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BATS: HOW AND WHERE TO FIND THEM

URBAN ROOST SELECTION, HABITAT PREFERENCES AND RECORDING DEVICE PERFORMANCE

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DANKE

„Wrong information is worse than no information: biases in the assessment of bat distribution or habitat preferences may lead to wrong management decisions with serious consequences for the conservation of bat populations."

Russo and Voigt 2016

Russo D, Voigt CC (2016) The use of automated identification of bat echolocation calls in acoustic monitoring: A cautionary note for sound analysis. Ecological Indicators 66:598-602.

ABSTRACT

Twenty-eight of the 38 European bat species can be found in Austria. Many of them are listed in Red Data Books; nearly all of them are listed in Appendix IV, eight additionally in Appendix II of the FFH directive. Therefore, detecting and monitoring bat populations have become increasingly important in the last decades and a profound knowledge of their life and habitat requirements is needed. A very important resource for bats are roosts. Our findings showed that in the City of Vienna bats mainly preferred crevices in trees and buildings as roosts. A tree diameter at breast height of >40 cm was essential for suitable roosts, whereas building dwelling species showed no evidence for a preference of a particular building category. Especially the protection of rare and cryptic species like *Myotis bechsteinii* and *M. alcathoe* is challenging due to the scarce knowledge of their geographic distribution. We buildt habitat models for both species by combining data from various sources. This technique enabled us to extend the expected range of *M. bechsteinii* to Upper Austria and Vorarlberg, and to provide a distribution map for Austria. For *M. alcathoe*, we recommended to introduce the species as “Data Deficient” in the Austrian Red Data Book, but nevertheless expect it to be threatened due to its highly specific habitat requirements and small population size.

A new and meanwhile indispensable method for recording bat presence is the use of automated ultrasound detectors. Since little is so far known about the factors influencing their field performance, we tested for effects of call detection ranges and vegetation clutter on the recording probability of bat calls. We found huge differences in recording performance among neighboring devices and could show that the number of vegetation strata did not play a significant role for the detecting probability, whereas the openness of vegetation did.

Keywords: Bats; batcorder system; bat roosts; Chiroptera; sound analysis

KURZFASSUNG

Viele der 28 in Österreich vorkommenden Fledermausarten sind in der Roten Liste gefährdeter Arten geführt; fast alle sind in Anhang IV, acht zusätzlich in Anhang II der FFH Richtlinie gelistet. Um einen gezielten Schutz der Arten zu gewährleisten, sind profunde Kenntnisse über ihre Lebensweise und Habitatansprüche notwendig. Eine wichtige Ressource für Fledermäuse stellt das Quartierangebot dar. Wir konnten zeigen, dass in Wien vorwiegend Spalten an Bäumen und Gebäuden genutzt werden. Geeignete Quartierbäume wiesen einen Brusthöhendurchmesser von >40cm auf, wogegen bei Gebäudequartieren keine Präferenz für eine bestimmte Gebäudekategorie festgestellt werden konnte. Aufgrund mangelnder Kenntnisse schwierig ist der Schutz seltener und kryptischer Arten wie *Myotis bechsteinii* und *M. alcathoe*. Mit Hilfe von Habitatmodellen konnte das bekannte Verbreitungsgebiet von *M. bechsteinii* auf die Bundesländer Oberösterreich und Vorarlberg erweitert und eine Verbreitungskarte für das gesamte Bundesgebiet erstellt werden. Die derzeit nicht in der Roten Liste geführte *M. alcathoe* empfehlen wir unter „Datenlage ungenügend" zu listen, gehen jedoch aufgrund ihrer spezifischen Habitatansprüche und geringen Populationsgröße von einer Gefährdung aus.

Eine mittlerweile nicht mehr wegzudenkende Methode um Fledermäuse störungsfrei nachzuweisen, ist der Einsatz autonom aufzeichnender Ultraschalldetektoren. Trotz großer Beliebtheit dieser Geräte ist bislang nur wenig über die Faktoren bekannt, welche die Aufnahmeperformance beeinflussen. Wir testeten unter Freilandbedingungen den Einfluss von Stratifikation der Vegetation und Offenheit von Untersuchungsstandorten auf die Aufnahmewahrscheinlichkeit von Fledermausrufen und konnten große Unterschiede in der Artenzahl und Fledermausaktivität (Anzahl aufgezeichneter Rufsequenzen) zwischen benachbarten Aufnahmegeräten feststellen. Die Stratifikation hatte keinen Einfluss auf die Anzahl der Aufzeichnungen, wogegen die Standort-Offenheit einen signifikanten Faktor darstellte.

Schlagworte: Fledermäuse; Batcorder; Fledermausquartiere; Chiroptera; Rufanalyse

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INTRODUCTION

With more than 1300 species worldwide, bats constitute the second largest order of mammals after the rodents (Schilling et al. 1983; Voigt and Kingston 2016). They can be found on every continent except Antarctica and occur in various ecosystems from boreal to tropical forests up to deserts (Dietz et al. 2007). About 15% of the species are listed as threatened by the IUCN (**I**nternational **U**nion for **C**onservation of **N**ature) in the categories Critical Endangered, Endangered or Vulnerable and another 18% are Data Deficient (Jung and Threlfall 2016).

The causes of threat are very diverse. In Europe, the ongoing loss of adequate shelters, especially in trees and man-made structures like buildings and bridges, and the massive landscape change (urbanization, intensification of agriculture, decline of grassland, reduction of free-range farming, decline of deciduous forests and reforestation with conifers, removal of hedgerows, …) which highly increased in the mid of the nineteenth century, caused dramatic population losses in many European bat species (Hutson et al. 2001; Dietz et al. 2007). Other factors that contributed to this process included the application of timber preservatives for attic woodworks in the 1960ies and 1970ies that mainly contained DDT (Dichlorodiphenyltrichloroethane), PCP (Pentachlorophenol) and Lindane. Bats which used treated roof structures as roosts absorbed the toxic substances through their skin and incorporated them also orally by licking their fur (Dietz and Weber 2000; Hutson et al. 2001; Dietz et al. 2007). Subsequently, the liposoluble substances accumulated in their bodies and led to death especially in times of high energy consumption, for instance following the arousal from hibernation (Dietz et al. 2007).

Also the use of leaded gasoline, which was in Austria not prohibited until 1993 and in use in various other European countries until 2000 (Bartenstein 1998), led to serious health implications. Lead causes neuronal defects which results, among others, in deaf. Since bats use acoustical orientation, many died in accidents as a consequence of disorientation (Dietz and Kiefer 2014). Further, the ongoing application of insecticides and pesticides in agriculture and private gardens leads not only to an enormous decrease of potential food insects (Hutson et al. 2001) but also poisons bats indirectly via ingestion of contaminated prey (Dietz et al. 2007).

New sources of threat for bat populations that are so far not completely predictable include the construction and operation of wind parks. Some bat species, like *Myotis bechsteinii*, *M. alcathoe*, *Nyctalus leisleri*, *N. noctula*, *Pipistrellus nathusii*, *Barbastella barabastellus* and *Plecotus auritus* (Hurst et al. 2015) suffer from loss of roosting sites, hunting grounds and commuting pathways during the construction period, whereas others experience disorientation due to ultrasounds that are emitted by the operating wind turbines or die because of collision with towers, rotating blades or due to the underpressure created by the rotating blades (Kuvlesky et al. 2007; Baerwald et al. 2008; Cryan and Barclay 2009; Rodrigues et al. 2011). The KFFÖ (**K**oordinationsstelle für **F**ledermausschutz und -**f**orschung in **Ö**sterreich; 2014) estimated that each year about eight individuals per wind turbine die in Austria. Plank (pers. comm. 2016) estimated that this number may even be higher – namely over nine individuals per wind turbine and year. Not all bat species are equally susceptible to this threat since fatalities mainly affect high-flying and migrating species (*Nyctaus leisleri*, *N. noctula*, *Pipistrellus nathusii* and *P. pipistrellus*; Hurst et al. 2015).

Voigt and Kingston (2016) pointed out that, their peculiar biology make bats live on the slow side of a rapidly changing world and therefore suffer massively from anthropogenic impacts. Barclay et al. (2004) described the order Chiroptera as slowly reproducing, and most species give birth to only one young per year – a strategy that only works because of the longevity of majority of the species (Wilkinson and South 2002; Brunet-Rossinni and Austad 2004; Munshi-South and Wilkinson 2010). However, the relatively low reproduction rate, paired with comparably late sexual maturity (at the age of one to two years for most bat species) hampers a quick compensation of extraordinary population losses (Dietz et al. 2007; Voigt and Kingston 2016). For instance, many European bat species seem not to have fully balanced the massive population decline of the 1960ies and 1970ies to this day (Dietz et al. 2007; Voigt and Kingston 2016).

In Austria, 28 of the 38 European bat species can be found (KFFÖ 2014) and many of them are listed in various categories of the Red Data Book of endangered species (Spitzenberger 2005). When Austria became member of the European Union in 1995, it put the FFH directive (Directive on the conservation of natural habitats and of wild fauna and flora; Council Directive 92/43/EEC of 21 May 1992) into national legislation and all regulations therein became obligatory. All bat species registered for Austria (except for *Myotis dasycneme* and *Tadarida teniotis* which are missing in the current FFH lists) are listed in Appendix IV ("European protected species of animal"), and therefore are under full protection. Eight species (*Rhinolophus ferrumequinum*, *R. hipposideros*, *Barbastella barbastellus*, *Miniopterus schreibersii*, *Myotis bechsteinii*, *M. blythii*, *M. emarginatus*, *M. myotis*) are additionally listed in Appendix II and hence the designation of special areas of conservation is obligatory (Nature 2000 sites; Council of the European Communities 1992, Article

17.1; Reiter 2005). Not least due to this legal protection, detecting and monitoring of bat populations became increasingly important in the last decades.

The loss of roosts as consequence of house renovations and the frequent pruning of old trees is discussed as one of the main threats for synanthropic bats worldwide. Roosts are an essential requisite for bat life (Kunz and Lumsden 2003; Dietz et al. 2007) and knowledge about their roosting sites is therefore essential for conservation. To contribute to a management concept for the 22 bat species of the city of Vienna (KFFÖ 2014), I conducted a radio-telemetry study in 2008 [manuscript 1]. I captured 30 bats of seven species with mist nets and attached radio transmitters on their back to identify their daytime roosts within the densely build parts of the city. To this date, this was the first radio-telemetry study on bats in cities and it enabled us not only to assess suitable roost characteristics but also to appraise the feasibility of this detecting method in this unique environment.

All captured species preferred crevices as roosts and as a result, I found that crevices in trees and in buildings are equally important as daytime roosts. However, the preference for trees or buildings depended on the species of bat: For tree dwelling species, a diameter at breast height of > 40 cm seemed to be decisive for the suitability as a roost. Regarding roosts in buildings, I found no evidence for a preference of a particular building category and therefore concluded that there was no shortage of roosting sites in city buildings in Vienna.

Capturing individuals with mist nets and subsequent telemetry is an appropriate method to identify unknown bat roosts. Unfortunately, it is not equally suitable for all species. Some are hard to detect and also hard to capture, mainly because of their efficient echolocation calls. The Bechstein's bat (*Myotis bechsteinii*), for example, is a quite rare species in Austria and listed in both in Annex II and IV of the FFH directive. Its echolocation calls are highly frequency modulated, start at 100 kHz and end at ca. 35 kHz (Dietz et al 2007). This results in a high spatial resolution (~ 3.4 mm), which usually permits the bat to detect the netting (Dietz et al. 2007; Dietz and Kiefer 2014), and a quite short detection range for ultrasound detectors (around 10 to 15 m; Barataud 2016). Because of its high conservation status and its poorly documented distribution in Austria, we built a habitat model for this species to improve the state of knowledge [manuscript 2]. We hypothesized that its occurrence is coupled to the presence of oaks (*Quercus spp.*) and warm air temperatures. As records of Bechstein's bat are scarce, the data used for the model originated from various sources including literature references, own projects, data from colleagues and museum material. The combination of this heterogeneous set enabled us to extend the species distribution map to hitherto unmapped regions, e.g. central Upper Austria and Vorarlberg. We indeed found a preference of *Quercus spp*., but were not able to clarify if this was due to a causal link (e.g., because bats prefer oaks for roosting), or due to a similar ecological response to an environmental factor (both bats and oaks prefer regions with mild climate).

Habitat models can also be helpful for predicting the distribution of recently described and therefore little known species like the Alcathoe bat (*Myotis alcathoe*). This species was first recorded in Austria in 2006 (Spitzenberger et al. 2006), five years after its original description (Helversen et al. 2001) and therefore is not yet included in the current Red Data Books of Europe and Austria. In 2014, we build a habitat model for this species [manuscript 3]. 90% of the data used originated from recordings collected with stationary acoustic devices and 10% were obtained by mist netting, which enabled us to also capture pregnant and lactating females. Therefore we could show that this species reproduces in Austria, even though maternity colonies have not yet been found. As our data contained no information about the size and dynamics of the population, we recommended to list *Myotis alcathoe* as DD (Data Deficient) in the Austrian Red List, but nevertheless expected this species to be threatened due to its very specific habitat requirements and small population size.

The studies discussed so far demonstrate that various methods for investigating bat ecology data can be applied, and that adequate use depends on the research question. Traditional capture methods like mist netting allow the determination of sex, age and reproductive status of individuals. Radio tracking can be a useful method to identify unknown roosts of bats. Both methods are very time consuming for the operators and highly stressful for the captured individuals. A method for determining the presence of bats at investigation sites without causing any disturbance is the use of ultrasound detectors. Bats orientate, hunt and navigate by processing the information of echoes they produce by emitting ultrasound calls. These calls are often species specific and sound analysis with bat detectors can therefore be used to identify species. These devices translate bat calls in audible sounds either with a time expansion, frequency division or heterodyne system (Limpens and McCracken 2004; Pettersson 2004). Time expansion devices sample and digitize the incoming signal and play it back over an expanded time, whereas frequency division systems count the waves of the incoming signals and produce a single wave for a set number of usually ten counted waves. Both systems are broadband systems that detect the entire frequency band of bat calls (Limpens and McCracken 2004; Pettersson 2004). In Europe, the heterodyne system is mostly used in the field. This narrow band system mixes the incoming bat signal with an internal signal produced by a variable-frequency oscillator. The resulting signal contains sum frequencies and difference frequencies and therefore transposes the bat sound into audible tones (Limpens and McCracken 2004; Pettersson 2004). The acoustical species determination is very challenging and in some cases even impossible: it not only depends on the experience of the operator, but also on the echolocation task confronting the bat. For example, the amount of vegetation clutter strongly influences the call structure of some species. Thus, calls depend on the calling situation, may be highly variable (Schnitzler and Kalko 2001), and misclassifications therefore likely.

In the decade a new generation of bat detectors has been established on the market. These new devices record bat calls in real time and register them for further analysis. As these devices work automatically, they can be placed during daytime and programmed to operate during the night. Thus, a big advantage of this system is that it helps to reduce the effort of field-, and especially of nighttime work considerably. If several devices are available, it enables the user to simultaneously sample multiple sites per night or to record bat activity over a long period of time (Murray et al. 1999; Gorresen et al. 2008). A disadvantage of this method (and of acoustic detectors in general) is that, no information about sex, age and reproductive state is available of the registered individuals.

Further, some species tend to be underrepresented in acoustical studies if their echolocation calls have low sound pressure levels and thus short detection ranges (Barataud et al. 2016). Nevertheless, these devices are becoming increasingly important not only in scientific research, but also for applied projects. However, little is yet known about the factors that potentially influence their field performance (Russo and Voigt 2016).

In our recent study [manuscript 4], we tested for effects of call detection ranges and vegetation clutter on the recording probability of bat calls in the field. The detector system we used (batcorders) consisted of automated, stationary devices that registered bat calls in real time and stored them on SD cards. In a second step, the acoustic properties of the sampled calls were automatically measured with the software bcAdmin (Marckmann and Runkel 2010) and the call parameters used to automatically identify species (software batIdent; Runkel 2010). Thus, all recorded call sequences were identified to species or higher level and species lists were produced for the study sites.

We could clearly show that the difference in recording performance among neighboring devices deployed at the same site can be huge. This was true for both total bat activity and species richness. The number of vegetation strata did not play a significant role for the detection probability, but the factor vegetation openness (clutter) did. Regarding the detection ranges of the calls of the recorded species, the data variability of calls with very short detection ranges (5 m) was much higher than that of longer ranges (up to 100 m), thus indicating that not all species are equally likely to be detected by automated stationary devices.

In summary, it can be said that depending on the research question different detecting methods or also combinations of several methods need to be applied to guarantee good, consistent and reliable data in bat research.

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ABSTRACT

Roosts are a very important resource for bats, and often play a central role in conservation projects. To evaluate the feasibility of identifying urban bat roosts, we trapped 30 individual bats from seven species, attached radio transmitters and located their daytime roosts. This enabled us to build hypothesis on the importance of trees and buildings as daytime roosts for urban bats.

None of the captured animals were reproducing or lactating, so we assumed all recorded roosts to be simple daytime roosts. Of the 30 marked bats, 18 individuals (six species) could be monitored, and a total of 114 roosts were located; 57 of which were in trees, and another 57 in buildings. Our results indicate that neither building condition nor green coverage in the immediate (≤ 20 m) surroundings of a building was a significant predictor for the presence of roosts in or on a building. For tree roosts, diameter at breast height (DBH) was the most important factor determining the choice of tree roosts, but was found insignificant in a Generalized Linear Mixed Model. We presume that the lack of significance regarding green coverage and DBH in the model can be explained by the limited sample size of our study.

KEYWORDS
bat daytime roosts; Generalized Linear Mixed Models; radio telemetry; urban ecology

INTRODUCTION

Bats use a variety of roosts, e.g. daytime, maternity and hibernation roosts, which provide places for social interaction, reproduction, hibernation, protection from predation and shelter from environmental extremes (Lewis 1995). Aside from pesticide contamination of prey and loss of habitat, the reduction of roost sites is one of the main threats for bats in Europe (Dietz et al. 2007). Due to the importance of this resource, roosts often play a central role in bat conservation (Meschede and Rudolph 2004; Kunz and Fenton 2005; Dietz et al. 2007).

Many European species of bats are listed as threatened, including all species occurring in Austria (Council of the European Communities 1992, Annex II, Annex IV). For these threatened species, the designation of protected areas (Nature 2000 sites), and the monitoring of populations and their habitats are important conservation measures. Moreover, these measures are obligatory for the member states of the European Union (Council of the European Communities 1992, Article 17.1).

Of the 28 species of bats in Austria, 22 species have been detected in the city of Vienna to date (KFFÖ 2013). Previous studies have shown a surprisingly high activity of flying and foraging bats in the densely built areas of Vienna (Distl 2008; Hüttmeir et al. 2010), thus suggesting a high frequency of roosts in the area.

In cities, many roosts can be found on trees and buildings (Kunz and Reynolds 2003; Bihari 2004; Dietz et al. 2007) and bats are very selective in choosing these sites based on characteristics such as temperature and quality of surrounding areas (Vaughan and O'Shea 1979; Entwistle et al. 1997; Sedgeley 2001; Kalcounis-Rüppell et al. 2005). For example, Entwistle et al. (1997) showed that *Plecotus auritus* Linnaeus, 1758 selected roosts in buildings that were highly correlated with the structural complexity of the building (e.g. large compartmentalized attics), and with the vicinity of food resources (e.g. woodland, trees and water bodies). The renovation of houses, as well as the pruning or replacement of old trees in cities may influence the quantity of adequate roosts available to bats, and therefore be a limiting factor for bat occurrence in cities.

Because knowledge of the biology of urban bats is scarce, especially with respect to their roosting ecology, further data are needed to develop profound management concepts for the conservation of the populations.

The aim of our study was to test the feasibility of identifying roosts of bats in urban areas and to contribute first empirical data for a management concept of Viennese city bats. We used radio telemetry to locate daytime roosts of bats in densely built parts of Vienna, where high bat activity was previously recorded (Distl 2008; Hüttmeir et al. 2010). We further evaluated the importance of trees and buildings as daytime roosts of bats in these areas.

MATERIAL AND METHODS

Study area

Austria is situated in central Europe and is characterized by a continental, warm temperate climate with rainfall in all four seasons (Auer and Böhm 2011).

The city of Vienna, which is Austria's capital, has 1.7 million inhabitants, and covers 415 km². About 46% of the city contains green spaces that consist of parks, sport and leisure facilities, forests, and agricultural areas (Lebhart 2012). Our study was conducted in summer between July and September, 2008 in a densely built part of Vienna including parts of the first, third and fourth district (ca. 11000 inhabitants per km²; Lebhart 2012). The study area (center: 48°12'N, 016°22'E) is approximately 4 km^2, and is characterized by residential buildings and a high ground sealing. Green areas in these districts are spread over the entire area and are restricted to parks, interspersed with green inner courtyards and avenues. The residential buildings of these districts are mainly built in Wilhelminian style and date back to the 19th and early 20th century. They usually have four to six floors and high-structured facades. Interspersed among these are newer buildings built mainly in the second part of the 20th century. Most of the buildings have green inner courtyards that are not accessible to the public (Wichmann et al. 2009).

Capturing, tagging and detection of daytime roosts

We captured a total of 30 bats of seven species (one *Pipistrellus kuhlii* Kuhl, 1817, one *P. nathusii* Keyserling and Blasius, 1839, one *Plecotus auritus* Linnaeus, 1758, two *P. pipistrellus* Schreber, 1774, six *P. pygmaeus* Leach, 1825, four *Eptesicus serotinus* Schreber, 1774 and 15 *Nyctalus noctula* Schreber, 1774), using mist nets in the Stadtpark and the Botanical Garden of the University of Vienna. Capture took place during seven nights, between 27 July and 21 August 2008 (Kubista 2009). Capturing and tagging was carried out with permission of the Viennese Environmental Protection Department (license MA22 - 2693/2008) and was performed following the ASM guidelines (Sikes et al. 2011).

