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Contributions on the southern distribution of *Vespertilio murinus* Linnaeus, 1758 (Chiroptera: Vespertilionidae) from Türkiye

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Abstract: *Vespertilio murinus* Linnaeus, 1758, has a wide distribution from France to Japan, and from Iran in the south to Scandinavia and Russia in the north. The only records of the parti-coloured bat, *Vespertilio murinus* known from Turkey so far were based on subfossils, remains from owl pellets, and ultrasound recordings. We present the first records of live individuals from two Turkish provinces, Ardahan and Bayburt. Additionally, based on echolocation call records, its known distribution in the Anatolian Peninsula was proved to be wider. The global distribution of the species has been mapped by using ecological niche modelling. The results revealed that its distribution is highly influenced by precipitation dynamics. Although no cases of domestic cat predation on bats have previously been documented in Turkey, this paper also provides the first case study of *V. murinus* predated by a domestic cat in Ardahan, in November 2003.

Key words: Echolocation, habitat, hunting, niche modelling, parti-coloured bat, range

1. Introduction

Vespertilio murinus Linnaeus, 1758 (the parti-coloured bat) has a wide distribution in the Palaearctic region (Rydell and Baagøe, 1994). The westernmost records were given by Pastor (1859) from Northern Spain, and by Galán (1997) from San Sebastian, Basque Country. However, these records were thought to be mistaken for *Myotis myotis* (Alberdi, 2012). As a result, the westernmost record of the species was updated to be from central France and the Pyrenees (Alberdi, 2012). In the Far East, the earlier records from Japan (Satō and Maeda, 2003) raised a concern due to the possibility of being mistaken for *Vespertilio sinensis*, but the species was later confirmed to be *V. murinus* based on mtDNA and morphological data (Kawai et al., 2010, 2015). In the south, the species has been recorded from Iran (DeBlase, 1980) and UAE (Monadjem et al., 2016), the southern Scandinavia, across southern Russia, the Caucasus, the Ussuri region of eastern Siberia, Mongolia, northern China, and the Korean peninsula (DeBlase, 1980; Baagøe, 2001; Simmons, 2005; Wilson and Mittermeier, 2019).

The species was also recorded from Turkey, although these records were scattered and unconfirmed. The presence of *V. murinus* in Turkey was first suggested by Bobrinskii et al. (1965) from north-eastern Anatolia (possibly Kars and Ağrı) without mentioning an exact locality (cf. Osborn 1963, Çağlar 1969). After a long interval, Obuch (1994) reported one individual based on the remains found inside the pellets of *Strix aluco* Linnaeus, 1758 (Strigiformes: Strigidae) from Karadut Cave (Adıyaman) in 1992. Benda and Horáček (1998) found a subfossil specimen from Buzluk Cave (Elazığ) in 1993, and they also recorded the calls of two individuals around Abant Lake (Bolu). However, there was no record based on an actual, entire specimen of this species from Turkey.

In this study, we document the presence of *V. murinus* in Turkey based on concrete evidence in the form of actual specimens for the first time, aside from skeletal remains, owl pellets, and call recordings. We also provided call recordings from new locations, and reapplied the global species distribution model with the addition of new *V.*

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murinus records from Turkey. Lastly, we report a domestic cat predation on the species for the first time from Turkey.

2. Material and methods

In order to obtain additional records on the distribution of *V. murinus*, we conducted field studies in several locations in Turkey. Our studies consisted of cave observations and mist-net studies that started in 1991, and echolocation call recordings between 2016 and 2020.

The species was determined in sound recordings received using the Pettersson D500 X sound recorder. Echolocation calls were analysed in detail by using the BatExplorer 2.1 and BatSound 4.0 software packages. In the analysis, five parameters were measured for each call: F_{\max} as the starting frequency at the onset of the call; F_{peak} as the peak frequency, or the frequency containing the most energy; F_{\min} as the final frequency measured at the end of the call; pulse duration, or the call duration; and the interpulse interval, from the onset of one call to the onset of the next call.

