MOTT MACDONALD

Norwich Northern Distributor Road

Post-Construction Barbastelle Bat radio tracking monitoring report: Year 1 2018

January 2020

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Contents

Executive summary

Radio-tracking to monitor barbastelle (Barbastella barbastellus) colonies in proximity to the newly constructed Norwich Northern Distributor Road (NDR) in Norfolk was commissioned from Insight Ecology for Norfolk County Council. Pre-construction surveys (2009 - 2013) identified barbastelle 'hot spots' (roost clusters and home ranges) in the Morton, Felthorpe and Rackheath areas. The new road was completed and fully opened in April 2018. In May, June and August 2018 (Year 1), we undertook bat trapping surveys at 13 different sites in the vicinity of the NDR. These were sites where barbastelles had previously been found and/or where potential barbastelle habitat was present, focussing on the Morton, Felthorpe and Rackheath areas.

A total of 259 bats were caught during the 14 trapping surveys. Barbastelles (31) were trapped at five of the 13 sites, with an individual radio-tracked to roosts at a sixth site. These six sites were all at the western end of (and located furthest from) the NDR, >2.5km from the new road. Five of the sites corresponded with the 'Morton Colony' area (Weston Park Golf Club, the Dinosaur Park, Hardingham Hills, Scotchwood Hills and Marriott's Way Attlebridge) and one with the 'Felthorpe Colony' area (Upgate Common). Barbastelles were most abundant during trapping surveys at Weston Park Golf Club and the adjacent Dinosaur Park.

Ten radio-tags were deployed on adult female barbastelles within the 'Morton Colony' area: in the pre-maternity period two tags were deployed at Marriott's Way Attlebridge and two at Weston Park Golf Club and in the post-maternity period three tags were deployed at Weston Park Golf Club and three at the Dinosaur Park. A total of 36 roosts (all in trees) were located through radio-tracking. Twenty-four of these were at Weston Park Golf Club, six at the Dinosaur Park, two at Hardingham Hills, one at Hockering Wood, one at Sparham Wood, one at Attlebridge Hills (north-west end) and one at Gravelpit Plantation (Ringland). Simultaneous roost counts (at all located tree roosts at or linked to the site) yielded a minimum estimate of 46 barbastelles (most likely adult females and juveniles) for the Weston Park Golf Club colony (this is likely to be an underestimate).

Whilst the trapping surveys were not intended to be a comprehensive survey, with the primary focus being to trap barbastelles for radio-tagging, the absence of any trapped female barbastelles in the Rackheath and Felthorpe areas warrants further investigation, as pre-construction of the NDR there were significant roost clusters in these areas. The Morton area remains important for barbastelles, in particular Weston Park Golf Club (with Hardingham Hills) and the Dinosaur Park. Recognition and protection of these key sites should be a priority for any future developments in these areas.

1 Introduction

This report provides factual survey and analysis of surveys carried out May - September 2018 to determine barbastelle bat activity in the vicinity of the newly-opened Norwich Northern Distributor Road (now called Broadland Northway).

Construction of the 22km long Norwich Northern Distributor Road (NDR, A1270) in Norfolk commenced in December 2015 and was completed, and all sections opened, in April 2018. The dual carriageway road runs from the A47 at Postwick, east of Norwich, to the A1067 Fakenham Road, north of Taverham (Figure 1). There is a requirement within the Development Consent Order granted by the Secretary of State to undertake post-construction monitoring of certain protected species, so that impacts of the new road on these species can be determined. This report captures the on-site monitoring for Bats in the first year after opening of the road, Year 1: 2018.

Barbastelles (Barbastella barbastellus) are one of only two of the UK's 17 resident breeding bat species to be listed as 'Near Threatened' globally on the IUCN Red List (all other UK species are listed as 'Least Concern') and they have a decreasing population trend (Piraccini 2016). Barbastelles are listed under Annexes II and IV of the European Union Habitats Directive (species considered to be most in need of conservation at a European level and whose conservation requires the designation of Special Areas of Conservation (SACs)). They are also listed as a Priority Species (formerly Biodiversity Action Plan Species) in the UK, under Section 41 of the NERC Act 2006.

Norfolk is a stronghold for barbastelles (Norfolk County Council 2009) and therefore ensuring the protection of the county's colonies is important for maintaining the UK's barbastelle population. In particular, new infrastructure schemes which have the potential to destroy or damage barbastelle habitat must be carefully planned and monitored to ensure any impacts on the species are minimised.

Extensive bat surveys were carried out pre-construction of the NDR (Mott MacDonald 2013) to inform design, mitigation and compensation measures. These surveys included radio-tracking of 40 barbastelles in three separate years: 2009 (n=31), 2012 (n=3) and 2013 (n=6). The radio-tracking was carried out to determine roost locations, commuting routes and foraging areas. The brief for post-construction barbastelle radio-tracking monitoring was: "Seven years (Years 1 and 7). May/June or August each year, focussing on the same areas identified as important through baseline surveys."

Post-construction static detector and transect bat surveys by Mott MacDonald have looked at use of bespoke bat-friendly crossing points over/under the new road (including by barbastelles) and bat activity in areas adjacent to the road. The post-construction barbastelle radio-tracking sought to add to this specifically by assessing the status of key barbastelle colonies identified during the pre-construction surveys.

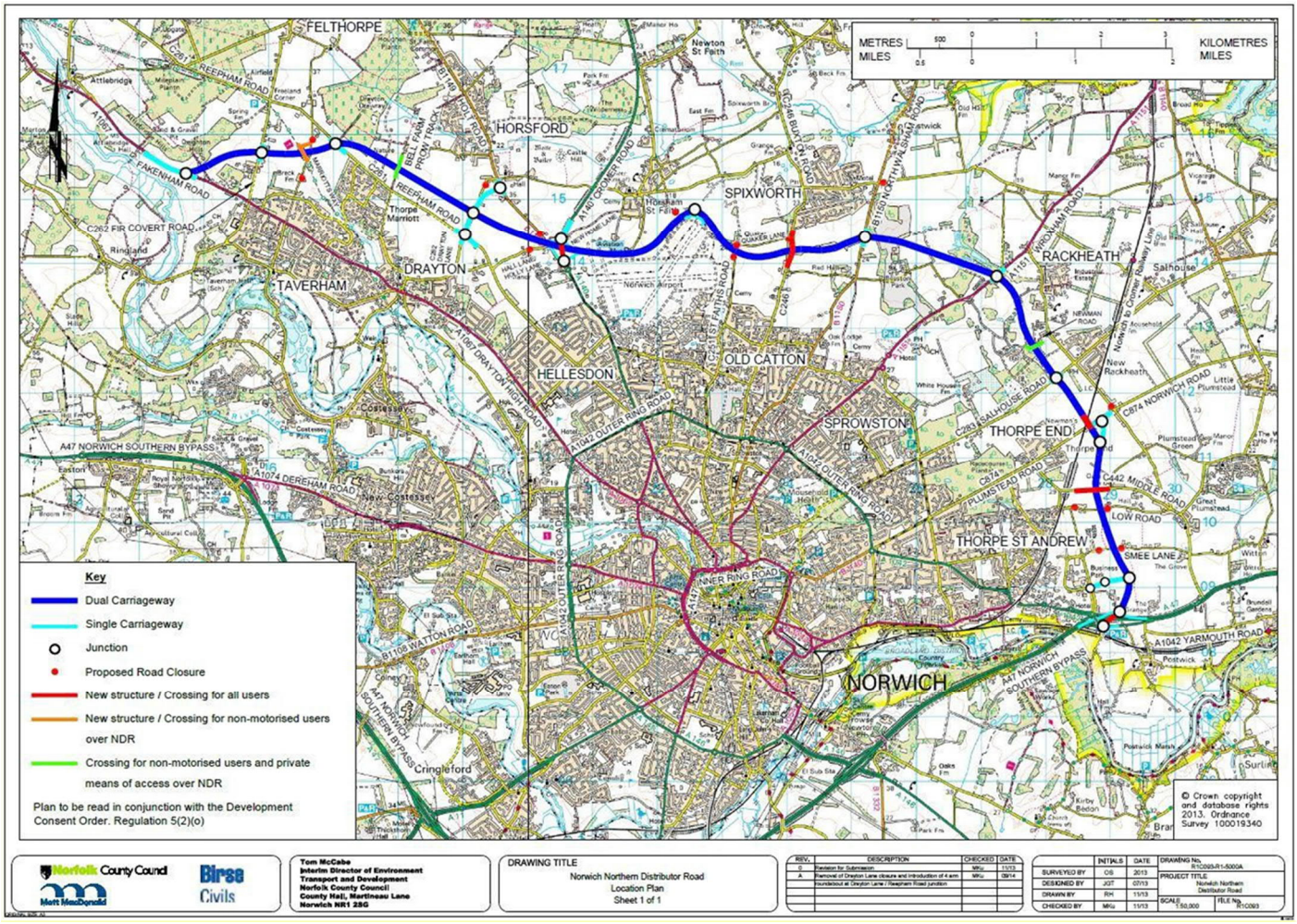

Figure 1 Norwich Northern Distributor Road location plan

2 Methodology

2.1 Project Licence, experience and expertise

Mott MacDonald commissioned Insight Ecology to undertake the required radio-tracking and provide a factual report of the surveys. A Science & Conservation Project Licence (2018-34928-SCI-SCI) was granted to Dr Charlotte Packman for this work, covering bat trapping (all species: by hand, hand-held static net, mist-net, harp-trap and acoustic lure) and radio-tagging of barbastelles in the vicinity of the NDR (within 20km of TG 231 085).

This work was led by C. Packman, who holds Level 3 and Level 4 Bat Survey Class Licences (registration numbers 2015-16479-CLS-CLS & 2015-11760-CLS-CLS) and is a Registered Consultant for the Bat Low Impact Class Licence (RC15) and the Bats in Churches Class Licence (Level 2, B32RC001), as well as holding a number of different Science & Conservation Project Licences (covering all species, all trapping methods and radio-tagging).

Primary surveyors carrying out bat trapping, radio-tracking and simultaneous roost counts (following appropriate training where necessary) were:

Dr Charlotte Packman CEcol MCIEEM (licence details given above)

Dr Iain Barr MCIEEM, Level 3 and 4 Bat Survey Class Licence holder (2015-12766CLS-CLS & 2015-12767-CLS-CLS) & Authorised Individual on the Project Licence

Jane Harris MCIEEM, Level 3 and 4 Licence holder (2015-11491-CLS-CLS & 201511492-CLS-CLS) & Authorised Individual on the Project Licence

James Goldsmith, Level 4 Licence holder (2015-13794-CLS-CLS) & Authorised Individual on the Project Licence

Anthony Gagen, Level 1 Licence holder (2018-33704-CLS-CLS)

Holly Nichols (Trainee/Assistant)

Steven Gilham (Trainee/Assistant)

Additional surveyors assisting with simultaneous roost counts were: Dr David White, Edward Stocker, Charlotte Keightley, Jake Collins, David Andrews, David Showler, William Soar, John Worthington-Hill, Kat Hodgkinson, Darrell Bean, Clemence Fowler, Christopher Bawler and Jefferson Kay.

