

WINTER HABITAT USE AND NOCTURNAL ACTIVITY OF THE KUHLL'S PIPISTRELLE (*PIPISTRELLUS KUHLII*) AND THE EUROPEAN FREE-TAILED BAT (*TADARIDA TENIOTIS*) IN A MEDITERRANEAN REGION (ALGERIA)

Karima Kaci^{a*}, Mourad Ahmim^a, Ridha Dalhoumi^b

^aLaboratoire de Recherche Ecologie et Environnement (LREE), Faculté des Sciences de la Nature et de la Vie, Université de Bejaia, 06000, Algérie;

^aLaboratoire de Recherche Ecologie et Environnement (LREE), Faculté des Sciences de la Nature et de la Vie, Université de Bejaia, 06000, Algérie;

^bLaboratoire de Bio surveillance de l'Environnement, Faculté des Sciences de Bizerte 7021 Zarzouna Bizerte, Tunisie

*Corresponding author. Email: Karima.kaci@univ-bejaia.dz

 Karima Kaci <https://orcid.org/0009-0008-6421-1014>

Kaci, K., Ahmim, M., Dalhoumi, R. 2024. Winter habitat use and nocturnal activity of the Kuhl's pipistrelle (*Pipistrellus kuhlii*) and the European free-tailed bat (*Tadarida teniotis*) in a Mediterranean region (Algeria). *Zoology and Ecology* 34(2), 169–179. <https://doi.org/10.35513/21658005.2024.2.10>

Article history

Received: 18 July 2024;
accepted: 26 November 2024

Keywords:

Chiroptera; bats;
echolocation; activity
patterns; winter activity;
acoustic survey

Abstract. In Algeria, data on bats are scarce, especially regarding their winter activity. In order to increase knowledge of this fauna, we studied the nocturnal behaviour as well as habitat use during the winter season 2020–2021 by two bat species, *Pipistrellus kuhlii* and *Tadarida teniotis*, using an acoustic survey in five different habitats in an area located in northern Algeria, southern Bejaia, part of the Bibans mountain range. There was a significant difference in activity levels between different habitat types used by the two species, and average passage rates varied significantly according to the time of night. For *P. kuhlii*, the ravine recorded the highest average number of visits per night, while the olive grove and the entrance to the Aleppo pine forest recorded the lowest. For *T. teniotis*, the highest average number of visits per night was recorded in the olive grove and ravine, and the lowest in the Aleppo pine forest and Aleppo pine forest entrance. This study confirms the activity of the two species during winter with distinct differences in temporal activity patterns between species, sites and over time. The decrease in temperature was accompanied by a decrease in activity of *T. teniotis* in the ravine. It was the same for *P. kuhlii* at the same site, but the decrease in activity was not as significant as for *T. teniotis*. Despite the decrease in temperature at the olive grove site, *T. teniotis* activity did not decrease. It can therefore be concluded that the activity pattern does not depend on temperature any more than it does on site.

INTRODUCTION

There are 27 bat species in Algeria. All are insectivorous and belong to seven families (Ahmim 2017, 2018, 2024). Most of them are considered vulnerable in many countries of the world and are listed on the IUCN Red List of Threatened Species (Ahmim 2018). Studies on bats in this region are limited. Since 1991, bat fauna studies have been conducted, and the only notable bioacoustic-based study was conducted in Algeria's south-west region, with the greater mouse-tailed bat (*Rhinopoma microphyllum* Brunnich, 1782) identified as a new species for that country (Loumassine et al. 2017). Likewise, the western barbastelle (*Barbastella barbastellus* Schreber, 1774), was recorded for the first time in Algeria – in a large forest of Akfadou, on the basis of several sound sequences (Ahmim 2024).

In order to protect these small mammals and better

conserve them and their habitats, studies like the ones above need to be extended to cover all regions of the country and all species present in Algeria. This will help to establish a national database for future conservation or management strategies, should a national policy be envisaged in the medium or long term. Furthermore, it will offer unique insights into the chiropteran fauna of the Mediterranean area, which is classified as one of the 36 global biodiversity hotspots, comprising some of the biologically richest areas on the planet and also some of the most threatened ones (Mediterranean-Basin-Biodiversity Hotspot 2017). Studies on bats in Algeria are scarce, especially on their winter activity, with the exception of that of Gaisler (1983), who reported nocturnal activity of bats in winter, although it was interrupted for several days. In fact, the author reported that bat activity ceased on nights with low temperatures and/or heavy rainfall, but always recovered after a few days.

Evidence of bat activity during winter was confirmed (Gaisler 1983–1984), and even individuals of three species were captured: *Pipistrellus kuhlii* (Kuhl, 1817), *Plecotus gaisleri* (Benda, Kiefer, Hanák & Veith, 2004) and *Pipistrellus pipistrellus* (Schreber, 1774). The latter one was caught at a temperature of 6.5°C measured at 1.8 m from the ground (Gaisler 1983–1984). The conservation status of *P. kuhlii* and *T. teniotis* is of least concern for Algeria (Ahmim 2019).

Bat activity patterns are closely linked to climatic conditions, particularly temperatures, which strongly influence their daily torpor and hibernation and can therefore affect individual survival and reproductive success (Stawski et al. 2014). Higher temperatures determine life style and behaviour, can save energy, reduce predator risk, give birth faster, and increase juvenile development (Neuweiler 2000). Climate is the factor that best explains the range expansion (approximately 394%) of *P. kuhlii* recorded over the last 40 years (Ancillotto et al. 2016). Indeed, despite its sedentary behaviour (Dietz et al. 2009), *P. kuhlii* has expanded its range north-eastward in recent years, colonizing regions of central and eastern Europe in the last three decades (Sachanowicz et al. 2006), and in most cases the first records of single individuals were followed by observations of reproductive bats or maternity colonies, indicating successful colonisation of the new region (Ancillotto et al. 2016). *P. kuhlii* provides a unique opportunity to investigate the relative effects of climate change on species distributions, for example, under a climate change scenario. This typically Mediterranean species is expected to expand its range in response to increasing temperatures, as regions at higher latitudes would become suitable (Ancillotto et al. 2016).

In the case of *T. teniotis*, Marques et al. (2004) reported that there is no evidence that temperature or wind speed affects the duration of foraging trips, but they do return to the roost in stormy weather. Sharma et al. (2021) reported its possible movement aloft in the Himalayas of Nepal, and its activity has only been recorded between 2100 m and 2500 m during autumn, whereas it has been observed in both altitude zones (800–1200 m and 2100–2500 m) during winter which may confirm, with more intensive studies, the seasonal migration of this species. Furthermore, the difficulty in capturing molossid makes it challenging to study their spatial foraging behaviour. There is also a lack of basic knowledge required to manage *T. teniotis* foraging areas (Marques et al. 2004), and there are undoubtedly gaps in our knowledge of their habitat preferences and distribution (Cotterill and Happold 2013). It is still one of the lesser known species of bats in the European fauna (Marques et al. 2004).

