ROOST SELECTION BY THE FOREST-DWELLING BAT *MYOTIS BECHSTEINII (MAMMALIA: CHIROPTERA)*: IMPLICATIONS FOR ITS CONSERVATION IN MANAGED WOODLANDS

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Keywords: Nursery colony, Redundancy analysis, Roosting behaviour, Switzerland, Woodland management

Mots-clés: Chiroptères, Colonie de reproduction, Murin de Bechstein, Gestion forestière, Suisse

Abstract

Roosting habits of a forest-dwelling bat, *Myotis bechsteinii*, were investigated with the aid of telemetry between June and September 2005 in Western Switzerland. The selection of twelve roosts occupied by seven radio-tagged Bechstein's bats was analyzed through redundancy analysis (RDA). Bechstein's bats selected roosts in the more thermophilous area of the forest. Females Bechstein's bats behaved differently according to their reproductive state: Pregnant and post-lactating females switched from their roosts more frequently than lactating females. *Myotis bechsteinii* selected different roost trees close to each other. More than 50 % of the bat's roosts were located within 0.6 km from the foraging grounds. Roost trees were selected according to functional criteria instead of specific ones. Consequences for forest management are discussed.

Résumé

L'utilisation des gîtes au cours de la période estivale par une chauve-souris forestière, *Myotis bechsteinii*, a été étudiée par télémétrie entre juin et septembre 2005 dans l'Ouest de la Suisse. La sélection de douze gîtes, occupés par sept murins de Bechstein suivis a été décrite par le bais d'analyses canoniques de redondance (ACR). Le murin de Bechstein choisi ses gîtes dans les régions les plus thermophiles de la forêt. Les femelles de Murin de Bechstein ont montré un comportement différent en fonction de leur état reproducteur. Les femelles gravides et post-allaitantes ont changé plus fréquemment de gîtes que les femelles

allaitantes. *Myotis bechsteinii* sélectionnait différents arbres-gîtes dans la même « parcelle » forestière, à moins de 500 mètres l'un de l'autre. Les gîtes des murin de Bechstein étaient proches des terrains de chasse puisque plus de 50% étaient situés à moins de 0.6 km de ceux-ci. Les arbres-gîtes ont été choisis en premier lieu sur la base de leurs caractéristiques fonctionnelles et non d'après l'espèce. Notre étude permet d'émettre quelques recommandations pour la gestion forestière. (1) Les mesures de conservation pour le Murin de Bechstein devraient prendre en considération un rayon de 600 mètres autour des gîtes. (2) La quantité de forêt et tout particulièrement la proportion de forêt caducifoliée thermophile de ces secteurs devrait être maintenue et où cela est possible étendue. La gestion sylvicole de ces secteurs devrait être extensive. (3) Les arbres à cavités devraient être conservés sur pied. (4) Comme les chauves-souris de cette espèce changent fréquemment de gîtes et ont un faible rayon d'action, la densité des arbres gîtes potentiels devrait être élevée et ceux-ci agrégés en lots. Les gestionnaires forestiers devraient laisser des groupes d'arbres matures distribués en patchwork à travers la forêt et connectés entre eux.

Zusammenfassung

Mittels einer Telemetriestudie ist die Nutzung der Quartiere durch die waldbewohnende Fledermaus / Myotis bechsteinii /von Juni bis September 2005 in der westlichen Schweiz näher untersucht worden. Die zwölf Quartiere, die von sieben mit Sender ausgerüsteten Bechsteinfledermäusen aufgesucht wurden, sind mittels kanonischer Redundanzanalyse beschrieben worden. Die Bechsteinfledermäuse bevorzugten Quartiere in den wärmsten Waldabschnitten. Die Weibchen zeigten in Anhängigkeit vom Reproduktionsstatus unterschiedliche Verhaltensweisen. Trächtige und post-laktierende Weibchen wechselten ihre Quartiere häufiger als laktierende Weibchen. Die Bechsteinfledermäuse suchten unterschiedliche Baumquartiere innerhalb des gleichen Waldabschnittes auf. Mehr als 50% der Quartiere lagen weniger als 0.6 km weit von den Jagdstreifgebieten entfernt. Die Wahl der Baumquartiere erfolgte in erster Linie in Abhängigkeit von ihrer Funktionalität und nicht aufgrund der Baumart. Die Schlussfolgerungen für die Waldbewirtschaftung werden diskutiert.