All captured bats were identified to species and their sex and age (adult/juvenile) was determined (Mitchell-Jones and McLeish 2004). To not exceed the recommended 5% of body weight (Mitchell-Jones and

McLeish 2004), individuals with insufficient body weight were not tagged but released immediately.
The radio tags (LB-2N, 0.35g and BD-2, 1.2g, Holohil Systems Ltd., Ontario, Canada) were attached between the scapulae of each bat with Histoacryl (B. Braun, Maria Enzersdorf, Austria) and Skinbond surgical cement (Smith & Nephew, Largo, FL, USA), after which the animals were released unharmed at the capture site. Each transmitter was assigned a distinct radio frequency that enabled us to locate up to 18 Individuals at the same time (Kubista 2009).
We started to locate the tagged individuals the day after capture by triangulation with a hand held XR100 receiver (Stabo Elektronik, Hildesheim, Germany) and an H-aerial antenna (F151-5FB, AF Antronics Inc., Urbana, IL, USA). Tracking was performed daily (28 July – 03 September 2008) by criss-crossing the study area on foot until no more transmitter signal could be received (03 September 2008). Bats were radiotracked for six days on average (range one to 13 days) and a total of 114 roosts were located; of those, 57 occurred in trees, and 57 in buildings (see table Anhang 1, pp 49 in Kubista 2009 for more detail). Because all detected daytime roosts were located in inaccessible places (e.g. on facades near the roof), none of the roosts were inspected closely.

Characterization of roosts

To determine the availability of adequate sites in buildings and trees in the study area, we assessed roost characteristics together with each located bat. We assumed that a shortage of roosts would be indicated by many triangulations clustered in a few especially suitable buildings and trees (or a particular type of these), while unlimited availability of roosts would result in many triangulations being randomly scattered over the

study area, or no apparent correlation to building/tree condition, respectively.
Building condition was placed in one of three categories: (1) not structured (i.e., no visible damages of the facade or the roof); (2) slightly structured (crevices on the facade, damaged or broken skylights, broken roof or wall shingles, etc.); and (3) highly structured (considerable damage and dominant crevices on the facade or roof; facades with complex stucco work).
Because of the high amount of green areas spread over the entire study area, we decided to consider green coverage of each building on a small scale (within a 20 m radius). Green coverage was classified into four categories: (1) no green; (2) one or two trees, (3) small green areas with more than two trees; and (4) large green areas with many trees. For each tree, we recorded the diameter at breast height (DBH) and characterized the condition of the tree using three categories: (1) slightly structured (no visible damages); (2) medium structured (small damages visible, like loose bark, small broken branches) and (3) highly structured (heavy damages visible, such as wood rot or woodpecker cavities in trunk or branches).
To test for influences of DBH, tree and building condition and green coverage on the roost choice, we additionally created a set of pseudo-absence data by randomly designating sampling points in the study area, selecting the nearest tree (n=57) or building (n=57), and characterizing the predictor variables for each tree and building as described above.

Statistical analysis

All statistical analyses were performed using R 2.15.1 (R Development Core Team 2012).

We analyzed a 3 x 4 contingency table and conducted a subsequent chi-square test on the tracked and pseudo-absence data to evaluate the probability of a bat choosing a roost in or on a building, depending on condition of the building (ordinal scale) and the green coverage (ordinal scale) in the surrounding area. To assess the importance of DBH (interval scale) and tree condition (ordinal scale) for the selection of roost trees by bats, we performed a classification tree analysis. This procedure aims to find subgroups in data sets by minimizing within-group and maximizing between-group variation. Explanatory variables of different scales may be combined (Zuur et al. 2007).

As the errors of tracking data cannot be considered statistically independent due to the resampling of marked individuals over time, we repeated both analyses with Generalized Linear Mixed Models (GLMM) with binomial error distributions (package lme4; Bates et al. 2012). In contrast to standard statistical procedures, Linear Mixed Models are able to account for the pseudoreplicated nature of longitudinal measurements and produce correct test statistics (Zuur et al. 2009).

RESULTS

Of the 30 marked bats, 18 individuals (one *Pipistrellus kuhlii*, one *P. nathusii*, one *Plecotus auritus*, two *Eptesicus serotinus*, five *P. pygmaeus*, eight *Nyctalus noctula*) were located, whereas 12 bats (one *P. pygmaeus*, two *P. pipistrellus,* two *E. serotinus*, seven *N. noctula)* could not be tracked down after release.

Because none of the captured animals was reproducing or lactating, we assumed all recorded roosts to be daytime roosts (i.e., no maternity roosts).

The number of roosts visited and the roost fidelity varied among individuals. For example, one individual (*P. auritus*) used a single roost for the entirely lifespan of its transmitter's battery (ten nights total). All others spent one to nine nights in the same roost before moving to a new location, and the number of roosts used by an individual varied between one and six sites (Kubista 2009).

Roosts in or on buildings

The contingency analysis of roost choice, building condition, and green coverage in the surrounding area showed that slightly structured buildings (category 2) and buildings with highly structured facades (category 3) were selected more often as daytime roosts than expected by chance, but only if a large green area with many trees (category 4) was located nearby (Fig. 1). However, by accounting for the repeated measurements of individuals with the GLMM, we found both building condition and green cover to be insignificant as fixed effects predictors of bat presence (Table 1). The species specific preferences for a roost in or on a building depending on the level of green cover in the surrounding are shown in Fig. 2.

Roosts in trees

The classification tree analysis of the importance of trunk diameter (DBH) and tree category for the choice of roost trees revealed DBH as the most important factor for day roost selection (Fig. 3). Trees with a DBH < 40.27 cm proved uninhabited. Again, as for building roosts, a GLMM found both DBH and tree category insignificant as predictors for bat presence (Table 2). The species specific preferences for a roost in a tree depending on the DBH of the tree are shown in Fig. 4.

DISCUSSION

Buildings and trees as roosting sites

In this study, roosts were found in trees and buildings, and not in other structures (e.g. bridges, underpasses, the extensive stonework of river gate of the Vienna river embankment), alluding to their importance as roosting sites in Vienna. We do not think to have missed any roosts in those other structures due to the intense search of the study area.

With respect to all species of bats recorded, we found indications, but no significant evidence that roosting sites in the crevices of city buildings are limited, because no particular category of building was favored over any other. Obviously, appropriate crevices are available independently from our building condition categories. We therefore reject our initial hypothesis that daytime roosts in buildings are a limited resource for bats in the city of Vienna. One reason for this finding could be that none of the captured individuals were reproducing or lactating, and we thus assumed that all recorded roosts were daytime roosts. Bats select these roosts in order to minimize their thermoregulatory costs, to reduce probability of predation, to lower ectoparasite loads and to decrease the costs of commuting to foraging areas (Vaughan and O'Shea 1979; Lewis 1995; Entwistle et al. 1997). Therefore, roost fidelity to daytime roosts is not as distinctive as roost fidelity to maternity roosts (Lewis 1995; Dietz et al. 2007). Bats have particular requirements with regard to maternity roosts. Those roosts have to provide special microclimate conditions for gestating females and their developing young (Humphrey 1975) and maternity roosts are usually used by colonies (Humphrey 1975; Zahn 1999; Dietz et al. 2007) over many years (Lewis 1995). Contrary to these roosts, daytime roosts of many species of bat, especially those of tree-dwelling ones, are known to be switched regularly (*N. noctula* for example switches roosts nearly every day - Kronwitter 1988; Lewis

1995), and bats are constantly prospecting new locations (Lewis 1995; Dietz et al. 2007). We therefore strongly suggest to focus on maternity roosts in future studies of the urban ecology of bats.

There was some indication but no significant evidence that the green cover surrounding a building which contained a roost had an influence on the selection of the roost by bats. However, Stürzenbaum (2011) found significantly more roosts in the attics of buildings when these sites were situated near a large green area. Similarly, Jenkins et al. (1998) showed that the percentage of tree cover within a radius of 50 m around a building was the best predictor for the presence of *P. pipistrellus* roosts. The *P. auritus* individuals in the study of Entwistle et al. (1997) selected roosts close to their woodland foraging sites, and roosts within the village could only be found in buildings situated within a suitable foraging habitat with high tree density. Although we are not able to draw general conclusions on the roosting preferences for *P. auritus* because of the single bat observed, our data support these findings: we located the individual for ten days in a convent containing a huge garden with old fruit trees, which is situated next to the Botanical Garden of the University of Vienna. This botanical garden contains a large number of old and large trees, and appears to provide suitable foraging resources for bats. The lack of significance of green coverage as a factor in the GLMM could possibly be explained by the small sample size of our study, or that other spatial scales than the 20 m radius considered here may be more relevant.

The roost trees sampled in our study had stem or branch cavities from wood rot, woodpeckers and storm damages, features that are typically associated with older trees of larger diameter (Evelyn et al. 2004). We showed that trees with a DBH less than 40 cm were never chosen for roosting by bats. This is in accordance with the results of Lunney et al.

(1988), Taylor and Savva (1988), Brigham et al. (1997), Bontadina et al. (1994) and Spada et al. (2008) which also showed that bats preferred trees of larger girth (DBH > 80 cm - Lunney et al. 1988; Taylor and Savva 1988; DBH > 52cm - Bontadina et al. 1994; DBH 56 cm - Brigham et al. 1997; DBH 66.8 ± 30.6 cm - Spada et al. 2008). Again, we assume that the lack of significance of DBH and tree category in the GLMMs resulted from the small number of individuals tracked - a statistically problematic, yet inevitable feature of telemetry studies. Nevertheless, as found in previous studies, the 57 tree roosts documented in this study were all confined to trees of larger size (≥ 40 cm), and we take this as strong evidence for the importance of tree size in the selection of roosts by bats.

From our observations, it is these very trees that the urban park administration habitually removes from avenues and parks because these trees are considered a threat for public safety. A reduced density of such large trees could lead to a population decline of tree-dwelling species of bat. According to our results, we strongly recommend the preservation of trees with trunk diameters > 40 cm. Arboricultural care, such as repeated thinning-out of the crown of older trees, can help prevent tree windthrow, thus safely prolonging the lifespan of the tree (Juillerat and Vögeli 2006). Additionally to secure an older tree, big branches can be supported by ropes and beams, or by ground anchoring (Juillerat and Vögeli 2006). To prevent people from entering a danger zone (e.g. next to an old tree with damaged branches that bears the potential risk of windthrow or breakage), we recommend planting thorny bushes (e.g. roses, raspberry, blackberry) within these areas to deter pedestrians (Juillerat and Vögeli 2006).

In places where preservation of trees is not possible due to safety concerns, we suggest providing artificial roosts in the form of bat boxes that may help to create new roosting opportunities for some species of bat. For example, several tree dwelling species, e.g. *Pipistrellus pygmaeus*, *P. nathusii*, *Plecotus auritus* and *Nyctalus noctula* have been reported to use new bat boxes (Ciechanowski 2005; Flaquer et al. 2006; Baranauskas 2007) and such roosts may be exploited by urban bats. It is nevertheless important to keep in mind that bat boxes can never substitute for the loss of a real roosting site (Dietz et al. 2007), because some species, e.g. male *N. noctula*, are fidelic to their daytime roosts, and may exploit these for many years even though they change single roosts almost daily (Kronwitter 1988).

Radio telemetry in cities

Of the 30 marked bats, 12 could not be found again after release. Reasons for this may include the large home range sizes of several of the captured species (mean 7.46 km² for *E. serotinus* - Robinson and Strebbings 1997; mean 8.2 km² for *N. noctula* - Mackie and Racey 2007) and detection problems of the transmitter signals due to urban construction.

We captured and marked 15 noctule bats (*N. noctula*), but obtained tracking data from only six individuals. This species has a large body size and is known for its extended home range (Dietz et al. 2007). For example, Mackie and Racey (2007) recorded a foraging noctule bat at a maximum distance of 6.3 km from its roost tree. It is thus highly probable that we lost nine of the noctule bat individuals in this study simply because they left our study area. To increase detection probability, we recommend selecting species with small home ranges, such as *P. pygmaeus* (Nicholls and Racey 2006), *P. auritus* (Entwistle et al. 1996) and *P. nathusii* (Flaquer et al. 2009) or, if more personnel for ground searching is available, to extend the study area size.

Urban construction caused many problems for the detection of transmitter signals that we had not yet experienced in other, non-urban settings. For example, signals were reflected off the facades of buildings, or were suppressed by particular fabrics making it difficult to locate the radio tagged bats. Due to the angled, sometimes labyrinth character of central Vienna, signals from transmitters (even at a close distance) could not be registered by the receiver, but the signals were clear just around the corner. Furthermore, noises of the same frequency and rhythm as the transmitter signals (e.g. traffic lights at pedestrian crossings) were a constant nuisance for the searching personnel. It might be that some of the bats that could not be tracked after release took roost within private and inaccessible inner courtyards and went undetected because the buildings shielded the transmitter signal to the streets.

Thus, radio telemetry within the districts of densely built cities involves unexpectedly intensive and time-consuming ground search on foot. However identification of roosts of urban bats by radio tracking is a promising method to reveal unknown roost of endangered bat species in a city.

We found it mandatory to intensively cover the whole study area and to literally "turn every corner", therefore, we suggest that future investigations using radio tracking of bats in similar environments, should allocate more personnel for ground searching activities than we did. In our experience, due to the dense construction in our study area, one person with a hand held antenna can sample an area of approximately 1.7 km² per day. As searching time increases with number of radio tagged individuals, we recommend not tracking more than two individuals in the same time, if only one person performs ground searching. Furthermore we recommend focusing on only one or two species simultaneously, to allow species-specific predictions on roost selection and exploitation.

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TABLES

Tab. 1 Results of a Generalized Linear Mixed Effects Model on the data of a radio tracking study on choice of building roosts by bats in the city of Vienna.

Random Effects				
Groups	Name	Variance	Std.Dev.	
ID	(Intercept)	2832.1	53.217	
Number of observations: 114, groups: ID, 68				
Fixed Effects				
	Estimate	Std.Error	z value	Significance (P)
(Intercept)	-14.8637	30.5760	-0.486	0.627
Building category	0.3785	10.6434	0.036	0.972
Green coverage	1.0209	9.1033	0.112	0.911

Note: Bat identity was selected as a random factor to account for multiple localizations of the same individual.

Tab. 2 Results of a Generalized Linear Mixed Effects Model on the data of a radio tracking study on choice of tree roosts by bats in the city of Vienna.

Random Effects				
Groups	Name	Variance	Std.Dev.	
ID	(Intercept)	2572.1	50.715	
Number of observations: 114, groups: ID, 67				
Fixed Effects				
	Estimate	Std.Error	z value	Significance (P)
(Intercept)	-17.35735	82.35658	-0.211	0.833
Tree category	2.19107	17.83394	0.123	0.902
DBH	0.01613	0.72122	0.022	0.982

Note: Bat identity was selected as a random factor to account for multiple localizations of the same specimens.

FIGURES

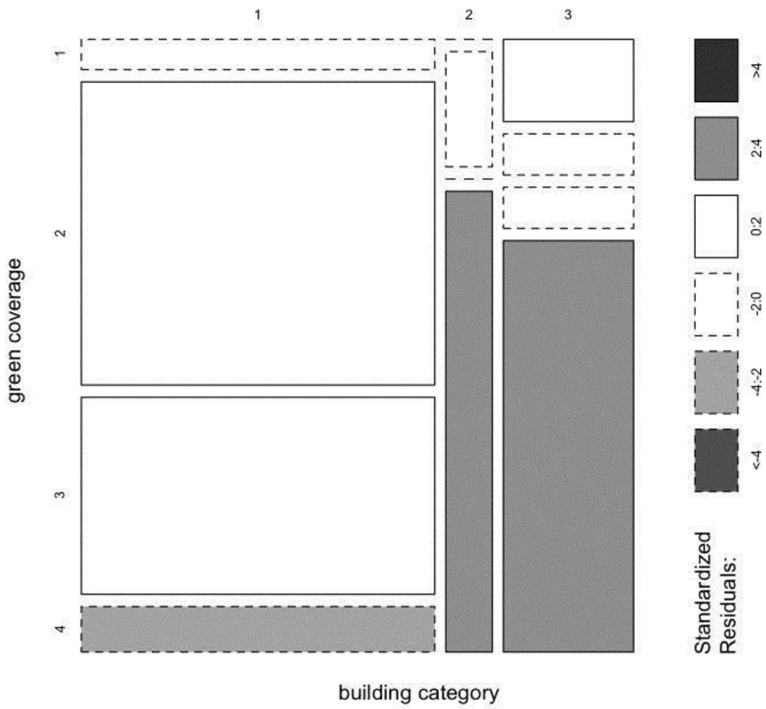

Fig. 1 Mosaic plot of the importance of building condition and green coverage for the presence of urban bat roosts in buildings in Vienna. Bar width indicates sample size and bar shading indicates if the number of cases in a given category was more or less than expected under the null hypothesis of no relation between roost frequency and category. For example, buildings of category 3 were more likely to have a roost if a green space of category 4 was situated within a range of 20 m than expected by chance.

Building category: **1** not structured; **2** slightly structured; **3** highly structured

Green coverage: **1** no green; **2** 1-2 trees; **3** small green area with > 2 trees; **4** large and highly structured green area

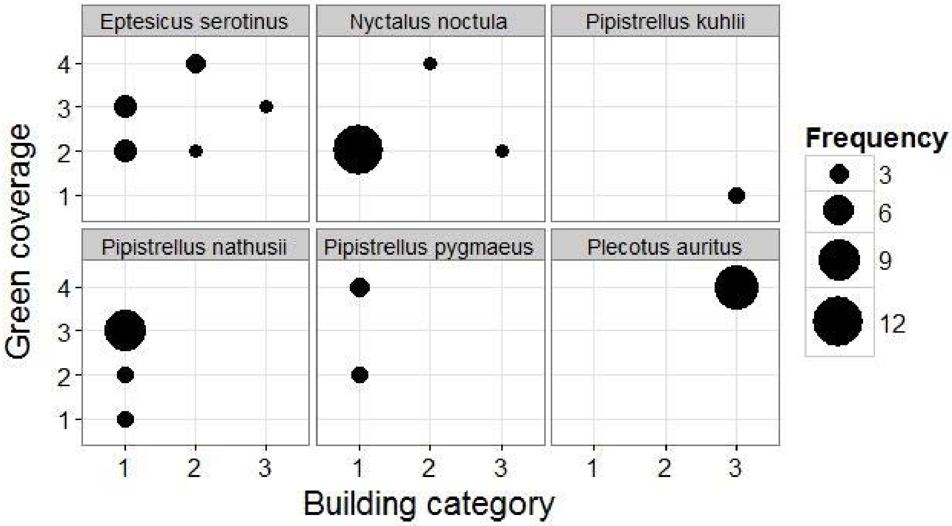

Fig. 2 Species specific preferences for roosts in buildings depending on building conditions and green coverage. The size of the dots indicate the frequency (number of telemetry fixes) of roosts.

Building category: **1** not structured; **2** slightly structured; **3** highly structured

Green coverage: **1** no green; **2** 1-2 trees; **3** small green area with > 2 trees; **4** large and highly structured green area

Number of observed individuals that used a roost in or on buildings: *Eptesicus serotinus* n=2, *Nyctalus noctula* n=4, *Pipistrellus kuhlii* n=1, *P. nathusii* n=1, *P. pygmaeus* n=2, *Plecotus auritus* n=1

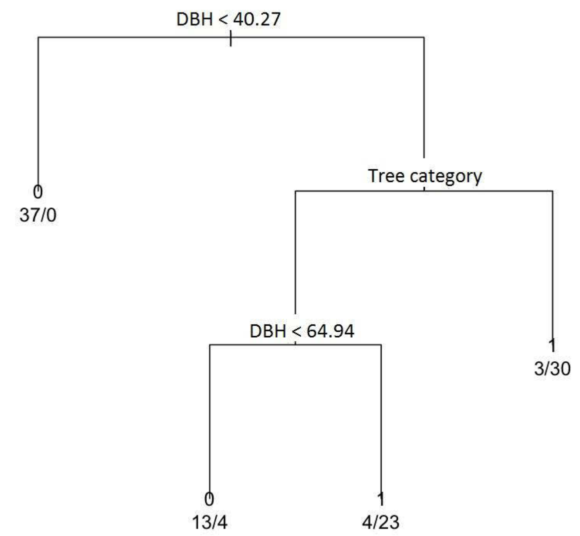

Fig. 3 Classification tree of the importance of stem diameter (DBH) and tree category for the choice of an urban tree as roost site in Vienna. DBH was the best predictor for the choice of a tree as roost (root). Explanatory variables are displayed in decreasing order of importance (here, DBH is most important). If a statement on top of a split is true, follow the left branch, and vice versa. The numbers at the terminal nodes are the predicted group (1: presence, 0: absence), followed below by the numbers of cases (e.g. for the leftmost branch, in 37 trees no roosts were found, and in 0 trees roosts were present).

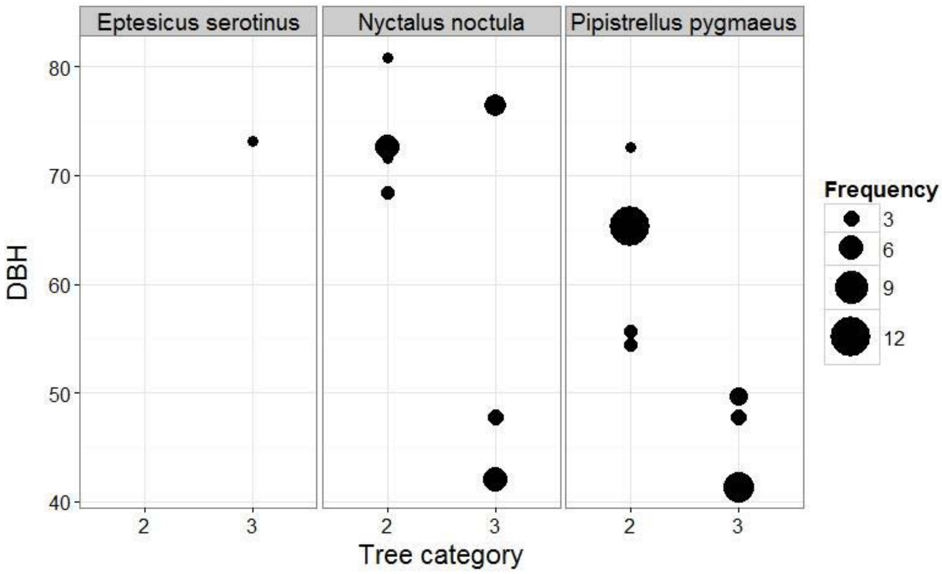

Fig. 4 Species specific preferences for roosts in trees depending on the stem diameter (DBH) and tree category. The size of the dots indicate the frequency (number of telemetry fixes) of roosts.

