Journal of Mountain Ecology, 11 (2018): 1–58

The bats of Gran Paradiso National Park: A preliminary characterization based on summer surveys

Elena Patriarca*, Paolo Debernardi, and Laura Garzoli

S.Te.P., Stazione Teriologica Piemontese, c/o Museo Civico di Storia naturale,
Carmagnola, Italy

ABSTRACT

From 2011 to 2015, we carried out summer surveys aimed at compiling an inventory of bat species and furnishing a preliminary characterization of their distribution in Gran Paradiso National Park, the largest protected area in the Western Italian Alps. Data were collected through mist-netting, acoustic recording and inspection of potential roost sites.

A total of 187 individuals were mist-netted, belonging to 10 different species. Among them, *P. pipistrellus* and *P. macrobullaris* were the most abundant and frequently caught, respectively on water bodies, and on alpine pastures and prairies.

At least 14 species were detected through acoustic surveys.

Most of the acoustic data resulted from operating according to standardized protocols involving early and late summer samplings at fixed points located far from artificial light sources. *P. pipistrellus*, genus *Myotis* and *H. savii*, in this order, were the most recorded taxa in ecotones (wood edges, clearings, forest trails) and open habitat types (pastures above current forest limits) between 800 and 2,200 m a.s.l. No clear dominance of any species or acoustic group could be recognized in the recordings collected between 2,200 and 2,600 m, although at a site where a greater sampling effort was performed genus *Plecotus* turned out to be the most recorded taxon. At high elevations, acoustic and mist-netting data revealed the presence of species such as *P. macrobullaris* and *T. teniotis* – which certainly find there both foraging and roosting opportunities – together with bats usually associated with lower elevations, such as *M. myotis* vel *blythii* and *N. leisleri*, possibly attracted to pastures and prairies by the availability of some prey.

As a general trend, mean bat activity decreased with elevation and when moving to zones with a simpler vegetation structure, but profound differences, both in terms of activity and species occurrence, were observed on a local basis.

Two open areas of one valley, both characterized by pastures, absence of artificial lighting and similar elevation (about 2,000–2,100 m), but differing in other ecological conditions (presence/absence of lentic water bodies, distance from woods, exposition, zootechnical use) were surveyed more in depth. In one area, bat activity was mostly dominated by *P. pipistrellus*, with genus *Myotis* and *E. nilssonii* following far behind; in the other area, co-dominance of *H. savii* and *P. pipistrellus* was observed, while the next most-recorded acoustic category was the group of species *Eptesicus serotinus/Vespertilio murinus/Nyctalus leisleri/Nyctalus noctula*.

---

* *Corresponding author:* Elena Patriarca, S.Te.P., c/o Museo Civ. St. Nat., via S. Francesco di Sales, 188; 10022 Carmagnola (TO); Email: teriologi@gmail.com

Published by the Gran Paradiso National Park.

Part of the acoustic surveys were carried out in the presence of insect-attractive artificial light sources. Results suggest that artificial lighting plays an important role in conditioning the presence and the activity of bats in the Park. According to the preliminary data collected along valley bottoms, genera *Myotis* and *Plecotus* and *B. barbastellus* seem to occur more frequently at unlighted rather than at lighted sites. At high elevations, profound differences were observed between a strongly-lighted and some unlighted sites: total bat activity was exceptionally higher at the former; moreover, data suggested different levels of attraction to forage at lamps among bat species and no attraction at all for genus *Myotis*.

Because of the scarcity of underground sites in the Park, only a few results were obtained by inspecting potential roost sites. Sixteen *roosts* (mainly in buildings) were identified; they were used by at least 5 species, among which *P. macrobullaris* prevailed.

As a whole, the presence of at least 16 bat species was ascertained in the Park: *M. daubentonii*, *M. mystacinus*, *Myotis myotis* vel *blythii*, *Myotis nattereri* complex, *P. kuhlii, P. pipistrellus, P. pygmaeus*, *H. savii*, *E. nilssonii*, *E. serotinus*, *V. murinus*, *N. leisleri*, *P. auritus*, *P. macrobullaris*, *B. barbastellus* and *T. teniotis.* For most of the species, national altitudinal records were recorded.

Keywords: Bats, Chiroptera, Parco Nazionale Gran Paradiso, Alps, distribution, elevation, artificial lighting

1. INTRODUCTION

Present knowledge about the distribution and ecology of bats in the Italian Alps is far from complete. Data collected in the past are largely questionable because of the need for taxonomic validation, and recent information is scanty.

This situation applied also to the Gran Paradiso National Park, the largest protected area in the Western Italian Alps. Some basic mammal surveys carried out in the area in the 1990s, only marginally dedicated to bats, led to record the presence of 4 bat species, at the time identified as *Myotis mystacinus*, *Pipistrellus pipistrellus*, *Plecotus auritus* and *Hypsugo savii* (Patriarca and Debernardi, 1997). Afterwards, following the discovery of cryptic species previously confused with the first three of them (respectively *Myotis alcathoe*, *Pipistrellus pygmaeus* and *Plecotus macrobullaris*), the question of possible bias in their identification was raised. A re-examination of the materials collected during the surveys made it possible to correct some of the *Plecotus* records, which were attributed to *P. macrobullaris*, but no definitive conclusion could be drawn about the other species based on the available material (Debernardi and Patriarca, 2008).

From September 2011 to September 2015, during the summer months, new surveys were carried out in the Park, aimed at collecting basic information on the occurrence of bat species and their ecological distribution. Attention was paid to the possible role of artificial lighting in conditioning bat presence, since it is known that different bat species react differently to this factor (some forage near lamps, others are light-averse). Moreover, the effects of artificial light sources might be more evident in an area still widely characterized by a low degree of light pollution.

Gaining a better knowledge about the bat fauna of the Park was of interest also in order to plan effective conservation strategies for a zoological group that notoriously provides ecosystem services (Kunz *et al.*, 2011), can be used as an excellent bioindicator (Jones *et al.*, 2009; Russo and Jones, 2015), and comprises species in a precarious conservation state (Hutson *et al.*, 2001; Voight and Kingston, 2016).

2. STUDY AREA

Gran Paradiso National Park is located in North-West Italy, in the Graian Alps, stretching across the regions of Piedmont (Orco and Soana valleys) and Aosta Valley (Rhemes, Savarenche and Cogne valleys) (Figure 1). It covers an area of 71,044 hectares, varying in elevation from about 800 to 4,061 m a.s.l.

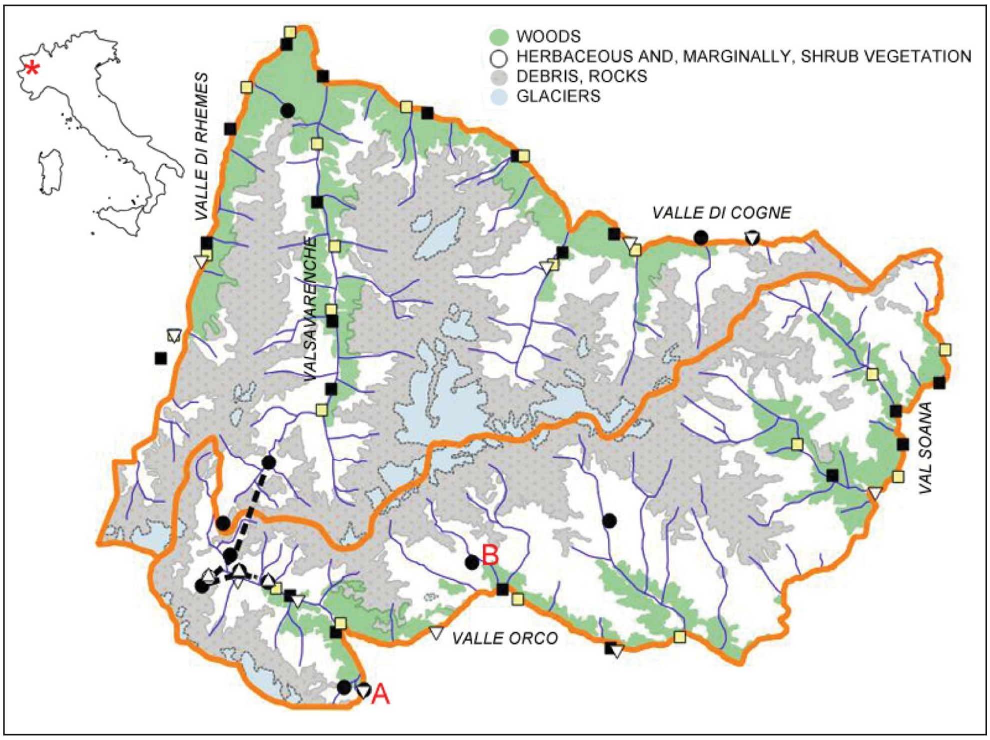

Figure 1 Study area: the Gran Paradiso National Park.

Bold line = Park borders and (inner line) partition between the Aosta Valley (*above*) and Piedmont (*below*).

Localization of the main surveying sites:

Squares = acoustic surveying points beneath current forest limits, in absence (black squares) or presence (yellow squares) of artificial light sources;

bJack circles = acoustic surveying points, in absence of artificial light sources, that have been considered for the general characterization of bat activity above current forest limits;

downward triangles = mist-netting points over water bodies;

upward triangles = mist-netting points on pastures/prairies;

A, B = areas which underwent a more intense acoustic surveying effort;

dotted line = altitudinal transect with acoustic surveying points in absence (black circles) or presence (white circles) of artificial light sources.

Climate is typically alpine, with a sublittoral rainfall regime and harsh winters, often characterized by abundant snowfalls.

Geological substrate is rather uniform and mainly dominated by acidic gneiss, which gives rise to acid soils; basic soils, derived from calcschists, cover a minor part of the area.

About 62% of the Park is occupied by glaciers and rocks, 17% by alpine prairies, meadows and pastures, and 20% by woods and bushes. Forest habitat types are mainly represented by coniferous woods dominated by either *Larix decidua* (largely favoured by man during the centuries) or *Picea abies*, or co-dominated by both such species; *Abies alba* and *Pinus sylvestris* are confined respectively to some damper and drier areas; *Pinus cembra* is localized on the Aosta Valley side and never forms pure communities, probably due to its selective felling during the past. Deciduous woods are confined to the lower elevations and mainly located on the Piedmontese side. They are often composed of mixed broad-leaved species (most common trees: *Fraxinus excelsior*, *Acer platanoides*, *A. pseudoplatanus*, *Betula pendula*, *Sorbus aucuparia* and *S. aria*) or, limited to the Piedmontese valleys, dominated by *Castanea sativa* (cultivated in the past) and, marginally, by *Fagus sylvatica*.

Upper limits of forests have been lowered during the centuries through timber cutting and pasture use, as it generally happened in large parts of the Alps.

Villages, the largest of which has about 1,500 residents, are present along valley bottoms, where they lay in large part just below the Park borders. Human activities are mainly connected with tourism and alpine zootechny (haying and grazing in the montane vegetation belt, and summer grazing, mainly by cattle, at higher elevations).

3. METHODS

In order to characterize the bat fauna of an area and, particularly, to inventory the occurring species, it is convenient to adopt a multiple-technique approach (Flaquer *et al.*, 2007). Therefore, surveys were conducted using different techniques: mist-netting, acoustic recording and inspection of potential roost sites.

3.1. Mist-netting

Bats in flight over water bodies (small lakes, ponds, stream pools) were captured at 11 sites (Figures 1 and 2). Seven sites were located between 800 and 1,800 m and 4 sites between 1,800 and 2,400 m. At the lower elevations the use of this surveying technique was limited due to the lack of suitable (lentic) water bodies, while at high elevations an important constraint was the low probability of capture, conditioned by a great abundance of water bodies (glacial and barrage lakes) that presumably cause dispersal of drinking/foraging individuals.

At each site, only one mist-netting session was performed, with the exception of a site in which the activity was carried out on 3 different nights, over a great distance of time, and yet capture results (species, sex, age of captured bats) allowed

Figure 2 Setting the nets over a pond in Rhemes Valley (Pellaud, 1,820 m a.s.l.).

for exclusion of recaptures. Consequently, all the captured bats can be assumed to be different individuals.

Additional mist-netting was performed at 4 sites on alpine pastures and prairies with capture success at 3 sites, located between 1,800 and 2,300 m (Figures 1 and 3).

As a whole, bats were captured at 14 sites, 7 of which were situated below 1,800 m and 7 above such elevation.

Nets (ultra-thin monofilament mist nets and hair nets with a 14×14 mesh size, ECOTONE) were kept open and continuously monitored between sunset and midnight or, in some cases, until 2:00 a.m., always operating in favourable weather conditions.

Morphological identification of captured individuals was carried out referring to the key by Dietz and von Helversen (2004). Body measurements were taken using a digital pocket scale (±0.1 g), a caliper (±0.1 mm) and, for the smallest measures of length, a scaled magnifying glass (10×). Observation of dental morphology, when important for identification, was made from photographs.

Bats belonging to the cryptic species *P. pipistrellus*/*P. pygmaeus* were discriminated by analyzing the echolocation calls they emitted when released, taking care to discard the initial calls of the sequences, which are usually emitted at frequency higher than normal.

Figure 3 Net-setting on an alpine pasture located at 1,978 m a.s.l. in Orco Valley.

Patagium tissue samples were collected using sterile biopsy punches from long-eared bats that proved difficult to identify on the basis of external morphology. Samples were preserved in 95% ethanol at –20 °C until processing. Afterwards, Ecogenics (www.ecogenics.ch) carried out Mt-DNA extraction, PCR amplification of 16S rRNA fragments, sequencing with the primers 16SPle1+ (forward) and 16SPle4– (reverse), and data analysis and interpretation using the identification engine BLAST of the NCBI database (www.ncbi.nlm.nih.gov).

Bats were released at the capture sites after the nets were closed.

All the activities were performed under the proper licences, provided by the Italian Ministry for the Environment and the Protection of Land and Sea (DPN–2008–0001053; DPN–2010–0011879; PNM–2012–0009746; 0008882/PNM), the National Park and the Provinces of Aosta and Turin.

3.2. Roost inspection

Potential roost sites, situated inside the Park or along its borders, were inspected. Sites were chosen based on past records of bats (sites found to be used by bats during the surveys carried out in the 1990s), information gathered by interviewing people who might have known of the presence of bats (park guards, speleologists, parish priests, etc.), the presence of features favourable to bats, and direct inspectability. Tree holes, rock crevices and other interstitial roosts were not inspected.

Bat occurrence was ascertained by the finding of signs of their presence (droppings, prey remains) or through direct observation of individuals, if necessary followed by their capture using hand nets. Furthermore, mist-netting during night-time was carried out at the entrances of the caves and other sites where abundant prey remains had been found.

Captured bats were identified as described above.

Droppings were dissected and, when bat hairs were present, attributed according to hair morphology observed using an optical microscope. Identification was carried out referring to published keys (Pierallini *et al.*, 2004; Dietz and Kiefer, 2014) and by comparison with a personal reference collection.

3.3. Acoustic surveys

This method was used to detect species and “acoustic groups” (i.e. groups of species that emit similar calls and cannot be individually discriminated with certainty), to collect preliminary information about their activity with respect to macro-habitat types and elevation and to point out, at a preliminary level, the possible factors influencing it. The number of bat passes (i.e. number of call sequences counted from spectrograms; recording time as specified below) per hour was used as an index of bat activity. All the surveys were performed from fixed recording points.

3.3.1. Data recording beneath the current forest limits

Data were collected at 20 sampling points – 4 points in each of the five main valleys of the Park – located between approximately 800 and 1,900 m a.s.l. along valley bottoms (Figure 1). All of them were established far from buildings and artificial light sources, in the presence of structural features considered favourable for bat activity: forest routes, clearings and wood edges. Lentic water bodies, which are known to be attractive for many bat species, are rare along the valley bottoms of the Park and, for this reason, they were represented only at 2 sampling sites.

Bat calls were manually recorded in real time on hearing, using a bat detector D1000X Pettersson Elektronik AB (Uppsala, S), set with a sampling rate of 384 kHz and a pre- and post-trigger time respectively of 2 and 3 seconds (actual recording length was about 5,340 ms). In order to detect any bat passing in the detector’s operating range, headphones were used with frequency division in one channel and heterodyne mode in the other, and the instrument was tuned regularly changing the value of the selected frequency to cover frequency ranges of all the bat species that might occur in the area. In a minority of cases, acoustic disturbance caused by insects impeded the listening in the frequency division mode and both the channels had to be kept in the heterodyne mode, varying listening frequency as described.

Records were saved as wave files onto a flashcard storage device. When operating manually as described above, it is possible to collect a maximum of 7 recordings per minute, while during a minute of continuous bat activity 11.2 recordings of 5,340 ms (the length resulting from the bat detector settings) should theoretically be obtained. For this reason, in the few cases when very intense bat activity was observed, the number of sequences identified from recordings collected during phases of continuous activity was multiplied by a factor of 1.6. To avoid bias due to the recorder’s personal skills, all the recordings were made by the same person.

Each one of the 20 sampling points was surveyed twice a year, at the beginning and, in order to detect possible migrants, at the end of summer (respectively on 26 June–5 July and 24 August–15 September) and this scheme was repeated for 2 years, from September 2011 to September 2013, for a total of 80 surveys.

In each survey session, the 4 points of the same valley were visited in the same night. Listening for bats began about 30 minutes before sunset and the time when the first bat pass was heard (and consequently recorded) was used to mark the beginning of the survey. After 30 minutes of listening and recording, the recorder moved by car to the next sampling point, where he immediately started a second surveying period of 30 minutes. The same procedure was repeated at the third and fourth points. The overall activity was finished within the third hour after the sunset or, in a minority of cases, at the beginning of the fourth hour after the sunset. In the second year of the survey, the sequence in which the 4 sites of each valley were surveyed was reversed, so that each site in each session was surveyed at a different hour within the sampling time.

In poor weather conditions, the survey was interrupted to be repeated in better conditions during another night.

Since the purpose of this work was to provide a preliminary characterization, and because of the limited surveying effort performed, data collected at each sampling point were pooled and the possible differences between early and late summer samplings were not investigated.

Simultaneously with the activities described above, a second recorder operated at a further 20 sampling points, each one situated within 3.2 km from the former ones (Figure 1), but, unlike them, located near buildings and artificial lights. Lighting was due to mercury or high pressure sodium lamps, which are known to attract insects and, consequently, also those bat species that have learned to take advantage of such a concentration of prey. The surroundings of the sampling points were marked by vegetation features and conditions of presence/absence of lentic water bodies similar to those of the unlighted sampling points.