Bat research efforts often focus on summer maternity colonies and winter hibernacula (Muthersbaugh et al. 2019),

leaving the immediate ecology of many species unknown on their hunting grounds, especially during the winter season. Non-invasive acoustic monitoring represents the optimal solution for monitoring bats while foraging, as well as understanding their feeding behaviour and habitat utilization during winter (Davy et al. 2007; Papadatou and Russo 2014). *T. teniotis* spend a short period (8 days) in the state of torpor during winter (Cotterill and Happold 2013). This species does not actually hibernate, but may exhibit short periods of lethargic inactivity (Colombo 2018). *T. teniotis* must indeed be considered a hibernating species as it undergoes torpor periods that typically last several days rather than occurring on a daily basis (Arlettaz et al. 2000). *P. kuhlii* has been reported to hibernate from November to March (Strelkov et al. 1985). In Morocco, the winter activity threshold appears to be below 5°C (Aulagnier et al. 2017). In Algeria and Tunisia, some individuals have been mist-netted in winter, either in the Mediterranean region or in the pre-Saharan region (Deleuil and Labbé 1955; Gaisler 1983–84; Gaisler and Kowalski 1986; Dalhoumi et al. 2015). Therefore, *P. kuhlii* does not enter a continuous, winter-long hibernation, but is active on and off throughout the winter (Dalhoumi et al. 2018). Ambient temperature has a significant effect on insect flight activity. The winter climate in the Mediterranean is known to be milder than in other parts of the range of these two species. We can therefore expect a difference in behaviour between the populations present in Algeria and those from other parts of their range, especially as Gaisler (1983) noted that bats in Algeria, unlike those in central Europe, are active during the winter months. Milder winters in Algeria may favour foraging during this season.

There is currently no information available regarding the spatial and temporal aspects of the foraging behaviour of *T. teniotis* or *P. kuhlii* in Algeria. It is vital for the conservation of bat species that we have an understanding of the patterns of habitat use and the factors influencing variability in bat activity levels (Molloy 1995; Racey and Entwistle 2003). To better understand the spatio-temporal patterns of these two species as they fly through the night in search of food in different habitats during the winter season, we used an ultrasonic detector at five sites in a Mediterranean area in the Bibans Mountains, Algeria, to compare their nocturnal winter activity. On the basis of our results, we provide an overview of the behaviour of these two species during winter nights.

MATERIALS AND METHODS

Study area

As a large country with contrasting relief, Algeria presents a diverse range of climates. The study area is located in northern Algeria, in the southern Bejaia region, within the Bibans mountain range. The Bibans

Table 1. Characteristics of five sites studied.

| Sites | GPS coordinates | Altitude (m) | Description | Distance from sites (m) |
|------------------------------------|--------------------|--------------|---|---|
| Aleppo pine forest (1) | 36.342925/4.431205 | 530 | Old Aleppo pine forest with trees up to 10 m | (6212.75 m from the 2 nd site) |
| Olive grove (2) | 36.319600/4.493500 | 798 | Old wild field of olive grove (open space) | (6212.75 m from the 1 st site) |
| Habitat near a street lamp (3) | 36.343907/4.425314 | 462 | Shrubs and bushes with a presence of a light source | (583.69 m from the 5 th site) |
| Ravine (4) | 36.356918/4.407153 | 325 | Ravine crossing houses (open space) | (2243.61 m from the 3 rd site) |
| Entrance to Aleppo pine forest (5) | 36.343389/4.430158 | 498 | Entrance to the forest with a managed non permanent water source and very recently regrown trees of Aleppo Pine | (147.04 m from the 1 st site) |

are composed of schistose and marly rocks (Troussset and Paskoff 1991). The Bibans massif is mainly a massive series of limestone and tawny dolomite (Audra et al. 2022), and its composition takes on the appearance of a karst relief where ravines, caves, crevasses, balconies, belvederes and inland rivers follow one another.

Five sites representative of the study area were chosen on the basis of their characteristics and their accessibility to study bat activity during the winter season. However, these sites were selected to represent the different geographical areas of the study region, i.e. relief, altitude, and dominant vegetation (Table 1). Due to its location in the north of Algeria, the climate in the region is Mediterranean with mild, rainy winters and hot, dry summers, with temperatures and precipitations for the study months (2020–2021): November: 16–21°C and 99 mm; December: 12–15°C and 312 mm; January: 11–15°C and 114 mm; February: 12–18°C and 108 mm.

Automatic bat detection

Data were collected by conducting acoustic bat surveys using a Wildcare EU Acoustic Elekon Batlogger M recorder (SKU 12675) from November 2020 to February 2021. We conducted observations on 20 nights at five sites across the study area. Each site was surveyed on four different nights over the course of the season. In order to record echolocation call sequences or bat passes, the bat detector was fixed to a fence post or tree at a height of approximately 1.5 metres above ground level. The detector was previously calibrated to the following instructions: Auto trigger max time, 5000 ms; Record, automatically. The sampling frequency was 312500 Hz, 16 bits/sample and 512 samples FFT (Fast Fourier Transformation). This was done to avoid triggering from low-frequency sounds. However, this does not affect the ability to trigger by all bat calls, including low-frequency calls (e.g., *T. teniotis*). Due to bat's normal circadian biorhythm, which is reflected in their winter activity at dusk, each nocturnal recording session was respected by a continuous sampling detection. This started before sunset and continued 30 min after

sunrise. Triggered recording was saved as WAV files. Bat activity was recorded for each night. A bat pass was defined as a single or several calls emitted by a single animal during a 5 second interval (Barataud 2012). The number of bat passes per hour per night provides a useful indicator of bat activity at a specific location or time, rather than offering a direct measure of the bat population size (Thomas 1988). Bat species were identified by analysing the calls using the Hanning window for spectrogram analysis in BatSound 3.3.1R software (Pettersen Elektronik AB). The confirmation of species was made by comparing the parameters of the variables with those described in Disca et al. (2014) and Ahmim et al. (2019). The calls of species were easily identified by the terminal frequency: 35.75 ± 1.88 (Disca et al. 2014), 37.96 ± 1.15 (Ahmim et al. 2019) for *P. kuhlii* and 13.3 ± 0.7 (Disca et al. 2014), 12.30 ± 1.02 (Ahmim et al. 2019) for *T. teniotis*, and maximum energy: 39.85 ± 1.57 (Disca et al. 2014), 38.71 ± 1.03 (Ahmim et al. 2019) for *P. kuhlii* and 14.4 ± 0.8 (Disca et al. 2014), 12.83 ± 1.14 (Ahmim et al. 2019) for *T. teniotis*.