Insight Ecology's survey findings (including those provided by their sub-consultant Wild Wings Ecology) were reviewed and edited into this document by Mott MacDonald.

2.2 Bat trapping

The primary aim of the bat trapping surveys was to capture adult female barbastelles for radio-tagging. Adult females were targeted around the maternity period with the aim of locating key maternity colony roosts. Consequently, trapping efforts were focused on late May/early June and August, when it was considered most likely that tagged females would lead us to maternity

roosts. The period when barbastelles are heavily pregnant and have young, dependent pups was avoided (in Norfolk, barbastelles typically give birth in the first and second weeks of July, J. Harris pers. comm. based on roost camera data).

Secondary to that, the bat trapping surveys provided an indication of bat activity levels within the woodlands and other species present ('bycatch') including species which may be under-represented in acoustic surveys (e.g. brown long-eared bat). They also provided information on reproductive status (i.e. if females are pregnant or lactating it may indicate the presence of a maternity colony nearby, particularly if captured in the species' expected emergence time window). The trapping surveys were not intended to be a comprehensive/systematic survey of bat presence within the woodlands (which would have required significantly more trapping nights), with the primary focus being on trapping barbastelles for radio-tagging.

Similarly, it was not possible to replicate survey effort or obtain comparable survey data to the pre-construction surveys, due to a limited number of trapping nights available (for both the pre- and post-construction surveys) and a lack of information provided regarding survey durations, exact trap types, numbers, lengths and locations used in the pre-construction surveys. Bat trapping sites were selected based on trapping sites used and roost sites located in the pre-construction surveys and knowledge and survey of local sites with barbastelle records and/or suitable habitat. Three main barbastelle colonies were identified during the pre-construction surveys: 'Morton', 'Felthorpe' and 'Rackheath' (Mott MacDonald 2013, see Figure 2). These were the focus for radio-tagging efforts.

A total of 14 night-time trapping surveys were carried out at 13 different sites in the vicinity of the NDR (see Figure 3 and Table 1). Some sites bordered the NDR (e.g. Rackheath Park March Covert), while the most distant site was 4.5km from the NDR (the Dinosaur Park). The more distant sites were included as they fell within the 'Morton Colony' area, known to be important for barbastelles. The Core Sustenance Zone (CSZ) for barbastelles is a 6km radius around a communal roost (Collins 2016), which even for the most distant 'Morton Colony' encompasses the western end of the NDR. The Bat Conservation Trust defines CSZs 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 using the roost" and also states that "there may be justification with Annex II and other rare species to increase the CSZ to reflect use of the landscape by all bats in a population" (Collins 2016).

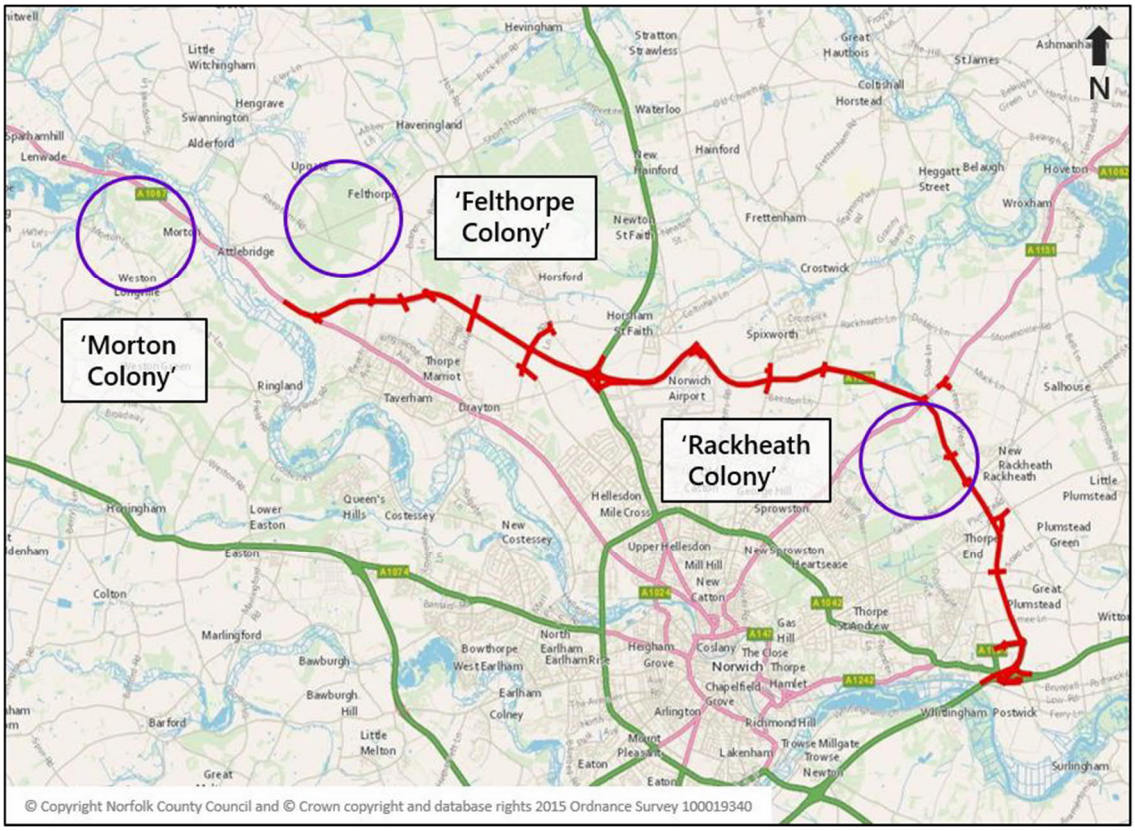

Figure 2. Main barbastelle colony areas identified during the pre-construction radiotracking surveys and targeted in the post-construction radio-tracking surveys (approximate main areas circled in purple). NDR route shown by red line

Bat trapping surveys were undertaken with a minimum of two Level 3 (mist-net) and/or Level 4 (harp-trap) licensed bat surveyors present. Level 1, 2 and 4 licensed bat surveyors and trainees also assisted with surveys.

Trapping surveys mostly utilised mist-nets (single, double and triple height, ranging from 3m-12m in length), as in Norfolk this approach has proved most successful for catching barbastelles. Typically, six or seven (single/double/triple height) mist-nets were deployed per trapping session (see **Table 1**). A harp-trap was also used on one occasion and an acoustic lure (Bat AT100 Ultrasonic Transmitter, Binary Acoustic Technology) on two occasions (see **Table 1).** Mostly the sites were not well-suited to deploying harp-traps for targeting barbastelles. Acoustic lures tend to attract males more than females (and we were targeting females), so these were mostly considered superfluous.

Traps were positioned across pathways, woodland rides and vegetation corridors. The primary focus was on the post-dusk period, when bat activity tends to be high. Acoustic data from the Norfolk Bat Survey show that the average number of barbastelle recordings peaks between one and two hours after sunset (Newson 2015), which corroborates the experience of the Norfolk Barbastelle Study Group. Trapping surveys finished either when there was little/no further bat activity, weather conditions became unsuitable, or the desired number of adult female barbastelles had been caught for tagging (e.g. at the Dinosaur Park on 25/08/18 traps were closed very early, after only 3 hours (see **Table 1**), as a sufficient number of barbastelles had

been caught for tagging purposes, see **Table 4**). Traps were typically open for 4-5 hours (see **Table 1**) before one of the above factors ended the survey.

Bats were extracted from traps as quickly as possible and held for as short a time period as feasible prior to release. Bats were briefly checked at the point of extraction; any females that were heavily pregnant were released immediately. Bats were placed into cloth bags and suspended, in capture order, inside a car (warm, dry and sheltered from any wind). Bats were processed in capture order and the following information recorded: species, age, sex, forearm measurement, weight and reproductive status.

Trapping surveys were undertaken for a total of approximately 55 hours (time when traps were open), with 89 traps deployed. This equated to a total of 255 trap-hours (per 12m trap length, Ralph 1976).

Constraints

Trapping surveys were constrained by landowner permission, particularly in the 'Felthorpe Colony' area and, to a lesser extent, in the 'Rackheath Colony' area. Consequently several sites in these area with potential to support barbastelle colonies (and indeed with pre-construction roost records, presumably obtained by triangulating radio-tagged bats from outside of the sites) could not be accessed (e.g. Felthorpe Hall and Tollshill Wood, Sprowston).

Weather conditions somewhat constrained trapping surveys, with rain and/or wind preventing some surveys from taking place or curtailing trapping sessions due to unsuitable or unsafe weather for bat trapping. However, it was possible to re-schedule all planned trapping surveys affected, and trap at all sites deemed suitable and where it was possible to gain landowner permission.

Figure 3. Bat trapping site locations (denoted by red stars) for May/June and August 2018 (see **Table 1**). NDR route shown by red line.

