A review of the barbastelle *Barbastella barbastellus* in Norfolk based on the work of the Norfolk Barbastelle Study Group

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Introduction

More than 20 years since the discovery of a maternity colony of barbastelle *Barbastella barbastellus* at Paston Great Barn Special Area of Conservation (SAC) in north east Norfolk, this nationally rare species is now regarded as something of a Norfolk speciality. Despite being widely cited as a species of riverine woodlands of the south and west of Britain, the barbastelle is also known to be widespread across Norfolk's more predominantly arable landscape. In order to understand more about the species' habitat preferences in Norfolk, the Norfolk Barbastelle Study Group (NBSG) has been studying the autecology of the species and the habitat and landscape features which support barbastelle populations in the county.

The NBSG was formed in 2007 and reported on the first five years of its' work in 2011 (Norfolk Barbastelle Study Group, 2011). At that time, the group had progressed from transect surveys designed to discover new sites for barbastelle to radio-tracking studies to locate maternity roosts and study foraging behaviour. These studies were focussed in the more extensive National Trust woodlands at Sheringham Park, the Felbrigg and Blickling estates and also on the private Ken Hill estate near Snettisham in west Norfolk.

Since 2012, the group has carried out more detailed radio-tracking studies of the Paston Great Barn colony to characterise the pattern of use of the surrounding area. In view of the unusual location of this maternity colony in a building surrounded by arable land, we have investigated the possibility that it is isolated from interactions with other colonies, which might compromise its long-term resilience to environmental and climatic change. These studies confirmed the importance of coastal cliffs as a foraging area for the Paston Great Barn colony. This led to further studies of barbastelle activity in different coastal habitats in north Norfolk which were funded by the Norfolk Coast Partnership.

Radio-tracking has provided information on the spatial distribution of maternity colonies and overlap of home ranges in north Norfolk. Population estimates gained from synchronised emergence counts at individual sites have helped to identify those that are of key importance for barbastelles in Norfolk and which may be worthy of conservation designations at local, national and/or international levels. Repeat counts may also provide a means of long-term monitoring of colonies and a greater understanding of population trends at key sites, as well as feeding into national-scale population assessments. We have also widened our study area to the claylands of south Norfolk and one site in The Broads with a view to comparing a range of landscape types, woodland size, composition and management.

This review pulls together the outcomes of our work which, it is hoped, will give a clearer insight into the autecology of the barbastelle, specifically in the Norfolk landscapes. The group also hopes that this work will help to underpin barbastelle conservation through future agri-environment schemes, informed woodland management practice, site protection and avoidance or mitigation of the impacts of development.

Maternity roosts

To date, the NBSG has located 15 barbastelle maternity colonies by radio-tracking pregnant or post-lactating females, all of which are in woodlands. The presence of maternity roosts is also inferred for a further three sites from trapping of post-lactating females in woodlands containing trees with high roost potential, one of which (Roarr! Dinosaur Adventure and Royal Norwich Golf Club; formerly Weston Park) has since been confirmed by radio-tracking for the Norwich Northern Distributor Road (NDR) pre-construction and post-works monitoring (Packman, 2019). The NBSG supported a University of East Anglia (UEA) Masters project which confirmed the presence of a maternity colony in the British Army's Stanford Training Area, or STANTA as it is known (Mackinnon, 2017). Ecological assessments for planning purposes such as the NDR, have identified a further three maternity colonies. Unusually, the colony at Holkham was discovered by chance when a dawn survey recorded barbastelles swarming at the roost entrance. The locations of all known 24 barbastelle maternity colonies are shown in Figure 1. All are in trees in woodlands with the exception of the Paston Great Barn SAC colony. Maternity colonies occur in the range of Norfolk landscapes, from the more heavily wooded Holt-Cromer ridge to the smaller scattered woodlands of south Norfolk. The absence of colonies in the fens to the west and The Broads to the east is probably a reflection of the lack of studies in those areas, but we expect colonies to be present wherever there are suitable roost woodlands.

