Short note

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First record of a Nathusius' pipistrelle (*Pipistrellus nathusii*) overwintering at a latitude above 60°N

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Abstract: Highly mobile species are considered to be the first to respond to climate change by transforming their ranges of distribution. There is evidence suggesting that *Pipistrellus nathusii*, a species capable of long-distance migration, is expanding both its reproduction and overwintering ranges to the North. We recorded the echolocation calls of bats at 16 sites in South-Western Finland on two consecutive winters, and detected calls of *P. nathusii* at one of the sites throughout the second winter. To our knowledge, this is the northernmost record of an overwintering *P. nathusii*, and contributes to evidence that the species is already responding to climate change.

Keywords: chiroptera; climate change; hibernation; migration; range expansion.

Climate change is already affecting the range limits and phenology of organisms across a plethora of taxa (Hickling et al. 2006; Parmesan and Yohe 2003; Tingley et al. 2009). According to a review by Thomas (2010), it is possible that more than half of observed animal range boundaries have shown a response to climate change. In most cases, range expansion has occurred on the boundary with lower ambient temperatures, which appears to take place more rapidly than local extinctions at the boundary with higher ambient temperatures (Brommer et al. 2012; Hickling et al. 2006; Thomas et al. 2006). Highly mobile species, such as bats, are most likely to be the first to respond to a changing climate by shifting their ranges towards the poles or to higher latitudes (Brommer et al. 2012; Warren et al. 2001). While it is difficult to differentiate changes caused by climate change from those resulting from habitat loss or other local changes, or an increase in sampling effort, there is some evidence that bats are also already responding to the changing climate through range expansion (Lundy et al. 2010; Sherwin et al. 2013).

Winter is often a critical time for animals inhabiting high latitudes, and the overwintering strategies of organisms have received considerable attention with regards to climate change and associated range shifts (Humphries et al. 2002; Maclean et al. 2008; Sorte and Iii 2007). For many relatively sedentary species, such as most hibernating mammals, climate change can have unfavorable effects (Lane et al. 2012). However, bats (order Chiroptera), as an example of hibernating mammals, are mobile and more capable of shifting their overwintering ranges as a response. Indeed, Humphries et al. (2002) suggest that the hibernation ranges of North American bats will shift towards the North because of climate change. Furthermore, according to Newson et al. (2009), climate change is likely to affect the hibernation site selection and species composition in hibernacula to an extent that the abundance of bats, and changes in the distribution and species composition at underground hibernation sites can be used as an indicator for climate change.

In Europe, *Pipistrellus kuhlii* (Ancillotto et al. 2016; Sachanowicz et al. 2006; 2017) and *Hypsugo savii* (Lehotská and Lehotský 2006; Uhrin et al. 2016) have shown a remarkable increase in their geographical range, whereas in North-America, Willis and Brigham (2003) reported the tree-roosting bat, *Lasiurus borealis*, in Southwestern Saskatchewan, Canada, 300 km from the nearest previous observation. In addition, *Pipistrellus nathusii* has expanded its range considerably during the past decades (Benda et al. 2008; Lundy et al. 2010; Sachanowicz and Ciechanowski 2006; Sachanowicz et al. 2019). Breeding colonies, and a likely increase in the amount of individuals, have been documented in the British Isles (Matthews et al. 2018; Russ et al. 2001), Northern Italy (Martinoli et al. 2000) and on the Iberian Peninsula (Flaquer et al. 2005).

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Table 1: Number of minutes (Min) with recordings of *Pipistrellus nathusii* at Härmälä cleft (Finland) during the winter 2018–2019.

Oct 2018	Min	Nov 2018	Min	Dec 2018	Min	Feb 2019	Min	Mar 2019	Min	Apr 2019	Min
6	29	3	5	20	2	15	5	23	2	16	2
8	9	13	10							17	1
9	21									24	4
10	6										
11	47										
12	21										
13	7										
14	6										
15	1										

The more northerly populations of *P. nathusii* are considered long-distance migrants, with distances of up to 1905 km between its breeding and overwintering areas (Pētersons 2004), whereas in central Europe the species is a short-distance migrant or even, a sedentary species (Sachanowicz et al. 2019). *P. nathusii* overwinters predominantly in Western, Central and Southern Europe, usually hibernating solitarily or in small groups above ground (Sachanowicz et al. 2019). Typical winter roosts are buildings, hollow trees, woodpiles and sometimes rock crevices (Dietz and Kiefer 2016). Therefore, hibernation surveys fail to record the species during the winter (Sachanowicz et al. 2019), and alternative methodology is needed to map the overwintering range of the species.