<u>Tree category:</u> **1** slightly structured; **2** medium structured; **3** highly structured

Number of observed individuals that used roosts in trees: *Eptesicus serotinus* n=1, *Nyctalus noctula* n=5, *Pipistrellus pygmaeus* n=4

[2] Distribution of Bechstein's bat, *Myotis bechsteinii* (Kuhl, 1817) in Austria

Reiter G, Bruckner A, Fritsch G, Kubista C, Pollheimer M, Hüttmeir U (2013) Distribution of Bechstein's bat, *Myotis bechsteinii* (Kuhl, 1817) in Austria. In: Dietz M (ed.): Populationsökologie und Habitatansprüche der Bechsteinfledermaus *Myotis bechsteinii*. Beiträge der Fachtagung in der Trinkkuranlage Bad Nauheim 25.-26. Februar 2011. Zarbock GmbH & Co. KG, Frankfurt, Germany. pp 175–190.

ABSTRACT

Bechstein's bat (*M. bechsteinii*) is listed in the Annex II and IV of the EU habitat directive. In this paper, we documented and analyzed all currently available records of *M. bechsteinii* in Austria. As its distribution is poorly documented in Austria, a habitat model could further improve the knowledge of the species.

M. bechsteinii is a thermophile species and its occurrence is often coupled with the presence of oak trees (*Quercus spp.*). In order to build an adequate habitat model, we need to discern which of these two factors, either temperature or the presence of oak, is of higher significance. We therefore compared 139 records of Bechstein's bat from across Austria (199 sites from 1980-2001) with data of oak distribution (Austrian Forest Inventory data, 1994) and mean monthly temperature (project HISTALP, aggregation period 1971-2000). We were able to prove that both Bechstein's bat and oaks prefer locations with high average summer temperatures, with a mean of 15.1°C. Summer records (May-September) of *M. bechsteinii* were mainly located around the periphery of the Alps as well as in some inner alpine valleys; their altitudinal distribution reached up to 800 m.a.s.l.. The winter records

(October-April), in contrast, showed a higher concentration within the Alps, with altitudinal preferences between 200-400 m.a.s.l. and 600-800 m.a.s.l.. Generally, we support the received knowledge about the distribution of this species in Austria but additionally we detected *M. bechsteinii* in two new regions – central Upper Austria and Vorarlberg. Furthermore, we can show that the distribution of oak in Austria is a significant factor for the distribution of the Bechstein's bat. The absence of recent records in some regions requires further investigation. However, we failed to discriminate the influence of oak stand characteristics from that of temperature due to the great spatial distances between the records of Bechstein's bat and the closest oak inventory sites. The distances were mostly in the range of several kilometers and therefore too large to allow an ecologically-relevant correlation. Proximate causes of Bechstein's bat association with oak forests may be twofold. On the one hand the very high average biomass and biodiversity of arthropods found in these forests provide optimal food resources. On the other hand the highest breeding densities of woodpeckers (above all Great Spotted and Middle Spotted Woodpecker *Dendrocopos major*, *D. medius*) are found in oak forests, and therefore higher numbers of tree cavities. The numerous tree holes meet the demands of *M bechsteinii* for a high number of maternity roosts.

INTRODUCTION

Bechstein's bat (*M. bechsteinii)* is listed under Annexes II and IV of the EU Habitats Directive and is therefore a species of special conservation concern. Conservation measures such as the designation of protected areas (Natura 2000 sites) and the monitoring of populations and their habitats are required. The distribution of this species in Austria is poorly documented, dated and probably biased towards winter records (see Spitzenberger and Bauer 2001).

To bridge the gap between scarce knowledge and conservation demands, habitat models may be a reasonable solution. They enable the prediction of the likely occurrence of a species at unsampled locations from its habitat requirements (Guisan et al. 2006). Naturally, the performance of a habitat model depends on how well the habitat dimensions of the species under study can assessed and defined empirically.

Bechstein's bat appears to be a good candidate for this type of modelling on first impression. It is generally considered to be a species of mild climates as it has been shown to prefer the warmer regions of Europe (Dietz et al. 2007). Furthermore, its occurrence seems to be coupled with the presence of old deciduous tree stands, especially those of oak (*Quercus spp.*). To build a habitat model, we need to discern which of these two (and potentially other) factors are of higher significance, as well as establishing if either of the factors is important at all.

As with the Bechstein's bat, the distribution of oak is linked to mild, lowland and sub-Mediterranean climate (Mayer 1984). Thus, the frequent association of *M. bechsteinii*, oaks and warm temperatures may be another example of collinearity, that is, the high correlation of explanatory (= predictor) variables in a statistical analysis (Quinn and Keough 2002).

Collinearity is likely to be ignored by biologists who model habitat requirements and distribution of species using a multiple regression (or related) approach, since complete absence of the phenomenon is improbable in many ecological data. However, high levels of collinearity may strongly affect the confidence of regression parameters (inflation of standard errors of estimated regression slopes) and may even show fake significant regression results when there are none (see Quinn and Keough 2002, for a thorough discussion).

We intended to use the data set of this study to assess the importance of warm climate versus oak presence for the distribution of *M. bechsteinii* in Austria.

In this paper, we have documented and analyzed all currently available records of *M. bechsteinii* in Austria. We found that both *M. bechsteinii* and *Quercus spp.* were restricted to the warm eastern lowlands of the country. Whilst we found strong indications of collinearity, we were unable to demonstrate it conclusively as the inventory data turned out to be insufficient.

MATERIAL AND METHODS

Austria is situated in central Europe and covers 83879 km². The Alps cover about 60% of the country. North of the River Danube are hill lands and there are extended lowlands in the eastern and south-eastern parts of Austria.

The climate ranges from alpine to the warm and dry continental "pannonic" climate in the eastern parts of the country.

Approximately 47% of Austria is covered by forests: coniferous forests (62%), mixed forests (26%) and broadleaved forests (12%). Oak trees could be found in approximately 11% of all plots with woodland surveyed in the Austrian Forest Inventory (Schadauer 1994).

Data sources

All available records of *M. bechsteinii* in Austria were summarised for this study. Data originated from various sources including own projects, data from colleagues and museum material, as well as literature data (Table 1). Hence, the data set used in this study is very heterogeneous.

Recording of echolocation calls

For this study only recordings of bat calls from automated ultrasound recording units of the same type ("batcorder", ecoObs, Nuremberg, Germany, http://www.ecoobs.de) were used. This batcorder device digitally records ultrasonic signals in real time (500 kHz, 16 bit, sensitivity range 16 – 150 kHz) and uses a built-in, realtime filter to distinguish between bat calls and ultrasound signals from other origins (e.g. bush crickets). This system was originally designed for studies on microhabitat use by bats in forests (Runkel 2008). Devices were calibrated and configured by ecoObs. No further adjustments of the settings were made (default settings: quality = 20, 400 ms post trigger, -27 dB threshold level, critical frequency 16 kHz). Bat calls recorded were automatically stored and measured with the software bcAdmin 2.06 (ecoObs Nuremberg). Subsequently measurements were analysed with the software batIdent 1.02 (ecoObs Nuremberg). This software compares unknown bat calls with reference calls based on a statistical approach using randomForest analyses and Support Vector Machines, programmed in R (R Development Core Team 2011).

For the purpose of this study we only used recordings of *M. bechsteinii* with a probability of correct classification higher than 75%. Furthermore, after the automated classification, each sequence was manually checked using bcAnalyze 1.11 (ecoObs Nuremberg) and published descriptions for bat calls of *M. bechsteinii* (Russo and Jones 2002; Obrist et al. 2004; Hammer et al. 2009).

Temperature and forest stand data

To assess the importance of temperature and the presence of oak trees for the summer occurrence of *Myotis bechsteinii* in Austria, we eliminated nine potential outliers from the data set (sampling date < 1980, height above sea level > 1100 m; resulting n=139 records).

Monthly mean temperatures of the recording sites were retrieved from the HISTALP project that provides gridded climate data for the larger region of the Alps, based on quality-improved, long-term weather station records (Böhm et al. 2009; http://www.zamg.ac.at/histalp/). We used data from the aggregation period 1971-2000 in a 5x5 minutes grid. For each bat record, the HISTALP grid data temperature value was corrected for height above sea level according to:

$\mathbf{temp}_{record} = \mathbf{temp}_{grid\ cell} - ((\mathbf{height}_{record} - \mathbf{heigth}_{grid\ cell}) * 0.0065))$ assuming an average temperature change of 6.5°C per 1000 m altitude difference.

The average temperature of the summer months (May to September) is closely and linearly correlated to the yearly average (Pearson's r=0.98), so we present only the former here.

Oak stand data were retrieved from the Austrian Forest Inventory (Schadauer 1994). The approximately 5600 survey units of this program (quadratic "tracts", each of 200 x 200 m size) were on the intersections of a 3.89 km^2 grid covering the Austrian territory. Stand characteristics were assessed in four 300 m^2 circular plots on the corners of each tract (Hauk and Schadauer 2009). Our oak data set comprised all 2423 plots nationwide where *Quercus spp.* were present with a diameter at breast height ≥ 50 cm (the three dominant oak species of Austria, *Quercus robur*, *Q. petraea*, and *Q. cerris,* were not differentiated in the inventory). These data were compared to a random sample of inventory plots from all over Austria (n=250 plots).

Altitude data from the inventory were only available with a resolution of 100 m.a.s.l.. We improved these figures using the digital elevation model of the Shuttle Radar Topography Mission (SRTM; http://www2.jpl.nasa.gov/srtm/). Then temperature data were calculated for each forest stand in the data set as given above.

For each record of *M. bechsteinii,* the linear distances between the closest inventory plot and the centre of the nearest HISTALP grid cell were calculated in ESRI ArcGIS 9.3, using the function "Near_analysis" with “search_radius 25000m”.

RESULTS

A total of 279 records of *Myotis bechsteinii* from 218 sites were included in the subsequent analysis. Nearly 50% of the recordings were from since 2001 and over 75% since 1976 (Fig. 1).

The records include findings of roosts (35%), bats captured in mist nets (18%), and recordings of echolocation calls (28%) as well as other types (19%).

Summer distribution

Recordings of *M. bechsteinii* during the summer season, from May to September, are mainly located around the periphery of the Alps with only a limited number of records from inner alpine valleys (Fig. 2). No difference in the spatial distribution of the different recording methods could be noticed. Local concentrations of recordings are in almost all cases the result of an increased sampling effort in these areas, for example in the course of inventory studies.

The majority of records (67%) originate from foraging areas made either by mist netting or recording of bat calls. Only a small number of records

represent roosts - maternity roosts (8%) or roosts of solitary individuals (11%). Other types of recordings or unknown situations account for 14%.
The altitudinal distribution of the summer records is heavily biased towards areas from 200-600 m.a.s.l. (Fig. 3). Also, since the one record above 1000 m.a.s.l. is a finding in a cave, we conclude that the recent summer distribution in Austria reaches up to 800 m.a.s.l..

Winter distribution

From October to April, more records are found in the Alps as compared to the summer distribution (Fig. 4), but there are still many records around the periphery of the Alps. The majority of the records originate from caves (52%), with much fewer from galleries (12%) and wine cellars and boiler rooms (10%). Other records are from bat or birds boxes (6%) or of unknown origin.
The more-alpine distribution of the winter records is reflected in their altitudinal distribution, with records up to 1400 m.a.s.l. (Fig. 5). However, the altitudinal belts between 200–400 m.a.s.l. and 600–800 m.a.s.l. are disproportionally more used compared to the area in Austria.

Distribution of *M. bechsteinii* and *Quercus spp.* in Austria

When plotted on a map, the distribution of oak trees and the summer records of Bechstein's bat overlapped to a very large extent (Fig. 6). We assume that their ranges were in fact identical, as the difference to total match might just be an effect of inadequate sampling of Bechstein's bat. Both taxa covered the lowland regions of the country, i.e. (clockwise from N to S) the Mühlviertel, Waldviertel, Weinviertel, Vienna Basin, Burgenland, and south-eastern Styra, and several warmer, inner-alpine valleys in Carinthia and Vorarlberg.

Accordingly, Bechstein's bats were only found at locations with high average summer temperatures, with a mean of 15.1°C (Fig. 7). The same was true for the stands of *Quercus spp*., that exhibited an average summer temperature markedly above that of a random collection of forest inventory plots from all over Austria (14.6 and 11.7°C, respectively; Fig. 8). Thus, there is substantial evidence for collinearity between the potential predicting factors - temperature and oak presence - in governing the distribution of Bechstein's bat.

We failed, however, to discern the influence of oak stand characteristics versus temperature influence, because the distances between the records of *M. bechsteinii* and the closest oak inventory sites were mostly in the range of several kilometers and therefore too large to allow an ecologically relevant correlation (Fig. 9). Information on the recording sites themselves (apart from geographic coordinates, altitude, and temperature) was not available.

DISCUSSION

Records of Bechstein's bat in Austria date back to the early Pleistocene (Spitzenberger and Bauer 2001) and are well documented from several caves in Bad Deutsch Altenburg (eastern Austria) by Rabeder (1973). The post-glacial recolonization is assumed for the early Holocene. Overall, Holocene records in Austria are mainly located in the eastern Alps, concentrated in the northern and southern limestone Alps and the Styrian carstic region (Spitzenberger and Bauer 2001).

The restriction of Holocene records to the eastern Alps seems to reflect the records in natural caves. Since there are rarely any natural caves outside the Alps, the recent distribution of hibernacula is very likely a consequence of the availability of man-made underground sites.

The distribution map published in Spitzenberger and Bauer (2001) shows that Bechstein's bat occurs mainly in the lowlands of eastern Austria. Few records are located in inner-alpine valleys of the Southern Alps (Spitzenberger and Bauer 2001). Thus, the additional findings presented here support the received knowledge of the distribution of this species in Austria. However, because of the increased sample size and new methods, such as the recording of ultrasound calls, a more confident and detailed picture could be obtained. Furthermore, *M. bechsteinii* was meanwhile found in new regions of Austria, including central Upper Austria and in Vorarlberg (Fig. 2).

Bechstein's bat is mainly a European species with only a few records outside Europe (Dietz et al. 2007).

The distribution of this species in neighbouring countries shows similar patterns to those in Austria. However, for some countries the distribution patterns may reflect the search effort rather than the actual distribution of this species.

In southern Germany (Bavaria) only a few records exist from the alpine region adjacent to the border with Austria. The main distribution is in the northern part of the country and only a few records are known from the region south of the River Danube (Rudolph et al. 2004). In Switzerland, higher latitudes are also avoided, with records distributed north of the Alps and in low alpine valleys (Zuchuat and Keller 1995).

In the Czech Republic and Slovakia, Bechstein's bat has a mosaic distribution, but is more abundant in warmer, wooded and hilly landscapes (Hanák et al. 2010). The same distribution pattern seems to occur in Hungary where it is more common in the northern and southwestern parts of the country (Estók and Szatyor 2007).

South of the Alps, this species seems to be rare. In Slovenia, the species is very rare and most records are from swarming sites. No maternity roosts have yet been found, but reproducing populations are assumed to occur in the southern parts of Slovenia (Koselj 2009). So far there is only one record of a nursery roost from Southern Tyrol (Niederfriniger and Drescher 2001).

We found a very close correlation between the occurrence of Bechstein's bat and oak trees, very much as in other areas like Luxemburg (Dietz and Pir 2009) and Spain (Napal et al. 2010). Furthermore, a link with oak trees was found at different geographical scales, such as the home ranges of individuals (Dietz and Pir 2009; Napal et al. 2010; Güttinger and Burkhard 2013) or the distribution pattern in larger areas as in Luxembourg (Dietz and Pir 2009).

However, the possibility that oak forests and mild climate are solely ultimate causes of the occurrence of Bechstein's bat must be envisaged. Possible proximate causes of Bechstein's bat association with oak forests may be twofold. On the one hand the far above average biomass and biodiversity of arthropods found in these forest types (e.g. Pasinelli and Hegelbach 1997; Southwood et al. 2004) provide optimal food resources.

Even more important may be the fact that mature oak forests hold the highest breeding densities of woodpeckers (above all Great Spotted and Middle Spotted Woodpecker *Dendrocopos major*, *D. medius*) compared to other European forest communities (Glutz von Blotzheim and Bauer 1994). Feeding mainly on surface-dwelling arthropods the Middle Spotted Woodpecker strongly depends on mature fissured barked oaks (Pasinelli and Hegelbach 1997; Kosiński and Winiecki 2005; Kosiński 2006). These two Woodpecker species provide a huge amount of tree cavities which meets the demands of Bechstein's bat for a high number of roosts (Napal et al. 2009; Dietz 2010; Dietz and Pir 2011).

However, there are indications that at least some populations of *M. bechsteinii* do neither depend on oak trees nor on deciduous trees at all (Steinhauser 2002; Albrecht et al. 2002). The question therefore remains unsolved as to whether there is a causal link between the bat and the trees, or whether their closely-matching distribution patterns are due to the preference of both taxa for regions of mild climate. Further research into this subject is needed and any modelling approach must be based on more appropriate environmental data than were available to us. Like many other similar databases, the Austrian Forest Inventory was never intended to be used for habitat-modelling of endangered animals, and it is not possible to clarify complex correlations with data of that kind. This is especially true for species' records that come from random findings and unsystematic sampling, as has been demonstrated with the *M. bechsteinii* data in this study.

Even if the occurrence of *Quercus spp.* is not causal for the summer records of Bechstein's bat, the distribution of the tree in Austria indicates where the presence of *M. bechsteinii* is clearly to be expected, but recent records are missing. Therefore, it will be necessary to check these areas for the presence of *M. bechsteinii* in order to get a complete picture of the distribution of this species in Austria. This is very important for the conservation of this species in Austria as well as for monitoring purposes.

Plank et al. (2012) pointed out that *M. bechsteinii* often forages in the canopy stratum of the woods. Therefore, canopy sampling should be undertaken when aiming to monitor such species for conservation purposes. Populations of *M. bechsteinii* will be underestimated, and maybe missed completely, by ground sampling alone (Plank et al. 2012).

Conclusions and implications for the conservation of *M. bechsteinii* in Austria

The following issues summarize the important goals for the conservation and management of this species in Austria:

i) Completion of the knowledge about the actual distribution of this species in Austria, especially searching for *M. bechsteinii* in areas with a high probability of occurrence but where records are lacking.
ii) Research about the autecology of this species in Austria is also called for, primarily on the habitat use in areas with sparse woodland or in areas with mainly coniferous woodland.
iii) Production of guidelines for the conservation of this species in protected areas.
iv) Production of guidelines for owners of working forests for the conservation of this species.
v) Establish a monitoring program for this species.

We strongly suggest that these points should immediately be put into action in order to promote this species in Austria and fulfil the obligations derived from the EU Habitats Directive.

VERBREITUNG DER BECHSTEINFLEDERMAUS IN ÖSTERREICH

Die Bechsteinfledermaus (*Myotis bechsteinii*) wird in Anhang II und IV der FFH-Richtlinie der EU aufgelistet und ist daher eine Art mit hoher naturschutzfachlicher Relevanz. Über die Verbreitung dieser Art in Österreich ist wenig bekannt und die bestehenden Verbreitungskarten weisen vermutlich eine Verzerrung aufgrund der Durchmischung von Sommer- und Winteraufnahmen auf.

Um für den Aufbau eines adäquaten Schutzkonzepts die bestehenden Wissenslücken ausreichend füllen zu können bieten sich Habitatmodelle an. Mit deren Hilfe kann, sofern die Ansprüche einer Art an ihr Habitat bekannt sind, die Vorkommenswahrscheinlichkeit der jeweiligen Art in einem zuvor nicht untersuchten Gebiet geschätzt werden.

So ist etwa bekannt, dass die Bechsteinfledermaus ein Bewohner milder Klimate ist. Sie bevorzugt die wärmeren Regionen Europas und ihr Auftreten scheint sich mit dem Vorhandensein von alten Laubwaldbeständen, im Besonderen dem von Eichen (*Quercus spp.*), zu decken. Da jedoch auch die Verbreitung von Eichen mit milden Klimaten gekoppelt ist, könnte die enge Assoziation der Bechsteinfledermaus mit Eichen und warmen Temperaturen eine Kollinearität darstellen. Um ein geeignetes Habitatmodell erstellen zu können muss daher im Vorfeld geklärt werden, welcher Faktor die Vorkommenswahrscheinlichkeit der Bechsteinfledermaus besser vorhersagt oder ob eventuell keiner der gewählten Faktoren von Relevanz ist.

Mit der vorliegenden Untersuchung sollte somit gezeigt werden, ob warmes Klima oder Eichenbestand eine bessere Abschätzung der Verbreitung von *M. bechsteinii* in Österreich ermöglicht.

Der für die Untersuchung verwendete Datensatz für den Nachweis der Bechsteinfledermaus in Österreich setzt sich aus einer Vielzahl verschiedener Quellen zusammen. Beinhaltet sind darin Daten aus eigenen Projekten, Museumsmaterial und Literatur sowie zur Verfügung gestellte Daten von Kollegen. Die Nachweise wurden in zwei Gruppen, Sommer (Mai bis September) und Winter (Oktober bis April), aufgeteilt.

Die Temperaturdaten wurden aus dem Datensatz des Projektes HISTALP entnommen. Dieser liefert monatlich gemittelte Messungen, welche in einem Raster für die größeren Regionen der Alpen mittels Langzeit-Messstationen erhoben wurden. Die für unsere Standorte verwendeten Temperaturdaten liegen in einem 5x5 Minuten Raster vor und stammen aus der Periode 1971-2000. Um die Temperaturwerte für die jeweiligen Höhenlagen der vorliegenden *M. bechsteinii* Fundorte bestmöglich anzupassen, wurden die bestehenden HISTALP Daten von uns adaptiert. Da weiter die durchschnittlichen Temperaturen der Sommermonate Mai bis September eng mit den jährlichen Durchschnittstemperaturen korrelierten, erfolgten alle weiteren Berechnungen nur mit letzteren.

Die Verbreitungsdaten der Eichen (*Quercus spp.*) stammen aus der österreichischen Waldinventur. Die Datenqualität bezüglich der gemessenen Seehöhen wurde unter Verwendung des digitalen Höhenmodells STRM für unsere Zwecke optimiert. Ebenfalls wurde, wie auch für die Nachweise der Bechsteinfledermaus, der jeweilige Temperaturwert für die Eichenstandorte berechnet.

Durch Ermittlung des nächstgelegenen Eichenstandortes (Luftlinie) und des nächstgelegenen Zentrums eines HISTALP Aufnahmequadrats, konnte nun die Umgebung der einzelnen *M. bechsteinii* Fundorte genauer charakterisiert werden.

Anhand der vorliegenden Daten konnte gezeigt werden, dass das Sommer-Verbreitungsgebiet von *M. bechsteinii* in Österreich vorwiegend am Alpenrand, mit Ausnahme von einigen inneralpinen Tälern liegt

(Fig.2) und die Art bis in eine Höhe von 800m Seehöhe vorkommt (Fig.3). Dabei konnte kein Unterschied in der räumlichen Verteilung zwischen den verschiedenen Nachweisquellen festgestellt werden.

