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Later is better: Optimal timing for walked activity surveys for a European bat guild

[Short communication submission]

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Abstract

Bat activity surveys (walked surveys combining transect and point counts) are extremely important for collecting data within both conservation and planning contexts throughout Europe. To ensure optimal data, it is vital to ensure synchronicity between survey time and peak bat activity, however, although protocols for undertaking two-hour dusk activity surveys are well accepted, start time in relation to sunset is a “best guess” rather than being based on empirical evidence. Accepted practice differs widely with recommended start times varying from 30 minutes pre-sunset (finishing 90 minutes post-sunset) to 30 minutes post-sunset (finishing 2.5 hours after sunset). We provide the first empirical test of the optimal start time for dusk activity surveys by comparing bat activity at the same sites on the same nights. Four sites were surveyed, viz. two high-quality woodland sites and two low-quality agricultural sites. At each site, surveyors walked the same route and stopped at the same pre-defined listening points for three repeat surveys per night: (1) starting 30 minutes pre-sunset; (2) starting at sunset; and (3) starting 30 minutes post-sunset. In total, 240 hours’ of data were collected. Four species – all widespread and common throughout Europe – were recorded: common pipistrelle *Pipistrellus pipistrellus*, soprano pipistrelle *P. pygmaeus*, Natterer's *Myotis nattereri*, and noctule *Nyctalus noctule.* Recorded bat activity was highest on sunset and post-sunset surveys both generally (total bat activity; species richness) and for all five specific species encountered. Findings were consistent for both high- and low-quality habitats. There was little difference between transect and point data in most cases but activity estimates based on point data were substantially higher for Natterer’s bat than those based on transect data. We recommend that: (1) two-hour dusk bat activity surveys start at/after sunset rather than before sunset and (2) both transect and point data are collected and analysed.

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Introduction

Bat surveys are used to inform conservation and development planning decisions. Within a conservation context, surveys are used to map species' distributions, monitor population change, and assess ecological value (Hutson et al., 2001; Walsh et al., 2004). Bat biodiversity is also an important bioindicator of habitat quality and ecosystem health (Racey and Entwistle, 2005; Lacki et al., 2007) and indeed, bat population trends are increasingly being used Europe-wide as biodiversity indicators as per the 2010 EUROBATS resolution (see review by European Environment Agency 2013). Within a planning context, surveys are used within an Environmental Impact Assessment to quantify baseline conditions, assess development impacts, and inform mitigation/compensation processes. Statutory Nature Conservation Organisations are then able to make informed decisions about whether licences to undertake activities detrimental to bat roosts (and sometimes feeding grounds and commuting pathways) should be granted (Bat Conservation Trust, 2012). This ensures compliance with the EC Habitats Directive (92/43/EEC) and European Protected Species licensing framework, as well as the national legislation through which these are implemented.

In the temperate zone, bat surveys typically fall into main three groups: (1) identification and inspection of day roosts, maternity roosts, and hibernacula; and (2) passive acoustic surveys to identify commuting pathways and feeding grounds using automated ultrasonic detectors; and (3) surveys of bat activity in the wider countryside at dusk using handheld ultrasonic detectors (termed dusk bat activity surveys by the Bat Conservation Trust, 2012). While roost and automated surveys are covered by detailed protocols (e.g. Bat Conservation Trust, 2007, 2012), the protocol for undertaking bat activity surveys using handheld ultrasonic detectors is less well defined and subject to numerous confounding factors. For example, since it is rarely possible to undertake activity surveys through the entire night (as is recommended for automated surveys: Richards, 2001), ensuring synchronicity between survey time and peak bat activity is vital. This can be difficult since: (1) most species have non-uniform nightly activity (typically showing a positively-skewed or bimodal activity pattern: Rydell et al., 1996; Hayes, 1997); and (2) different species have different time-activity patterns due to relative predation risk, energy demands, and synchrony with different food resources, as well as for temporal niche partitioning in multi-species guilds (Kunz, 1973; Rydell et al., 1996; Duvergé et al., 2000; Russ, 2012).

