Advanced survey effort required to obtain bat assemblage data in temperate woodlands (Chiroptera)

Pokročilé prieskumné úsilie je potrebné na získanie údajov o spoločenstve netopierov v lesoch mierneho pásma (Chiroptera)

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Abstract. There is a lack of precise guidelines concerning the survey effort required for advanced bat surveys in temperate European woodlands, resulting in a lack of standardisation in survey methods. In this study we assess catch data from 56 bat trapping surveys at 11 UK woodland sites in order to provide recommendations for mist net survey effort required to gain meaningful bat assemblage data in temperate woodlands. Species accumulation curves were produced and were used to develop two novel values for survey effort: the minimum survey threshold (MST), whereby surveyors are more likely than not to encounter less dominant species; and the known species threshold (KST), the point where a given percentage (in our case, 75%) of the known species assemblage for a site is likely to be reached and beyond which there are diminishing returns for survey effort. For our data, the mean of MST was 17.4 net hours, and for KST, the mean was 29.8 net hours. The MST and KST values were reached during the second and third surveys, respectively. These proposed values are adaptable based on location and known species assemblage and may be used for planning advanced bat surveys in temperate woodlands not only to maximise survey efficacy and use of limited resources but to ensure ethical viability of undertaking advanced surveys in the first place.

Key words. Species accumulation, woodland bat assemblages, mist netting, survey effort, woodland bats.

INTRODUCTION

Existing UK and European guidelines for advanced bat surveys lack specificity and consistency with regard to number of survey visits, start times, survey duration and deployment of equipment (Barlow 1999, Battersby 2010, Collins 2016). While it is generally agreed that surveys should commence at the same time relative to sunset on each night, recommended start times and durations vary substantially (Battersby 2010, Collins 2016). Trapping until a specified time, rather than for a specified duration, can create variation in survey length and is thus problematic and biased. For example, the UK trapping season (April to October) experiences

a variation in sunset times which would result in some surveys exceeding twice the length of others if in trapping until 2–3 a.m. as per COLLINS (2016).

Guidelines on the amount of equipment to be deployed is also variable, but with suggestions that net deployments should be standardised (BARLOW 1999). UK Guidelines state that the equipment deployed should depend on the extent of habitat but give no guidance for assessing that extent (COLLINS 2016). Eurobats recommended a minimum of 60 m length of net per netting site but this stipultion is not present in their final document, which includes guidelines regarding 'netting sites' based on woodland size (e.g. one netting site per woodland <30 ha) but not quantity of nights per netting site (BATTERSBY 2010). The Bat Conservation Trust (COLLINS 2016) provides a measure of a 'trap night' being one lure/net or lure/trap combination per night. Given this variation in recommendations, the need to standardise survey effort is clear. Mist net effort is quantified using 'net hours', calculated either as a product of net length and time, with one net hour equating to a 12×2.4–3 m net deployed for one hour (FENTON et al. 1992, KALKO et al. 1996, HARVEY & GONZÁLEZ VILLALOBOS 2007, PEREIRA et al. 2009) or as the product of the total net area (m^2) and time (MORENO & HALFFTER 2000, JOHNSON et al. 2008).

The financial cost of trapping has been noted (FRANCIS 1989, COTTERILL & FERGUSSON 1993, HOURIGAN et al. 2008), with harp traps costing over £ 2,000 / € 2,300. While poles to support mist nets can be fashioned out of inexpensive materials (BARLOW 1999, KUNZ & PARSONS 2009), standard monofilament mist nets have a starting cost of £ 50 / € 55 for a 6 m net. Additionally, advanced bat surveys require skilled, licensed surveyors (COLLINS 2016), which can result in financial outlay in staff costs (HOURIGAN et al. 2008). For voluntary, bat group and research projects, availability of skilled surveyors is likely to be limited, even if there is no financial outlay associated with their time. Given these constraints, the need to know the minimum survey effort required to adequately inventory sites is important. Evidence-based guidelines would allow surveyors to trap with efficacy and confidence in the best use of limited resources.

Little work has been published regarding numbers of survey visits required to inventory temperate woodland bat assemblages (WELLER & LEE 2007). UK guidelines (COLLINS 2016) recommend at least three surveys for small projects and "many trapping nights" for larger projects (with no reference to woodland size or what constitutes small/large projects). Using predictive statistics, WELLER & LEE (2007) recommended (in North American forests) three post-June surveys in order to record the nine species of bat present. The aims of this study were to develop evidence-based guidelines for minimum and maximum survey effort for advanced bat surveys in temperate European woodlands.