Bat activity sampling

Bat activity was recorded in five different habitats. The first one is a forest of Aleppo pine (*Pinus halepensis* Mill, 1768). The second is an olive grove (*Olea europea* Linné, 1753). The third one is a habitat mainly composed of shrubs and bushes with the presence of a source of light (a street lamp). The fourth one is a ravine, and the fifth one is the entrance to the Aleppo pine forest, which differs from the interior of the Aleppo pine forest in that it has a managed non-permanent water source and very recently regrown trees (Table 2). It should be noted that both habitats, ravine and olive grove, are open spaces. Sampling was not done on rainy nights, and recordings started before sunset and continued 30 min after sunrise for all nights in all habitats, with no difference in the length of the recording period from one night to the next. The temperature was noted for each night. The total number of bat passes (BP) or passes and terminal buzzes, i.e. sounds associated with feeding (FB), which

Table 2. The parameters of five sites studied.

| Sites | Dates | Temperature (°C) | | | <i>P. kuhlii</i> | | <i>T. teniotis</i> | |
|--------------------------------|------------|------------------|-----|------|------------------|----|--------------------|----|
| | | Min | Max | Mean | BP | FB | BP | FB |
| Aleppo pine forest | 11/11/2020 | 12 | 20 | 18.6 | 28 | 0 | 20 | 0 |
| | 10/12/2020 | 10 | 11 | 10.4 | 16 | 0 | 12 | 0 |
| | 24/01/2021 | 12 | 15 | 13.6 | 6 | 0 | 1 | 0 |
| | 26/02/2021 | 11 | 16 | 14.7 | 30 | 0 | 5 | 0 |
| Olive grove | 13/11/2020 | 11 | 22 | 13.9 | 2 | 0 | 43 | 1 |
| | 08/12/2020 | 11 | 16 | 13.2 | 1 | 0 | 156 | 0 |
| | 20/01/2021 | 8 | 15 | 10.8 | 2 | 0 | 443 | 20 |
| | 04/02/2021 | 13 | 20 | 16.7 | 11 | 0 | 470 | 0 |
| Near a street lamp | 07/11/2020 | 18 | 23 | 20.6 | 7 | 1 | 10 | 0 |
| | 17/12/2020 | 12 | 18 | 16 | 138 | 1 | 14 | 0 |
| | 28/01/2021 | 5 | 14 | 7.5 | 0 | 0 | 0 | 0 |
| | 11/02/2021 | 11 | 22 | 16.6 | 13 | 0 | 30 | 0 |
| Ravine | 04/11/2020 | 16 | 25 | 20.0 | 1025 | 10 | 173 | 1 |
| | 01/12/2020 | 10 | 17 | 13.1 | 1442 | 15 | 378 | 90 |
| | 23/01/2021 | 14 | 17 | 14.8 | 53 | 0 | 101 | 1 |
| | 18/02/2021 | 12 | 16 | 13.1 | 107 | 0 | 10 | 4 |
| Entrance to Aleppo pine forest | 20/11/2020 | 12 | 20 | 18.8 | 19 | 0 | 11 | 0 |
| | 03/12/2020 | 10 | 11 | 10.3 | 12 | 0 | 8 | 0 |
| | 15/01/2021 | 9 | 15 | 11.8 | 7 | 0 | 2 | 0 |
| | 28/02/2021 | 10 | 14 | 13.2 | 19 | 0 | 4 | 0 |

were too low to be compared with all activity, were recorded during the night (Table 2). While the number of bat passes and feeding buzzes provides a relative index of bat activity, the absolute numbers of individual bats cannot be ascertained from these.

Statistical analysis

The indicator of activity was measured by the number of bat passes per hour with 95% confidence intervals (CI). The Kruskal-Wallis (H) test was used to analyse the differences in activity between the two species according to habitat type, and analysis of temporal activity during the night was carried out using the Temporal Pass Plot technique (TPP, see Beason et al. 2020), which shows the activity patterns of the two bat species at the different sites. We also analysed the level of activity in relation to temperature variations. The nature and intensity of this relationship was estimated using Spearman's rank coefficient (*rs*).

RESULTS

Activity in different habitats

After 300 hours of sampling in the five habitats, we recorded 2965 passes of *P. kuhlii* bats (60%) and 2008 passes of *T. teniotis* bats (40%). The average activity of *P. kuhlii* was 741 passes per night for all habitats. The activity recorded in the ravine was in an average of 663 passes per night, followed by 40 passes per night at shrubs and bushes near a street lamp, 20 passes per night in the Aleppo pine forest, 14 passes per night at the entrance to the Aleppo pine forest, and 4 passes per

night at the olive grove. There was a significant difference in activity levels between the different habitat types ($H = 44.31, p < 0.001, df = 4$). The ravine recorded the highest average number of passes per night, while the olive grove and the entrance to the Aleppo pine forest recorded the lowest. The average activity of *T. teniotis* was 502 passes per night for all habitats: 283 passes per night were recorded in the olive grove, 190 passes per night in the ravine, 14 passes per night at the habitat near the street lamp, 9 passes per night at the Aleppo pine forest, and 6 passes per night at the entrance to the Aleppo pine forest. There were notable variations in activity levels across different habitat types ($H = 76.96, p < 0.001, df = 4$). The highest average number of visits per night was recorded in the ravine and olive grove, while the lowest was recorded in the Aleppo pine forest and entrance to the Aleppo pine forest (Figure 1).

Temporal model of activity

The temporal analysis of *P. kuhlii* was restricted to the ravine, which accounted for 89.5% of the species' total activity. Figure 2 shows the activity of *P. kuhlii* during the nights of recording at the ravine. The temporal activity was recorded around 50 minutes after, but not before, sunset for the months of November and February and from around 18 to 30 minutes after sunset for the months of December and January. There is some consistency in the pattern with respect to sunset, although activity began after 50 minutes for the months of November and February. Peak activity was recorded between 6 pm and 8 pm on all four nights studied. In November and December, activity continued throughout the night until

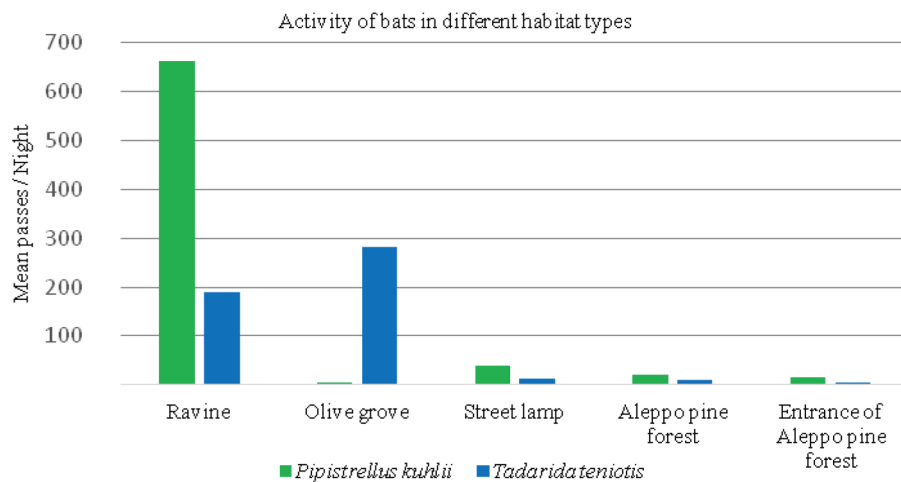


Figure 1. The mean activity of bats in different habitats per night.