2.1. Species distribution modelling

In order to understand the present distribution of *V. murinus*, we benefited from the Ecological Niche Modelling approach. We conducted the modelling in area stretching between the longitudes of 32.450 and 76.769 East and the latitudes of 6.99 South and 53.546 North, covering the Western Palearctic realm. Occurrence data records for *V. murinus* were gathered from two main sources: i) our own field surveys, as mentioned above, and ii) the literature (Bobrinskii et al., 1965; Topál, 1976; Baagøe, 1986, 2001; Blant and Jaberg, 1995; Benda and Horáček, 1998; Hanák et al., 2001; Il'in et al., 2002; Benda et al., 2003, 2012; Pavlinić and Tvrtković, 2003; Zgamajster, 2003; Bukhnikashvili et al., 2004; Pervushina and Pervushin, 2005; Rakhmatulina, 2005; Murariu, 2007; Ivanitsky, 2010, 2018; Toffoli and Culasso, 2011; van Toor et al., 2011; Alberdi et al., 2012; Godlevska, 2013; Presetnik et al., 2013, 2014; Micevski et al., 2014; Dondini and Vergari, 2015; Monadjem et al., 2016; Presetnik, 2015; Bačkor, 2016; Smirnov et al., 2016, 2018, 2019; Vlaschenko et al., 2016; Orlova et al., 2017; Shpak, 2017; Belkin et al., 2019; Rachwald et al., 2019; GBIF, 2020; NBN, 2020; NDF, 2020). We gathered a total of 822 occurrence data records, all of which are given in a complete list provided in online resource 1. In order to avoid bias on the distribution of *V. murinus*, and the possibility of mistaking the record of the same individual in two close locations as two different individuals, we rarefied the occurrence data records spatially with removing one of localities within each 50 km by using SDM Toolbox 2.0 (Brown, 2014). We downloaded nineteen spatial climatic variables from the WorldClim database version 1.4 (Hijmans et al., 2005) having a resolution of 2.5 arcminutes. In addition to these standard variables, we added six extra

climatic variables that might have an influence on the species distribution (Gavashelishvili and Tarkhnishvili, 2016). All these variables are given in online resource 2. Lastly, we clipped the layers by using ArcGIS 10.6.1 for the study area, and calculated the Pearson correlation coefficient between parameters in ENM Tools 1.3, by excluding correlated variables with more than 0.75 from the analysis to eliminate adverse consequences from other bioclimatic variables (Warren et al., 2010) (online resource 3).

In order to predict the distribution of *V. murinus*, we constructed SDM combined with occurrence data and bioclimatic layers by using MaxEnt 3.4.1 (Phillips et al., 2006). MaxEnt algorithm generates the probability of presence of the studied species that varies from 0 to 1 (Kozak et al., 2008). Seven thousand five hundred background points were created for test gain performance. Moreover, we ran ten crossvalidated replicates for the studied species. To test the bioclimatic variable importance, we applied the jack-knife test (Elith et al., 2006). For the efficiency of the model, it is important to determine the values of the area under the curve (AUC): (< 0.5: strongly recommended not to run, > 0.6: not bad to run, > 0.7: relatively good, > 0.8: good, > 0.9: very good, = 1: excellent) (Raes and ter Steege, 2007; Gallien et al., 2012).

3. Results

3.1. External features and measurements

As the name implies, the parti-coloured bat, *Vespertilio murinus*, has a striking contrast between the dorsal and ventral coloration. Although much bulkier, its coloration resembles to that of Savi's Pipistrelle, *Hypsugo savii* (Bonaparte, 1837). The broad ears are short and roundish. The wings are narrow, and the ears and face are also black. The dorsal side is reddish dark-brown, with silver-white-frosted hair. The ventral side is grey on the belly part and exhibits white colouring close to the wing base (Figure 1). According to the external morphometric measurements of the adult female (ZDNU 2003/141) taken from Göle (Ardahan), the total length is 110 mm, tail length is 45 mm, hindfoot length is 10 mm, ear length is 16 mm, forearm length is 50 mm, tragus length is 3.5 mm, and the weight is 10 g.

