
Shrubs Wood	8.1	
Balmore Wood	29.5	68.8
Greatsea Wood	13.3	
Romer Wood	26.0	
Total area of woodland	**348.4**	

The four woodland blocks that are designated as SSSI cover approximately 198 ha (56% of the woodland in the Bernwood area), and include:

- Finemere Wood (46.2ha): designated for Ancient Pedunculate Woodland, Black Hairstreak and Wood White Butterflies.
- Grendon and Doddershall Woods (69.5ha): designated for Broadleaved Woodland and Butterflies.

[2] The areas recorded here may differ from those shown in NERR130 'Bernwood Focus Area NVC Surveys of Woodland and Grassland sites', due to differences in recording open habitat and other areas of non-woodland habitat.

- Sheephouse Wood (59.8ha): designated for Ancient Pedunculate Oak Woodland and invertebrate fauna.
- Ham Home-cum-Hamgreen Woods (23.0ha) – designated for Woodland and Black Hairstreak Butterfly.

The intervening farmland is predominantly used for pasture and arable production, as well as areas of permanent grassland managed for nature conservation, most notably Finemere Meadows Nature Reserve. These habitats provide relatively undisturbed conditions that are necessary for the population of Bechstein's bats to move between roosts and foraging areas. The Bernwood area contains a range of linear habitats such as mature overgrown species-rich hedgerows; tree and scrub-lined streams, ponds and ditches, and wooded bridleways and railway cuttings. Many of the natural linear features act as 'dark corridors' along which bats can safely move between roosts and foraging areas. These dark corridors and the associated agricultural land either side provide essential habitat connectivity for Bechstein's bats between the woodland areas and are described below in a description of commuting corridors in the discussion of Bechstein' bat behaviour in the Bernwood area.

The Aylesbury Link Railway Line and the Calvert Landfill Site and Energy from Waste facility are subject to significant changes in scale and operation. Change is particularly associated with the construction and operation of parts of HS2 Phase 1 and East West rail along the existing railway alignment, ongoing use and restoration of the landfill and construction of new railway sidings for the energy from waste facility. Where necessary these changes have a commensurate level of mitigation and compensation so that adverse effects on the Bechstein's bat population can be avoided. However, the scale and nature of consented and proposed development in the Bernwood area means that all the habitats necessary for the favourable conservation status of the Bechstein's bat population should be identified and appropriately protected.

The Bernwood Bechstein's Population

Population size and status

Bat trapping and radio-tracking surveys between 2011 and 2022 identified 57 separate maternity roosts across the Bernwood area. Bat roost dusk emergence surveys on these maternity roosts recorded roost sizes ranging from 7 to 95 individuals. Based on this data, the maximum size of the Bernwood population is estimated to be approximately 300 individuals.

The methodology used to estimate the population size in the Bernwood area is the same method used to provide an estimate of the Bechstein's bat population across the UK (Mathews *et al.* 2018). The typical maternity roost density across the survey area was multiplied by twice the typical number of adult females per roost, i.e. it was assumed that all bats in pre-maternity roosts were female and that males would be in equal numbers in

the surrounding habitat. It should be noted, however, that no definitive data was available on the exact sex ratio of the Bernwood population.

Population estimates are available for several other known Bechstein's bat maternity or hibernation sites in the UK (JNCC, 2024). These include three of the nine Special Areas of Conservation (SAC)[3] that are designated for the presence of Bechstein's bat:

- Bath and Bradford-on-Avon SAC – minimum 20, maximum 20
- Bracket's Coppice SAC, Dorset – minimum 51, maximum 100, and
- Briddlesford Copses SAC, Isle of Wight - minimum 51, maximum 100.

At approximately 300 individuals, the Bernwood population therefore represents one of the largest known Bechstein's bat populations in the UK.

The population of approximately 300 individuals in the Bernwood area represents more than 1% of the estimated 21,600 population of Bechstein's bat in England (1.40%). While both estimates were derived using the same methodology, it is acknowledged that the degree of error variation is unknown. However, even with an error variation of 20%, the Bernwood population would still represent more than 1% of the UK population. Moreover, the position of this colony at the edge of its European range increases its vulnerability to environmental changes, which could result in the population becoming unviable.

The past twelve years of research confirmed that Bechstein's bat maintain a viable population in the Bernwood area and that is the most north-easterly population in the UK (Wright *et al.* 2018). The nearest breeding record of Bechstein's bats to the Bernwood area comprises a breeding colony at Black Park County Park in South Buckinghamshire, 50km south-east and a breeding colony at Grafton Wood SSSI, approximately 70 km north-west.

Research into the genetic structure and diversity of eight populations of Bechstein's bat in England by Wright *et al.* (2018) showed that the Bernwood population exhibited less genetic diversity and higher levels of inbreeding than the other populations included in the study. This is likely to be due to the geographical isolation of the Bernwood population and strongly indicates that there is no interaction between the Bernwood population and the other known populations in England (Wright *et al.* 2018). It might reflect landscape scale fragmentation of woodland cover in Buckinghamshire and Oxfordshire resulting in the

[3] Special Areas of Conservation (SACs) are protected areas in the UK designated under the Conservation of Habitats and Species Regulations 2017 (as amended) in England and Wales

isolation of the Bernwood area, that has prevented breeding between the Bernwood Bechstein's population and those further west and south (Wright et al in prep).

The Bernwood population is therefore likely to be more sensitive to changes in the landscape, including habitat loss, fragmentation and degradation. Furthermore, given their sedentary nature, there is currently no evidence that Bechstein's bat will successfully adapt to warmer conditions caused by climate change by movement of populations to cooler locations further north. The surveys undertaken between 2011– 2022 varied in coverage area of the Bernwood area making any fluctuations in population size difficult to ascertain. However, taking the survey data from years where area coverage was similar, the data does show that roost sizes and the Bernwood population has remained stable with no significant declines.

Bechstein's Bat Activity

Roosting

The surveys undertaken at the Bernwood area between 2011 – 2022 were undertaken between the months of May to September and covered the period before bats gave birth (pre-maternity), i.e. May to early-June, and the period after bats had given birth (post-maternity), i.e. July to September. Bechstein's bats maternity colonies begin to form in early April and most young are born in June (Natural England, 2023). Adult male bats tend to roost alone or in small groups throughout the breeding period but from the end of August and early-September maternity colonies tend to disperse and male and female bats interact at the entrance of underground sites in what is known as 'swarming' behaviour. Mating and hibernation will also occur at these underground sites.

The roosts identified in the Bernwood area during the surveys undertaken between 2011 – 2022 comprised 57 confirmed maternity roosts and 81-day roosts (i.e. roosts where individual or low numbers of bats (1-5) rest during the daytime). All roosts were recorded in trees and no Bechstein's bats were recorded roosting in the many bat boxes that are present throughout Finemere Wood and Sheephouse Wood.

The summary of information on Bechstein's roosts below considers maternity roosts only, see **Figure 3: Bechstein's bat roosts** No information on hibernation sites has been obtained and data on the numbers and use of day or transitory roosts does not contribute significantly to the understanding of Bechstein's bat activity in the Bernwood area.

Maternity Roosts

Three distinct maternity colonies were identified during the surveys undertaken within the Bernwood area. A maternity colony is a group of reproductive female bats that roost together and give birth to, nurse and wean their young. The three colonies are listed below

with the number of separate maternity roosts, the peak and average emergence counts recorded and the number of emergence surveys that informed the data:

- Finemere Wood SSSI and its immediate surroundings comprised 12 maternity roosts with a peak count of 68 bats and an average of 32 bats during 16 emergence surveys
- Grendon and Doddershall Woods SSSI and its immediate surroundings comprised 29 maternity roosts with a peak count of 75 bats and an average of 32 bats during 40 emergence surveys, and
- Ham Home-cum-Ham Green Woods SSSI and its immediate surroundings comprised 10 roosts with a peak count of 95 and an average of 29 bats during 11 emergence surveys.

