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Roosts used by bats in late autumn and winter at northern latitudes in Norway

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Abstract. In Norway, very few bats are found in caves and mines in winter, thus other habitats must be primary hibernation sites in this region. To explore roost site selection in late autumn and early winter at 62° N in western Norway, 18 bats of three genera of the Vespertilionidae family that are known to use underground hibernation sites were tagged with radio transmitters. The bats were tracked mostly during daytime between late September and up to early January. Mainly three habitats were used by bats in late autumn in this study; buildings, crevices in rock walls and rock scree. Roosts were distributed from sea level to the low alpine zone. Rock scree was confirmed as a hibernation site for bats.

Key words: hibernation, *Eptesicus nilssonii*, *Myotis daubentonii*, *Myotis mystacinus*, *Plecotus auritus*, rock scree

Introduction

Several species of temperate bats, in particular members of the *Myotis* genus and the barbastelle *Barbastella barbastellus*, hibernate in underground sites with suitable temperatures and humidity, such as caves, mines and bunkers (e.g. Baagøe et al. 1988, Nagel & Nagel 1991, Baagøe 2001, Jurczyszyn & Bajaczyk 2001, Humphries et al. 2002, Altringham 2003, Ruczynski et al. 2005, Baranauskas 2006, Dietz et al. 2007, Masing & Lutsar 2007, Siivonen & Wermundsen 2008, Baagøe & Degn 2009, Wermundsen & Siivonen 2010). Still, in most parts of Europe, only a small proportion of bat populations are accounted for in winter, even where caves and mines are readily available.

Studies suggest that more bats are present in underground sites than those found during surveys of these structures (e.g. Baagøe et al. 1988, Kugelschafter 2000, Baagøe 2001, Parsons et al. 2003, Baagøe & Degn 2004, Meschede & Rudolph 2004, Glover & Altringham 2008, Baagøe & Degn 2009), but no one knows exactly where all bats go when winter sets in. Species that do use caves and mines are also found in various other habitats in winter, including cellars, hollow trees, hollow brick walls and even wells (e.g. Rydell 1989, Lesinski et al. 2004, Baagøe 2007). These sites could hold a substantial proportion of bat populations of some species, but bats hibernating in such inaccessible crevices are difficult to find and usually impossible to count. Thus, our present knowledge of hibernation site selection in bats must be highly biased for many species. Further, climate and anthropogenic factors (e.g. number of available artificial sites) will affect roost site selection. Although man has increased the number of potential roosts for many bat species (e.g. Altringham 2003), this is perhaps less pronounced to the north in Europe with lower human population densities. Thus, bats in this region may still show a greater fidelity to traditional roosts of their natural history compared to the densely populated areas further south. Siivonen & Wermundsen (2008) found that hibernating bats available for inspection in Finland preferred natural stone as hibernation substrate, perhaps indicating some affinity for natural habitats.

In Norway less than 300 bats of the genera *Eptesicus*, *Myotis* and *Plecotus* are found each winter, almost all in south eastern Norway (Isaksen 2007, Michaelsen & Grimstad 2008, van der Kooij & Olsen 2011). Preliminary results using equipment that automatically counts bats leaving these caves in spring do not differ much from visual counts made inside the hibernation sites during winter (van der Kooij et al. 2011, van der Kooij & Olsen 2011). In western parts of the country,

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caves, mines and bunkers with presumably suitable temperature gradients hold no bats in most years and the maximum number recorded in a single man-made underground site is two (authors' unpublished data). Bones from bats, dating back more than 3600 years during warmer climatic periods, have been found in natural caves in the study area (Stormark 1998), but no bats have been found in such habitats at present time (authors' unpublished data). Thus, the primary hibernation habitat for several bat species also found in mines and caves must be elsewhere. Bats at northern latitudes in western Norway could hibernate in various building structures, crevices in rock walls or even in rock scree (Michaelsen & Grimstad 2008) and at least northern bats *Eptesicus nilssonii* have previously been found in these habitats in late autumn. In this note we present a full account of 18 bats of four species of the genera *Myotis*, *Plecotus* and *Eptesicus*, tagged with transmitters in late autumn in western Norway from 2005 to 2012. The main purpose was to search for roost sites used by bats at a time when bat activity ends at northern latitudes (62° N). The topography in the study area yields a number of natural underground sites, such as crevices in rock walls and rock scree, and at least some of these sites will have suitable temperatures for bats (Michaelsen & Grimstad 2008). As few bats are found in man-made underground sites, we expected natural sites to be important roosting habitats. An important focus throughout this study was to exclude the use of man-made habitats such as mines or buildings, thus much of the tracking effort was directed at such structures.