Verglichen mit den Sommeraufnahmen, lagen hingegen die Winternachweise (Oktober-April) vermehrt im Gebiet der Alpen (Fig.4). Die höchstgelegenen Nachweise erfolgten in einer Seehöhe von 1400m, wobei jedoch Höhenlagen zwischen 200-400m und 600-800m über dem Meeresspiegel bevorzugt wurden (Fig.5).

Durch das Verschneiden der Eichenstandorte mit den Sommernachweisen der Bechsteinfledermaus, konnte weiter gezeigt werden, dass diese sich stark decken (Fig.6). Beide lagen in Regionen mit einer durchschnittlichen Sommertemperatur von 15.1°C, wodurch eine starke Kollinearität nachgewiesen werden konnte. Leider gelang es uns nicht herauszufinden welcher der beiden Prädiktoren (Eichenbestand oder Temperatur) eine bessere Abschätzung der Verbreitung von *M. bechsteinii* in Österreich ermöglicht. Wir gehen davon aus, dass der für unsere Zwecke grobe Maßstab der Waldinventurdaten der Grund hierfür ist. Oftmals lagen mehrere Kilometer zwischen einem *M. bechsteinii*-Nachweispunkt und dem nächstgelegenen dokumentierten Eichenstandort. Aufgrund dieser großen Distanzen war eine biologisch relevante Korrelation nicht möglich (Fig.9).

Über die jeweiligen Nachweispunkte selbst lag abgesehen von den geografischen Koordinaten, der Höhenlage und der Temperatur keine detaillierte Information vor.

Die unmittelbaren Ursachen für die enge Bindung der Bechsteinfledermaus an Eichenwälder können folgende sein: Zum Einen gilt die Biodiversität und Biomasse von Arthropoden in Eichenwäldern als die höchste aller europäischen Waldgesellschaften; dadurch sind die

Nahrungsressourcen in diesem Waldtyp überdurchschnittlich hoch. Zum anderen sind in Eichenwäldern die Siedlungsdichten von Spechten (v.a. Bunt- und Mittelspecht *Dendrocopos major*, *D. medius*) und damit auch das Angebot an Spechthöhlen als Wochenstubenquartiere höher als in allen anderen europäischen Waldgesellschaften.

Der für unsere Studie verwendete Datensatz stützt somit die bisherigen Verbreitungskarten, welche ein Vorkommen der Bechsteinfledermaus im Tiefland von Ost-Österreich und einige wenige Vorkommen in den inneralpinen Tälern der Südalpen zeigen. Durch die erhebliche hinzugekommene Datenmenge und das Einbringen neuer Untersuchungsmethoden, wie der Aufzeichnung von Fledermausrufen durch sogenannte Batcorder, kann überdies ein detaillierteres und sichereres Bild zur Verbreitung dieser Art gezeichnet werden. Zusätzlich konnte erstmals die Bechsteinfledermaus in weiteren Regionen Österreichs (z.B. Teile Oberösterreichs und Vorarlberg) nachgewiesen werden (Fig.2). Da *M. bechsteinii* historisch betrachtet Höhlen als Winterquartiere nutzt und diese außerhalb des Alpenlandes selten vorzufinden sind, erklären sich die rezenten Winternachweise durch menschliche Bauten welche als Ersatzquartiere angenommen wurden.

Die Bechsteinfledermaus gilt als vorwiegend europäische Art, da nur wenige Nachweise außerhalb Europas bekannt sind. Vergleicht man ihr Vorkommen in Österreich mit dem in benachbarten Ländern, so zeigen sich ähnliche Verbreitungsmuster.

In Deutschland findet man die Bechsteinfledermaus hauptsächlich im nördlichen Teil des Landes. Nur wenige Nachweise stammen in Bayern aus Regionen südlich der Donau. Auch in der Schweiz werden höher liegende Regionen gemieden. Die Nachweise hier stammen vorwiegend aus dem nördlichen Gebiet der Alpen sowie niederalpinen Tälern. In Tschechien, der Slowakei und Ungarn zeigt *M. bechsteinii* eine eher fragmentarische Verbreitung, wobei jedoch wärmere, bewaldete und hügelige Regionen bevorzugt werden.

Südlich der Alpen scheint diese Art weniger häufig vorzukommen. So ist sie beispielsweise in Slowenien sehr selten. Der Großteil der Nachweise stammt von wenigen Schwarmquartieren. Obwohl keine Wochenstuben bekannt sind, vermutet man jedoch die Existenz solcher im Süden des Landes. Der einzige Nachweis aus Südtirol stammt aus einer Wochenstube.

Weiter konnte eine Korrelation zwischen dem Vorkommen von Eichen und der Bechsteinfledermaus auch in Luxemburg und Spanien nachgewiesen werden.

Trotz der Kollinearität zwischen dem Sommer-Verbreitungsgebiet von *M. bechsteinii* und dem Vorkommen von Eichen, zeigt die resultierende Karte Regionen in Österreich in denen mit der Art zwar gerechnet werden muss, gesicherte Nachweise bislang jedoch fehlen. Um daher ein vollständiges Bild der Verbreitung dieser Fledermausart in Österreich zeichnen zu können, ist es äußerst wichtig die betreffenden Regionen auf Vorkommen hin zu untersuchen. Da diese Fledermausart oftmals im Kronenbereich der Bäume jagt sollte dies bei der Nachweismethode berücksichtigt werden. Bodennahe Aufnahmen allein führen mitunter zu unterrepräsentierten oder gar fehlenden Daten.

Um in Zukunft die Bechsteinfledermaus in Österreich gezielt schützen und fördern zu können, empfehlen wir das Hauptaugenmerk auf folgende Forschungsschwerpunkte zu legen:

i) Erstellen einer weiter aktualisierten Verbreitungskarte für Österreich mit Hilfe der vorliegenden *M. bechsteinii*- und der Eichenbestand Verbreitungskarten.

ii) Gezielte Forschung im Bereich der Autökologie dieser Art, mit besonderem Fokus auf die Habitatnutzung in waldarmen und Nadelholz dominierten Waldgebieten.
iii) Erstellung von Richtlinien zum Schutz von *M. bechsteinii* in Schutzgebieten.
iv) Erstellung von Richtlinien zum Schutz von *M. bechsteinii* in forstwirtschaftlich genutzten Waldgebieten.
v) Erstellung eines umfassenden Monitoring Programms zur Populationsentwicklung von *M. bechsteinii*.

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TABLES

Tab. 1 Data sources used for the distribution maps and further analysis.

Amon et al. (1993)
Artenschutzprojekt Fledermäuse Kärnten 2010-2013, unpubl. Data
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Bruckner A. unpubl. data
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Hüttmeir et al.. (2010)
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Natural History Museum Vienna
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Pollheimer M., Müller A., & Thurner B., unpubl. data
Pysarczuk & Reiter (2010)
Pysarczuk S., unpubl. data
Reiter et al. (2009)
Spitzenberger & Bauer (2001)
Spitzenberger (2007)
Wegleitner S., unpubl. data
Wieser D., Krainer K., Mixanig H., & Reiter G., unpubl. data

FIGURES

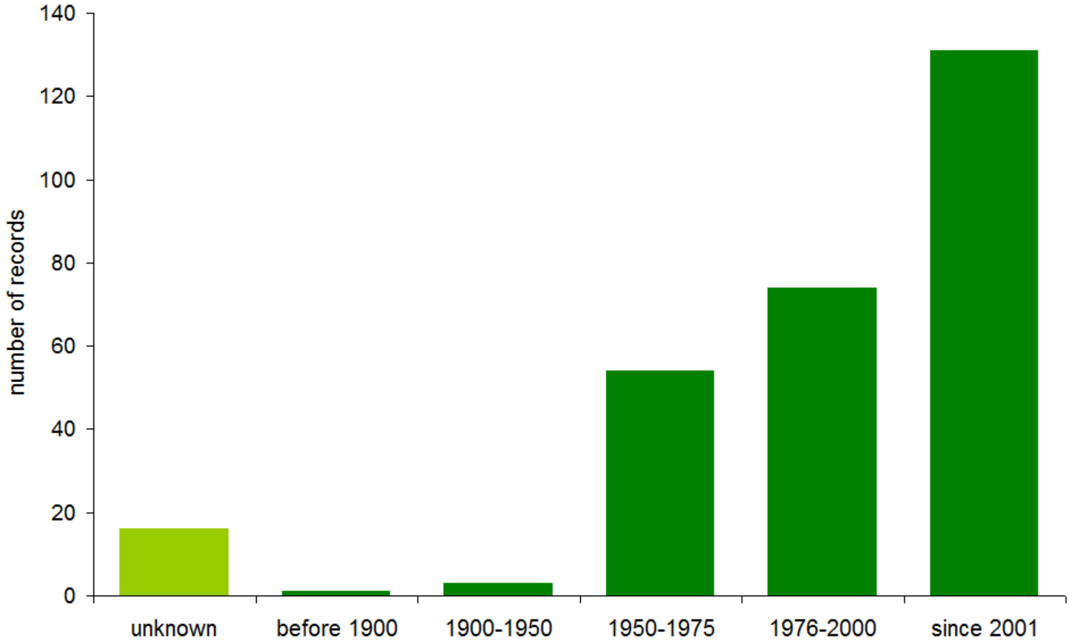

Fig. 1 Temporal distribution of records of *M. bechsteinii* in Austria (n=279).

Abb. 1 Zeitliche Verteilung der Nachweise von *M. bechsteinii* in Österreich (n=279).

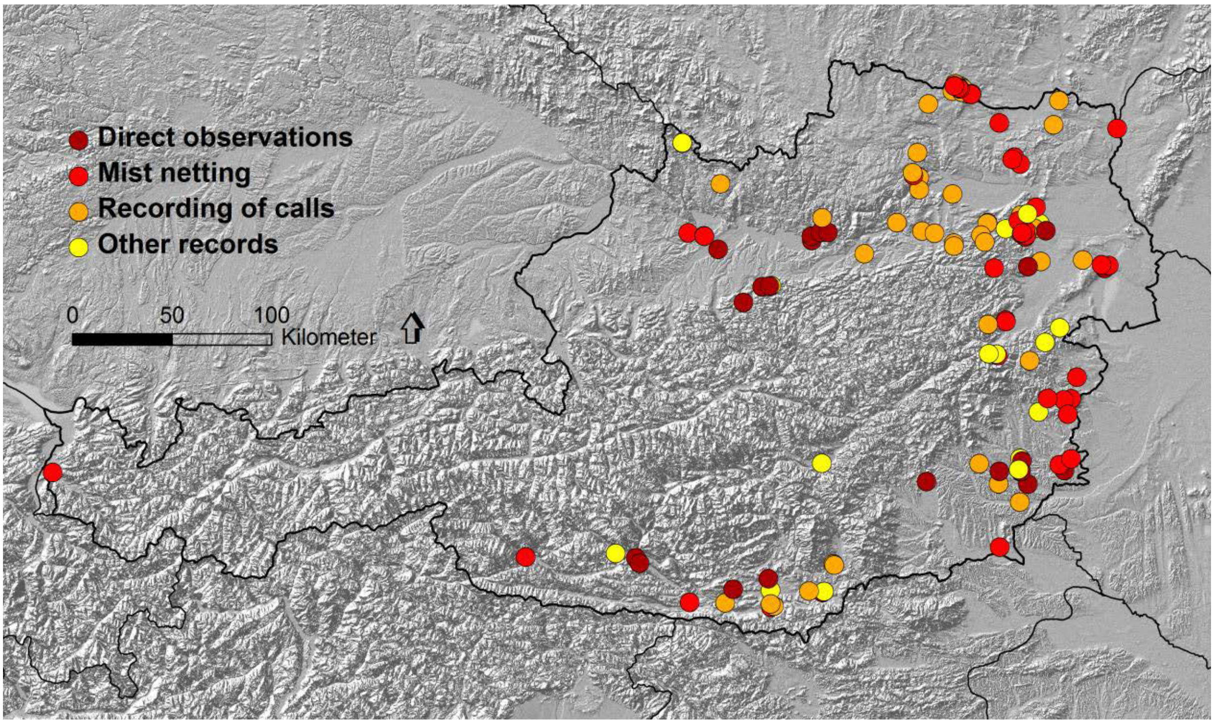

Fig. 2 Locations with records of *M. bechsteinii* in Austria from May to September (n=148).

Abb. 2 Sommernachweise von *M. bechsteinii* in Österreich (Mai bis September) (n=148).

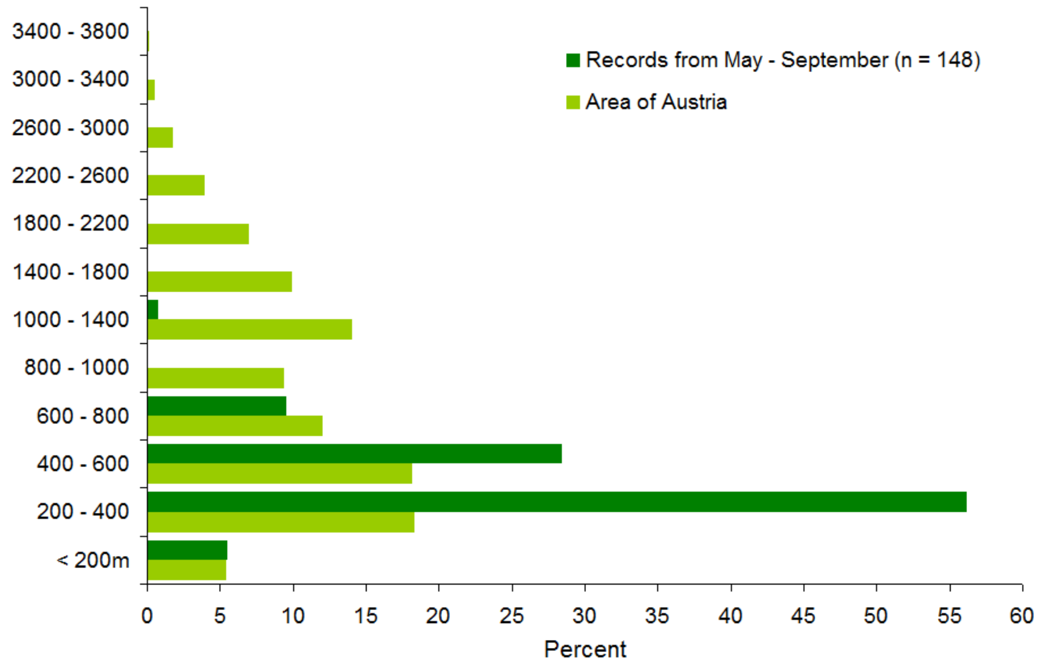

Fig. 3 Altitudinal distribution of *M. bechsteinii* from May to September, including maternity roosts, summer roosts, foraging areas and probably some transitory roosts.

Abb. 3 Höhenverteilung der Nachweise (Wochenstuben, Sommerquartiere, Jagdgebiete und Zwischenquartiere) von *M. bechsteinii* in den Monaten Mai bis September.

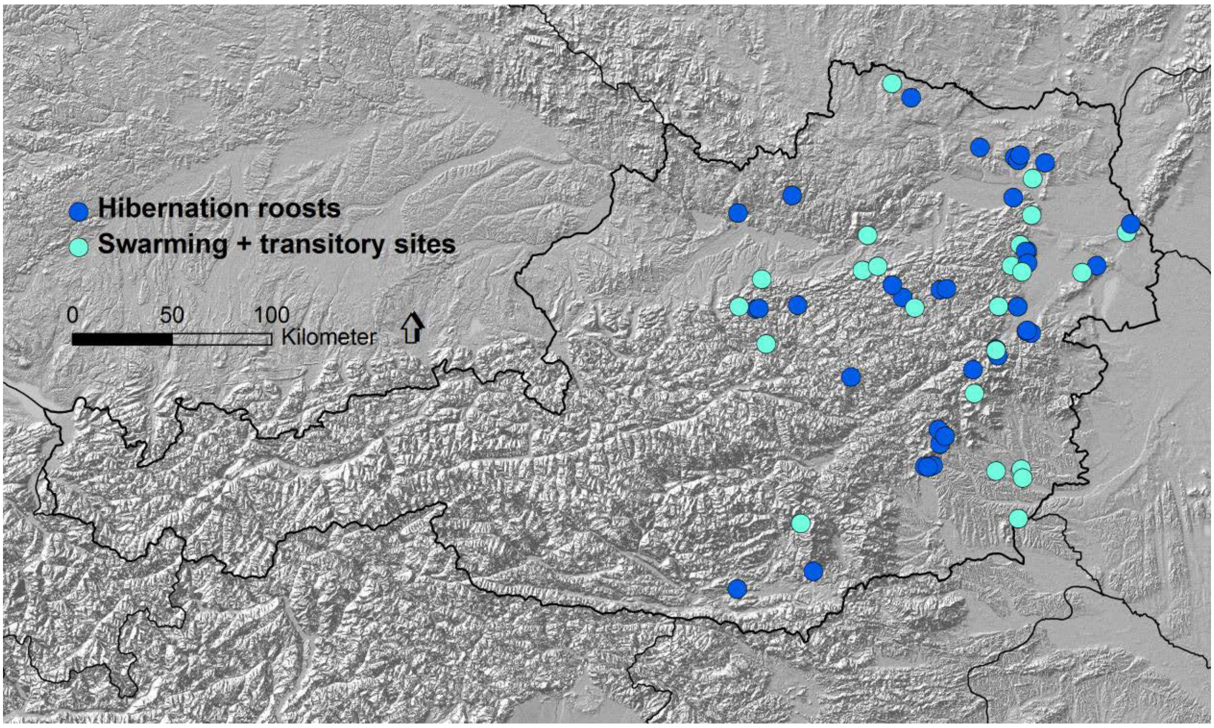

Fig. 4 Locations with records of *M. bechsteinii* in Austria from October to April (n=70).

Abb. 4 Winternachweise von *M. bechsteinii* in Österreich (Oktober-April) (n=70).

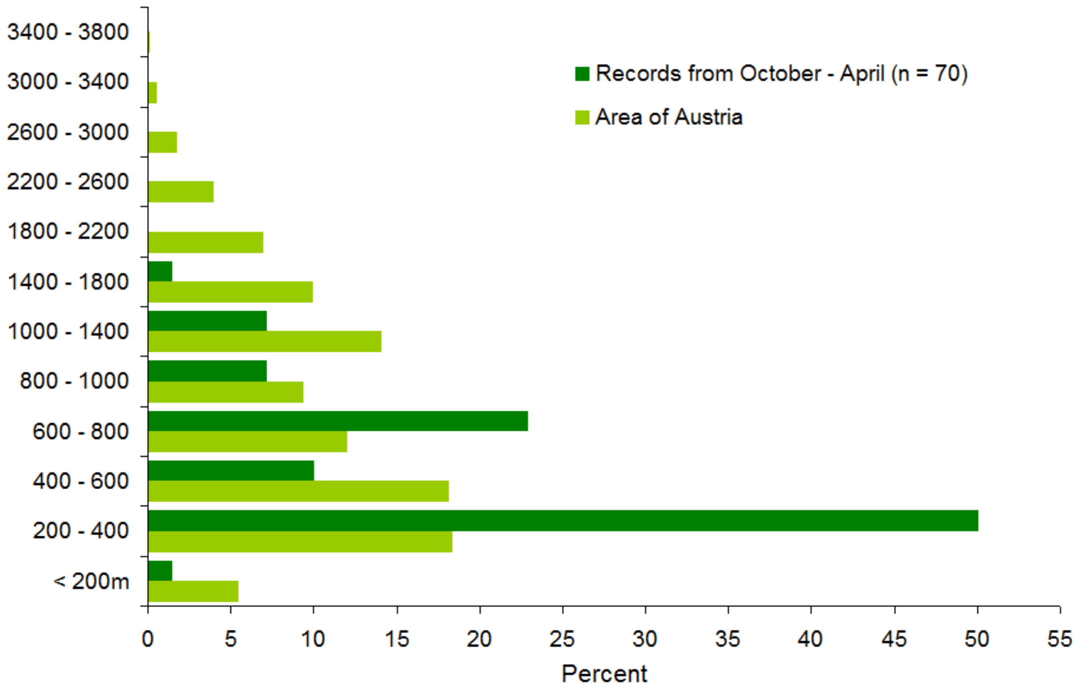

Fig. 5 Altitudinal distribution of *M. bechsteinii* from October to April, including hibernation roosts, swarming sites and transitory roosts.

Abb. 5 Höhenverteilung der Nachweise (Winterquartiere, Schwärmquartiere und Zwischenquartiere) von *M. bechsteinii* in den Monaten Oktober bis April.

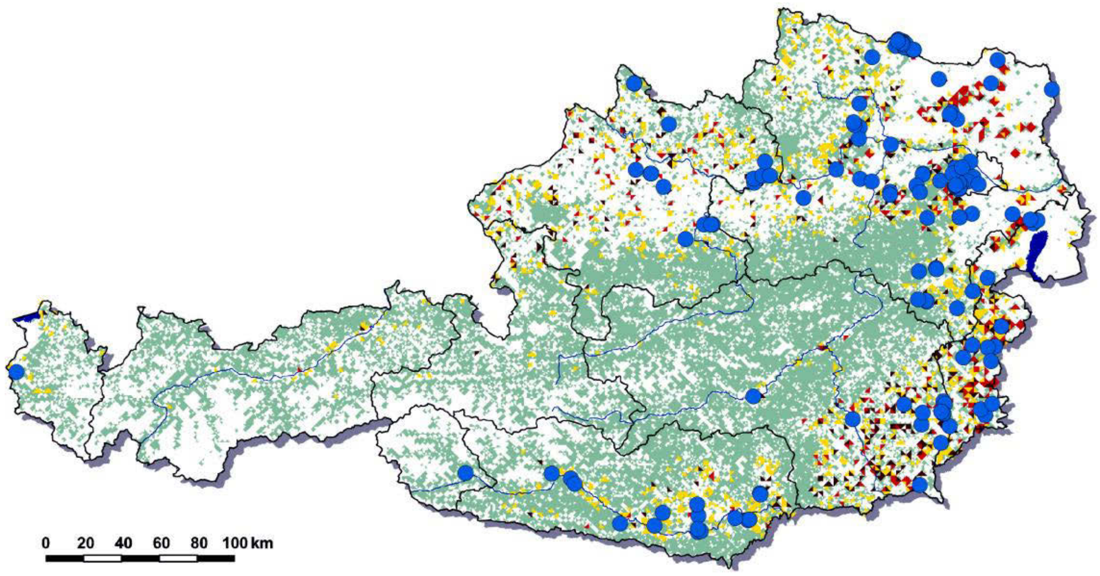

Fig. 6 Distribution of oak (*Quercus spp.*) and summer records of *M. bechsteinii* in Austria. ■ = high, ■ = medium, ■ = low stand dominance of oak, ■ = woodland, ■ = records of *M. bechsteinii.*

Abb. 6 Eichennachweise (*Quercus spp.*) und Sommernachweise von *M. bechsteinii* in Österreich. ■ = hohe, ■ = mittlere, ■ = niedere Eichendominanz am Standort, ■ = Waldgebiet, ■ = *M. bechsteinii* Nachweise.