It is of note that the seven maternity roosts within and adjacent to Knapps Hook Farm were used by the same breeding females that occupied roosts in Grendon and Doddershall wood SSSI and its immediate surroundings. The Grendon and Doddershall wood maternity colony therefore comprises 22 maternity roosts in and immediately around the Grendon and Doddershall woods and seven maternity roosts at Knapps Hook Farm, approximately 1km to the southeast.

A further six single and isolated maternity roosts were recorded outside Finemere Wood, Grendon and Doddershall Woods and Ham Home-cum-Ham Green Woods, see **Figure 3**. It is very likely that these roosts are functionally linked with one of the three maternity colonies but there is insufficient evidence to confirm which. Further, one of these roosts was first identified in 2022 and no subsequent survey data is available. It is expected that future survey and assessment will help inform which colonies these breeding females belong to.

Of the 57 maternity roosts across the three colonies, 44 were recorded in the existing SSSIs and 13 were recorded outside the SSSIs in old deciduous trees located in hedgerows, in small areas of woodland, along watercourses, standing alone in arable fields and one on the edge of Home Wood, see **Table 2** and **Figure 3**. The maternity roosts located outside of the woodland were consistently found to support greater average number of bats than those in the existing SSSI woodlands.

Table 2: Maternity roosts recorded outside the existing SSSIs

Ref	Roost Location	Peak emergence count	Associated Maternity Colony *(Assumed)*
1	Woodland immediately south of Knapps Hook Farm	66	Grendon and Doddershall Woods SSSI

Ref	Roost Location	Peak emergence count	Associated Maternity Colony *(Assumed)*
2	Woodland copse east of Knapps Hook Farm	75	Grendon and Doddershall Woods SSSI
3	Woodland copse east of Knapps Hook Farm (*a separate roost in the same woodland as Ref 2 above*)	33	Grendon and Doddershall Woods SSSI
4	Woodland immediately east of Knapps Hook Farm	37	Grendon and Doddershall Woods SSSI
5	Small copse south-west of Knapps Hook Farm	9	Grendon and Doddershall Woods SSSI
6	Small copse south-west of Knapps Hook Farm (*a separate roost in the same woodland as Ref 4 above*)	75	Grendon and Doddershall Woods SSSI
7	Woodland immediately west of Knapps Hook Farm	42	Grendon and Doddershall Woods SSSI
8	Isolated tree west of Ham Home-cum-Ham Green Woods	95	*Ham Home-cum-Ham Green Woods SSSI*
9	Isolated tree south of Greatsea Wood and north-west of Finemere Wood	34	*Finemere Wood SSSI*
10	Isolated tree north of Finemere Wood	14	*Finemere Wood SSSI*
11	Home Wood	11	*Finemere Wood SSSI*
12	Isolated tree north-west of Grendon and Doddershall Woods	48	*Grendon and Doddershall Woods SSSI*
13	Isolated roost 2.3km west of Grendon and Doddershall Woods	13	*Grendon and Doddershall Woods SSSI*

The maternity roosts close to but outside Finemere Wood were up 125m from the SSSI boundary with peak counts of 68 bats and average count of 44 bats based on seven

separate roost surveys. The maternity roosts close to but outside Grendon and Doddershall Woods were up to 500m from the SSSI boundary with peak counts of 75 bats and an average count of 51 bats based on three separate roosts surveys. Comparison of the numbers of bats present in maternity roosts within and outside of the SSSI woodlands clearly demonstrates that the roosts beyond the boundaries of the existing SSSI form an extremely important resource for the healthy functioning of the Bernwood Bechstein's population.

Bechstein's bat maternity colonies regularly switch between different roosts throughout the breeding period. This regular dissolution and re-merging of maternity colonies throughout the breeding period is known as fission-fusion dynamics and is thought to reduce parasite load and provide more favourable microclimatic conditions which contribute to the healthy functioning of the colony and breeding success (Kerth *et al*. 2001; Reckardt and Kerth 2007).

The 2011 to 2022 field surveys demonstrated that each maternity colony exhibited roost switching behaviour within their respective SSSI woodlands, and associated roosts outside of the woodlands, throughout the breeding period. Bats from different colonies were recorded sharing the same woodland but never the same roost. Individual roosts always remained unique to each colony. Bats from the colony at Grendon and Doddershall Woods SSSI were recorded roosting within Decoypond Wood to the northwest, and a bat from the colony in Ham Home-cum-Ham Green Woods SSSI was recorded in a maternity roost in unnamed woodland northwest of Grendon and Doddershall Woods SSSI. A further small maternity roost of 13 bats was recorded 2.3km from the Grendon and Doddershall Woods SSSI which supported a bat that was also recorded in a day roost in the Grendon and Doddershall Woods SSSI. The roost switching behaviour between two of the colonies and other areas of woodland in the Bernwood area indicates the presence of one interacting population rather than three wholly separate colonies.

Commuting

The radio-tracking surveys carried out between 2011 – 2022 demonstrated how Bechstein's bats use natural linear features to commute throughout the home range in the Bernwood area. They provide connectivity for Bechstein's bats that enable them to move between roosts and foraging areas in the Bernwood area and are also a part of the foraging resource in the home range. Key commuting corridors within the Bernwood area, for which use by Bechstein's bats was recorded regularly during the 2011 – 2022 survey period, are summarised below and illustrated in **Figure 4**.

This information reflects baseline conditions, prior to the start of construction of HS2 Phase 1, East West Rail and Greatmoor Siding. Information on the landscape level changes caused by these projects is provided in the final section of this report.

The former Aylesbury Link Railway: Parts of the largely wooded former goods line through the Bernwood area that provided a commuting route for Bechstein's bat and

indirectly linked the four woodland SSSIs with a north-south connection and several of the other described commuting corridors.

The River Ray: A stretch of the River Ray comprising an incised tree and hedgerow lined stream extending east from Grendon and Doddershall Woods SSSI and then north, over the Aylesbury Link railway line close to a crossing point provided by Adams Underbridge, to Finemere Wood SSSI**,** provides a commuting route for bats between these woodlands.

Hewins Wood Bridleway: Hewins Wood bridleway (Bridleway GUN/28) comprises a public right of way lined on both sides with mature trees and hedgerows that runs parallel to Hewins Wood and extends northeast for approximately 700m. A ditch also runs parallel along the full extent of the bridleway in this area. Hewins Wood bridleway provides a commuting route for bats to move from Grendon and Doddershall Woods SSSI across the Aylesbury Link railway line, close to Grendon Junction and Benfields overbridge. Here the habitat connectivity links with two other commuting routes and the 'Mega Ditch' which extends northwest, towards Sheephouse Wood SSSI, and east along vegetation towards Finemere Wood SSSI.

Mega Ditch: The Mega Ditch comprises a wide and deep, vegetated drainage channel that extends from the northern end of Hewins Wood Bridleway and then runs along the western side of the Aylesbury Link Railway northwest to link southern edge of Sheephouse Wood SSSI, where it joins the Muxwell Brook, another commuting route described below.

Finemere Wood SSSI to Hewins Wood Bridleway: This strip of vegetation comprised mature hedgerows and secondary deciduous woodland that provided a commuting route for bats between the northern end of Hewins Wood Bridleway to the westernmost tip of Finemere Wood SSSI.

Muxwell Brook: The Muxwell Brook comprises a ditch system that extends north from Grendon and Doddershall Woods SSSI to Sheephouse Wood SSSI providing a commuting route for bats between these woodlands. In this location it comprises ditches adjacent to hedgerows bordering agricultural fields. Costello underbridge provided a crossing point of the Aylesbury Link Railway close to the culvert of the Muxwell Brook at the southern edge of Sheephouse Wood.