3.2. Echolocation calls

The sounds belong to bats flying in open areas at an average height of 7 to 10 m, and are of FM/CF types. We analysed more than 5000 echolocation calls. According to the analyses, the average values for echolocation calls of *Vespertilio murinus* are as follows: maximum frequency (F_{\max}): 41.5 kHz, minimum frequency (F_{\min}): 22.8 kHz, peak frequency (F_{peak}): 24.8 kHz, distances between calls: 216.8 ms, and call duration: 11.7 ms (Figures 2A and 2B). The average, minimum, and maximum values for these parameters are given in Table 1.



Figure 1. A subadult male *Vespertilio murinus* from Bayburt Province (photograph: Abdurrahman Sefali).

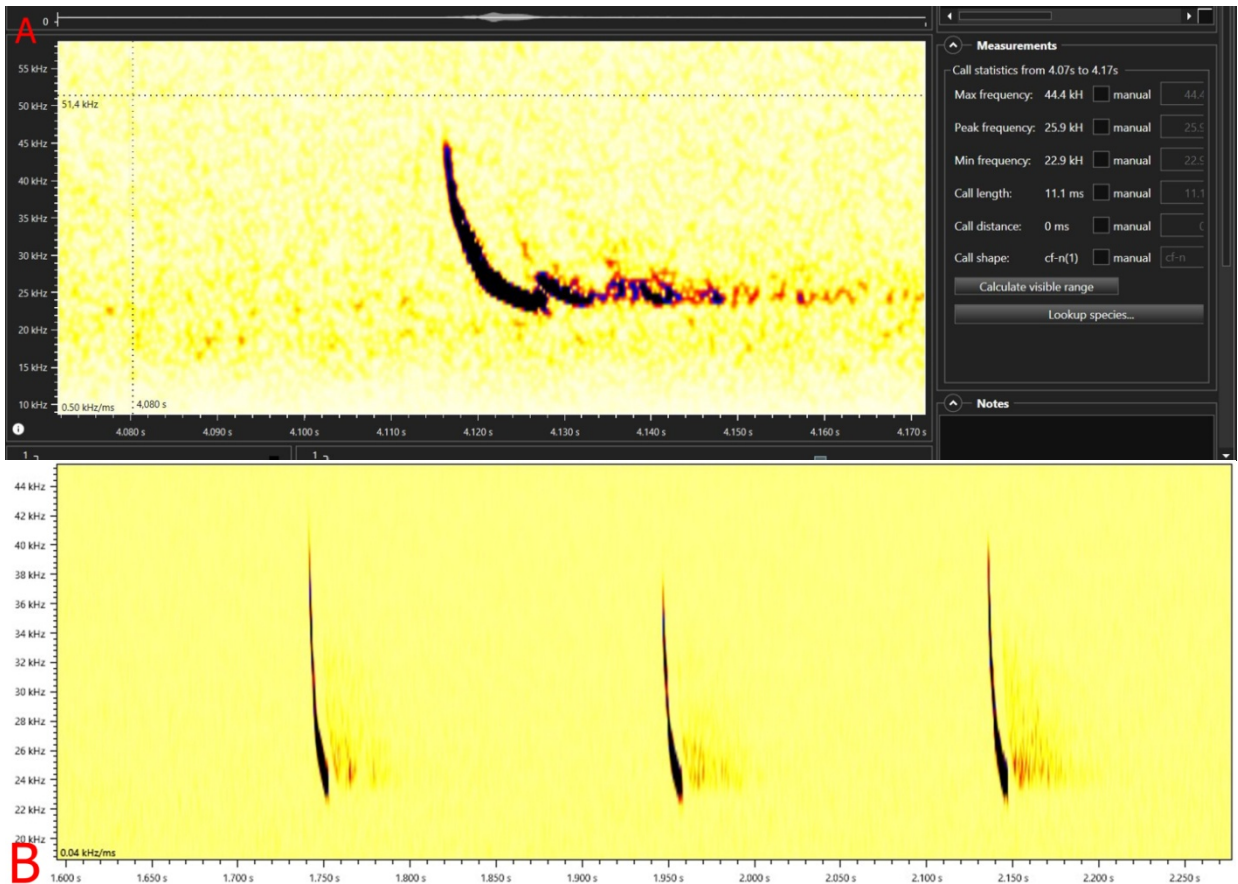


Figure 2. Echolocation calls of *Vespertilio murinus* on A) sonogram and B) spectrogram from Üçpınar on 25.05.2020.

