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R. Dalhoumi, P. Aissa, H. Beyrem, S. Aulagnier. Bat species richness and activity in Dghoumes National Park (Southwest Tunisia): a preliminary survey. *Arxius de Miscelx`l`ania Zool`ogica*, 2020, 18, pp.89-100. 10.32800/amz.2020.18.0089 . hal-02972158

HAL Id: hal-02972158

<https://hal.inrae.fr/hal-02972158>

Submitted on 20 Oct 2020

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Bat species richness and activity in Dghoumes National Park (Southwest Tunisia): a preliminary survey

R. Dalhoumi, P. Aissa, H. Beyrem, S. Aulagnier

Dalhoumi, R., Aissa, P., Beyrem, H., Aulagnier, S., 2020. Bat species richness and activity in Dghoumes National Park (Southwest Tunisia): a preliminary survey. *Arxius de Miscel·lània Zoològica*, 18: 89–100, Doi: <https://doi.org/10.32800/amz.2020.18.0089>

Abstract

Bat species richness and activity in Dghoumes National Park (Southwest Tunisia): a preliminary survey. Bat fauna in eight of the main habitat types of Dghoumes National Park was inventoried using mist-netting, acoustic detection and roost search. Bats were active at night and recorded near water bodies and street lamps. We recorded the echolocation calls of six bat species: *Eptesicus isabellinus*, *Pipistrellus kuhlii*, *Vansonia rueppellii*, *Asellia tridens*, *Tadarida teniotis* and *Rhinopoma cystops*. Two bat colonies containing 111 individuals of *R. cystops* were found roosting in Jebel Morra cave and 54 individuals of *A. tridens* were found roosting in the ceiling of the Ecomuseum. Due to potential disturbance by visitors to the museum, we suggest strengthening management practices to ensure the usage of this roosting site in order to promote the conservation of *A. tridens*.

Data published through [GBIF](#) (Doi: [10.15470/0u03uz](https://doi.org/10.15470/0u03uz))

Key words: Chiroptera, Acoustic, Night activity, Water bodies, Northwest Africa

Resumen

Riqueza de especies y actividad de murciélagos en el Parque Nacional de Dghoumes (suroeste de Túnez): un estudio preliminar. Se estudió la fauna de murciélagos en ocho de los principales tipos de hábitats del Parque Nacional de Dghoumes utilizando redes de niebla, detección acústica y búsqueda de refugios. Los murciélagos estuvieron activos durante la noche y se localizaron en la proximidad de masas de agua y farolas de alumbrado público. Se registraron seis especies de murciélagos: *Eptesicus isabellinus*, *Pipistrellus kuhlii*, *Vansonia rueppellii*, *Asellia tridens*, *Tadarida teniotis* y *Rhinopoma cystops*. Se localizaron dos colonias, una de *R. cystops* con 111 individuos colgados en la cueva de Jebel Morra y otra con 54 individuos de *A. tridens* en el techo del Ecomuseo. Ante la posible perturbación causada por los visitantes del museo, sugerimos reforzar las medidas de gestión del público para garantizar el uso de este lugar de descanso de los murciélagos, lo que impactaría positivamente en la conservación de *A. tridens*.

Datos publicados en [GBIF](#) (Doi: [10.15470/0u03uz](https://doi.org/10.15470/0u03uz))

Palabras clave: Chiroptera, Detección acústica, Actividad nocturna, Masas de agua, Noroeste de África

Resum

Riquesa d'espècies i activitat de ratpenats al Parc Nacional de Dghoumes (sud-oest de Tunísia): un estudi preliminar. Es va portar a terme un estudi de la fauna de ratpenats en vuit dels principals tipus d'hàbitats del Parc Nacional de Dghoumes utilitzant xarxes de boira, detecció acústica i cerca de refugis. Els ratpenats van estar actius durant la nit i es van localitzar prop de masses d'aigua i fanals d'enllumenat públic. Es van registrar sis espècies de ratpenats: *Eptesicus isabellinus*, *Pipistrellus kuhlii*, *Vansonia rueppellii*, *Asellia tridens*, *Tadarida teniotis* i *Rhinopoma cystops*. Es van localitzar dues colònies, una de *R. cystops* amb 111 individus penjats a la cova de Jebel Morra i una altra amb 54 individus d'*A. tridens* al sostre de l'Ecomuseu. Davant la possible pertorbació causada pels visitants del museu, suggerim reforçar les mesures de gestió del públic per garantir l'ús d'aquest lloc de descans dels ratpenats, la qual cosa impactaria positivament en la conservació d'*A. tridens*.

Dades publicades a GBIF (Doi: [10.15470/0u03uz](https://doi.org/10.15470/0u03uz))

Paraules clau: Chiroptera, Detecció acústica, Activitat nocturna, Masses d'aigua, Nord-oest d'Àfrica

Received: 29/01/2020; Conditional acceptance: 17/04/2020; Final acceptance: 17/07/2020