Three Points Lane: Three Points Lane comprises part of a public right of way that runs between Finemere Hill (approximately 160m northwest of Finemere Wood SSSI) and then west along the southern edge of Greatsea Wood and Romer Wood eventually connecting to Sheephouse Wood SSSI and Decoypond Wood to the west. This section of Three Points Lane is approximately 10m wide and is lined on either side with mature trees and hedgerows creating a high-quality commuting corridor for bats to move between Finemere Wood SSSI, Greatsea Wood and Romer Wood, Sheephouse Wood SSSI and Decoypond Wood.

The commuting routes, provide habitat links within and also beyond the Bernwood area to the wider landscape, for example, the River Ray provides a commuting corridor for

Bechstein's bats between Grendon and Doddershall Wood SSSI to a known roost to the west of the village of Grendon Underwood 2.5km to the west. Bats were also recorded using less frequently used commuting routes across the site between 2011 – 2022. The less used routes comprise mature hedgerows, treelines and watercourses and ditches that connect the 12 main woodlands within the Bernwood area.

The commuting corridors discussed above provide connectivity for Bechstein's bats between roosting and foraging habitat within the Bernwood area. These corridors therefore represent a vital component of the functionality and reproductive success of the Bernwood Bechstein's population. Due to the fragmented nature of the woodland habitats within the Bernwood area, these corridors comprise relatively thin linear strips of commuting habitat and as such are particularly vulnerable to disturbance.

Foraging

Radio tracking surveys undertaken between 2011 and 2022 identified important areas for foraging within the home range for the Bechstein's bat population in the Bernwood area. Core foraging areas are locations where bats spend the majority of their time searching for prey and are therefore critical to the population viability. In the Bernwood area the core foraging area largely centred on the 12 woodlands, particularly Decoypond Wood, Sheephouse Wood SSSI, Home Wood, Runts Wood, Greatsea Wood, Finemere Wood, Grendon and Doddershall Woods and Ham Home-cum-Ham Green Woods, see **Figure 5**.

The data gathered demonstrates that Decoypond Wood, Runts Wood and Greatsea Wood do not support maternity tree roosts, but they are functionally linked to provide critical foraging resource for two of the maternity colonies, namely the maternity roosts at Finemere Wood SSSI and its immediate surroundings and Grendon and Doddershall Woods SSSI and its immediate surroundings.

Core foraging areas also included some habitat adjacent to the woodlands, including pasture, hedgerows, treelines and watercourses. The most frequently used non-woodland core foraging areas included:

- habitat immediately north, south and west of Finemere Wood SSSI;
- habitat immediately east of Grendon and Doddershall Woods SSSI, and
- habitat immediately north, east and west of both Decoypond Wood and Sheehouse Wood SSSI.

The field surveys confirmed that some of the key commuting routes described above, see **Figure 4**, were also regularly used by foraging Bechstein's bats. The most frequently used commuting routes used for foraging included:

- the River Ray south of Finemere Wood SSSI
- the River Ray east of Grendon and Doddershall Woods SSSI

- part of Three Points Lane west of Finemere Hill, and
- hedgerows and treelines between Finemere Wood SSSI and Hewins Wood Bridleway.

In high quality habitat, Bechstein's bats tend to forage close to their roosts and rarely fly further than 1,500m to forage (Natural England, 2023). Breeding females tend to utilise their own foraging areas of up to 2-3 ha of high-quality habitat and make repeated returns to their roost sites throughout the night (Natural England, 2023). The survey data showed that Bechstein's bats mainly foraged within the woodland where their roosts were located and in close proximity to their roosts. This was demonstrated through the presence of core foraging areas for the Bernwood Bechstein's bat population and the constituent woods. The varied structure and well-developed understorey of the woodlands that represent the majority of the core foraging habitat therefore provide a high-quality resource for Bechstein's bats. The size of these woodlands provides ample opportunities for several breeding females to retain their own foraging territories.

However, the data also showed Bechstein's bats roosting within one woodland and regularly commuting to other woodlands to forage. **Table 3** presents the woodlands that provided core foraging areas for two of the maternity colonies, Finemere Wood SSSI, and Grendon and Doddershall Woods SSSI. The maternity colony at Ham Home-cum-Ham Green Wood SSSI mainly foraged around Ham Home-cum-Ham Green wood itself.

Table 3: The core foraging areas for the Finemere Wood SSSI and Grendon and Doddershall Woods maternity colonies

Maternity roost location / colony	Locations of core foraging areas
Finemere Wood SSSI	Sheephouse Wood SSSI Decoypond Wood Shrubs Wood Home Wood Romer Wood Greatsea Wood Balmore Wood Runts Wood
Grendon and Doddershall Woods SSSI	Sheephouse Wood SSSI Decoypond Wood Romer Wood Greatsea Wood Hewins Wood

The data shows that core foraging areas for breeding females from the Finemere Wood SSSI colony do not extend into the core foraging areas for the Grendon and Doddershall SSSI or Ham Home-cum-Ham Green Wood SSSI maternity colonies and vice-versa. Woodlands that do not support the maternity roosts of the three colonies are however, included in the core foraging areas for the Finemere Wood SSSI and the Grendon and Doddershall Woods SSSI colonies. The data therefore demonstrates that, although there are three separate colonies within the Bernwood area, all the woods represent important foraging areas and are therefore essential in supporting the viability and reproductive success of the Bernwood population. Although the core feeding areas of high value foraging habitat close to roost resource are likely to be important to breeding females whilst raising their pups; foraging areas for the entire Bernwood Bechstein's population (including male Bechstein's) comprised a much wider area within the wider Bernwoood landscape. This was identified through the radio-tracking surveys carried out between 2011 – 2022.

Between 2017 and 2022 field surveys included DNA analysis of Bechstein's bat droppings to identify the invertebrate species present in their diet. The aim of the research was to provide qualitative comparative analysis of the composition of food items and, indirectly, habitat types being used by Bechstein's bats for foraging (HS2 Ltd, 2018 and HS2 Ltd, 2019). The results of the faecal DNA analysis have so far shown that the majority of the invertebrate prey species are associated with woodland habitats (69.4% - 74%), as expected given Bechstein's bats strong association with woodland. The remainder of the invertebrate prey species were associated with open habitats or wetland habitats (HS2 Ltd, 2018, HS2 Ltd, 2019, and HS2 Ltd 2023). As core and peripheral foraging areas overlap with these habitat types, the findings indicate that a proportion of foraging activity takes place in non-woodland habitat. A significant number of the species identified are associated with multiple habitat types so it was not considered possible to draw correlations between Bechstein's bat foraging and specific habitats (HS2 Ltd, 2018, HS2 Ltd, 2019, and HS2 Ltd 2023).

Home range analysis and Core Sustenance Zones

The home range of an animal is defined as the total area within which it lives and moves on a regular basis and contains all the resources that the animal requires to survive and reproduce. The home range of the Bechstein's bat population within the Bernwood area has been ascertained through bat trapping and radio-tracking studies between 2011 and 2022. The Bernwood area home range comprises an area of approximately 4,160 ha centred around the woodlands described above and shown on **Figure 2**.

A Core Sustenance Zone (CSZ) is a tool used to delineate the bat home range. It refers to the area surrounding a maternity roost within which habitat availability and quality will have a significant influence on the resilience and conservation status of the colony using the roost (BCT, 2016). The CSZ size for Bechstein's bat has been determined as being a 3km radius from each maternity roost. The collective CSZ area for all maternity roosts identified within the Bernwood area through bat trapping and radio-tracking studies between 2011

and 2022 is approximately 7,934 ha around the Bernwood area. The CSZ for the Bernwood population of Bechstein's bats is presented in **Figure 5**.

The majority of the habitats present within the Bernwood population home range and CSZ comprises arable and pastoral farmland. The percentage of woodland within the home range and CSZ is 8.5% and 4.5% respectively. These percentages of woodland within the home range and CSZ are considered small given the species strong association with the woodland and highlights how isolated the Bernwood Bechstein's population is and how susceptible it could be to change.