Activity surveys following predefined sampling methods using ultrasonic detectors provide the most robust and repeatable surveillance (Battersby, 2010). Such surveys typically involve a surveyor walking a pre-defined transect at a constant pace carrying a bat detector and stopping at pre-defined listening points for a set time period (at least 3 minutes). Bat activity is recorded at each point and continually along the transect, thereby combining the advantages of transect sampling (Walsh et al., 2001) and point sampling (Verboom 1998; Stahlschmidt and Brühl, 2012). This combined approach is recommended by EUROBATS Guidelines for Surveillance and Monitoring of European Bats as providing the best estimates of relative abundance of species being surveyed in the wider countryside (Battersby, 2010). At a European level, the only guidance on timing of surveys is that they should be consistent with respect to sunset and last 1-3 hours (Battersby, 2010). In the UK, the Bat Conservation Trust (BCT) recently revised the dusk activity survey protocol for British bats

(Bat Conservation Trust 2012) to become more prescriptive than previously (Bat Conservation Trust 2007). The new protocol recommends that dusk surveys should start 15-30 minutes before sunset and last around two hours (differing from the 2007 protocol when starting at sunset was recommended). The new protocol has now been adopted by English, Welsh and Scottish statutory regulators. In contrast, the main UK monitoring scheme – National Bat Monitoring Scheme (NBMP) – continues to suggest that surveys should commence at sunset. The new BCT protocol also conflicts with the fact that the vast majority of species do not emerge until at least 30 minutes after sunset (Jones and Rydell 1994; Russ, 2012).

The recommendation of starting to survey 15-30 minutes before sunset is not based on any empirical evidence. Instead, it is a "best guess" based on emergence time data for a few individual species, which may not translate to the best time to survey multiple species (Walsh et al., 2004). As highlighted previously (Milne et al., 2004), it is somewhat surprising that there has never been a direct published assessment of bat transect activity survey data from the same site at different times of the same night. The only direct testing that has been done focuses on the best time of night to survey species using passive monitoring. For example, in South Australia, Law et al. (1998) found bat activity to be concentrated in the hour after sunset and noted that even for the few species that peaked activity later in the night, there was still a "mini-peak" of recordable activity during this period. Findings were similar in North America and North Australia, where the two-hour period following sunset allowed most species present to be recorded on most nights (Hayes, 1997; Milne et al., 2004) but not in urban landscapes in Australia when bat activity peaked more than 2 hrs after sunset (Scanlon and Petit, 2009). All four studies used passive monitoring (i.e. automated data collection using a remote unit rather than walked activity transects) and were undertaken on completely different Chiropteran species communities. There are thus substantial knowledge gaps regarding the optimal timing of bat activity surveys in general, and for the UK/European guild in particular (Hutson et al., 2001). The only study seemingly undertaken on European bats is that of Downs and Racey (2007), where pipistrelle bats (*Pipistrellus* spp.) were monitored throughout the nights at several sites in Scotland at a single point in relation to time, site and weather – this was active in the sense the researcher was present and recording the data but passive in the sense that only a single point was surveyed. There is a need for more evidence-informed guidelines on how to design optimal bat-detector surveys to ensure data are as accurate and robust as possible (Jones 2004; Walsh et al., 2004; Stahlschmidt and Brühl, 2012).

In this study we compare bat activity at the same sites, on the same nights, for replicate transects at different times in relation to sunset to determine whether there is an optimal time to undertake dusk bat activity surveys. Given that the most recent survey protocol for British bats (Bat Conservation Trust 2012) recommended that dusk activity surveys start before sunset, we hypothesise that bat activity levels will be highest for the pre-sunset surveys and decline as survey start time gets later. We also compare bat activity as recorded from the transect itself (transect data) and from the listening points (point data). Point and transect bat activity data have only been directly compared once previously by Stahlschmidt and Brühl (2012) in Germany, which showed that more bat passes were recorded at points than on the transect but that the precision of the activity estimate was lower. We hypothesise that this is likely to be the same in our study and is likely to be more pronounced at sites with more heterogeneous landscapes.