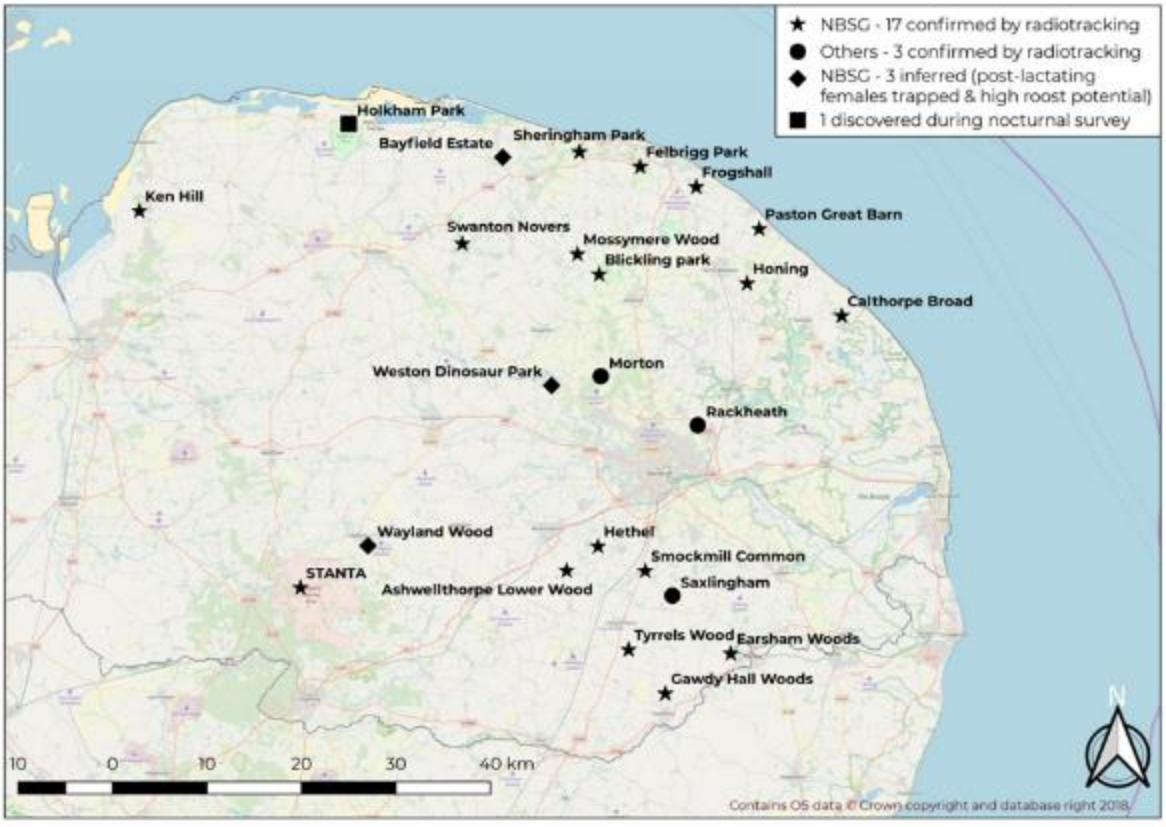

Figure 1: Locations of barbastelle maternity colonies.

Roost woodlands

The size and landscape connectivity of roost woodlands supporting maternity colonies varies greatly. The large estate woodlands of north and west Norfolk (100 - 250ha) are also part of more extensively wooded landscapes, such as the Holt-Cromer Ridge woods,

whereas the small woodlands of south Norfolk (<50ha) are usually more isolated from other woodland blocks. Tree species composition varies both between and within sites. Pedunculate oak *Quercus robur* and sweet chestnut *Castanea sativa* are the dominant species in north and west Norfolk and north of Norwich, but are frequently mixed with Scot's pine *Pinus sylvestris*, other exotic conifers and beech *Fagus sylvatica*. Ash *Fraxinus excelsior* and hornbeam *Carpinus betulus* are more typical of south Norfolk woodlands, but pedunculate oak is also frequent or occasional. At Calthorpe Broad National Nature Reserve (NNR), an isolated wet woodland site in east Norfolk, oak is interspersed through the alder *Alnus glutinosa*, willow *Salix* species and birch *Betula* species woodland.

Most of the woodlands that support barbastelle maternity colonies are predominantly high canopy with mature trees, and classed as ancient or semi-natural, but may also exhibit a range of age classes through new planting. Blocks of new plantation are often established to fill in gaps between and around older woodland. The understorey usually comprises hazel *Corylus avellana*, holly *Ilex aquifolium*, rhododendron *Rhododendron ferrugineum* and tree saplings, but the level of cover is generally low and some roost woodlands have a sparse understorey.

The majority of roost woodlands identified to date are non-intervention or have minimal management, In contrast, Ashwellthorpe Lower Wood Norfolk Wildlife Trust Reserve/Site of Special Scientific Interest (SSSI), Swanton Novers NNR/SSSI and Wayland Wood SSSI have extensive areas of managed coppice, but at all these sites, areas of non-intervention woodland remain, often around the margins, with blocks of mature high canopy trees. No clear pattern of woodland size, species composition or structure has emerged from the Group's studies, but the consistent feature is the presence of mature trees with loose bark, and especially oak.

Maternity roost trees

Barbastelle maternity colonies show a clear preference for roost sites under loose bark, although splits and fissures may also be used. The data from all the roost woodlands studied by radio-tracking showed that 70-100% of roosts were under loose bark at each site. This roost feature generally falls into two types: bark slabs and bark collars. Bark slabs persist on the trunks of larger trees, usually dead, and are between 2 to 4m above ground level. Bark collars persist on moderately sized aerial boughs of living or dead trees and are at canopy level, often obscured by foliage (Figure 2).

Maternity roosts occur under loose bark on a variety of tree species. Oak is the most frequently used followed by sweet chestnut, indicative of the predominant woodland tree species and consequent roost availability. Roosts in wild cherry *Prunus avium*, Scot's pine, ash, false acacia *Robinia pseudoacacia*, beech, horse chestnut *Aesculus hippocastanum* and under ivy *Hedera helix* on sycamore *Acer pseodoplatanus* have also been recorded, but these were usually post-maternity roosts with small numbers or single females. Roost features in oak and sweet chestnut appear to be favoured during the maternity period, but a wider range of tree species are used post-maternity. Roost feature rather than tree species is the key factor.