MATERIALS AND METHODS

From April to October in 2018 and 2019, advanced bat surveys were undertaken at eleven woodlands (Fig. 1) in the administrative area of Birmingham and the Black Country, UK. Each site was subject to a minimum of three visits across the active bat season, comprising a total of 56 surveys. Surveys took place under Natural England project licences (2018-33578-SCI-SCI and 2019-39455-SCI-SCI) using standard methodology (BARLOW 1999, KUNZ & PARSONS 2009, COLLINS 2016). As per BATTERSBY (2010) and COLLINS (2016), surveys commenced at dusk; they continued for five trapping hours unless weather conditions curtailed the surveys.

Ecotone standard 4-shelf (2.4 m high) mist nets were assembled in double-high arrangements in 6, 9 or 12 m lengths as canopy height allowed, supplemented by two triple-bank Austbat® harp traps deployed with Apodemus® Batlure acoustic lures. Equipment at each survey was deployed to provide a minimum of two trap nights (COLLINS 2016) and 10 net hours (PEREIRA et al. 2009) per night. Harp trap effort was identical for all surveys. As such, the dataset included all bats caught in both harp traps and mist nets.

As per UK guidelines (COLLINS 2016) acoustic monitoring supplemented the survey, with two Elekon® Batlogger M bat detectors deployed for the duration of each survey. Bat Explorer Pro (Elekon AG 2019) was used to analyse recordings.

In order to determine the threshold at which one could expect to begin to catch more than common or ubiquitous species, an analysis of encounter rates was undertaken, separating species into two groups: Group A: Dominant Species comprising species representing more than 10% of encounters and Group B: Non-dominant Species comprising remaining species. To remove bias in species encounters caused by variation in emergence times, catch times were corrected by subtracting the published mean emergence time of each species (JONES & RYDELL 1994). R (R Development Core Team 2014) was used to tabulate encounter data, determining how many times (over all surveys at all sites) each species was the first, second, third, fourth and fifth species to be encountered (E1, E2, E3, E4, and E5, respectively). Data were subject to χ^2 and binomial tests in R to determine the likelihood of catching one group over another. The Vegan package in R was used to produce species accumulation curves for net hours.

Two novel values were established: (1) the minimum survey threshold (MST), the number of net hours below which only common species are likely to be encountered; (2) and the known species threshold (KST), the point at which a given percentage of the known species assemblage for a site can be predicted to be captured.

Known species assemblage estimates comprised all available data, including biological records (EcoRecord 2018) and all species recorded during surveys including both those caught in nets and traps and those recorded on audio detectors. Of the resultant twelve species in the study area, 25% (*Eptesicus*
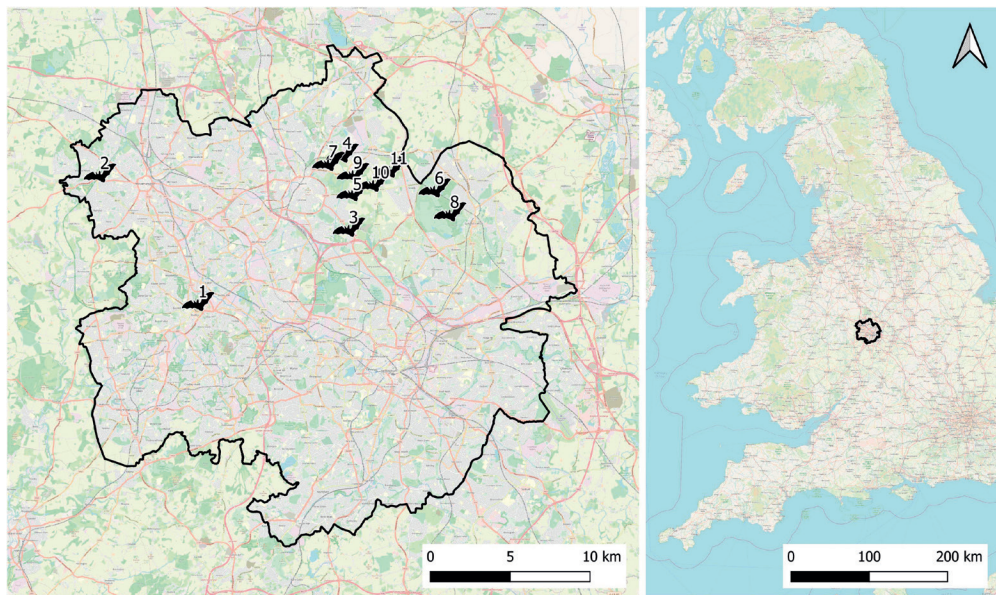