Materials and methods

Fieldwork was undertaken in June and July 2013 at four sites in Gloucestershire, UK, two characterised as high-quality bat habitat and two characterised as low-quality habitat (following Bat Conservation Trust 2012). The habitat at the high-quality sites (centred on 51.93N,-2.03E) was open deciduous woodland with scattered shrub and field layers, high hedgerow connectivity, and adjacent to tree-lined waterways. The low-quality sites (centred on 51.92N, -2.09) were pastoral farmland with some hedgerows 2m high but low hedgerow connectivity and isolated from both woodland and water. At each site, a 3 km transect was devised, which linked 10 listening points. Transects were walked three times per night. The first survey replicate started 30 min before sunset and finished 90 min after sunset following the Bat Conservation Trust (2012) protocol (henceforth the pre-sunset survey). The second replicate started at sunset and finished 2 hrs after sunset following the NBMP protocol (henceforth the sunset survey). The third replicate started 30 min after sunset (in accordance with the emergence times of the majority of bat species: Jones and Rydell 1994; Russ, 2012) and finished 2.5 hrs after sunset (henceforth the post-sunset survey). In all cases, surveyors walked the same route and stopped at the same pre-defined listening points for 3 minutes. In total, 240 hours' of data were collected (6 hrs per night x 10 nights at each site x 4 sites). To avoid each site being sampled during a different part of the season, we rotated between sites on successive nights. Data were only collected when weather conditions were suitable (dry, minimal wind, temperature >7°C) so the sampling period was not entirely continuous.

Rather than each surveyor using a bat detector with an audio output and identifying the bat species in the field by sound alone, data were recorded continually to compact flash cards using frequency division AnaBat SD2 bat detectors fitted with a broad spectrum microphone (Titley Electronics, Ballina, Australia). The time of arrival and departure from each listening point was noted. Post-fieldwork, data were downloaded using CFCread (version 4.4) and analysed using AnalookW (version 3.9c) (http://www.hoarybat.com/Beta) so species could be identified using sonograms to improve accuracy (Walsh et al., 2004). Species-specific data were converted to the standard metric of the number of species-specific bat Passes Per Hour (PPH) (as per Law, 1998; Walsh et al., 2004; Bat Conservation Trust 2012) both while walking (transect data) and from the listening points (point data). For this study, a bat pass was defined as a close sequence of three or more calls that increased in volume to a peak and then decreased again (as the bat came nearer to the detector and then flew away from it). All Analook analysis was done jointly by co-authors LD and LW for all transect replicates. This de-coupled bat identification from specific individual fieldworkers and ensured that there was no potential for bias between transect replicates due to inter-observer differences in bat identification or the way that bat passes were counted. From species-specific information, two new variables were quantified: (1) bat species richness (i.e. the number of different bat species recorded); and (2) total bat activity.

To establish whether there were differences in total bat activity, a two-way repeated measures ANOVA was undertaken for each habitat using IBM SPSS version 21. This approach was used because sites were subject to repeated sampling on the same night. Survey replicate number (pre-sunset, sunset, post-sunset) and data type (transect data or point data) were entered as factors. The same approach was used to examine species richness and species-specific patterns. Post-hoc tests were calculated using the Bonferroni method to control for family-wise error.

Results

In total, there were 1,184 individual bat passes from the four sites combined. Data from the two high-quality woodland sites were extremely similar to one another and were thus pooled for the purposes of analysis. The same approach was taken for the two low-quality farmland sites. Several species were identified: common pipistrelle (*Pipistrellus pipistrellus*) and soprano pipistrelle (*Pipistrellus pygmaeus*) in both high- and low-quality habitat; Natterer's bat (*Myotis nattereri*) in high-quality woodland habitat and noctule (*Nyctalus noctula*) in low-quality open farmland habitat (Table 1; Fig. 1). All the species found are widespread across Europe.

Mean total bat activity was 2.9 Passes Per Hour (PPH) at the high-quality habitat (range 1.8-3.6 PPH depending on survey start time) and 2.0 PPH at the low-quality open farmland habitat (range 1.4-2.5 PPH). All bat activity was higher for surveys that started at or after sunset relative to surveys that started pre-sunset (full statistical results given in Table 1). Total bat activity was significantly higher for sunset and post-sunset surveys compared to pre-sunset surveys for both high-quality and low-quality habitat (post-hoc $P \leq 0.035$; Fig. 1 a&b). Species richness was significantly higher for sunset and post-sunset surveys compared to pre-sunset surveys for low-quality habitat (post-hoc $P \leq 0.001$; Fig. 1c), however, there was no statistical difference in species richness at the high-quality habitat (post-hoc $P \geq 0.198$; Fig 1d).