Material and Methods

Bats were trapped and fitted with transmitters on three large islands and two mainland localities in Møre og Romsdal county on the south west coast of Norway at 62° N; location A) Hareid, Hareid municipality (62°22′ N-05°59′ E), location B) Ellingsøy, Ålesund municipality (62°30′ N-06°13′ E), location C) Solavågsfjellet, Sula municipality (62°24′ N-06°18′ E), locality D) Austefjorden, Volda municipality (62°05′ N-06°15′ E) and E) Tafjord, Valldal in Norddal municipality (62°18′ N-07°17′ E). In Norddal municipality (unlike all the other locations) several abandoned mines have been available to bats for decades.

All localities have strong or some oceanic influence and lie within the boreonemoral to south boreal vegetation zone (Moen 1998). Normal monthly temperatures for January in the lowlands are 0° to +4 °C (Aune & The Norwegian Meteorological Institute 1993), thus these areas are generally without lasting snow cover in winter. First day of snow in lowlands is usually between November 1 and November 14, but can be as early as late September/early October or as late as December. In alpine areas first snow fall is usually between October 15 and October 31 (Bjørbæk & The Norwegian Meteorological Institute 1993). In general, coastal parts of south western Norway, where this study was carried out, have milder winters than neighbouring countries to the south, such as Denmark and Sweden, as well as the bulk of eastern Europe, where winters are continental (Schönwiese & Rapp 1997). In this paper we follow the general meteorological definition of winter for the northern hemisphere to be the three months with lowest temperatures; December, January and February, but acknowledge that winterly condition, with snow and sub-zero temperatures can be found from October and up to April in many years (see Schönwiese & Rapp 1997 for a detailed climatic description). Thus, for some observations of special interest, meteorological conditions are discussed in some detail. We consider late September and through November as late autumn, a time when night-frost sets in and growth season ends.

Northern bats were trapped around street lamps using mist nets (pole-flicking), except for two that were taken from a BCI-type bat box. Aerial northern bats were lured down by throwing small stones into the air (northern bats commonly dive to catch the lure). Whiskered bats *Myotis mystacinus* and a long eared bat *Plecotus auritus* were trapped using a Sussex Autobat (Hill & Greenaway 2005) combined with puppet hair nets. All Daubenton's bats *Myotis daubentonii* were trapped outside a single swarming site in a concrete tunnel. Transmitters were fitted to the first bat(s) to be trapped that evening/night (i.e. random selection). We used transmitters from Titley Electronics PTY/LTD, Australia (LTM Single stage, 0.5 g), Holohil Systems Ltd., Canada (LB2N, 0.35 g and 0.42 g) and Biotrack, U.K. (PicoPip AG376, appr. 0.6 g). Up till 2012, bats were tracked using two TRX48S receivers combined with 3-element Yagi antennas (Wildlife Materials, UK). This receiver has an attenuator switch, allowing exact positioning at short distances. In 2012, in addition to one TRX48S, a Sika receiver (Biotrack, U.K.) with a MAG108 omni-directional antenna (Sirio Antenna, Italy) was used when driving a car and when inspecting mines. This equipment allowed the observers to search for all frequencies when driving, a necessity when tracking as much as 7 bats at the same time.

Table 1. Sex, age, biometry, tracking period and roost site selection of the bats in this study. Coordinates and other data for the four different sites (A-E) can be found in the Material and Methods section. *Last known roost site, **The bat was found dead in roost, ***Three different roosts in scree. Y – calendar year of birth.