Fig. 1. Location of woodland survey sites (numbered icons) within the administrative areas of Birmingham and the Black Country on left (shown in UK geographical context on right) © OpenStreetMap 2020.
Obr. 1. Vľavo poloha miest prieskumov v lesoch (očíslované symboly) v administratívnych oblastiach Birmingham a Black Country (zobrazené v geografickom kontexte Spojeného kráľovstva vpravo) © OpenStreetMap 2020

Table 1. Species encounter rates for all sites; the number of times each species was the 1st (E1), 2nd (E2), 3rd (E3), 4th (E4) and 5th (E5) species encountered
Tab. 1. Hodnota záznamu výskytu druhov na všetkých stanovištiach; počet záznamov, kedy sa druh zaznamenal ako prvý (E1), druhý (E2), tretí (E3), štvrtý (E4) a piaty (E5)

species / druh	E1	E2	E3	E4	E5	Σ	Σ%
Pipistrellus pipistrellus	15	11	3	3	0	32	24
Pipistrellus pygmaeus	4	9	8	1	0	22	16
Myotis daubentonii	14	6	2	0	1	23	17
Plecotus auritus	12	9	3	1	1	26	19
Myotis nattereri	3	2	2	1	0	8	6
Myotis mystacinus	0	2	4	1	2	9	7
Myotis brandtii	0	0	1	2	0	3	2
Nyctalus noctula	2	1	3	2	2	10	7
Rhinolophus hipposideros	0	0	0	0	1	1	1
Σ	50	40	26	11	7	134	
group A: dominant species / dominantný druh	45	35	16	5	2		
% of each encounter / % záznamov	90.0	87.5	62.0	45.0	29.0		
group B: non-dominant species / nedominantný druh	5	5	10	6	5		
% of each encounter / % záznamov	10.0	12.5	38.0	55.0	71.0		

serotinus, *Rhinolophus hipposideros*, and *Pipistrellus nathusii*) were considered unlikely to be caught in nets in woodlands due to their foraging habits (Braun de Torrez et al. 2017) or to their trap-avoidance behaviour (Berry et al. 2004). Based on this, a KST of 75% was used in this study (the percentage of the known assemblage considered likely to be caught in traps should all of the species be present in a woodland). Minimum, maximum and mean MST and KST values were then used to calculate the numbers of required surveys (based on net hours per hour). R script for the above analysis has been uploaded into the public domain and is available at https://figshare.com/articles/software/Hughes_et_al_2021_Lynx_nx_R/13553981.

RESULTS

A total of 383 bats, comprising nine species (*Myotis brandtii*, *M. daubentonii*, *M. mystacinus*, *M. nattereri*, *Nyctalus noctula*, *Pipistrellus pipistrellus*, *P. pygmaeus*, *Plecotus auritus*, and *Rhinolophus hipposideros*) were caught across the eleven sites; with a further three species (*Eptesicus serotinus*, *Nyctalus leisleri*, and *Pipistrellus nathusii*) being recorded on detectors. Of the bats caught, 134 represented the first five species encountered on each survey, and form the dataset on which the MST calculation is based.

Determining MST

In separating species into two groups: Group A: Dominant Species was determined to comprise *Pipistrellus pipistrellus*, *Pipistrellus pygmaeus*, *Myotis daubentonii*, and *Plecotus auritus*, with

the remainder of species falling into Group B: Non-dominant Species (Table 1). Analyses for the encounter rates of Groups A and B showed that the relation between Species Group and Encounter Number was significant, $\chi^2(4, N=26.11)=8.9$, $p=0.00003$.