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Introduction

With more than 1,421 species (Simmons and Cirranello, 2020), Chiroptera is the second most speciose mammalian order in the world, constituting about a quarter of all mammal species (Hutson et al., 2001; Wilson and Reeder, 2005). Bats have colonized all continents except Antarctica, with different levels of species richness (Owen, 1990; Georgiakakis et al., 2010; Curran et al., 2012; Fenton and Simmons, 2014; Weber and Cáceres, 2018). Bat species richness peaks in equatorial zones and is lowest in desert areas (Ramos Pereira and Palmeirim, 2013; Monadjem et al., 2018). As for other North–western African countries (Ahmim and Oubaziz, 2017 for Algeria; Aulagnier et al., 2017 for Morocco), few data have been collected in Tunisia from sub-Saharan and Saharan areas (Dalhouni et al., 2011; Puechmaille et al., 2012). The first data on southern Tunisian bats were published by Baker et al. (1974) and Cockrum (in Dalhouni et al., 2011). These authors recorded 6 bat species: *Rhinolophus ferrumequinum*, *Asellia tridens*, *Eptesicus isabellinus*, *Pipistrellus kuhlii*, *Plecotus gaisleri* and *Myotis punicus*. Later, Rebelo and Brito (2006) studied bat activity in several Tunisian desert localities but they did not provide details about species diversity. More recently, Bendjeddou et al. (2016) described a new species, *Nyctinomus aegyptiacus*, for the Tunisian fauna during a touristic visit. To date, only 47 records corresponding to 13 species of bats have been made for this area. In addition, little ecological information

is available for the most common areas that cover around a third of the country. The lack of knowledge of bat fauna in Tunisia requires intensive surveys focusing mainly on habitat use in this harsh environment.

Bat acoustic surveys are standard in Europe and recommended for surveillance and monitoring of many species (Battersby, 2010). Acoustic monitoring in Northern Africa only started in the last decade (Dietz et al., 2007; Liéron et al., 2008; Benda et al., 2010; Dieuleveut et al., 2010; Disca et al., 2014), including surveys in Tunisia by Rebelo and Brito (2006) and Puechmaille et al. (2012). More recently, Dalhoumi et al. (2014, 2016, 2019) studied bat activity and habitat use in Tunisian localities and showed that acoustic monitoring is useful to study bats in this type of ecosystems as it can more accurately describe the species richness than methods such as mist-netting and cave monitoring. Due to logistic constraints, acoustic monitoring was often limited to only recording bat activity during the first part of the night, however, modern automatic bat detectors are now widely available and can record bat calls overnight (e.g. Adams et al., 2012).

The goal of this study was to obtain information on bat species richness and habitat use in a desert area in Tunisia. We recorded bat activity in eight sites at Dghoumes National Park during the nursing season, when bats are most active. This survey aimed to assess activity patterns of bats at Dghoumes National Park and identify their most important habitats. Understanding bat activity and diversity could provide information relevant to the conservation of several species within and outside the limits of the park.

Material and methods

Study area

Dghoumes National Park (34° 01' N–34° 06' N, 8° 28' E–8° 39' E) is located 30 km east of Degueche (Tozeur governorate, southwest Tunisia) (fig. 1). The park covers approximately 8,000 ha. It borders with Chott el-Jérid in the south and the mountain ridge of Jebel Morra, Jebel El Kebiriti and Jebel Taferma in the north. The southern flank of the mountain range is cut through by wadis (Tamaxid, El Akreb, El Behim, El Kebiriti, Bou Moussa, El Oussif) that flow to Chott el-Jérid across a broad sandy plain (3,800 ha). The park has two small hillside lakes (Marzoug and Tamxid basins) and several permanent ponds (Sassia pond, El Kebiriti pond, and others). The bioclimate is arid with cool winters. The annual rainfall is about 100 mm/year. The average temperature ranges from –3°C in winter to more than 50°C in the summer. Evaporation reaches 1,200 mm/year. The sirocco wind blows for more than 50 days/year, especially in the summer (A. Chetoui, pers. comm.). The dominant biome is steppe with herbaceous vegetation such as *Suaeda mollis*, *Zygophyllum album*, *Salsola tetrandra*, *Traganum nudatum*, *Artemisia campestris*, *Rhus tripartitum*, *Periploca laevigata* and *Retama retam*, and sparse trees of *Acacia tortilis raddiana* and *Tamarix aphylla*. The main terrestrial mammals are *Ctenodactylus gundi*, *Hyaena hyaena*, *Lepus capensis*, *Ammotragus lervia* and reintroduced *Oryx dammah* and *Gazella dorcas* (Jebali, 2012).

Data collection and species identification

From June 16 to 24, 2018, we studied bat activity at eight sites of Dghoumes National Park (fig. 1): 1) at the main entrance to the park, which is illuminated by solar white street lamps (34° 2' 30.62" N, 8° 33' 51.95" E); 2) at Tamxid basin (34° 3' 53.93" N, 8° 31' 13.27" E) with a wet sludge; 3) at Marzoug basin (34° 3' 57.73" N, 8° 29' 38.31" E) with a dry sludge; 4) at El Kebiriti pond (34° 3' 57.19" N, 8° 33' 8.42" E); 5) at Sassia pond (34° 4' 15.44" N, 8° 31' 13.24" E); 6) at Jmal Ribeh pond (34° 4' 14.80" N, 8° 29' 55.83" E) surrounded by phragmites and sunk into high banks; 7) at the dry wadi El Oussif (34° 2' 53.24" N, 8° 33' 31.56" E) with some retama bushes; and 8) at a plain (34° 2' 55.13" N, 8° 33' 59.12" E) characterized by sparse vegetation and five small water bodies.

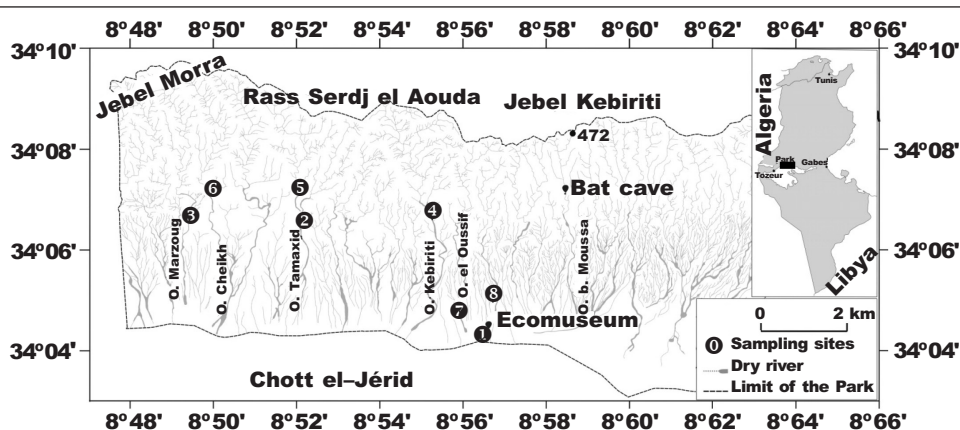


Fig. 1. Study sites of a bat community in Dghoumes National Park (southwest Tunisia): 1, main park entrance; 2, Tamxid basin; 3, Marzoug basin; 4, El Kebiriti pond; 5, Sassia pond; 6, Jmal Ribeh pond; 7, El Oussif wadi; 8, plain.