Causes of Change in the Bernwood Area

Overview

Information provided in preceding sections of this non-technical report provides baseline information on the Bernwood area and the characteristics and behaviour of population of Bechstein's bats it supports. The changes associated with infrastructure development have been acknowledged and are discussed below, with other causes of change, as they are relevant to the resilience and viability of the population. The main causes of change in the Bernwood area include:

- changes in the extent and distribution of roosting, commuting and foraging habitat from the removal and replacement (through compensation) of habitat associated with the new infrastructure, including
    - habitat fragmentation from severance of commuting routes and subsequent reinstatement (with interim measures to provide temporary connectivity)
    - disturbance of retained habitat and compensation during construction and operation
    - potential for killing and injury of bats during operation
- changes in land management associated with forestry, agricultural and nature conservation management practices
- ecological changes associated with climate change, and
- future, as yet unknown or unconsented developments that could affect the Bechstein's population

In summary, the changes in habitat extent and disturbance, risk of uncoordinated land management, habitat degradation resulting from climate change and the potential pressure from forthcoming development are all extremely relevant to the long-term viability of the Bechstein's bat population in the Bernwood area. With such a number and variety of possible future changes, measures are required to coordinate planning and management that will increase the resilience of the population.

Changes in habitat from new 2016 infrastructure

The development of HS2 Phase 1, East West Rail and the Greatmoor sidings has led to the loss of roosting, commuting and foraging habitat, predominantly from the removal of vegetation along the former Aylesbury Link Railway, and also the removal of parts of adjoining or parallel commuting corridors. The impacts on key commuting corridors includes:

- the temporary severance of the River Ray;
- the loss of parts of Hewins Wood Bridleway close to the railway alignment and habitat linkages across it provided by existing structures (for example Grendon Junction and Benfields overbridge);
- the Mega Ditch will no longer be available as a continuous bat commuting route post-construction;
- the loss of vegetation associated with Finemere Wood SSSI to Hewins Wood Bridleway; and
- the removal of a crossing point over the Aylesbury Link Railway at Costello underbridge, close to the culvert of the Muxwell Brook at the southern edge of Sheephouse Wood.

Disturbance associated with the new railway infrastructure may include increased noise and light pollution, exacerbated by habitat loss and fragmentation. Disturbance is highly likely to cause a reduction, or even cessation of the use of commuting corridors by Bechstein's bats. This could result in lowered functionality and reproductive success of the Bernwood population and lead to further fragmentation and isolation of colonies within the Bernwood area.

The mitigation for impacts on commuting habitat described above are part of a wider strategy to address the impacts of the construction and operation of the infrastructure of HS2 Phase 1, East West Rail and the Greatmoor sidings, and to account for the operation of the Greatmoor Energy from Waste Facility. The mitigation relies on the following broadly defined constituents:

- underbridges and green overbridges across the HS2 and East West Rail alignment to provide east/west connectivity between maternity colonies at, or close to the location of the habitat features and structures that bats were recorded using during the 2018-2022 surveys. Those provided to compensate for the loss of crossing points along Bechstein's commuting routes include:
    - the reinstatement of the underbridge close to the River Ray as the Adam's accommodation underbridge and planting to replace vegetation that has been removed, once construction is complete
    - reconnecting Hewins Wood Bridleway across the new railway infrastructure through the construction of Bridleway QUA/36 Accommodation Green Overbridge and Bridleway GUN/28 Accommodation Green Overbridge and associated planting
    - the replacement of vegetation associated with Finemere Wood SSSI to Hewins Wood Bridleway with planted trees
    - the replacement of Costello underbridge with Footpath CAG/2 Underbridge, with associated planting to link to Three Points Lane
- further crossing points are provided by greening the approaches to the Edgcott Road Overbridge to the south of the Bernwood area, the Footpath SCL/13 Green

Overbridge at the northern boundary of Sheephouse Wood, the Calvert Green Overbridge north of Decoypond Wood and School Hill Green Overbridge at School Hill immediately north of Calvert

- reinstating, strengthening and where necessary realigning the habitat corridors of which the crossing points noted above are a part, so that the connectivity of habitats used Bechstein's bats and is reestablished in the landscape
- providing an alternative north-south green corridor to replace that associated with the Aylesbury Link Railway and the Mega Ditch, to the east of the new railways that links Finemere Wood, Sheephouse Wood, Decoypond Wood and Calvert Jubilee Nature Reserve. It includes planting to strengthen the commuting route along Three Points Lane and woodland creation between Finemere Wood and Sheephouse Wood that will provide a foraging resource and increase the value of the commuting route, and
- various measures to reduce the risk of killing and disturbing bats during the operational phase of the new infrastructure as Bechstein's bat commute through the Bernwood area, including:
    - planting to guide bats to new crossing points and corridors
    - the design of the green bridges to attract bat to fly along the middle of the structure rather than along the edges
    - vegetation management to discourage bats from flying along or close to the new railway corridor especially if they depart from established commuting routes
    - noise and light barriers to separate bats from sources of disturbance that could cause them to diverge from safe crossing points, and
    - the construction of the Sheephouse Wood Mitigation Structure that will stop bats from emerging from the western edge of Sheephouse Wood immediately into the railway corridor.

In addition to the compensation relating to the rail infrastructure, the Greatmoor Energy from Waste plant has a commitment to undertake major habitat restoration works across its land ownership, which includes the existing landfill site at Calvert. This will result in the planting of extensive new woodland and grassland creation south of Sheephouse Wood SSSI and Decoypond Wood.

The compensatory planting from the rail infrastructure construction works and the habitat restoration works from the Greatmoor Energy from Waste plant have the potential to provide increased habitat cover and connectivity for the Bernwood Bechstein's bat population.

Much of the mitigation described above is integral to maintaining the home range and CSZ of Bechtein's bats in the Bernwood area, as well as mitigating the specific impacts generated by the new infrastructure.

Habitat Management

There are different purposes and approaches to the management of the 12 main woodlands in the Bernwood area, with the potential to have both positive and negative influences on the Bernwood Bechstein's bat population.

As previously discussed in this report, breeding and foraging Bechstein's bats have specific habitat requirements including:

- woodlands over 25 ha in extent with high proportions of oak in the canopy
- mature oaks of differing age classes with holes and cavities
- well-developed understorey with a variety of native species, and
- streams or ditches retaining water within woodlands.

The woodlands within the Bernwood area (described in Appendix 1) that have been shown to support breeding colonies of Bechstein's bats and support foraging areas for Bechstein's bats each exhibit all or some of these features. Any future management that would negatively impact these characteristics would therefore have the potential to negatively affect the Bernwood Bechstein's population. Potential effects therefore need to be considered when thinning, clearing or coppicing are undertaken. To minimise any negative impacts, the following measures should be adopted (BCT, 2013):

- known roosts and mature and veteran trees with woodpecker holes or other suitable potential roosting features, e.g. hollows and cavities, should be protected and retained to ensure the retention of roosting habitat
- the clearance or coppicing of woodland understorey should be avoided or minimised to protect and retain the favourable conditions required by invertebrate prey species, and
- dead and fallen deadwood should be retained to further support invertebrate prey species.

The current management of the woodlands supporting the three maternity colonies, Finemere Wood, Grendon and Doddershall Woods and Ham Home-cum-Ham Green Wood SSSI does not at present appear to involve any forestry operations. The same is apparent for Sheephouse Wood SSSI. Due to their current SSSI designations, there are lists of operations requiring Natural England consent, which includes the introduction of or changes in tree or woodland management such as afforestation, planting, clear and selective felling, thinning, coppicing, modification of the stand or understorey, changes in species composition or the cessation of current management. The woodlands already designated as a SSSI are therefore, in theory, well protected. Little should therefore need to be done other than monitor the woodlands to ensure the natural regeneration of oak trees. The natural regeneration of oaks will maintain and improve the diversity and range of tree age classes required to provide ample natural roosting habitat (Greenaway and Hill, 2004).