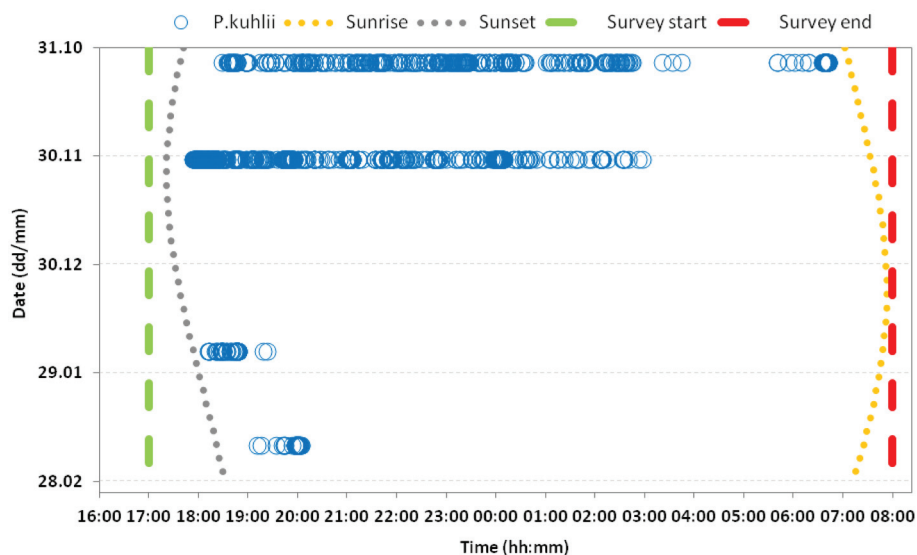


Figure 2. Temporal analysis of the activity of *P. kuhlii* bats at the ravine, TPP showing activity of *P. kuhlii* bats in the ravine. Each point represents activity within a 5-s time period; sunset and sunrise time obtained from <https://www.sunrise-and-sunset.com/fr/sun/algerie/bejaia>

3 am. In November, activity resumed an hour before sunrise. In January and February, there was no activity after 8 pm for the rest of the night. The consistency of the pattern in relation to sunset, combined with the general lack of activity during the rest of the night observed in January and February, suggests the presence of a roost or migration route nearby. The TPP technique makes it possible to estimate the probability of the presence of a roost or migration route in the vicinity. According to Miller (2001), in our case, the probability is 0.2.

The temporal analysis of the activity of *T. teniotis* was carried out for two habitats (ravine and olive grove), which accounted for 94% of the total activity of this species. The remaining three habitats were not included in the subsequent analysis, given an insufficient number of passes per hour. The activity of *T. teniotis* recorded at the same period and in the same location as *P. kuhlii* (at the ravine) is shown in Figure 3a. The temporal pat-

tern of activity of *T. teniotis* was almost similar to that of *P. kuhlii*, with the same consistency of the pattern in relation to sunset and in relation to the peak of activity. The difference was in the level of activity after 8 pm, which was maintained throughout the night, but at a low rate. This pattern was observed during the nights of December and January and, to a lesser extent, in November. In contrast, *T. teniotis* activity at another site (olive grove) showed a different pattern of activity (Figure 3b). It is immediately apparent that the activity started at the olive grove site rather than at the ravine site (16 min after sunset in January and 9 min after sunset in February), and the activity was not at the same rate during the night with a fluctuation in activity. However, the activity was maintained throughout the night, although it decreased around 4 am. Again, the presence of activity peaks suggests the presence of a nearby roost or migration route for this site.

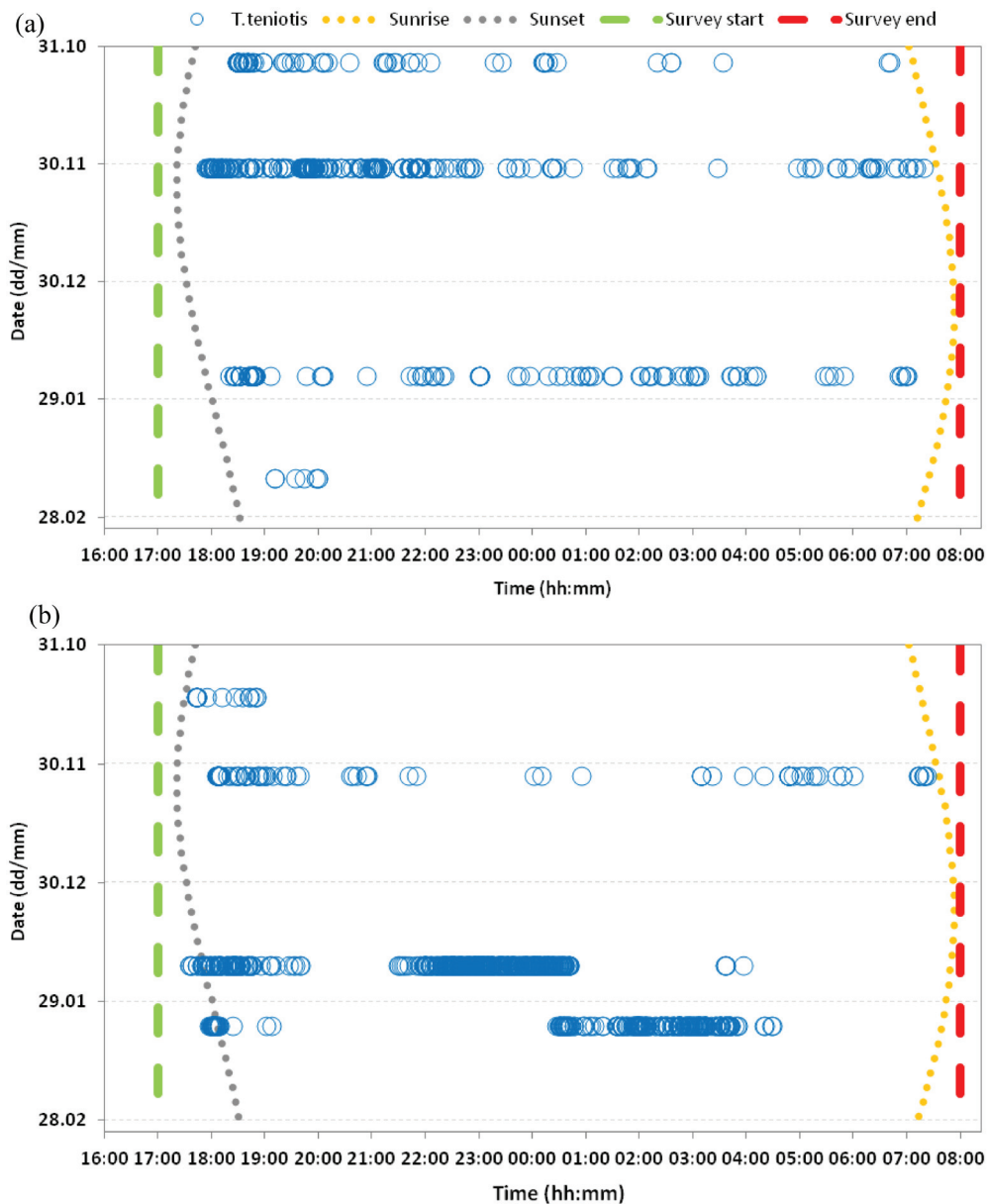


Figure 3. Temporal analysis of the activity of *T. teniotis* bats at the two sites, TPPs comparing differences in *T. teniotis* activity between two sites, ravine (a) and olive grove (b), on the same four nights. Points represent activity within 5-s time periods; sunset and sunrise time obtained from <https://www.sunrise-and-sunset.com/fr/sun/algerie/bejaia>

Figures 3a and 3b show 432 and 788 time blocks, respectively, containing *T. teniotis* activity. This illustrates how intra-specific temporal activity patterns can vary between sites.