Binomial tests comparing Group A with Group B at each encounter showed that at the probability of the first and second species encountered being from Group B is 10% ($p<0.001$), 13% ($p<0.001$), respectively. In contrast, the probability of the 3rd bat encountered being from Group B increases to 38% ($p=0.3269$), increasing to 55% ($p=1$) and 71% ($p=0.4531$) for Encounters 4 and 5, respectively. As the lower three quartiles of Group B at the third encounter fall below the mean of Group A (Fig. 2), and because the encounter rate of Group B vs. Group A did not exceed 50% until Encounter 4, we elected to place the MST value at the fourth species encounter, and that subsequent minimum survey effort recommendations be calculated accordingly.
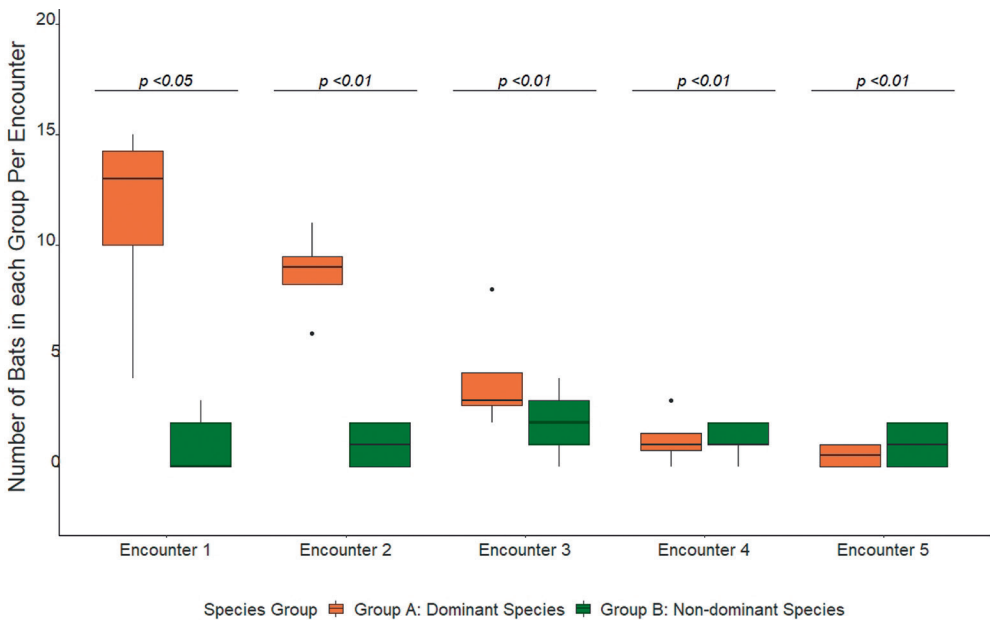

Fig. 2. Species groups per Encounter (i.e. the number of times species within each group were the first (1), second (E2), third (E3), fourth (E4) and fifth (E5) species encountered in overall surveys). Data are corrected for mean emergence time per species. Solid horizontal lines represent the medians; box height corresponds to the interquartile range; whiskers indicate the maximum and minimum values.
Obr. 2. Skupiny druhov v jednotlivých záznamoch, tj. počet prípadov, pri ktorých sa druh vo všetkých prieskumoch zaznamenal ako prvý (E1), druhý (E2), tretí (E3), štvrtý (E4) a piaty (E5). Údaje sú korigované na priemerné hodnoty každého druhu. Plné vodorovné čiary predstavujú mediány; výška boxu zodpovedá medzikvartilovému rozsahu; čirky označujú maximálnu a minimálnu hodnotu.
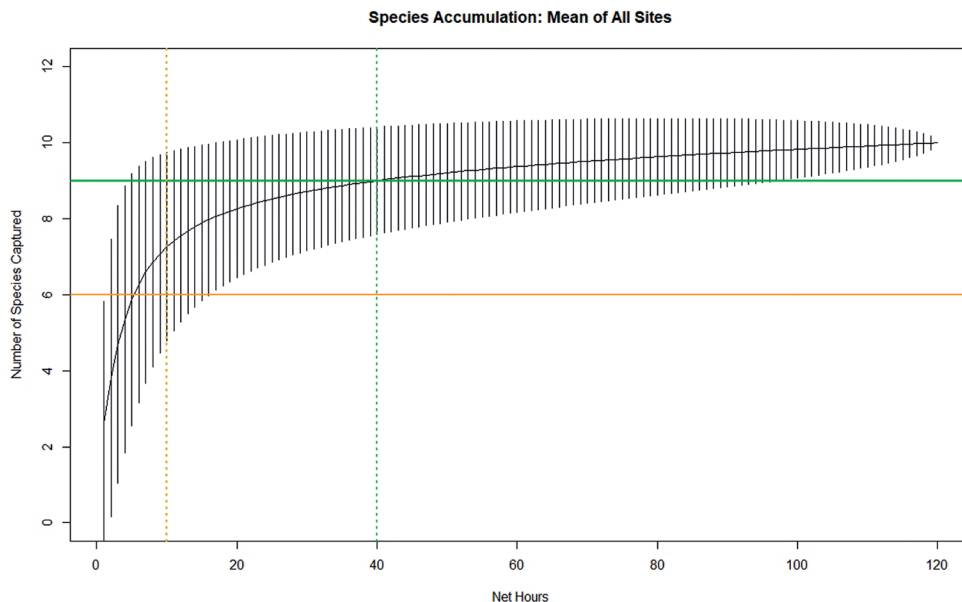
Species Accumulation: Mean of All Sites

Fig. 3. Species accumulation curve for survey duration (Net Hours); mean data from all sites. Vertical and horizontal bars show mean MST (orange lines) and KST (green lines) values.
Obr. 3. Krivka akumulácie druhov (Number of Species Captured) prieskumoch v závislosti od času (sie-ťo-hodiny; Net Hours); použité sú priemerné hodnoty zo všetkých stanovíšť. Vertikálne a horizontálne pruhy ukazujú priemerné hodnoty MPP (oranžové čiary) a PH (zelené čiary).