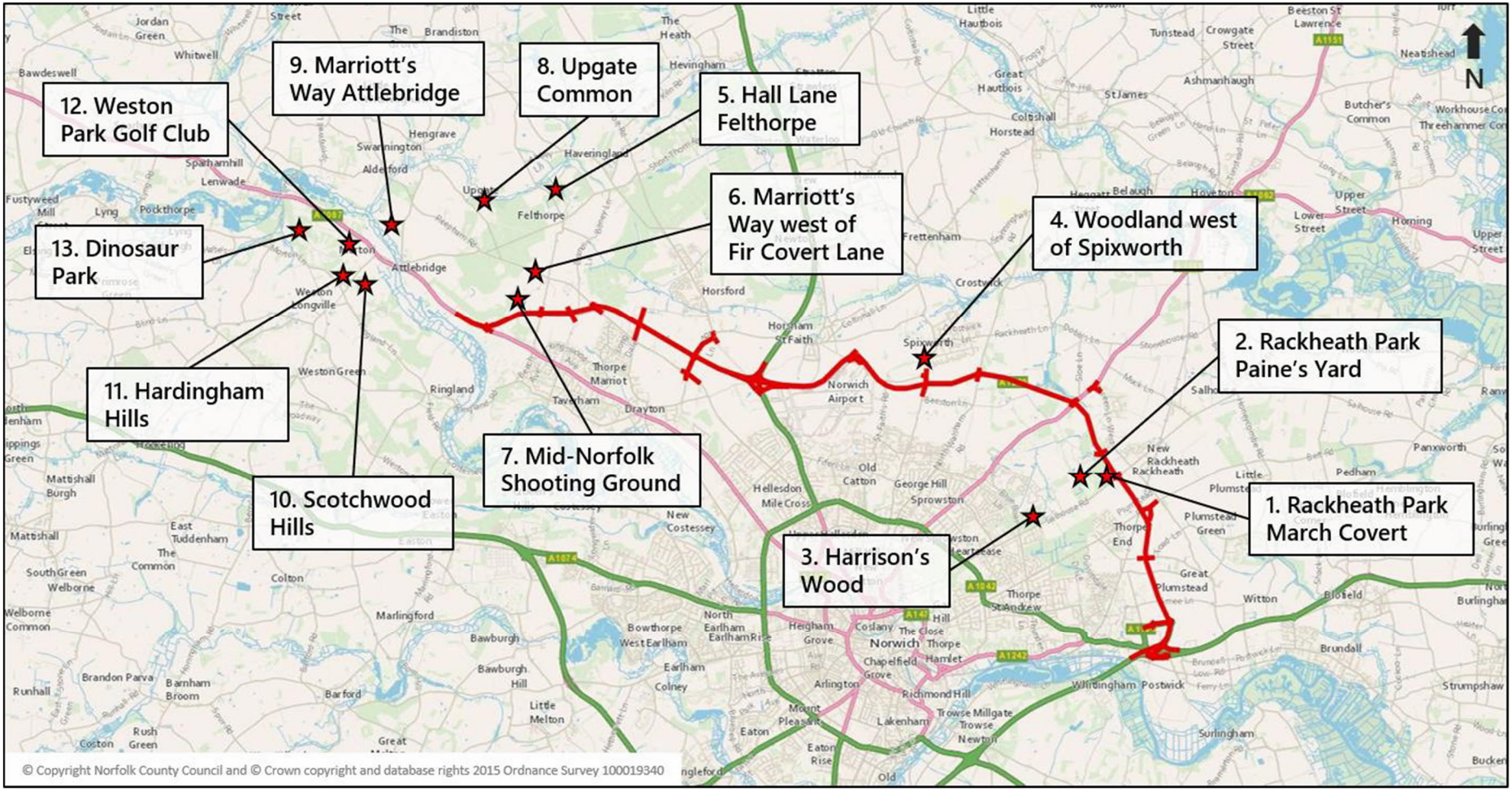

Table 1. Bat trapping survey details. Sites are listed in location order from east to west along the NDR route (see Figure 3. for map). Under 'date & timings' timings given are: SS = sunset time, TO = time traps opened, TC = time traps closed (+1 = following day), trapping hours (rounded to nearest half hour) are given in brackets. Under 'weather conditions': TS = temperature at start of survey, TE = temperature at end of survey, Wd = wind (BS = Beaufort Scale), CC = cloud cover, Pp = precipitation. Under 'trap types & length': SMN = single-height mist-net (SMNs = two single-height mist-nets linked together next to each other), DMN = double-height mist-net (two mist-nets stacked on top of each other), TMN = triple-height mist-net (three mist-nets stacked on top of each other), HT = harp trap, * = with acoustic lure playing barbastelle calls. Trap coordinates given in British National Grid.

Site no.	Site name	Date & timings	Weather conditions	Trap types & length	Trap coordinates
1.	Rackheath Park March Covert	14/08/18 SS: 20:24 TO: 20:15 TC: 01:10^{+1} (5hr)	TS: 19°C TE: 16°C Wd: BS0 CC: 100% Pp: nil	SMN: 6m SMNs: 12m + 6m SMN: 6m TMN: 9m x3 SMN: 9m SMN: 9m	TG 27922 12278 TG 27883 12296 TG 27852 12359 TG 27832 12388 TG 27812 12425 TG 27793 12465
2.	Rackheath Park Paine's Yard	08/06/18 SS: 21:15 TO: 21:15 TC: 02:00^{+1} (5hr)	TS: 16°C TE: 13°C Wd: BS0 CC: 100% Pp: nil	SMN: 12m SMN: 6m SMN: 3m SMN: 6m SMN: 12m SMN: 6m SMN: 9m	TG 27409 12233 TG 27383 12175 TG 27351 12139 TG 27320 12145 TG 27318 12170 TG 27257 12262 TG 27312 12273
3.	Harrison's Wood	09/06/18 SS: 21:15 TO: 21:15 TC: 00:15^{+1} (3hr)	TS: 13°C TE: 13°C Wd: BS0 CC: 100% Pp: drizzle - rain @ 00:15	SMN: 9m SMN: 6m SMN: 9m SMN: 9m SMN: 9m SMN: 9m	TG 26331 11287 TG 26265 11259 TG 26367 11323 TG 26332 11314 TG 26321 11349 TG 26269 11374
4.	Woodland west of Spixworth	10/08/18 SS: 20:32 TO: 20:35 TC: 01:15^{+1} (4hr)	TS: 13°C TE: 12°C Wd: BS0 CC: 50% Pp: nil	SMN: 4m SMN: 6m SMN: 9m HT* SMN: 3m SMN: 9m SMN: 6m	TG 23914 14724 TG 23944 14726 TG 24024 14685 TG 24041 14638 TG 24049 14629 TG 24076 14568 TG 24040 14491
5.	Hall Lane, Felthorpe	27/05/18 SS: 21:02 TO: 21:18 TC: 01:00^{+1} (4hr)	TS: 15°C TE: 13°C Wd: BS0 CC: 100% Pp: nil	SMN: 6m SMN: 6m SMN: 4m SMN: 3m	TG 16187 18479 TG 16137 18426 TG 16475 18856 TG 16346 18726

Site no.	Site name	Date & timings	Weather conditions	Trap types & length	Trap coordinates
6.	Marriott's Way west of Fir Covert Lane	26/05/18 SS: 21:00 TO: 21:00 TC: 01:00^{+1} (4hr)	TS: 13°C TE: 12°C Wd: BS1 CC: 10% Pp: nil	SMN: 6m DMN: 6m x2 SMN: 6m SMN: 6m SMN: 6m	TG 15996 16473 TG 15918 16528 TG 15826 16582 TG 15735 16626 TG 15679 16642
7.	Mid-Norfolk Shooting Ground	27/05/18 SS: 21:02 TO: 21:02 TC: 00:45^{+1} (3hr)	TS: 15°C TE: 13°C Wd: BS0 CC: 100% Pp: nil	SMNs: 6m + 9m SMNs: 9m + 9m SMN: 12m SMN: 9m SMN: 6m	TG 15253 15995 TG 15170 16014 TG 15131 16042 TG 15121 16038 TG 15125 16009
8.	Upgate Common	15/08/18 SS: 20:21 TO: 20:15 TC: 01:15^{+1} (5hr)	TS: 21°C TE: 18°C Wd: BS2 CC: 100% Pp: nil	SMNs: 9m + 12m SMN: 6m SMN: 3m SMNs: 9m + 6m SMN: 6m SMN: 9m	TG 14762 18072 TG 14725 18090 TG 14709 18099 TG 14732 18167 TG 14582 19095 TG 14619 18041
9.	Marriott's Way Attlebridge	28/05/18 SS: 21:04 TO: 21:05 TC: 03:15^{+1} (6hr)	TS: 13°C TE: 12°C Wd: BS3 CC: 100% Pp: mist - light drizzle @ 03:15	SMN: 9m SMN: 9m SMN: 6m SMN: 6m SMN: 6m SMN: 6m	TG 12749 17634 TG 12709 17635 TG 12677 17651 TG 12579 17693 TG 12508 17721 TG 12455 17737
10.	Scotchwood Hill	08/08/18 SS: 20:36 TO: 20:45 TC: 01:15^{+1} (4.5hr)	TS: 20°C TE: 17°C Wd: BS0 CC: 20% Pp: nil	SMN: 6m* SMN: 6m SMN: 6m SMN: 9m SMN: 3m SMN: 3m	TG 12045 16518 TG 12003 16504 TG 11995 16492 TG 12006 16487 TG 11999 16425 TG 12009 16377
11.	Hardingham Hills	06/08/18 SS: 20:38 TO: 20:45 TC: 01:00^{+1} (4hr)	TS: 19°C TE: 13°C Wd: BS0 CC: 5% Pp: nil	SMN: 6m + 9m SMN: 6m SMN: 9m TMN: 9m x3 SMN: 9m	TG 11670 16422 TG 11665 16457 TG 11704 16495 TG 11715 16463 TG 11779 16523
12.	Weston Park Golf Club	03/06/18 SS: 21:10 TO: 21:10 TC: 02:00^{+1} (5hr)	TS: 14°C TE: 12°C Wd: BS0 CC: 0% Pp: nil	SMN: 9m SMN: 9m SMN: 12m SMN: 6m SMN: 6m SMN: 9m	TG 11748 17203 TG 11779 17232 TG 11819 17242 TG 11784 17285 TG 11858 17289 TG 11872 17297

Site no.	Site name	Date & timings	Weather conditions	Trap types & length	Trap coordinates
12.	Weston Park Golf Club	12/08/18 SS: 20:28 TO: 20:30 TC: 00:20[+1] (4hr)	TS: 19°C TE: 16°C Wd: BS0 CC: 100% Pp: brief, light	SMN: 12m SMN: 9m TMN: 9m x3 SMN: 6m SMN: 9m SMN: 6m SMN: 6m	TG 11755 17217 TG 11782 17235 TG 11799 17285 TG 11849 17285 TG 11873 17310 TG 11895 17297 TG 11825 17186
13.	Dinosaur Park	25/08/18 SS: 20:00 TO: 19:55 TC: 23:00 (3hr)	TS: 14°C TE: 10°C Wd: BS0 CC: 0% Pp: nil	SMN: 6m SMN: 9m SMN: 9m SMN: 6m SMN: 9m SMN: 12m SMN: 9m	TG 10564 17288 TG 10573 17370 TG 10579 17402 TG 10637 17454 TG 10658 17390 TG 10626 17365 TG 10654 17249

2.3 Barbestelle Radio-tracking

Funding was provided for 10 radio-tags for barbastelles. Tag parameters were optimised for day roost tracking i.e. a slower pulse rate could be used as not tracking flying bats, while detection range and tag lifespan were maximised (see **Table 2**). Tag detection distance ranged from around 300m to 1.5km.