								Days in different roost habitats				
Bat no.	Species	Age	U.A. (mm)	Weight (g)	Sex	Location	First-last record	Building	Scree	Rock crevice	Scree or crevice	Manmade underground habitat
1	Northern bat	2Y+	NA	NA	F	A	24. September-12. October 2005	4	2*	0	0	0
2	Northern bat	1Y+	39.3	11.8	M	A	25.-27. September 2006	3*	0	0	0	0
3	Northern bat	2Y+	38.0	10.5	M	B	25.-26. September 2006	0	2*	0	0	0
4	Northern bat	1Y+	38.6	8.5	M	B	30. September-21. October2007	10*	0	11	0	0
5	Northern bat	1Y+	37.7	9.8	F	B	19. September-8. October 2009	20*	0	0	0	0
6	Whiskered bat	1Y/2Y	34.7	5.5	F	B	29. September-7. October 2010	0	?	?	8*	0
7	Long eared bat	1Y+	41.4	8.0	F	C	21. October-6. November 2009	0	0	13*	0	0
8	Whiskered bat	1Y/2Y	33.2	4.8	F	C	6. October-28. October 2010 (**)	0	0	18*	0	0
9	Northern bat	1Y+	37.7	7.3	M	D	19. September-6. October 2009	5	12*	0	0	0
10	Whiskered bat	1Y+	36.8	5.8	M	D	23. October-9. November 2009	0	7*	5	0	0
11	Whiskered bat	1Y/2Y	34.4	5.5	F	D	9. October-2. November 2010	0	0	13*	0	0
12	Northern bat	1Y+	37.9	9.0	F	B	23.September 2012-6. January 2013 (***)	0	22*	3	1	0
13	Northern bat	2Y+	37.8	8.75	F	E	26. September 2012	1*	0	0	0	0
14	Northern bat	1Y+	37.5	8.0	M	E	26. September 2012	1*	0	0	0	0
15	Daubenton's bat	2Y+	37.5	9.25	M	E	26. September-30. September 2012	0	0	1*	0	1
16	Daubenton's bat	1Y+	36.8	8.75	M	E	30. September 2012	0	0	1*	0	0
17	Daubenton's bat	1Y+	37.0	8.25	M	E	No records	0	0	0	0	0
18	Daubenton's bat	1Y+	36.0	7.5	M	E	No records	0	0	0	0	0

All bats were banded with metal rings, except for bat no. 1 (see Table 1), using rings issued by Stavanger Museum (2.9 mm alloy) to avoid pseudo replication, and further, bats were sexed and attempts were made to determine age in females based on signs of previous reproduction. This late in the season, it was not possible to age bats on characters in the joints of fingers without the use of x-ray techniques (Baagøe 1977).

The bats were tracked during daytime and occasionally during the evening. Bats were not tracked every day. One scree (at location D) was surveyed in the evening using ultrasound detectors (D240X, Pettersson Elektronik AB, Sweden). Bats heard and seen around the scree were recorded in time expansion (3.4 seconds). At location E we walked through all mines in December to confirm that the telemetry bats had not hidden in crevices concealed from direct observation. At one of these mines, 0-2 *Myotis* sp. has been found per year. Temperatures measured at this location should be within the range for most bat species (0.5 °C to 6 °C over a gradient of the mine, authors' unpublished data).

All four species in this study are widespread and common or fairly common in south western Norway. Northern bats are active from late April or early May and are usually heard on detectors up till late September or early October (Michaelsen et al. 2003a, authors' unpublished data). Daubenton's bats are in most years active from April till October (unpublished data). No useful information on annual activity patterns exists for the two other species, but we know that some young whiskered bats are active well into October and that these bats can hunt during daytime (Michaelsen & Olsen 2012). There is no evidence of longer migrations in any of the four species at these latitudes, but some bats may undertake shorter movements from the cooler eastern parts and into the winter-mild sections of western Norway where this study was carried out (Michaelsen 2011).

Results

Telemetry

All four species fitted with transmitters used crevices in rock walls. Only northern bats used buildings in this study. Both northern bats and whiskered bats used rock scree as roosts after their hunting activity ended in late autumn or early winter. One northern bat with long lasting battery lifetime was recorded in rock scree till January 6, 2013. It had previously used two other screes and a crevice in a rock wall. The bat did not leave the scree even though temperatures plummeted well below zero and it remained in the scree through the 11. coldest December in Norway in 112 years. It did however shift sites within the scree at least once during winter. Only one individual, a Daubenton's bat, was recorded in a man-made underground structure (concrete tunnel). This was at the swarming site where it was trapped two days earlier and during a time when Daubenton's bats are still highly active. No bats hibernate at this site.

Roosts used by bats were found at elevations from 0.5 to 750 m a.s.l., the highest altitude was in the low alpine zone at these latitudes. One bat was found dead on October 28 at its roost site in a rock crevice 0.5 m above maximum sea level. The bat probably drowned during stormy weather followed by tall waves reaching beyond its position in the crevice. Detailed data for all bats, including age, sex, biometry, tracking period and roost site selection, are presented in Table 1.

Random observations

One undetermined bat was observed leaving a scree at location D in early October (200 m from the site used by bat no. 9). It flew just above the scree and into the foliage of a birch at the end of this scree. This bat was not picked up by the detector at a distance of approximately 10 m. Low range ultrasound and flight in the foliage of a tree suggest that this was a long eared bat.