3.3. Distribution

Turkey is located on the southern edge of the distribution range of *Vespertilio murinus*, which is one of the least documented bat species in the country. The evidence

of occurrence has largely been based on remains in owl pellets, skeletal remains in subfossils, and recordings of echolocation calls. During this study, we obtained the first actual specimens from Turkey, and prepared an

updated distribution map based on both new records and the already existing literature records from this country (Figure 3). With respect to the echolocation calls recorded from Üçpınar (Çanakkale) and Ahlat (Bitlis), we revealed that the species has broader distribution area in Turkey than previously considered.

Before 2003, no researchers managed to capture a live individual of *Vespertilio murinus* in Turkey. We found one bat predated by a domestic cat in Ardahan in the autumn of 2003. This specimen was an adult female, which was still in good shape despite the predation and we prepared the specimen as a standard museum specimen to be preserved in the mammals' collection at Niğde University (ZDNU 2003/141). We caught the other bat in a building in the autumn of 2018, in Bayburt. This was a subadult male and we released it after taking photographs.

New records: – **Ardahan:** Göle, Büyükkaltınbulak Village [1], 01.XI.2003: 1 Ad. ♀ (ZDNU 2003/141). – **Bayburt:** Campus of Bayburt University [2], 23.X.2018: 1 Sad. ♂ (released). – **Bitlis:** Ahlat [3], 24.VIII.2018: det.

1 ind. – **Çanakkale:** Lapseki, Üçpınar [4], 20 - 25.V.2020: det. 2 ind.

Literature records: – **Adıyaman:** Kâhta, Karadut (caves) [5], 1300 m a.s.l., 07.VI.1992: 1 ind. ex *Strix aluco* pellets (Obuch 1994); – **Bolu:** Abant Lake [6], 24.VI.1994: det. 1 ind., 26.VI.1994: det. 1 ind. (Benda and Horáček, 1998); – **Elazığ:** Harput, Buzluk Cave [7], 27.X.1993: subfossil remains of 1 ind. (Benda and Horáček, 1998) (Figure 3).

3.4. Performance and analysis of species distribution predictions

The estimated distribution area for the studied species is given in Figure 4. We constructed this area with the following variables: Bio 2 (mean diurnal range), Bio 3 (isothermality), Bio 5 (maximum temperature in the warmest month), Bio 7 (temperature annual range), Bio 8 (mean temperature of the wettest quarter), Bio13 (precipitation of wettest month), Bio 15 (precipitation seasonality), Bio 17 (precipitation of the driest quarter), Bio

Table 1. The maximum, minimum, and peak frequencies (kHz); and pulse interval and duration (ms) parameters of echolocation calls of *Vespertilio murinus*.

F_{max}	F_{max} (mean)	F_{min}	F_{min} (mean)	F_{peak}	F_{peak} (mean)	pulse intervals	pulse duration
41.5 (44.4– 38.8) ± 1.87	40.0 (42.9–35.6) ± 3.13	22.8 (24.2–21.6) ± 0.75	23.1 (24.2–22.5) ± 0.78	24.8 (25.9–23.4) ± 0.85	24.9 (25.9–23.9) ± 0.85	216.8 (249–184) ± 23.73	11.7 (14.5–9.7) ± 1.42



Figure 3. Records of *Vespertilio murinus* from Turkey (⊙ – sampling localities [1–2], Δ – echolocation call records [3–4]; ⊙ – literature data [5–7] after Obuch, 1994; Benda and Horáček, 1998). The striped parts show the possible distribution areas of *V. murinus* based on echolocation calls. The orange regions in the Balkans and the Caucasus show the distribution of this species according to IUCN (2016).