Fig. 1. Emplazamientos de estudio de la comunidad de murciélagos en el Parque Nacional de Dghoumes (suroeste de Túnez): 1, entrada principal del parque; 2, cuenca de Tamxid; 3, cuenca de Marzoug; 4, estanque El Kebiriti; 5, estanque Sassia; 6, estanque Jmal Ribeh; 7, Uadi El Oussif; 8, llanura.

Each site was surveyed for one night under similar hot and dry weather conditions. We used automatic echolocation call recordings at fixed points starting 30 minutes before sunset and lasting 30 minutes after sunrise. A Song Meter SM2BAT+ recorder (Wildlife Acoustic, Inc. Concord, Massachusetts, U.S.A.) was connected to a BMX-US1 ultrasonic microphone by a 3 m cable (Biotope, France). Real-time recordings were made at a sampling frequency of 384 kHz and an activation frequency of -18dB and 8 Hz. Recorded sequences were unzipped, analyzed and split into 5-second sequences with Kaleidoscope (Wildlife Acoustic, Inc. Version 4.1.0a). Only 5-second sequences containing bat calls were analyzed using the real-time analysis software BatSound, v.3.10 (Petterson Elektronik AB) for spectrogram analyses. We used a sample frequency of 38,400 samples/s, 16 bits/sample and selected 512 pt FFT with a Hamming window for analysis (Russ, 1999). Recorded calls, including feeding and drinking buzzes, were manually identified to species level using shape and other call parameters (Barataud, 2012). Echolocation calls of *Tadarida teniotis*, *Eptesicus isabellinus*, *Pipistrellus kuhlii* and *Rhinopoma cystops* were identified using reference calls collected in various sites in Tunisia (Dalhoumi et al., 2014, 2016, 2019). *Asellia tridens* uses a typical signal with constant frequency at 108–122 kHz (Jones et al., 1993). *Vansonia rueppellii* was identified by shallow FM/QCF calls at a frequency of maximum energy of 53.6 ± 1.3 kHz (Disca et al., 2014). A specimen of this species has been previously mis-netted at the entrance of the park and recorded after release during a visit on April 2, 2010. Additionally, temperature and hygrometry were recorded every 30 minutes during the nights of June 17–18 and 21–22 using a C.A. 846 pocket thermo-hygrometer (Chauvin Arnoux, Taiwan; precision $\pm 0.5^\circ\text{C}$ and $\pm 2.5\%$ RH) for potential bat roosts in caves, crevices and buildings, and visually counted emerging or resting individuals.

Table 1. Number of bat passes, species richness and indexes recorded at eight sites of Dghoumes National Park (southwest Tunisia) in June 2018 (one night per site): SL, street lamps; TWB, temporary water bodies; PWB, permanent water bodies; DW, dry wady; S, steepe. (For abbreviations of sites see fig. 1 and text).

Tabla 1. Número de pasos de murciélagos, riqueza de especies e índices registrados en ocho emplazamientos del Parque Nacional de Dghoumes (suroeste de Túnez) en junio de 2018 (una noche por emplazamiento): SL, farolas de alumbrado público; TWB, masas de agua temporales; PWB, masas de agua permanentes; DW, uadí seco; S, estepa. (Para las abreviaturas de los sitios, véase la figura 1 y el texto).

	SL		TWB		PWB		DW	S
	1	2	3	4	5	6	7	8
<i>Asellia tridens</i>	66	975	107	2	11	6	–	–
<i>Rhinopoma cystops</i>	–	180	–	583	24	–	–	–
<i>Tadarida teniotis</i>	–	33	7	9	115	95	–	–
<i>Eptesicus isabellinus</i>	395	5,087	1,088	5,929	5,237	1,428	–	–
<i>Pipistrellus kuhlii</i>	12,496	4,833	4,177	3,902	1,869	1,728	–	–
<i>Vansonia rueppellii</i>	–	–	3	–	–	9	–	–
No. of passes	12,957	11,108	5,382	10,425	7,256	3,266	0	0
Species richness	3	5	5	5	5	5	0	0

Statistical analyses

Bat activity was estimated by counting the number of passes (Russo and Jones, 2003). A bat pass was defined as a single or several calls emitted by a single animal during a 5 s interval (Barataud, 2012). Within each night, we considered 19 periods of 30 minutes to investigate activity patterns; the number of bat passes recorded during each period was used as a proxy of bat activity. Call recordings were used to calculate species richness at each site. Bat community analysis was performed using the number of bat passes. We used Kruskal–Wallis tests, followed by post–hoc multiple comparison tests, and Friedman tests to assess differences in bat activity among sites and periods. Statistical analyses were performed with Tanagra v.5, '97 edition (Rakotomalala, 2005).