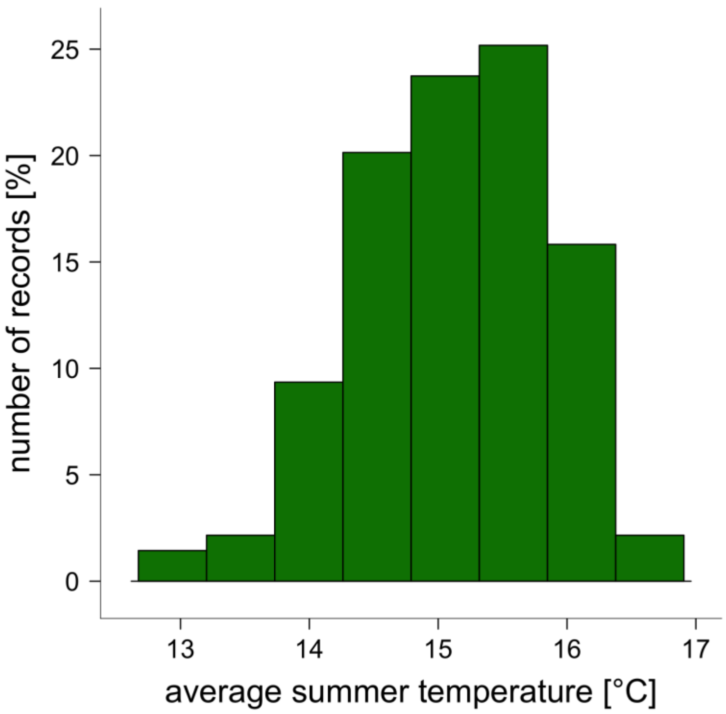

Fig. 7 Frequency distribution of average monthly temperatures of summer records (May to September) of *M. bechsteinii* in Austria.

Abb. 7 Häufigkeitsverteilung der Monatsdurchschnittstemperaturen (Mai bis September) von *M. bechsteinii*-Fundstellen in Österreich.

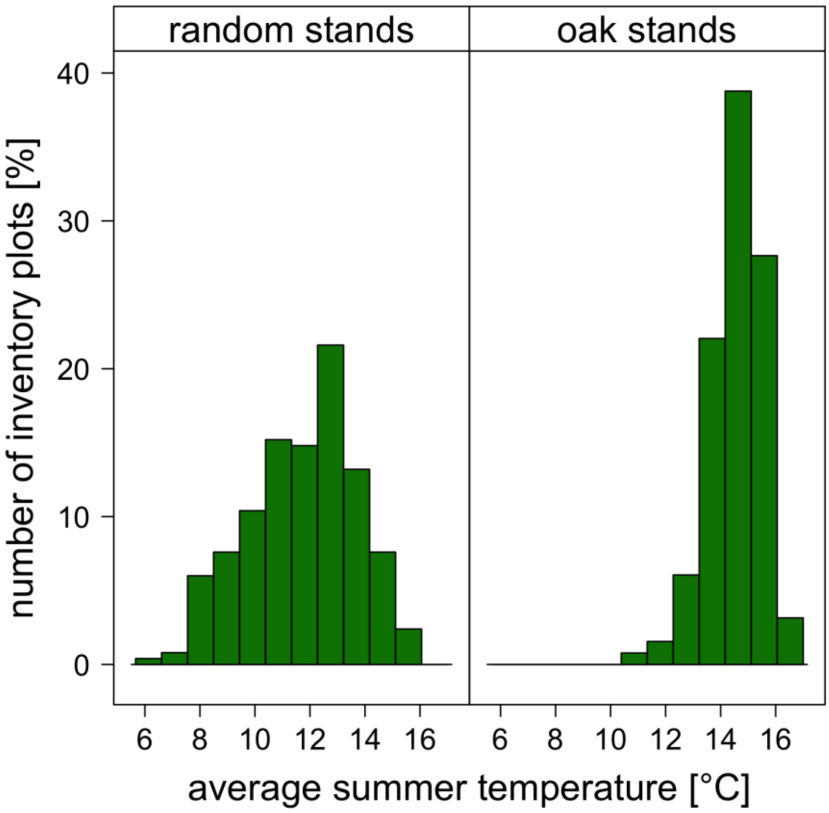

Fig. 8 Frequency distributions of summer temperatures (May to September) of a random collection (n=250) and of all plots containing oak trees (n=2423) of the Austrian Forest Inventory.

Abb. 8 Häufigkeitsverteilung der Sommertemperaturen einer Zufallsauswahl von Waldstandorten (n=250) und von Eichenstandorten (n=2423) der Österreichischen Waldinventur.

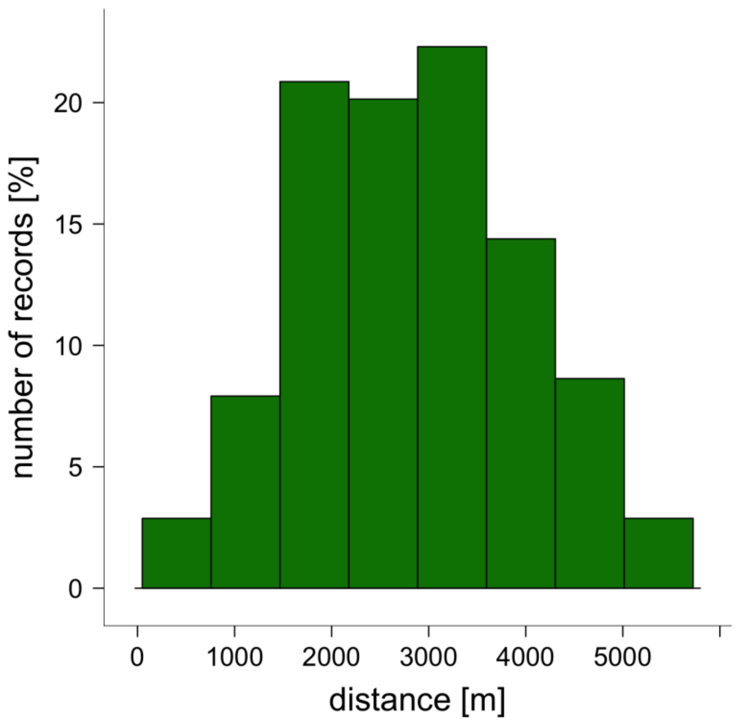

Fig. 9 Frequency distribution of the distance of *M. bechsteinii* records to the closest inventory site of the Austrian Forest Inventory.

Abb. 9 Häufigkeitsverteilung der Entfernungen zwischen *M. bechsteinii*-Fundorten und dem nächstgelegenen Punkt der Österreichischen Waldinventur.

[3] Vorkommen der Nymphenfledermaus, *Myotis alcathoe* (Helversen & Heller, 2001), in Österreich

Reiter G, Bruckner A, Kubista CE, Plank M, Pollheimer M, Suarez-Rubio M, Wegleitner S, Hüttmeir U (2015) Vorkommen der Nymphenfledermaus, *Myotis alcathoe* (Helversen & Heller, 2001), in Österreich. In: Rudolph BU, Hammer M, Pfeifer B (eds.): Verbreitung und Ökologie der Nymphenfledermaus, Fachtagung des LfU am 22. März 2014. Kessler Druck + Medien GmbH & Co. KG, Bobingen, Germany. pp 85–97.

ZUSAMMENFASSUNG

Die erst 2001 wissenschaftlich beschriebene Nymphenfledermaus (*Myotis alcathoe*) gehört mit der Bartfledermaus (*Myotis mystacinus*) und der Brandtfledermaus (*Myotis brandtii*) zur Gruppe der sehr ähnlichen „Bartfledermäuse“ und wurde 2006 erstmalig in Österreich nachgewiesen.

In der vorliegenden Arbeit werden 70 Nachweise von 65 Standorten aus dem Zeitraum von 2006 bis 2014 analysiert. Die Nachweise wurden zu 71% mit akustischer Rufaufzeichnung (batcorder) und zu 29% durch Netzfänge erbracht. Funktionell erfolgten 89% der Nachweise im Jagdgebiet (insgesamt 61 Gebiete) und 11% an Schwärmquartieren der Nymphenfledermaus (vier Karsthöhlen). Fänge trächtiger und laktierender Weibchen zeigen, dass die Art in Österreich erfolgreich reproduziert. Wochenstuben und Winterquartiere sind bislang nicht bekannt.

Die räumliche Verbreitung der Nachweise zeigt einen Schwerpunkt in Ostösterreich (Niederösterreich, Burgenland, Steiermark), wenige Nachweise stammen aus dem Süden (Kärnten). In den westlichen Landesteilen sind bislang keine Vorkommen bekannt. Dementsprechend

stammen die meisten Nachweise in Jagdgebieten aus den Niederungen (Schwerpunkt zwischen 200 und 400 m N.N., Bereich 153–863 m), während die wenigen Nachweise an Schwärmquartieren von 398 m bis 945 m Seehöhe streuen.

In den Roten Listen ist die Nymphenfledermaus auf europäischer Ebene als „DD" (Datenlage ungenügend) eingestuft, in Österreich ist sie noch nicht aufgeführt. Da sich aus den hier präsentierten Daten keine oder nur unzureichende Informationen zu Populationsgröße und -entwicklung, Arealentwicklung oder Habitatverfügbarkeit ableiten lassen, muss für Österreich ebenfalls die Einstufung „DD" gelten. Nichtsdestotrotz ist davon auszugehen, dass die Nymphenfledermaus aufgrund ihrer speziellen Habitatansprüche und ihrer vermutlich geringen Populationsgröße gefährdet ist.

Für den Schutz der Nymphenfledermaus ist es notwendig, das Wissen um Verbreitung, Biologie und Ökologie dieser Art auch in Österreich zu vertiefen. Daraus können Maßnahmen zum Schutz des Lebensraumes und eine Einstufung in den Roten Listen abgeleitet werden. Ein Monitoringprogramm sollte möglichst rasch eingerichtet werden.

ABSTRACT

Occurrence of the Alcathoe Bat *Myotis alcathoe* in Austria

Myotis alcathoe is a recently described and little known species and belongs together with *M. mystacinus* and *M. brandtii* to the group of the very similar whiskered bats. For the first time it was recorded in Austria in the year 2006, five years after its original description.

This paper analyzes 70 records from 65 Austrian sites between 2006 and 2014. Of these records, 71% were recordings of bat calls (batcorder), and 29% of mist netting. 89% of the records were obtained at foraging areas and 11% at swarming sites (natural caves). Captures of

pregnant and lactating females provide evidence that the species successfully reproduces in Austria. So far, we have no knowledge of hibernacula and maternity roosts in the country.
The records of *M. alcathoe* are restricted to the eastern part of the country (Lower Austria, Burgenland, Styria, few in Carinthia) and the species has not yet been found in the western federal countries of Vorarlberg, Tyrol, Salzburg and Upper Austria. Accordingly, most of records in the foraging areas originate from lowland altitudes (mainly between 200–400 m above sea level, range 153–863 m). Records of swarming sites were spread over a greater range (398–945 m).
Due to insufficient information, *M. alcathoe* is not listed in the current European and Austrian Red Lists. Also from the information presented in this paper, we are neither able to conclude on the species' population size and changes in population size, nor on the availability of its habitat in Austria. We therefore have to leave its conservation status as "DD" (data deficient). Due to its high habitat requirements and its presumably low population size, we nevertheless consider *M. alcathoe* an endangered species in Austria. For a proper assessment of the conservation status of the species, its geographic distribution, biology and ecology needs to be investigated and a monitoring program implemented.

EINLEITUNG

Die Nymphenfledermaus (*Myotis alcathoe*) gehört unter den heimischen Fledermausarten zusammen mit der Bartfledermaus (*Myotis mystacinus*) und der Brandtfledermaus (*Myotis brandtii*) zur Gruppe der sehr ähnlichen „Bartfledermäuse“. Erst im Jahr 2001 wurde die Nymphenfledermaus anhand von Individuen aus Griechenland und

Ungarn als eigenständige Art beschrieben (Helversen et al. 2001). Seitdem erfolgten Nachweise aus nahezu ganz Europa zwischen Südschweden und Spanien, Großbritannien und dem westlichen Teil der Türkei sowie der Ukraine (Dietz und Kiefer 2014). Nach Osten reicht die Verbreitung über den Westkaukasus bis Georgien und Armenien. Dabei gibt es jedoch kein kontinuierliches Verbreitungsgebiet, die Vorkommen sind vielmehr auf geeignete Lebensräume beschränkt und sehr lokal (Dietz und Kiefer 2014).

Die ersten Funde in Österreich gelangen im Jahr 2006 im Burgenland (Spitzenberger et al. 2008). Im Bundesland Niederösterreich wurde die Nymphenfledermaus erstmals 2009 im Nationalpark Thayatal nachgewiesen (Hüttmeir und Reiter 2010a), im gleichen Jahr wurde ein Vorkommen auch in Wien (Lainzer Tiergarten) entdeckt (Hüttmeir und Reiter 2010b).

Ziel dieser Arbeit ist es, alle bislang erbrachten Nachweise zu dieser Fledermausart zusammenzufassen und damit ein erstes Bild über ihr Vorkommen und ihren Status in Österreich zu zeichnen. Zudem soll eine mögliche Einstufung in der Roten Liste der gefährdeten Säugetiere Österreichs geprüft sowie Vorschläge zum Schutz und zur Erforschung dieser Art gemacht werden.

MATERIAL UND METHODEN

Datenquellen

Grundlage der Arbeit sind die uns zum Zeitpunkt der Fertigstellung verfügbaren Nachweise. Diese stammen aus verschiedensten Literaturquellen, zu einem großen Teil aber aus eigenen Studien der Autoren (Tabelle 1). Die Datengrundlage ist daher naturgemäß heterogen und die räumliche Abdeckung mittels Rufaufzeichnungen ist für den Osten Österreichs intensiver einzustufen als jene im Westen des Bundesgebiets.

Aufzeichnung von Fledermausrufen

Die aus unpublizierten Quellen stammenden Daten (Tabelle 1) sind ausschließlich akustische Nachweise, welche mit automatisch arbeitenden Aufzeichnungsgeräten (batcorder, ecoObs, Nürnberg, Deutschland, www.ecoobs.de) erbracht wurden. Dabei werden alle Ultraschallgeräusche in Echtzeit aufgenommen (Samplingrate 500 kHz, Amplitudenauflösung 16 bit, Empfindlichkeitsbereich 16–150 kHz). Mithilfe eines integrierten Filters werden die Fledermausrufe direkt von anderen Ultraschallquellen (z. B. Heuschrecken) unterschieden. Alle Geräte wurden vom Hersteller kalibriert und eingestellt. Durch die Bearbeiter wurden keine weiteren Veränderungen an den Einstellungen vorgenommen (Standardeinstellungen: quality = 20, 400 ms post trigger, –27 dB threshold level, critical frequency 16 kHz). Die aufgezeichneten Fledermausrufe wurden in weiterer Folge mit der Software bcAdmin 2.2 bzw. 3.0 (ecoObs, Nürnberg, Deutschland) vermessen. Auf Basis der vermessenen Rufe erfolgte die Artbestimmung mit der Software batIdent 1.5 (ecoObs, Nürnberg, Deutschland). Dabei werden die zu bestimmenden Fledermausrufe mit Referenzrufen abgeglichen und mithilfe eines statistischen Verfahrens (Random Forest) einer Art bzw. Artengruppe zugeordnet. In den Ergebnissen gibt ein Prozentwert das Maß der Übereinstimmung mit den Referenzrufen an und je höher dieser Wert liegt, desto sicherer ist in der Regel die Bestimmung. Sämtliche Nachweise wurden jedoch manuell nachkontrolliert und gegebenenfalls korrigiert (vgl. Hafner et al. 2015 und Pfeiffer et al. 2015, jeweils in diesem Band).

Kategorien der Nachweissicherheit

Da die Bestimmung der Nymphenfledermaus nicht einfach ist, wurden die Nachweise in drei Kategorien unterteilt. Dadurch soll sowohl die Beurteilung der einzelnen Nachweise als auch jene der Vorkommensgebiete erleichtert werden. Hierfür wurden die folgenden drei Kriterien verwendet:

Kategorie 1: genetisch verifizierte Nachweise von Fängen oder Funden.
Kategorie 2: Fänge oder Funde, welche nur anhand von morphologischen Merkmalen bestimmt wurden.
Kategorie 3: Akustische Nachweise: mindestens drei Rufsequenzen an einem Standort / Nacht, davon mindestens eine Rufsequenz mit einer Übereinstimmungswahrscheinlichkeit von über 90%. Alle Aufnahmen wurden durch eine/n BearbeiterIn manuell überprüft. Alle anderen Nachweise wurden nicht in die Analyse einbezogen (meist akustische Nachweise geringerer Qualität als von Kategorie 3 vorgegeben).

ERGEBNISSE

Im Zeitraum 2006 bis 2014 konnten in Österreich insgesamt 70 Nachweise der Nymphenfledermaus an 65 Fundorten registriert werden. Die gegenüber den Fundorten höhere Anzahl an Nachweisen ist auf Mehrfachnachweise an drei Standorten zu unterschiedlichen Zeiten zurückzuführen.

Von 2009 bis 2012 waren die meisten Nachweise zu verzeichnen, nach 2013 nahm deren Anzahl wieder ab (Abb. 1).

Die Nachweise umfassen 20 Netzfänge (29%) und 50 Rufaufzeichnungen (71%). Der überwiegende Teil der Nachweisorte stellt Jagdgebiete dar (n=61), und nur wenige Nachweise erfolgten an

Schwärmquartieren (n=4). Wochenstuben der Nymphenfledermaus konnten bislang ebenso wenig entdeckt werden wie Winterquartiere.
In Österreich wurden bisher nur wenige Funde genetisch verifiziert (n=7) und es existieren damit nur sehr wenige Nachweise mit der höchsten Nachweissicherheit. Von den restlichen Nachweisen entfielen 13 auf die Kategorie 2 (= morphologische Bestimmung von Fängen) und 50 auf die Kategorie 3 (= Rufdaten hoher Qualität).
Die räumliche Verteilung der Funde zeigt einen klaren Schwerpunkt in der Osthälfte Österreichs (Abb. 2). Die Verteilung der Nachweise ist hier jedoch relativ weit gefächert. Nachweisakkumulationen finden sich vor allem im Nationalpark Thayatal und etwas geringer im Kremstal. Genetisch verifizierte Nachweise finden sich nur im Nationalpark Thayatal und im Südburgenland.
Schwärmquartiere konnten bislang lediglich in Niederösterreich und der Steiermark nachgewiesen werden (Abb. 2).
Nachweise im Jagdgebiet waren im Vergleich mit dem Angebot (= Gesamtösterreich) bis 600 m Seehöhe vermehrt festzustellen (Abb. 3). Der höchste diesbezügliche Nachweis erfolgte auf 863 m Seehöhe.
Demgegenüber waren die wenigen Nachweise an Schwärmquartieren bis in 945 m Seehöhe anzutreffen (Abb. 3).
Nachweise im Jagdgebiet stammen aus Fundorten in Wäldern (Eichenwald, Eichen-Hainbuchenwald, Buchenwald, Weiden-Pappel-Auwald) bzw. entlang von Bachläufen.
Sämtliche Nachweise an Schwärmquartieren erfolgten an natürlichen Höhlen. Diese Untertagequartiere waren von sehr unterschiedlicher Gestalt und Lage. Die Nachweise gelangen im Eingangsbereich durch Netzfänge und Rufaufzeichnungen.
Durch den Fang trächtiger, laktierender und postlaktierender Weibchen gelangen mehrere Reproduktionsnachweise der Nymphenfledermaus in

Österreich: Nationalpark Thayatal (Niederösterreich, Hüttmeir und Reiter 2010a), Kremstal, Naturwaldreservat „Heimliches Gericht“ (Niederösterreich, Pollheimer et al. 2014), Europaschutzgebiet Lainzer Tiergarten (Wien, Hüttmeir und Reiter 2010b).

DISKUSSION

Trotz fehlender spezifischer Projekte zur Nymphenfledermaus in Österreich konnten in den letzten Jahren zahlreiche Nachweise zusammengetragen und analysiert werden. Die Anzahl der Nachweise für diese Art in Österreich (n=70) ist dabei jedoch deutlich geringer als beispielsweise für die Bechsteinfledermaus (n=279 Nachweise, vgl. Reiter et al. 2013).

Der Großteil der Nachweise stammt von Rufaufzeichnungen mittels automatischer Aufzeichnungsgeräte. Dadurch verbleibt eine gewisse Unsicherheit hinsichtlich der Bestimmung der Nachweise (vgl. Fritsch und Bruckner 2014). Im Rahmen der vorliegenden Arbeit wurden daher nur Rufdaten mit vergleichsweise hoher Nachweissicherheit berücksichtigt.

An insgesamt 19 Standorten in Österreich erfolgten bislang Netzfänge der Nymphenfledermaus, wobei jedoch nur an sieben Standorten auch eine genetische Verifizierung der Bestimmung durchgeführt wurde. Hierzu ist anzumerken, dass sämtliche Fänge ohne genetische Nachbestimmung durch Personen erfolgte, die mit der Bestimmung der Art bereits vertraut waren (Hüttmeir U und Reiter G, vgl. Hüttmeir und Reiter 2010a und 2010b).

Bislang stammten österreichische Nachweise lediglich aus dem Burgenland (Spitzenberger et al. 2008), aus Niederösterreich (Hüttmeir und Reiter 2010a) und Wien (Hüttmeir und Reiter 2010b). Aufgrund des nun vorliegenden Datenmaterials kann das Verbreitungsgebiet der

Nymphenfledermaus in Österreich auf die Bundesländer Steiermark und Kärnten ausgeweitet werden. Für Kärnten ist jedoch eine Bestätigung der Rufaufzeichnungen durch Fang und wenn möglich genetische Verifizierung anzustreben.