In addition to changes in nocturnal activity patterns, seasonal changes can also be observed for *P. kuhlii* in Figure 2. During the months of November and December, activity was sustained from sunset and throughout the night. In contrast, during the months of January and February, activity occurred around sunset and was completely absent during the night. As the season progressed, nocturnal activity disappeared. For *T. teniotis*, we see that there is activity throughout the season, although it varies from site to site (Figure 3).

Level of activity in relation to temperature variations

The mean temperature of the 4 nights of monitoring at the ravine was 15.3°C (Table 2). The mean hourly temperature varied between 14°C and 18.5°C. The highest temperatures were recorded between 5 pm and 10 pm with an average of 17.3°C. It was during this period that most of the *T. teniotis* activity was recorded (75% passes). From 10 pm, the temperature decreased relatively, reaching an average of 14.2°C. This decrease of 3°C was accompanied by a decrease in activity (Figure 4). Spearman's rank coefficient (r_s) was 0.668, with a p -value of 0.006. This pattern was also observed for the species *P. kuhlii* (Figure 5), but the drop in activity was not as significant as for *T. teniotis*. The Spearman

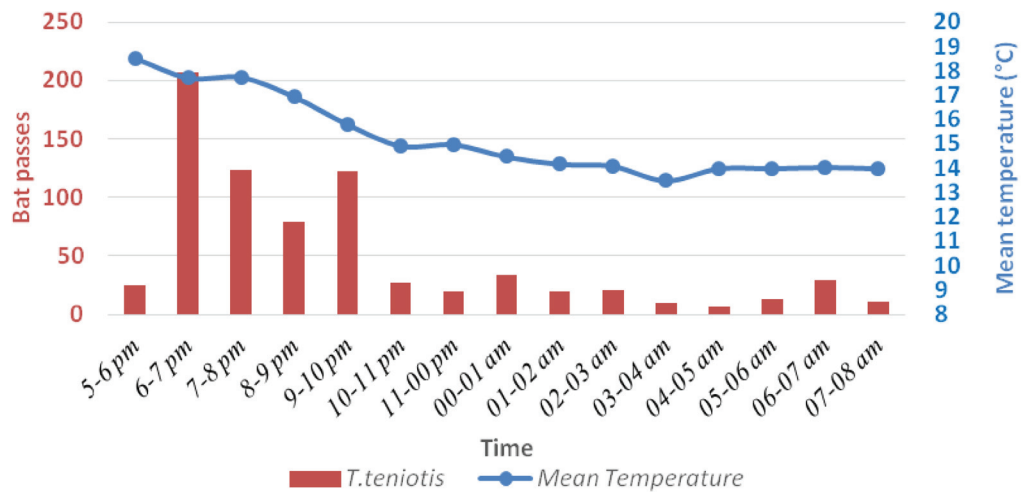


Figure 4. Activity of *T. teniotis* in the ravine in relation to variation in temperature.

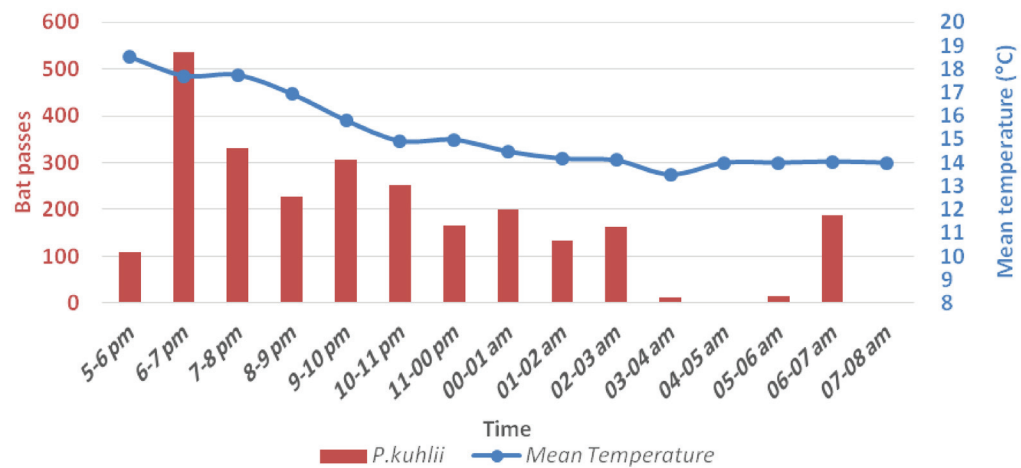


Figure 5. Activity of *P. kuhlii* in the ravine in relation to variation in temperature.

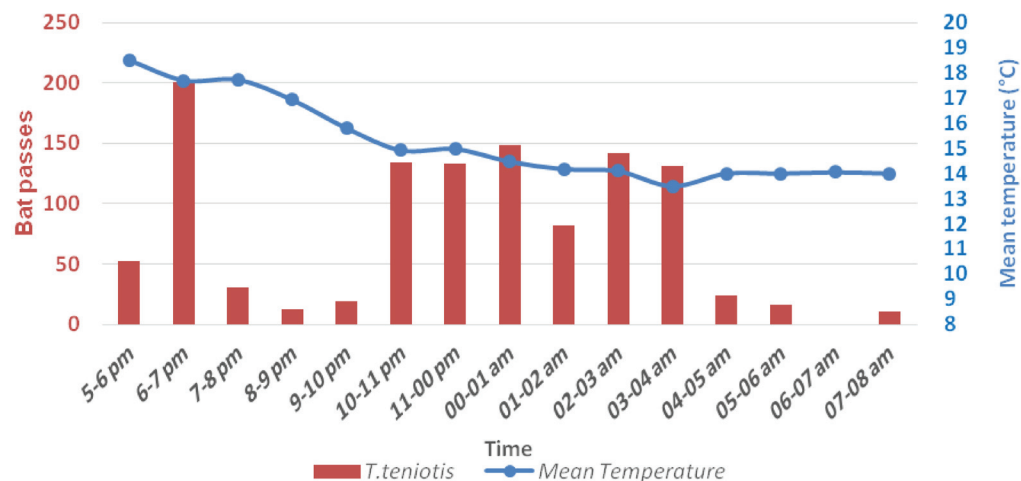


Figure 6. Activity of *T. teniotis* in the olive grove in relation to variation in temperature.

correlation coefficient (r_s) was 0.624, with a p -value of 0.013.

At the other site (olive grove), the mean temperature of the 4 nights of monitoring was 13.6°C (Table 1). The mean hourly temperature varied between 11.8°C and 18.3°C. Between 5 pm and 10 pm, the mean tempera-

ture increased to 16.3°C and then decreased by 4°C to around 12.3°C for the rest of the night. Despite the 4°C drop in temperature, *T. teniotis* activity did not decrease (Figure 6). The Spearman's rank coefficient revealed no significant correlation ($r_s = 0.124$; p -value = 0.659).