Bat acoustic emissions were detected by a D240X Pettersson Elektronik AB bat detector: listening was performed in the heterodyne mode, regularly changing the tuning to cover frequency ranges of all possible occurring bat species; the selected storage time was 3.4 seconds. When a bat was heard, its time expanded (10×) calls were recorded and stored as wave files on a Tascam DR05 digital recorder.

Because of the time required to save the recordings (which made it impossible to collect all bat passes), data collected at the lighted points were compared with those from unlighted points only in terms of frequency of occurrence of each recorded taxon in the overall surveys (80 both at lighted and unlighted sites).

As was done for the unlighted sites, in the second year of the survey the sequence in which the 4 sampling sites of each valley were surveyed was reversed.

3.3.2. Data recording above the current forest limits

Data were collected from fixed points, at several sites across the Park area, during the summers from 2012 to 2015. Three bat detectors were used: a D1000X and a

240X Pettersson Elektronik AB (employed manually as already specified), and an SM2BAT+ Wildlife Acoustics Inc. (Maynard, MA). The latter was equipped with an SMX-UT microphone and was used passively: bat calls were detected and recorded as wave files onto a memory card, operating in real time, with a sampling rate of 384 kHz, Dig HPF fs/48 (8 kHz), Dig LPF off, trigger level 12 dB, trigger window 2 s and maximum length of recordings set to 6 s.

The duration of samplings varied from about one hour to the whole night, and the number of times they were repeated was not the same for each sampling site. Therefore, while the whole data set was used with the aim of inventorying the species of the Park and exploring their altitudinal distribution, only the samplings carried out in unlighted areas, during the first 3 hours after sunset and for 2 different sessions, were considered in order to provide a preliminary characterization of bat activity and to make comparisons with the activity values collected at the sites located beneath the current forest limits. Each sampling lasted a whole period of 3 hours: one was performed earlier (in July) and the other later in summer (12 August–1 September), in order to take into account possible seasonal differences due to the occurrence of migrants. Values collected at each sampling point during the 2 sessions were then averaged. In some cases, samplings were repeated more times during each session and, in order to standardize the results, the mean values observed in each session were considered and then averaged. Sampling points at a distance of less than 500 m from each other and located in areas characterized by homogeneous ecological features were treated as a single sampling site.

The conditions of sampling effort for the characterization of bat activity were met at 13 sites overall (Figure 1). Eight of them were located in the altitudinal range from 1,800 to 2,200 m a.s.l., in open areas below the natural (potential) treeline, currently dominated by herbaceous species as a consequence of timber cutting and pasture use. Hereafter this environmental condition is identified as “alpine 1” habitat type.

The other 5 sites were at higher elevations, between 2,200 and 2,600 m a.s.l. They were characterized by mosaics of alpine prairie, rocks (screes, large boulders, rock faces), peat bogs and lentic water bodies. Due to the altitude and related climatic factors, they are naturally open areas, although they cannot be considered completely natural areas because of their use to graze domestic cattle in summer. Hereafter the habitat type encountered at these sites is referred to as “alpine 2”.

The use of three different bat detectors could represent a limit in the standardization of the surveys, because of the differences in the sensitivity of the microphones and in trigger activation, and, above all, due to the time spent in saving files recorded by the D240X bat detector. To overcome the latter problem, the use of the D240X bat detector was limited to some sampling points located at high elevations, where the low bat activity made it possible to record all the bat passes that were heard.

A more detailed characterization was performed in two areas of the Orco Valley with similar elevation (about 2,000–2,100 m a.s.l.). Such areas were involved in land management projects funded in the framework of the Rural Development

Plan 2007–2013 and a better naturalistic knowledge of them was needed. This provided an occasion for an insight into the differences that can occur, as a consequence of natural and artificial factors, in the bat fauna of the same elevation and geographic sector, in areas characterized by “alpine 1” habitat type and an absence of artificial light sources.

One of the two areas, hereafter named “A”, is located on the north-facing slope of the valley (Figures 1 and 13) and has been subjected to limited anthropic usage. It is reached by the current upper limits of coniferous woods, and some isolated trees and shrubs occur in pastures, which during the years of the survey were used to graze sheep herds.

The other area, named “B”, is located on the opposite, south-facing, side of the valley (Figures 1 and 13). For centuries it has been intensely used for summer livestock raising and deprived of ligneous plants. It is currently entirely covered by herbaceous vegetation, the nearest woods being at a distance of about 700 m from the points where data were collected. During the survey the area was mainly pastured by cows, and marginally by goats and equines.

The two areas also differ in the presence of water bodies: The A area features a small lake (Dres), a pond, several streams (some of which have slow water flow and a meandered course) and peat bogs, while in the B area only very small streams of fast flowing water are present. Boulders and screes occur in both areas and rocky cliffs can be found nearby.

Data were collected in 2013 and 2014, each year repeating exactly the following surveying scheme. In the second half of July, during a first night, two recorders equipped with D1000X and 240X bat detectors operated from 2 fixed points, starting about 15 minutes before sunset and finishing at the end of the third hour after sunset; at a third point, the SM2BAT+ detector was left to record automatically for the entire night. Automatic recording was then repeated for the following 3 nights or, in cases of bad weather, for more nights until the goal of 3 further nights of recording in adequate weather conditions was achieved. In the second half of August, during a single night, the procedure adopted in the first night of July was repeated.

Surveying time was quantified from sunset to the end of the listening period, i.e. the end of the third hour after sunset for manual recordings and sunrise time for automatic recordings. It must be noted that, during the whole survey in the Park, the first bat passes have always been heard after sunset time and the later ones about 15 minutes before sunrise. Sunset and sunrise times were calculated on the bases of geographic latitude and longitude of each sampling site.

The usage of the three different bat detectors and the operators involved were exactly the same in the two areas and in the 2 years of the survey.

During the summer of 2015, another possible cause of local differences in bat activity in open habitat types was explored: artificial lighting at high elevation. Sampling points were identified along an altitudinal transect, roughly near to the road connecting upper Orco Valley to upper Savarenche Valley, at 1,845, 1,978, 2,292, 2,295, 2,355 and 2,460 m a.s.l. (Figure 1). The two lower points were characterized by “alpine 1” habitat type, the others were “alpine 2” sites. All the points were in conditions of natural darkness, except the one at 2,292 m, established near the strong metal halide lamps which illuminate the dam of Lake Serrù. The point at 2,295 m was situated near the same lake, at a distance of 617 m from the former but in natural lighting conditions, and was used as a control "dark" site.

The sites were surveyed monthly from June to September, in the same night or in close nights, firstly for a whole night period and then, during a second night, for the first 3 hours after sunset. Afterwards, in order to compare bat activity at the different points, we selected the data collected during the first 3 hours after sunset characterized by the best weather conditions.

SM2BAT+ and D1000X detectors were mainly employed, limiting the use of the D240X bat detector to a few samplings at sites where bat activity was very scarce (this made it possible to record all bat passes despite the time spent in saving the recordings). Each instrument was operated as already described.

Four of the sites (those at 1,845, 1,978, 2,292 and 2,355 m a.s.l.) were the locations of the mist-netting activity on alpine pastures and prairies. At each of them, mist-netting was performed 1 or 2 days after the acoustic surveys, except in the case of the site with artificial lighting, where in one of the sampling nights acoustic recording and mist-netting were carried on at the same time. This may have affected the acoustic results obtained during that sampling night, since captured bats were released only at the end of the activities.

The sampling site at the highest elevation (2,460 m) has a peculiar naturalistic interest, being situated in the Nivolet plateau, one of the largest mosaics of peat bogs, alpine prairie and small lakes in the Alps. For this reason, it was surveyed for a longer time (overall 18 nights) and the data collected during the 13 nights characterized by best weather conditions (absence or only faint precipitations; minimum temperatures of 6.95 ± 2.18 °C) are presented hereafter.

3.3.3. Sound analysis

Sound analysis was performed in two steps.

Search-phase echolocation calls were first analyzed using the software BatSound version 4.03 (Petterson Elektronik AB, Uppsala, S). A 512-pt Hamming window (98% overlap) was applied.

Myotis, *Plecotus* and *Nyctalus* were identified to genus level and, in the case of noctules, the identification was limited to the sequences of calls showing peak frequency alternation. Sequences characterized by typical short-band FM calls with peak frequency of 31–34 kHz alternating with QCF/descending FM calls peaking at 38–43 kHz were attributed to *B. barbastellus* (Denzinger *et al.*, 2001). Sequences of QCF calls with a peak frequency of 27–29 kHz were preliminarily referred to *E. nilssonii* and afterwards checked according to the second step of analysis (below). *T. teniotis* was identified according to information from several works (among them: Zbinden and Zingg, 1986; Haquart and Disca, 2007; Bayefsky-Anand *et al.*, 2008; Barataud, 2012), referring particularly to frequency of maximum energy (mainly ≤ 12 kHz), duration of the calls (mainly < 17 ms) and length of inter-pulse intervals (mainly < 600 ms).

For *Pipistrellus* species and *H. savii* we adopted the criteria of Table 1, based on values reported in different literature sources (among which: Russo and Jones, 2002; Obrist *et al.*, 2004; Preatoni *et al.*, 2005; Skiba, 2009; Barataud, 2012). Calls characterized by peak energy frequencies intermediate between the more typical values of *P. pipistrellus* and *P. pygmaeus* were conservatively attributed to *Pipistrellus* "50 kHz". The procedure of the second step of analysis (described below) did not provide results reliable enough for their identification, as in many cases it gave contradictory attributions (different calls extracted from the same sequence were attributed to more than one of the following species: *P. pipistrellus*, *P. pygmaeus* and *M. schreibersii*). Discussing the results anyway, we will take into account the high probability that these calls belong to *P. pipistrellus*, since in Piedmont and Aosta Valley *P. pygmaeus* and *M. schreibersii* are rare species. At present, in particular, the latter is known to occur with certainty only at a site located at a low elevation in central Piedmont, about 100 km from the Park: we therefore assumed that the risk of misidentifying *Miniopterus* as genus *Pipistrellus*, in the case of calls recorded in the Park, is remote. Finally, we often observed "50 kHz" echolocation calls in association with social calls of *P. pipistrellus*.

When present, social calls were used for specific identification, referring to descriptions reported by Russo and Jones (1999 and 2000), Pfalzer (2002 and 2007), Pfalzer and Kusch (2003), Skiba (2009), Barataud (2012) and Middleton *et al.* (2014).

The second step of analysis was performed using the software SonoBat 3.11P (DNDesign, Arcata, CA) to measure the calls, and iBatsID (https://sites.google.com/site/ibatsresources/iBatsID; Walters *et al.*, 2012) to classify them. The procedure was applied to the sequences already attributed to genus *Myotis* and characterized by calls of particularly good quality (well-defined, with a good signal-to-noise ratio), to all the sequences attributed to genus *Nyctalus* and *E. nilssonii*, and to the remaining sequences of echolocation calls of good quality that were not identifiable according to the criteria followed in the first step of the analysis.

A highly conservative approach was adopted. For each sequence 3–11 search-phase calls were examined (average 6.2). Identifications suggested by iBatsID were accepted if concordant (i.e. calls extracted from the same sequence were classified in the same way), for the most part associated with a probability of correct classification ≥95%, and referred to species or groups of species for which the software had proved to provide a correct classification rate of at least 75% (Walters *et al.*, 2012). The latter condition led to us exclude *V. murinus* (for this species only social calls were accepted as diagnostic and possible echolocation calls were classified as belonging to the group *E. serotinus*/*N. leisleri*, *N. noctula*/*V. murinus*) and, in genus *Myotis*, to limit the possibility of reaching the last stage of classification to the only *M. nattereri* (complex), while the other species were attributed at best to groups of species. The identification of the couple *M. myotis*/*M. blythii*, was considered reliable in the case of the few sequences recorded in open areas and characterized by FM calls with peak energy of 30–32 kHz, end frequency mostly ≤25 kHz, bandwidth >45 kHz and duration >7 ms.

Identification of long-eared bats was always limited to the genus level because iBatsID does not applies to *P. macrobullaris*, which is present in the study area.

In some cases, the identification of *E. serotinus* was aided by prolonged direct sighting, in good light conditions, of the emitting bats.

3.3.4. Data analysis

A large part of the data collected represented qualitative information or was obtained through a limited surveying effort; consequently it was not treated for statistical significance.

Some basic analysis was performed with reference to the two best surveyed areas of the Orco Valley (A and B). Due to non-normal distribution of data, non-parametric tests were used.

Pearson's Chi-square for two independent samples was used to test for differences in the composition of the overall samples of bat passes recorded in the two areas. Proportions of each species/acoustic group in the samples of both areas (i.e. the total numbers of bat passes of each taxon/acoustic group vs. the sum of bat passes of all other taxa/acoustic groups recorded in each area) were then compared using the same test and applying Yates' correction for continuity and Bonferroni's correction for multiple comparisons.

Since the more general evaluations of bat activity across the Park were performed on data collected during the first part of the night, sub-samples consisting of the bat passes recorded in the two areas during the first 3 hours after sunset were checked in the same way for differences in their proportional composition.

Table 1 Criteria used in the first step of sound analysis to identify part of the echolocation calls emitted by the species of genera *Pipistrellus* and *Hypsugo*. In parentheses, extreme values of peak energy frequency, which have been considered only if other calls of the same sequences showed more typical values, within the specified range. With QCF we refer to calls with a broadband ≤5 kHz

Criteria	Taxa
QCF calls with peak energy frequency of (30.0) 31.0–33.5 (34) kHz.	*H. savii*
QCF calls with peak energy frequency of (35.0) 36–41 (41.5) kHz or FM-QCF calls with peak energy frequency of (38) 38.5–43 (43.5) kHz.	*P. kuhlii* vel *nathusii*
QCF calls with peak energy frequency of (42.5) 43.5–47 (48) kHz or FM-QCF calls with peak energy frequency of (45) 46.0–49.0 (50) kHz.	*P. pipistrellus*
QCF calls with peak energy frequency of 48.0–50.0 kHz or FM-QCF calls with peak energy frequency of (50) 51.0–54.0 (55) kHz.	*Pipistrellus* "50 kHz"
QCF calls with peak energy frequency of (53) 54.0–56.0 kHz or FM-QCF calls with peak energy frequency of >56.0 kHz.	*P. pygmaeus*

Moreover, the values of the activity index (mean number of bat passes/hour, of all species and each taxon/acoustic group) observed during the same 3-hour period in each sampling night were compared by a Mann Whitney *U*-test (two-tailed) for unmatched samples.

Finally, to evaluate if the values collected during the first 3 hours after sunset were a good sample to detect species presence and characterize bat activity, a subsample of data, represented by all the recordings performed during the whole night period, was examined. In each area these data were collected using the same bat detector (SM2BAT+) for 10 nights. Comparisons were made between the values of the activity index recorded in each area during the 3-hour period and in the remaining part of the night; a Wilcoxon signed-rank test (two-tailed) for matched pairs was used.

Further preliminary data analysis was made to compare frequencies of occurrence of species/acoustic groups at lighted and unlighted points surveyed along valley bottoms. Differences were tested by Fisher's exact test (two-tails).

In all tests, significance level was set at $P < 0.05$.

4. RESULTS AND DISCUSSION

4.1. Mist-netting

A total of 187 bats were mist-netted (Figure 5).

Bats captured over water bodies totalled 103 and belonged to at least 8 species: *M. daubentonii*, *M. mystacinus*, *M. nattereri* complex, *P. pipistrellus*, *H. savii*, *E. serotinus*, *V. murinus* and *P. auritus*. Two individuals, classified as *Pipistrellus* "50 kHz", could not be identified to species level because of their ambiguous echolocation calls.

P. pipistrellus largely dominated the sample, being mist-netted with the largest number of individuals (at least 41.7 % of total captures; 43.7% if also the individuals conservatively attributed to *Pipistrellus* "50 kHz" belong to this species) and at nearly all surveyed sites. The second most abundant species was *H. savii* (26.2 % of captured bats), followed by *M. mystacinus* and *P. auritus* (both representing 10.7 % of captures). Among other species, the capture on the Aosta Valley side of the Park of one *V. murinus*, a species never recorded before in the Aosta Valley, was worthy of note (Figure 4).

Different results were obtained through mist-netting on pastures and prairies, where 84 individuals were captured. They belonged to 5 species (*M. mystacinus*, *P. pipistrellus*, *H. savii*, *P. macrobullaris* and *B. barbastellus*) and *P. macrobullaris* was by far the most prevalent (at least 77% of captures). The capture of *B. barbastellus* was unexpected for both the high elevation (2,292 m) and the habitat type ("alpine 2") of the capture point, in which a strong artificial light source was present.

At least for what concerns the two most captured species (*P. pipistrellus* and *P. macrobullaris*), results, although insufficient to be treated statistically, seem consistent with the existence of a sexual segregation depending on elevation, with

Figure 4 The male *Vespertilio murinus* captured in Rhemes Valley (Carrè, 1,644 m) on 23/09/2013.

males occurring at a higher elevation than females: male bats represented 70% of *P. pipistrellus* captured below 1,800 m (72% if also the 2 individuals identified as *Pipistrellus* "50 kHz" are attributed to this species), and 84% of those captured above; *P. macrobullaris*, although present also at lower altitudes (see roost surveys), was mist-netted only at sites above 1,800 m and 95% of captured individuals were males (Figure 5).

Morphological identification of *Plecotus* species and *M. mystacinus* was sometimes problematic.

Only female *P. auritus* were captured and consequently it was not possible to rely on the character of penis shape for identification. Their body measurements and other external traits were consistent with those reported for this species in Dietz and von Helversen (2004), with one exception: the presence of hairs on hind feet was limited to the toes in all the captured individuals and according to the key this is proper of *P. macrobullaris*, while *P. auritus* should have hairs on the whole hind foot and toes. Moreover, hind-foot length ranged from 8.0 to 9.0 mm, while according to some authors (Marchesi *et al.*, 2008) such values are more typical of *P. macrobullaris*, and *P. auritus* has a larger foot (>9 mm). Anyway, genetic analysis confirmed the identification of the individuals as *P. auritus*.