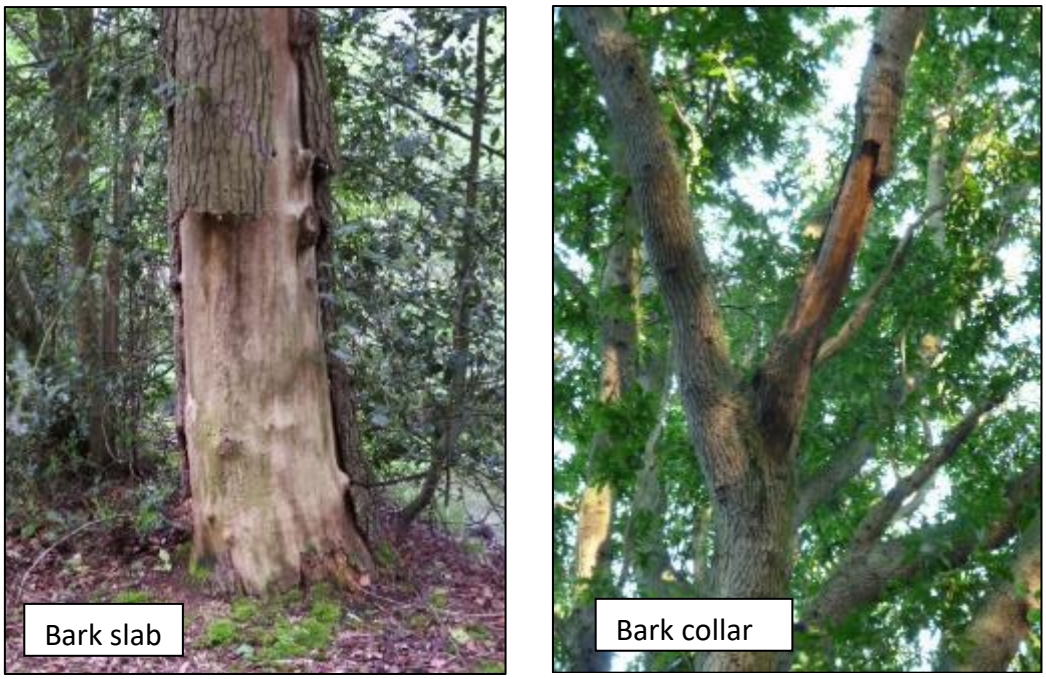

Figure 2: Roost types under loose bark.

Roost trees are usually in an enclosed environment within the woodland and undisturbed, although one in the Felbrigg woods was within 10m of the busy A148. Another exception is a veteran oak tree in pasture approximately 20m from the edge of woodlands at Earsham. Whilst roosts high in the canopy were screened by foliage, lower roosts were often very exposed with no surrounding understorey shrubs. Roost selection may be influenced by temperature, humidity and light penetration and, therefore, by the structure of the woodland.

Roost fragility

Loose bark is a fragile, transient roost feature, lost through natural decay and windblow. Dead or diseased wood may also be deliberately removed as part of woodland management. Monitoring of 11 maternity roosts located at Ken Hill in 2009/11 showed that all ten bark roost features had decayed beyond use within ten years. The only remaining roost was in an intact fissure. Roost loss can be rapid. Four out of nine roost features disintegrated over one winter at Ken Hill and three within two years at Felbrigg Park. Roost potential of the woodland will only be maintained if there is continued availability of suitable roost trees in the long term. This is of concern in woodlands where there are few trees older than 100 years old.

Roost switching

Barbastelle maternity colonies start to form in late May, initially in small groups in different roosts, but then coalesce to form larger groups in late June before the pups are born in early July. No radio-tracking is undertaken during late pregnancy and lactation, so it is not certain if, or how often, the colonies move roosts during this period, but they exhibit roost switching behaviour once the young are volant. The colonies start to fragment in mid to late August and multiple roosts are used. On average, we found that individual females use between two and six different roosts during a tracking period of 7-14 days, a mean of approximately four roosts. The mean number of days in each roost is approximately three,

but this is influenced by weather. Barbastelles may not emerge during periods of adverse weather and remain in the same roost for longer periods.

Tree roosts are located throughout the woodlands, depending on the locations of suitable roost trees. At Ashwellthorpe Lower Wood, the roosts were confined to the south west non-intervention area, the only location with mature oak trees (Figure 3). We have also observed the use of small satellite woodlands for two colonies. The Tyrell's Wood SSSI/County Wildlife Site (CWS) colony used roosts in Bales Plantation (1.2ha) approximately 170m from the main wood (Figure 3). The Hethel colony used Ash Plantation (0.5ha) located 0.9km from the main wood. Roosts in Ken Hill woods were clearly divided into north and south clusters and suggested the presence of sub-groups (Figure 3). Two females radio-tagged in early August in Gawdy Hall Woods remained with separate groups, each comprising 25 females and young, for the tracking period of 12 days, with no sharing of tree roosts. The early studies of barbastelle in Sussex woodlands identified sub-groups (Greenaway, 2008) and it is likely that colony subdivisions occur in large, high quality roost woodlands.