Table 2. Radio-tag specifications

Tag parameters	Settings
Model	Biotrack PicoPip Ag317
Type	Backpack
Potting	Medium
Tag weight (average)	0.38g
Pulse length	30ms
Pulse rate	40ppm
Estimated tag lifespan	14 days
Antenna length	20cm
Tag length	14mm
Tag width	6mm
Tag height	3mm
Tag activation/switch type	Magnet

Only adult female barbastelles were radio-tagged, first checking that they were in good condition, not heavily pregnant and that they were of sufficient weight (minimum 7.6g) that the tag would be ⩽5% of their bodyweight. Lactating females were only tagged if they were in good condition and met the weight criterion. These criteria were compliant with the Project Licence conditions.

Radio-tag functionality was checked prior to deployment. Tags were fitted by first separating the fur in a central line on the upper dorsal side between the scapulars (using a cocktail stick), then trimming the fur in a radio-tag-sized central patch between the scapulars, before applying a layer of surgical glue [1]to the trimmed patch and coating the radio-tag. The glue was allowed to dry for a few minutes (until tacky but no longer wet) before gently pressing the tag onto the trimmed and glued patch and folding the adjacent fur over the top of the tag (using the cocktail stick). The glue was then allowed to dry fully with the bat held securely and gentle pressure maintained on the tag. Care was taken to ensure no glue spread on the bat or onto the tag antenna and that there was no tackiness to the antenna (which could lead to it becoming caught). Final tag tuning (to determine the 'peak frequency') was carried out when each tagged bat was released.

See **Appendix A** for photographs of barbastelle trapping and radio-tagging.

Radio-tracking

The aim of the radio-tracking was to locate roosts to determine colony locations and obtain colony size estimates, where possible.

Radio-tracking was carried out daily to locate roosts from the first day post-tagging (although sometimes an atypical 'panic roost' was used on the first day, away from the subsequent usual roosts, a common phenomenon when radio-tagging bats). Radiotracking ceased when the tag detached; either located on the ground/in vegetation or the signal remained at the roost for multiple nights post-emergence at the time when tag detachment would be expected. Barbastelles can travel long distances (Zeale et al. 2012) and therefore locating day roosts can be challenging. If a day roost could not be located, the signal would be checked from dusk at the capture site to determine the bearing of approach to help to focus the subsequent daytime search area.

Radio-tracking utilised Biotrack Sika receivers and 3- and 5- element Yagi antennas. A car roof-mounted omni-directional antenna and roof-mounted telescopic 5-element Yagi antenna were also used when covering larger areas. Aerial images and OS maps were used to identify habitat areas for searches. Paper maps were used to record areas searched and routes taken and sketch on signal bearings (taken with a compass) and tracker locations (recorded with a handheld GPS). Searches were undertaken by car and on foot. Radio-tag tuning was checked, where necessary amended and recorded daily.

Once a roost was located, the specific roost feature was determined (when possible) and the feature type and tree species recorded. GPS coordinates of the tree location were recorded and photos taken of the tree and (where possible) the roost feature. Roost trees were assigned an identification code and, where permitted by the landowner, temporarily marked with flagging ribbon (with the roost code written on the ribbon). Smartphones were also used to record approximate roost locations as Google Map pins along with photos of the roost trees, their

[1] Surgical glues used: Perma-Type Surgical Cement, Torbot Bonding Cement and Salts Health Care Ostomy Adhesive

identification codes and roost features, so that these could be quickly and easily shared between multiple trackers to aid survey coordination and information sharing.

Constraints

Landowner permission was the main constraint for radio-tracking, as bat roost locations could rarely be predicted in advance (if away from the trapping sites) and therefore prior arrangements for access could not be made. Instead, for new roost sites, first the landowner had to be determined and then contacted to request access (which was usually granted but often involved some delays).

2.4 Simultaneous roost counts

As barbastelle maternity colonies tend to be split between a number of different roost trees on any given day and individuals regularly switch roosts (Russo et al. 2005), a 'simultaneous roost count' approach was used to try to estimate minimum colony sizes for the Weston Park Golf Club and Dinosaur Park colonies. This involved accruing day roost trees over the tracking period and then carrying out emergence surveys on all trees identified on the same night with a large team of surveyors. This approach is most likely to succeed when at least some (ideally all) of the radio-tags are still attached to the bats and functioning. However, counts carried out early on in the tracking session will inevitably involve fewer trees (but tags are likely to still be attached and functioning), while for later counts more days have passed and consequently more roost trees have been found, as the bats continue to switch roosts (but the tags may fail/detach before the count). Bats tagged and counts conducted too early in the pre-maternity season or too late in the post-maternity season are less likely to adequately represent the maternity colony (as bats may be more dispersed). Russo et al. (2005) report that the rate of roost switching and distance moved between roosts is lowest during the middle of the lactation period. Therefore there is a narrow optimal window for carrying out the simultaneous roost counts, especially once weather conditions and the logistics of arranging a large team of surveyors to attend on a single night are factored in.

Table 3 provides details of the simultaneous roosts counts. Counts were carried out with one surveyor positioned at each roost tree. Surveys commenced 15 minutes before sunset and continued for a minimum of 90 minutes (or 15 minutes after the last bat emerged, whichever was later). Surveyors were equipped with bat detectors to enable barbastelle calls to be identified. For roosts with poor visibility, infrared cameras (with infrared floodlights) were used and the footage subsequently reviewed to check numbers emerging.

Constraints

The un-manned infrared camera failed to record at tree T1 on 27 August 2018. Therefore, no count was obtained for this tree on this survey date.

Period	Survey date	Colony	Tagged bat nos.	Days since tagging	No. roosts (Roost IDs)	Survey timings	Weather conditions
Pre-maternity	13/06/18	Weston Park Golf Club	1, 2, 3, 4	10	7 (B1, C1, E1, F1, G1, H1, I1)	SS: 21:19 ST: 21:00 ET: 22:45	TS: 18°C TE: 17°C Wd: BS1 CC: 100% Pp: nil
Post-maternity	17/08/18	Weston Park Golf Club	5, 6, 7	5	7 (G1, J1, K1, L1, M1, N1, O1)	SS: 20:18 ST: 20:03 ET: 21:48	TS: 20°C TE: 16°C Wd: BS0 CC: 100% Pp: nil
Post-maternity	27/08/18	Weston Park Golf Club	5, 6, 7	15	17 (B1, G1, J1, K1, L1, M1, N1, O1, P1, Q1, R1, S1, T1, U1, V1, W1, Z1)	SS: 19:56 ST: 19:41 ET: 21:26	TS: 18°C TE: 16°C Wd: 0BS CC: 100% Pp: nil
Post-maternity	31/08/18	Dinosaur Park	8, 9, 10	6	6 (X1, Y1, A2, B2, C2, D2)	SS: 19:56 ST: 19:41 ET: 21:11	TS: 17°C TE: 13°C Wd: BS0 CC: 0% Pp: nil
Post-maternity	05/09/18	Dinosaur Park	8, 9, 10	11	9 (C2, X1, Y1, A2, B2, D2, E2, F2, G2)	SS: 19:36 ST: 19:21 ET: 20:52	TS: 16°C TE: 16°C Wd: BS1 CC: 20% Pp: nil

Table 3. Details of simultaneous roost counts carried out for the Weston Park Golf Club and Dinosaur Park colonies. The tagged bats' identification numbers for the radio-tracking sessions are given, along with the number of days since the bats used to identify the roosts were radio-tagged and the total number of roost trees identified and surveyed (with roost identification codes in brackets). Under 'survey timings' timings given are: SS = sunset time, ST = start time, ET = end time. Under 'weather conditions': TS = temperature at start of survey, TE = temperature at end of survey, Wd = wind (BS = Beaufort Scale), CC = cloud cover, Pp = precipitation

3 Results

3.1 Bat Trapping

Barbastelles were trapped at five of the 13 sites (the presence of two barbastelle roost trees was also confirmed at a sixth site, Hardingham Hills, when a bat (no. 6), radiotagged at Weston Park Golf Club, roosted there), see Figure 4. These sites are clustered at the western end of (and furthest from) the NDR, the nearest (Upgate Common and Scotchwood Hills) being >2.5km from the NDR. These sites corresponded with the 'Morton Colony' area, with only one site where barbastelles were caught, Upgate Common, corresponding with the 'Felthorpe Colony' area and none with the 'Rackheath Colony' area (see **Figure 2**).

During the 14 trapping surveys, a total of 31 barbastelles were caught (18 males and 13 females, see **Table 4**). Barbastelles appeared particularly abundant during trapping surveys at the Dinosaur Park (where 10 were caught in just three hours of trapping, with nets then closed as sufficient adult females for tagging had been captured) and at Weston Park Golf Club (where nine were caught in only four hours of trapping during the August survey). Habitat between the two sites is contiguous, forming a roughly 2km x 0.5km L-shaped corridor.

In total, 259 bats were caught during the 14 trapping surveys (see **Table 4**). The most abundant species was common pipistrelle (Pipistrellus pipistrellus), accounting for 39% of the captures, followed by soprano pipistrelle (Pipistrellus pygmaeus), 20% of the captures, and barbastelle as the third most abundant species, 12% of all captures. Other species/genera captured (in decreasing order of abundance) were: brown long-eared bat (Plecotus auritus), Pipistrellus species, Natterer's bat (Myotis nattereri), noctule (Nyctalus noctule) and Daubenton's bat (Myotis daubentonii). Bats were recorded as 'Pipistrellus species' either because they had a mixture of common and soprano pipistrelle features (and therefore could not be assigned to a species) or because they were pregnant females, released straight from the net and therefore not examined to determine species (to avoid unnecessary handling/capture time).

It is not possible to make direct comparisons between sites as only a single trapping survey was carried out at each site (except at Weston Park Golf Club, where two surveys were undertaken). The most bats were caught along the Marriott's Way (55 at Attlebridge (2.62 bats per trap-hour, 12m) and 36 west of Fir Covert Lane (3.00 bats per trap-hour, 12m)). Rackheath Park Paine's Yard (0.13 bats per trap-hour, 12m) had a particularly low capture rate, with just three bats captured, despite seemingly good habitat and suitable weather conditions. Harrison's Wood was also poor, but results were compounded by sub-optimal weather conditions. Both of these sites sit 'inside' (Norwich side) of the NDR, in the eastern section.