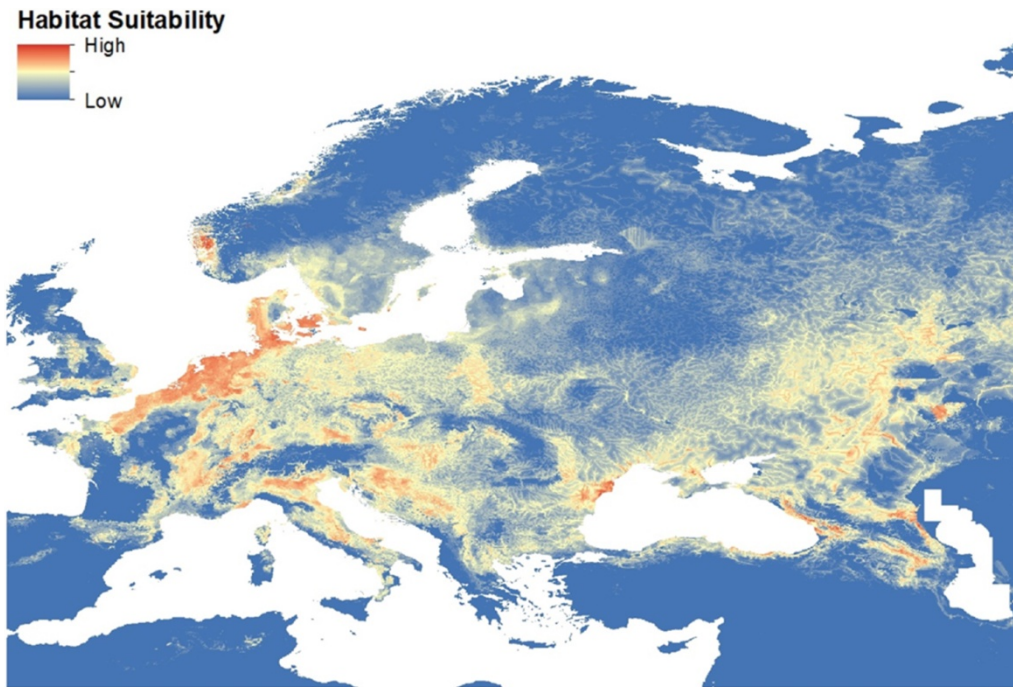


Figure 4. Species distribution model of *Vespertilio murinus* in the Western Palearctic realm. Warmer colours refer to the high suitability level.

19 (precipitation of the coldest quarter), *r_dist* (distance from the river), *s_max* (maximum snowfall in the coldest quarter). Contributions of the variables to this predicted distribution are given in Table 2. We calculated the AUC value as 0.896 ± 0.011 (mean \pm SD); therefore, this value is good for interpreting the outcomes of our analyses.

4. Discussion

The advertisement calls of *V. murinus* are unique among the European bats and are easy to recognise (Ahlén and Baagøe, 1999). However, a variety of echolocation calls are known in the call types FM, CF, and QCF. The call types and their details are described in many publications (Ahlén, 1981, 1990; Schober and Grimmberger, 1997; Baagøe, 2001; Schaub and Schnitzler, 2007; Dietz et al., 2016). The parameters we used for echolocation call analysis are similar to the values given in these publications. However, some of the recordings we received from other locations such as Antalya, Denizli, Kars, and Muş, were excluded from the study because the sound quality was not good, and the preliminary analysis we made with BatExplorer 2.1 and BatSound showed a similarity of around 60%–70%. The presence of the parti-coloured bat in Bitlis and Çanakkale was determined based on call recordings of sufficient quality (90%–99%) taken between 2018 and 2020. Thus, these provided us two additional new locality records. Because the species uses QCF calls with a frequency of minimum energy of 22–27 kHz, pulses

Table 2. Contribution of bioclimatic variables to model prediction.

Bioclimatic variable	Percentage contribution
Bio 17	35.2
Bio 15	24.6
Bio 7	14
Bio 3	10.2
Bio 5	4.3
Bio 2	3.3
Bio 13	2.3
Bio 8	2.1
Bio 19	1.7
<i>r_dist</i>	1.1
wet	0.9
<i>s_max</i>	0.3

generally have a first FM component, followed by a CF cue containing the peak frequency. This makes them difficult to identify, since the echolocation calls of *V. murinus* can be easily confused with those of *Nyctalus leisleri* (Kuhl, 1817), *Eptesicus serotinus* (Schreber, 1774) (shorter pulse interval), and *Eptesicus nilssonii* (Keyserling et Blasius, 1839) (higher end frequency). However, territorial calls are

very distinctive, especially during the mating season. The analysis of echolocation calls alone may not be enough for species identification, without visual observations (Dietz et al., 2016; Wilson and Mittermeier, 2019).