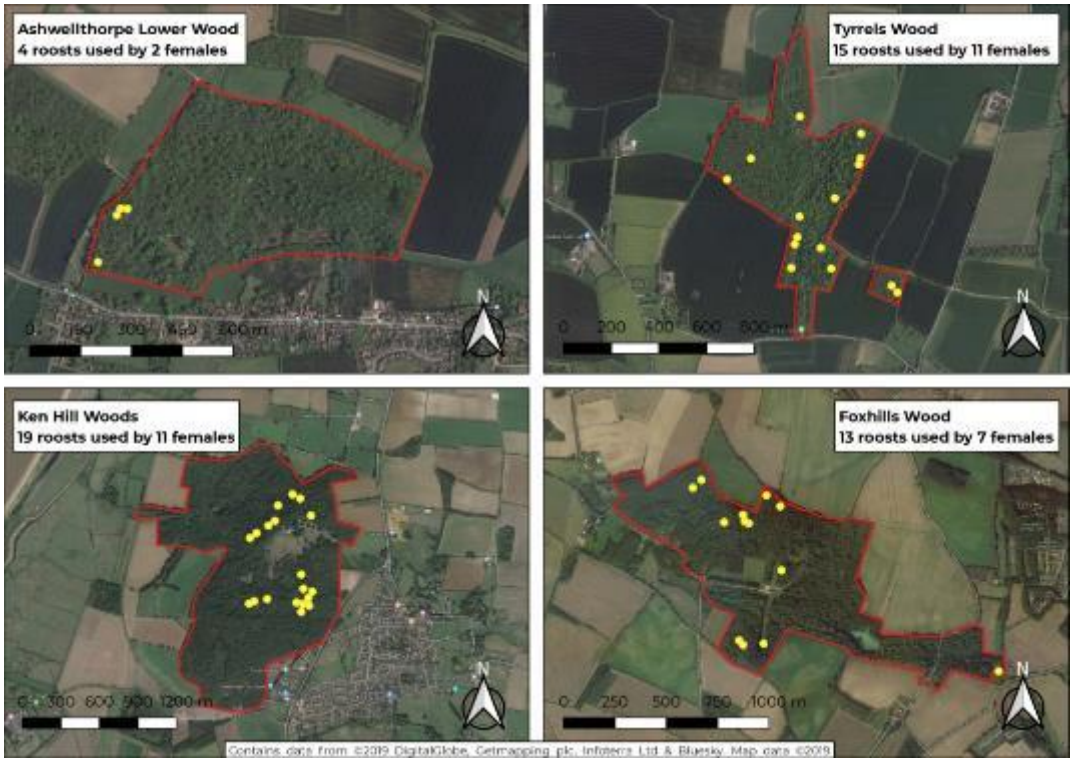

Figure 3: Multiple roosts in maternity colony woodlands.

Roosts in buildings

We are not aware of any maternity colonies in buildings in Norfolk other than at Paston Great Barn, but agricultural buildings are frequently used for roosting by individual barbastelles. Radio-tracking has shown that both females and males occasionally night-roost in undeveloped barns and sheds, usually brick and pantile. We have also recorded females in barns in autumn once the maternity colony has dispersed. Visual inspections for planning applications for barn conversions often record individual barbastelles roosting in barns and sheds at all times of the year.

Roost size
Emergence counts on individual roost trees vary greatly due to splitting and coalescing of the maternity colony in multiple roosts. Pre-parturition emergence counts on individual roost trees range from two to 24 bats, with numbers increasing from mid-May to mid-June as the maternity roosts coalesce. Post-parturition counts for single roost trees have varied from eight to 38 bats, which includes adults and juveniles. Post-parturition counts (with volant young) of 20 to 25 bats are not unusual for a single roost tree, but 38 is the maximum we have recorded to date. Roost size may be influenced by the available space, especially in bark collars on aerial boughs. Space is not limited in the long crevices in the Paston Great Barn timbers and the maximum post-parturition roost size recorded is 55 bats.

Colony size
Maternity colony size is a key parameter for determining the importance of sites in both the county and wider context, as well as for long-term monitoring to assess the impacts of land management changes, conservation actions and other environmental factors, such as climate change. Ideally, the number of adult females in a roost woodland is determined from emergence counts before the young are volant. In practice, this is very difficult to achieve for barbastelles due to their use of multiple roosts and roost switching behaviour, the poor visibility of roosts in the high canopy, the short window between formation of the maternity roost (maximum numbers of adult females) and the young flying and, finally, welfare considerations which preclude trapping and tagging of heavily pregnant and lactating females. In addition, this approach is expensive in time and materials, requiring numerous surveyors and a large number of radio-tagged females to increase the chance of identifying all roosts used by the colony.

To date, we have attempted simultaneous post-parturition emergence counts in Ken Hill Woods on all known roost trees identified by radio-tracking between May and early August in 2011. Surveyors were deployed to watch individual roost trees and this was repeated on two nights in August. Total counts which would include females, juveniles and possibly some males, were 50 and 54 bats. Given the practical difficulties and short window before the maternity colony begins to fragment in mid-August, future work will focus on timing simultaneous emergence counts to coincide with peak numbers of adults and volant young. These counts will also be a measure of annual breeding success.

The highest emergence counts and estimated colony sizes to date have been recorded in woodlands with numerous roost trees, and this may be a key factor influencing colony size. The data so far indicate that woods with few roost trees such as at Ashwellthorpe Lower Wood SSSI and Hethel CWS support smaller colonies (<10 individuals). This has led us to suggest that small colonies may move between woodlands to increase the number of suitable roost trees available to them, particularly in south Norfolk. Future work will try to answer this question.

Foraging behaviour
Radio-tracking of female barbastelles, both pre-parturition and post-parturition, has provided detailed information on nocturnal behaviour and landscape use. After emergence, barbastelles remain within the woodland for up to 45min, following the darker flight paths along internal rides. At Tyrrel's Wood, for instance, they follow the circular tunnel-like paths

in the central area, gradually gravitating towards the south or east boundaries of the wood from which they eventually fly out into open countryside when light levels are low enough. Similar behaviour was observed in other woodlands. However, at Paston Great Barn, where barbastelles fly inside the barn after emergence, it is not unusual to see them emerge before dark and follow flight-lines at great speed towards their foraging areas. In wet and windy weather, barbastelles may continue to fly and forage within the roost woodland, making use of the shelter and available prey.

Similar post-parturition patterns of nocturnal activity were observed in the Paston Great Barn, Old Hills Woods (Honing), Foxhills Woods (Frogshall) and Tyrrel's Wood colonies which have been studied most intensively. After emergence and leaving the roost woodland or Paston Great Barn, barbastelles follow flight-lines to their core foraging areas, feeding continuously for up to three hours. They then return to the roost woodland, or to Paston Great Barn, sometimes becoming stationary for a short period. This may be to visit juveniles reluctant to leave the roost or staying close to it. Females then leave for a second bout of foraging. The same foraging areas may be visited, or only those closest to the roost. Barbastelles were not recorded foraging further away from the roost in the latter part of the night.