Results

We recorded 50,394 passes of six species at six of the eight sites surveyed in Dghoumes National Park (table 1; dataset published through [GBIF](https://doi.org/10.15470/Ou03uz), Doi: 10.15470/Ou03uz); no bat calls were recorded at the dry El Oussif Wadi (site 7) or on the plain (site 8). Even when sites without bat activity were excluded, this acoustic survey revealed a significant difference in activity between sites (Kruskal–Wallis test: $H = 17.74$; $df = 5$; $P = 0.003$). Most calls were recorded near the street lamps (site 1, 25.7% of total bat passes), followed by activity at the Tamxid basin (site 2, 22.0%), El Kebiriti pond (site 4, 20.7%), Sassia pond (site 5, 14.4%), Marzoug basin (site 3, 10.7%), and Jmal Ribeh pond (site 6, 6.5%). Differences were only significant between street lamps, Tamxid basin, El Kebiriti pond, Sassia pond and Jmal Ribeh pond ($p < 0.001$ for the four paired comparisons; the post–hoc multiple comparison tests are very conservative).

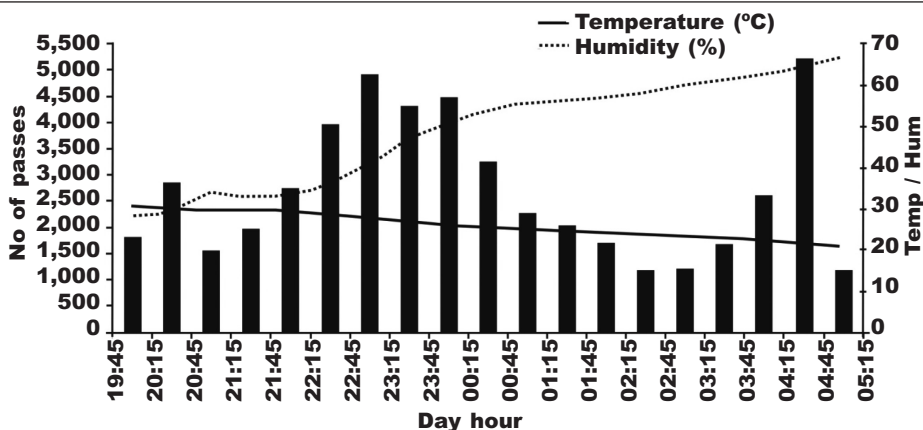


Fig. 2. Overnight activity pattern of bats for each 30-minute period starting after sunset in Dghoumes National Park (southwest Tunisia): sum of number of passes recorded at six sites (one night per site) from June 16 to 24, 2018.

Fig. 2. Patrón de actividad nocturna de los murciélagos en periodos de 30 minutos a partir de la puesta del sol en el Parque Nacional de Dghoumes (suroeste de Túnez): suma del número de pasos registrados en seis emplazamientos (una noche por emplazamiento), del 16 al 24 de junio de 2018.

Three species were recorded near the street lamps at the park entrance (site 1) with *Pipistrellus kuhlii* more commonly recorded (96.4% of passes) than *Eptesicus isabellinus* and *Asellia tridens*. Four species were recorded at each water body (sites 2 to 6): *E. isabellinus*, *P. kuhlii*, *A. tridens* and *Tadarida teniotis*, the latter being the least recorded. *E. isabellinus*, which was the only species that was mist-netted, and *P. kuhlii* were by far the most active. *A. tridens* was mainly recorded at temporary water bodies. *Rhinopoma cystops* was recorded at three water bodies (sites 2, 4 and 5), and *Vansonia rueppelli* was very rarely detected at two water bodies (sites 3 and 6) (table 1).

Bats were most active overnight when temperature declined, and hygrometry increased (fig. 2) with a significant difference in activity between periods (Friedman test: $H = 15.21$, $df = 5$, $P = 0.009$). *P. kuhlii* (29,005 passes) and *E. isabellinus* (19,164 passes) were active overnight at water bodies and emitted feeding and drinking buzzes; differences between periods were significant ($H = 86.15$, $df = 7$, $P < 0.001$; $H = 106.46$, $df = 7$, $P < 0.000$, respectively). *P. kuhlii* displayed three periods of high activity: just after sunset near water bodies; three to four hours after sunset, mainly near the street lamps; and just before sunrise near the street lamps and water bodies (fig. 3A). *E. isabellinus* exhibited a similar pattern except that its activity was low just after sunset, and was very low overnight near the street lamps (fig. 3B). *A. tridens* was active late after sunset (fig. 4), activity peaked 1–2 hours after sunset and decreased slightly until sunrise. *R. cystops* was active soon after sunset (5 to 20 min) and was irregularly active until three hours before sunrise (fig. 4). The numbers of passes of the two remaining species were too low to determine a pattern.

Our visual bat census recorded 111 individuals of *R. cystops* emerging from the Jebel Morra cave on June 19, 2018, and 54 individuals of *A. tridens* resting in the dome of the Ecomuseum exhibition room on June 23, 2018.