Discussion

Perhaps the most interesting result from this study is that northern bats and whiskered bats will use rock scree and crevices in rock walls as roosts at a time of the year when activity comes to a halt and during winterly conditions. In addition to the probable long eared bat found to emerge from scree in this study, this species has previously been found hibernating on a rock wall covered by a massive scree (Michaelsen & Grimstad 2008), confirming that three genera (*Myotis*, *Plecotus* and *Eptesicus*) will venture into this habitat. During a pilot study (Michaelsen & Grimstad 2008), at least three different northern bats (telemetry and random observations) were confirmed to use the same scree (at location B), but with different entrance/exit points. Further, several random observations of bats leaving scree have been made in Norway (van der Kooij 1999, Michaelsen & Grimstad 2008) and possible records of bats roosting in scree have been made even north of the Arctic circle (Frafjord 2007).

We did not make any attempts to investigate if bats use scree during pregnancy and lactation (May-July). With the light conditions available during nights at these latitudes in summer, we would expect to have observed bats leaving such structures if they actually used them. Still, mainly reproducing females are accounted for at roosts during summer and we cannot exclude that males and non-reproducing females extend their use of scree beyond autumn and winter.

Bats roosting in scree at high altitudes (e.g. bat no. 10, Table 1) are likely to be snowed in even by October in most years, thus suggesting that at least some bats will hibernate (voluntarily or not) in this habitat for shorter or longer periods. Here bats will benefit from additional insulating effect of the snow cover during hibernation. Lowlands will in some years face snow cover in October. Here the snow usually lasts for only a short period of time and bats will, in most years, be able to switch sites during the winter.

The high proportion of telemetry bats that we have found to use scree in this study, even though they are difficult to detect by radio telemetry, does suggest that this could be an important habitat for bats in Norway. Also, it is important to acknowledge that bats that used man-made habitats may well have shifted roosts to rock crevices or scree after they were lost or when battery lifetime ended. During all searches for bats with transmitters, we focused on covering as many buildings as possible, several tens of kilometers away from the bats last known whereabouts. All villages from sub-alpine areas in the east, to island in the west on the north side of the fiord were included in our searches. Most buildings, even in the only city in the region (Ålesund), were passed with a distance of less than 300 m. Thus, it is unlikely that bats lost in this study, used buildings within the searched areas. We can however not exclude that bats have undertaken movements beyond our study area, thus we cannot confirm that bats did not hibernate in such structures. Only a small portion of the total number of screes and crevices in the study area was within the distance that we would expect to succeed in receiving a signal from the transmitters. Thus, finding bats in scree or crevices is associated with luck even if this habitat was commonly used by bats fitted with transmitters.

The use of scree could be associated with risks in terms of predation, but scattered entrance/exit points used by single bats as found in this study should make predictions of the bats whereabouts difficult for predators such as owls or birds of prey. This is different from swarming sites or hibernation sites in caves or mines where a number of bats fly through the same area during the night. Here, the learning curve of predators should be less steep. Further, unlike scree, caves and mines have historically not been safe from disturbances from humans, possibly even causing population declines (Altringham 2003, Dietz et al. 2007). Some mice (e.g. *Apodemus flavicollis*) could have the potential to kill bats, but were not found in scree during a study carried out by the authors (unpublished data). *Apodemus* spp., as well as rats *Rattus norvegicus*, are however found in buildings in the area and could pose a threat to bats hibernating here. We have not found stoat *Mustela erminea* or least weasel *Mustela nivalis* or feaces of these species in screes used by bats, but they do occur throughout the study area. We assume that these two predators would have difficulty to find bats in the gravel under the surface of these screes, and should only pose a threat during the short period when bats leave or enter a scree. Snakes, in the study area *Vipera berus* is the only species, could pose a threat to bats, at least when moving about in the warmer parts around the surface of a scree. Finally, bats entering cellars or similar man-made habitats may encounter domestic cats *Felis catus*, an introduced species that, in rural areas, occurs in higher densities than any native predator. Cats kill a number of bats at roosts in buildings in Norway (Michaelsen et al. 2003b, Michaelsen & van der Kooij 2006, van der Kooij 2007, Værnesbranden 2007) as they do elsewhere in Europe (e.g. Bekker & Mostert 1991, Woods et al. 2003) and could cause population decline (see Altringham 2003 for a general discussion of the problem). Most natural habitats used by bats in this study are outside the reach of this pest species.

Further research on bat hibernation in natural habitats should be undertaken in other regions in Europe, in particularly where large portions of hibernating bats are unaccounted for. Such studies would perhaps yield the most interesting results in areas with complex topography. Our study did not focus on climatic conditions preferred by bats in natural roosts, but we do encourage other researchers to do so.

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