Deutlich schwieriger zu beurteilen sind die fehlenden Nachweise in den westlichen Bundesländern. Hierbei kommt sicher die Tatsache zum Tragen, dass der Einsatz von automatischen Registriereinheiten in Ostösterreich intensiver ist als im Westen des Landes und das Ergebnis vermutlich von diesem Unterschied mit beeinflusst ist. Zumindest in tieferen Lagen sind Vorkommen auch in den Bundesländern Oberösterreich, Salzburg, Tirol und Vorarlberg nicht gänzlich auszuschließen. Entsprechende Nachweise, einschließlich an Schwärmquartieren, stehen jedoch aus.

Diese erstmals 2001 aus Griechenland und Ungarn beschriebene Art (Helversen et al. 2001) konnte mittlerweile in vielen Teilen Europas, von Spanien und Frankreich über Italien, den Balkan, Zentraldeutschland und Süd-Polen bis in die Türkei (Dietz et al. 2007, Niermann et al. 2007, Dietz und Kiefer 2014) nachgewiesen werden. Der Erstnachweis in Deutschland gelang in Baden-Württemberg (Brinkmann und Niermann 2007), seitdem wurde die Art aber auch in anderen deutschen Bundesländern nachgewiesen, so in Sachsen-Anhalt (Ohlendorf und Funkel 2008), in Sachsen (Ohlendorf et al. 2008), Thüringen (Prüger et al. 2012), Hessen (Dietz und Höhne 2015, in diesem Band) und Bayern (Pfeiffer et al. 2015, in diesem Band). In den Wäldern im Nordosten Ungarns scheint *M. alcathoe* nicht selten zu sein (Niermann et al. 2007, Estók et al. 2006).

Danko et al. (2010) beschreiben *M. alcathoe* als eine reine Waldart, welche in der Slowakei im Südosten ab einer Höhenlage von 300 bis 700 m Seehöhe vorkommt und Standorte mit permanent vorhandenen

Wasservorkommen (Quellen, Sickerwasser, kleinere Bäche und künstliche Wasserreservoirs) bevorzugt. Die bevorzugten Waldtypen sind alte Eichen-, Hainbuchen-Eichenmischwälder sowie Buchenwälder. Selbiges konnte auch für die Habitatpräferenzen von *M. alcathoe* in Tschechien gezeigt werden (Lučan et al. 2009), und auch die bisher umfangreichste Habitatstudie aus Deutschland (Dietz und Dietz 2015, in diesem Band) bestätigt diesen hohen Grad der Spezialisierung. Dies deckt sich im Wesentlichen auch mit unseren Daten: Jagdgebiete wurden bevorzugt in einer Höhenlage von etwa 200 bis 400 m Seehöhe (> 60% der Daten), Schwärmquartiere bis fast 1000 m Seehöhe nachgewiesen. Höhere Verbreitungsgebiete konnten in La Rioja, Spanien (Höhenverbreitung 790–1390 m Seehöhe; Agirre-Mendi et al. 2004) und in Frankreich festgestellt werden (Höhenverbreitung bis 2000 m Seehöhe; Niermann et al. 2007). Hierbei wurde jedoch nicht zwischen Jagdgebiet und Schwärmquartieren unterschieden.

Die Nymphenfledermaus kann insgesamt als die am stärksten an urwaldähnliche Bedingungen angepasste Fledermausart gelten (Dietz und Kiefer 2014). Sie findet sich in Wäldern, die von zahlreichen anderen spezialisierten Waldfledermausarten, insbesondere Bechstein- und Brandtfledermaus genutzt werden (Dietz und Kiefer 2014).

Die in Österreich festgestellten Jagdhabitate befanden sich in unterschiedlichen Laubwaldtypen: Eichenwald, Eichen-Hainbuchenwald, Buchenwald, Weiden-Pappel-Auwald. Damit fügen sich die Befunde gut in das bestehend Bild zur Habitatnutzung dieser Art ein.

Die Ergebnisse von Plank et al. (2012) sowie Telemetrie-Ergebnisse in Tschechien (Lučan et al. 2009) zeigen, dass die Nymphenfledermaus bevorzugt den Kronenbereich der Wälder nutzt und sich sowohl ihre Jagdgebiete als auch Quartiere schwerpunktmäßig in dieser Schicht

befinden. Zeitweise werden aber auch tiefere Lagen (bspw. Bachläufe) genutzt, wo Nachweise dann einfacher zu erbringen sind.
Aufgrund dieses Verhaltens kann die Nymphenfledermaus auch leicht „übersehen“ bzw. „überhört“ werden. Sichere Nachweise für ein Gebiet können einen erheblichen Untersuchungsaufwand notwendig machen. Empfehlenswert sind daher immer auch akustische Erhebungen im Kronenbereich.

Gefährdungsstatus der Nymphenfledermaus in Österreich

In der aktuellen Roten Liste gefährdeter Säugetiere Europas (Temple und Terry 2007) erfolgte aufgrund ungenügender Datenlage („DD – data deficient“) keine Einstufung der Nymphenfledermaus. In den Roten Listen gefährdeter Säugetiere Österreichs (Spitzenberger 2005) ist die Nymphenfledermaus nicht angeführt, da zum Zeitpunkt der Bearbeitung noch keine Nachweise vorlagen.
Für eine Einstufung nach den IUCN-Richtlinien für regionale Rote Listen (IUCN 2012) oder nach der für Österreich entwickelten Methodik (Zulka et al. 2001) muss von den Kriterien Populationsgröße bzw. -entwicklung, Areal bzw. Arealentwicklung und Habitatverfügbarkeit bzw. Entwicklung der Habitatsituation mindestens eines in ausreichendem Ausmaß bekannt sein, um eine Einstufung durchführen zu können.
Aus den vorliegenden Nachweisen der Nymphenfledermaus in Österreich sind jedoch keine anwendbaren Aussagen zu Populationsgröße und -entwicklung abzuleiten. Das Verbreitungsgebiet in Ostösterreich ist auf der Basis dieser Publikation zwar schon abzuschätzen, aber für eine Verwendung im Einstufungsprozess immer noch zu lückenhaft bekannt. Zudem ist zur Arealentwicklung noch keine Aussage möglich.

In dem für Österreich entwickelten Einstufungsprozess (Zulka et al. 2001) spielt die Habitatverfügbarkeit bzw. die Entwicklung der Habitatsituation (alternativ zu Population und Areal) eine wesentliche Rolle. Systematische Untersuchungen zur Habitatnutzung der Nymphenfledermaus in Österreich fehlen und eine deskriptive Zusammenfassung der Charakteristika der hier dokumentierten Fundorte kann zwar Tendenzen aufzeigen, erscheint aber für eine Verwendung im Einstufungsprozess als noch nicht ausreichend.

Aus den genannten Gründen kann eine Einstufung der Nymphenfledermaus derzeit nicht erfolgen und ihr Status muss bis auf weiteres als „Datenlage ungenügend" („data deficient" – „DD") geführt werden.

Aufgrund der bislang bekannt gewordenen vergleichsweise hohen Habitatansprüche der Nymphenfledermaus und einer anzunehmenden geringen Populationsgröße ist allerdings von einer starken Gefährdung dieser Art auszugehen. Dies umso mehr, als die Intensivierung der Forstwirtschaft (Biomassenutzung) in großen Teilen der Wälder zu einer Veränderung der Waldstruktur und zu einer Verringerung des Anteils an Stark- und Totholz im Wald führen wird.

Wie die Ergebnisse einer Studie aus dem Biosphärenpark Wienerwald zeigen, ist die Rufaktivität der Nymphenfledermaus in den Kernzonen höher als in den Wirtschaftswäldern (Reiter et al. 2014). Die Nymphenfledermaus sollte hier von der Außernutzungstellung der Kernzonen profitieren und sowohl die Antreffhäufigkeit als auch ihre Rufaktivität müssten dadurch in Zukunft zunehmen. Ähnliches ist für alle Gebiete zu erwarten, deren Management auf urwaldähnliche Strukturen abzielt.

Erforderliche nächste Schritte für den Schutz der Nymphenfledermaus in Österreich

Die Erfüllung nachfolgend aufgelisteter Punkte ist erforderlich, um den Schutz der Art in Österreich gewährleisten zu können:

i) Vervollständigung des Wissens um die Verbreitung in Österreich. Hierbei sind einerseits die Nachsuche in Bundesländern ohne bisherige Nachweise als auch die Bestätigung von Rufnachweisen in anderen Bundesländern erforderlich.

ii) Erforschung der Biologie und Ökologie in Österreich. Hierbei sind vor allem die Nutzung von Quartieren und Jagdlebensräumen im Sommer (unter anderem für eine Einschätzung des möglichen Gefährdungsgrades) als auch die Überwinterungsstrategien von besonderer Bedeutung.

iii) Auf Basis der autökologischen Untersuchungen und des bestehenden Wissens können nachfolgend konkrete Maßnahmen für den Lebensraumschutz abgeleitet und umgesetzt werden (z.B. über Managementpläne in Natura-2000-Gebieten), wobei sich schon jetzt aus den Untersuchungen in anderen Regionen Mitteleuropas abzeichnet, dass dem strikten Schutz sehr alter Laubwälder eine Schlüsselrolle zukommt.

iv) Etablierung eines Monitoringprogrammes: Ein solches Monitoringprogramm erscheint am besten über Rufaufzeichnungen möglich zu sein und sollte so bald wie möglich eingerichtet werden.

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TABELLEN

Tab. 1 Als Datengrundlage verwendete Datenquellen.

Bruckner A., unpubl. Daten
Biome, Plank M., unpubl. Daten
Fritsch G., unpubl. Daten
Hüttmeir U., unpubl. Daten
Hüttmeir U. & Reiter G. (2010a)
Hüttmeir U. & Reiter G. (2010b)
Kubista C. E., unpubl. Daten
Koordinationsstelle für Fledermausschutz und -forschung in Österreich, unpubl. Daten
Pollheimer M. & Hovorka W. (2014)
Pollheimer M. et al. (2014)
Reiter G. et al. (2014)
Spitzenberger F. et al. (2008)
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Wegleitner S., unpubl. Daten
Wieser D. (2012)

ABBILDUNGEN

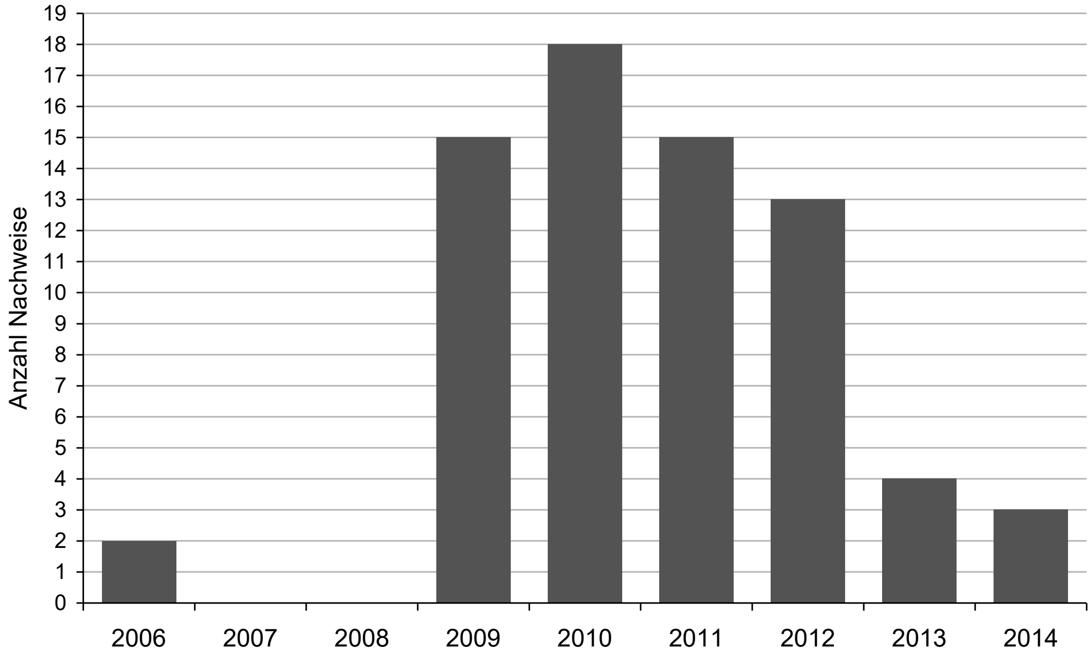

Abb. 1 Zeitliche Verteilung der Nachweise von *Myotis alcathoe* in Österreich (n=70).

Fig. 1 Temporal distribution of records of *Myotis alcathoe* in Austria (n=70).

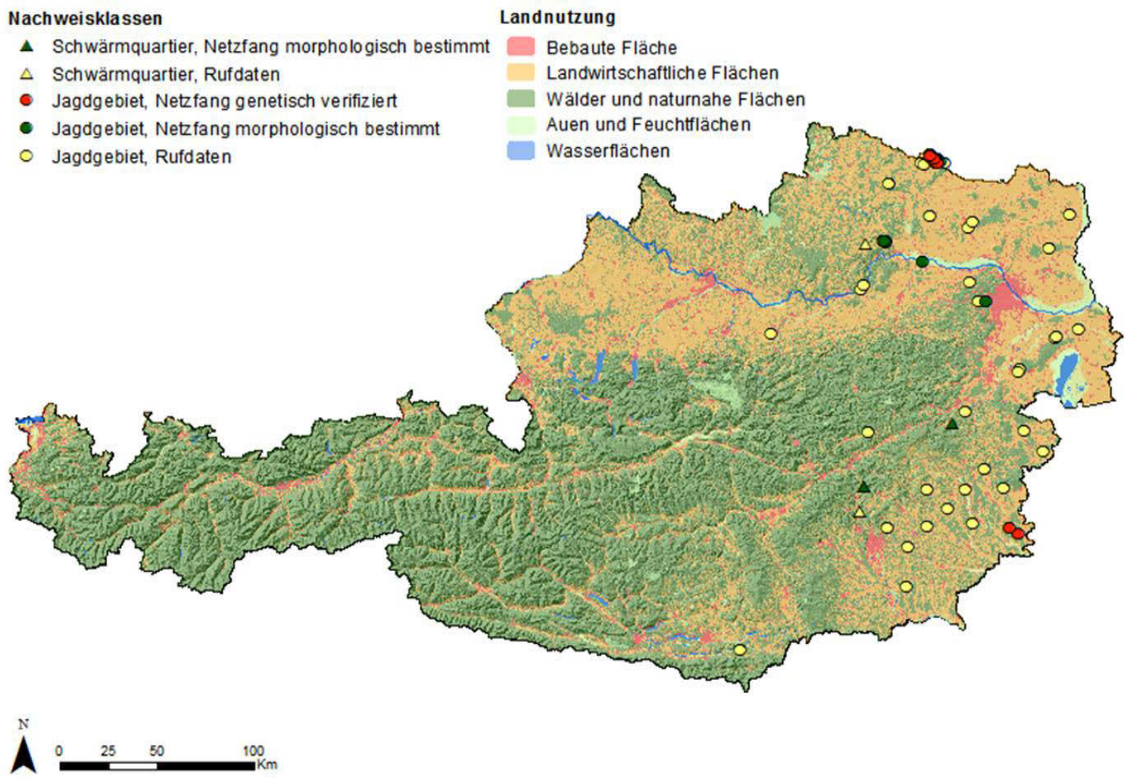

Abb. 2 Verteilung der Fundorte von *Myotis alcathoe* in Österreich (n=65).

Fig. 2 Locations with records of *Myotis alcathoe* in Austria (n=65).

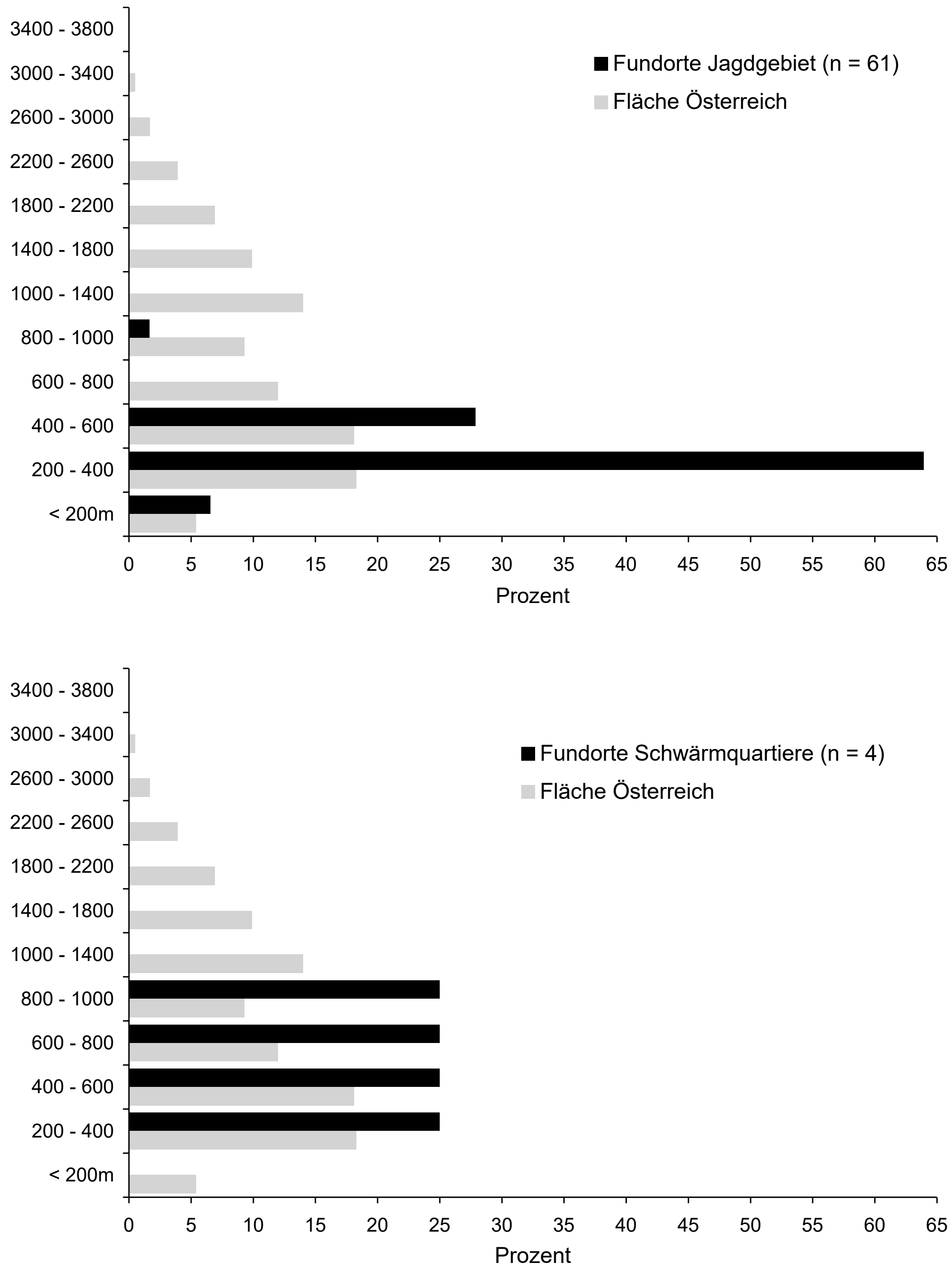

Abb. 3 Höhenverteilung der Fundorte von *Myotis alcathoe* im Jagdgebiet (oben) und an Schwärmquartieren (unten). Grau dargestellt ist die Verteilung der Höhenklassen über das gesamte Bundesgebiet Österreichs.

Fig. 3 Altitudinal distribution of *Myotis alcathoe* in foraging areas (above) and swarming sites (below). Grey bars indicate the altitudinal distribution for Austria.

Abb. 4 Fangstandort von *Myotis alcathoe* im Naturwaldreservat „Heimliches Gericht“, Kremstal, Niederösterreich. Foto: Pollheimer, M.

Fig. 4 Mist netting location of *Myotis alcathoe* in the natural forest reserve „Heimliches Gericht“, Kremstal, Lower Austria. Foto: Pollheimer, M.

[4] Within-site variability of field recordings from stationary passively working detectors

Kubista CE, Bruckner A (in press) Within-site variability of field recordings from stationary passively working detectors. Acta Chiropterologica

ABSTRACT

Passively working devices (with no operator input) that register bat calls in real time are very important in conservation and environmental risk assessment, but data on their performance and limits under field conditions are mostly missing. We characterized the recording variability among three batcorders placed in proximate vicinity (~ 10 m apart) to each other at 157 sites in Austria (Europe). We found this variability perplexingly high, both for bat activity and species richness estimates. Specifically, the ratio of the highest to the lowest total sequence length (all species combined) was over fivefold in 23%, and over tenfold in 8% of the sites. In only 17% of the sites, we found the same number of species for all three devices – in most sites it varied between one and five species. The maximum call ranges of the recorded bat species affected the recording variability between the devices only for short ranges (5 m) but showed similar or relatively low variability for longer ranges. There was significantly less recording variability in sites with no woody vegetation present than in sites with open to dense vegetation structure. The results clearly indicate that the common practice of deploying only one device per site and night very likely leads to several of the resident bat species being missed and produces unreliable activity estimates.

KEYWORDS

Detection probability; bat species; ultrasound detectors; batcorder system; Chiroptera; vegetation clutter

INTRODUCTION

Passively working ultrasound detectors (with no operator input) that record bat calls in real-time are nowadays widely used in scientific bat research. These devices not only permit nonintrusive sampling of species assemblages, but can also be deployed in habitats that otherwise would be ineffectively sampled with traditional methods like mist-netting (e.g., open fields, rivers; O'Farrell 1997; Britzke et al. 2010). They can also be comfortably placed during daytime and programmed to operate automatically during the night without an observer present. This not only reduces the effort in the field, and especially nighttime work, but also enables the user to sample multiple sites simultaneously per night or to record bat activity over a long period of time (Murray et al. 1999; Gorresen et al. 2008). It is thus only natural that the devices had become a standard in scientific work and are also widely used by consultants. However, we consider it crucial for all users to have a very clear understanding of the capacities and limits of the devices before initiating their fieldwork.