Bats are known to regularly arouse (Thomas et al. 1990), fly and even forage outside hibernacula during the winter (Bernard and McCracken 2017; Hope and Jones 2012). We recorded the echolocation calls of bats at 16 sites in South-Western Finland over two consecutive winters (2017–2018 and 2018–2019) by using SongMeter SM2 + Bat passive ultrasound detectors and SMX-US ultrasound microphones (Wildlife Acoustics). These sites included four outcrop formations, three ancient shores, three glacial erratic or boulder formations, three cellars and three control sites in diverse environments where we did not expect bats to be hibernating. We filtered the data using Kaleidoscope Pro (Wildlife Acoustics) and identified the calls manually. In our data, the echolocation calls of *P. nathusii* occurred regularly at a single site, Härmälä cleft, on several occasions during the winter of 2018–2019 (Table 1, Figure 1), suggesting that the species overwintered at the site. Due to similarities in echolocation characteristics (Zsebok et al. 2012), we cannot fully disclose the possibility of our recordings belonging to *P. kuhlii*, or its subspecies, *P. kuhlii lepidus*. This species has not been observed in Finland previously, but both *P. kuhlii* and *P. kuhlii lepidus* has shown considerable range expansion during the last decades (Ancillotto et al. 2016; Sachanowicz et al. 2006, 2017). The probability of either of these taxa occurring in Finland is still small, but the observed range shifts call for increased vigilance in identification procedures.

Härmälä cleft (N60.488358, E22.006638) is an outcrop formation on the shore of the Baltic Sea in the Masku municipality, South-Western Finland. The cleft is approximately 20 meters high with multiple deep crevices. While winter activity, as evidenced by acoustic data, suggests bats hibernate in the cleft, we never observed a bat in the crevices. We cannot disclose the possibility of the bat occupying cavities in large trees for hibernation in the vicinity of the recorder.

In addition to being the coldest month of that winter with a mean temperature of −4.4 °C, January was also the only month without any recordings of *P. nathusii*. The lowest

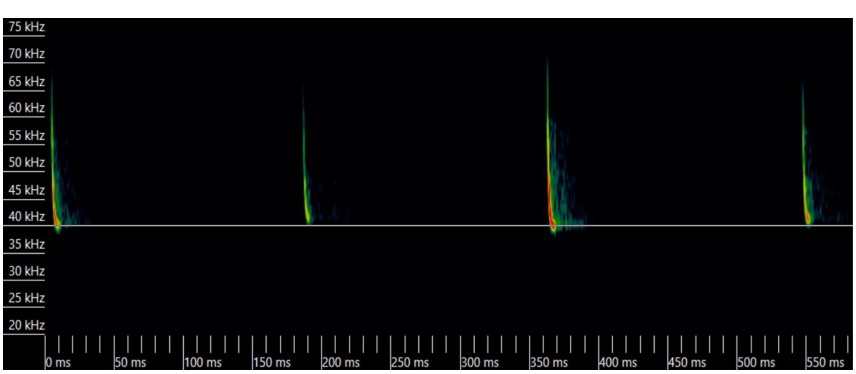

Figure 1: Sonogram of *Pipistrellus nathusii* calls recorded at Härmälä cleft (Finland) on February 15, 2019.