The identification of *P. macrobullaris* proved easier because 97% of the captured individuals showed the characteristic triangular pad on the lower lip (Figure 6), and almost all of them were males, with the possibility to consider, together with the other classification criteria, also the penis shape. Only one of the long-eared

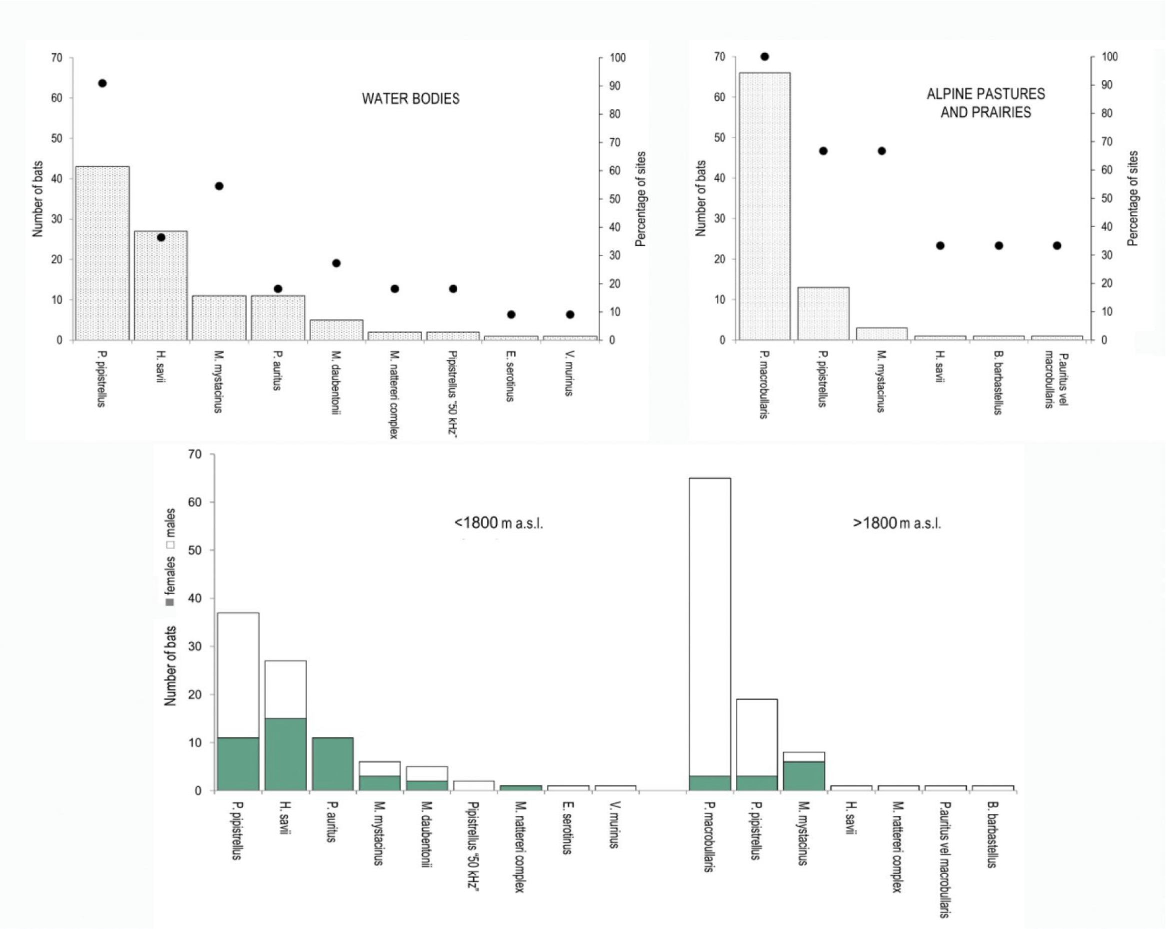

Figure 5 Results of mist-netting: bats captured (bars) and percentage of sites in which they were captured (dots) operating over water bodies (*above, left*) and on pastures/prairies (*above, right*); sex of the captured individuals with respect to elevation (*below*).

Figure 6 A male *Plecotus macrobullaris* captured in Orco Valley, at a site (Lake Serrù, 2,292 m a.s.l.) where 52 individuals of this species were mist-netted on 12/08/2015.

bats captured at high elevation had to be cautiously classified as *P. macrobullaris* vel *auritus* since morphological traits were unclear and its genetic identification has not yet been performed.

M. mystacinus belongs to a group of cryptic species still insufficiently known with respect to their taxonomy and distribution. A preliminary identification of the individuals captured in the Park (Table 2; Figure 7) was carried out on the basis of their external measurements (large enough to exclude *M. alcathoe*), dental characters (singular cusp of the posterior upper premolar absent or very small and middle premolars, compared with the anterior ones, much shorter than in classical

Table 2 Characters recorded on whiskered bats captured in the Park

Elevation of capture site (m a.s.l.)	Sex, age	Forearm (mm)	3rd finger (mm)	5th finger (mm)	Body mass (g)	Singular cusp pm4	pm3	pm3	Penis shape
1,618	F juv.	35.2	51.2	43.0	3.7	absent	MYS	MYS	–
1,644	F ad.	36.0	53.6	44.6	6.2	absent	AUR	MYS	–
1,644	M ad.	34.8	51.7	42.2	4.8	small	AUR	AUR	cyl.
1,665	M ad.	35.2	53.7	43.6	4.8	absent	AUR	n.r.	cyl.
1,665	M ad.	35.1	50.0	43.2	4.8	small	MYS	MYS	cyl.
1,700	F ad.	36.4	53.6	41.2	6.4	absent	lacking	MYS	–
1,720*	M ad.	34.4	53.5	38.9	4.9	absent	MYS	MYS	cyl.
1,820	F ad.	37.2	55.9	45.3	7.1	small	AUR	MYS	–
1,820	F ad.	37.4	57.0	46.9	7.0	small	AUR	AUR	–
1,820	F ad.	36.7	53.7	43.8	6.5	absent	MYS	MYS	–
1,820	F juv.	34.5	49.9	41.2	4.2	small	MYS	MYS	–
1,845	M ad.	34.9	51.2	41.7	5.5	small	MYS	MYS	cyl.
1,880	F juv.	33.5	47.8	39.9	4.3	absent	AUR	AUR	–
2,292	F ad.	36.7	57.0	46.1	6.6	absent	MYS	MYS	–
2,292	M ad.	34.6	54.1	43.4	4.9	small	MYS	MYS	cyl.

"Small" for cingular cusp of upper posterior premolar means there was only a hint of the character, and the cusp was lower than pm^3.

AUR, MYS refer to characters reported by Dietz and von Helversen (2004) respectively for *M. aurascens* and *M. mystacinus*: AUR = middle upper and lower premolars "pm^3" and "pm_3" very small; MYS = middle upper and lower premolars "pm^3" and "pm_3" larger than in AUR, but smaller than in *M. brandtii*.

"cyl." = uniformly cylindrical; n.r. = not recorded; * mist-netted at the entrance of a cave during roost surveys.

Figure 7 A male whiskered bat captured in Rhemes Valley, at 1,644 m a.s.l., and detail of teeth characters of a young female captured in Orco Valley at 1,880 m a.s.l.: both the individuals showed traits described for *M. mystacinus bulgaricus* (see also Table 2).

descriptions of *M. brandtii*), and penis shape (uniformly cylindrical and not club-shaped as is in *M. brandtii*). Referring to the identification criteria reported by Dietz and von Helversen (2004), it was also noticed that some individuals of the Park showed dental characters of *M. aurascens* (middle upper and lower premolars very small), and body measurements recorded on the largest individuals captured – together with their relatively lighter coloration of ear, tragus and facial skin – resembled descriptions of the same specie as well. *M. aurascens* is known to occur in Caucasus and Bulgaria, but morphological traits similar to those of this species have been described for *M. mystacinus bulgaricus*, which occurs in Piedmont according to Benda and Karatas (2005; *sub aurascens*, see also Lanza, 2012). A further survey, comprising genetic analyses, would be needed to clarify these taxonomical aspects and draw conclusions about the whiskered bats of the Park.

4.2. Roost inspection

Thirty-two sites, located inside the Park or along its borders, were inspected. They comprised the only two known caves and all the cemeterial buildings of the area and – in Rhemes, Savarenche and Cogne valleys – all the parish churches and their bell towers. In the count of inspected sites, each cemetery was counted as a single site and the same was done for each church and related bell tower.

It must be specified that churches represent the only monumental buildings of the area and that abandoned mines, with the exception of two small galleries (one of which was inspected, the other was not found), are located above 2,000 m of elevation and this limits their potential to attract bats.

Signs of recent presence and/or direct observation of bats were recorded at 16 sites, in some cases hosting more than one species; in 2 further sites only droppings of old deposition were found. Recent data could be referred to at least 5 species: *M. mystacinus*, *M. nattereri* complex, *P. pipistrellus* vel *pygmaeus*, *H. savii* and *P. macrobullaris* (Table 3).

Genus *Plecotus* was the *taxon* most frequently encountered in the inspected sites. Night roosts used by long-eared bats were ascertained up to 2,444 m a.s.l., an elevation corresponding to the highest potential roost site that was inspected and, therefore, that should not be considered an altitudinal limit of occurrence. Data collected at 2,285 m could be specifically referred to *P. macrobullaris*, which was recorded also at a low elevation, in a probable breeding roost situated at 1,234 m.

No signs of bat usage were observed, neither individuals were mist-netted during a night survey at the smallest of the two caves known in the Park (“Boo d’la Faia”, Orco Valley), while in the largest cave (“Borna du Ran”, Savarenche Valley) two male bats belonging to *M. mystacinus* and *M. nattereri* complex were captured while entering the site during the night, in late summer. It would be interesting to verify whether this cave is used to hibernate, but its location, on a steep slope which becomes covered with ice and snow in winter, made it impossible to address this issue during the years of the survey.

Table 3 Observations at roost sites where present or recent use by bats was ascertained

Taxon	Elevation and site type	Type of record and biological role of the site
M. mystacinus *M. nattereri* complex	1,720 m, cave 1,720 m, cave	Single male bats captured while entering the cave during the night, on 31/08/13. Possible role of the site for resting during the night or for purposes more typically associated with the season, such as mating and exploring potential winter roost sites.
P. pipistrellus vel *pygmaeus*	884 m, church and bell tower	Droppings beneath interstices probably used for day roosting.
H. savii	1,040 m, house (outside, hanging from a wall)	Droppings and direct sighting of one individual using the site to rest during the night.
P. macrobullaris	1,234 m, church and bell tower	Abundant droppings (probable use as maternity site), prey remains (feeding perch) and direct sighting of 2 individuals resting in the attic during the day. One of them, a female bat, was captured and identified genetically, since morphological traits did not allow a clear identification.
P. macrobullaris	2,283 m, small bunker; 2,285 m, small bunker	Droppings and abundant prey remains. Several long-eared bats – 7 of which captured and identified – observed while entering the two sites during the night to eat prey. Repeated surveys allowed to exclude a use of the sites for resting during the day.
Plecotus sp.	884 m, church and bell tower; 1,534 m, church	Droppings. Probable use as day roost by one or few individuals.
Plecotus sp.	1,440 m, church; 1,540 m, cemetery (sheltered recess); 1,795 m, rural house (cellar).	Droppings and prey remains (night feeding perches and possible day roosts used by single individuals). In the 1990s single individuals were observed during daytime at two of the sites; one of them, captured (at 1,540 m), was identified as a male *P. macrobullaris*.
Plecotus sp.	2,427 m, rural house (external sheltered recess); 2,444 m, rural house (stable).	Few droppings, prey remains and, at the 2,427 m site, sightings of one individual at dawn (night feeding perches and resting sites).
Chiroptera not otherwise identified	1,530 m, cemetery (sheltered recess); 1,580 m, cemetery (sheltered recess); 1,723 m, bell tower; 1,835 m, abandoned mine.	Scarce droppings, without hairs inside (probable occasional day roosts). In the 1990s, at two sites (1,580 and 1,835 m) single *Plecotus* bats had been recorded during daytime.

Note: Sites where the same type of records were recorded are grouped in the same row.

4.3. Acoustic surveys

4.3.1. Bat activity beneath the current forest limits

At the 20 sampling points in unlighted areas and beneath the current forest limits, during the overall 40 hours of listening and recording 3,415 bat passes were recorded. They were emitted by the following taxa: *Myotis nattereri* complex, at least one of the species of the group *Myotis brandtii*/*M. bechsteinii*/*M. daubentonii*/*M. mystacinus*, *P. pipistrellus*, *P. kuhlii*, *H. savii*, *E. nilssonii*, *E. serotinus*, *N. leisleri*, genus *Plecotus*, *B. barbastellus*, *T. teniotis* and, possibly, further species classified under *Pipistrellus* "50 kHz", genus *Myotis* and other groups of acoustically similar species (Table 4).

About 85% of the total number of bat passes were ascribable to 3 taxa – *Pipistrellus* spp. *Myotis* spp. and *H. savii* – the first of which alone accounted for more than 50% of them.

P. pipistrellus proved to be the dominant species, a result evident even without considering that a large part of the calls attributed to *Pipistrellus* "50 kHz" (if not all) might belong to this species as well.

In contrast, the activity of the acoustic couple *P. kuhlii*/*P. nathusii*, although slightly higher at the lowest elevations of the Park, was everywhere very low, even if we take into account the possibility that bat passes of these species could have been attributed to the group *P. kuhlii*/*P. nathusii*/*P. pipistrellus*. Some of the sequences recorded consisted of QCF echolocation calls showing peak frequency values of 36.0–37.5 and of 39.5–40.0 kHz, which, according to Toffoli *et al.* (2016), should be regarded as diagnostic for identifying respectively *P. kuhlii* and *P. nathusii*, but social calls, generally considered more reliable for the identification of these species, were recorded only on one occasion, proving the occurrence of *P. kuhlii* at a site situated at 1,850 m a.s.l.

Among other recorded taxa, considering the conservation interest of the species, it should be stressed the occurrence of *B. barbastellus* in all the considered elevational ranges and habitat types, although with a geographically uneven distribution of records: the species was recorded at 9 of the 12 surveyed sites located in the Aosta Valley and in only 1 out of the 8 sites of the Piedmontese side of the Park.

No notable particularities were observed at the only two sampling points located near lentic water bodies, neither in the list of occurring species nor in bat activity, which turned out to be in the range of values recorded at the other sites of the same elevational ranges and forest habitat types.

At the 20 lighted points, during the 40 hours of surveying, the occurrence of the following taxa was ascertained: *Myotis nattereri* complex, at least one species of the couple *M. myotis*/*M. blythii* and one of the group *M. brandtii*/*M. bechsteinii*/*M. daubentonii*/*M. mystacinus*, *P. pipistrellus*, *P. pygmaeus*, *P. kuhlii, H. savii*, *E. serotinus*, *N. leisleri*, genus *Plecotus*, *B. barbastellus* and *T. teniotis*. Other sequences, possibly due to further species, were assigned to *P. kuhlii*/*P. nathusii*,

Table 4 Mean number of bat passes per hour (p/h) of each species/acoustic group and the relative percentage (%) of the total number of bat passes recorded beneath the current forest limits at sampling points without artificial lighting, according to elevation range and habitat type.

Elevation/habitat type	800–1,200 m		1,200–1,600 m		1,600–2,000 m		Ecotones, deciduous		Ecotones, mixed		Ecotones, coniferous	
N. sampling points	7		7		6		6		5		9	
Total N. bat passes	1,426		1,198		791		1,961		574		880	
	p/h	%	p/h	%	p/h	%	p/h	%	p/h	%	p/h	%
M.bra/M.bec/M.dau/M.mys	1.21	1.2	2.00	2.3	0.92	1.4	3.33	2.0	0.30	0.5	0.72	1.5
M.nattereri complex	0.57	0.6	0.21	0.3	0.67	1.0	0.58	0.4	0.40	0.7	0.44	0.9
Myotis not otherwise identified	4.50	4.4	14.29	16.7	25.00	37.9	20.33	12.4	0.50	0.9	17.44	35.7
P.kuh/P.nat	1.29	1.3	0.21	0.3	0.33	0.5	1.67	1.0	0.10	0.2	0.22	0.5
P.kuh/P.nat/P.pip	0.29	0.3	0.07	0.1	0.00	0.0	0.17	0.1	0.20	0.3	0.06	0.1
P.pipistrellus	57.71	56.7	34.86	40.7	22.67	34.4	72.17	44.2	38.8	67.6	17.44	35.7
Pipistrellus"50 kHz"	11.50	11.3	5.93	6.9	4.33	6.6	18.25	11.2	1.80	3.1	3.28	6.7
H.savii	12.36	12.1	7.07	8.3	7.67	11.6	12.67	7.8	10.8	18.8	5.78	11.8
H.sav/P.kuh	0.43	0.4	0.07	0.1	0.33	0.5	0.50	0.3	0.10	0.2	0.22	0.5
E.nilssonii	0.07	0.1	0.07	0.1	0.00	0.0	0.08	0.1	0.00	0.0	0.06	0.1
E.serotinus	2.86	2.8	0.00	0.0	0.00	0.0	3.33	2.0	0.00	0.0	0.00	0.0
N.leisleri	0.43	0.4	0.07	0.1	0.08	0.1	0.33	0.2	0.30	0.5	0.06	0.1
E.ser/V.mur/N.lei/N.noc	2.50	2.5	0.21	0.3	0.67	1.0	2.58	1.6	0.60	1.0	0.50	1.0
Plecotus spp.	0.43	0.4	0.21	0.3	0.75	1.1	0.17	0.1	0.50	0.9	0.61	1.3
B.barbastellus	1.29	1.3	1.64	1.9	1.08	1.6	2.08	1.3	1.40	2.4	0.83	1.7
T.teniotis	0.14	0.1	0.00	0.0	0.00	0.0	0.17	0.1	0.00	0.0	0.00	0.0
Myotis/Barbastella (*)			16.07	18.8			18.75	11.5				
Chiroptera not otherwise identified	4.29	4.2	2.57	3.0	1.42	2.1	6.25	3.8	1.60	2.8	1.22	2.5

Sampling points ($N = 20$) were chosen in ecotonal conditions (forest edges/routes/clearings) in forest habitat types (deciduous, mixed, coniferous). They were surveyed for 2 hours each (30 minutes during the first 3–4 hours after sunset repeated for 2 sessions, in early and late summer, for 2 years).

Taxa separated by slash bars were considered as "acoustic groups" and referred to whenever impossible to reach a more precise identification applying the conservative criteria adopted.

Abbreviations (here and in the following tables and figures):

M.bra = *M. brandtii*, *M.bec* = *M. bechsteinii*, *M.dau* = *M. daubentonii*, *M.mys* = *M. mystacinus*, *P. kuh* = *P. kuhlii*, *P.nat* = *P. nathusii*, *P.pip* = *P. pipistrellus*, *H.sav* = *H. savii*, *E.ser* = *E. serotinus*, *V. mur* = *V. murinus*, *N.lei* = *N. leisleri*, *N.noc* = *N. noctula*.

(*) Sequences of faint calls, not suitable to take reliable measurements, recorded on one occasion at a single site.

P. kuhlii/*P. nathusii*/*P. pipistrellus*, *Pipistrellus* "50 kHz", *P. kuhlii*/*H. savii*, *E. serotinus*/*N. leisleri*/*N. noctula*/*V. murinus* and order Chiroptera.