These patterns were similar for the four individual species. For common pipistrelle, recorded activity was significantly ($P \leq 0.004$) higher on post-sunset surveys compared to other survey times (low-quality habitat: mean = 1.7 PPH versus 0.5 PPH; high-quality habitat: mean = 3.0 PPH versus 1.7 PPH: Fig. 1 e&f). For soprano pipistrelle, activity was significantly ($P \leq 0.049$) higher on sunset surveys compared to other survey times for high-quality habitat (mean = 1.3 PPH versus 0.5 PPH: Fig. 1g). For the low-quality habitat for this species, activity on sunset and post-sunset surveys was similar but both were significantly higher (1.0 PPH and 1.4 PPH, respectively) than that recorded on the pre-sunset survey (no passes recorded) (Fig. 1h). Noctules were only recorded in low-quality habitat, where activity was significantly higher on sunset and post-sunset surveys (1.7 PPH and 1.2 PPH, respectively) compared to pre-sunset surveys (0.3 PPH) ($P \leq 0.019$ in all cases; Fig. 1j). Between-night variability in the presence of Natterer's bats was too high to compute a meaningful ANOVA, but recorded bat activity was higher on post-sunset surveys (2.0 PPH) than sunset surveys (0.5 PPH) or pre-sunset surveys (no passes recorded) (Fig 1i).

All bat species recorded at a given site were represented in both point and transect data. The only exceptions for specific survey replicates were common pipistrelle in low-quality habitat (point data only on the pre-sunset survey) and Natterer's (point data only on the sunset survey). There were significant differences in activity between point and transect data for: (1) species richness for high-quality habitat; (2) overall activity for low-quality habitat; and (3) noctule activity (higher activity levels recorded at listening points for both high- and low-quality habitat; statistical results given in Table 1). There was a significant interaction between replicate and data type for overall bat activity and common pipistrelle for the low-quality habitat (Table 1), with point data became increasingly more important the later the survey commenced (Fig 1b&f).

Discussion

This study, the first to compare data from multiple dusk bat activity surveys at the same sites on the same nights empirically, has found that surveys in the UK starting before sunset (as per Bat Conservation Trust 2012 guidelines) record lower bat activity and pick up fewer species than surveys that start at sunset (as per Natural England, 2012) or 30 minutes after sunset. This finding was consistent for low-quality (open farmland) and high-quality (woodland) habitats. Generally there was no difference between the sunset and post-sunset surveys – recording for all or most of the two-hour period following sunset allowed most species to be recorded (Hayes, 1997; Milne et al., 2004). This general finding differs from work on recording activity using passive techniques for Australian bats when peak activity was the first hour after sunset (Law et al. 1998).

In terms of specific species, the species identified here are widespread across Europe. Findings here agree with the only work on European species seemingly done previously: a study of common and soprano pipistrelles in Scotland (Downs and Racey, 2007). That study found orientation calls of both species increased in 45 minute blocks after sunset peaking in block 3 (1hr 30 mins – 2hrs 15 mins after sunset), the time period covered completely in the post-sunset survey here, which is when the highest number of common and soprano pipistrelles were recorded. Although it is recognised that our study has not surveyed all species in the UK guild, and only a very small part of the European guild, it is notable that noctule, the UK species with the earliest emergence (Russ 2012) and the second earliest of the species occurring is Europe listed in Jones and Rydell (1994), conforms to this trend along with the later-emerging species.

Point and transect data have only been directly compared once previously (Stahlschmidt and Brühl, 2012), when point data were found to be less variable than transect data; something that was not seen here. However, the aims and methods of the two surveys were different. In Stahlschmidt and Brühl's study data from each of three points were considered separately and compared to transect data, whereas here data from 10 points per site were pooled and compared to transect data. Generally point and transect data gave similar results but any differences were because species were detected at points and not while walking. Listening points are therefore important but walking data are still valuable and can be collected with little effort while moving between points.