Determining KST

Species accumulation curves (mean values shown in Fig. 3) showed that MST values ranged from six to 42 net hours with a mean MST value of 17.4 net hours. KST 75% values range from 14 net hours to 43 net hours, with a mean KST value of 29.8 net hours. Analyses of net hours (based on a survey time of 5 hours and a minimum deployment of two net hours per hour) indicated that the MST for temperate woodlands would be reached during the second survey and the KST would be reached during the third survey.

DISCUSSION

The study was successful in using catch data from the 2018 and 2019 survey season to calculate region-specific MST and KST levels to inform planning of advanced surveys for assessment of woodland bat assemblages.

In the absence of existing guidelines, the MST provides a benchmark for the ethical feasibility of advanced bat surveys. For example, in this study the four dominant species recorded can confidently be identified using a bat detector alone. BCT (COLLINS 2016) state that priority

should be given to non-invasive techniques if the required information can be obtained thereby. Therefore, if assemblage data alone is the aim of a survey, it is recommended that the MST should be exceeded in order to make advanced surveys ethically justifiable.

In this survey, KST values indicated the point at which 75% of the known species assemblage for each site was reached (based on the assumption that only 75% were likely to be caught in nets/traps). The KST indicates the point beyond which additional species may be recorded, but with diminishing returns for survey effort. It is beyond the KST that surveyors may wish to consider whether time and resources would be better spent at alternative sites and if further disturbance is justified. It was certainly the case that we did record additional species after considerable survey time, and the surveyor may determine that the diminishing returns are worth the effort. Survey planners may adapt the KST value depending on the percentage of the regional or county species assemblage they deem likely to be caught.

In conclusion, based on a survey time of five hours and a minimum deployment of two net hours per hour, it is recommended that (in our study area) a minimum of two surveys be undertaken in temperate, deciduous woodlands in order to reach the MST for ethical feasibility, and that three surveys be undertaken in order to reach the KST and to optimise survey efficacy. These values, calculated regionally, would afford surveyors the ability to employ an evidence-based standardised survey effort, allowing surveyors to trap with efficacy, utilising their resources accordingly.

SÚHRN

V súčastnosti neexistuje podrobná metodika s rozpracovanými postupmi na rozsah a spôsob výskumu, ktorý je potrebný na pokročilý prieskum netopierov v európskych lesoch mierneho pásma. V tejto štúdii hodnotíme údaje z 56 odchytov netopierov na 11 lesných lokalitách vo Spojenom kráľovstve, aby sme mohli odporučiť rozsah a spôsob výskumu, ktorý je potrebný pri použití ultratenkých nárazových sietí a tym získali efektívne údaje o populáciách netopierov v lesoch mierneho pásma. Pre rôzne druhy netopierov sme vytvorili akumulačné krivky a použili sme ich na vývoj dvoch nových hodnôt na zistenie potrebného rozsahu a spôsobu výskumu: (1) tzv. minimálny počet prieskumov (MPP [MST]), pri ktorom je pravdepodobnejšie, že chiropterológ počas prieskumu nájde menej dominantné druhy netopierov; a (2) prahová hodnota pre konkrétne druhy netopierov (PH [KST]), čo je bod, pri ktorom je možné odchytiť dané percento (v tomto prípade 75%) konkrétnej netopierej populácie a nad rámec tohto bodu sa zníži účinnosť prieskumu. V našej štúdii MPP priemer bol 17,4 hodín prieskumu a PH priemer bol 29,8 hodín. Hodnoty MPP boli dosiahnuté počas druhého prieskumu a PH hodnoty počas tretieho prieskumu. Tieto navrhnuté hodnoty sú prispôsobiteľné na základe lokality a populácií netopierov, ktoré sa tam vyskytujú. Hodnoty je možné použiť na plánovanie pokročilých prieskumov netopierov v lesoch mierneho pásma, a to nielen na maximalizáciu účinnosti prieskumu a efektívne využitie obmedzených zdrojov, ale predovšetkým na to, aby boli prieskumy únosné z etických dôvodov.

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