Similarly, comparisons with the pre-construction bat trapping data (Mott MacDonald 2013) cannot be made, as this would have required repeated surveys at each site (both pre- and post-construction) and survey effort could not be replicated in the postconstruction surveys as the numbers of traps used, trap locations, mist-net lengths and times of traps being open were not consistently recorded/reported in the preconstruction surveys (see Table 5). Survey months were also not always comparable. Numbers of bats caught and species composition are shown in Figure 5 for the 2018 surveys, with 2009, 2012 and 2013 (pre-construction) data also given, where the same sites were visited. For 2018 sites with previous survey data, barbastelles were trapped in both 2018 and pre-construction of the NDR (2009) at Marriott's Way Attlebridge, only. At three sites (Woodland west of Spixworth, in 2009, Hall Lane Felthorpe, in 2009 (but not in 2013) and Marriott's Way west of Fir Covert Lane, in 2013) barbastelles were trapped pre-

construction but not post-construction of the NDR. At one site (Upgate Common), a barbastelle (male) was trapped in 2018 but none were trapped in the 2009 pre-construction survey.

Figure 4. Bat trapping sites where barbastelles were captured during the 2018 trapping survey or the presence of a barbastelle roost was confirmed by radio-tracking barbastelles tagged at another site, denoted by blue stars and blue label boxes, with number of adult female barbastelles radio- tagged in the pre- and post-maternity periods given. Sites where no barbastelles were trapped (or radio-tracked to) denoted by red stars with black label boxes. NDR route shown by red line.

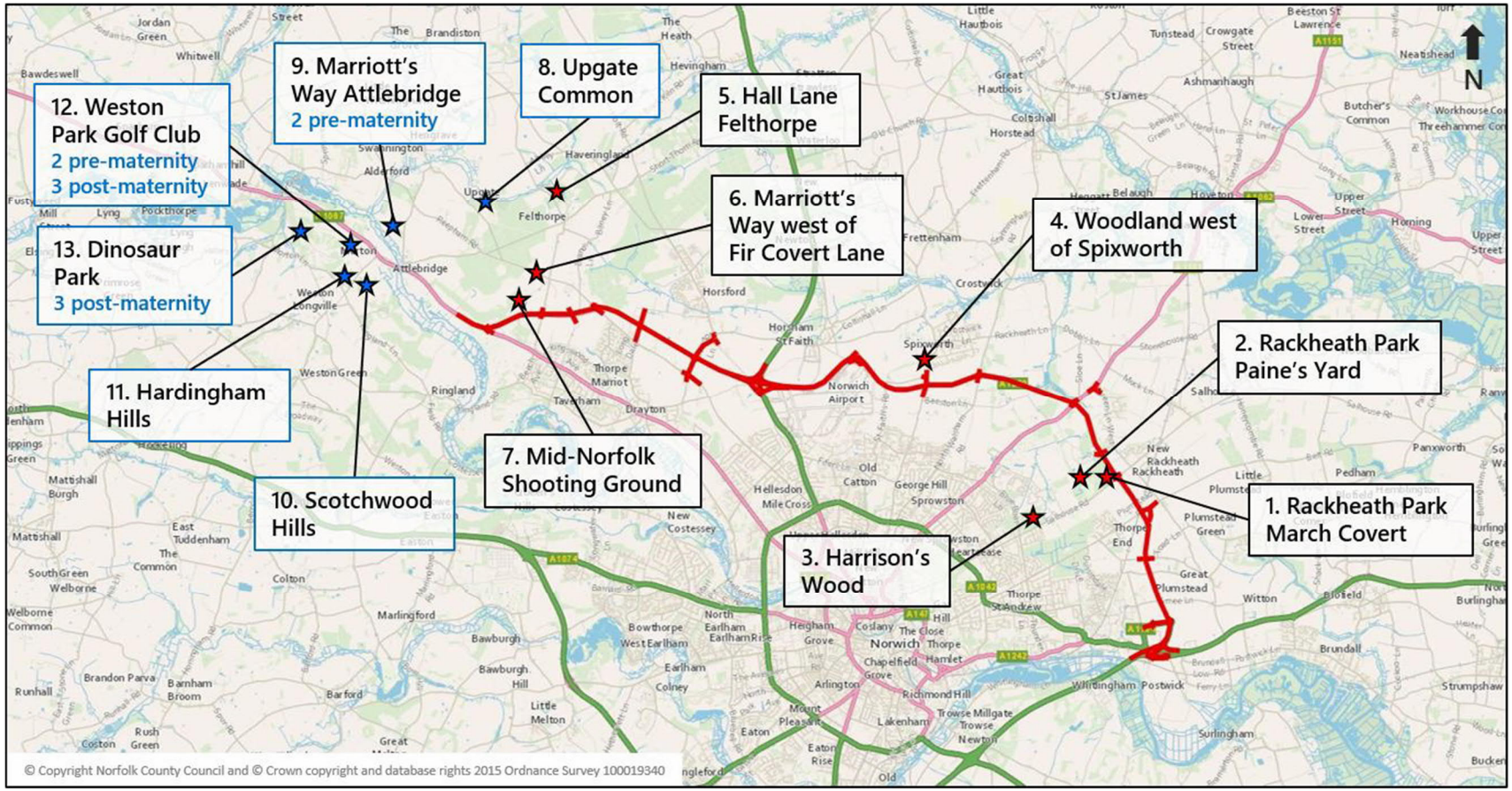

Table 4. Results from bat trapping surveys. Species given as: Ppip = Pipistrellus pipistrellus (common pipistrelle), Ppyg = Pipistrellus pygmaeus (soprano pipistrelle), P sp. = Pipistrellus species, Bbar = Barbastella barbastellus (barbastelle), Paur = Plecotus auritus (brown long-eared bat), Nnoc = Nyctalus noctula (noctule), Mnat = Myotis nattereri (Natterer's bat) and Mdau = Myotis daubentonii (Daubenton's bat). Numbers of females (F) and males (M) for each species are given. Superscript numbers for females show number that were pregnant or lactating. In the Total (site) column, mean number of bats per trap-hour (in 12m units) is given in brackets so that numbers caught between sites can be compared (standardised for variable trap lengths and trap hours, see Ralph 1976).

Site no.	Site name	Date	Ppip	Ppyg	P sp.	Bbar	Paur		Mnat	Mdau	Nnoc	Total (site)
1.	Rackheath Park March Covert	14/08/18	3(F), 1(M)	3(M)	1(F), 1(M), 1		1(M)				3(F)	14 (0.45)
2.	Rackheath Park Paine's Yard	08/06/18		1(M)	1(F^1)		1(F^1)					3 (0.13)
3.	Harrison's Wood	09/06/18	1(M)						2(M)			3 (0.24)
4.	Woodland west of Spixworth	10/08/18	11(F), 5(M)	2(F), 1(M)					3(F)		1(F)	23 (1.77)
5.	Hall Lane, Felthorpe	27/05/18	1(F)	7(F), 1(M)	1(F)					1(M)		11 (1.74)
6.	Marriott's Way west of Fir Covert Lane	26/05/18	6(F), 5(M)	6(F)	12(F^{11}), 1(M), 1		3(F)		1(F), 1(M)			36 (3.00)
7.	Mid-Norfolk Shooting Ground	27/05/18	1(F), 1(M)	1(F), 2(M)					1(F^1), 2(M)			8 (0.53)
8.	Upgate Common	15/08/18	6(F), 7(M)	4(F), 1(M)		1(M)	4(F), 5(M)		1(M)			29 (1.16)
9.	Marriott's Way Attlebridge	28/05/18	27(F^1), 6(M)	5(F), 8(M)	1(F)	2(F), 3(M)	1(F),		1(M)	1(M)		55 (2.62)
10.	Scotchwood Hills	08/08/18				1(M)	2(F), 1(M)			1(F)	1(F)	6 (0.48)
11.	Hardingham Hills	06/08/18	1(F), 4(M)		2(M)				2(F), 1(M)			10 (0.45)

12.	Weston Park Golf Club	03/06/18	4(F), 4(M)			2(F), 3(M)	1(F)		5(F[1])			19 (0.89)
12.	Weston Park Golf Club	12/08/18		2(F), 1(M)		3(F), 6(M)	2(F), 2(M)					16 (0.64)
13.	Dinosaur Park	25/08/18	1(F), 5(M)	1(F), 6(M)	1(M)	6(F), 4(M)	1(F), 1(M)					26 (1.73)
Total (species)			100	52	23	31	25		20	3	5	Total all: 259