Especially in environmental consultancy, efficiency of time and cost is a major concern for bat workers. In our experience this often results in sampling bat call data for only one night with one device to inventory a local fauna and characterize activity. This can lead to a very restricted species list, presumably due to the low detection probabilities of many species. For example, Duchamp et al. (2006) showed that applying two devices for a single night in close vicinity to each other (5 m) increased the probability of detecting bats by 1.6 times compared to a single device. Bruckner (2016) found that five consecutive detector-nights are not sufficient to reach a plateau in the species sampling curves of most of the investigated sites. These results are consistent with those of Hayes (1997) and Fischer et al. (2009). Hayes (1997) pointed out that the recording variability may be high among nights and that sampling a site fewer than six to eight nights is likely to result in biased estimates of activity. Also the time of year plays an important role for detectability as species activity varies across seasons (Skalak et al. 2012). The latter authors therefore suggested surveying for at least two to five nights in spring, summer and fall to detect between 40% to 60% of the species richness of an area. It took > 20 nights to detect 80% of the resident species in summer. They also showed that the probability of detecting species increased with the number of detectors used in a sampling region of 95 km^2 size (Skalak et al. 2012).

Adams et al. (2012) found that the detection performance varied among bat detector brands (Anabat SD2, Batlogger, Batcorder etc.) and detection seemed to be most affected by the main frequency of the signal and the distance from the source. Further, several authors strongly recommended to calibrate the devices before operating them, as their recording sensitivity can vary highly (Larson and Hayes 2000; Fischer et al. 2009).

To date, no information is given on how many parallel devices are needed to reach a plateau in species sampling curves (but see Froidevaux et al. 2015 for optimizing sampling across forest microhabitats). Likewise, little is known about the factors influencing the within-site variability of detection probability.

We know that solid structures may absorb, disperse and reflect ultrasound calls, causing cluttered echoes (Forrest 1994; Schnitzler and

Kalko 2001) and downgrading the quality of the recordings. Certain frequencies may even be cancelled out depending on the frequency of the emitted sound and the distance between bats and devices (Forrest 1994; Pettersson 2004). Thus devices need to be placed at least two meters away from trees, bushes, walls, or fences, and from the ground (Schuster and Runkel 2014). Atmospheric attenuation reduces the range of sounds (Griffin 1971), increases with higher sound frequencies, and variously influences the detectability of species (Schnitzler and Kalko 2001; Dietz et al. 2007). From all this we expect that the optimal sampling effort is site-specific and depends on the call ranges of the resident species (Barataud 2016) and the spatial configuration of solid structures, especially of woody vegetation.

In this paper, we use the data of an unpublished study on the distribution of bat species in eastern Austria (temperate Europe). Three stationary devices, each equipped with an omnidirectional microphone, were set close to each other (~ 10 m apart) at 157 sampling sites to register bat calls for one night each site. We used this parallel setup to yield more calls of high quality and thus make call identification more confident. To our surprise, the recordings of the neighboring devices were far from being identical in many sites. We here quantify this variability to point to potential within-site differences of recording performance, that is, of call activity and the number of species registered. Specifically, we predict that the variability of recorded activity was inversely related to (i) the call range of species (that is, "louder" species were more likely detected by all neighboring devices than "quiet" ones); and (ii) the structure of woody vegetation (that is, the denser and more stratified the vegetation, the more divergent the records of total bat activity and species numbers).

MATERIAL AND METHODS

Study area and sampling sites

The study region was situated in eastern Austria and was defined as all territory east of the connecting line between the cities Linz (48°18'N, 14°17'E) and Graz (47°02'N, 15°26'E) and covered 25 600 km^2.

We sampled a total of 157 sites on the nodes of a 10 x 10 km grid. Sampling was restricted to water bodies (streams and standing water bodies) since they are known to attract bats (Grindal et al. 1999; Mickevičiené and Mickevičius 2001) and thus offer the highest probability to detect species (Bruckner 2016).

Bat recordings and site parameters

Bat activity was recorded between early June and late September 2010 and 2011. Bat calls were recorded with 15 batcorders (version 1.0, 2.0, 3.0; ecoObs GmbH, Nürnberg, Germany; default settings for all batcorder versions: quality 20, threshold -27 db, posttrigger 600 ms, critical frequency 16 kHz). These ultrasound detectors automatically register calls of passing bats in real time and save them as individual files on a SD storage card. In the following, "call sequence" refers to the calls of a single bat passing a detector. To ensure consistent microphone sensitivity of our devices (Larson and Hayes 2000; Fischer et al. 2009) the batcorders were calibrated by the manufacturer prior to the sampling seasons.

Each site was sampled for a single night with three neighboring devices. According to the manufacturer, the devices were calibrated for a 10 m detection range (ecoObs GmbH 2010). We therefore decided to place them at a maximum of approximately 10 m from each other so that site characteristics were similar for all three devices (with respect to land use, vegetation etc.; Fig. 1), but distances had sometimes to be adjusted to site conditions. Detectors were placed on top of poles at 2.5 m height. Microphone orientation was set parallel to the ground and allowed to swivel freely with the wind. Recordings were taken from 7 pm to 6 am the following morning.

As bat activity is influenced by weather (Scanlon and Petit 2008; Fischer et al. 2009; Amorim et al. 2012; Bondarenco et al. 2013), sites with unfavourable conditions like rain, wind speed > 3 Beaufort, or cool weather (criteria: minimum night temperature less than 10°C or temperature sum lower than 200°C with a 30 minute reading interval) were resampled in order to meet these criteria. To determine the influence of site characteristics on the probability of recording bat calls, we classified the number of vertical strata (no vegetation, one, two, more than two layers) and the openness of woody vegetation (no vegetation, open (~ 0,1 trees * 100 m^{-2}), park-like (~ 0,6 trees), closed (~ 8,8 trees), dense (≥ 11,3 trees and bushes intermixed)).

Species identification

The acoustic properties of the sampled calls (pulse lengths and slopes, minimum and maximum pulse frequencies, etc.) were automatically measured with bcAdmin 2.06 (ecoObs GmbH, Nürnberg, Germany; Marckmann and Runkel 2010).

These call parameters were used to automatically identify species with batIdent 1.02 (ecoObs GmbH, Nürnberg, Germany; Runkel 2010). This software compares the parameters of each recorded call with an internal database of reference calls (Runkel 2010) by applying Random Forest algorithms for classification and support vector machine procedures to detect and eliminate outliers. Each of the recorded call sequences was identified to species or a higher level. As this output usually contains a varying number of misclassified call sequences, we manually validated all call sequences by inspecting calls with the program bcAnalyze 1.1 (ecoObs GmbH, Nürnberg, Germany; Runkel and Marckmann 2010), and by comparing the call sonograms to the literature (Hammer et al. 2009). Further, we checked parameters like start, main and end frequency of the calls, and assessed the plausibility of the identifications with species distribution maps and habitat preferences (Dietz et al. 2007; Hammer et al. 2009; Skiba 2009). The species *Pipistrellus nathusii* and *P. kuhlii*, as well as *Myotis brandtii* and *M. mystacinus*, could not be discerned with confidence by their sounds. Therefore we lumped their sequences together to form call species (*P. nathusii/kuhlii* and *M. brandtii/mystacinus*) and treated them like proper species in the analysis. Likewise, the *Plecotus* spp. could not be differentiated and therefore the genus was treated as a species.

Based on these data we created a validated species list for each of the sampled sites. At two of the sites no bat calls were registered, and we eliminated those from the data set, hence the sampling effort for analyses of total bat activity was n = 155 sites. Three more sites did not yield any identifiable bat calls so we also eliminated those, thus the sampling effort for analyses of species richness and species specific aspects was n = 152 sites (Fig. 2).

Statistical analysis

We used the coefficient of variation (CV, calculated as the ratio of standard deviation divided by the mean) for characterizing the variability of the call sequence lengths (total length of each call sequence in seconds) of the three devices at each site. To identify the parameters determining this variability, we tested for significant differences between the levels of the factors (i) vegetation stratum and (ii) openness of woody vegetation. The CV data were heteroscedastic with respect to these factors and not normally distributed (Shapiro-Wilk normality test: $W = 0.928$, $P < 0.001$; Levene homoscedasticity test for factor vegetation story: $F = 0.989$, $P = 0.400$; and for factor openness: $F = 2.844$, $P = 0.026$). A Box-Cox transformation (procedure boxCox() in package car; Fox and Weisberg 2011) successfully resolved the normality, but not the heteroscedasticity (Shapiro-Wilk: $W = 0.988$, $P = 0.204$; Levene for vegetation story: $F = 1.216$, $P = 0.306$; and for openness: $F = 2.627$, $P = 0.037$). We thus tested the original (non-transformed) version of the CV data with a robust ANOVA for medians that could handle heteroscedasticity (procedure med1way() in package WRS2; Mair et al. 2016). We also encountered heteroscedasticity and non-normality in the sequence length data of the 15 batcorders but a Box-Cox transformation was successful here and we used the transformed data in the analysis. We thus tested for potential sensitivity differences among the 15 batcorders with an ordinary parametric one-way ANOVA of the transformed sequence length data.

To identify the influence of the call ranges of verified species calls, we used the maximum call ranges in tables 28a and 28b in Barataud (2016; Tab. 1). Here, two different call ranges are reported, namely for open/semi-open environments and for forest understories. We used the longer call range for species records from sites where the openness of woody vegetation was classified as "no vegetation", "open", and "park-like", and the shorter range for "closed" and "dense".

All statistical analyses were performed in R 3.2.3 (R Development Core Team 2015).

RESULTS

We recorded a total of 21 bat species (including the genus *Plecotus* and the call species *Pipistrellus nathusii/kuhlii* and *Myotis brandtii/mystacinus*) and recorded 1 078 082 calls in 165 280 call sequences.

The acoustic sensitivity of the 15 batcorders was comparable, since there was no significant difference in total length of the recorded call sequences among the devices (one-way ANOVA, F = 1.187, P = 0.282). Using graphical checks, we did not find any changes in sensitivity due to sampling season or year (details not shown), and therefore concluded that the devices worked properly throughout the study period.

Most sites showed negligible variability of total sequence length, but at some sites the recording performance of the three devices deviated considerably from each other (Fig. 3). The ratio of the longest to the shortest total sequence length recorded was over fivefold in 23% and over tenfold in 8% of the sites. In one extreme case the ratio was even 37-fold (Fig. 4). We found the same number of verified species for all three neighboring batcorders in only 17% of the sites (i.e., the ratio highest/lowest species richness = 1). In 25% of the sites, the ratio was twofold or higher, and in one case the best batcorder outperformed the worst by the factor of six (Fig. 5).

The number of vegetation strata at the sampling sites did not significantly influence the coefficient of variation (CV) of call sequence lengths of the three devices (one-way ANOVA for medians, test statistic = 1.528, P = 0.165). By contrast, the openness of woody vegetation significantly affected the CV (one-way ANOVA for medians, test statistic = 4.964, P = 0.013), and despite limited data in the lowest and highest openness levels, sites with open, park-like, closed and dense woody vegetation on average exhibited a 63% higher CV than sites with no woody vegetation (Fig. 6).

The coefficient of variation for the maximum call range of the recorded bat species (according to Barataud 2016) was noticeably increased only for the recordings of species with very short call ranges (ca. 5 m, *Rhinolophus hipposideros* and *Plecotus* spp.), but not for calls of species with longer call ranges (10-100 m; Fig. 7). As Barataud's (2016) call ranges for several species differed from those given in Skiba (2009) and Dietz and Kiefer (2014) (Tab. 1), we replotted Fig. 7 with the numbers from those publications. Despite the differences, the results were very similar and also exhibited higher CVs only for calls with call ranges < 10 m (details not shown).

DISCUSSION

The results of this study clearly demonstrate that differences in the recording performance between neighboring ultrasound detectors may be huge; this concerns not only total bat activity but also species richness. Surprisingly, the number of vegetation strata did not play a significant role for the variability among the three devices. This result contradicts the findings of Darras et al. (2016) who could show that understory height was positively correlated with ultrasound transmission if a sound source was placed at heights of 2 and 5 m, whereas understory density negatively affected frequencies above 12 kHz for sound sources at 5 m height.

In contrast to vegetation stratification, we found that the factor vegetation openness did significantly influence the variation among detectors: sites without any woody vegetation showed the lowest recording variability (CV) among the devices, while open to dense conditions exhibited higher variability. One reason could be that in the open there were no structures that could have operated as obstacles for flying bats, or could have produced distorting reflections of calls. Therefore bats presumably emitted longer calls of lower frequency to increase the detection range (Schnitzler and Kalko 2001; Jones 2005; Dietz et al. 2007), which made it more probable for the neighboring devices to record the same bat call. On the other hand, bats flying in denser vegetation structure probably tended to emit shorter calls of higher frequency to better acoustically resolve the objects in their vicinity (Schnitzler and Kalko 2001; Jones 2005; Dietz et al. 2007). We assume that due to reflections and high atmospheric attenuation of these short high-frequency calls (Forrest 1994; Schnitzler and Kalko 2001), the probability to record calls was lower in more cluttered sites (denser vegetation) and the variability among the devices consequently high.

We also showed that the coefficient of variation (CV) among the devices was much higher for very short maximum call ranges (5 m) than for longer ranges. The species that belonged to this category were *R. hipposideros* and *Plecotus* spp., which respectively emitted calls with frequencies of 108-114 kHz (constant-frequency calls of 19-50 ms in length and a high sound pressure level (SPL) of 85 db peak equivalent SPL measured at 1 m distance from the mouth), and 80-20 kHz (frequency-modulated calls of 2 ms in length and a low pressure level of 68-77 db peak equivalent SPL measured at 1 m distance from the mouth; Jones and Rayner 1989; Waters and Jones 1995; Barataud 2016). The short call ranges for *R. hipposideros* calls thus result from their very high frequency, whereas that of *Plecotus* spp. comes from the low pressure level and short duration. In both cases the structure of the emitted calls decreased the recording probability.

Contrary to what we expected, the CV did not decrease linearly with call range, but was rather constant for ranges greater than 10 m (however with much variability in the data). This indicates that call range might not have been the main factor influencing the detection probability of bat calls above this threshold.

The most important conclusion from the results presented here is that the common practice of setting just one device per site and night very likely results in missing resident bat species and produces unreliable activity estimates. The high number of call sequences that are usually acquired with automated ultrasound detectors (10^2 to 10^5 a night) can all too easily give the impression of a "complete" sample, especially when compared with mist-netting (see Murray et al. 1999; O'Farrell and Gannon 1999) or recordings collected with mobile hand held detectors. Our data show that this impression may be entirely false since the variability of detection performance can be perplexingly high, even among neighboring devices in seemingly "homogenous" sites. Unfortunately we did not firmly identify factors correlating with the variability of recording performance of the three devices. Vegetation openness and maximum call range proved significant, but we expected much stronger patterns (for example, a substantial and steady increase of sequence length variability toward denser stands, and much less variability of bat species with higher call ranges). We therefore cannot provide substantiated guidelines to optimize sampling under particular site conditions from our data.

As a simple remedy for studies aiming at inventorying a local fauna and/or estimating its activity, we advocate either the deployment of several devices in parallel for one night (Fischer et al. 2009), or to record several nights in sequence with a single device (Hayes 1997; Fischer et al. 2009). More advanced solutions can and should be found in the rich literature on sampling optimization, e.g. by inspecting and extrapolating species rarefaction curves (Colwell et al. 2012).

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TABLES

Tab. 1 Maximum call ranges (m) of recorded bat species according to literature for the habitat types "open to semi-open environments" and "forest understories". Data originated from Barataud (2016), Dietz and Kiefer (2014) and Skiba (2009).

open/semi-open environments				forest understories			
	Barataud 2016	Skiba 2009	Dietz and Kiefer 2014		Barataud 2016	Skiba 2009	Dietz and Kiefer 2014
Species	**call range (m)**	**call range (m)**	**call range (m)**	**Species**	**call range (m)**	**call range (m)**	**call range (m)**
Rhinolophus hipposideros	5	6	5	*Rhinolophus hipposideros*	5	6	5
Myotis emarginatus	10	25	10	*Plecotus spp.*	5	20	40
Myotis alcathoe	10	20	10	*Myotis emarginatus*	8	25	10
Myotis brandtii/mystacinus	10	25	10	*Myotis nattereri*	8	25	15
Myotis daubentonii	15	45	15	*Myotis alcathoe*	10	20	10
Myotis nattereri	15	25	15	*Myotis brandtii/mystacinus*	10	25	10
Myotis bechsteinii	15	20	15	*Myotis daubentonii*	10	45	15
Barbastella barbastellus	15	35	10	*Myotis bechsteinii*	10	20	15
Myotis myotis	20	30	20	*Barbastella barbastellus*	15	35	10
Plecotus spp.	20	20	40	*Myotis myotis*	15	30	20
Pipistrellus pygmaeus	25	30	25	*Pipistrellus pygmaeus*	20	30	25
Pipistrellus pipistrellus	25	35	30	*Miniopterus schreibersii*	20	40	30
Pipistrellus nathusii/kuhlii	25	50	30	*Pipistrellus pipistrellus*	25	35	30
Miniopterus schreibersii	30	40	30	*Pipistrellus nathusii/kuhlii*	25	50	30
Hypsugo savii	40	55	40	*Hypsugo savii*	30	55	40
Eptesicus serotinus	40	80	40	*Eptesicus serotinus*	30	80	40
Eptesicus nilssonii	50	70	50	*Eptesicus nilssonii*	50	70	50
Vespertilio murinus	50	105	50	*Vespertilio murinus*	50	105	50
Nyctalus leisleri	50	85	80	*Nyctalus leisleri*	80	85	80
Nyctalus noctula	100	135	100	*Nyctalus noctula*	100	135	100
Myotis dasycneme	15*	55	15*	*Myotis dasycneme*	10*	55	15*

* no data available, value is adopted from *M. daubentonii*

FIGURES

Fig. 1 Sample image of bat detector disposition in the field. Per site three devices were set in approximate vicinity (10 m maximum, distances had sometimes to be adjusted to site conditions) from each other so that site characteristics were similar for each device (with respect to land use, vegetation etc.). All devices were placed on top of poles at 2.5 m height. Microphone orientation was allowed to freely position with the wind.

Fig. 2 Distribution map of the sampling sites (n=152) in eastern Austria which were considered for further calculations. Sites were sampled on the nodes of a 10 x 10 km grid and were restricted to water bodies (streams and standing water bodies).

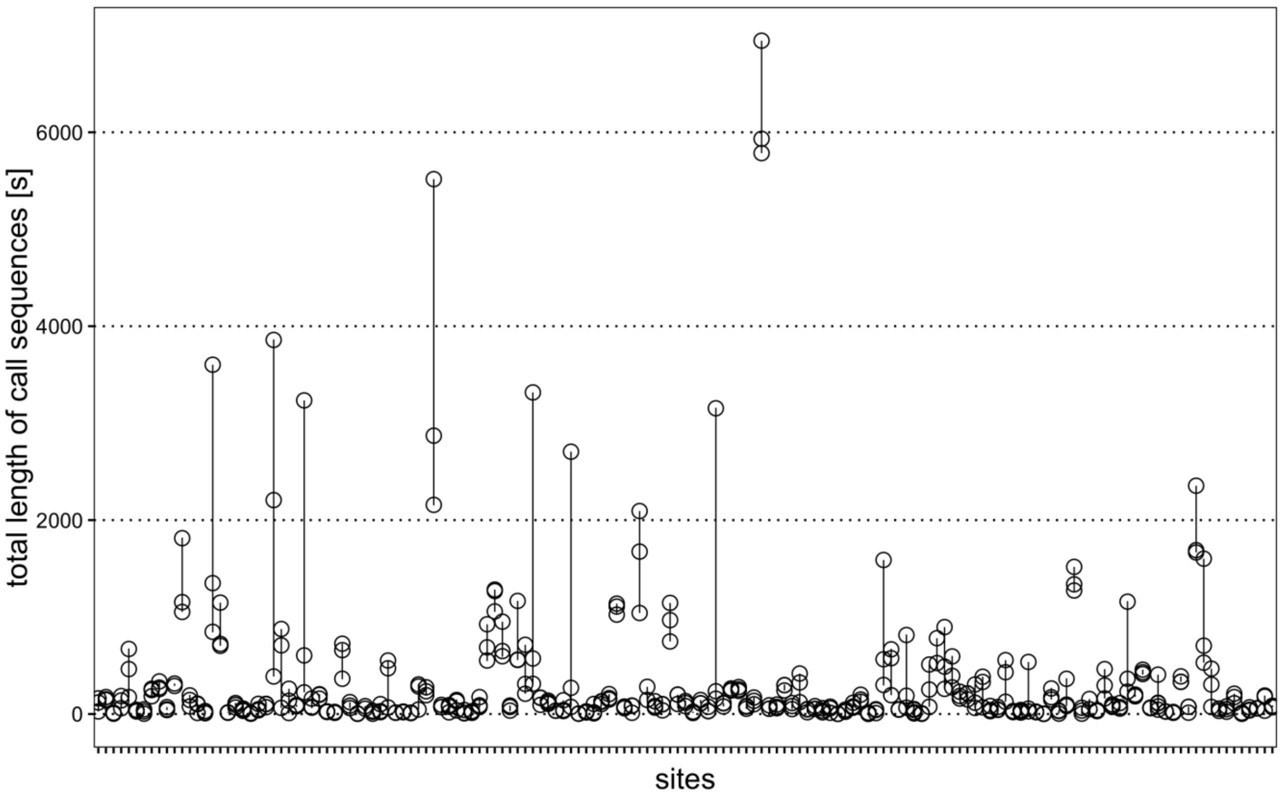

Fig. 3 Variability of the performance of three neighboring ultrasound detectors in recording bat activity (all species pooled). Each dot represents a detector. For clarity, the three dots of each site are connected by a line (n = 152 sites in eastern Austria).