DISCUSSION

Habitat use by bats

The data presented illustrate distinct differences in temporal activity patterns between species, sites and over time. The peaks in activity observed at sunset or afterwards, or even before sunset, as shown in Figures 2 and 3, could potentially indicate roosting behaviour (Swift 1980; Maier 1992). The findings of the Russo and Jones (2003) study, which was based on data gathered with the use of ultrasonic detectors in southern Italy, indicate that there are no notable variations in the utilisation of different foraging habitats by *T. teniotis* bats. The study by Marques et al. (2004) showed that *T. teniotis* bats use habitats very selectively. We think that the difference between the observations of these authors may be related to the method used: active for one, and passive for the other.

Our study shows that *T. teniotis* bats are more active in open spaces like olive groves and ravines than in other habitats. However, given that *T. teniotis* bats appear to focus on prey swarms, it is probable that their habitat preferences fluctuate seasonally in response to shifts in prey abundance (Marques et al. 2004). Also, the study revealed a notable increase in the activity of *P. kuhlii* bats in ravines compared to other habitat types. Nevertheless, we noted a notably low level of activity in the habitat near the street lamp, which was still considered higher than in the other remaining typical habitats (Aleppo pine forest, entrance to Aleppo pine forest, and olive grove). This implies that the presence of a light source has a positive influence on the activity of *P. kuhlii*, although we have not measured the abundance of insects in these habitats and all data on this is lacking in this region. Temporary concentrations of prey, such as insect swarms, are suggested by the higher activity rates of *T. teniotis* bats recorded in the olive grove and ravine compared to the site near a streetlight, the Aleppo pine forest and the entrance to the Aleppo pine forest, because the species is an opportunistic forager (Zbinden and Zingg 1986; Marques et al. 2004; Colombo 2018) concentrating their activity in the valleys (Marques et al. 2004).

Both the ravine and the olive grove are open spaces, since *T. teniotis* bats hunt in open spaces (Zbinden and Zingg 1986), avoiding dense forests. However, the higher activity rates of *T. teniotis* bats in the olive grove and ravine, and of *P. kuhlii* bats in the ravine, compared to those in the other habitats, may indicate the proximity of common roosts, which can significantly affect the level of activity. The consistency of the patterns in relation to sunset, combined with the general lack of activity during the rest of the night observed in January and February, suggests the presence of a roost or migration route nearby. In our case, at the ravine, the probability was 0.2 (Miller 2001). Flying has high

energy costs (Thomas et al. 1990; Speakman and Racey 1991), and by reducing travel between foraging sites and roosts, bats may save energy. Whether or not the high activity levels reflect increased movement rates near roosts is not known, so it will be interesting to look for roosts in this region in future studies, especially since while their home range may extend over 30 km, most foraging areas may be concentrated within about 5 km (Marques et al. 2004). The suggestions linking temporal activity patterns to habitat use targets for bats are speculative. Other, more varied and more in-depth studies are needed in the region to gain a better understanding of the activities of bats and to enable a better assessment of the various relationships that may exist at intra-specific or extra-specific levels and between species and different habitats.

Temporal patterns of habitat use

Most insectivorous bats have a bimodal activity pattern, with a peak in foraging activity at dusk and a second peak late at night (Erkert 1982). However, a clearly unimodal pattern of activity, peaking about 3 hours after sunset and decreasing throughout the night, was observed in the *T. teniotis* studied in Marques et al. (2004). This species is known to make only one long foraging trip per night, with no significant resting period between foraging trips (Marques et al. 2004). This should allow *T. teniotis* to emerge early, as it is a large and fast flying species and is therefore less vulnerable to predators than most bats (Rydell and Arlettaz 1994; Rydell et al. 1996). We found that the *T. teniotis* bats in the olive groves were active throughout the night, with flights recorded from the first hour after the sun has set until just before the sun rises, which confirms a unimodal activity pattern. Activity patterns differed significantly between habitats. Although activity was continuous, a significantly higher number of passes were recorded during the second hour. These foraging periods of *T. teniotis* bats could be determined by the timing of prey availability. This could explain the higher number of passes recorded during the second hour. But it remains a hypothesis. There is no proof that there is a peak in the availability of insects at this time, because there is no study about this in this area. Activity during the rest of the night may be influenced by success foraging, as Aldridge and Brigham (1991) suggested for *Eptesicus fuscus*. Activity in the ravine was also sustained throughout the night, with the highest average pass rate during the first third of the night, possibly related to foraging success in this habitat.

The peak activity of *P. kuhlii* bats in the ravine habitat was recorded during the second hour after sunset, then there was an irregular decrease in activity, then activity became very low (lowest during the 12th hour) compared to the previous period, then increased again and

finally decreased, marking a second peak of activity, which confirm a bimodal activity pattern. Kowalski and Rzebik-Kowalska (1991) reported a bimodal circadian activity pattern in this bat. This species has a tendency to feed in insect-rich areas, showing no preference for particular insects or food habitats (Goiti et al. 2003). Our results may therefore indicate foraging success in this habitat, so the richness of this habitat in terms of insects. If activity increases again after reaching its lowest level, this may confirm the bimodal nature of foraging by this species. According to Russo and Jones (2003), *P. kuhlii* shows remarkable behavioural and ecological flexibility in roosting and foraging. With no significant effect of any of the habitat characteristics, it prefers roosts surrounded by 'urban habitat' (Ancillotto et al. 2015). In fact, this species also hunts along forest edges and hedgerows, generally following these elements (Arthur and Lemaire 2015). Given its regularity, roosts are suspected in the surrounding ravine habitat as it passes through an urban area.

According to Amichai and Korine (2020), *P. kuhlii* is behaviourally and physiologically capable of adapting to climatic conditions outside its optimal range. In the northern part of its range, *P. kuhlii* hibernates from November to March (Strelkov et al. 1985). According to Dalhoumi et al. (2018), *P. kuhlii* does not enter a continuous, winter-long hibernation, but is active on and off throughout the winter. The patterns of seasonal change observed for this species in Figure 2 confirm that this species does not enter complete hibernation in this region, perhaps because of the mild climate that characterizes winter in this region as well as the availability of food. According to Cotterill and Hapold (2013) and Colombo (2018), *T. teniotis* spends a short period (8 days) in a state of torpor during winter and does not actually hibernate. The activity patterns observed in Figure 3 confirm that *T. teniotis* is not a fully hibernating species in this region, and our data do not allow us to say whether it undergoes periods of torpor during this period (Arlettaz et al. 2000).

Activity patterns in relation to temperature variations

The activity of flying invertebrates, and therefore the activity of bats, generally increases with temperature (O'Donnell 2000). The decrease in temperature was accompanied by a decrease in activity of *T. teniotis* in the ravine (Figure 4), but despite the drop in temperature at the olive grove site, *T. teniotis* activity did not decrease (Figure 6). It can therefore be said that the activity pattern does not depend on temperature any more than it does on site. The activity of *P. kuhlii* in the ravine (Figure 5) was the same as that of *T. teniotis* at the same site, but the decrease in activity was not as significant as for *T. teniotis*.