V. murinus has been known to occur only in seven localities in Turkey. Additionally, Bobrinski et al. (1965) gave a map for the distribution of this species in the former USSR and neighbouring areas, without providing exact locations (cf. Osborn, 1963; Çağlar, 1969). When this map is overlapped with a Google-Earth image of the current geography, two of the symbols on it are likely to remain in the Turkish territory. Although the locations are not exact, considering that the researchers mainly concentrated around Kars and Mount Ağrı while collecting data 80–100 years ago, we may assume that they might have obtained samples at these two locations or at least, predicted the presence of the species around these areas with regard to its possible distribution.

Ardahan and Bayburt, the provinces where we found the two *V. murinus* individuals, are both located at high altitudes (1550–2070 m a.s.l.). The fact that the period when we found the bats, October and November, undoubtedly coincides with the winter in these regions suggests that the bats were in their migration period and that these regions are likely their wintering grounds. Although there is no information on the migration of *V. murinus* in Turkey, it is known as a migratory species (Schober and Grimmberger, 1997).

The distribution of species is affected by several biotic and abiotic factors (Peterson, 2011). Ecological niche modelling, also known as species distribution modelling, is a practical and beneficial tool to evaluate the potential distribution of a species by using bioclimatic parameters. Our results indicated that the distribution of *V. murinus* is highly affected by the precipitation dynamics (64.5% contribution rate of the entire data). This result is compatible with the bat's migratory behaviour (Dietz et al., 2016). On the other hand, we may claim that in addition to Caucasus and Balkans, Northern Europe in particular provides suitable habitats for *V. murinus*. The Alpine mountainous vegetation regime may also provide suitable habitats in the northern part of Italy. Vegetation dynamics in this area play a similar role to that of the Scandinavia (Hickler et al., 2012). Finally, the Black Sea region of the Anatolian Peninsula has suitable habitats for this species, and each of the localities for the Anatolian records are discussed in depth below.

All records of *V. murinus* in Turkey were obtained from the southern margin of its distribution range in the Eastern Mediterranean. According to Benda and Horáček (1998), Strelkov (1997a, 1997b) supposed that the Mediterranean Region was not among the breeding grounds of *V. murinus* (i.e. a region used by nursery colonies), but was only used for seasonal migrations. On the other hand, frequent

occurrences of this species in winter in Scandinavia and parts of continental Europe, such as the Bohemian forest, proves *V. murinus* to be sedentary and that some populations may be nonmigratory, although the East European populations are migratory (Rydell and Baagøe, 1994; Dietz et al., 2016).

The longest migration distances recorded so far are 1440 km from Estonia to Austria, and 1787 km from Rybachy (Russia) to France. Migration takes place in the autumn, mainly towards southwest, also towards southeast from Belarus and Russia (Dietz et al., 2016).

Habitat: The first bat discussed above was found in Büyükaltınbulak. Both this village and Göle town have an elevation of more than 2000 m a.s.l. The second individual was found in October 2018, in Bayburt, at an altitude of 1550 m. On a cold autumn day, a subadult male entered one of the faculty buildings of Bayburt University. The city of Bayburt is located just south of the Eastern Black Sea Mountains, while most of its central district lies within the steppe environment of the Central Anatolia region, which also includes the Erzurum-Kars Plateau. Here, tree groups such as poplars (*Populus* spp.) are mostly seen in valleys and around streams. The other locality, Göle, is a high plateau with montane meadows as the predominant habitat type. However, Scots pine (*Pinus sylvestris* L.) forests intensely cover the areas outside the meadow in the region.

One of the places where *V. murinus* was recorded via sound analysis, the town Ahlat, is similar to Bayburt in terms of its vegetation structure and elevation of about 1650 m. The main difference is that Bayburt is located in the Kelkit River Valley, which is a tributary of the Yeşilirmak River in the Black Sea hinterland, while Ahlat is located between the volcanos Nemrut and Süphan in the hinterland of Lake Van, Turkey's largest lake.