Individual females show high fidelity to core foraging areas. Once these have been located by radio-tracking, we have found that behaviour is quite predictable, with females following the same flight-lines, and visiting the same areas night after night, provided weather conditions are favourable. Flight-lines and foraging areas closest to the roost woodland are often shared by several females, but individuals have specific foraging areas further afield. Females from the Foxhills Woods colony (Figure 4) ranged to the north, south and east of the woods. Flight-lines usually followed linear features with vegetation cover such as woodland edge, watercourses, hedgerows and green lanes, but 'female 4' repeatedly crossed open countryside to reach her favoured foraging area on Overstrand cliffs.

Females from the Paston Great Barn colony showed weather-related foraging behaviour. On nights with no wind or light to moderate offshore winds, the coastal cliffs at Mundesley were a favoured location where all six tagged females foraged for prolonged periods. When onshore winds or cold, foggy conditions prevailed at the coast, inland foraging areas were used instead. On some occasions, females flew immediately to the coast after emergence, but returned inland if foraging conditions were poor. Inland core foraging areas were often shared (Figure 5).

High fidelity of individuals to core foraging areas is a means of resource partitioning and is demonstrated by the radio-tracking of 11 females at Tyrrel's Wood (Figure 6). Four females foraged to the east, three to the south and two to the west, crossing the busy A140. Three bats remained within 3km of the wood.

Figure 4: Flight-lines (shown in red) and foraging areas (outlined in yellow) for Foxhills Woods (Frogshall) females.

Habitat preferences and landscape features

One of our targets has been to determine the key habitats in the agricultural landscape that support the foraging requirements of barbastelles. We have radio-tracked females from maternity colonies, and a few males too, and identified the areas in which they spend most time feeding. For colonies within 5km of the coast, coastal cliffs are a major foraging area and the importance of the coast is discussed later on in this review.

All the maternity colonies studied are located in woodlands in predominantly arable landscapes. The roost woodlands are foraging areas in their own right, and especially important in bad weather. Beyond the woodlands, the agricultural landscape is a mosaic of arable, hedges, small woodlands, tree belts, riparian, pasture, country roads, rural villages and farms with gardens and grounds. The foraging areas targeted by barbastelles are typically arable mosaics ranging from 30 to 229ha in area in which the bats move around visiting the habitat features described above. Within these mosaics, linear features (30 to 40ha) are particularly important for foraging, including tall hedgerows, overhung or sunken tracks and country lanes, disused railway embankments and cuttings and woodland edge.

Small tributary watercourses are regularly used. These are usually bordered by pasture on low-lying land but are invariably fringed with tall shrubs and young trees. The Old Hills Woods maternity colony is a typical example. All radio-tracked females foraged along the vegetated section of the North Walsham and Dilham Canal within the home range of the colony, but non-vegetated, open sections were not visited.

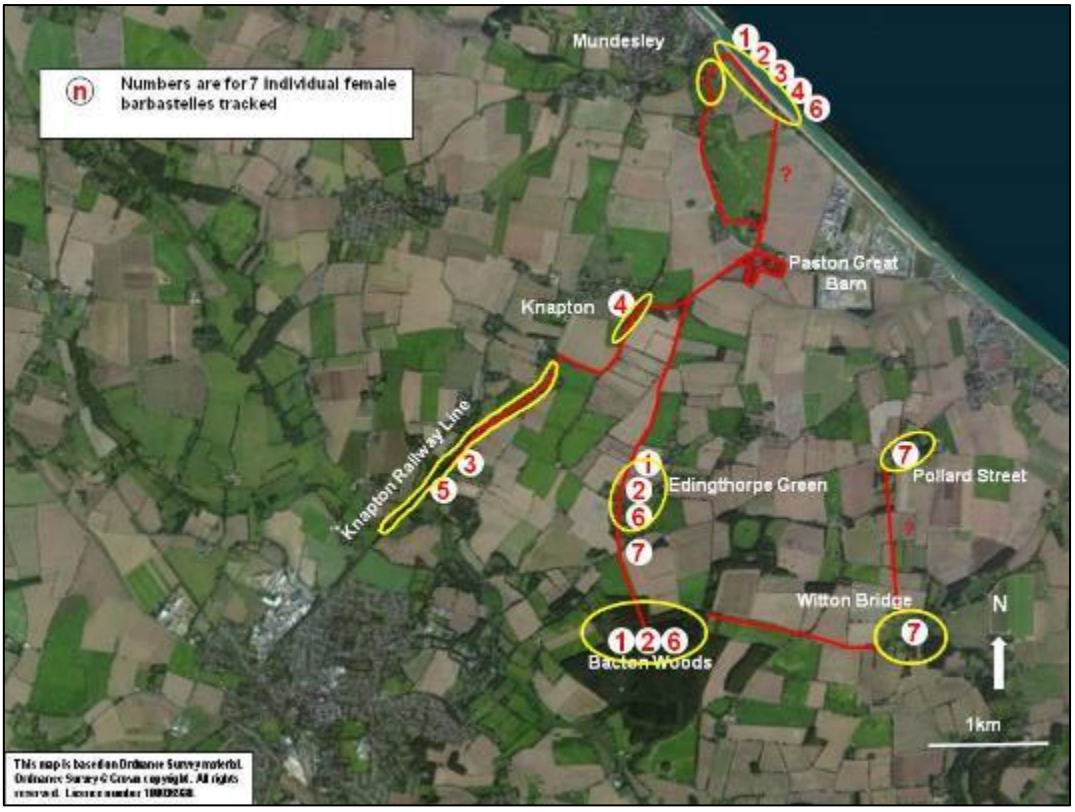

Figure 5: Flight-lines (shown in red) and foraging areas (outlined in yellow) for Paston Great Barn females.