CONCLUSION

Significant differences in temporal activity patterns were observed between species, sites and over time. *T. teniotis* bats were more active in open areas such as olive groves and ravines than in other habitats. *T. teniotis* bats were active throughout the night, with flights recorded from the first hour after sunset until just before sunrise, confirming a unimodal activity pattern. The observed activity patterns confirm that *T. teniotis* is not a fully hibernating species in this region, and our data do not allow us to say whether it undergoes torpor during this period. The decrease in temperature was accompanied by a decrease in the activity of *T. teniotis* in the ravine, but despite the decrease in temperature in the olive grove site, the activity of *T. teniotis* did not decrease. It can therefore be said that the activity pattern is no more dependent on temperature than it is on site.

The study showed a significant increase in activity of *P. kuhlii* bats in the ravine compared to other habitat types. However, we found a remarkably low level of activity in the habitat near the street lamp, which was still considered higher than in the other remaining typical habitats. This suggests that the presence of a light source has a positive influence on the activity of *P. kuhlii*. The activity of *P. kuhlii* increases again after reaching its lowest level, confirming the bimodal nature of foraging by this species. The patterns of seasonal change observed for this species confirm that this species does not hibernate completely in this region, perhaps because of the mild climate that characterises winter in this region. The decrease in temperature was accompanied by a decrease in activity of *P. kuhlii* in the ravine, but the decrease in activity was not as significant as for *T. teniotis*.

The consistency of the patterns in relation to sunset, combined with the general lack of activity during the rest of the night observed, suggests the presence of a roost or migratory route nearby. In our case, in the ravine, the probability was 0.2. It will be interesting to look for roosts in this area in future studies. Other, more varied and in-depth studies are needed in the region to gain a better understanding of bat activity and to enable a better assessment of the various relationships that may exist, both intra- and extra-specific, and between species and different habitats.

ACKNOWLEDGEMENTS

We would like to thank Mr Adjout Samir for helping us with the statistical analysis and Mr Dalhoumi for helping us in identification of species, and also, we would like to thank the reviewers for all the comments they made which enabled us to produce this article.

REFERENCES

- Ahmim, M. 2017. Current status, distribution and conservation status of Algerian bats (Mammalia: Chiroptera). *Journal of Threatened Taxa* 9, 9723–9733. <https://doi.org/10.11609/jott.2576.9.1.9723-9733>
- Ahmim, M. 2018. *The Bat: A benefactor animal poorly understood in Algeria*. <http://dx.doi.org/10.5772/intechopen.75547>
- Ahmim, M. 2019. *Algerian chiropterological biodiversity current status and prospects*. <http://dx.doi.org/10.13140/RG.2.2.14863.12966>
- Ahmim, M. 2024. *Barbastella barbastellus* (Chiroptera: Vespertilionidae) a new bat record in Algeria by the echolocation method. *International Journal of Zoology And Animal Biology* 7, 2.
- Ahmim, M., Dalhoumi, R., & Măntoiu, D.S. 2019. First data on the acoustic characteristics of some Chiropteran species from northern Algeria. *Bioacoustics* 29, 499–517. <https://doi.org/10.1080/09524622.2019.1620634>
- Aldridge, H.D.J.N., & Brigham, R.M. 1991. Factors influencing foraging time in two aerial insectivores: the bird *Chordeiles minor* and the bat *Eptesicus fuscus*. *Canadian Journal of Zoology* 69, 62–69.
- Amichai, E., & Korine, C. 2020. Kuhl's pipistrelle *Pipistrellus kuhlii* (Kuhl, 1817). *Handbook of the Mammals of Europe*, 1–19.
- Ancillotto, L., Tomassini, A., & Russo, D. 2015. The fancy city life: Kuhl's pipistrelle, *Pipistrellus kuhlii*, benefits from urbanization. *Wildlife Research* 42, 598–606.
- Ancillotto, L., Santini, L., Ranc, N., Maiorano, L., & Russo, D. 2016. Extraordinary range expansion in a common bat: The potential roles of climate change and urbanisation. *The Science of Nature* 103, 1–8. 103. <https://doi.org/10.1007/s00114-016-1334-7>
- Arlettaz, R., Ruchet, C., Aeschimann, J., Brun, E., Genoud, M., & Vogel, P. 2000. Physiological traits affecting the distribution and wintering strategy of the bat *Tadarida teniotis*. *Ecology* 81, 1004–1014.
- Arthur, L., & Lemaire, M. 2015. *Bats of France, Belgium, Luxemburg and Switzerland*. 2nd Ed. Biotope, Paris, 544 pp.
- Audra, P.H., Cailhol, D., Gazquez, F., Jaillet, S., Cheng H., Edwards, R., Fehdi, C., & Baali, F. 2022. The hypogean cavities and karstifications – sulfuric and thermal – of Azrou, Bibans chain, Algeria; a milestone in the evolution of the Tell Atlas since 3 Ma. *Karstologia Mémoires* 27, 103–125.
- Aulagnier, S., Cuzin, F., & Thévenot, M. 2017. Chiroptera. In *Wild mammals of Morocco. Population, distribution, ecology*, edited by Aulagnier, S., Cuzin, F., & Thévenot, M., 117–154. French Society for the Study and Protection of Mammals, Paris, France.
- Barataud, M. 2012. Acoustic ecology of European bats. Identification of species, study of their habitats and hunting behaviors. Paris, France: Biotope – M.N.H.N.
- Beason, R., Riesch, R., & Koricheva, J. 2020. Temporal Pass Plots: An intuitive method for visualising activity patterns of bats and other vocalising animals. *Ecological Indicators* 113. <https://doi.org/10.1016/j.ecolind.2020.106202>
- Colombo, R. 2018. First observation of Cestoni's Molossus, *Tadarida teniotis*, in a substitute shelter and new elements on the ecology of the species in shelter. *Conference: Chiroptera Meetings of the SFPEM At: Bourges*.
- Cotterill, F., & Happold, M. 2013. Family Molossidae Free-tailed Bats. *Mamals of Africa* 3.
- Dalhoumi, R., Aissa, P., & Aulagnier, S. 2015. Annual activity cycle of bats in the Bou-Hedma National Park (Tunisia). *Ecology Review, Earth Life* 70, 261–270.
- Dalhoumi, R., Morellet, N., Aïssa, P., & Aulagnier, S. 2018. Seasonal activity pattern and habitat use by the Kuhl's pipistrelle (*Pipistrellus kuhlii*) in an arid environment. *European Journal of Wildlife Research* 64(36). <https://doi.org/10.1007/s10344-018-1193-y>
- Davy, C.M., Russo, D., & Fenton, M.B. 2007. Use of native woodlands and traditional olive groves by foraging bats on a Mediterranean island: consequences for conservation. *Journal of Zoology* 273, 397–405.
- Deleuil, R., & Labbé, A. 1955. On the variability of Kuhl's pipistrelle (*Pipistrellus kuhlii*). *Bulletin de la Société des Sciences Naturelles de Tunisie* 8, 237–242.
- Dietz, C., von Helversen, O., & Nill, D. 2009. *Bats of Britain, Europe and Northwest Africa*. London: A & C Black.
- Disca, Th., Allegrini, B., & Prié, V. 2014. Acoustic characteristics of the echolocation calls of 16 species of chiroptera (Mammalia, Chiroptera) from Morocco. *Vesppère* 3, 209–229.
- Erkert, H.G. 1982. Ecological aspects of bat activity rhythms. In *Ecology of Bats*, edited by Kunz, T.H. Boston, MA: Springer.
- Gaisler, J. 1983. New data on the chiropterans of northern Algeria. *Mammalia* 47, 359–370.
- Gaisler, J. 1983–1984. Bats of northern Algeria and their winter activity. *Myotis* 21–22, 89–95.
- Gaisler, J., & Kowalski, K. 1986. Results of the netting of bats in Algeria (Mammalia, Chiroptera). *Věstník Československé společnosti zoologické* 50, 161–173.
- Goiti, U., Vecin, P., Garin, I., Saloña Bordas, M.-I., & Aihartza, J. 2003. Diet and prey selection in Kuhl's pipistrelle *Pipistrellus kuhlii* (Chiroptera, Vespertilionidae) in south-western Europe. *Acta theriologica* 48, 457–468. <https://doi.org/10.1007/BF03192492>
- Jones, G., & Rydell, J. 1994. Foraging strategy and predation risk as factors influencing emergence time in echolocating bats. *Philosophical Transactions of The Royal Society B: Biological Sciences* 346, 445–455. <https://doi.org/10.1098/rstb.1994.0161>