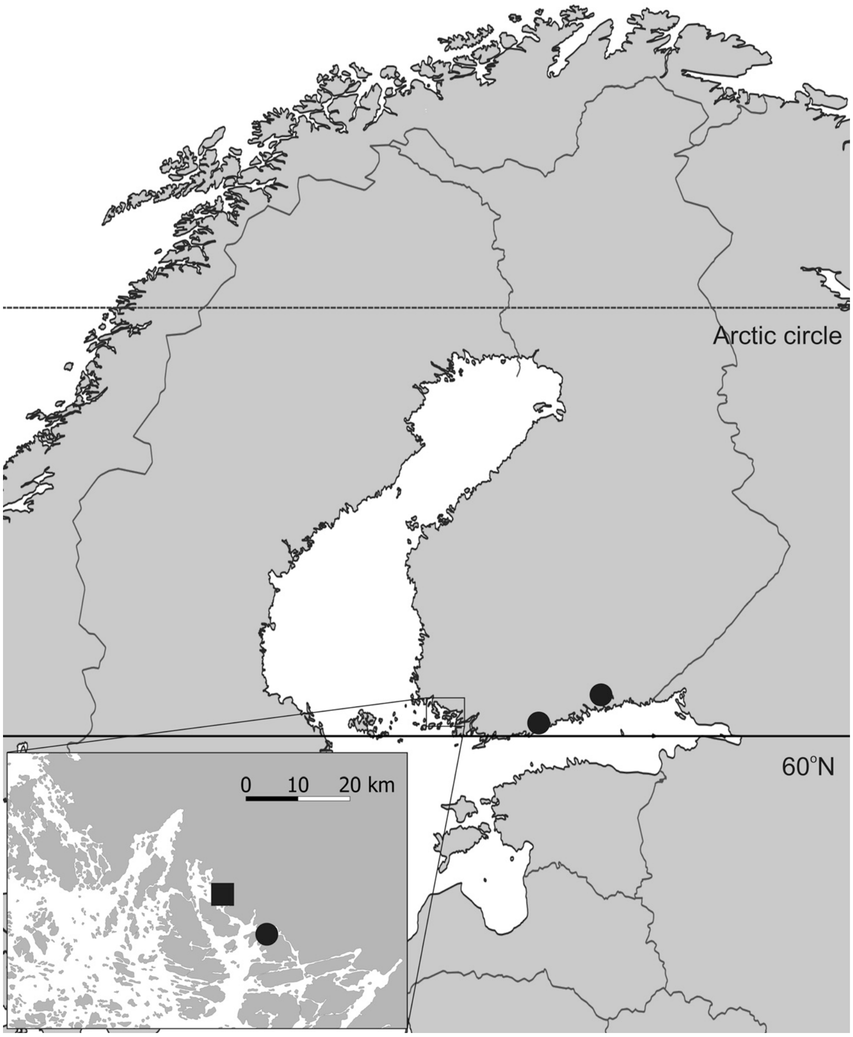

Figure 2: Known breeding colonies (round symbols) and overwintering site (square symbol) of *Pipistrellus nathusii* in Finland.

ambient temperature with observed *P. nathusii* activity was −2.9 °C on 20th of December 2018. At the other 15 sites, no *P. nathusii* were recorded later than 5th of November.

There is an increasing number of records of hibernating individuals to the east of earlier records, mainly from Poland, Slovenia, Slovakia and Hungary (Benda and Hotový 2004; Nusová et al. 2019; Sachanowicz and Ciechanowski 2006; Sachanowicz et al. 2019). Our record is the northernmost so far. The previous northernmost record to our knowledge was from Riga, Latvia, (16.01.2014), where an individual was found hibernating in a crevice between a window frame and concrete wall (authors' own data). Sachanowicz et al. (2019) stated that *P. nathusii* might be utilizing urban heat islands to extend their overwintering range towards North-Eastern Europe. As a result, the breeding and overwintering areas of *P. nathusii* are now overlapping in Central Europe (Sachanowicz et al. 2019). Our observations in Finland are consistent with such overlapping as, in the summer of 2017, we captured two *P. nathusii* weanlings in Turku, approximately 10 km from Härmälä cleft, indicating that the species is also breeding in the area.

While climate change may lead to loss in biodiversity especially in Southern Europe, many studies predict that species richness in Northern Europe and Scandinavia will increase (Levinsky et al. 2007; Rebelo et al. 2010). According to Mikkonen et al. (2015), the mean annual temperatures in Finland have risen 2.3 ± 0.4 °C from the mid-nineteenth century. The highest increases have taken place over the winter months, most notably in December when the monthly mean temperature has risen 4.8 °C. The spring months have also warmed more than the annual average. Until recently, *P. nathusii* has been considered a vagrant species in Finland during migration periods in late May and late August- early October (Ijäs et al. 2017; Rydell et al. 2014). The current range of the species in Finland covers the coastal areas in Southern and South-Western Finland, with observations as north as 64°15′N (Tidenberg et al. 2019). The first breeding colony was found in Southern

Finland in 2006 (Hagner-Wahlsten and Kyheröinen 2008). Since then, records of *P. nathusii* have become more frequent outside the migration period and more breeding colonies have been discovered (Hagner-Wahlsten and Karlsson 2009, Eeva-Maria Tidenberg, personal communication, authors' own data). However, until now, the species has never been recorded in Finland during the hibernation period (Figure 2). Haarsma et al. (2019) reported that *Myotis dasycneme* males have altered their overwintering areas, suggesting that hibernating closer to breeding areas extend their mating season while saving energy needed for migration. We propose that the recent findings on the range expansion of *P. nathusii* may indicate that the migratory behavior of the species could be shifting in a similar way and that the sedentary populations of *P. nathusii* may be expanding towards the North.

Our finding indicates that acoustic surveillance of hibernation sites can yield valuable information on elusive bat species. Winter activity of bats has also been studied using acoustic monitoring in similar climatic conditions in North America, revealing unexpected levels of activity at low temperatures and new information about the ecology of several species (Lemen et al. 2017). In Alberta, Canada, bats were active even when temperatures were as low as −8 °C (Lausen and Barclay 2006) and −10.4 °C (Klüg-Baerwald et al. 2016). Acoustic monitoring during the hibernation period can also give insight to sickness behavior demonstrated by bats as a result of white-nose syndrome (WNS) (Bernard and McCracken 2017; Carr et al. 2014). Therefore, acoustic monitoring can be used as a surveillance tool for WNS (Schwab and Mabee 2014).

It is likely that recent advancements in technology used for acoustic surveillance as well as an increase in the number of bat workers has contributed to the elevated number of *P. nathusii* records in Finland. However, we suggest that these factors cannot explain the increased occurrence of the species, as observations have also increased on sites where monitoring has been continuous for more than a decade (authors' own data). Bat species previously known to overwinter above 60°N in Fennoscandia include *Eptesicus nilssonii*, *Myotis daubentonii*, *Myotis brandtii*, *Myotis mystacinus*, *M. dasycneme*, *Myotis nattereri* and *Plecotus auritus* (Siivonen and Wermundsen 2003; Wermundsen and Siivonen 2010). Our results suggest that *P. nathusii* has now joined these seven species.

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