These data enable us to integrate the acoustic couple *M. myotis*/*M. blythii* and *P. pygmaeus* into the preliminary inventory of species based on the data collected at the unlighted sampling points. *P. pygmaeus* was identified from echolocation sequences recorded in the Orco Valley in the end of August (Figure 8).

B. barbastellus was recorded at 4 of the 12 lighted sites located in Aosta Valley and never in the 8 sites surveyed in the Piedmontese valleys.

Even at a preliminary level, data suggested differences in the distribution of some species depending on the presence/absence of artificial lighting. For genus *Myotis*, genus *Plecotus* and *B. barbastellus* a positive association between dark and presence was found (Figure 9). For the other species/acoustic groups no significant differences were observed, although they were recorded more frequently at lighted sites, with the only exception of *P. pipistrellus*. This species, which is known to intensely exploit light sources for foraging (Arlettaz *et al.*, 1998), was recorded with almost the same frequency at lighted and unlighted points and in both cases its frequency of occurrence was the highest observed among the recorded taxa. The ecotones along the valley bottoms of the Park evidently guarantee optimal conditions for *P. pipistrellus*, i.e. the species is present independently from artificial lighting. It must be stressed that these observations are preliminary, since we have compared only frequencies of occurrence and not activity levels.

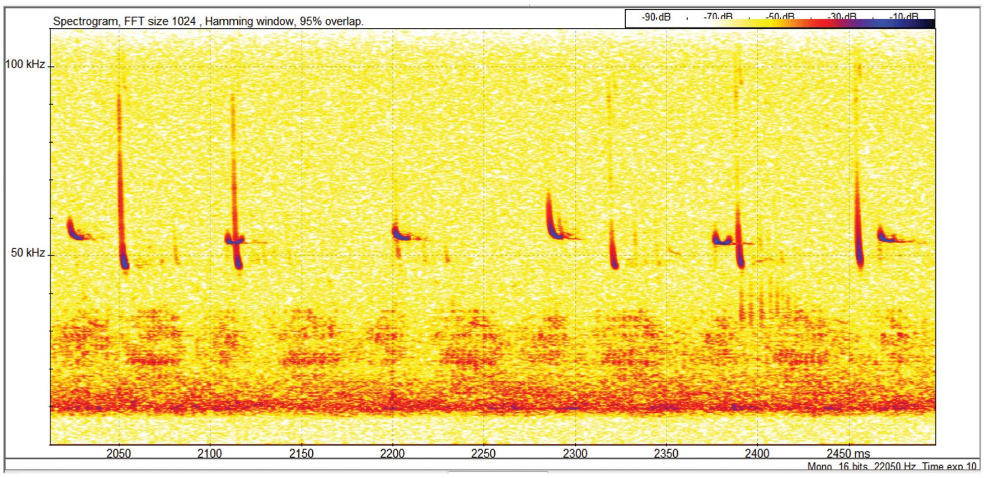

Figure 8 Echolocation sequences of *P. pygmaeus* and *P. pipistrellus* recorded in Orco Valley (Noasca, 1,032 m a.s.l.) on 31/08/12.

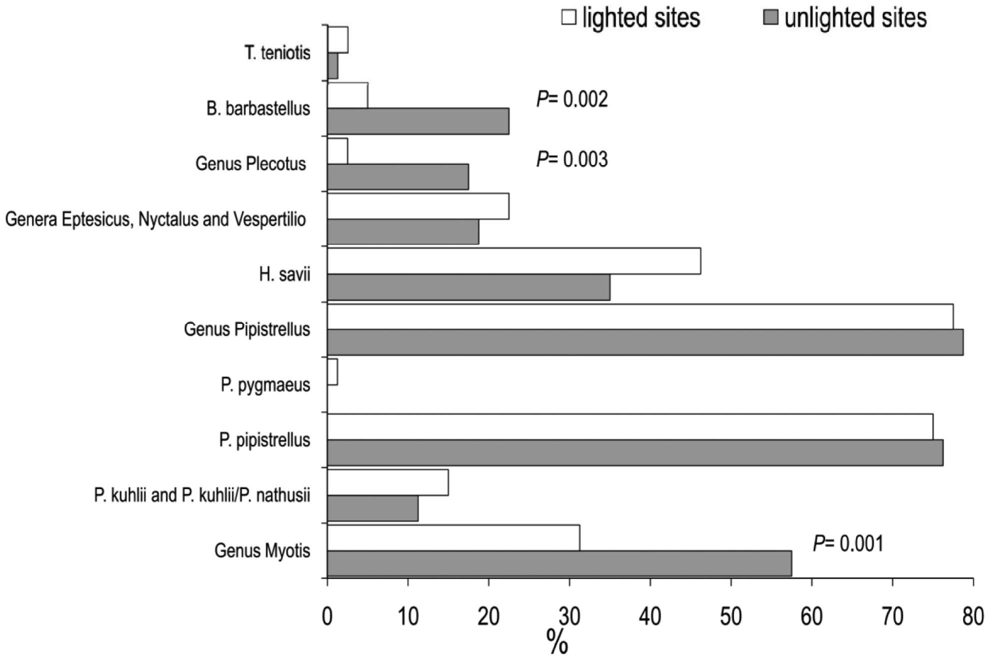

Figure 9 Percentage of surveys in which the presence of each species/acoustic group was detected at unlighted and lighted sampling points located beneath current forest limits.

Surveys, performed simultaneously at each couple of dark and lighted sites, were 80 both at dark and lighted sites.

For *Pipistrellus*, results are shown referring both to the whole genus and to single species or group of species.

P-values are reported for significant differences at Fisher's exact test (two-tails).

4.3.2. Bat activity above the current forest limits

4.3.2.1. General characterization and comparison with data collected beneath the current forest limits

At the 8 sampling points located between 1,800 and 2,200 m a.s.l., at sites characterized by "alpine 1" habitat type and no artificial lighting, at least 10 species were detected (Figure 10), comprising *V. murinus*, whose recording added a further species to the list resulting from the acoustic surveys along valley bottoms. The occurrence of the parti-coloured bat was verified from social calls referable to descriptions of the display songs emitted by males in autumn, presumably aimed at attracting females to mating sites (Ahlen and Baagøe, 1999; Zagmajster, 2003; Suba *et al.*, 2010). Yet, in the case of the Park, some of the sequences were recorded in July, i.e. earlier in the year than reported in literature. All the calls lacked the part made of short FM sweeps that is present in the more typical calls or the same

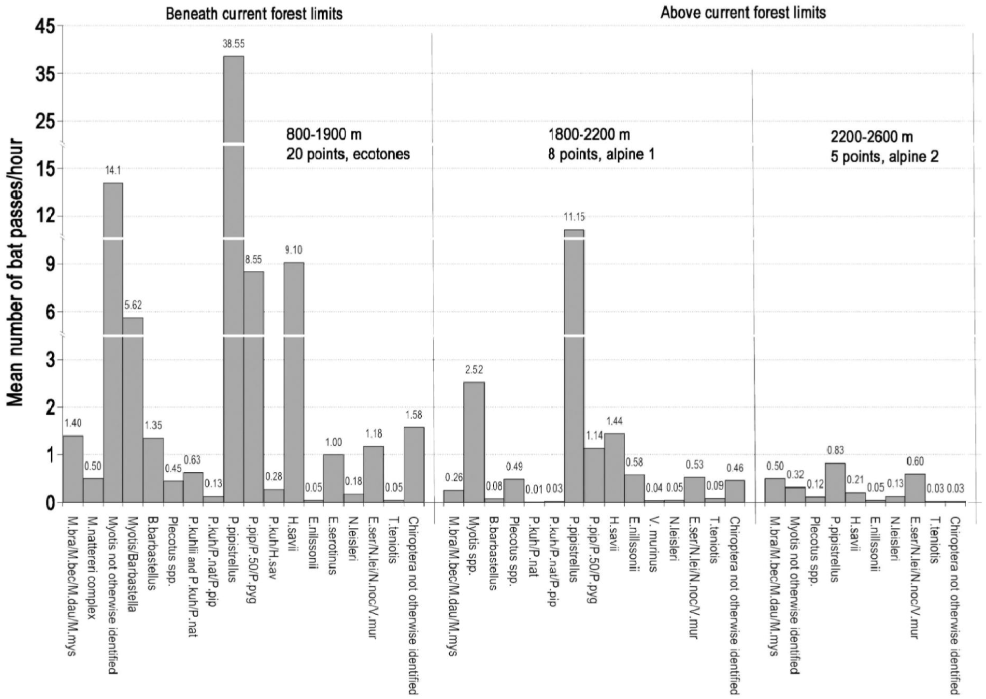

Figure 10 Average activity of the different species/acoustic groups recorded at sampling points in absence of artificial light sources, beneath and above current forest limits.

Data refer to the first 3 hours after sunset and to 2 sampling sessions – in early and late summer – equally represented.

Taxa are arranged on X-axes approximately according to the loudness of their acoustic emissions (from faint to loud, with the exception of "chiroptera not otherwise identified").

Ecotones = edges/clearings/trails in forest habitat types (deciduous/mixed/coniferous).

Alpine 1 = pastures above current forest limits, but under the natural (potential) treeline.

Alpine 2 = mosaics of prairie, debris and rocks above the natural (potential) treeline.

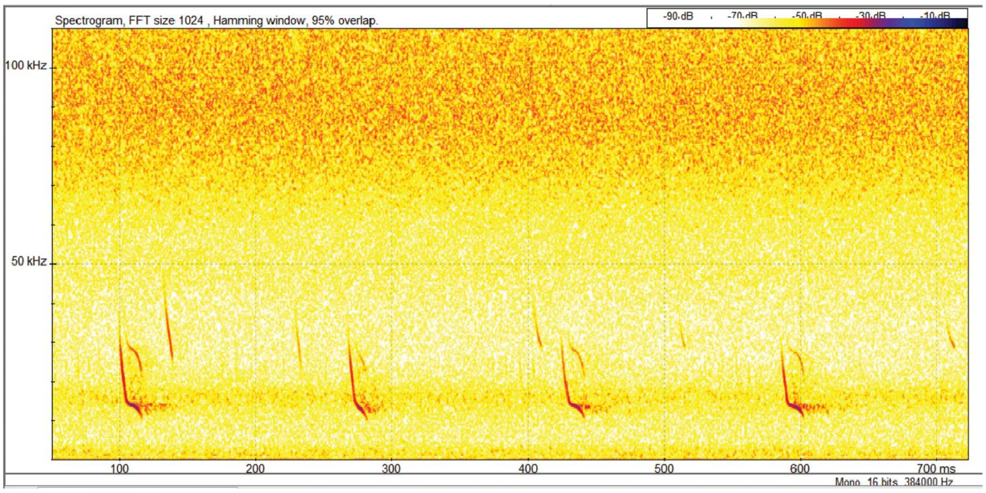

Figure 11 Social calls of *V. murinus* recorded in Orco Valley (point 1 of the transect, 1,845 m a.s.l.) on 18/07/2015.

part was only very faintly hinted (Figure 11); however, according to Barataud (2012), this component of the calls is not always present.

Activity, quantified as mean numbers of bat passes/hour during the first 3 hours following sunset, was lower than beneath the forest limits for all the species and acoustic groups, with the exception of *E. nilssonii*, genus *Plecotus* and *T. teniotis*, for which slightly higher values were recorded (Figure 10). *Pipistrellus* spp., *Myotis* spp. and *H. savii* were confirmed to be the three most recorded taxa. Also in this case, *P. pipistrellus* was the dominant species and the couple *P. kuhlii*/*P. nathusii* proved to be very rare.

Data collected in the same 8 sites later in the night (from the fourth hour after sunset to sunrise) and the overall data recorded at some other "alpine 1" sites, where only a marginal surveying effort was carried out, did not lead to recording of any species other than those reported in Figure 10.

At the 5 sampling points located in areas representative of "alpine 2" habitat type, situated between 2,200 and 2,600 m a.s.l. and in the absence of artificial light sources, bat activity was even lower than at "alpine 1" sites, with the exception of the group *E. serotinus*/*V. murinus*/*N. leisleri*/*N. noctula*, which was slightly more recorded; among these species only *N. leisleri* could be clearly identified. A strong decrease in activity values was observed for *P. pipistrellus*, while *Myotis*, *Plecotus* and *T. teniotis* showed proportionately slighter decreases and, consequently, contributed to the total sample of bat passes with higher proportions than at "alpine 1" sites. None of the recorded taxa appeared to be dominant in the acoustic scenery (Figure 10), probably because of the limited size of the data sample.

Data collected later in the night in the same 5 sites, and the few data recorded at other "alpine 2" sites without artificial lighting were identified as belonging to the same taxa recorded during the first 3 hours after sunset, with the addition of at least one species of the couple *M. myotis/M. blythii*.

Considering the whole sample of activity data collected during the 3 hours after sunset at unlighted sites of the Park, beneath and above forest limits, it can be concluded that average bat activity decreases with elevation and when moving to zones with a simpler vegetation structure. Yet, it should be noted that standard error values are very large (Figure 12), as a consequence of the great variability in activity values often recorded at different sites of the same altitude range or habitat type, and even at the same sites on different nights. Notoriously, bat activity data are very variable, being strongly influenced by conditions that can fluctuate nightly, such as temperature, humidity, and insect availability (Hayes, 1997). During the survey, for example, the two maximum activity values were recorded during peaks of mosquitoes, respectively at a site located at 1,300 m, in a mixed deciduous wood, and at the site located at 1,885 m, in a larch wood, while at the same sites much lower activity values were recorded on other dates. Therefore, it must be stressed that more surveying would be needed in order to establish more precise mean activity values, particularly in the elevation ranges and habitat types where proportionally higher values of standard error were recorded, i.e. in mixed woods and between 1,200 and 1,600 m.

4.3.2.2. Comparison between two "alpine 1" areas of similar elevation

A more precise characterization is possible for the two areas of Orco valley, named A and B, more intensively surveyed (Figure 13). Sampling effort, equally divided between 2 years and applied with identical methodology, amounted to 114.77 hours in area A and 116.63 hours in area B (the small difference, about 2 hours, was due to differences in night length resulting from having operated in different, although close, dates).

In area A, a total of 2,802 bat passes were recorded (Figure 14). Most of them (69.8%) could be attributed to genus *Pipistrellus*, mainly represented by *P. pipistrellus* (at least 63.9% of the total bat passes) and secondly by *Pipistrellus* "50 kHz" (5.7%), possibly corresponding to the former species as well; the presence of the acoustic couple *P. kuhlii/ P.nathusii* was ascertained only in one case. The second most recorded taxon was genus *Myotis* (20.0%), followed far behind by *E. nilssonii* (4.0%) and *H. savii* (1.9%); other species and acoustic groups (genus *Plecotus*, *N. leisleri*, *N.leisleri/ N.noctula*, *E.serotinus/ V.murinus/ N.leisleri/ N. noctula* and *T. teniotis*) accounted together for about 1% of the overall sample. The remaining bat passes (3.3%) were generically attributed to the order Chiroptera because of the low quality of the calls, which impeded a more precise identification (1.8%), or the lack of criteria for a sure identification (in literature we could not find criteria for a sure identification of 1.5% of the sequences recorded on water and characterized by FM calls repeated in rapid succession at intervals, although the fact they were often recorded just before or after sequences of *Myotis* suggests they were probably emitted by *Myotis* bats; Figure 15).

Feeding buzzes were detected only for the taxa which contributed more than 1% of the overall bat passes, ranging in proportion from 1 feeding buzz every 28

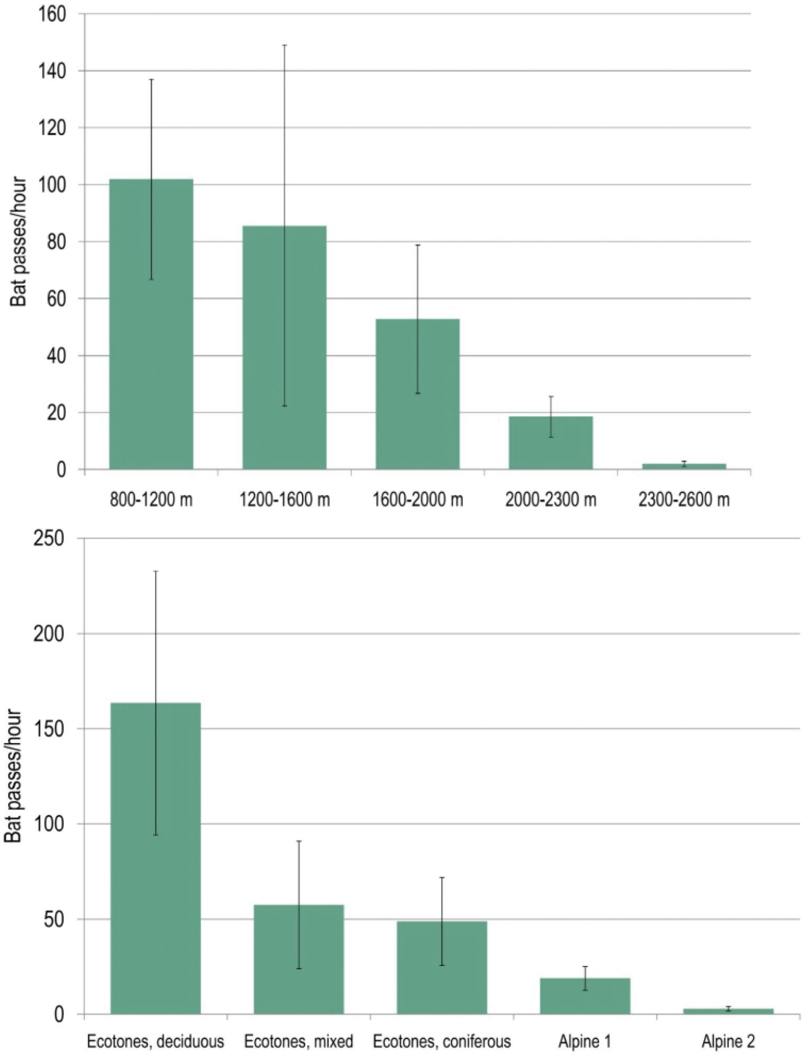

Figure 12 Bat activity (mean number of bat passes per hour ± standard error of the mean) during the first 3 hours after sunset recorded at sampling points in natural darkness, according to elevation (*above*) and habitat type (*below*).

Ecotones = edges/clearings/trails in forest habitat types (deciduous/mixed/coniferous).

Alpine 1 = pastures above current forest limits, but under the natural (potential) treeline.