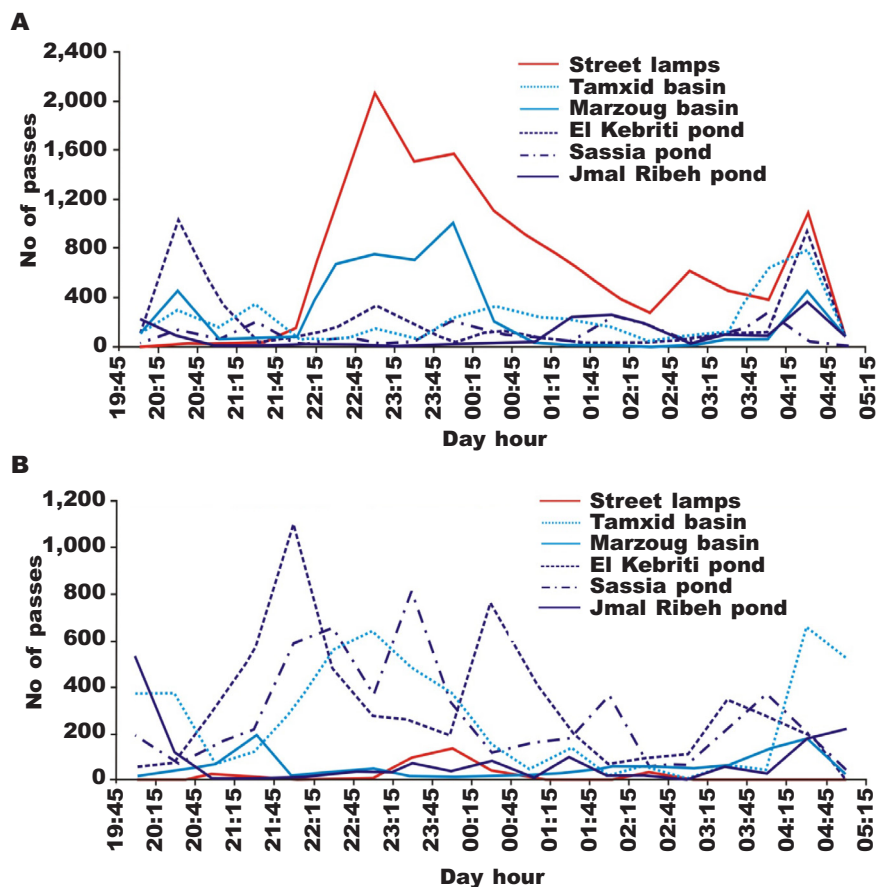


Fig. 3. Overnight activity pattern of *Pipistrellus kuhlii* (A) and *Eptesicus isabellinus* (B) for each 30-minute period starting after sunset at six sites of Dghoumes National Park (southwest Tunisia) in June 2018 (one night per site).

Fig. 3. Patrón de actividad nocturna de *Pipistrellus kuhlii* y *Eptesicus isabellinus* (B) en periodos de 30 minutos a partir de la puesta del sol en seis emplazamientos del Parque Nacional de Dghoumes (suroeste de Túnez) en junio de 2018 (una noche por emplazamiento).

Discussion

Bat richness was lower than that in similar studies in central and northern Tunisia (11 species in Jebel Mghilla National Park and Mastouta–Bishshouk region, Dalhoumi et al., 2014, 2019). Our results reflect the difficulty in detecting bat fauna in deserts even in areas where water is available throughout the year.

The bat assemblage recorded in this study included three Mediterranean (*P. kuhlii*, *E. isabellinus* and *T. teniotis*) and three Saharan bat species (*R. cystops*, *A. tridens* and *V. rueppellii*). Previously reported in this park (Puechmaile et al., 2012), *P. kuhlii* is widespread

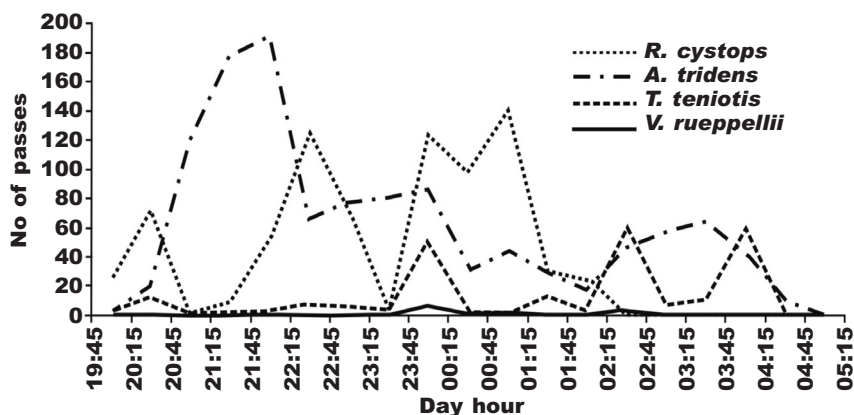


Fig. 4. Overnight activity pattern of *Rhinopoma cystops*, *Asellia tridens*, *Tadarida teniotis* and *Vansonia rueppellii* for each 30-minute period starting after sunset in Dghoumes National Park (southwest Tunisia) in June 2018 (one night per site).

Fig. 4. Patrón de actividad nocturna de *Rhinopoma cystops*, *Asellia tridens*, *Tadarida teniotis* y *Vansonia rueppellii* en periodos de 30 minutos a partir de la puesta del sol en el Parque Nacional de Dghoumes (suroeste de Túnez) en junio de 2018 (una noche por emplazamiento).

in Tunisia (Dalhoumi et al., 2011) and in northern Sahara (Happold and Happold, 2013). The ranges of *E. isabellinus* and *T. teniotis* only reach the Saharan border (Happold and Happold, 2013), and are possibly restricted to Chott el-Jérid in southwestern Tunisia. *R. cystops* and *A. tridens*, both widely distributed in the Sahara (Happold and Happold, 2013), were also reported in this Park by Gharaibeh (1997) and Puechmaille et al. (2012). *V. rueppellii* is considered rare in the Sahara (Happold and Happold, 2013) and only one specimen was collected by G. Nobis near Matmata, Tunisia (east of Chott el-Jérid) (Dalhoumi et al., 2011).