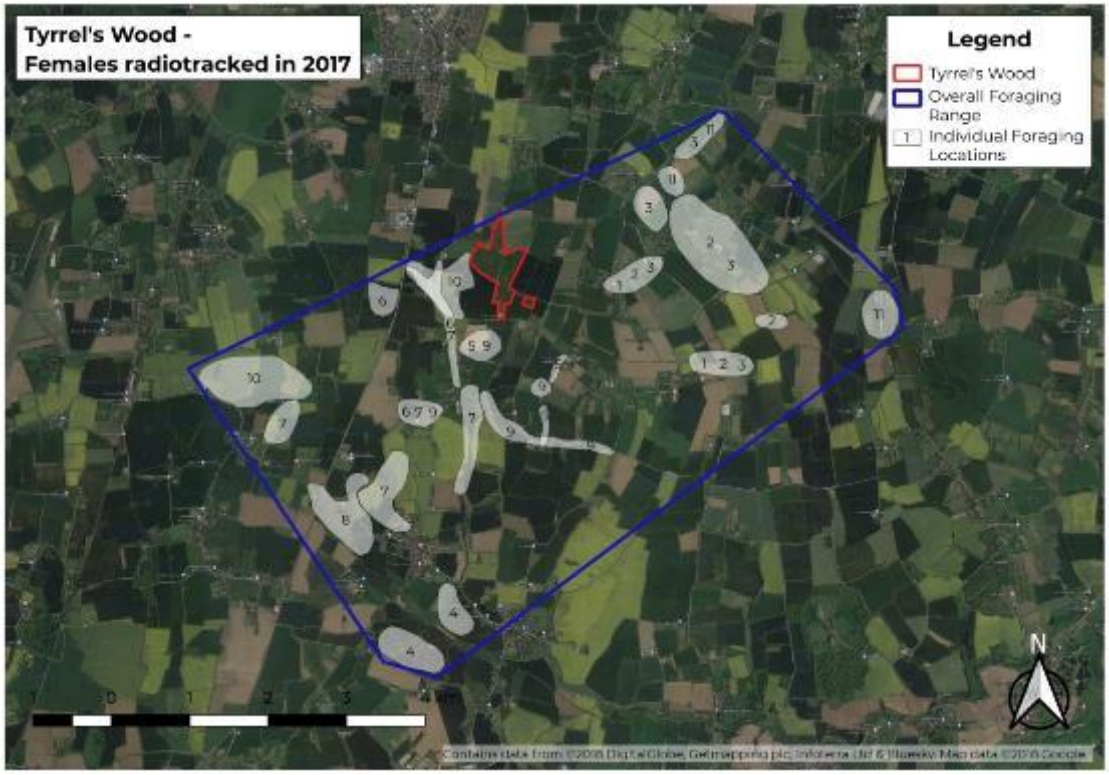

Figure 6: Home range and core foraging areas for the Tyrell's Wood maternity colony.

Pasture and derelict grassland are also targeted, but always in combination with tall boundary hedgerows and hedgerow trees. Tall hedgerows are one of the most important landscape features for barbastelles, and provide foraging opportunities in arable-only areas. Lastly, barbastelles exploit gardens and grounds surrounding rural settlements which typically have an abundance of trees, shrubs and hedgerows, but no street lights. Large country houses with extensive grounds and mature trees are often targeted.

It is clear from our studies that the extent and variety of habitats in the agricultural landscapes of north and south Norfolk contain sufficient insect prey to support barbastelle colonies, although there will be annual variations influenced by weather conditions. To date, we have not fully investigated The Broads landscape to determine if the wet woodlands and wetland habitats provide suitable roosting and foraging potential respectively, although we know that numerous roost trees are generated in the succession to oak woodland at Calthorpe Broad. It would also be of value to determine if the sparsely wooded fens of west Norfolk and the intensively arable areas of east Norfolk support barbastelle colonies.

Home ranges

Home ranges were calculated for the most intensively tracked maternity colonies (Table 1). As expected, colony home range increased with the number of bats tracked, and is likely to be underestimated. The maximum distance travelled from the roost woodland averaged 3.5km with no bats travelling more than 5.5km. This is perhaps surprising for a wide-ranging fast-flying species, but females still in their maternity groups may range less widely than non-breeding females or males.

Table 1: Individual and colony home ranges (minimum and maximum values in parentheses).

Maternity colony	Number of females tracked	Mean individual home range (ha)	Colony home range (ha)	*Mean-maximum foraging radius (km)
Paston Great Barn	7	460 (208 - 755)	1,709	3.5 (2.1 – 4.0)
Old Hills Woods	5	532 (260 – 720)	1,400	3.4 (4.9 – 4.2)
Foxhills Woods	5	427 (353 – 577)	1,253	3.0 (2.2 – 3.8)
Tyrrel’s Wood	11	388 (172 – 677)	3,447	3.7 (2.3 – 5.4)

*Maximum foraging radius is measured from roost cluster or centre of roost woodland

Core Sustenance Zones (CSZ) are defined as the area surrounding a communal bat roost within which habitat availability and quality will have a significant influence on the resilience

and conservation status of the colony. CSZ is a valuable tool to assess the potential impacts of development on bats. It is calculated to be 6km for barbastelles (Collins, 2016). The mean-maximum foraging radius from our work is consistently less than this figure. This may be due to the smaller number of barbastelles tracked. However, it does appear that the agricultural Norfolk landscape provides sufficiently productive foraging areas close to roost woodlands which can be intensively exploited by barbastelles, thus avoiding energetically expensive long-distance flights.

Colony interactions

Radio-tracking has revealed territory overlap between adjacent maternity colonies. These are the Paston Great Barn and Old Hills Woods colonies (5.8km apart) and Blickling Park and Mossymere Wood colonies (3km apart). This finding is of particular interest in respect of the Paston Great Barn colony which was considered to be relatively isolated (Figure 7). We have no evidence for movement of females between the Paston Great Barn and Old Hills Woods colonies but the shared use of foraging areas may be indicative of colony interactions.