INTRODUCTION

Roosts play an important role in bat biology (e.g. HUMPHREY, 1975; LEWIS, 1995; KUNZ & LUMSDEN, 2003). They provide protection from predators and weather, improve information transfer, are important for thermoregulation parental care and provide mating opportunities, further they reduce commuting costs to foraging sites and competition (ALTRINGHAM, 1996). Thus, roost choice has a strong influence on the bat's survival and fitness (VONHOF & BARCLAY, 1996). HUMPHREY (1975) showed that nursery roosts are the most limiting resource in distribution and diversity of Nearctic bat species. Accordingly, roosting requirements are determined by the physiological needs of adults and/or juveniles, predation, parasitism or weather conditions (FINDLEY, 1993; RECKARDT & KERTH, 2007).

Bats roost in different structures such as caves, buildings, rock crevices, tree foliage and tree cavities (KUNZ & LUMSDEN, 2003). Because they constitute large and spatially well localised aggregations, species roosting in caves and man-made structures were preferred in most studies. On the other hand, few studies have focused on roosting preferences and habits of forest-dwelling bats (BARCLAY & KURTA, 2007). Most data on tree roosts are only descriptive (STEINHAUSER, 2002; see references in KUNZ & FENTON, 2003). However, in few recent studies, specific tree characteristics and roost localization were compared with random samples of available trees in order to investigate roost selection more rigorously (VONHOF & BARCLAY, 1996; SEDGELEY & O'DONNELL, 1999, 2004; RUSSO *et al.*, 2004; BARCLAY & KURTA, 2007).

Myotis bechsteinii is a medium sized European forest-dwelling bat species, which is scarcely distributed in Europe and Switzerland. It is known to roost in tree cavities and is regularly found in bat boxes (MESCHEDE & HELLER, 2002) but very few summer or nursery roosts are known (BAGGØE, 2001; MESCHEDE & HELLER, 2002). The Bechstein bat is considered a vulnerable (HUTSON *et al.,* 2001) or a rare species (e.g. DUELLI, 1994). Moreover, few studies have examined roosting preferences of this species (KERTH *et al.,* 1996, 2001) and guidelines for its conservation remain therefore largely insufficient due to the lack of knowledge of basic their biology.

In this study, we examined roost selection in a breeding population of *Myotis bechsteinii* located at the foot of the inner chain of the Jura Mountains (Western Switzerland) at two levels: (1) the environmental structure of the roost site and (2) the intrinsic characteristics of the roost tree.

MATERIAL AND METHODS

Trapping and tagging bats

Roost selection of Bechstein's bats was investigated in the piedmont of the canton of Neuchâtel (N 46 9667°, E 6 8667°, Western Switzerland). The animals were caught from June to mid of August 2005 using mist-nets (mesh size = 12 mm and 19 mm) on their foraging areas during the first part of the night (3-5 h from sunset) and just before sunrise when the bats came back to their roost.

All bats were sexed and put in a nylon stocking for weighing with a 60g spring-scale (precision: 0.5 g, Pesola AG, Switzerland). The animals' forearms were measured with a calliper rule (precision 0.1 mm). We determined the bats' age by examining the epiphyseal fusion of their phalanges. Also, we described the physiological conditions of females: pregnant, nursing and perhaps lactating, or nulliparous. Numbered alumi-nium rings marked all captured bats in order to identify individuals.

The bigger females were chosen in order to limit the supplementary load of the transmitters to 5-10% of their body mass. Seven *Myotis bechsteinii* were fitted with 0.43 g BD-2N and 0.67 g BD-2T transmitters (Holohil System Ltd., Ontario, Canada). The transmitters were glued between the scapulae, after shaving the fur with surgical Skin-Bond cement (Medimprax gmbh, Allschwil, Switzerland). The transmitter batteries had a minimum life of 13 and 17 days, respectively. The distance of reception ranged between 100 and 1'200 meters.

Roost localization

We searched for radio-tracked bats' roosts on foot in the daytime according to the homing-in technique. A Yeasu FT290 receiver (modified by Andreas Wagener, Telemetrieanlagen HF-NF Technik, Köln, Germany) with a hand-held Yagi 3 elements antenna (Wildlife material Inc., USA) was used. When no contact could be established, we searched for tagged bats by car with an omni-directional antenna. Once a roost tree was localized, we identified the cavity by assessing radio signal strength and direction standing close to the tree. Visual inspection of the cavity from the ground with binoculars and observation of emerging bats were also conducted.

Data recorded at roost plot

Roost localizations were registered with a GPS (precision 4-12 m, Summit GPS, Garmin Ltd.). We identified the species of each roost tree and measured its DBH (stem diameter at breast height). Tree and trunk height were determined with a clinometer and percentage of canopy closure around roost trees was assessed visually from the base of the tree. Number of cavities and cavities' height above ground were also identified and cavities' exposure was meas-

ured with a compass. Finally we registered decay stages of the roost tree: no dead limbs or bark intact = 1, < 25 % = 2, < 50 % = 3, < 75 % = 4, < 95 % =5, dead = 6.