Alpine 2 = mosaics of prairie, debris and rocks above the natural (potential) treeline.

passes, recorded for genus *Myotis* (for which N = 20 feeding buzzes were recorded), to 1 buzz every 16–18 passes, observed for genus *Pipistrellus* (N = 117 feeding buzzes), *E. nilssonii* (N = 7) and *H. savii* (N = 3). A further 5 feeding buzzes were detected within echolocation sequences of unidentified bats, raising the total of sampled buzzes to 152 and the feeding buzz/bat pass ratio to 1 to 18.43.

Figure 13 Views of area A (*above*) and area B (*below*), in Orco Valley, where acoustic surveys were performed during the summers of 2013 and 2014.

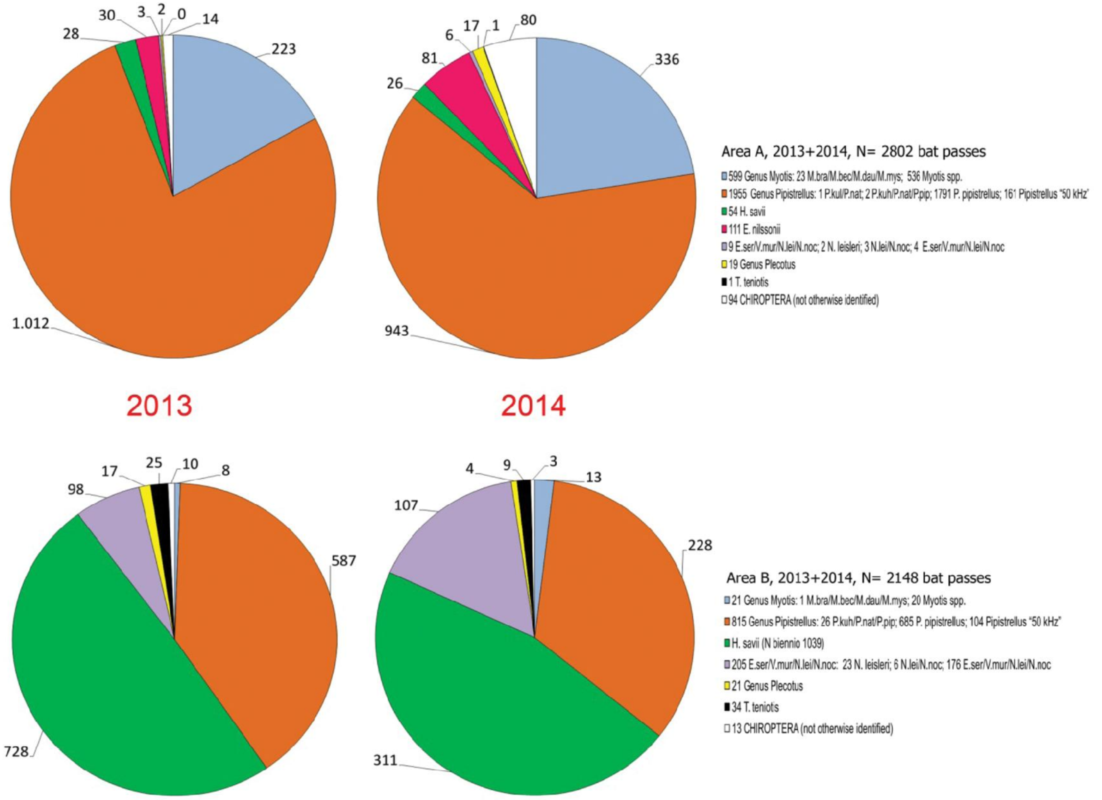

Figure 14 Composition of the overall sample of bat passes recorded in the two areas of the Park (A, B) more intensively surveyed using bat detectors during 2 years (2013 and 2014).

Both areas are located in the same valley (Orco), at similar elevation (about 2,000–2,100 m a.s.l.) and are referable to "alpine 1" habitat type, but they differ in other environmental features: exposition (north in A, south in B), presence of lentic water bodies (only in A), distance from woods (higher in B) and current presence of livestock during summer (sheep in A, cows in B).

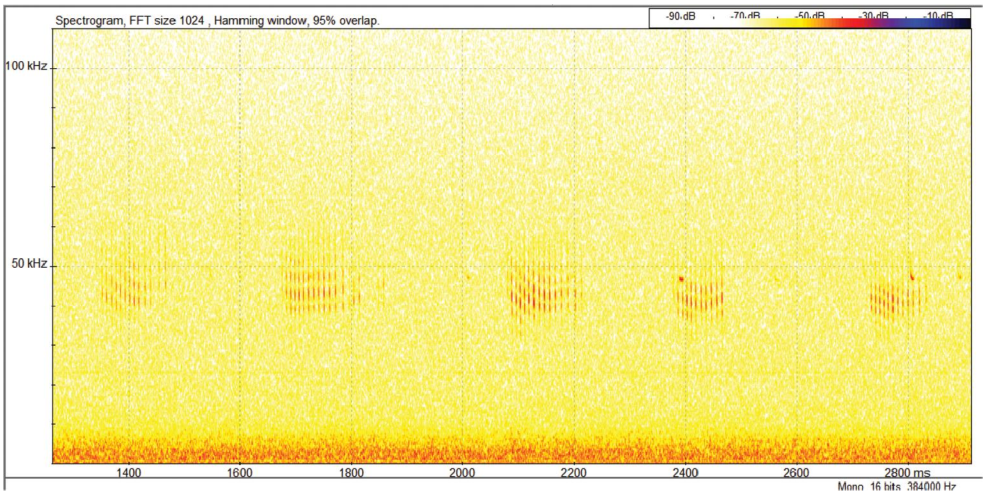

Figure 15 Bat calls recorded several times over the water bodies of area A (Orco Valley) and attributed to "chiroptera not otherwise identified".

In area B, 2,148 bat passes were recorded (Figure 14), mainly attributed to *H. savii* (48.4%) and genus *Pipistrellus* (37.9%). As in the area A, almost all the bat passes of the latter were assigned to *P. pipistrellus* (31.9%), followed by *Pipistrellus* "50 kHz" (4.8%); the few remaining sequences of the genus were identified as belonging to the group *P. kuhlii/ P. nathusii/ P. pipistrellus* (1.2%). A considerable number of bat passes (9.5%) were classified into the group *E. serotinus/ V. murinus/ N. leisleri/ N. noctula*, comprising several sequences that could be identified as belonging to *N. leisleri*. Other recorded taxa, marginally represented in the sample, were *T. teniotis* (1.6%) and the genera *Myotis* (1%) and *Plecotus* (1%). Bat passes classified as unidentified Chiroptera corresponded to a few recordings of bad quality (0.6%).

In the same area, a total of 150 feeding buzzes were recorded, i.e. 1 to every 14.32 bat passes. They were emitted by genus *Pipistrellus* (N = 85; 1 feeding buzz to every 9.6 bat passes), *H. savii* (N = 50; 1 buzz to 20.8 passes) and the group *E. serotinus/ V. murinus/ N. leisleri/ N. noctula* (N = 15; 1 buzz to 13.7 passes).

Comparing the numbers of bat passes of each taxon/acoustic group recorded within each area in 2013 with those recorded in 2014 (Figure 14) statistically significant differences emerged both for area A ($\chi^2 = 57.17$; d.f. = 5; $P < 0.001$; in order to meet requirements for Chi-square computation, *T. teniotis*, for which only one bat pass had been recorded, was omitted) and for area B ($\chi^2 = 57.49$; d.f. = 5; $P < 0.001$). In these and in the following significance tests bat passes classified under "Chiroptera not otherwise identified" were omitted as mainly corresponding to low quality sequences (their exclusion can be assumed as a lowering of detector sensitivity). The results of the tests do not change if the sequences recorded in area A, and attributed to the same category because of lack of identification criteria, are included in *Myotis* genus, to which they probably belong.

Table 5 Mean air temperatures recorded in areas A and B during the nights of the surveys (NS) and at the nearest weather stations (both located in the valley bottom) during the period (1–15 July) preceding the samplings; in brackets the number of days with rain

	NS, area A	NS, area B	1–15 July, valley bottom A	1–15 July, valley bottom B
2013	10.04 ± 1.46	13.61 ± 0.96	14.16 (5)	18.83 (6)
2014	8.83 ± 3.67	11.10 ± 1.72	11.86 (11)	15.65 (12)

Since no habitat changes occurred in the two areas during the 2 years, the differences observed must be related to other possible causes, such as variations in weather conditions and factors weather-related, like prey availability (and consequent attractiveness of the areas as foraging grounds) and breeding success (which conditions demographic densities). In 2014 weather conditions were poorer than in 2013: mean nightly temperatures during the survey were lower in both the areas and worse conditions characterized also the period before (Table 5). This might have differently affected the different species and, possibly, have differently affected them in the different environmental conditions of the two areas. It is not the aim of this work to analyze these aspects, but we judged important to underline the variability of results obtained even within each sampling area. In the meanwhile we must remark that an incidence of bias, due to an insufficient sampling effort, cannot be excluded. In this study the comparison between data collected within each area in the 2 years is based on five all-night samplings plus four 3-hour samplings performed during two of the same nights from further listening points, i.e. a surveying effort similar to that recommended by Hayes (1997) to account for night-to-night variation in echolocation activity (approximately six nights of recording, with possible differences from site to site), but not so large as to absolutely exclude the possibility of bias.

Looking at Figure 14 it is anyway clear that greater and much more evident differences emerge if the data collected in area A are compared with those of area B, both during each year (in 2013: $\chi^2 = 1{,}233.14$; d.f. = 6; $P < 0.001$; in 2014: $\chi^2 = 958.23$; d.f. = 5, excluding *Plecotus*, very scarcely represented, to meet Chi-square requirements; $P < 0.001$) and in the overall biennium ($\chi^2 = 2{,}139.77$; d.f. = 6; $P < 0.001$). The latter comparison involved data sets obtained through ten all-night samplings plus eight 3-hour samplings, i.e. a large surveying effort which limits the risk of bias.

Comparing the proportion of each taxon/acoustic group in the samples collected in the two areas (i.e. comparing numbers of bat passes of each taxon/acoustic group and overall numbers of bat passes of the other taxa/acoustic groups recorded in each of the two areas) Chi-square test highlights significant differences for all of them with the exception of genus *Plecotus* (Table 6).

During the 3 hours following sunset, i.e. within the period of the night considered in the present study to furnish a general characterization of bat activity across the

Table 6 Results of statistic tests used to compare values recorded for each taxon/acoustic group in areas A and B

	Differences between proportions of each taxon/acoustic group on total bat passes recorded in each area with reference to the whole data set (data of Figure 14) or to the only data collected in the first 3 hours after sunset.				Differences between activity levels recorded for each taxon/acoustic group in the two areas during the first 3 hours after sunset (18 surveys in each area, mean values in Figure 17).		
	χ^2, whole data set	χ^2, first 3 hours	d.f.	*P**	*U*	$n_1 = n_2$	*P,* two tails
Genus *Myotis*	435.80	238.12	1	<0.001	54.5	18	<0.001
Genus *Pipistrellus*	562.97	165.61	1	<0.001	104	18	n.s.
H. savii	1,485.33	782.55	1	<0.001	27	18	<0.001
E. nilssonii	87.74	57.29	1	<0.001	54	18	<0.001
E.ser/V.mur/N.lei/N.noc	240.68	151.88	1	<0.001	48	18	<0.001
Genus *Plecotus*	0.84	0.94	1	n.s.	193.5	18	n.s.
T. teniotis	38.12	56.56	1	<0.001	87.5	18	<0.01

* Applying Bonferroni's correction *P* value has to be less than 0.007 to be significant at the $P < 0.05$ level.

Park area, 54 hours of sampling effort (27 hours per year) were performed in both areas. In A the number of bat passes during this part of the night resulted almost identical in the 2 years of the survey (Figure 16) and the mean value of bat passes per hour (45.83) was similar to the average value observed along valley bottoms in the vegetation zone of coniferous woods (Figure 12); in area B lower numbers of bat passes were recorded, particularly in the second year of the survey, and the mean value of bat passes per hour (24.28) resulted roughly one half of that recorded in area A (Figure 16) and closer to the values generally recorded at "alpine 1" sites (Figure 12). In both areas activity values showed large variations in some nights, but Mann-Whitney *U*-test did not detect significant differences between medians recorded yearly neither in area A ($U = 34$; $n_1 = n_2 = 9$) nor in area B ($U = 23$; $n_1 = n_2 = 9$) suggesting that the disparity in the total number of bat passes observed in the latter during the 2 years was mainly due to extreme values.

The composition of total samples of bat passes collected in the 3-hour period in the two areas differed significantly ($\chi^2 = 1{,}210.13$; d.f. = 6; $P < 0.001$) and significant differences were observed between the proportions of each taxon/acoustic group in the two samples, with the exception of genus *Plecotus*, confirming, despite the lower surveying effort, what had already emerged analyzing the whole data sets (i.e. including the data collected later in the night) (Table 6).

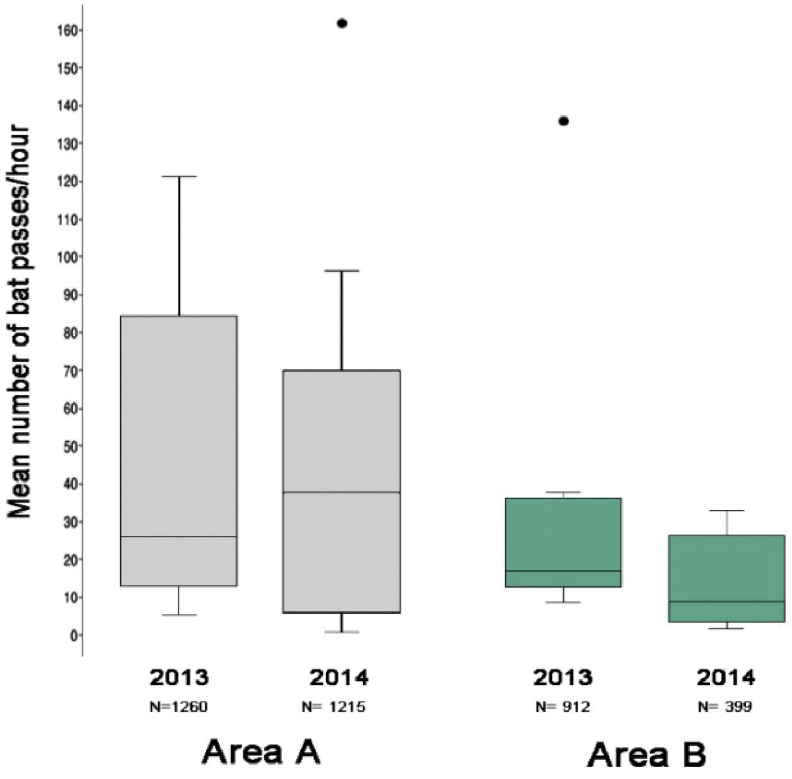

Figure 16 Bat activity (all species) recorded in areas A and B within the first 3 hours after sunset (9 surveys per area, repeated for 2 years).

Whiskers represent the lowest and the highest values within 1.5 IQR; dots are outliers.

Comparing by Mann Whitney *U*-test the mean numbers of bat passes/hour recorded in the two areas in each sampling night, activity of genus *Myotis* and of *E. nilssonii* turned out to be significantly higher in area A, while that of *H. savii*, *T. teniotis* and the group *E. serotinus*/*V. murinus*/*N. leisleri*/*N. noctula* was higher in area B; no significant differences were recorded for genera *Plecotus* and *Pipistrellus* (Figure 17; Table 6). Since the latter was almost exclusively represented by *P. pipistrellus* in both the areas, we should conclude that the environmental differences of the two areas do not seem to affect this species significantly.

The limits of acoustic identification made it impossible to investigate the potential differences between the two areas in the occurrence of the different species of the genera *Myotis* and *Plecotus*. Since area A is reached by coniferous woods, locally at their current upper limits, it can be expected to be used also by slow-flying species dependent on the presence of ligneous, vertically structured, vegetation; on the contrary the area B, currently devoid of trees and shrubs, appears less suitable for them. Although not a prove, the abundance of recordings of genus *Myotis* in area A and their extreme scarcity in area B suggests the probability of

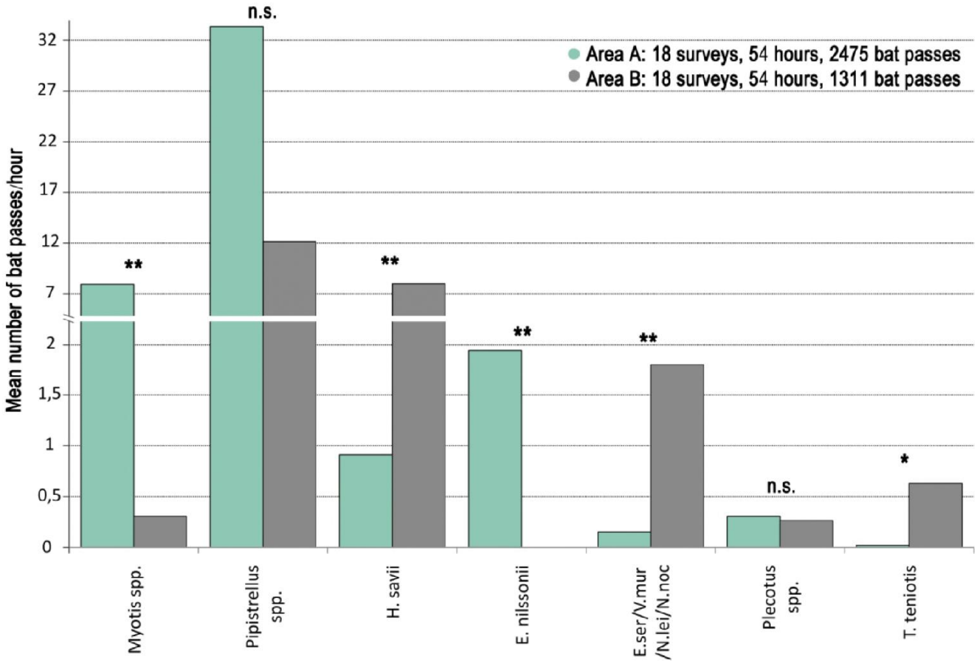

Figure 17 Bat activity of each species/acoustic group recorded in areas A and B within the first 3 hours after sunset.

Significant differences at Mann Whitney *U*-test: * $P < 0.01$; ** $P < 0.001$.

more *Myotis* species occurring in the area A, which looks more attractive to these bats also because of the presence of lentic water bodies.