The bat assemblage in Dghoumes National Park could perhaps be expanded by one species, *Myotis punicus*, as it was previously reported close by in Nefta (Wandeler, 1967). Future studies in the area should aim at finding *R. ferrumequinum*, *Otonycteris hemprichii* and *Plecotus gaisleri*, which were reported in arid areas to the north and south-east of the Chott region in Tunisia (Dalhoumi et al., 2011; Puechmaille et al., 2012), and from similar zones of neighbouring countries (Kowalski and Rzebiak-Kowalska, 1991; Ahmim and Oubaziz, 2017; Aulagnier et al., 2017). However, these species are difficult to detect during a short survey with a Song Meter detector (SM2+) because they emit signals with low intensity (Holderied et al., 2011; Barataud, 2012); this detector has a significant rate of attenuation with distance (Adams et al., 2012). *Nyctinomus aegyptiacus* was only reported in Ksar Ghilane (south Tunisia), where a dead specimen was identified (Bendjeddou et al., 2016); the echolocation calls of this bat have not been described previously in North Africa. Future studies should also aim at building high-quality echolocation call libraries.

In this survey, we only recorded bat echolocation calls at water bodies and street lamps. Our data confirm the strong affinity that bats have to water bodies in desert areas (Williams and Dickman, 2004; Rabe and Rosenstock, 2005; Rebelo and Brito, 2006; Razgour et al., 2010; Adams and Kwiecinski, 2018). Bats use these places to forage and drink, as in other Mediterranean areas (Russo and Jones, 2003; Di Salvo et al., 2009; Lisón and Calvo, 2011; 2014; Dalhoumi et al., 2014, 2016). The main entrance to the park is the only lit area in

20 km; the white light attracts some insects (Rowse et al., 2016) that may be preyed by bats such as *Pipistrellus* spp. (Haffner and Stutz, 1985–86; Blake et al., 1994; Lacoueilhe et al., 2014). This type of lighting could deter other local fauna that also depend on the water bodies in the area. Following Voigt et al. (2018), who considered that all external artificial light should be avoided at night, we suggest that the present lamps should be replaced by lamps with a colour temperature < 2,700 K. This would ensure that the area is sufficiently lit for human visitors while simultaneously decreasing disturbance to the local fauna.

In Dghoumes National Park, the activity of most species of bats, mainly recorded as feeding and drinking buzzes, started at dusk near water bodies. Similarly, Griffiths (2013) and Russo et al. (2016) reported drinking buzzes only early on in the night, suggesting that bats cover their water requirements as soon as they emerge from their roost. For *P. kuhlii*, this first peak of activity was similar at water bodies in Bou Hedma National Park (central Tunisia; Dalhousmi et al., 2017) and in Algerian capture records (Gaisler and Kowalski, 1986). In our study, activity peaked for the second time 3h 30' after sunset and for the third time one hour before sunrise. In the Negev desert, Razgour et al. (2011) also recorded three peaks of activity for *P. kuhlii*, with the two first peaks occurring slightly later in the night.

Foraging activity of *E. isabellinus* was concentrated in around several water bodies (Tamaxid basin, Sassia pond and El Kebriti pond) until midnight. It decreased shortly afterwards and ended at sunrise. This pattern, including a maximum soon after sunset, is in accordance with previous records of early night foraging (Brosset, 1955; Gaisler and Kowalski, 1986; Pérez Jordá, 1995). Contrary to our previous findings in Bou Hedma National Park (Dalhousmi et al., 2017), no significant activity was recorded near street lamps, suggesting they are not a swarming place (Altringham, 2011).

Finally, the activity of *A. tridens* peaked late after sunset and stopped before sunrise. This pattern should be confirmed as this species is known to be tolerant to light when roosting; it has been sighted flying in broad daylight in Morocco (Aulagnier et al., 2017), and reported to emerge before dusk in Algeria (Kowalski and Rzebiak–Kowalska, 1991).

Conservations perspectives

The activity pattern of the six bat species recorded in Dghoumes National Park confirmed the importance of permanent water bodies for Mediterranean or desert bats. Considering the fast changing environmental conditions that we are facing, the rapid expansion of the desert, and the importance of environmental education that attracts visitors to this area, we suggest creating artificial ponds along the main wadi of the park and changing the type of lighting at the entrance to the park. These changes would encourage local bat fauna, and potentially other species, to use Dghoumes National Park as a refuge. Additionally, as the Ecomuseum hosts the most important colony of *A. tridens* known to date in Tunisia, and is jeopardized when the exhibition room is open to the public, we suggest restricting access to areas where the colony is roosting by fitting a false ceiling. Our recommendations are in line with the expectations of the World Bank donation to implement a series of conservation actions that better protect the fauna at Dghoumes National Park.

Acknowledgements

Bats were sampled and collected under Permit No. 1257 issued by the Directorate–General for Forests, Tunis. Chokri Issaoui manager of Dghoumes National Park and forest rangers provided great support and help in the field. Abdelkader Chitoui shared unpublished data, Hibat–Allah Loumassine counselled on the identification of some bat calls, and anonymous reviewers helped to improve this manuscript by their comments. We are grateful to Eurobats for supplying us with the bat detectors.