Figure 7: Overlap of home ranges of Paston Great Barn (outlined in red) and Old Hills Woods (outlined in yellow) maternity colonies.

Importance of the coast

Radio-tracking has established that coastal cliffs are core foraging areas for females from maternity colonies close to the coast. To investigate and compare the importance of different coastal habitats, we deployed static detectors at ten sites along the north Norfolk coast in 2013 (Table 2).

Some detector sites were within foraging range (5km) of known or inferred maternity colonies, or within 5km of woodlands with roost potential, whilst other sites were not. Activity was recorded for one week every month from March to November (Figure 8).

Table 2: Coastal locations of static detectors.

Detector sites (west to east)	Maternity colonies within 5kms	Woods with roost potential within 5km	Minimum distance of colony from coast (km)	Coastal habitat
Inner Trial Bank, The Wash		None		Salt marsh
Snettisham RSPB	Ken Hill	Sandringham Estate Woods	2.0	Open dunes, lagoons
Holme Bird Observatory		Hunstanton Park		Dunes with tall pines
Scolt Head		None		Saltmarsh
East Hills, Wells	Holkham Park		2.0	Dunes with tall pines
Cley	*Bayfield Woods		5.0	Saltmarsh, shingle bank
Cromer	Felbrigg Park		2.3	Coastal cliffs
Mundesley	Paston Great Barn		1.1	Coastal cliffs
Sea Palling	Calthorpe Broad		2.4	Open dunes
Horsey Gap	Calthorpe Broad		2.5	Open dunes

*Inferred maternity colony

High levels of activity were recorded on the cliffs at Mundesley and Cromer where radio-tracking had confirmed that this was a core foraging area for females from the maternity colonies at Paston Great Barn and Felbrigg Hall respectively. Activity increased through the summer, peaking in September. Barbastelles visited East Hills and the Holme Bird Observatory where the dunes are covered in pines and scrub, offering some shelter. Both are within 5km of suitable woodlands and within barbastelle foraging distance. Activity was low behind the shingle bank at Cley, despite being within 5km of the Bayfield Estate woods. Although Sea Palling and Horsey Gap dunes are within foraging distance of the Calthorpe Broad colony, barbastelles were only occasionally recorded there. Radiotracking of the Calthorpe Broad colony showed that females did not target the dunes, but foraged behind them or further inland along woodland edge, hedgerows, lanes and water courses fringed

with shrubs. The lack of activity at Snettisham also suggests that the nearby Ken Hill colony rarely forages along the shingle bank. The single barbastelle call in September on the Inner Trial Bank in the Wash was surprising, and we have conjectured that this might have been a migrant/vagrant from the continent.

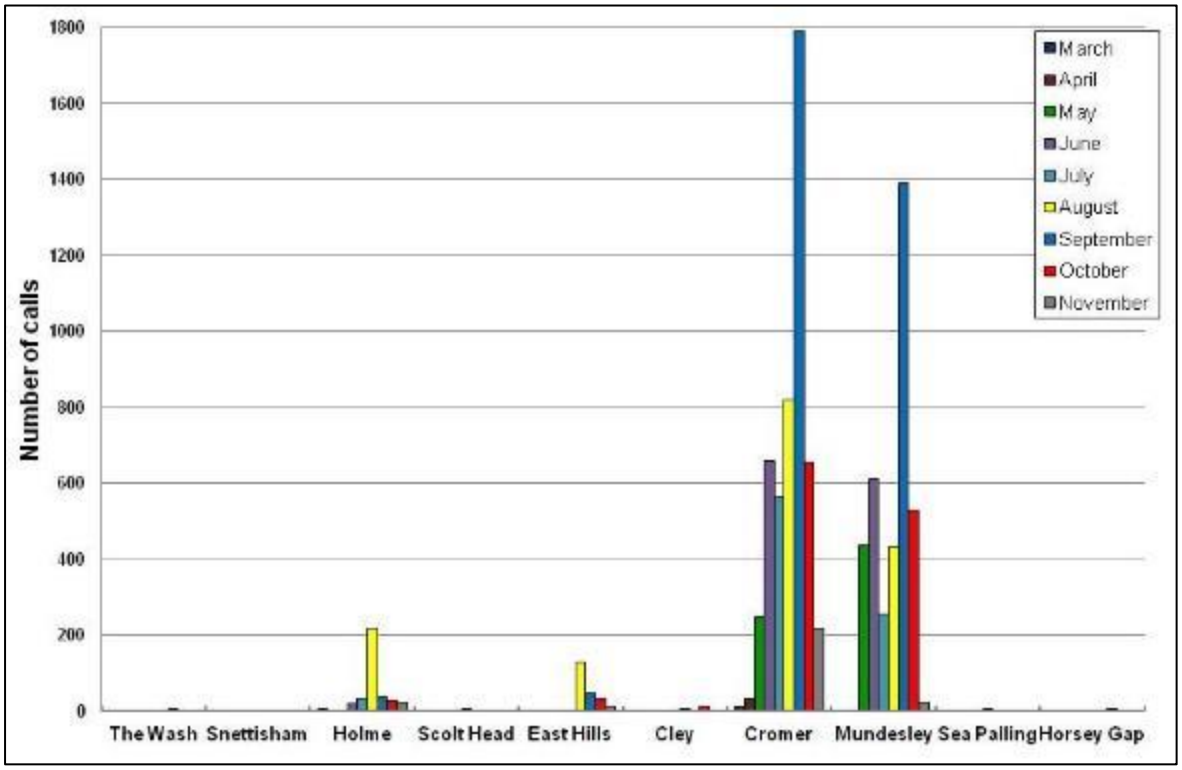

Figure 8: Barbastelle activity at ten coastal locations in 2013.