In area B most of the activity could be referred to moderate (*P. pipistrellus*, *H. savii*) or fast-flying species (*T. teniotis*, *N. leisleri*), which commonly or at least not rarely cross open spaces. *N. leisleri* could be attracted into the area by the availability of beetles associated with cattle dung, which is locally abundant (an important use of dung beetles by *N. leisleri* has been reported for pasture areas in England and Ireland in Shiel *et al.*, 1998) while the activity of *H. savii* and *T. teniotis* could be favoured by the local presence of cliffs facing south, providing potential summer roost sites for these species. Yet, regarding *H. savii* – one of the commonest species in the Park according to the overall data collected in this work – what is most striking is not the abundance of records collected in area B, but the very low levels of activity recorded in area A, where higher values of activity were recorded for *E. nilssonii*, a species that on the contrary has been scarcely recorded across the Park. Considering that *E. nilssonii* and *H. savii* have an approximately complementary geographic distribution and show some similarities in their foraging and acoustic behaviour, it would be worth investigating the possible role of eco-ethological factors in explaining the results obtained.

Data collected later in the night in the two areas did not lead to ascertain the occurrence of species or acoustic groups other than those observed in the first 3 hours after sunset.

Moreover, the subsamples of data passively collected by SM2BAT+ during the 10 all-night surveys performed in each area (N = 1,785 bat passes in area A and 1,768 in area B) mainly consisted of bat passes detected in the first 3 hours of the night (81.7% and 52.7% of the total collected respectively in areas A and B), in spite of the fact that these represented only a third of the night period. Tested by the Wilcoxon signed-rank test, significant differences in the mean number of bat passes/hour – higher in the first 3 hours following sunset – emerged in the case of area A for *P. pipistrellus*, *E. nilssonii* and the all-species sample, and, in the case of area B, for *P. pipistrellus*; for the other species and acoustic groups the test did not evidence significant differences or could not be performed due to the limited sample size (Table 7). As a whole, we conclude that in this case study, referring to

Table 7 Mean number of bat passes per hour recorded in areas A and B in the first 3 hours after the sunset and from the forth hour to sunrise during the 10 all-night surveys performed in each area and significance of differences among the values recorded in each survey tested by Wilcoxon signed-rank test (two tails)

	Area A			Area B		
	First 3 hours	After	Differences	First 3 hours	After	Differences
Genus *Myotis*	4.73	1.66	N = 6; T = 2; n.s.	0.20	0.06	N = 6; T = 6; n.s.
Genus *Pipistrellus*	40.10	3.31	N = 10; T = 0; $P < 0.01$	17.43	2.14	N = 10; T = 5; $P < 0.05$
H. savii	0.97	0.10	Inadequate data	10.30	9.24	N = 10; T = 27; n.s.
E. nilssonii	1.90	0.08	N = 8; T = 2; $P < 0.05$	Not recorded		
E.ser/V.mur/N. lei/ N.noc	0.07	0.02	Inadequate data	2.23	1.72	N = 9; T=14; n.s.
Genus *Plecotus*	0.30	0.03	Inadequate data	0.37	0.11	N = 7; T = 6; n.s.
T. teniotis	Not recorded			0.50	0.00	Inadequate data
ALL SPECIES	48.6	5.38	N = 10; T = 0; $P < 0.01$	31.03	13.36	N = 10; T = 12; n.s.

N = number of matched pairs whose difference was not zero.
Inadequate data = the comparison was not possible for the restrictions in the use of Wilcoxon's test.

the 3 hours after sunset was a valuable choice to obtain a quick preliminary characterization of the local bat fauna.

4.3.3. Comparison among sampling points at different elevations, including one point with artificial lighting

A total of 4,450 bat passes were counted in the sample of recordings collected in the best weather conditions, during the first 3 hours following sunset, at the 6 points located along an altitudinal transect between Orco and Savarenche valleys.

In the 5 sites characterized by natural darkness, activity values showed a decrease along the elevational gradient and moving away from forest limits (Figure 20).

At the highest sampling point (2,460 m a.s.l.; Figure 18), during 13 entire nights of sampling, a mean value of only 5.15 passes/night was recorded (Table 8). Despite the low activity, at least 7 species were identified and, taking into account the additional occurrence of *E. nilssonii*, recorded in previous surveys, it can be concluded that the area is used by at least 8 bat species.

The highest number of bat passes recorded at the site was due to genus *Plecotus* and the results of mist-netting at other sites of high elevation (Figure 5) strongly suggest they belonged to *P. macrobullaris*, which could be resident in the area throughout the entire summer: all *Plecotus* species are slow-flying bats and *P. macrobullaris*, in other geographic contexts, is known to use high-elevation environments for both foraging and roosting (Alberdi *et al.*, 2012b and 2015).

Table 8 Bat passes recorded at point 6 (2,460 m a.s.l.) of the altitudinal transect during 13 whole nights of sampling in favourable (relative to the elevation) weather conditions (absence of, or only faint, precipitations; minimum temperatures of 6.95 ± 2.18 °C)

	26/27Jun	27/28Jun	28/29Jun	29/30Jun	30Jun/01Jul	23/24Jul	26/27Jul	27/28Jul	20/21Aug	21/22 Aug	23/24 Aug	25/26 Aug	24/25Sep
M.myotis/M.blythii		4			1								
M.bra/M.bec/M.dau/M.mys		1											
Myotis not otherwise id.				1		1		1	1	1		2	
P.pipistrellus				1	1	1			1			2	
H.savii						2			5	1		2	
N.leisleri									5				2
E.ser/V.mur/N. lei/N.noc					1	1			5				
Genus *Plecotus*			1	1	5	5	2	2		3			
T.teniotis			2			1							
Chiroptera not otherwise id.				2									
TOTAL	0	5	3	5	8	11	2	3	17	5	0	6	2

Figure 18 The recording site at point 6 of the altitudinal transect (Nivolet plateau, 2,460 m a.s.l., Savarenche Valley).

Among the other bats recorded at the site, there are species which fly much faster and, presumably, can cover long distances daily: *T. teniotis*, at least one species of the couple *M. myotis*/*M. blythii* (Figure 21), *N. leisleri* and possible further species of the group *E. serotinus*/*V. murinus*/*N. leisleri*/*N. noctula*. According to literature descriptions, among them only *T. teniotis* finds in the surroundings of the sampling point typical roosting sites (cliff crevices); the others are usually associated with different roost types (caves, abandoned mines, large buildings, trees), not available at the site. For them, a daily commuting to the alpine prairies from roosting sites of lower elevations and, in the case of migrant species, an increase of occurrences during migrations can be hypothesized, although the possibility that these species also may roost at high elevation, inside rock crevices and screes, should not be excluded since their eco-ethology in the alpine environment is still poorly known.

Results for the sampling point in the presence of artificial lighting (2,292 m a.s.l.; Figure 19) did not conform to the pattern of decrease with altitude of bat activity, diverging from the unlighted sites. Under favourable weather conditions, the lighted point showed much higher bat activity than that recorded at the other 5

Figure 19 Insect concentrations at lights that illuminate the dam of Lake Serrù (Orco Valley) attract several bat species to forage. In the box, two bats, one of which clearly belonging to genus *Plecotus*, chase near one of the lamps.

sites of the transect (Figure 20), and this was of two orders of magnitude greater than in every unlighted "alpine 2" site surveyed in the Park (Figure 12). Activity was particularly intense in August, when a maximum of bat passes was recorded in spite of the fact that, during the recordings, 68 individuals (mainly *P. macrobullaris*) were mist-netted and temporarily impeded to contribute to the value. Bats concentrated at the site to prey upon light-attracted insects, primarily moths. Acoustic analyses revealed the presence of at least 8 species, comprising at least one of the couple *P. kuhlii*/*P. nathusii* (Table 9), and mist-netting allowed for the identification at the species level of *M. mystacinus* and *P. macrobullaris* and for adding to the list *B. barbastellus*.

At the lighted site, only the activity levels recorded for genus *Myotis* (0.92 bat passes/hour) were within the range observed at the other 5 sites (0.17–3.16 bat passes/hour), and lower than the value recorded at the control site (1.58) situated in the same environmental conditions but not lighted (Table 9). For all the other species/acoustic groups, much higher activity resulted at the lighted point: compared with values collected at the sites ranked as second for activity level due to the same taxa, 6.6 times more bat passes/hour were observed for genus *Plecotus* and higher

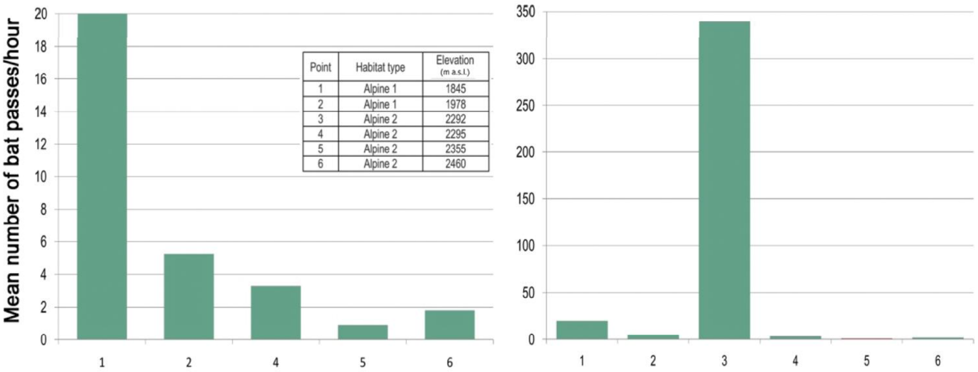

Figure 20 Bat activity during the first 3 hours after sunset at points located along an altitudinal transect, in absence of artificial light sources (*left*: points 1, 2, 4, 5, 6) and with inclusion of a point (3) in the presence of strong artificial lighting (*right*: with Y-axis re-proportioned).

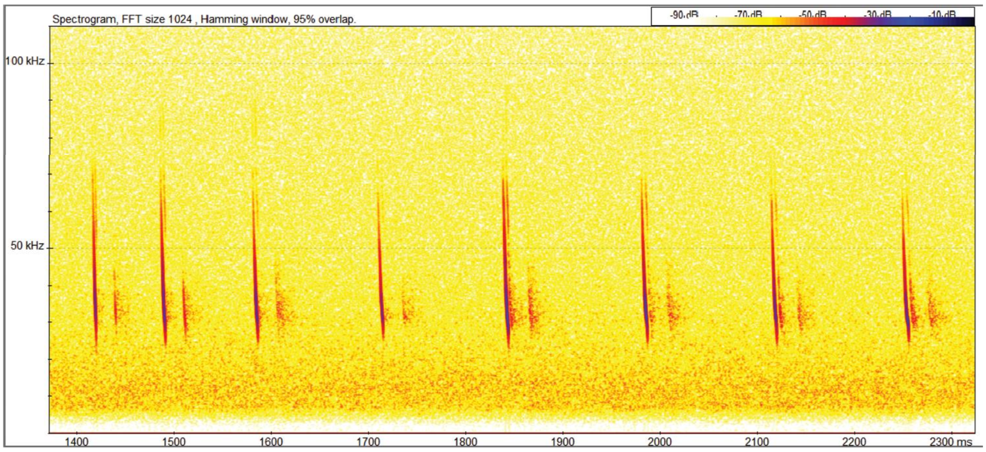

Figure 21 Echolocation sequence of *Myotis myotis vel blythii* recorded in Savarenche Valley (point 6 of the transect, 2,460 m a.s.l.) on 27/06/2015.

values for genus *Pipistrellus* (8.9 times more), the group *E. serotinus*/*V. murinus*/*N. leisleri*/*N. noctula* (48.5), *H. savii* (60.4), *E. nilssonii* (137.5) and *T. teniotis* (315.7).

For what concerns genus *Pipistrellus,* which in natural lighting conditions showed a clear decrease in activity along the elevational gradient, it must be furthermore observed that the high activity at light was recorded in spite of the high elevation of the site. As for genus *Plecotus*, it should be considered that during one of the surveys at the lighted point a relevant number of long-eared bats were captured and temporarily impeded to contribute to bat activity, resulting in an underestimation of the activity of this taxon. Moreover, there is the possibility that, in proximity to light

Table 9 Mean number of bat passes per hour (p/h) of each species/acoustic group and relative percentage (%) on the total number of bat passes recorded in the first 3 hours following sunset at 6 sampling sites along an altitudinal transect. Sampling point number 3 was in presence of artificial lighting, the other points were in natural darkness

Sampling points and their elevation	1 (1,845 m)		2 (1,978 m)		3 (2,292 m)		4 (2,295 m)		5 (2,355 m)		6 (2,460 m)	
Total N. bat passes	240		63		4,074		40		11		22	
	p/h	%	p/h	%	p/h	%	p/h	%	p/h	%	p/h	%
M.bra/M.bec/M.dau/M.mys	0.58	2.9	0.25	4.8	0.00	0.0	1.00	30.0	0.25	27.3	0.00	0.0
Myotis not otherwise identified	2.58	12.9	0.33	6.3	0.92	0.3	0.58	17.5	0.00	0.0	0.17	9.1
P. pipistrellus	11.33	56.7	3.75	71.4	97.83	28.8	0.92	27.5	0.08	9.1	0.08	4.5
Pipistrellus"50 kHz"	0.58	2.9	0.08	1.6	7.42	2.2	0.00	0.0	0.00	0.0	0.00	0.0
P.kuh/P.nat/P.pip	0.00	0.0	0.00	0.0	0.17	0.1	0.00	0.0	0.00	0.0	0.00	0.0
P.kuh/P.nat	0.00	0.0	0.00	0.0	0.08	0.0	0.00	0.0	0.00	0.0	0.00	0.0
H.savii	1.08	5.4	0.17	3.2	65.25	19.2	0.00	0.0	0.08	9.1	0.50	27.3
H.sav/P.kuh	0.00	0.0	0.00	0.0	0.75	0.2	0.00	0.0	0.00	0.0	0.00	0.0
E.nilssonii	0.00	0.0	0.00	0.0	11.00	3.2	0.00	0.0	0.08	9.1	0.00	0.0
V.murinus	0.25	1.3	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
N.leisleri	0.08	0.4	0.08	1.6	12.00	3.5	0.00	0.0	0.00	0.0	0.50	27.3
E.ser/V.mur/N.lei/N.noc	0.83	4.2	0.25	4.8	44.25	13.0	0.00	0.0	0.08	9.1	0.33	18.2
Plecotus spp.	2.50	12.5	0.33	6.3	16.50	4.9	0.75	22.5	0.08	9.1	0.25	13.6
T.teniotis	0.00	0.0	0.00	0.0	78.92	23.3	0.00	0.0	0.25	27.3	0.00	0.0
Tadarida/Nyctalus	0.00	0.0	0.00	0.0	1.08	0.3	0.00	0.0	0.00	0.0	0.00	0.0
Chiroptera not otherwise identified	0.17	0.8	0.00	0.0	3.33	1.0	0.08	2.5	0.00	0.0	0.00	0.0

sources, some bats rely on visual clues more often than usual and, consequently, use echolocation less frequently than at dark: basing on bat detector data would lead to overlook the presence of these species at light and this can be conjectured in particular for *Plecotus* bats, since they have large-size eyes and comprise species (*P. auritus*) for which the ability to locate prey by sight has been demonstrated (Eklof, 2003). On the other side, always concerning *Plecotus* bats, it must be pointed out that the presence at the lighted site of two buildings used by long-eared bats as feeding perches might have contributed to concentrate individuals in the area, so that the lighting may not be considered the sole influence on the values recorded.

It can be concluded that more research is needed to precisely clarify the consequences of lighting at the studied site; although preliminary, anyway, the activity values collected demonstrate that bats strongly respond to this factor and they suggest that different species show different levels of attraction to foraging opportunities provided by lamps and, in the case of *Myotis*, no attraction at all.

5. CONCLUSIONS

The occurrence of 16 bat species was ascertained in the Gran Paradiso National Park (Table 10). Compared to prior to the survey, when records identified according to current criteria were available for 2 species only, the list represents a considerable improvement in knowledge, although it cannot be assumed to be a

Table 10 Bats of ascertained presence in Gran Paradiso National Park and the elevation range in which they were detected (note that 800 m a.s.l. is the lower elevation in the Park). Values in **bold** type represent the maximum elevation recorded in Italy so far

	Elevation of recording sites (m a.s.l., min–max)
Myotis daubentonii	940–1,665
Myotis mystacinus	1,618–**2,292** (2,460*)
Myotis nattereri complex	800–1,885
Myotis myotis vel *blythii*	1,180–**2,460**
Pipistrellus kuhlii	800–**1,850**(**)
Pipistrellus pipistrellus	800–**2,460**
Pipistrellus pygmaeus	1,032
Hypsugo savii	800–**2,460**
Eptesicus nilssonii	1,050–**2,460**
Eptesicus serotinus	800–1,780
Vespertilio murinus	1,644–1,810
Nyctalus leisleri	1,050–**2,460**
Plecotus auritus	1,618–1,700
Plecotus macrobullaris	1,234–**2,292** (2,500*)
Barbastella barbastellus	800–**2,292**
Tadarida teniotis	1,050–**2,560**

* The maximum elevation recorded for the genus and probably referred to the same species.

** Some records attributed to *P. kuhlii* vel *nathusii* were recorded at 2,292 m.

complete inventory. Moreover, during the survey, many questions on different issues have arisen and further research is needed to answer them.

The list comprises one species – *B. barbastellus* – currently considered of high conservation interest (included in Annexes II and IV of the Habitats Directive) and largely dependent on forests for its foraging and roosting needs. Results suggest this species to be widespread on the side of the Park situated in Aosta Valley, from deciduous woods to the current upper limits of woods, and more rare in the Piedmontese area. Its occurrence was recorded more frequently at sites characterized by an absence of artificial lighting, yet a noteworthy record of presence was collected at a lighted site of high elevation (2,292 m), situated well above current forest limits.

Other inventoried species deserve attention since they are scarcely recorded in the broader context of Northwestern Italy (*V. murinus*, *P. pygmaeus* and *E. nilssonii*) or because their biology is still insufficiently known, having been recognized (*P. pygmaeus*, *P. macrobullaris*) or proposed (*M. nattereri* "species A" sensu Salicini *et al.*, 2013; Figure 22) as good species only recently, or even for the possibility they "hide" further cryptic species (*M. mystacinus* complex).