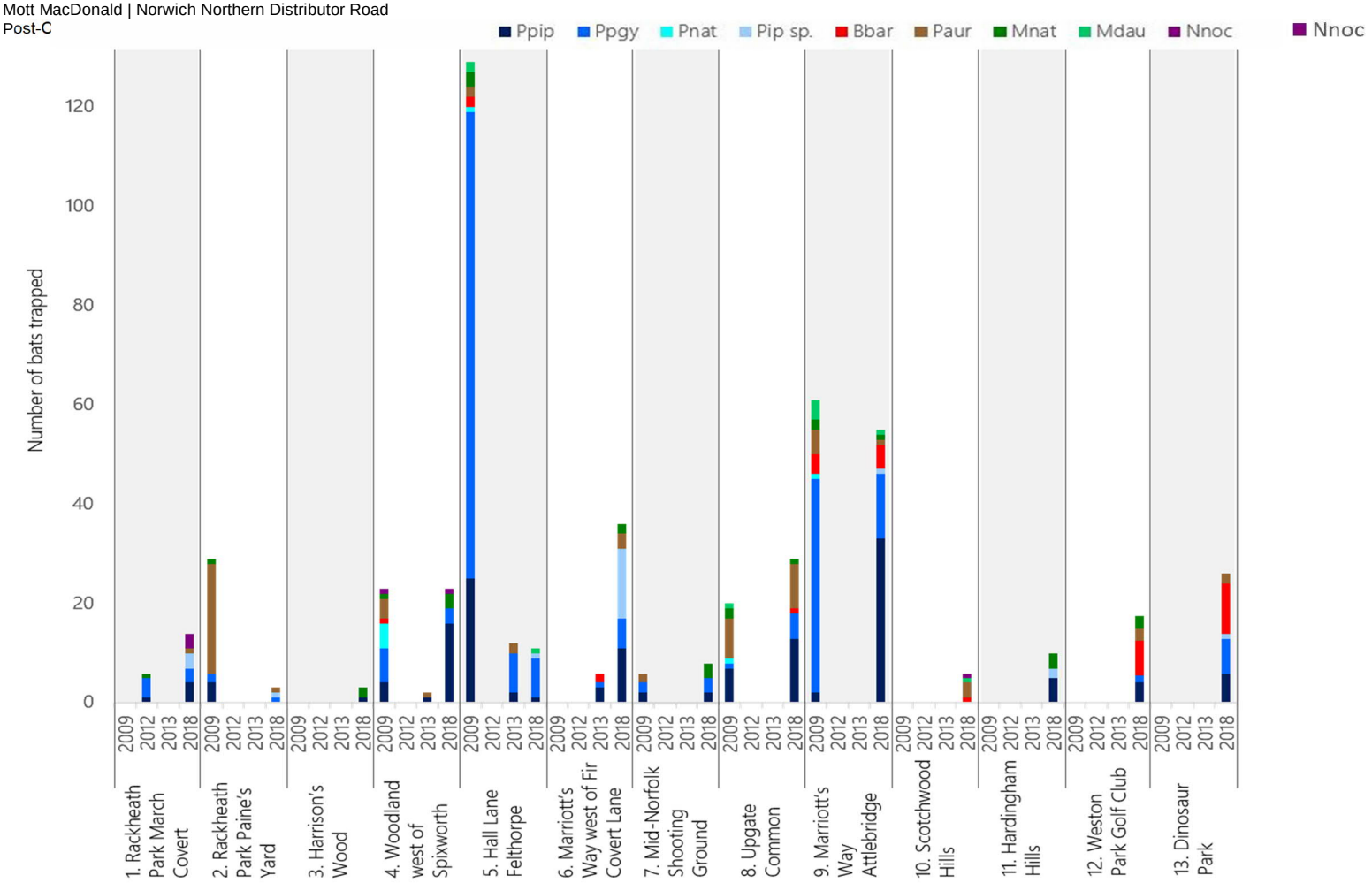

Figure 5. Number of bats of each species (names as given in Table 4) caught during trapping sessions (2009, 2012, 2013 & 2018) shown for the 2018 trapping sites. Between years, sites were treated as the same if at the same location or nearby, such as would be considered the same site. Where multiple surveys were conducted at a site in a single season (2009), the results for the survey which was closest in seasonal timing to the 2018 survey is given. For Weston Park (with no previous surveys and where both pre- and post-maternity surveys were carried out) the average of the two trapping sessions is given. No bar indicates no survey was carried out. See Table 5 for comparison of survey effort at these sites between years (and site names/numbers used).

Table 5. Comparison of survey effort for 2018 trapping sites with pre-construction NDR bat trapping surveys (Mott MacDonald 2013). Only sites with multiple survey years are shown (see Table 1 for full details for all 2018 trapping surveys). Under survey month & effort, the first three letters of the survey month are given, SMN = single-height mist-net, DMN = double-height mist-net (two mist-nets stacked on top of each other), TMN = triple-height mist-net (three mist-nets stacked on top of each other), HT = harp trap, ^{x}* = number of acoustic lures used with traps. For times of traps being open (2018 only), $^{+1}$ = following day.

2018 site no. & name	Pre-construction surveys site no. & name	Survey month & effort			
		2009	2012	2013	2018
1. Rackheath Park March Covert	Location 25. Pig's Park Rackheath	n/a	AUG. SMN x3, HT x4$^{(1*)}$. Mist-net lengths not given. 'Dusk-dawn' (timings not given).	n/a	AUG. SMN: 12m x1, 9m x2, 6m x3, TMN: 9m x1. Traps open: 20:15-01:10^{+1}.
2. Rackheath Park Paine's Yard	Location 5. Rackheath	JUN. Effort information not given.	n/a	n/a	JUN. SMN: 12m x2, 9m x1, 6m x3, 3m x1. Traps open: 21:15-02:00^{+1}.
4. Woodland west of Spixworth	Location 12. Spixworth	JUN. Effort information not given.	n/a	MAY. SMN x7, HT x2. Mist-net lengths not given. 'Dusk-dawn' (timings not given).	AUG. SMN: 9m x2, 6m x2, 4m x1, 3m x1, HT x1$^{(1*)}$. Traps open: 20:35-01:15^{+1}.
5. Hall Lane Felthorpe	Locations 9. & 13. Hall Lane (Felthorpe)	JUN. Effort information not given.	n/a	MAY. SMN x3, HT x2. Mist-net lengths not given. 'Dusk-dawn' (timings not given).	MAY. SMN: 6m x2, 4m x1, 3m x1. Traps open: 21:18-01:00^{+1}.
6. Marriott's Way west of Fir Covert Lane	Location 27. Marriott's Way	n/a	n/a	MAY. SMN x5, HT x4$^{(1*)}$. Mist-net lengths not given. 'Dusk-dawn' (timings not given).	MAY. SMN: 6m x4, DMN: 6m x1. Traps open: 21:00-01:00^{+1}.
7. Mid-Norfolk Shooting Ground	Location 2. Deighton Hills 2	AUG. Effort information not given.	n/a	n/a	MAY. SMN: 12m x1, 9m x4, 6m x2. Traps open: 21:02-00:45^{+1}.

8. Upgate Common	Location 18. Swannington / Swiffler's Lane	AUG. Effort information not given.	n/a	n/a	AUG. SMN: 12m x1, 9m x3, 6m x3, 3m x1. Traps open: 20:15-01:15^{+1}.
9. Marriott's Way Attlebridge	Location 20. Marriott's Way 4 – Attlebridge car park & river crossing	AUG. Effort information not given.	n/a	n/a	MAY. SMN: 9m x2, 6m x4. Traps open: 21:05-03:15^{+1}.

3.2 Barbastelle radio-tracking

Radio-tagging

Despite efforts to target all three colony areas ('Morton', 'Felthorpe' and 'Rackheath', see Figure 2), adult female barbastelles were only caught in the 'Morton Colony' area. Details of radio-tagging dates, sites, female reproductive status and radio-tag identification numbers are given in **Table 6.** See **Appendix 1** for photographs of barbastelle radio-tagging.

Table 6. Details of radio-tagged adult female barbastelles.

Period	Date	Site	Reproductive status	Tag ID
Pre-maternity	28/05/18	Marriott's Way Attlebridge	Not visibly pregnant	1
			Not visibly pregnant	2
Pre-maternity	03/06/18	Weston Park Golf Club	Not visibly pregnant	3
			Not visibly pregnant	4
Post-maternity	12/08/18	Weston Park Golf Club	Post-lactating	5
			Post-lactating	6
			Post-lactating	7
Post-maternity	25/08/18	Dinosaur Park	Post-lactating	8
			Post-lactating	9
			Lactating	10

Radio-tracking

A total of 36 roosts, all of which were in trees, were located from the 10 radio-tagged adult female barbastelles (**Table 7** and **Figures 6 & 7**). Twenty-four of these were at Weston Park Golf Club, six at the Dinosaur Park, two at Hardingham Hills, one at Hockering Wood, one at Sparham Wood, one at Attlebridge Hills (north-west end) and one at Gravelpit Plantation (Ringland), see **Figures 6 & 7**. Twenty of the roosts were in pedunculate oak (Quercus robur), 10 in sweet chestnut (Castanea sativa), two in beech (Fagus sylvatica), one in a birch (Betula sp.) and one in a cedar of Lebanon (Cedrus libani) (**Table 7**) – the latter two roost trees were in a very decomposed state. Each roost was used by between one and four of the 10 radio-tagged bats: G1 was used by 4 tagged bats, B1, Y1 and E2 by 3 tagged bats and E1, N1, P1 and B2 by 2 tagged bats (the remaining roost trees were used by individual tagged bats only, **Table 7**). By far the most utilised roost feature was loose bark, with some splits also used (**Table 7**), photographed examples given in **Appendix 2**.

Roost ID	Site name	GPS coordinates (British National Grid)	Tagged bats used by	Tree species (D = dead)	Roost feature (where possible to determine)
A1	Attlebridge Hills (NW end)	c. TG 13497 16376	2	Exact location could not be determined as no access. 1st night 'panic roost'.	
B1	Weston Park Golf Club	TG 11504 17205	1, 2, 5	Quercus robur (D)	Loose bark, south facing.
C1	Weston Park Golf Club	TG 11400 17386	1	Quercus robur (D)	Loose bark collar.
D1	Gravelpit Plantation (Ringland)	c. TG 12944 14525	3	Exact location could not be determined as no access. 1st night 'panic roost'.	
E1	Weston Park Golf Club	TG 11421 17399	3, 4	Quercus robur	Tear-out.
F1	Weston Park Golf Club	TG 11603 17202	3	Castanea sativa	Exact feature could be not located.
G1	Weston Park Golf Club	TG 11907 17289	3, 4, 5, 7	Quercus robur (D)	Loose bark collar, C-shaped gap, north facing.
H1	Weston Park Golf Club	TG 11934 17305	3	Quercus robur	Exact feature could be not located.
I1	Weston Park Golf Club	TG 11947 17292	3	Quercus robur	Exact feature could be not located.
J1	Weston Park Golf Club	TG 11010 17060	6	Castanea sativa	Broken limb with loose bark (c.7m up).
K1	Weston Park Golf Club	TG 11066 17045	6	Quercus robur	Limb with splits and loose bark.
L1	Hardingham Hills	TG 11713 16549	6	Quercus robur	Dead side limb (c.10m up) with loose bark.
M1	Hardingham Hills	TG 11682 16531	6	Betula sp. (D)	Loose bark (c.3-4m up), east facing.
N1	Weston Park Golf Club	TG 11878 17340	5, 7	Castanea sativa	Elongated gap through trunk (c.3m up).
O1	Weston Park Golf Club	TG 11082 16843	6	Castanea sativa	Join between two limbs with loose bark and knot.
P1	Weston Park Golf Club	TG 11704 17363	5, 7	Quercus robur	Loose bark collar (c.12m up).
Q1	Weston Park Golf Club	TG 11891 17391	5	Quercus robur (D)	Rectangle of loose bark (c.3m up).
R1	Weston Park Golf Club	TG 11342 17365	7	Quercus robur	Loose bark collar (c.4-5m up).
S1	Weston Park Golf Club	TG 11414 17022	6	Castanea sativa	Split limb (c.8m up) with loose bark.
T1	Weston Park Golf Club	TG 11786 17408	5	Quercus robur	Dead limb with loose bark collar (c.8m up).
U1	Weston Park Golf Club	TG 11383 17320	7	Quercus robur	Loose bark collar (c. 2-3m up).
V1	Weston Park Golf Club	TG 11289 16747	6	Fagus sylvatica	Oblong hole (c.10m up).
W1	Weston Park Golf Club	TG 11927 17301	7	Quercus robur	Dead broken limb with loose bark collar (c.10m up).
X1	Dinosaur Park	TG 10565 17464	10	Quercus robur (D)	East facing (c.6-7m up).
Y1	Dinosaur Park	TG 10607 17165	8, 9, 10	Castanea sativa	Broken limb (c.6m up).
Z1	Weston Park Golf Club	TG 11463 17157	7	Castanea sativa	Lightning strike (c.4-5m up).