In summary, coastal cliffs are an important resource for maternity colonies within 5km of coastal cliffs at Sheringham Park, Felbrigg Park, Foxhills Woods and Paston Great Barn. This comparison of barbastelle activity at coastal habitats suggests that the major factor is the degree of shelter afforded by cliffs or tall vegetation. Insect abundance is expected to be higher in the lee of the coastal cliffs or tall pines on the dunes compared to open dune and saltmarsh habitats.

Autumn dispersal

We have trapped and radio-tagged a small number of female barbastelles in September and October 2015 to gain information on autumn dispersal. Two females trapped in Foxhills Woods on 30th October continued to roost in trees in the woodland, but switched roosts less often as the weather deteriorated. One female night-roosted in a barn just outside the wood. Two females from the Paston Great Barn colony roosted both in trees and agricultural barns, all within 5km of the maternity colony. On this limited evidence, females do not appear to disperse more than 5km from the maternity roost location and agricultural barns are of importance for roosting outside the maternity period.

Winter foraging and hibernation

Barbastelles are winter-active and are frequently recorded flying in woodlands throughout the winter. NBSG monitors a number of underground hibernation sites, some located in barbastelle maternity roost woodlands, but barbastelles are rarely found. Although there

are historic Norfolk records for ice houses, brick kilns and tunnels, it appears that barbastelles are likely to remain in tree roosts and only move to underground sites in very harsh winters. Numerous records of single barbastelles in agricultural barns during the winter months emphasize the importance of these buildings for winter roosts. Crevices in brickwork, timbers, cladding and roof coverings are the usual locations, but a hibernating barbastelle was found under plastic sheeting in a disused agricultural barn in January 2012 (Figure 6).

Figure 6: Barbastelle hibernating under plastic sheeting. © Jane Harris.

Males

Our work has been focussed on females and maternity colonies which are of high conservation status, but we have also radio-tracked three males. From this limited study, we have found that males roost separately from females, show the same roost switching behaviour and use a wider variety of roosts. These included more unusual tree species (yew *Taxus baccata*) and buildings such as brick and pantile barns and small sheds. One male at each of Foxhills Woods and Old Hills Woods foraged in similar locations to the females and showed fidelity to foraging areas. They did not forage further than 5km from the roost woodland. Males are known to be wide-ranging and responsible for gene flow between colonies, but we have not observed this with the limited numbers tracked to date.

Threats and opportunities

From our current knowledge, we can assess the threats facing barbastelles in Norfolk and where action is needed to avoid or mitigate against potentially damaging land management and development actions. Beyond this, there are opportunities to support existing populations and secure their viability in the long-term. These threats and opportunities are

summarised in Table 3 and we hope they will influence and guide barbastelle conservation strategies in Norfolk.

Table 3: Threats and opportunities for barbastelle conservation in Norfolk.

Management	Threats	Opportunities
Site identification and protection	• Known key sites are not designated • Importance of small woodlands not known or underestimated • No monitoring protocol	• Designate key sites • Survey more woodlands, especially CWS • Develop monitoring protocol
Woodland management	• Roost loss through felling and dead wood removal • Exposure of roost trees • Opening up of dark rides	• Retain dead wood • Retain vegetation structure around roost trees • Retain dark flyways • Leave areas of non-intervention in all woodlands • Encourage natural cycle of growth, damage and decay (non-intervention) • Woodland creation in sparse woodland areas to improve connectivity to the wider landscape • Toolkit for woodland owners[1] • Integrate opportunities into woodland management schemes
Long-term roost availability	• No trees less than 100 years old at some sites • Decline in roost availability within sites	• Encourage planting and regeneration of oak and sweet chestnut • Develop bat boxes to mimic roost features • Use bat boxes where roost availability is limited or declining • Investigate veteranisation of trees to generate roost features
Field boundary management	• Reduction in prey availability through hedgerow loss and intensive management • Loss of sheltered foraging habitat through intensive hedgerow management • Clearance of woody vegetation along watercourses	• Retain and increase mixed native-species hedgerows with nectar-rich trees and shrubs • Plant hedgerow trees • Management prescriptions to encourage untrimmed hedgerows • Maintain a strip of rough grass and woody vegetation along watercourses

[1] A new woodland wildlife toolkit was launched in early 2019. https://woodlandwildlifetoolkit.sylva.org.uk/home

Management	Threats	Opportunities
	• Lack of connectivity between habitat features for roosting and foraging	• Enhance connectivity between woodlands and woodlands and foraging areas
Landscape-scale management	• No recognition of habitat use by barbastelle • Small-scale management by individual landowners	• Agi-environment schemes to identify, retain and create barbastelle habitat features on farm units • Expand to farm clusters to enrich large areas surrounding or adjacent to roost woodlands • Initiatives to halt the decline in insect populations
Coastal development	• Illumination of cliffs • Loss of flight-lines to cliffs	• Reduce existing illumination by low intensity lighting • Hedgerow and tree planting to link to coast
Barn conversions	• Loss of autumn, winter, spring roosts • Loss of night roosts	• Planning conditions to condition installation of barbastelle roosting places in barn conversions within 6km of maternity roost
Infrastructure projects	• Fragmentation of flight-lines to high fidelity foraging areas • Colony fragmentation within roost woodlands • Modification of roost environment, availability and continuity • Disturbance of roosts through public access, new roads	• Risk map for Norfolk barbastelles based on locations of maternity colonies • Planning policy to recognise CSZ • All barbastelle habitat features to be identified and maintained within CSZ • Enhance and create barbastelle habitat features within 6km of maternity roosts

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