References

- Adams, A. M., Jantzen, M. K., Hamilton, R. M., Fenton, M. B., 2012. Do you hear what I hear? Implications of detector selection for acoustic monitoring of bats. *Methods in Ecology and Evolution*, 3(6): 992–998.
- Adams, R. A., Kwiecinski, G. G., 2018. Sonar surveys for bat species richness and activity in the Southern Kalahari Desert, Kgalagadi Transfrontier Park, South Africa. *Diversity*, 10(3): 1–10.
- Ahmim, M., Oubaziz, B., 2017. New data on the distribution of bats (Chiroptera) in Algeria. *Acta Societatis Zoologicae Bohemicae*, 81: 17–30.
- Altringham, J. D., 2011. Bats. *From evolution to conservation* (2nd edition). Oxford University Press, New York, N.J.
- Aulagnier, S., Cuzin, F., Thévenot, M., 2017. Chiroptera. In: *Mammifères sauvages du Maroc. Peuplement, répartition, écologie*: 117–154 (S. Aulagnier, F. Cuzin, M. Thévenot, Eds). Société Française pour l'Etude et la Protection des Mammifères, Paris, France.
- Baker, R. J., Davis, B. L., Jordan, R. G., Binous, A., 1974. Karyotypic and morphometric studies of Tunisian mammals: bats. *Mammalia*, 38(4): 695–710.
- Barataud, M., 2012. Ecologie acoustique des Chiroptères d'Europe. *Identification des espèces, étude de leurs habitats et comportements de chasse*. Biotope – Publications Scientifiques du Muséum, Paris, France.
- Battersby, J. (comp.), 2010: Guidelines for surveillance and monitoring of European bats. *Eurobats Publication Series*, 5: 1–95.
- Benda, P., Červený, J., Konečný, A., Reiter, A., Ševčík, M., Uhrin, M., Vallo, P., 2010. Some new records of bats from Morocco (Chiroptera). *Lynx, n. s. (Praha)*, 41: 151–166.
- Bendjeddou, M. L., Loumassine, H. E., Metallaoui, W., Chiheb, K., Farfar, A., Bounaceur, F., Boukheroufa F., Bouslama Z., Dietz, C., 2016. First record of *Nyctinomus aegyptiacus* for Tunisia. *Vespertilio*, 18: 23–27.
- Blake, D., Hutson, A., Racey, P., Rydell, J., Speakman, J., 1994. Use of lamplit roads by foraging bats in southern England. *Journal of Zoology*, 234(3): 453–462.
- Brosset, A., 1955. Observations sur la biologie des Chiroptères du Maroc oriental. *Bulletin de la Société des Sciences naturelles et physiques du Maroc*, 35(4): 295–306.
- Curran, M., Kopp, M., Beck, J., Jakob, F., 2012. Species diversity of bats along an altitudinal gradient on Mount Mulanje, southern Malawi. *Journal of tropical Ecology*, 28: 243–253.
- Dalhoumi, R., Aissa, P., Aulagnier, S., 2011. Taxonomie et répartition des Chiroptères de Tunisie. *Revue suisse de Zoologie*, 118(2): 265–292.
- 2016. Bat species richness and activity in the Bou Hedma National Park (central Tunisia). *Turkish Journal of Zoology*, 40: 864–875.
- Dalhoumi, R., Hedfi, A., Aissa, P., Aulagnier, S., 2014. Bats of Jebel Mghilla National Park (central Tunisia): first survey and habitat-related activity. *Tropical Zoology*, 27(2): 53–62.
- Dalhoumi, R., Morellet, N., Aissa, P., Aulagnier, S., 2017. Seasonal activity pattern and habitat use by the Isabelline serotine bat (*Eptesicus isabellinus*) in an arid environment of Tunisia. *Acta Chiropterologica*, 19(1): 141–153.
- Dalhoumi, R., Nefla, A., Bedoui, W., Ouni, R., Aulagnier, S., 2019. Preliminary habitat-related bat fauna of Mastouta–Bishshouk region (Northwest Tunisia). *Vestnik Zoologii*, 53(1): 23–30.
- Di Salvo, I., Russo, D., Sará, M., 2009. Habitat preferences of bats in a rural area of Sicily determined by acoustic surveys. *Hystrix, the Italian Journal of Mammalogy (n.s.)*, 20(2): 137–146.
- Dietz, C., Von Helversen, O., Nill, D., 2007. *Handbuch der Fledermäuse Europas und Nordwestafrikas*. Franckh–Kosmos, Stuttgart, Germany.
- Dieuleveut, T., Liéron, V., Hingra, Y., 2010. Nouvelles données sur la répartition des Chiroptères dans le Maroc oriental (années 2007 à 2009). *Bulletin de l'Institut Scientifique, Rabat, Section Sciences de la Vie*, 32(1): 33–40.
- Disca, T., Allegrini, B., Prié, V., 2014. Caractéristiques acoustiques des cris d'écholocation