The place where we recorded the calls in Çanakkale is the Üçpınar Wind Power Plant (WPP) project application area. It consists of a mountainous topography that stretches in the east-west direction at altitudes of 500–900 m, rising from the valleys located in the north and south, and integrated with the summits in which the main rock surfaced. The northern landscape includes slopes located at a distance of 15 km from the Çanakkale Strait, and the vegetation consisting of maquis at the sea level transforms into deciduous and coniferous forests after about 300 m, retaining the humid conditions of the seaside. This vegetation continues up to 500 m, where it turns into a Turkish pine (*Pinus brutia* Tenore) forest. The forest oak (*Quercus* spp.) becomes dominant at altitudes of 600 m and above, along with some old oak trees. As the southern slopes receive less humidity, the forest structure there consists of the black pine (*Pinus nigra* J. F. Arnold). During the WPP installation, open areas were created when the forest vegetation was cleared at the locations for turbines,

and the bats used these open areas for feeding flights in the forest. In addition, there are natural openings in the forest and less covered areas along the field. Old oak trees and pine trees, which can be daily roost spots for bats, are located in and around the area.

In central Europe, *V. murinus* is most commonly seen in forested upland areas at altitudes of around 1000 m. Individuals have been found at 1920 m in the Alps, at 2000 m in the Caucasus Mountains during hibernation, and at 3050 m in Gilgit in the western Himalayas (Rydell and Baagøe, 1994). Wilson and Mittermeier (2019) reported records of *V. murinus* from the sea level up to 3400 m. Therefore, the detection of *V. murinus* at high altitudes in Turkey is concordant with the literature.

Predation: We surveyed Göle and its surrounding villages, including Büyükaltınbulak in 2002 and 2003. Even though one of the authors (F. T.) worked as a teacher in the village for three years, our extensive detection efforts yielded no evidence of bat presence through surveys in suitable bat roosting spots or the analysis of collected owl pellets. We concluded that the absence of bats in the region was due to high altitude, since both Büyükaltınbulak village and Göle town have an elevation of above 2000 m a.s.l. When we asked the local people if they had seen any bats, it was evident that many of them did not know how to distinguish bats, since they often took us to the nests of barn swallows (*Hirundo rustica* L., 1758). We encountered a domestic cat with a live bat in its mouth in November 2003. The cat had bitten the bat on its right wing, with the rest of the bat's body dangling from its mouth. Frightened by this sudden encounter, the cat dropped the bat and walked away. The bat was a *Vespertilio murinus*.

We observed domestic cats hunting mammals, birds, and reptiles for dozens of times during our field studies in Türkiye. Personal communication with the local people also confirmed such predations were common occurrences. However, so far, no publications have reported domestic cat predation on bat species in nature in Turkey. Thus, we present here the first case report of a domestic cat predation on a bat from Turkey. In one of the few publications that supported us, Baagøe (2001) stated that *V. murinus* was occasionally deliberately killed by humans or hunted by cats and dogs, since it is a house bat.

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5. Conclusion

V. murinus is a species that is distributed along the Western Palearctic realm. Although this bat is known to have a migratory behaviour for regulating its biological dynamics, we did not have any data for understanding its distribution patterns so far. On the other hand, our study has confirmed the presence of *V. murinus* in Anatolia via echolocation records and a live specimen under predation risk. Therefore, it is recommended that upcoming studies based on local presence data should not only display the conflict between wild and domestic animals, but also provide new perspectives to predict the species distribution under different scenarios, with regard to the global climate change.

Compliance with ethical standards

Ethical approval was not needed for this study, as the study design did not include laboratory or field-based experiments on animals.

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Conflict of interest

The authors declare they have no conflict of interest.

Contribution of authors

AK initiated the study; AK, FT, AS, ŞÖ collected field records from the Anatolian Peninsula; AK, ŞÖ and ŞB analysed echolocation outputs; MKŞ performed species distribution modelling; AK and MKŞ wrote the manuscript; and all authors provided substantial input to the final version of the manuscript.

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Supplementary materials

Online resource 1. Raw occurrence records of *Vespertilio murinus* evaluated in this study. Coordinates are displayed in decimal degree format.

Online resource 2. Bioclimatic variables used in this study for developing species distribution models.

Online resource 3. Pearson correlation table of bioclimatic variables for *V. murinus*.