Following SEDGELEY & O'DONNELL (1999), we marked four quadrants around each roost tree and localized the nearest potential roost tree (hereafter called companion tree) in each quadrant. These companion trees are those should have a direct influence on the roost tree and by their proximity with the roost tree these should be preferentially select by bats during the roost-switsching. We considered as companion trees only those with a DBH ≥ 30 cm and a height above ground > 3m. It is the minimum size to shelter suitable cavities (RUSSO et al., 2004). Each roost tree and its four companion trees composed a roost plot (SEDGELEY & O'DONNELL, 1999). The distance between the roost tree and the companion trees were measured and a potential roost density per hectare was calculated.

For each companion tree, we measured the same characteristics as for the roost trees, i.e. species, decay stage, DBH, tree and trunk height, canopy closure, total number and direction of cavities.

Selection of random tree plots

To investigate whether bats selected particular roost trees, 109 trees were chosen at random in the study area and checked for their potential roost availability. Their features where also compared with those of roost trees. The location procedure of random trees was derived from SEDGELEY & O'DONNELL (1999) and adapted to the local situation. After we tracked all bats, the minimum convex polygon (MCP) around all locations was determined using the Animal Movement 2.04 extension for ArcView® 3.3 GIS. We selected 25 random plot localizations which were included in the MCP and localized with a GPS the nearest potentially suitable tree (DBH > 30 cm and height above ground > 3m). As for

the roost plots, we located the nearest available tree in each quadrant around the first random tree. These five random trees (the central one and its four neighbours) constitute a random tree plot in which a potential roost density per hectare was calculated (see roost tree above). The nine tree characteristics (see roost tree above) were described for each random tree.

Environmental descriptors of roost plots and random plots

The descriptors of landscape structure within roost and random plots were derived from raster or vector resolution data provided by the Federal Office of Topography, Bern (topography, hydrography, roads) and the Federal Office of Statistics, Neuchâtel (conifers cover in woodland). The Forestry division of the Canton of Neuchâtel provided phytosociological data. A circle with a 20 meter radius was defined around each roost or random location using ArcView® 3.3 GIS (ESRI, Redlands, California, USA). A mean value of elevation was calculated from a 2 x 2 m resolution digital elevation model (DEM) within these buffers. The same was done with the slope, the topographic aspect (using two directions North-South and East-West) and the forest height, which were derived from the digital elevation model and digital surface model. The distance between the circle centre and the nearest forest edge and water (pond or river) was calculated. Finally series of land-cover classes were used to test the selection of various landscape elements (presence of conifers in woodland, phytosociology). Cover measures were given in percentage. Environmental data within roost and random buffers were extracted into tables, which were used in the statistical analyses.

Statistical analyses

Redundancy analyses (RDA) were used as discriminant analysis to assess and to test

if there were differences between the plots' or tree features according to their utilisation by the bats (roost vs. random or companion). The RDA, also known as reduced-rank regression, is a constrained ordination technique derived from principal component analysis (PCA) and multiple regressions. It could be considered as a multivariate form of multiple regression (Ter Braak & Prentice 1988) used for relating to sets of variables (plots or trees x descriptors and plots or trees x utilisation by bats). The ordination of the fist data set produce axis, which are constrained to be linear combinations of the 'utilisation' variables. When the second matrix contains a series of dummy variables reflecting a single-factor classification of the samples, as in our case (tree utilisation by bats can be categorised into roost tree, companion tree or random), RDA can be assimilated to a discriminant analysis (TER BRAAK & PRENTICE, 1988). Furthermore, the drawbacks of the latter (high sensitivity to non-independence of samples and descriptors and to non-homogeneity of within groups' variances, exclusive use of quantitative descriptors) are advantageously circumvented by the more robust RDA (BORCARD & BUTTLER, unpubl.). Note that the RDA was preferred to the unimodal canonical correspondence analysis (CCA, TER BRAAK, 1996) because our data were clearly symmetric. First, we computed an analysis to compare the environmental features of the roost plots with the random plots (level 1, environmental analysis). Secondly, we performed three analyses to compare tree features from (i) all tree types (roost, companion and random), (ii) roost vs random trees and (iii) roost vs companion tree (level 2, tree characteristics analysis). Redundancy analyses were performed with the CANOCO 4.52 computer program (Microcomputer Power, Ithaca, NY, USA). To assess the significance of canonical axes, we computed a Monte Carlo permutation test of significance. The significance of the regression coefficients of each response variables (tree or plots features) on the regressors (utilisation by bats) was deduced from the t-value biplot (TER BRAAK, 1996).