We recommend that more multi-transect-per-night bat activity survey data be collected from across the UK, and in other countries for other Chiropteran guilds, to establish the generality of these findings. In the meantime, we recommended that 2-hour dusk bat activity surveys start at or after sunset rather than 30 minutes before sunset (for 3-hour surveys, starting at sunset is recommended) and continue to combine listening point data and data obtained while walking between points.

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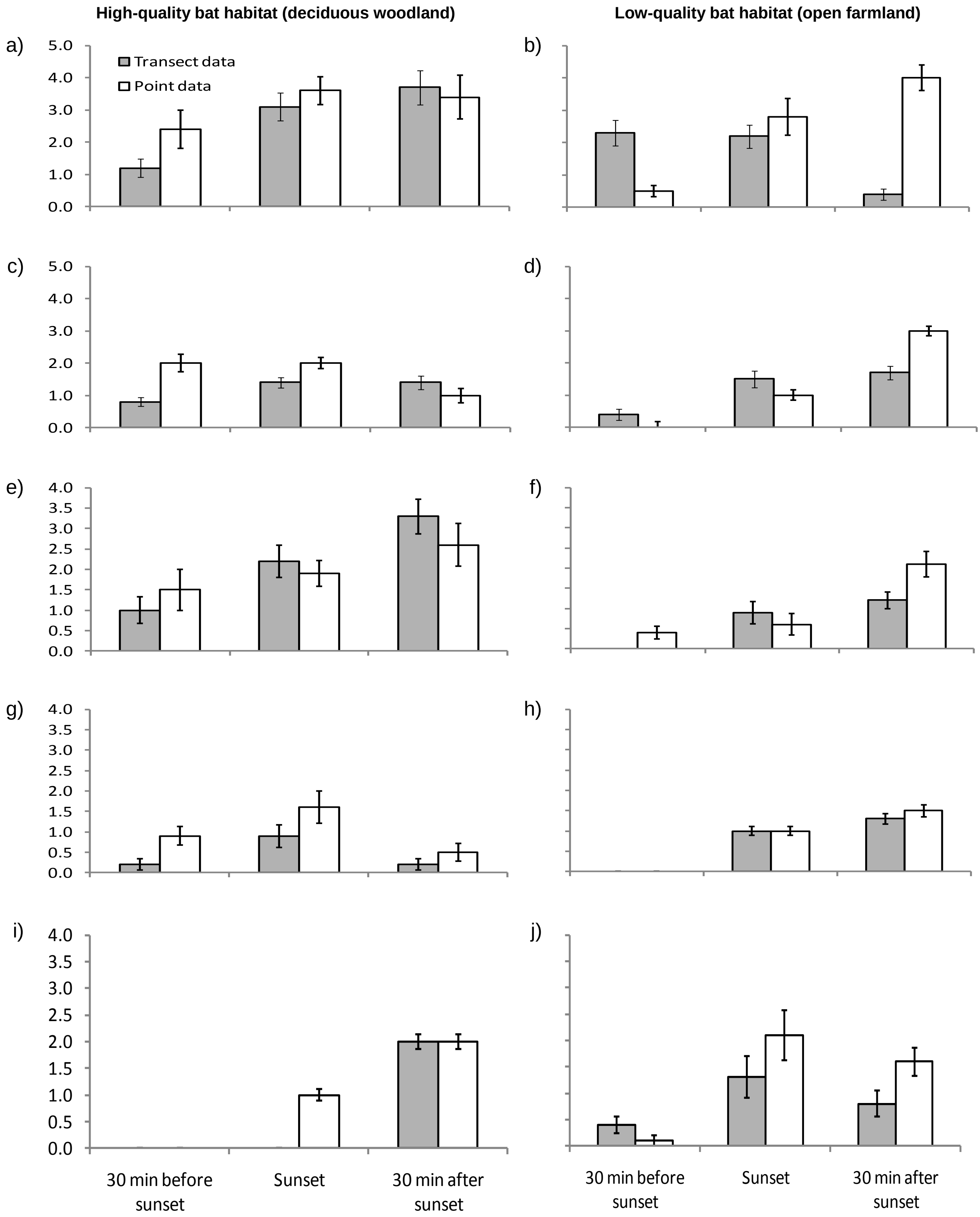
Table 1: Results of two-way repeated measures ANOVAs with survey replicate (pre-sunset, sunset, post-sunset) and data type (transect or listening point records) entered as fixed factors; the interaction term was also calculated. Post-hoc tests were calculated using the Bonferroni method to allow for family-wise error.