- de 16 espèces de Chiroptères (Mammalia, Chiroptera) du Maroc. *Vespère*, 3: 209–229.
- Fenton, M. B., Simmons, N. B., 2014. *Bats: A world of science and mystery*. University of Chicago Press, Chicago, IL.
- Gaisler, J., Kowalski, K., 1986. Results of the netting of bats in Algeria (Mammalia: Chiroptera). *Vestník Československé Společnosti Zoologické*, 50: 161–173.
- Georgiakakis, P., Vasilakopoulos, P., Mylonas, M., Russo, D., 2010. Bat species richness and activity over an elevation gradient in Mediterranean shrublands of Crete. *Hystrix, the Italian Journal of Mammalogy*, 21(1): 43–56.
- Gharaibeh, B. M., 1997. Systematics, distribution and zoogeography of mammals in Tunisia. PhD Thesis, Texas Tech University, Lubbock, TX.
- Griffiths, S. R., 2013. Echolocating bats emit terminal phase buzz calls while drinking on the wing. *Behavioral Processes*, 98: 58–60.
- Haffner, M., Stutz, H. P. B., 1985–86. Abundance of *Pipistrellus pipistrellus* and *Pipistrellus kuhlii* foraging at street lamps. *Myotis*, 23–24: 167–172.
- Happold, M., Happold, D. C. D. (Eds.), 2013. Mammals of Africa. Volume IV: *Hedgehogs, shrews and bats*. Bloomsbury Publishing, London, UK.
- Herk, K. M. B., Barnikel, G., Skidmore, A. K., Fahr, J., 2016. A high-resolution model of bat diversity and endemism for continental Africa. *Ecological Modelling*, 320: 9–28.
- Holderied, M. W., Korine, C., Moritz, T., 2011. Hemprich's long-eared bat (*Otonycteris hemprichii*) as a predator of scorpions: whispering echolocation, passive gleaning and prey selection. *Journal of comparative Physiology A*, 197(5): 425–433.
- Hutson, A. M., Mickleburgh, S. P., Racey, P. A., 2001. *Microchiropteran bats: global status survey and conservation action plan*. IUCN/SSC Chiroptera specialist group, IUCN, Gland, Switzerland.
- Jebali, A., 2012. *Recensement et sex-ratio des antilopes sahélo-sahariennes réintroduites dans les aires protégées du Sud Tunisien*. Rapport Technique préliminaire N°1 pour EWA Conservation Committee et DGF.
- Jones, G., Morton, M., Hughes, P. M., Budden, R. M., 1993. Echolocation, flight morphology and foraging strategies of some West African hipposiderid bats. *Journal of Zoology*, 230(3): 385–400.
- Kowalski, K., Rzebić-Kowalska, B., 1991. *Mammals of Algeria*. Ossolineum, Wrocław, Poland.
- Lacoeuilhe, A., Machon, N., Julien, J. F., Le Bocq A., Kerbiriou, C., 2014. The influence of low intensities of light pollution on bat communities in a semi natural context. *Plos One*, 9(10): e103042.
- Liéron, V., Poulouin, E., Amezian, M., Qninba, A., Thévenot, M., 2008. Inventaire des Chiroptères de l'arrière-pays du port Tanger-Méditerranée (nord-ouest du Maroc). *Bulletin de l'Institut Scientifique, Rabat, Section Sciences de la Vie*, 30: 53–54.
- Lisón, F., Calvo, J. F., 2011. The significance of water infrastructures for the conservation of bats in a semi-arid Mediterranean landscape. *Animal Conservation*, 14(5): 533–541.
- 2014. Bat activity over small ponds in dry Mediterranean forests: implications for conservation. *Acta Chiropterologica*, 16(1): 95–101.
- Monadjem, A., Conenna, I., Taylor, P. J., Schoeman, C., 2018. Species richness patterns and functional traits of the bat fauna of arid southern Africa. *Hystrix, the Italian Journal of Mammalogy*, 29(1): 19–24.
- Owen, J. G., 1990. Patterns of mammalian species richness in relation to temperature, productivity, and variance in elevation. *Journal of Mammalogy*, 71(1): 1–13.
- Perez-Jorda, J. L., 1995. Ecología del murciélago hortelano, *Eptesicus serotinus*, en Andalucía. *Boletín SECEM*, 6: 12–17.
- Puechmaille, S., Hizem, W. M., Allegrini, B., Abiadh, A., 2012. Bat fauna of Tunisia: review of records and new records, morphometrics and echolocation data. *Vespertilio*, 16: 211–239.
- Rabe, M. J., Rosenstock, S. S., 2005. Influence of water size and type on bat captures in the lower Sonoran Desert. *Western North American Naturalist*, 65(1): 87–90.

- Rakotomalala, R., 2005. *TANAGRA: A free software for research and academic purposes*. In: *Proceedings of European Grid Conference 2005*. RNTI–E–3, Amsterdam, The Netherlands.
- Ramos Pereira, M. J., Palmeirim, J. M., 2013. Latitudinal diversity gradients in New World bats: are they a consequence of niche conservatism? *Plos One*, 8(7): e69245.
- Razgour, O., Korine, C., Saltz, D., 2010. Pond characteristics as determinants of diversity and community structure in desert bats. *Animal Conservation*, 13: 505–513.
- 2011. Does interspecific competition drive patterns of habitat use in desert bat communities? *Oecologia*, 167(2): 493–502.
- Rebelo, H., Brito, J. C., 2006. Bat guild structure and habitat use in the Sahara desert. *African Journal of Ecology*, 45(2): 228–230.
- Rowse, E. G., Harris, S., Jones, G., 2016. The switch from low–pressure sodium to light emitting diodes does not affect bat activity at street lights. *Plos One*, 11(3): e0150884.
- Russ, J., 1999. *The bats of Britain and Ireland: Echolocation calls, sound analysis, and species identification*. Alana Ecology Books, Belfast, Northern Ireland.
- Russo, D., Ancillotto, L., Cistrone, L., Korine, C., 2016. The buzz of drinking on the wing in echolocating bats. *Ethology*, 122(3): 226–235.
- Russo, D., Jones, G., 2003. Use of foraging habitats by bats (Mammalia: Chiroptera) in a Mediterranean area determined by acoustic surveys: conservation implications. *Ecography*, 26(2): 197–209.
- Simmons, N. B., Cirranello, A. L., 2020. Bat species of the World: a taxonomic and geographic database, <https://batnames.org/explore.html> [Accessed on 24 June 2020].
- Voigt, C. C., Azam, C., Dekker, J., Ferguson, J., Fritze, M., Gazaryan, S., Hölker, F., Jones, G., Leader, N., Lewanzik, D., Limpens, H. J. G. A., Mathews, F., Rydell, J., Schofield, H., Spoelstra, K., Zagamajster, M., 2018. Guidelines for consideration of bats in lighting projects. *Eurobats Publication Series*, 8: 1–62.
- Wandeler, A. I., 1967. Die Wirbeltiere von Nefta. Beitrag zur Ökologie einer Oase. *Naturhistorisches Museum Bern Jahrbuch*, 1963–1965: 229–292.
- Weber, M., Cáceres, N., 2018. Spatial variation in bat species richness in a forest–grassland transitional region of southeastern South America. *Oecologia Australis*, 22(2): 156–167.
- Williams, A. J., Dickman, C. R., 2004. The ecology of insectivorous bats in the Simpson Desert central Australia: habitat use. *Australian Mammalogy*, 26(2): 205–214.
- Wilson, D. E., Reeder, D. M., 2005. *Mammal species of the World. A taxonomic and geographic reference* (3rd edition). The Johns Hopkins University Press, Baltimore, MD.