Areas of plantation within woodlands have been shown to provide important foraging areas for the Bernwood Bechstein's bat population. The value of these areas for Bechstein's bats is dependent on a diverse woodland structure present, i.e. the presence of linked canopy cover with a well-developed understorey (Greenaway and Hill, 2004). Approaches to improving plantation management that are beneficial for Bechstein's bats are available from the Bat Conservation Trust's publication Bechstein's bat, an introduction for woodland owners (2013) and include:

- ensuring, by new planting where necessary, that all deciduous blocks in nursery colony areas have deciduous woodland connections
- creating minimum-intervention strips along all watercourses within woodlands
- zoning important areas as minimum-intervention continuous cover forestry areas , subject to selective felling of only the best sound hardwood timber on a slow continuing basis at appropriate times of year
- monitoring stands of trees used as nest sites by woodpeckers and leaving these stands as minimum-intervention areas
- leaving the immediate stand of trees surrounding potential roost trees, e.g. trees with woodpecker holes, hollow trees, and
- managing grasslands and glades within or adjacent to woodlands to increase ant numbers to encourage woodpeckers.

The responsibility for management of woodlands within the Bernwood area that are outside of SSSI currently lies with three different owners, whilst the extensive compensatory woodland planting described above will be managed on behalf of commercial organisations. Differing woodland management techniques and timings undertaken by these organisations could have a detrimental impact on the Bernwood population if, for example, uncoordinated concurrent forestry operations were carried out in different areas. A holistic approach to the management of the woodlands within the Bernwood area would therefore be beneficial to the resilience of the Bernwood Bechstein's bat population.

Climate change

Lowland mixed broadleaved woodland is expected to undergo changes in range, species composition and age structure caused by warmer, drier summers and milder, wetter winters (Ray et al. 2010). Within the Bernwood area, these changes could lead to several detrimental outcomes for the Bernwood population such as (Ray et al. 2010):

- reduction in oak and ash cover due to the colonisation of other tree species more tolerant to warmer summers and milder winters
- increase of mortality in older trees, and
- localised changes in ground flora and understorey composition.

These changes therefore have the potential to reduce roost and foraging habitat availability for Bechstein's bat within the Bernwood area. Whilst the precise extent and timing of changes caused by climate change are unpredictable, woodland management with a clear and robust plan for woodland resilience within the Bernwood area is necessary to maintain the suitability of the habitat for the Bechstein's population, which is already vulnerable due to its isolation.

Future development

Future known potential development within the Bernwood area includes a Nationally Significant Infrastructure project in the form of a 2,100 acre solar farm. This project would be constructed on agricultural land to the north of Sheephouse Wood SSSI and Decoypond Wood, between Sheephouse Wood SSSI and Greatsea Wood and north of Finemere Wood SSSI to Runts Wood and beyond to the village of Botolph Claydon. There is published research of solar farms affecting bat behaviour (Szabadi *et al* 2023) and, as such, a project of this scale could potentially affect or alter the Bechstein's bat's foraging behaviour in the Bernwood area. Part of the existing landfill site is also proposed for a smaller separate solar farm and the infrastructure investment could attract more development.

The impacts of the rail infrastructure schemes within the Bernwood area are subject to annual ecological monitoring surveys which began in 2022 and include annual passive bat monitoring surveys and four-yearly trapping and radio-tracking surveys until 2040. The impacts of the scheme and the success of the mitigation are not therefore currently fully understood. The cumulative impact of the developments within the Bernwood area may, however, have a serious detrimental impact on bat populations within the Bernwood area through increased noise, lighting and habitat loss and degradation.

Conclusions

The Bechstein's bat distribution in the UK comprises an area across southern England from Gloucestershire to Sussex, although breeding individuals have been recorded as far north as Herefordshire and Worcestershire (Natural England, 2023). The Bechstein's bat population in the Bernwood area represents the most north-easterly extent of the species known UK range and is geographically and genetically isolated. The closest known breeding populations are at Black Park County Park 50 km south-west and Grafton Wood SSSI 70 km north-west.

The adult population size for the Bechstein's bat in England is estimated at 21,600 individuals (Mathews et al. 2018). This estimate was based on expert opinion and data from 75 roosts and a total derived extent of available broadleaved woodland. A separate assessment (Natural England 2023), based on habitat suitability estimated that the favourable population size in England is 28,000 individuals. Given the discrepancy

between the two estimates, Bechstein's bat in England are not in a favourable conservation status.

Data collected during field surveys undertaken between 2011 and 2022 implies that the Bernwood Bechstein's bat population size is approximately 300 individuals, which is 1.4% of the UK population. A total of 57 maternity roosts were confirmed in the Bernwood area with roosts sizes ranging from 7 to 95 individuals.

The Bernwood population comprises three maternity colonies which are centred on Finemere Wood SSSI, Grendon and Doddershall Wood SSSI and Ham Home-cum-Ham Green Wood SSSI, respectively. The survey data does not indicate that these colonies interbreed with each other, but it does clearly show that they share common foraging areas within surrounding woodlands such as Sheephouse Wood SSSI and therefore together, form one population.

Genetic research has shown that the Bernwood population exhibits higher levels of inbreeding and lower genetic diversity when compared with other populations within the UK and is genetically distinct to other populations studied in the UK. The population is however genetically viable and stable. Despite this, the geographic and genetic isolations of the Bernwood population makes it very vulnerable to future changes such as climate change, habitat loss and disturbance.

The current SSSI woodlands within the Bernwood area comprise Finemere Wood SSSI, Grendon and Doddershall Wood SSSI, Ham Home-cum-Ham Green Wood SSSI and Sheephouse Wood SSSI. These SSSIs are not currently designated for bats and are primarily designated for the presence of rare invertebrate populations. The three maternity colonies are therefore indirectly afforded a certain degree of protection. The data confirms however, that the Bernwood population uses all of the other woodlands within the Bernwood area for foraging and roosting. Day roosts have been recorded in the majority of the woodlands. Maternity roosts associated with each colony have also been recorded within mature trees outside of the current SSSI boundaries. These roosts tend to have comparatively high numbers of individuals roosting within them and are therefore extremely functionally important to the colonies.

Also, of vital importance to these colonies and the Bernwood population, are the commuting corridors that link the various woodland blocks such watercourses, hedgerows and treelines. These corridors provide vital safe passage for bats to travel between roosting and foraging areas and provide an important foraging resource in their own right. These corridors comprise narrow and exposed linear strips of habitat and are therefore very vulnerable to disturbance through habitat loss, disturbance and light pollution.

Bechstein's bats are rare in the UK and while the population in the Bernwood area is very large, it is genetically and geographically isolated. The stability and management of the habitat in the Bernwood area and any future enhancements are therefore extremely important to the long-term viability of the Bechstein's bat population in the Bernwood area. Changes in the extent and connectivity of the area's woodland and surrounding habitats,

and associated changes in noise and light disturbance from current and forthcoming local developments, the risk of uncoordinated land management, and habitat degradation resulting from climate change are of relevance. With such a number and variety of possible future changes, coordinated measures in habitat planning and management are essential to increase the resilience of the population.

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Appendices

Appendix 1: Habitat descriptions of the 12 woodlands that make up the Bernwood area

Finemere Wood SSSI: Finemere Wood SSSI is owned and managed by a wildlife charity. Formerly owned by the Forestry Commission, the charity have undertaken major habitat restoration including the removal of conifers which were planted by the Forestry Commission for commercial timber extraction (Natural England, 2023b). This restoration work has allowed the woodland to recover well and ongoing management by the charity comprises areas of thinning and coppicing, ride-side coppicing and the maintenance of grassy glades (Natural England, 2023b).