- Kowalski, K., & Rzebiak-Kowalska, B. 1991. *Mammals of Algeria*. The Ossolinski National Institute, Publishing House of the Polish Academy of Sciences, 370 pp.
- Loumassine, H.-E., Allegrini, B., Bounaceur, F., Peyr, O., & Aulagnier, S. 2017. A new mammal species for Algeria, *Rhinopoma microphyllum* (Chiroptera, Rhinopomatidae): morphological and acoustic identification. *Mammalia* 82, 85–88.
- Maier, C. 1992. Activity patterns of pipistrelle bat (*Pipistrellus pipistrellus*) in Oxfordshire. *Journal of Zoology* 228, 69–80.
- Marques, J., Rainho, A., Carapuço, M., Oliveira, P., & Palmeirim, J. 2004. Foraging behaviour and habitat use by the European free-tailed bat *Tadarida teniotis*. *Acta Chiropterologica* 6, 99–110. <https://doi.org/10.3161/1508110042176680>
- Mediterranean-basin-biodiversity hotspot. 2017. Ecosystem profile, Mediterranean Basin biodiversity hotspot. Detailed technical synthesis. Critical Ecosystem Partnership Fund.
- Miller, B.W. 2001. A method for determining relative activity of free flying bats using a new activity index for acoustic monitoring. *Acta Chiropterology* 3, 93–105.
- Molloy, J.C. 1995. Bat (*Peka peka*) recovery plan (*Mystacina, Chalinobus*). *Threatened Species Recovery Plan Series* No. 15. Wellington: Department of Conservation.
- Muthersbaugh, M.S., Ford, W.M., Silvis, A., & Powers, K.E. 2019. Activity patterns of cave-dwelling bat species during pre-hibernation swarming and post-hibernation emergence in the central Appalachians. *Diversity* 11(9), 159. <https://doi.org/10.3390/d11090159>
- Neuweiler, G. 2000. *The biology of bats*. Oxford: Oxford University Press, 310 pp.
- O'Donnell, C.F.J. 2000. Influence of season, habitat, temperature, and invertebrate availability on nocturnal activity by the New Zealand long-tailed bat (*Chalinobus tuberculatus*). *New Zealand Journal of Zoology* 27, 207–221.
- Papadatou, E., & Russo, D. 2014. Acoustic identification of free-flying Schreiber's bat, *Miniopterus schreibersii* by social calls. *Hystrix Italian Journal of Mammalogy* 25, 119–120.
- Racey, P.A., & Entwistle, A.C. 2003. Conservation ecology of bats. In *Bat ecology*, edited by Kunz, T., Fenton, M.B., 680–743. Chicago, USA: University of Chicago Press.
- Russo, D., & Jones, G. 2003. Use of foraging habitats by bats in a Mediterranean area determined by acoustic surveys: conservation implications. *Ecography* 26, 197–209.
- Rydell, J., & Arlettaz, R. 1994. Low-frequency echolocation enables the bat *Tadarida teniotis* to feed on tympanate insects. *Proceedings. Biological sciences. The Royal Society* 257, 175–8. 10.1098/rspb.1994.0112
- Rydell, J., Entwistle, A., & Racey, P.A. 1996. Timing of foraging flights of three species of bats in relation to insect activity and predation risk. *Oikos* 76, 243–252.
- Sachanowicz, K., Wower, A., & Bashta, A.T. 2006. Further range extension of *Pipistrellus kuhlii* Kuhl, 1817, in central and eastern Europe. *Acta Chiropterologica* 8, 543–548.
- Sharma, B., Chakravarty, R., & Acharya, P. 2021. The first record of European free-tailed bat, *Tadarida teniotis* Rafinesque, 1814, and note on probable elevational movement from Nepal, *Journal of Asia-Pacific Biodiversity* 14(2), 248–253. <https://www.sciencedirect.com/science/article/pii/S2287884X21000157#sec4>
- Speakman, J.R., & Racey, P.A. 1991. No cost of echolocation for bats in flight. *Nature* 350, 421–423.
- Spitzenberger, F., Kugelschafter, K., & Weiss, E. 2024. Hibernation phenologies and winter activities of four congeneric bat species hibernating simultaneously in an eastern alpine cave studied by phototrapping (Chiroptera, Vespertilionidae). *Lynx new series* 54, 155–172. doi.org/10.37520/lynx.2023.011
- Stawski, C., Willis, C.K.R., & Geiser, F. 2014. The importance of temporal heterothermy in bats. *Journal of Zoology* 292, 86–100.
- Strelkov, P.P., Unkurova, V.I., & Medvedeva, G.A. 1985. Newly discovered species of ternary terns (*Pipistrellus kuhlii*) and other area dynamics in the SSSR. *Zoology Journal* 64, 87–97.
- Swift, S.M. 1980. Activity patterns of pipistrelle bats (*Pipistrellus pipistrellus*) in north-east Scotland. *Journal of Zoology* 190, 285–295.
- Thomas, D.W. 1988. The distribution of bats in different ages of douglas-fir forests. *Journal of Wildlife Management* 52, 619–626.
- Thomas, D.W., Dorais, J., & Bergeron, J.M. 1990. Winter energy budgets and cost of arousals for hibernating little brown bats, *Myotis lucifugus*. *Journal of Mammalogy* 71, 475–9.
- Trousset, E.B.P., & Paskoff, R. 1991. Biban (The Doors). *Berber Encyclopedia* 10.
- Zbinden, K., & Zingg, P. 1986. Search and hunting signals of echolocating European free-tailed bats, *Tadarida teniotis*, in southern Switzerland. *Mammalia* 50, 9–26. <https://doi.org/10.1515/mamm.1986.50.1.9>