Roost ID	Site name	GPS coordinates (British National Grid)	Tagged bats used by	Tree species (D = dead)	Roost feature (where possible to determine)
A2	Dinosaur Park	TG 10682 17564	8	Castanea sativa	Split (c.4m up).
B2	Dinosaur Park	TG 10658 17516	8, 9	Quercus robur (D)	Loose bark (c.4m up).
C2	Dinosaur Park	TG 10684 17555	10	Quercus robur	Large broken limb with split (c.1m up).
D2	Hockering Wood	TG 07355 14457	10	Fagus sylvatica	Elongated gap (c.2.5m up).
E2	Weston Park Golf Club	TG 10775 17659	8, 9, 10	Castanea sativa	Loose bark
F2	Weston Park Golf Club	TG 10851 17129	10	Cedrus libani (D)	Loose bark (c.2.5m up).
G2	Weston Park Golf Club	TG 10698 17823	10	Quercus robur (D)	Split (c.4m up).
H2	Dinosaur Park	TG 10582 17142	9	Castanea sativa	(c.12m up).
I2	Sparham Wood	TG 07500 20248	8	Quercus robur	Loose bark (c.2.5m up).
J2	Weston Park Golf Club	TG 11191 17152	10	Quercus robur (D)	Large split & loose bark (c.5m up).

Table 7. Details of the 36 barbastelle roosts located through radio-tracking 10 adult females (May/June and August 2018). See **Figures 6 & 7** for roost location maps. Tree species/genera are Quercus robur (English oak), Castanea sativa (sweet chestnut), Fagus sylvatica (beech), Betula sp. (birch species) and Cedrus libani (cedar of Lebanon). See **Appendix B** for photographed examples

Figure 6. All barbastelle roosts located (red markers with 'R') overlaid on a 2017 aerial image (Google Earth Pro). Outlying roosts' identification codes (A1, D1, D2 & I2) are shown in red. Site names (referred to in Table 7) are labelled in yellow. See Figure 7 for details of the Weston Park Golf Club, Hardingham Hills and Dinosaur Park roost clusters.

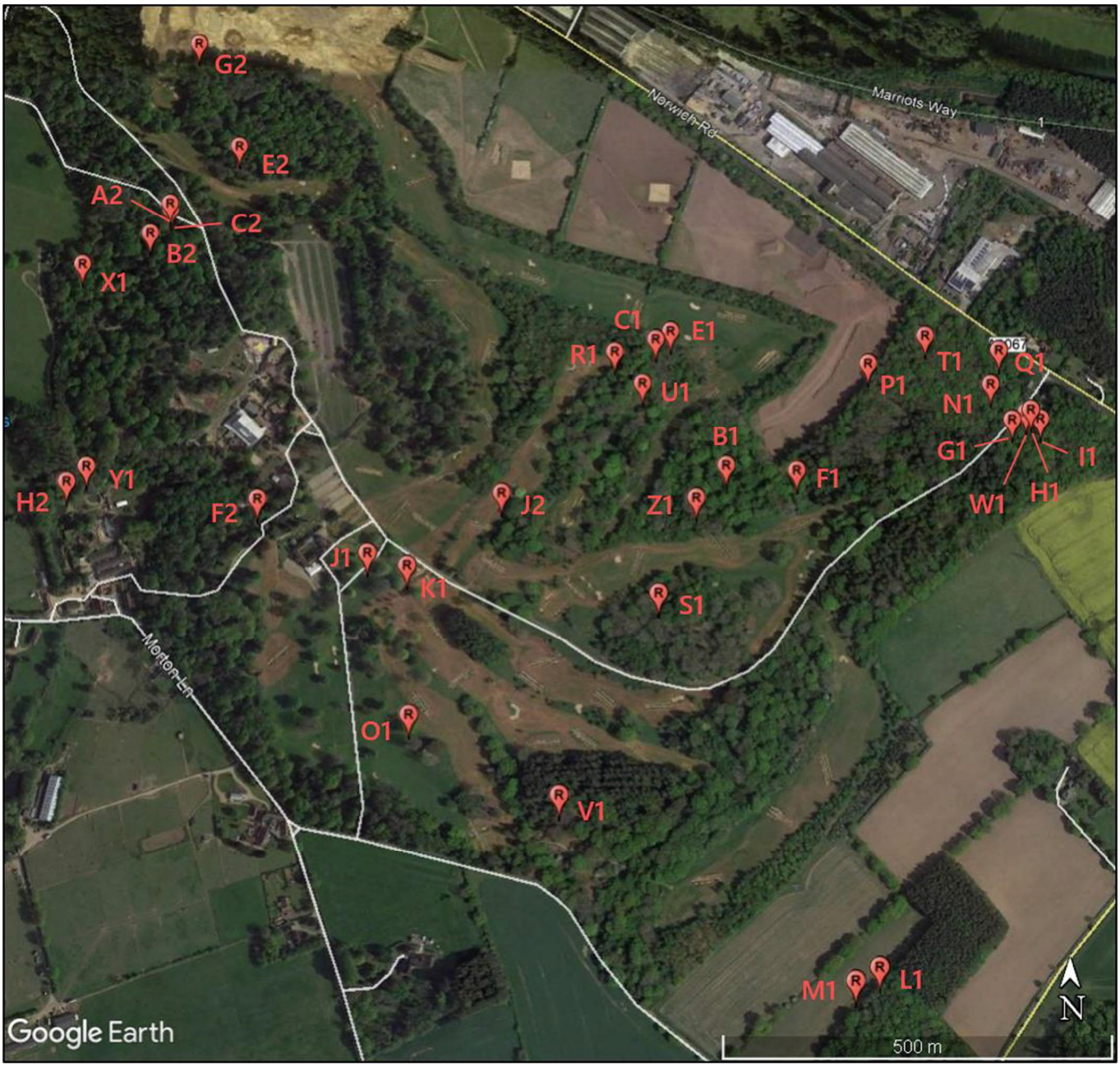

Figure 7. Barbastelle roosts located at Weston Park Golf Club, Hardingham Hills and the Dinosaur Park (red markers, labelled with roost identification codes), overlaid on a 2017 aerial image (Google Earth Pro). See Figure 6 for area location and Table 7 for roost details.

3.3 Simultaneous roost counts

The simultaneous roost counts produced a minimum estimate of 46 barbastelles (likely to consist of adult females and juveniles in the maternity roosts) for the Weston Park Golf Club

colony (on 17th August 2018). The simultaneous roost count conducted in the prematernity period (13th June 2018) did not record any barbastelles emerging from the known roost trees. For the Dinosaur Park colony, simultaneous roost counts (on 31st August and 5th September 2018) were very low, with only four and three barbastelles (respectively) observed emerging from roost trees. See Table 8 for details of the count results.

	Weston Park Golf Club 'Colony'			Dinosaur Park 'Colony'	
Roost ID	13/06/18	17/08/18	27/08/18	31/08/18	05/09/18
A1 (AH)	Not surveyed - first night 'panic roost'.				
B1 (WP)	0		0		
C1 (WP)	0				
D1 (GP)	Not surveyed - first night 'panic roost'.				
E1 (WP)	0				
F1 (WP)	0				
G1 (WP)	0	19	5		
H1 (WP)	0				
I1 (WP)	0				
J1 (WP)		0	1		
K1 (WP)		0	0		
L1 (HH)		0	0		
M1 (HH)		17	0		
N1 (WP)		9	5		
O1 (WP)		1	0		
P1 (WP)			18		
Q1 (WP)			2		
R1 (WP)			0		
S1 (WP)			0		
T1 (WP)			*[2]		
U1 (WP)			0		
V1 (WP)			0		
W1 (WP)			0		
X1 (DP)				0	0
Y1 (DP)				0	0
Z1 (WP)			9		
A2 (DP)				3	0
B2 (DP)				0	0
C2 (DP)				0	0
D2 (HW)				1	0
E2 (WP)					3
F2 (WP)					0
G2 (WP)					0

[2] *T1 was surveyed with an un-manned infrared camera which failed to record therefore no count was obtained for this roost.

H2 (DP)					
I2 (SW)					
J2 (WP)					
TOTAL	0	46	40	4	3

Table 8. Number of barbastelles counted emerging from roost trees during simultaneous roost counts. Only those roosts used by radio-tagged bats during the applicable radio tagging/tracking session were surveyed (those not surveyed are greyed out). Roost locations given in brackets after the Roost ID, as follows: AH = Attlebridge Hills, WP = Weston Park Golf Club, GP = Gravelpit Plantation, HH = Hardingham Hills, DP = Dinosaur Park, HW = Hockering Wood, SW = Sparham Wood) - see **Table 7** for roost details.

4 Discussion

4.1 Bat trapping

In general, post-construction, those sites 'outside' of the NDR, further away and further to the west of the road seemed to be more productive in the trapping surveys. Whilst this was in no way a comprehensive survey of pre- and post-construction bat activity (and it did not set out to be), we would tentatively suggest that there could be a pattern here worthy of further investigation. Whilst acoustic surveys may shed more light on this, they have the inherent problem of not providing information on bat numbers (i.e. a single barbastelle could fly around a detector all night producing hundreds of records, or 30 records could be produced by 30 different barbastelle individuals making a single pass next to the detector). A combined assessment of both trapping survey data and acoustic survey data could be a useful approach for determining if sites closer to the NDR/'inside' the NDR/further east may have been impacted by the road.

Barbastelles were particularly abundant during trapping surveys at the Dinosaur Park and Weston Park Golf Club (with good numbers caught in a short period of time and barbastelles being recorded very frequently on bat detectors). These sites correspond with the 'Morton Colony' area (the furthest of the three colonies areas from the NDR).

Despite trapping attempts at a number of sites in the 'Rackheath' (3) and 'Felthorpe' (4) Colony areas, only a single male barbastelle was trapped (at Upgate Common, within the 'Felthorpe Colony' area). This is in contrast to the pre-construction trapping surveys, where barbastelles were also caught at the Woodland west of Spixworth and Marriott's Way west of Fir Covert Lane sites. Rackheath Park Paine's Yard was particularly poor, where after five hours only two pipistrelles and a brown long-eared bat had been trapped. At this site, no bat activity was heard on detectors until midnight and even then, was very infrequent. This was very surprising given the apparent suitability of the habitat and weather conditions, good capture numbers in the 2009 survey (29 bats, also in June) and clusters of barbastelle and brown long-eared bat roosts located there in the preconstruction surveys.