Grendon and Doddershall Woods SSSI: Grendon and Doddershall Woods SSSI is owned and managed by a private estate. The woodlands comprise large areas of good-quality, oak dominated woodland with remnant coppice-with-standards structure (Natural England, 2023b). The woodlands are dominated by relatively uniform size and age oaks with a high canopy layer throughout. The woodland understorey is well-developed and comprises a good variety of shrub species. An extensive ride system criss-crosses the woodlands parts of which comprise species-rich grassland (Natural England, 2023b). Evidence of deer browsing is present within the woodlands (Natural England, 2023b).

Ham Home-cum-Ham Green Wood SSSI: Ham Home-cum-Ham Green Wood SSSI comprises a similar structure to Grendon and Doddershall Woods SSSI but is much smaller, has a more mixed canopy of oak and ash and has more variation in the structure of the rides and woodland edges. As Grendon and Doddershall Woods SSSI, it has a pronounced remnant coppice-with-standards structure in which mature oak is prominent in the canopy and well-developed understorey with a variety of shrub species (Natural England, 2023b). A section of the woodland that lies between the ‘separate’ woodland blocks named Ham Home Wood and Ham Green Wood is not designated as SSSI and comprises mixed broadleaved and coniferous woodland the majority of which has been recently felled (Natural England, 2023b). Evidence of deer browsing is present within the woodlands (Natural England, 2023b).

Sheephouse Wood SSSI: Sheephouse Wood SSSI is owned and managed by a private estate. The estate also own and manage Decoypond Wood, Shrubs Wood, Home Wood, Balmore Wood, Greatsea Wood, Romer Wood and Runts Wood. The woodland comprises mainly good-quality, oak dominated woodland with small areas of recent plantation and scrub (Natural England, 2023b). Many veteran or near-veteran trees are present within the woodland and the understorey is well-developed with a variety of shrub species. An extensive ride system is present through the woodland with woodland glades also present. Evidence of deer browsing is present within the woodland (Natural England, 2023b).

Decoypond Wood: Decoypond Wood is designated as a Local Wildlife Site (LWS). LWS are areas recognised as having high wildlife value or containing rare or threatened habitats and species. The woodland is dominated by mainly mature oak with no veteran trees present. The understorey comprises ash, hazel and hawthorn with much of the ash and hazel historically coppiced (Natural England, 2023b). Moderate levels of deer browsing are evident within the woodland (Natural England, 2023b).

Hewins Wood: Hewins Wood is designated as a LWS. The woodland comprises a mixture of even-aged oak with some pine. Trees present are mostly young with no old or veteran trees present within the main body of the woodland although some near veteran trees are present on the western boundary adjacent to a ditch (Natural England, 2023b). The woodland has a sparse understorey and no ride system.

Home Wood: Home Wood is designated as a LWS. Home Wood is a relatively large woodland within the complex and comprises areas of remnant coppice-with-standards structure, areas where standards have been harvested with the understorey thinned out or removed and some areas of recently felled and replanted trees (Natural England, 2023b). The woodland has an extensive ride system.

Romer, Greatsea and Balmore Woods: Romer, Greatsea and Balmore Woods are designated as LWSs. These woodlands are all managed plantation woodlands with areas of recent clear felling and areas of recent re-planting. Smaller blocks and strips of older undisturbed woodland are, however, present (Natural England, 2023b). The plantation areas comprise even-aged oak and pine with little structural diversity. The undisturbed areas comprise higher-quality woodland with mature oak, birch and ash with a hazel and hawthorn understorey (Natural England, 2023b).

Runts Wood: Runts Wood is designated as a LWS. The woodland canopy is dominated by oak with ash and sparse conifers are also present (Natural England, 2023b). The woodland is a managed plantation woodland with selective felling of young and mature ash recently undertaken (Natural England, 2023b). The understorey comprises mostly hazel and hawthorn and has been cleared in some areas (Natural England, 2023b). Evidence of deer browsing is present within the woodland (Natural England, 2023b).

Shrubs Wood: Shrubs Wood is designated as a LWS. The woodland is dominated by mature oak with some mature ash and old hazel coppice understorey. Most of the site comprises older, established woodland with a strip of more recent plantation in the middle of woodland comprising mixed tree species including oak, birch, ash and alder (Natural England, 2023b). The woodland is a managed plantation woodland and quite substantial felling works have been recently undertaken (Natural England, 2023b).

Figures

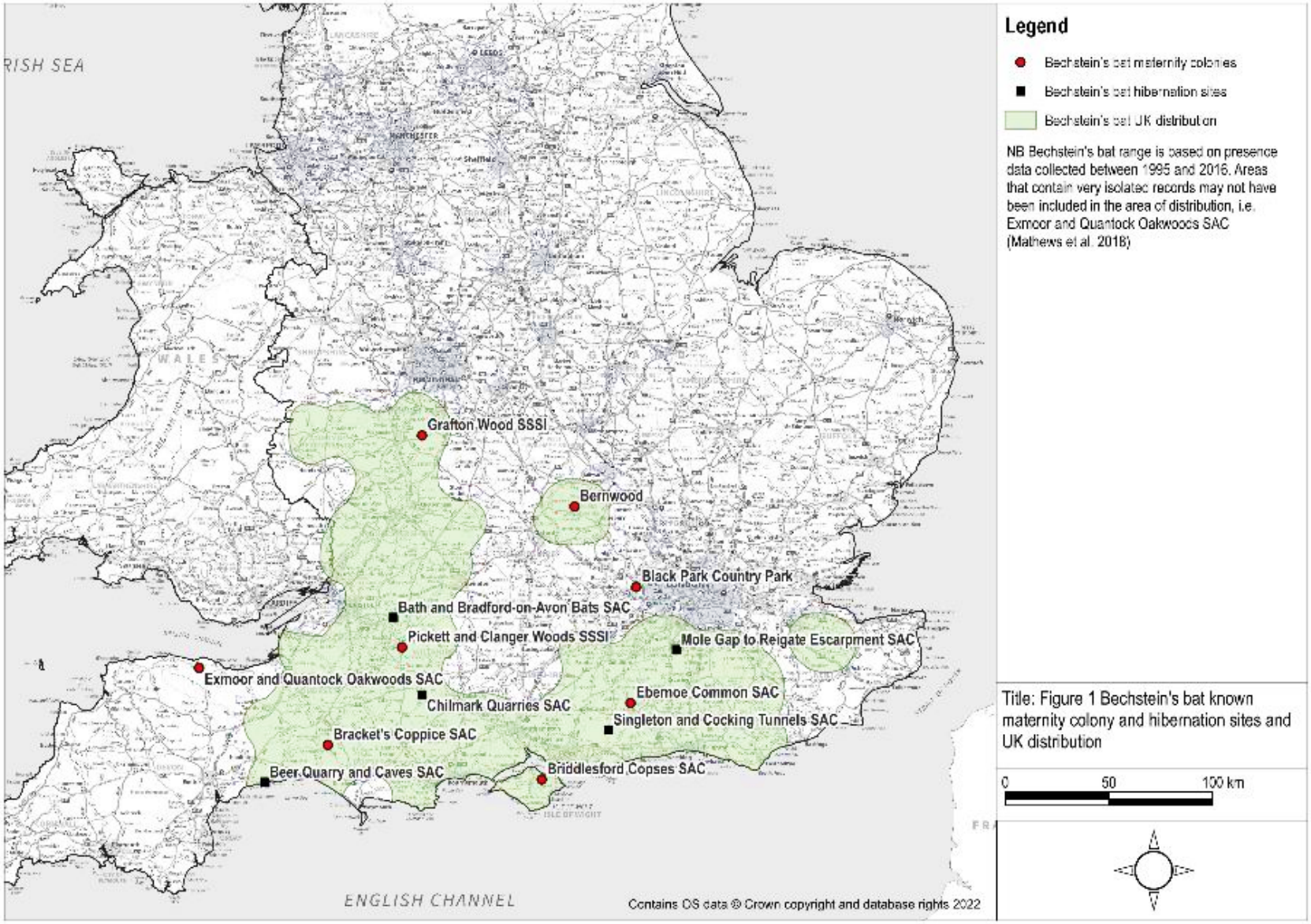

Figure 1: Bechstein's bat known maternity colony and hibernation sites and UK distribution