Prior to the survey in the Park, for *V. murinus* only two positive recordings (derived from direct observation of two individuals) were known for the entire territory of Piedmont (in Toffoli and Culasso, 2011, who also cited some data

Figure 22 A female belonging to the *Myotis nattereri* group captured in Cogne Valley (Paradisia alpine botanic garden, 1700 m a.s.l.) on 03/08/2012.

from echolocation calls, although these could not be considered of sure identification); and none for the Aosta Valley, whose bat inventory has been updated including the record of the species obtained through mist-netting in the Park (Patriarca and Debernardi, 2014). In the latest years, *V. murinus* have been recorded several times in almost all the regions of Northern Italy, and for Trentino-Alto Adige there is also some evidence, judged certain by Lanza (2012), that the species was already present at the end of the nineteenth century. The scantiness of records for the past, together with recent findings of individuals in areas where only questionable records existed for the past – comprising Canton Ticino (Mattei-Roesli *et al.*, 2011), Central Italy (Dondini and Vergari, 2014), Central and Southern France (review by Alberdi *et al.*, 2012a) and Spain (Alberdi *et al.*, 2012a; Ortega and Merino, 2015) – has raised the question of whether the species is expanding its range or the new recordings are simply due to an increased survey effort. For what concerns Gran Paradiso National Park – where the only captured individual was a male mist-netted in September but some social calls referable to the species had been collected in July – more sampling is required to determine the exact period of the year in which the species occurs and to verify if only males are present, as up to now recorded at the species' recording sites located farthermost from its known breeding range.

P. pygmaeus, whose presence in the Park was ascertained at a single site and date, is a species of recent taxonomic identification and there are no available data about its historic distribution. Regarding its current distribution in Piedmont and Aosta Valley, some records of occurrence are published in conventional literature (Debernardi and Patriarca, 2008; Seglie and Sindaco, 2012; Toffoli, 2015; Toffoli *et al.*, 2016) or reported in "grey literature" (Patriarca and Debernardi, 2015; https://faunaviva.wordpress.com/progetti-conclusi/monitoraggio-chirotteri-toce/). Recording sites, located at low and middle elevations, are scattered across the two regions, proving that the species is widespread in the area. On the other hand, the scarce quantity of records, mainly represented by isolated acoustic data, shows that it is uncommon in the two regions; it must be verified whether it breeds and if its occurrence is conditioned by migratory movements. Seasonal migrations have not been studied in this species but the existence of long-distance movements has been suggested based on genetic structure (Bryja *et al.*, 2009; Sztencel-Jabłonka and Bogdanowicz, 2012) and has been proved, at least for some populations, by preliminary banding data and observations carried out in Northern Europe (Ahlén *et al.*, 2007; Dietz and Kiefer, 2014). In this context of scarce knowledge, any further information about the occurrence of the species in the Park area can be useful and, for this purpose, it would be crucial to identify at species level the "intermediate" echolocation calls that in this study have been classified under "*Pipistrellus* 50 kHz", since some of them could be due to *P. pygmaeus*. A genetic survey would help to shed light on the subject and the different factors that may underlie the "intermediate" echolocation calls: the probable absence in the Park of *Miniopterus schreibersii*, which emits calls of intermediate frequency, and the consequent possibility that one or both of the two smallest *Pipistrellus* species emit in a broader range of frequencies than where Schreiber's bat is present (for other bat species it has been suggested that the frequency of echolocation calls may be conditioned by the presence of species with similar emissions: Russo *et al.*, 2007); the presence of a further cryptic *Pipistrellu*s species (up to now not supported by any clear evidence) or that of hybrids of *P. pygmaeus* and *P. pipistrellus* (hybridization between the two species has been proved in Central Europe, as reported by Sztencel-Jabłonka and Bogdanowicz, 2012, but this possibility should be considered unlikely in the Park for the rarity of *P. pygmaeus*).

For *E. nilssonii*, no historical records of occurrence are known for Piedmont and Aosta Valley. During the past years, mainly thanks to the possibility of acoustic identification, some records of presence have been collected and published for Aosta Valley (Patriarca and Debernardi, 2014) and southern Piedmont (Toffoli *et al.*, 2016). A few additional records are reported in grey literature (data provided by Piedmont Region for 2007–2012 reporting under article 17 of the Habitats Directive; Patriarca and Debernardi, 2015), but the overall data collected are far less than those available for Central and Eastern Italian Alps, where many records of past and present occurrence of the species exist, even obtained from random sources (found dead or in distress, entered in houses) (Lanza, 2012; Lapini *et al.*, 2015). This is consistent with a greater rarity of the species in Northwestern Italy; nevertheless, the activity values recorded in the Park during the present survey suggest that the Northern bat is not rare at some sites located in the area above 2,000 m. It would be worthy to verify this assumption with further surveying, in the Park as well as in other areas of the Western Italian Alps. As already mentioned, until now little surveying effort has been made in this part of the Alpine chain; moreover, surveys have mainly concerned areas below 2,000 m. Finally, it must be remembered that climatic zones and corresponding vegetation belts in Western Alps are wider and shifted towards elevations higher than in Eastern Alps, so that the occurrence of a cold-tolerant species could be expected to reach, and perhaps prefer, much higher elevations in Northwestern than in Northeastern Italy.

For what concern *M. nattereri* complex, in the Park area the lineage referred to as “species A” by Salicini *et al.* (2013) is expected to occur, since genetic identification of the same was performed also on material taken from individuals captured in the Aosta Valley, not far from Gran Paradiso National Park (Debernardi and Patriarca, 2008) and because this is the only lineage of “Natterer’s bat” so far recorded in Northern Italy (Salicini *et al.*, 2008 and 2013; Galimberti *et al.*, 2012). Yet, the exact taxonomic status of this lineage is still a matter of discussion (Hempel *et al.*, 2016) and more information, also on ecological aspects, is needed in order to clarify the question.

Regarding *P. macrobullaris*, the altitude of the sites where it has been recorded in the Park, together with literature records for sites of low elevation in Piedmont and Aosta Valley (Trizio *et al.*, 2003; Patriarca and Debernardi, 2014), confirms that the species occurs in a wide altitudinal range, as it results also from the geographic review by Alberdi *et al.* (2013). Moreover, results obtained through mist-netting in the Park are consistent with those of surveys carried out mainly in the Pyrenees (Alberdi *et al.*, 2013 and 2015): *P. macrobullaris* is able to live and is abundant, at least during summer, in open alpine environments above the treeline.

This contrasts with the ecological characterization of the species as mainly linked with deciduous forests and moderate elevations (up to about 1,500 m) obtained through a modelling approach starting from data collected in the Swiss Alps (Rutishauser *et al.*, 2012) and probably biased towards ecosystems of lower elevation because of the scarcity of surveys at upper elevations.

The maximum altitude where the species was captured in the Park (2,292 m) represents its highest altitudinal record for Italian Alpine chain, and coincides with an open alpine habitat type, but the highest altitude ascertained in the Park for genus *Plecotus* (2,500 m), very probably attributable to *P. macrobullaris*, suggests that the species can reach even higher elevations and tolerate harsher environmental conditions. Previous highest elevation record for the species in the Italian Alps – 2,050 m – had been recorded in Aosta Valley and reported by Alberdi *et al.*, 2013, who wrongly considered it the first record of the species for the region (first record in Debernardi and Patriarca, 2008).

Among whiskered bats, only *M. mystacinus* was ascertained to occur in the Park. The species was identified from the external characters of captured individuals, some of which showed features reported in literature for *M. mystacinus bulgaricus*. Further mist-netting, coupled with genetic analysis, would help to clarify the tassonomic status of such individuals, and in the meanwhile it would make it possible to verify if *M. brandtii*, not recorded in the present survey, is really absent in the area. *M. brandtii* is known to occur in Piedmont in the Lepontine Alps, where it has been captured in larch woods (Toffoli, 2006) but, up to now, no other evidence of its occurrence has been gathered elsewhere in Piedmont or in the Aosta Valley.

Species that are probably present in the Park but have not been recorded, or at least have not been recorded with certitude, are *P. nathusii* (we recorded some QCF echolocation calls that should be referred to this species according to Toffoli *et al.*, 2016, but we failed in gathering more positive evidence of occurrence, from social calls or captured individuals), *R. ferrumequinum* (which is regularly recorded at an hibernaculum and day-resting site located 6 km from the Park boundaries; Debernardi and Patriarca, 2008) and *M. bechsteinii* (recorded at sites more distant from the Park, yet considered of probable occurrence at the lower altitudes of the area because of the presence of favourable ecological conditions). Further research is needed to establish if these species of probable occurrence and/or other possible bat species inhabit or at least occasionally visit the Park area.

It must be underlined that the scarcity of suitable underground sites in the Park, notably caves, negatively conditions the role of the area for many bat species, influencing their detectability as well. In Alpi Marittime Park, where the occurrence of 21 bat species has been reported, 6 species (*R. ferrumequinum*, *M. bechsteinii*, *M. emarginatus*, *M. myotis*, *M. blythii/ oxygnathus* and *P. macrobullaris*) were detected only through inspection of underground sites or mist-netting at the entrance of the same roosts and most of the related data were collected at a single underground complex (Toffoli *et al.*, 2016).

The altitudinal ranges of the data collected for each recorded taxon during the present survey (Table 10) furnish preliminary information about the highest elevation they reach. For 10 taxa, the upper elevations where they were recorded in the Park constitute maxima for Italy (for comparisons with previous maximum records, see: Agnelli, 2006; Lanza, 2012; Lapini *et al.*, 2015). Together with *P. macrobullaris*, whose altitudinal record was already mentioned, they comprise *M. mystacinus*, *P. kuhlii*, *P. pipistrellus*, *H. savii*, *E. nilssonii*, *N. leisleri*, *B. barbastellus*, *T. teniotis* and one of the species of the couple *M. myotis*/*M. blythii*, probably *M. myotis*, since the relative data were recorded in Aosta Valley, where only this species of the couple is known to occur (Patriarca and Debernardi, 2014). An altitudinal record is also represented by the acoustic record collected at 2,292 m and attributed to *P. kuhlii* vel *nathusii*.

It should be expected that these national altitudinal records will be overcome with the improvement of knowledge, within the Park (part of the records were in fact obtained at the highest sites sampled, that means presence/absence of the same species was not investigated at higher altitudes) and/or in other sectors of the Alpine chain (in southernmost areas of the chain, the milder climatic conditions may facilitate bat occurrence at higher elevations). Concerning the latter possibility, we observe that the recent work on bats of Alpi Marittime Park (Toffoli *et al.*, 2016), which is the southernmost area of Italian Alpine chain, has been based on surveys carried out up to 2,100 m, and consequently possible occurrences at higher elevation may have been missed. The same work reports a national altitudinal record for *M. daubentonii* (1,900 m a.s.l.), although it does not specify if the source of the record itself is absolutely certain (capture, social calls) or questionable (echolocation calls).

For what concerns the lower altitudinal limits, evidence was gathered for several species proving their presence at the lower altitudes of Gran Paradiso National Park (Table 10). Anyway, all the inventoried species are known to occur along the valley bottom of Aosta Valley and/or in the plain or low mountain areas of Piedmont: consequently, it can be assumed that the lower borders of the Park, situated at about 800 m, do not represent an inferior altitudinal limit for any of them.

At sampling points characterized by an absence of artificial light sources, as a general trend, acoustic activity (referred to all bat species) decreased with elevation. Highest values were observed at ecotones (open/wooden areas) in the vegetation belt of deciduous forests, in some nights that were characterized by almost continuous activity during the first 3 hours after sunset; lowest values, generally less than 10 bat passes in the whole night-time, were recorded at high elevation, in mosaics of alpine prairie and rocks.

P. pipistrellus, genus *Myotis* and *H. savii*, in this order, were the most recorded taxa in acoustic surveys performed between 800 and 2,200 m, at unlighted sites situated beneath the current forest limits or just above them, in open areas covered by pastures of man-made origin.

Instead, probably because of the limited size of the acoustic sample, no clear dominance of any species or acoustic group could be recognized in the overall recordings collected between 2,200 and 2,600 m in natural open areas characterized by an absence of lighting. Acoustic data (together with mist-netting results for what concerns long-eared bats) revealed the presence of species such as *P. macrobullaris* and *T. teniotis* at high elevations, where they certainly find both foraging and roosting opportunities. Other recorded bats, notably *M. myotis* vel *blythii* and *N. leisleri*, might be attracted to sites of high elevation by prey abundance associated with some favourable environmental factors, such as prairie flora, cattle dung and cattle themselves. Dung beetle fauna, which in the Park is rich and diverse (Borghesio *et al.*, 2001), could be particularly attractive for *N. leisleri*, since an important use of dung beetles by the species has been reported for pasture areas, although situated in lowland, in other countries (Shiel *et al.*, 1998). Obviously, the presence of *N. leisleri* must be influenced also by its migratory behaviour: actually, the preliminary data collected in the Park mainly referred to the late summer (i.e. during migration time), but the species was recorded also in June and July, demonstrating its occurrence in the area throughout the whole summer.

For *M. myotis* an additional favourable factor is represented by the short grass of prairies and grazed pastures, which could facilitate the species in its ground preying behaviour. *M. myotis* is usually considered a species of low/medium altitude, but in the Pyrenees it has been mist-netted in pastures above the timberline up to 2,050 m (Alberdi *et al.*, 2013).

Mist-netting data were important in the survey to draw up the species inventory, but they were quantitatively marginal in comparison with acoustic data and, for this reason, less useful for speculating about the relative abundance of the different species. Nevertheless, captures on water bodies, mainly obtained in valley bottom areas, are consistent with identifying *P. pipistrellus* as the most common and widespread species in the Park beneath 2,200 m, and *H. savii* and genus *Myotis* as abundant in the same altitudinal range; besides, they suggest that *M. mystacinus* is the most common and widespread species among genus *Myotis*.

Capture effort in open areas was very limited and the most mist-netted species, *P. macrobullaris*, although certainly abundant at the sampled sites, cannot necessarily be considered the most common species in the same areas because it must be taken into account that, flying close to the ground, this species is much easier to catch than other bats (Alberdi *et al.*, 2013).

Compared to the general description given above, profound differences were observed on a local basis, both in terms of activity and species occurrence. Acoustic data collected at the two best surveyed areas of the Park, located in the Orco valley at similar elevation, showed that the taxa characterized above as common in the Park – like genus *Myotis* and *H. savii* – can be locally rare, and that ranking taxa according to acoustic activity can reveal important differences, depending on local environmental factors.

Results of acoustic surveys suggest that artificial lighting plays an important role in conditioning the presence and activity of bats. According to the preliminary data collected along valley bottoms, genera *Myotis* and *Plecotus* and *B. barbastellus* seem to occur more frequently at “dark” than at lighted sites. Current knowledge concerning how different species of bats react to artificial lighting is far from comprehensive, but it is known that many species belonging to the genera *Pipistrellus*, *Hypsugo*, *Nyctalus*, *Eptesicus* and *Tadarida* forage close to light sources that are attractive for insects, while other bats, including *Myotis* and

Plecotus species, are considered light-averse (Stone *et al.*, 2012 and 2015; Lacoeuilhe *et al.*, 2014; for reviews of earlier works: Rydell, 2006 and Patriarca and Debernardi, 2010); for *B. barbastellus* no clear relation between lighting and species occurrence has been proved up to now (Lacoeuilhe *et al.*, 2014) although anecdotal reports of light avoidance are reported (Jones, 2000).

At high elevation, profound differences were observed between a strongly lighted and some unlighted sites: total bat activity was exceptionally higher at the former; moreover, data suggested different levels of attraction to forage at lamps among bat species and no attraction at all for genus *Myotis*, whose activity resulted higher at the unlighted control site. To our knowledge, this is the first case in which the effects of artificial lighting on bats are considered with reference to an area of high elevation. The surveyed lighted site is surrounded by large areas in natural darkness and this enhances the contrast between light and background, a condition that increases the attractive power of light on insects (Bowden, 1982; Frank, 2006) and, consequently, very likely contributes to explaining the high levels of bat activity recorded.

As light can attract also swarms of migrating insects, it would be interesting to verify if this could possibly drive bats towards the site following the swarms; this might be the case of the barbastelle bat which was mist-netted at the site during a night of local great abundance of moths, but we have no elements to say if the bat itself was migrating or not. Barbastelles are considered sedentary bats, which may occasionally migrate or disperse (Hutterer *et al.*, 2005), but knowledge of this aspect is still far from exhaustive.

In the perspective of bat conservation, the consequences of artificial lighting should deserve closer attention. Conditioning prey availability (by affecting its spatial distribution and selectively destroying it or causing abnormal predation, even from diurnal predators, upon it) and eliciting different reactions in bat species (different degrees of attraction to forage near lamps, different levels of repulsion when crossing a lighted area) lighting shows the potential for conditioning bat movements, migrations included, and for altering bat communities.

ACKNOWLEDGMENTS

We thank an anonymous referee, who provided useful comments, and Thierry Disca, Danilo Russo and Olivier Vinet for their help with the identification of some acoustic sequences.

Logistic support and funding for the surveys were provided by the Gran Paradiso National Park.

FURTHER READING

Agnelli, P. (2006) Mammalia Chiroptera. In: A. Ruffo and F. Stoch (eds.), *Checklist e distribuzione della fauna italiana. 10.000 specie terrestri e delle acque interne*. Memorie del Museo Civico di Storia Naturale di Verona, 2a serie, sez. Scienze della Vita, 16. 307 pp. + CD-ROM. http://faunaitalia.it/documents/CKmap_ITA.pdf

Ahlén, I. and Baagøe, H. J. (1999) Use of ultrasound detectors for bat studies in Europe: experiences from field identification, surveys, and monitoring. *Acta Chiropterologica*, 1(2): 137–150. Available at: http://www.chiroptera.se/ahlen/Hans%20B%20-%20Use%20of%20ultrasound%20detectors.pdf (accessed 2 November 2017).

Ahlén, I., Bach, L., Baagøe, H. J., and Pettersson, J. (2007) Bats and offshore wind turbines studied in southern Scandinavia. The Swedish Environmental Protection Agency, Report 5571. Available at: https://www.naturvardsverket.se/Documents/publikationer/620-5571-2.pdf (accessed 2 November 2017).

Alberdi, A., Aihartza, J., Albero, J. C., Aizpurua, O., López-Baucells, A., Freixas, L., Puig, X., Flaquer, C., and Garin, I. (2012a) First records of the parti-coloured bat *Vespertilio murinus* (Chiroptera: Vespertilionidae) in the Pyrenees. *Mammalia*, 76(1): 109–111. Available at: http://dx.doi.org/10.1515/MAMM.2011.106 (accessed 2 November 2017).

Alberdi, A., Garin, I., Aizpurua, O., and Aihartza, J. (2012b) The foraging ecology of the mountain long-eared bat *Plecotus macrobullaris* revealed with DNA mini-barcodes. *PLoS One*, 7(4): e35692. doi:10.1371/journal.pone.0035692

Alberdi, A., Garin, I., Aizpurua, O., and Aihartza, J. (2013) Review on the geographic and elevational distribution of the mountain long-eared bat *Plecotus macrobullaris*, completed by utilising a specific mist-netting technique. *Acta Chiropterologica*, 15(2): 451–461.