4.2 Barbastelle radio-tracking

At Weston Park and the Dinosaur Park, with their mature oak and sweet chestnut woodlands, 30 different roost trees were located. These two sites, with contiguous habitat, would seem to provide a key area of habitat for barbastelles, offering a large number of suitable roosting features. Combined with the findings of the trapping surveys and, for Weston Park, the simultaneous roost counts, this population, at >3km from the NDR, is certainly persisting, but we lack comprehensive pre-construction survey information for these sites. Mist-netting/harp-trapping surveys were not undertaken here pre-construction, but barbastelles trapped at Marriott's Way Attlebridge were tracked to Weston Park (as also experienced in the 2018 tracking), where 12 roosts were located. One barbastelle radio-tagged, and regularly roosting, at Weston Park also used two roost trees at Hardingham Hills: one of these trees was used by 17 barbastelles. Weston Park and Hardingham Hills are clearly connected within the 'Morton

Colony' area, being close together and used by radio-tagged bats (in 2009 and 2018) moving between the two sites. In 2018, the nearest located Weston Park roost tree was only c.450m from the Hardingham Hills roost trees. Interestingly, there was very little crossover in roost use between bats tagged at Weston Park and the Dinosaur Park, despite the two sites being adjacent to each other (with contiguous habitat). There were also no instances of bats tagged at the Dinosaur Park using any of the roost trees used by the bats tagged at Weston Park.

More distant roosts were located at Hockering Wood and Sparham Wood, in late August and early September, by which point the Dinosaur Park barbastelles appeared to be dispersing from the main roost cluster. 'Outlying' roosts were also located at Attlebridge Hills (near Attlebridge) and Gravelpit Plantation (near Ringland) as first night only 'panic roosts' of two barbastelles trapped and radio-tagged at Marriott's Way Attlebridge and Weston Park, respectively.

4.3 Simultaneous roost counts

At Weston Park and Hardingham Hills, two repeated simultaneous roost counts in August 2018 yielded a minimum maternity colony estimate of 46 individuals (very likely to consist of adult females and juveniles). In reality, given the abundance of barbastelles evident during the trapping surveys (ease of capture and frequency of acoustic records on bat detectors), it seems very likely that the colony size is considerably larger (also with males, which were caught during trapping surveys but are unlikely to have been counted at the maternity roosts). The pre-maternity simultaneous roost count at Weston Park was not successful; on the day of the evening count the remaining tags had detached and individuals from the colony were not present in any of the trees previously located and surveyed that night.

At the Dinosaur Park, only very low counts were obtained (minimum count of four), despite the very evident abundance of individuals during trapping surveys and recorded on bat detectors. These counts were conducted at the end of August and in early September, by which point it seemed the colony was already dispersing from the maternity roosts, with individuals trapped here located roosting at distant sites: Hockering Wood and Sparham Wood (both sites are >4km from the Dinosaur Park).

Limited roost count data are available for barbastelle roosts located through radiotracking pre-construction of the NDR, and counts were carried out on individual tree roosts (not as simultaneous roost counts). In 2009, counts of 40+, 6+, 13+ and 10+ were reported for individual roost trees at Weston Park and 55-59 for a tree roost at Hardingham Hills. The highest individual tree count in 2018 was 19 individuals for a tree at Weston Park and 17 individuals from one (of two) roost trees located at Hardingham Hills, but with a minimum maternity colony estimate of 46 from the simultaneous roost counts. It is difficult to draw any direct comparisons pre- and post-construction (as simultaneous roost counts were not carried out pre-construction), but simultaneous counts can be continued in future monitoring surveys (if radio-tracking is used to locate roosts). Whilst the 'Morton Colony' clearly persists and this area stands out as having high barbastelle activity, it is not possible to determine whether overall numbers have increased or decreased post-construction of the NDR.

5 Conclusions

It was not possible to trap female barbastelles within the former 'Rackheath' and 'Felthorpe' Colony areas. Whilst based on limited trapping effort, the results are concerning as these areas, pre-construction, held a significant number of barbastelle roosts. Whilst the trapping surveys by no means rule out the presence of barbastelle in these areas, if they were still abundant we would have expected to have trapped some individuals. Acoustic surveys should provide more information on barbastelle activity within these areas. Access to a former key site at Felthorpe was not granted and so it is possible that this barbastelle colony still persists. In the Rackheath area, impacts directly attributable to the NDR would be difficult to differentiate from other large-scale developments (mostly housing) which have taken place since the pre-construction surveys.

The 'Morton Colony' area, furthest from the NDR, is still well used by barbastelles, with numerous roosts located at Weston Park Golf Club (with Hardingham Hills) and the Dinosaur Park. These sites would seem to be particularly important for barbastelles and arguably, with further investigation, may well exceed the criteria required for designation of a barbastelle Special Area of Conservation (SAC). Their importance may be elevated further should other colonies in the vicinity of the NDR be found to have been displaced. Protecting the Weston Park Golf Club, Hardingham Hills and Dinosaur Park roost areas should be a priority, along with protection of the surrounding habitat, including maintaining connectivity to the Marriott's Way and to suitable foraging areas.

6 Recommendations

Broad recommendations which may be taken up by different organisations/stakeholders (not necessarily Norfolk County Council in the first instance): -

- Develop a robust long-term monitoring strategy for the Weston Park, Hardingham Hills and Dinosaur Park barbastelle colonies;
- Explore protected site designation with landowners at Weston Park Golf Club, Hardingham Hills and the Dinosaur Park;
- Ensure protection (including maintenance of connectivity, habitat quality and 'dark corridor') of the Marriott's Way, which has high levels of bat activity;
- Conduct acoustic surveys to determine barbastelle activity levels in the 'Rackheath' and 'Felthorpe' Colony areas – do the colonies still persist?, and;
- Consider additional barbastelle radio-tracking monitoring in Years 3 & 5 (the next radio-tracking monitoring is not scheduled until Year 7, in 2024).

7 References

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A. Barbastelle radio-tagging photographs

Photo 1. Barbastelle in the hand (trapped at Weston Park Golf Club in June 2018).

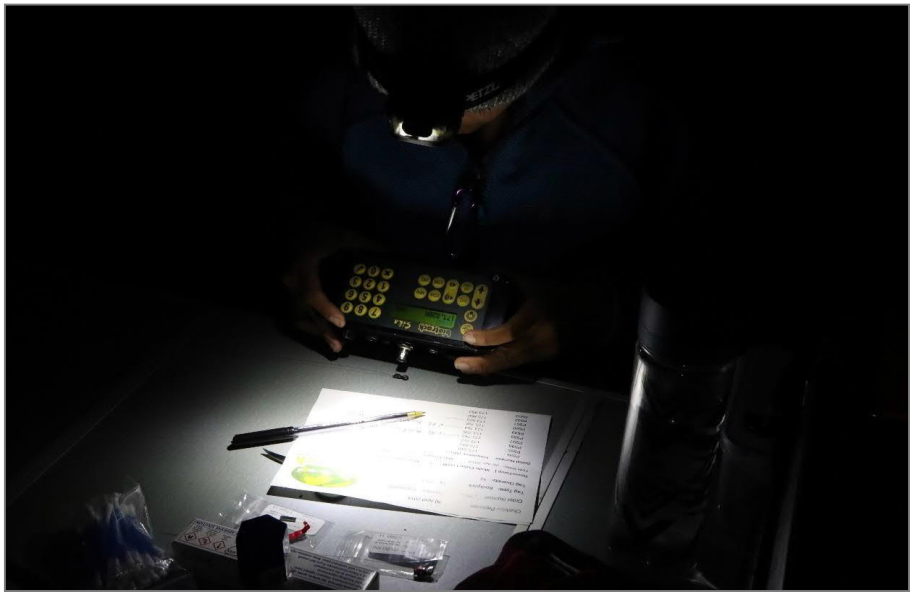

Photo 2. Testing radio-tags with a Biotrack Sika receiver immediately prior to deployment.

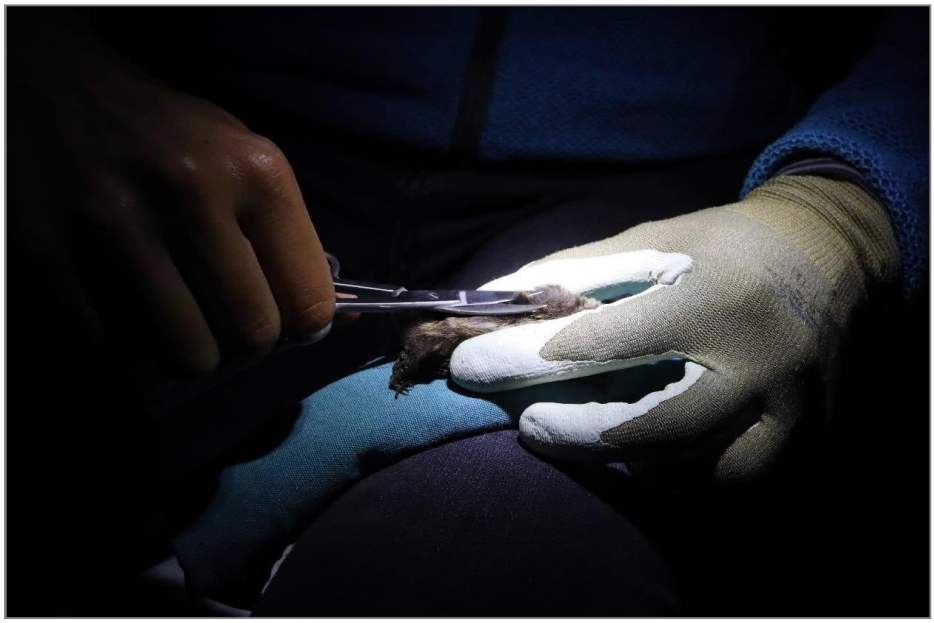

Photo 3. Fur-trimming prior to tag attachment.

Photo 4. Barbastelle with radio-tag attached (Weston Park Golf Club, June 2018).

B. Samples of the barbastelle roosts located

Roost features are circled in red (if exact feature could be determined). Roost location is given in brackets (WPGC = Weston Park Golf Club, DP = Dinosaur Park).

Photo 1. Roost M1 (Hardingham Hills).

Photo 2. Roost N1 (WPGC).

Photo 3. Roost O1 (WPGC).

Photo 4. Roost Q1 (WPGC).

Photo 5. Roost U1 (WPGC).

Photo 6. Roost V1 (WPGC).

Photo 7. Roost X1 (DP).

Photo 8. Roost Y1 (DP).

Photo 9. Roost Z1 (WPGC).

Photo 10. Roost A2 (DP).

Photo 11. Roost C2 (DP).

Photo 12. Roost D2 (Hockering Wood).

Photo 13. Roost E2 (WPGC).

Photo 14. Roost F2 (WPGC).

Photo 15. Roost I2 (Sparham Wood).

Photo 16. Roost J2 (WPGC).