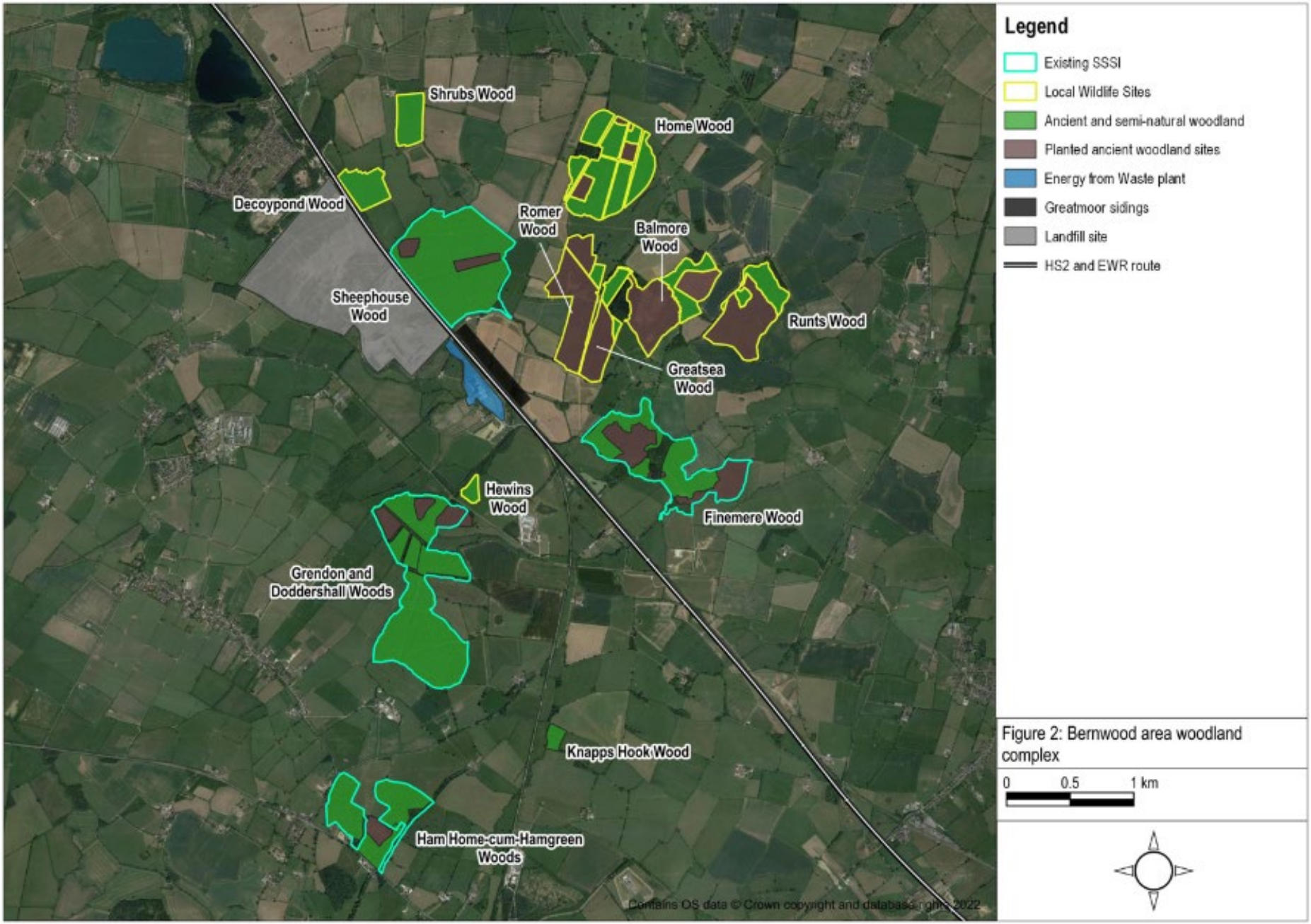

Figure 2: Bernwood area woodland complex

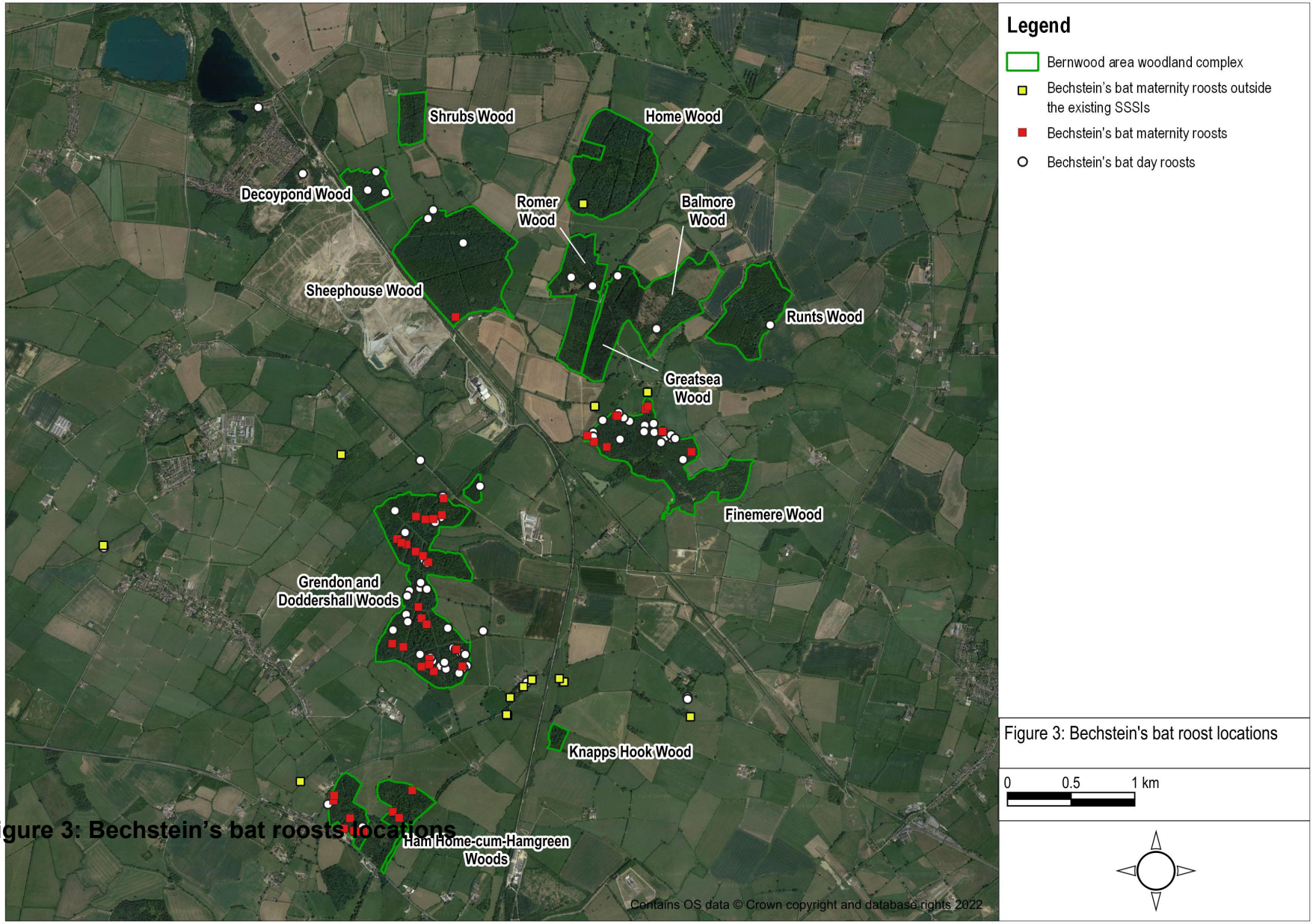

Figure 3: Bechstein's bat roosts locations

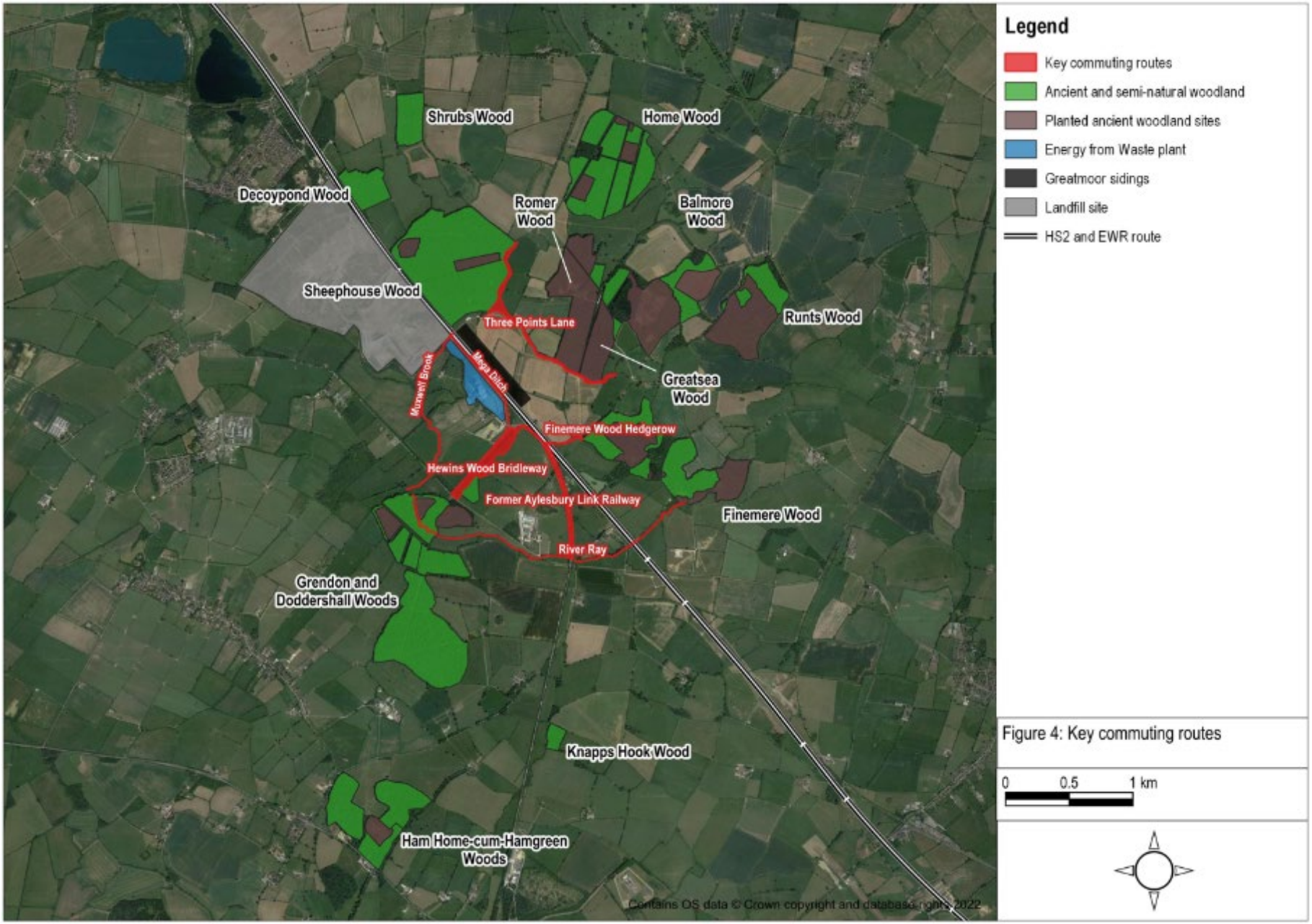