Alberdi, A., Aihartza, J., Aizpurua, O., Salsamendi, E., Brigham, R. M., and Garin, I. (2015) Living above the treeline: Roosting ecology of the alpine bat *Plecotus macrobullaris*. *European Journal of Wildlife Research*, 61(1): 17–25. doi 10.1007/s10344–014–0862–8

Arlettaz, R., Berthoud, G., and Desfayes, M. (1998) Tendances démographiques opposées chez deux espèces sympatriques de chauves-souris, *Rhinolophus hipposideros* et *Pipistrellus pipistrellus*: Un possible lien de cause à effet. *Le Rhinolophe*, 13: 35–41.

Barataud, M. (2012) *Ecologie acoustique des chiroptères d'Europe. Identification des espèces, étude de leurs habitats et comportements de chasse*. Biotope Editions, Muséum national d'Histoire naturelle, Paris. 344 pp. + CD ROM.

Bayefsky-Anand, S., Skowronski, M. D., Fenton, M. B., Korine, C., and Holderied, M. W. (2008) Variations in the echolocation calls of the European free-tailed bat. *Journal of Zoology*, 275(2): 115–123.

Benda, P. and Karatas, A. (2005) On some Mediterranean populations of bats of the *Myotis mystacinus* morpho-group (Chiroptera: Vespertilionidae). *Lynx* (*NS*), 36: 9–38. Available at: http://www.tramem.org/pdf/2403.pdf (accessed 2 November 2017).

Bogdanowicz, W., Piksa, K., and Tereba, A. (2012) Hybridization hotspots at bat swarming sites. *Plos One*, 7(12): e53334. doi:10.1371/journal.pone.0053334

Borghesio, L., Palestrini, C., and Passerin d'Entrèves, P. (2001) The dung beetles of Gran Paradiso National Park: A preliminary analysis (Insecta: Coleoptera: Scarabaeoidea). *Journal of Mountain Ecology*, 6: 41–48. Available at: http://www.mountainecology.org/index.php/me/article/view/23/19 (accessed 2 November 2017).

Bowden, J. (1982) An analysis of factors affecting catches of insects in light-traps. *Bulletin of Entomological Research*, 72(4): 535–556. doi:10.1017/S0007485300008579

Bryja, J., Kaňuch, P., Fornůsková, A., Bartonička, T., and Řehák, Z. (2009) Low population genetic structuring of two cryptic bat species suggests their migratory behaviour in continental Europe. *Biological Journal of the Linnean Society*, 96(1): 103–114.

Debernardi, P. and Patriarca, E. (2008) Prima segnalazione di *Myotis bechsteinii*, *Myotis daubentonii, Myotis nattereri, Nyctalus leisleri, Pipistrellus pygmaeus, Plecotus macrobullaris e Tadarida teniotis* in Valle d'Aosta. Aggiornamento dell'inventario dei chirotteri noti per la regione. *Rev. Valdôtaine Hist. Nat.*, 61–62: 5–27.

Denzinger, A., Siemers, B. M., Schaub, A., and Schnitzler, H. U. (2001) Echolocation by the barbastelle bat, *Barbastella barbastellus*. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology*, 187(7), 521–528.

Dietz, C. and von Helversen, O. (2004) Illustrated identification key to the bats of Europe. Electronic Publication Version 1.0, released 15.12.2004. Tuebingen and Erlangen (Germany), 72 pp.

Dietz, C. and Kiefer, A. (2014) *Die Fledermäuse Europas: kennen, bestimmen, schützen*. Franckh-Kosmos Verlags-GmbH and Co, KG, Stuttgart.

Dondini, G. and Vergari, S. (2014) Range expansion? First record of parti-coloured bat (*Vespertilio murinus* Linnaeus, 1758) in Tuscany, Italy. *Barbastella*, 8 (1).

Eklöf, J. (2003) Vision in echolocating bats. PhD Thesis, University of Göteborg, Sweden. Available at: http://www.fladdermus.net/thesis.htm (accessed 2 November 2017).

Flaquer, C., Torre, I., and Arrizabalaga, A. (2007) Comparison of sampling methods for inventory of bat communities. *Journal of Mammalogy*, 88(2): 526–533.

Frank, K. D. (2006) Effects of artificial night lighting on moths. In: C. Rich and T. Longcore (eds), *Ecological Consequences of Artificial Night Lighting*, Island Press, Washington, pp. 305–344.

Galimberti, A., Spada, M., Russo, D., Mucedda, M., Agnelli, P., Crottini, A., Ferri E., Martinoli A., and Casiraghi, M. (2012) Integrated operational taxonomic units (IOTUs) in echolocating bats: A bridge between molecular and traditional taxonomy. *PloS One*, 7(6): e40122. doi:10.1371/journal.pone.0040122

Haquart, A. and Disca, T. (2007) Caractéristiques acoustiques et nouvelles données de Grande Noctule *Nyctalus lasiopterus* (Schreber, 1780) dans le sud de la France. *Le Vespère*, 1: 15–20.

Hayes, J. P. (1997) Temporal variation in activity of bats and the design of echolocation-monitoring studies. *Journal of Mammalogy*, 78(2): 514–524.

Hempel, E., Coraman, E., Dietz, C., and Mayer, F. (2016) Evolution of 'Natterer's bats' inferred by sequencing mitochondrial and nuclear DNA. *Mammalian Biology-Zeitschrift für Säugetierkunde*, 81: 9.

Hutson, A.M., Mickleburgh, S.P., and Racey, P.A. (comp.) (2001) *Microchiropteran Bats: Global Status Survey and Conservation Action Plan*. IUCN/SSC Chiroptera Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. x + 258 pp. Available at: https://portals.iucn.org/library/efiles/documents/2001-008.pdf (accessed 2 November 2017).

Hutterer, R., Ivanova, T., Meyer-Cords, C., and Rodrigues, L. (2005) *Bat Migrations in Europe. A Review of Banding Data and Literature*. Naturschutz und Biologische Vielfalt, 28. BfN, Federal Agency for Nature Conservation, Bonn. 162 pp. + appendixes.

Jones, J., (2000) Impact of lighting on bats. Available at: http://downloads.gigl.org.uk/website/lighting_and_bats.pdf

Jones, G., Jacobs, D. S., Kunz, T. H., Willig, M. R., and Racey, P. A. (2009) Carpe noctem: the importance of bats as bioindicators. *Endangered Species Research*, 8(1–2): 93–115. doi:10.3354/esr00182

Kunz, T. H., Braun de Torrez, E., Bauer, D., Lobova, T., and Fleming, T. H. (2011) Ecosystem services provided by bats. *Annals of the New York Academy of Sciences*, 1223(1): 1–38. doi:10.1111/j.1749–6632.2011.06004.x

Lacoeuilhe, A., Machon, N., Julien, J. F., Le Bocq, A., and Kerbiriou, C. (2014) The influence of low intensities of light pollution on bat communities in a semi-natural context. *PloS One*, 9(10), e103042. Available at: http://journals.plos.org/plosone/article/asset?id=10.1371/journal.pone.0103042.PDF (accessed 2 November 2017).

Lanza, B. (2012) *Mammalia V. Chiroptera*. Fauna d'Italia. Il Sole 24 Ore, Edagricole, 786 pp.

Lapini, L., Dorigo, L., Zagmajster, M, and Dall'Asta, A. (2015) Distribution of two alpine-boreal bat species, *Eptesicus nilssonii* (Keyserling and Blasius, 1839) and Vespertilio murinus Linnaeus, 1758, in Friuli Venezia Giulia Region (NE Italy). *Gortania,* 36: 115–121.

Marchesi P., Blant, M., and Capt, S. (eds) (2008) *Clés de détermination des mammifères de Suisse*. Fauna-Helvetica 21, CSCF and SSBF, Neuchâtel, 294 pp. ISBN 978–2–88414–033–1.

Mattei-Roesli, M., Zingg, P. E., Zbinden, K., Obrist, M. K., and Sattler, T. (2011) *Vespertilio murinus* – una nuova specie di pipistrello per il Cantone Ticino. *Bollettino della Società ticinese di Scienze naturali,* 99: 117–119. Available at: http://www.wsl.ch/wsl/info/mitarbeitende/obrist/pdf/11330.pdf (accessed 2 November 2017).

Middleton, N., Froud, A., and French, K. (2014) *Social calls of the Bats of Britain and Ireland*. Exeter, Pelagic Publishing Ltd, 176 pp.

Obrist, M. K., Boesch, R., and Flückiger, P. F. (2004) Variability in echolocation call design of 26 Swiss bat species: Consequences, limits and options for automated field identification with a synergetic pattern recognition approach. *Mammalia*, 68(4): 307–322.

Ortega, S. and Merino, D. (2015) First record of parti-coloured bat (*Vespertilio murinus*) in the Iberian Peninsula, in the southern Pyrenees [Primera observación de murciélago bicolor (*Vespertilio murinus*) en la Península Ibérica al sur de los Pirineos]. Available at: http://dx.doi.org/10.14709/BarbJ.8.1.2015.01 (accessed 2 November 2017).

Patriarca, E. and Debernardi, P. (1997) Insectivora, Chiroptera, Lagomorpha, Rodentia and Carnivora of the Gran Paradiso National Park: Checklist and preliminary ecological characterization. *Ibex, Journal of Mountain Ecology*, 4: 17–32. Available at: http://mountainecology.org/index.php/me/article/view/27/22 (accessed 2 November 2017).

Patriarca, E. and Debernardi, P. (2010) Pipistrelli e inquinamento luminoso, pp. 29. Bats and light pollution, pp. 27. Available at: http://www.centroregionalechirotteri.org/download/eurobats/pipistrelli%20e%20inquinamento%20luminoso%20EUROBATS.pdf (accessed 2 November 2017), and http://www.centroregionalechirotteri.org/download/eurobats/Bats%20and%20light%20pollution.pdf (accessed 2 November 2017).

Patriarca, E. and Debernardi, P. (2014) A checklist of bats (Mammalia: chiroptera) of Aosta Valley (NW Italy). In: S. Imperio, S. Mazzaracca, and D. G. Preatoni (eds), IX Congr. It. Teriologia. *Hystrix, the Italian Journal of Mammalogy*, 25(Supplement):127.

Patriarca, E. and Debernardi, P. (2015) Monitoraggio delle principali colonie di chirotteri note in Valle d'Aosta e approfondimento delle conoscenze sulla distribuzione dei chirotteri in Valpelline e Valle di Gressoney. Rapporto interno Regione Autonoma Valle d'Aosta – Assessorato agricoltura e risorse naturali, pp. 44.

Pfalzer, G. (2002) *Inter- und intraspezifische Variabilität der Soziallaute heimischer Fledermausarten* (*Chiroptera: Vespertilionidae*). Dissertation. Fachbereich Biologie der Universität Kaiserslautern, 275 pp.

Pfalzer, G. (2007) Verwechslungsmöglichkeiten bei der akustischen Artbestimmung von Fledermäusen anhand ihrer Ortungs- und Sozialrufe. *Nyctalus* (*NF*), 12(1): 3–14.

Pfalzer, G. and Kusch, J. (2003) Structure and variability of bat social calls: Implications for specificity and individual recognition. *Journal of Zoology*, 261(1): 21–33.

Pierallini, R., Keller, A., and Moretti, M. (2004) Chiave di determinazione dei Chirotteri (Mammalia) della Svizzera attraverso l'osservazione al microscopio ottico della struttura dei peli. *Revue suisse de Zoologie*, 111(2): 381–394. Available at: http://centrostudinatura.it/public2/documenti/471-44432.pdf

Preatoni, D. G., Nodari, M., Chirichella, R., Tosi, G., Wauters, L. A., and Martinoli, A. (2005) Identifying bats from time-expanded recordings of search calls: Comparing classification methods. *Journal of Wildlife Management*, 69(4): 1601–1614.

Russo, D. and Jones, G. (1999) The social calls of Kuhl's pipistrelles *Pipistrellus kuhlii* (Kuhl, 1819): Structure and variation (Chiroptera: Vespertilionidae). *Journal of Zoology,* 249: 476–481. doi:10.1111/j.1469-7998.1999.tb01219.x.

Russo, D. and Jones, G. (2000) The two cryptic species of *Pipistrellus pipistrellus* (Chiroptera: Vespertilionidae) occur in Italy: Evidence from echolocation and social calls. *Mammalia*, 64(2): 187–198.

Russo D. and Jones G. (2002) Identification of twenty-two bat species (Mammalia: Chiroptera) from Italy by analysis of time-expanded recordings of echolocation calls. *Journal of Zoology*, 258: 91–103.

Russo, D. and Jones, G. (2015) Bats as bioindicators: An introduction. *Mammalian Biology*, 80: 157–158. doi: 10.1016/j.mambio.2015.03.005

Russo, D., Mucedda, M., Bello, M., Biscardi, S., Pidinchedda, E., and Jones, G. (2007) Divergent echolocation call frequencies in insular rhinolophids (Chiroptera): A case of character displacement? *Journal of Biogeography*, 34(12): 2129–2138.

Rutishauser, M. D., Bontadina, F., Braunisch, V., Ashrafi, S., and Arlettaz, R. (2012) The challenge posed by newly discovered cryptic species: Disentangling the environmental niches of long-eared bats. *Diversity and Distributions*, 18(11): 1107–1119.

Rydell, J. (2006) Bats and their insect prey at streetlights. In: C. Rich and T. Longcore (eds), *Ecological Consequences of Artificial Night Lighting*, Island Press, Washington, pp. 43–60.

Salicini, I., Garcia-Mudarra, J.bL., Ibáñez, C., and Juste, J. (2008) Primi risultati nello studio della filogeografia del complesso specifico del vespertilio di Natterer (*Myotis nattereri*). In: C. Prigioni, A. Meriggi, and E. Merli (eds), VI Congr. It. Teriologia, *Hystrix, It. J. Mamm.* (*NS*), SUPP. 2008: 60.

Salicini, I., Ibáñez, C., and Juste, J. (2013) Deep differentiation between and within Mediterranean glacial refugia in a flying mammal, the *Myotis nattereri* bat complex. *Journal of Biogeography*, 40(6): 1182–1193.

Seglie, D. and Sindaco, R. (2012) Segnalazioni Faunistiche Piemontesi e Valdostane, V. (Amphibia, Reptilia, Mammalia). *Rivista piemontese di Storia naturale*, 33: 457–472.

Shiel, C. B., Duvergé, P. L., Smiddy, P., and Fairley, J. S. (1998) Analysis of the diet of Leisler's bat (*Nyctalus leisleri*) in Ireland with some comparative analyses from England and Germany. *Journal of Zoology*, 246(04): 417–425.

Skiba, R. (2009) Europäische Fledermäuse–Kennzeichen, Echoortung und Detektoranwendung. 2, aktualisierte und erweiterte Auflage von 2009. VerlagsKG Wolf., 220 pp..

Stone, E. L., Jones, G., and Harris, S. (2012) Conserving energy at a cost to biodiversity? Impacts of LED lighting on bats. *Global Change Biology*, 18(8): 2458–2465.

Stone, E. L., Harris, S., and Jones, G. (2015) Impacts of artificial lighting on bats: A review of challenges and solutions. *Mammalian Biology-Zeitschrift für Säugetierkunde*, 80(3): 213–219.

Šuba, J., Vietniece, D., and Pētersons, G. (2010) The parti-coloured bat *Vespertilio murinus* in Rīga (Latvia) during autumn and winter. *Env Exp Biol*, 8: 93–96.

Sztencel-Jabłonka, A. and Bogdanowicz, W. (2012) Population genetics study of common (*Pipistrellus pipistrellus*) and soprano (*Pipistrellus pygmaeus*) pipistrelle bats from central Europe suggests interspecific hybridization. *Canadian Journal of Zoology*, 90(10): 1251–1260.

Toffoli, R. (2006) Record of Brandt's bat *Myotis brandtii* (Eversmann, 1845) in Piedmont (Chiroptera, Vespertilionidae). *Hystrix, The Italian Journal of Mammalogy*, 17(2): 167–171. Accessible at: http://www.italian-journal-of-mammalogy.it/article/download/4375/4311 (accessed 2 November 2017).

Toffoli, R. (2015) Ai chirotteri il riso piace bio! In: M. Mucedda, F. Roscioni, and D. G. Preatoni (eds), III Convegno Italiano sui Chirotteri, Trento, 9–11 ottobre 2015. Gruppo Italiano Ricerca Chirotteri – Associazione Teriologica Italiana, p. 50.

Toffoli, R., and Culasso, P. (2011) *Vespertilio murinus* (Linneo, 1758): Una nuova specie per la chirotterofauna piemontese. *Bollettino Museo regionale Scienze naturali Torino*, 28: 191–196.

Toffoli, R., Culasso, P., Locatelli, A. G., and Giraudo, L. (2016) Bats of Alpi Marittime Nature Park (North West Italy) and Site of Community Importance IT1160056: Distribution and status. *Natural History Sciences*, 3(1): 3–13. Available at: http://dx.doi.org/10.4081/nhs.2016.254 (accessed 2 November 2017).

Trizio, I., Patriarca, E., Debernardi, P., Preatoni, D., Tosi, G., and Martinoli, A. (2003) The Alpine Long-Eared Bat (*Plecotus alpinus* Kiefer and Veith, 2001) is present also in Piedmont Region: First record revealed by DNA analysis. *Hystrix, The Italian Journal of Mammalogy*, 14(1–2): 113–115. Available at: http://www.italian-journal-of-mammalogy.it/article/download/4321/4257 (accessed 2 November 2017).

Voigt, C. C., and Kingston, T. (eds.) (2016) *Bats in the Anthropocene: Conservation of Bats in a Changing World*. (SpringerOpen), 606 pp. doi:10.1007/978-3-319-25220-9

Walters, C. L., Freeman, R., Collen, A., Dietz, C., Brock Fenton, M., Jones, G., Obrist, M. K., Puechmaille, S. J., Sattler, T., Siemers, B. M., Parsons, S., and Jones, K. E. (2012) A continental-scale tool for acoustic identification of European bats. *Journal of Applied Ecology*, 49(5): 1064–1074. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2012.02182.x/epdf (accessed 2 November 2017).

Zagmajster, M. (2003) Display song of parti-coloured bat *Vespertilio murinus* Linnaeus, 1758 (Chiroptera, Mammalia) in southern Slovenia and preliminary study of its variability. *Natura Sloveniae*, 5(1): 27–41.

Zbinden, K. and Zingg, P. E. (1986) Search and hunting signals of echolocating European free-tailed bats, *Tadarida teniotis*, in southern Switzerland. *Mammalia*, 50(1): 9–26.

IBEX JOURNAL OF MOUNTAIN ECOLOGY

Volume 11 (2018) Pages 1–58

Front cover: A female *Plecotus auritus* captured in Cogne Valley (Paradisia alpine botanic garden , 1,7000 m a.s.l.) on 03/08/2012.

Credits: All the pictures are from P. Debernardi