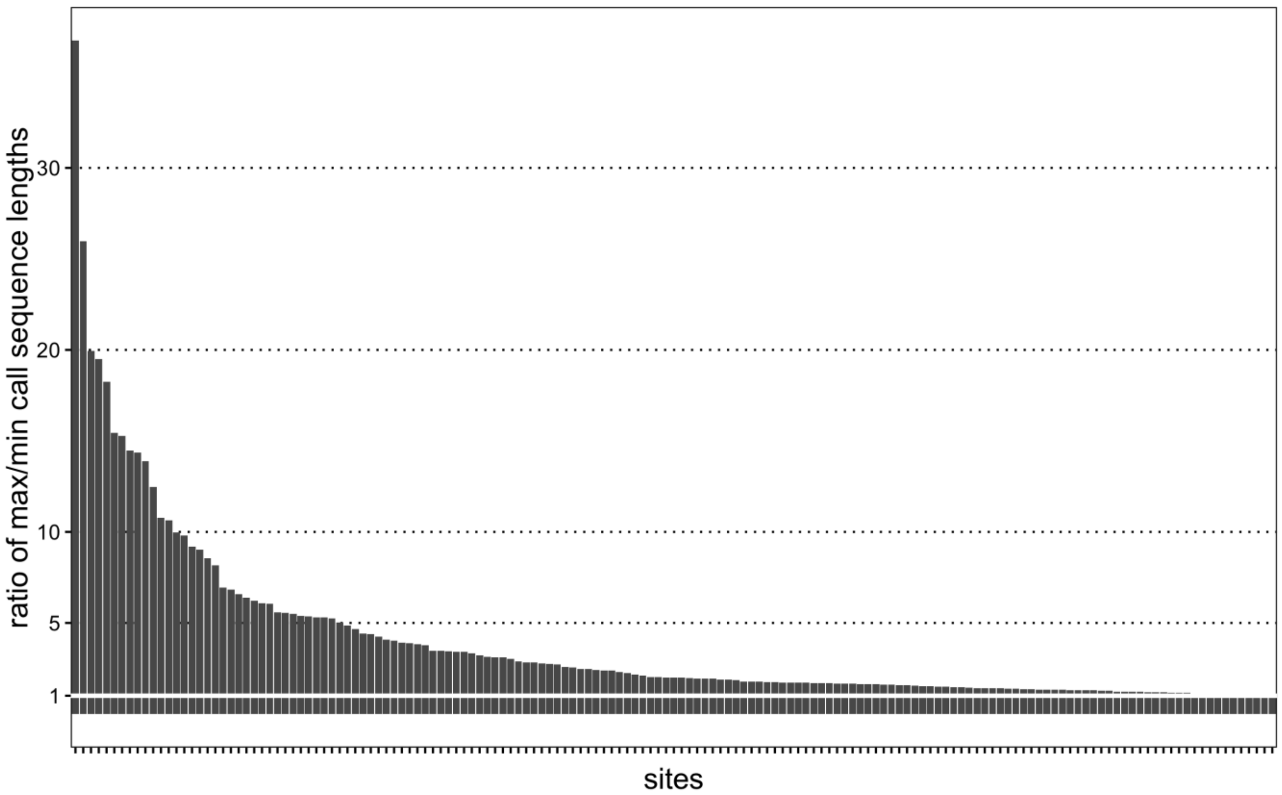

Fig. 4 Ratio of best to worst performance in recording bat activity (all species pooled) of three neighboring ultrasound detectors. The horizontal white line indicates no difference between the minimum and maximum call sequence length (ratio =1). n = 152 sites in eastern Austria.

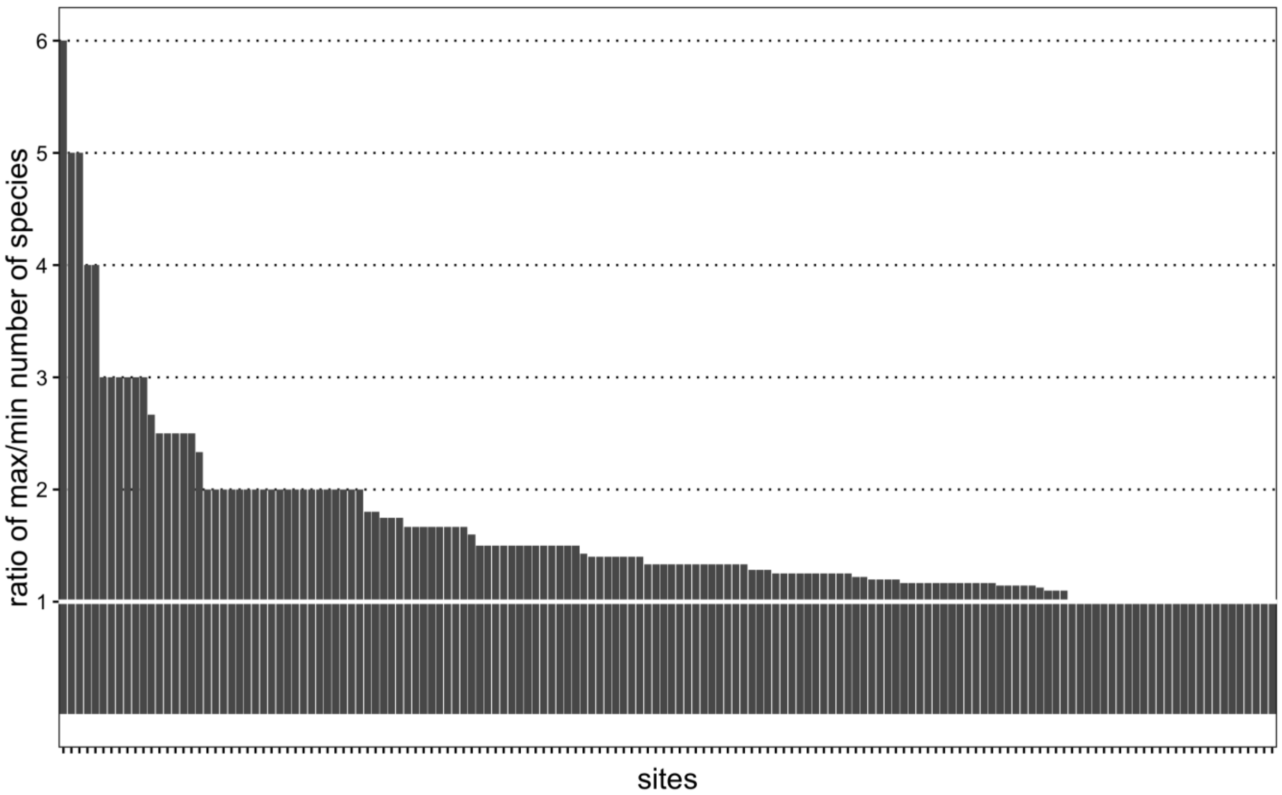

Fig. 5 Ratio of best to worst performance in recording bat species of three neighboring ultrasound detectors. The horizontal white line indicates no difference between the minimum and maximum call sequence (ratio =1). n = 152 sites in eastern Austria.

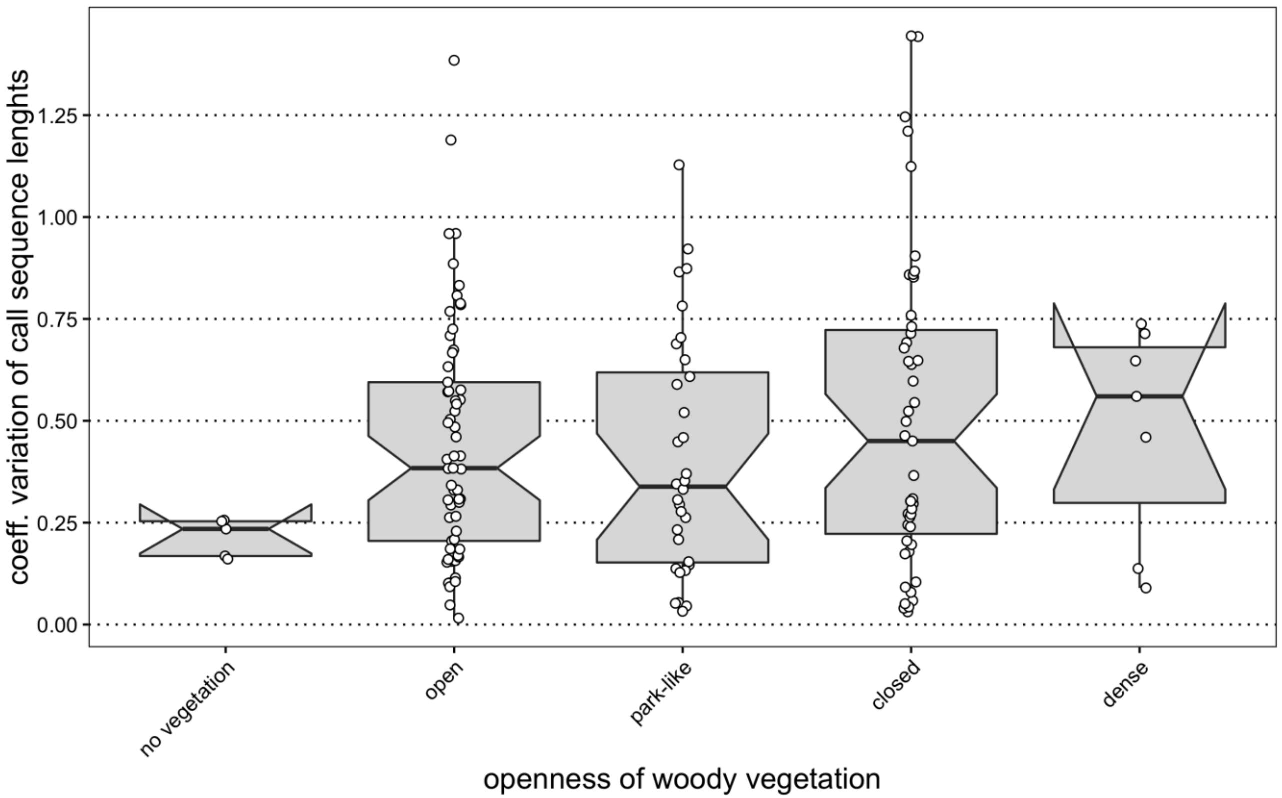

Fig. 6 Relationship between the variability of recording performance (all species pooled) of three neighboring ultrasound detectors and the openness of vegetation. Each dot represents a site; in addition to the boxes, dots are displayed to indicate the varying sampling effort in the vegetation categories. n = 152 sites in eastern Austria.

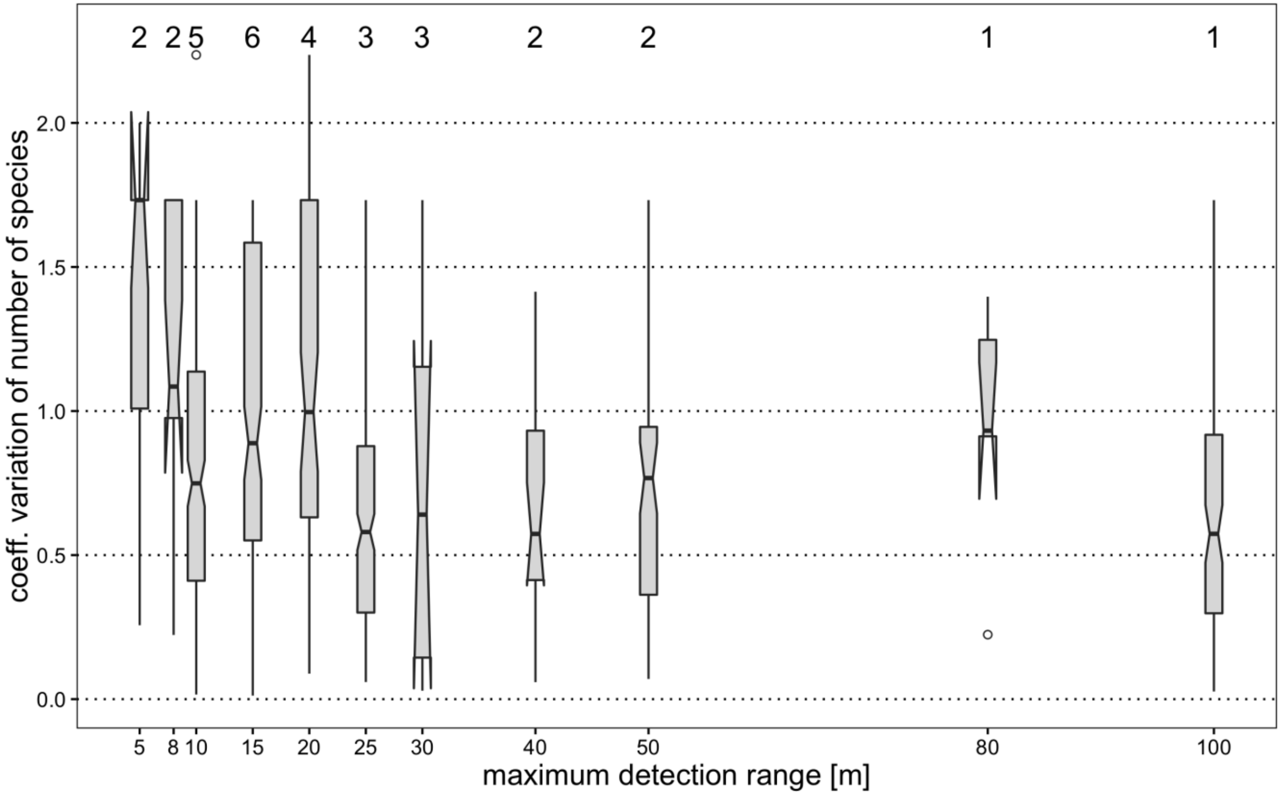

Fig. 7 Relationship between the variability of recording performance (all species pooled) of three neighboring ultrasound detectors and the maximum call ranges of the registered bat species. The figures on top indicate the number of bat species contributing to each box. n = 152 sites in eastern Austria.

CURRICULUM VITAE

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SCHULBILDUNG:

2009-2017 Doktoratsstudium an der Universität für Bodenkultur Wien

2002-2009 Biologie/Zoologie Studium an der Universität Wien, Abschluss als Mag.rer.nat.

1994-2002 Bundesrealgymnasium der Stadt Wien, Brigittenauer Gymnasium BRGXX

1991-1996 Italienische Schule der Italienischen Kongregation (Volksschule) am Minoritenplatz, Wien

1990-1994 Volksschule Pöchlarngasse, Wien

WEITERFÜHRENDE PRAKTIKA, FREIWILLIGENTÄTIGKEIT:

Seit 2009 Mitwirkende bei der Langen Nacht der Forschung
Fledermausforschung an der Universität für Bodenkultur Wien

Laufend seit 2008 aktives Mitglied des Vereins KFFÖ (Koordinationsstalle für Fledermausschutz und –forschung in Österreich), Mitwirkung bei Fangnächten, Veranstaltungen, Fledermausführungen, Pflege von verletzten Tieren, Quartierbetreuung, Wissensvermittlung
(Mentoren: Dr. Guido Reiter, Mag. Katharina Bürger, Ulrich Hüttmeir)

2015 GIS im Wildtier und Habitatmanagement, Universität für Bodenkultur Wien
(Lehrveranstaltungsleiter: Ass. Prof. Dr. Rosemarie Parz-Gollner)

2014 Mediation, Universität für Bodenkultur Wien
(Lehrveranstaltungsleiter: Dr. Sigrid Schwarz)

2010 Einführung in GIS, Universität für Bodenkultur Wien
(Lehrveranstaltungsleiter: Dr. Karolina Taczanowska)

2008 Ethologie Praktikum, Universität Wien
(Lehrveranstaltungsleiter: Ao. Univ.-Prof. Dr. Eva Millesi)

2008 Taxidermie für Insekten, Universität Wien
(Lehrveranstaltungsleiter: Ao. Univ.-Prof. Dr. Wolfgang Waitzbauer)

2008 Morphologie und Taxidermie heimischer Vögel (Nonpasseres und Passeres), Naturhistorisches Museum der Stadt Wien
(Mentor: PhD. Anita Gamauf)

2007 Naturschutzpraktikum zum Schutz der Meeresschildkröten (*Caretta caretta*) im Mittelmeer, Fethiye, Türkei
(Lehrveranstaltungsleiter: Privatdoz. Dr. Michael Stachowitsch)

18.10-21.10.2007 Praktikum Vogelberingung, Verein AURING – Biologische Station Hohenau
(Mentor: Mag. Martin Rössler)

04/2006 Naturschutzpraktikum Krötenwanderung, Stadt Wien, Wienerberg

2006 Praktikum in der Eulen- und Greifvogelstation Haringsee (EGS).
Haringsee, Österreich
(Mentor: Dr. Hans Frey)

ARBEITSERFAHRUNG:

Laufend seit 2013 Lehrbeauftragung als externer Lektor an der Universität für Bodenkultur Wien, Inst. Zoologie, Dept. Integrative Biologie und Biodoversitätsforschung
Lehrveranstaltungen:

- Fledermäuse – Bestimmung und Freilandübung
- Agrarökologie Übungen
- Biologie terrestrischer Tiere

Laufend seit 2012 Naturführungen als selbstständige Biologin im Auftrag von privaten Personen, Firmen, Magistratsabteilung 49, Kulturlotsinnen des Österreichischen Gewerkschaftsbundes, Österreichische Bundesforste, Wiener Wildnis

Laufend seit 2009 Mitarbeiterin der zoopädagogischen Abteilung im Tiergarten Schönbrunn
(Vorgesetzte: Gabriele Schwammer)

2015 Gutachtertätigkeit: Erhebung der Fledermausfauna im Untersuchungsgebiet Göpfritz an der Wild in Hinblick auf eine mögliche Beeinträchtigung durch den Bau von Windkraftanlagen
(Auftraggeber: Naturschutzbund Niederösterreich)

2015 Darsteller im Theaterstück „Nachtschicht" unter der Regie von Jessica Glause
(Dienstgeber: Volkstheater Wien)

25.04.2013 Vortrag in der VS Waldschule (Dr. Schoberstraße, Wien) als Experte für heimische Fledermausarten

2012 externer Projektmitarbeiter der Technischen Universität München
Erstellung einer Fledermaus-artenliste und Monitoring der Arthropoden auf vier Untersuchungsflächen in Wien, Niederösterreich und Burgenland
Projektname: Beech Forests for Future
(Auftraggeber: Prof. Dr. R. Schopf)

2012 Gutachtertätigkeit: Erhebung der Fledermausfauna im Untersuchungsgebiet Hollabrunner Wald für die Bürgerinitiative „Freunde des Hollabrunner Waldes“ in Hinblick auf eine mögliche Beeinträchtigung durch den Bau von Windkraftanlagen
(Auftraggeber: Verein Freunde des Hollabrunner Waldes)

2011/2012 Projektmitarbeiter des MINT – Projekts „Biodoversität und Citizen Science“
Planung, Implementierung und Abhaltung einer Universitären Lehrveranstaltung mit praktischem Übungsteil zum Schutz heimischer Fledermausarten für StudentInnen der Universität für Bodenkultur Wien
Universität für Bodenkultur Wien, Inst. Zoologie, Dept. Integrative Biologie und Biodiversitätsforschung
(Projektleitung: Dr. Julia Kelemen-Finan, ao. Univ. Prof. Dr. Christiane Brandenburg, ao. Prof. Dr. Alexander Bruckner, ao. Prof. Dr. Monika Kriechbaum)

2010/2011 Projektmitarbeiter des Generation Innovation Regionen – Projekts „Fledermäuse im Biosphärenpark Wienerwald – Kinder und Jugendliche aktiv in Forschung und Artenschutz
Anstellung bei der Universität für Bodenkultur Wien, Inst. Zoologie, Dept. Integrative Biologie und Biodiversitätsforschung
(Projektträger: Österreichische Bundesforste AG (ÖBf), Projektleitung: DI Ulrike Kirchweger)

2010 Tutor und Übersetzer (Italienisch) für die Lehrveranstaltung „Landschaftsökologisches Freilandpraktikum“ der Universität für Bodenkultur Wien
(Lehrveranstaltungsleitung: ao.Univ.Prof. Dr. Christiane Brandenburg, ao.Univ.Prof. Dr. Alexander Bruckner, Ass.Prof. Dr. Axel Mentler, ao.Univ.Prof. Dr. Erich Mursch-Radlgruber, ao.Univ.Prof. Dr. Franz Ottner, Dipl.-Ing. Gabriele Bassler)

08/2006 Praktikant im Vertrieb der KLINGER Dichtungstechnik, Gumpoldskirchen, Österreich

08/2005 Praktikant im Sekretariat der KLINGER Dichtungstechnik, Gumpoldskirchen, Österreich

07/2004 Angestellte im Verkauf bei der Supermarktkette BILLA. Wien, Österreich

07/2003 Praktikant im Sekretariat und der Buchhaltung der KLINGER Dichtungstechnik, Gumpoldskirchen, Österreich

08/2002 Praktikant im Sekretariat und der Buchhaltung der KLINGER Dichtungstechnik, Gumpoldskirchen, Österreich

KONFERENZEN UND VORTRÄGE:

04.2017 4. Tagung Fledermausforschung in Österreich
Universität für Bodenkultur Wien, Inst. Zoologie und Koordinationsstelle für Fledermausschutz und –forschung in Österreich
Universität für Bodenkultur, Wien
Organisation

04.2015 3. Tagung Fledermausforschung in Österreich
Universität für Bodenkultur Wien, Inst. Zoologie und Koordinationsstelle für Fledermausschutz und –forschung in Österreich
Haus der Natur, Salzburg
Organisation, Vortrag

09.2015 Fachtagung Fledermausschutz in der Kulturlandschaft
Naturpark Obst-Hügelland, Oberösterreich
Vortrag

09.2014 XIIIth European Bat Research Symposium
State Institute for Nature Protection, Šibenik, Kroatien
Vortrag

03.2013 3th International Berlin Bat Meeting
Leibnitz Institut für Zoologie und Wildtierforschung, Berlin, Deutschland
Vortrag und Poster

10.2012 2. Tagung Fledermausforschung in Österreich
Universität für Bodenkultur Wien, Inst. Zoologie und Koordinationsstelle für Fledermausschutz und –forschung in Österreich
Universität für Bodenkultur, Wien
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10.2011 1. Tagung Fledermausforschung in Österreich
Universität für Bodenkultur Wien, Inst. Zoologie und Koordinationsstelle für Fledermausschutz und –forschung in Österreich
Universität für Bodenkultur, Wien
Organisation, Vortrag

05.2010 „Fragen des Alltags - Antworten der Wissenschaft“, Vortragsreihe der Universität für Bodenkultur Wien
Städtische Bücherei, Wien
Vortrag

DIVERSES:

21.10.2009 Wissenschaftlicher Förderpreis der Stadt Wien, Magistratsabteilung 22

11.2008-04.2009 Ausstellung zum Thema Fledermäuse im botanischen Garten der Universität Wien

PERSÖNLICHE FÄHIGKEITEN:

Italienisch in Wort und Schrift

Englisch in Wort und Schrift

Computerprogramme MS-Office, SPSS 16, R, EcoSim

Fang und Handling von Fledermäusen, Singvögeln

Umgang mit Batdetektor

Umgang mit Batcorder (ecoObs GmbH) und dazugehörende Software (bcAdmin, batIdent, bcAnalyze)

Präparation (Skelett und Stopfpräparat); vorwiegend von Fledermäusen, sowie von Passeriformes und Nonpasseriformes

Führerschein Kategorie B