Figure 4: Key Bechstein's bat commuting routes

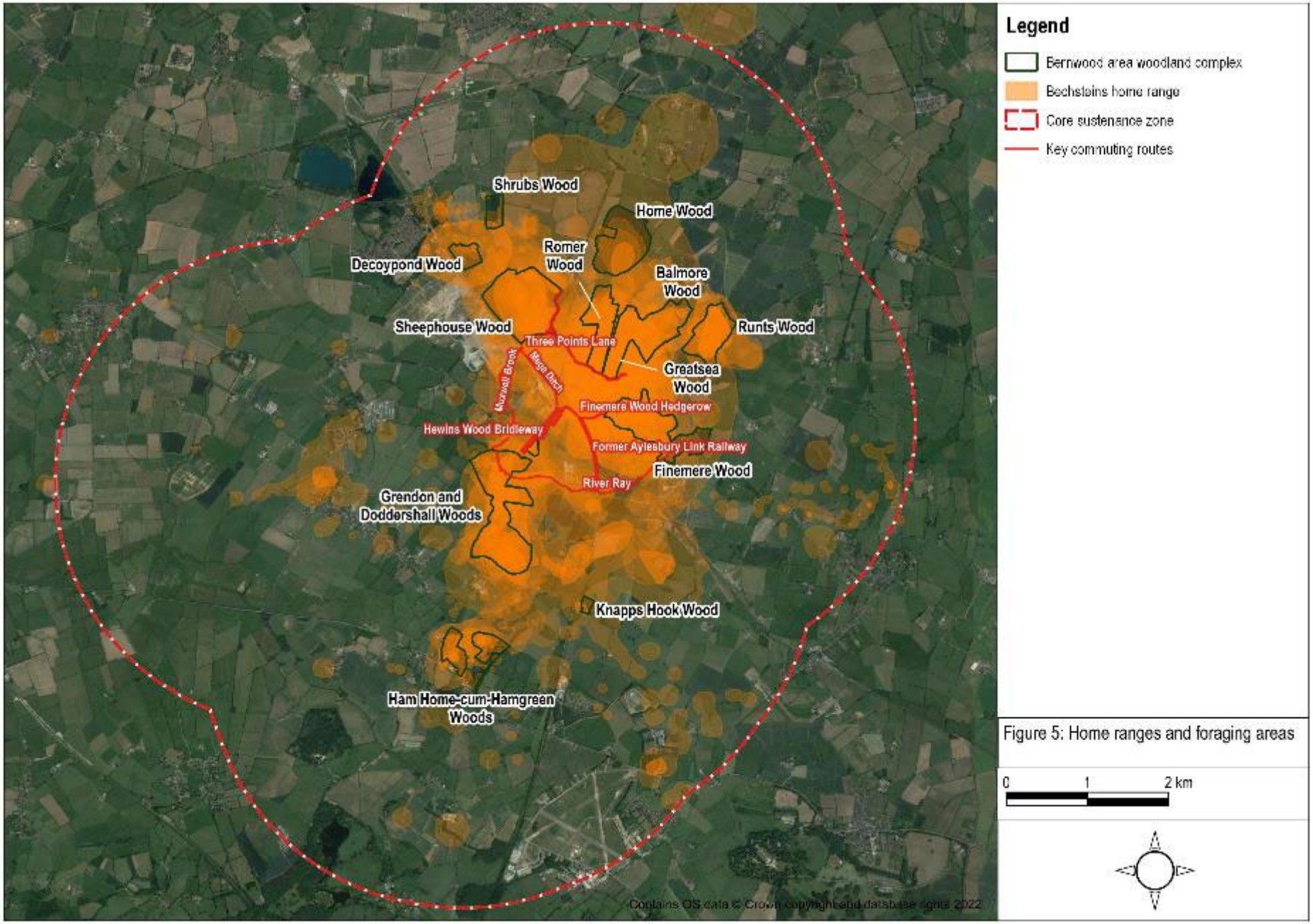

Figure 5: Bernwood area's Bechstein's bat home range and foraging areas

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