Dependent Variable	**Metric**	**High-quality bat habitat (woodland)**		**Low-quality bat habitat (farmland)**	
Overall bat activity (total passes)	Replicate	F_2 = 5.973; **p = 0.010**		F_2 = 9.646; **p = 0. 001**	
		Pre-sunset : Sunset	**p = 0.035**	Pre-sunset : Sunset	**p = 0.005**
		Sunset : Post-sunset	p = 1.000	Sunset : Post-sunset	p = 0.940
		Pre-sunset : Post-sunset	**p = 0.015**	Pre-sunset : Post-sunset	**p = 0.032**
	Point/Transect	F_1 = 1.030; p = 0.209		F_1 = 9.893; **p = 0.012**	
	Interaction	F_2 = 1.634; p = 0.223		F_2 = 24.892; **p < 0.001**	
Bat species richness (number of species)	Replicate	F_2 = 2.640; p = 0.099		F_2 = 27.904; p **< 0.001**	
		Pre-sunset : Sunset	p = 0.198	Pre-sunset : Sunset	**p < 0.001**
		Sunset : Post-sunset	p = 0.928	Sunset : Post-sunset	p = 0.198
		Pre-sunset : Post-sunset	p = 0.198	Pre-sunset : Post-sunset	**p < 0.001**
	Point/Transect	F_1 = 11.172; **p = 0.009**		F_1 = 2.613; p = 0.143	
	Interaction	F_2 = 1.268; p = 0.305		F_2 = 1.939; p = 0.173	
Common pipistrelle *Pipistrellus pipistrellus*	Replicate	F_2 = 9.504; p = **0.002**		F_2 = 19.485; **p < 0.001**	
		Pre-sunset : Sunset	p = 0.134	Pre-sunset : Sunset	p = 0.073
		Sunset : Post-sunset	p = 0.223	Sunset : Post-sunset	**p = 0.036**
		Pre-sunset : Post-sunset	**p = 0.004**	Pre-sunset : Post-sunset	**p < 0.001**
	Point/Transect	F_1 = 0.328; p = 0.581		F_1 = 2.500; p = 0.148	
	Interaction	F_2 = 1.874; p = 0.182		F_2 = 5.737; **p = 0.012**	
Soprano pipistrelle *Pipistrellus pygmaeus*	Replicate	F_2 = 6.092; **p = 0.010**		F_2 = 2.053; p = 0.157	
		Pre-sunset : Sunset	**p = 0.042**	Pre-sunset : Sunset	**p = 0.042**
		Sunset : Post-sunset	**p = 0.049**	Sunset : Post-sunset	p = 0.437
		Pre-sunset : Post-sunset	p = 0.437	Pre-sunset : Post-sunset	**p = 0.031**
	Point/Transect	F_1 = 0.367; p = 0.560		F_1 = 0.310; p = 0.591	
	Interaction	F_2 = 0.310; p = 0.737		F_2 = 0.310; p = 0.737	
Noctule *Nyctalus noctula*	Replicate	- - -		F_2 = 9.169; **p = 0.002**	
				Pre-sunset : Sunset	**p = 0.019**
				Sunset : Post-sunset	p = 0.586
				Pre-sunset : Post-sunset	**p = 0.010**
	Point/Transect	- - -		F_1 = 15.059; **p = 0.004**	
	Interaction	- - -		F_2 = 3.310; p = 0.060	
Natterer's *Myotis nattereri*		ANOVA could not be computed due to very high variability. Refer to Fig. 1i to see results.		- - -	

Figure 1: Bat activity recorded on two-hour bat activity walked transects and associated listening points (see Materials and methods) three times per night with different start times at two different habitat types. Graphs show: (a-b) total bat activity; (c-d) bat species richness; (e-f) Common pipistrelle, *Pipistrellus pipistrellus*; (g-h) Soprano pipistrelle, *Pipistrellus pygmaeus*; (i) Natterer's, *Myotis nattereri*; and (j) Noctule, *Nyctalus noctula* Bars show mean number of bat passes per hour for activity data and number of species for richness data. Error bars show standard error.



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