RESULTS

Tagging bats and roosting behaviour

We tagged seven *Myotis bechsteinii* (three pregnant females, one lactating female, two post-lactating females and one juvenile male) between the 1st of June and September 2nd. The bats were tracked for 9.4 ± 5.6 days (range: $1 - 16$ days). We located 12 roosts used by the seven *Myotis bechsteinii* (2.0 ± 1.2 roosts/bat, range: $1 - 4$). All Bechstein's roosts were located in tree cavities. Three tagged bats roosted together in the same tree.

Bechstein's bats switched roosts frequently: four bats used more than one tree over the study period, and for a given bat a new roost was discovered on average every 2.1 ± 1.1 days (range: $1 - 4$ days, n = 4 bats). These data would underestimate roost-switching frequency since not all bats could be located every day. Six Bechstein's bats occupied the same roost on average 5 ± 4.2 days (range: $1 - 16$ days) days during all the tracking period. For three bats only one roost was found before the contact was lost. The number of bats in a colony was counted in six cases, and averaged 13.7 ± 6.2 bats (range: $3 - 22$).

Landscape characteristics of roost sites

We could measure environmental features from 12 roost plots and only 22 random plots of the 25 selected. Descriptive statistics of roost sites and random sites features are shown in table 1. The area in which roosts were found was a forested side of a mountain located between settlements and farmland in lower altitudes and wooded pasture in higher altitudes. The roost trees were found at an altitude of 603 ± 14 m a.s.l and they were located on a slope (mean = 30%) exposed to the southeast. All roosts

Variable	Roost plots		Random plots	
	Mean ± SD	Range	Mean ± SD	Range
Altitude (m a.s.l.)	603 ± 14	578-625	757 ± 200	553-1129
Slope (%)	30 ± 9	16-42	14 ± 7	2-28
Orientation (degrees)	149 ± 23	114-201	173 ± 36	134-279
Forest height (m)	11 ± 1	9-13	9 ± 4	1-17
Distance to forest edge (m)	101± 46	21-203	160 ± 119	3-419
Distance to nearest water (m)	422 ± 225	70-873	637 ± 476	4-1372

Table 1. Descriptive statistics of roost sites (n = 12) and random sites (n = 22) environmental features.

were localized inside the forest, principally in xerothermophilous forests (*Quercion pubescenti-petreaea* and *Cephalanthero-Fagenion* = 70 %) or dry mesophilous forest (*Luzulo-Fagenion* = 28 %) in mature stations with few conifers.

Comparison between roost plots and random plots

Testing the selection of *Myotis bechsteinii* on the roosting site was achieved through the creation of a matrix of site features with the 20 environmental characteristics and a constraining matrix describing to which types of site belonged the samples (roost plot or random plot). The RDA performed on both matrices demonstrated that sites differed significantly according to the presence of bats (Monte Carlo test, P = 0.033, 1000 permutations), but only 5.1 % of sites' total variance was related to the presence of bats (fig. 1a). The correlation biplot of sites features and regressors (bat presence) (fig. 1b) demonstrates that roost site selection is positively affected by eastness and by the surface of *Luzulo-Fagenion* and *Quercion pubescenti-petraeae* forests and negatively by the altitude (narrow angles with canonical axis). The t-value biplot showed that only the *Luzulo-Fagenion* forest, the eastness and the altitude were significantly correlated with roost presence.

Characteristics of roost trees

We measured tree features from 60 trees from 12 roost plots and 97 trees from 22 random plots (the quota of 110 possible tree measurements were not obtained, because occasionally trees were absent from some quadrants near to the forest edge). Oaks (*Quercus ssp.*) comprised 83.3 % (n = 10) of all roosts. The two other roosts were located in beeches (*Fagus sylvatica*). The mean stem diameter of the selected trees was 45.1 ± 10.6 centimeters. 50 % of the roosts trees had a canopy closure between 40 % and 52.5 %. All roost trees had a little less than 50 % of dead material (dead limbs or barks remaining). Selected trees had on average 1.4 ± 0.7 cavities. The majority of cavities were old woodpecker nest holes (66.7 %) facing South (mean 171.6 ± 111.1°).

COMPARISON BETWEEN ROOST TREES AND ALL AVAILABLE TREES

Roost, companion and random trees

The first RDA was performed on a 19 characteristics tree matrix constrained by the tree type (roost, companion or random tree). It revealed a significant difference in overall tree features between roost, companion and random trees (Monte Carlo test on all canonical axes, F-ratio = 3.16, P = 0.001, 1000 permutations) (fig. 2a). However, only 3.9 % of tree features' total variance were group-specific. The biplot of tree features and regressors (fig. 2b) and the corresponding t-value biplot demonstrate that the tree feature 'Oaks (*Quercus ssp.*)' was significantly and positively correlated to roost and companion trees and that the number of cavities was significantly correlated with the
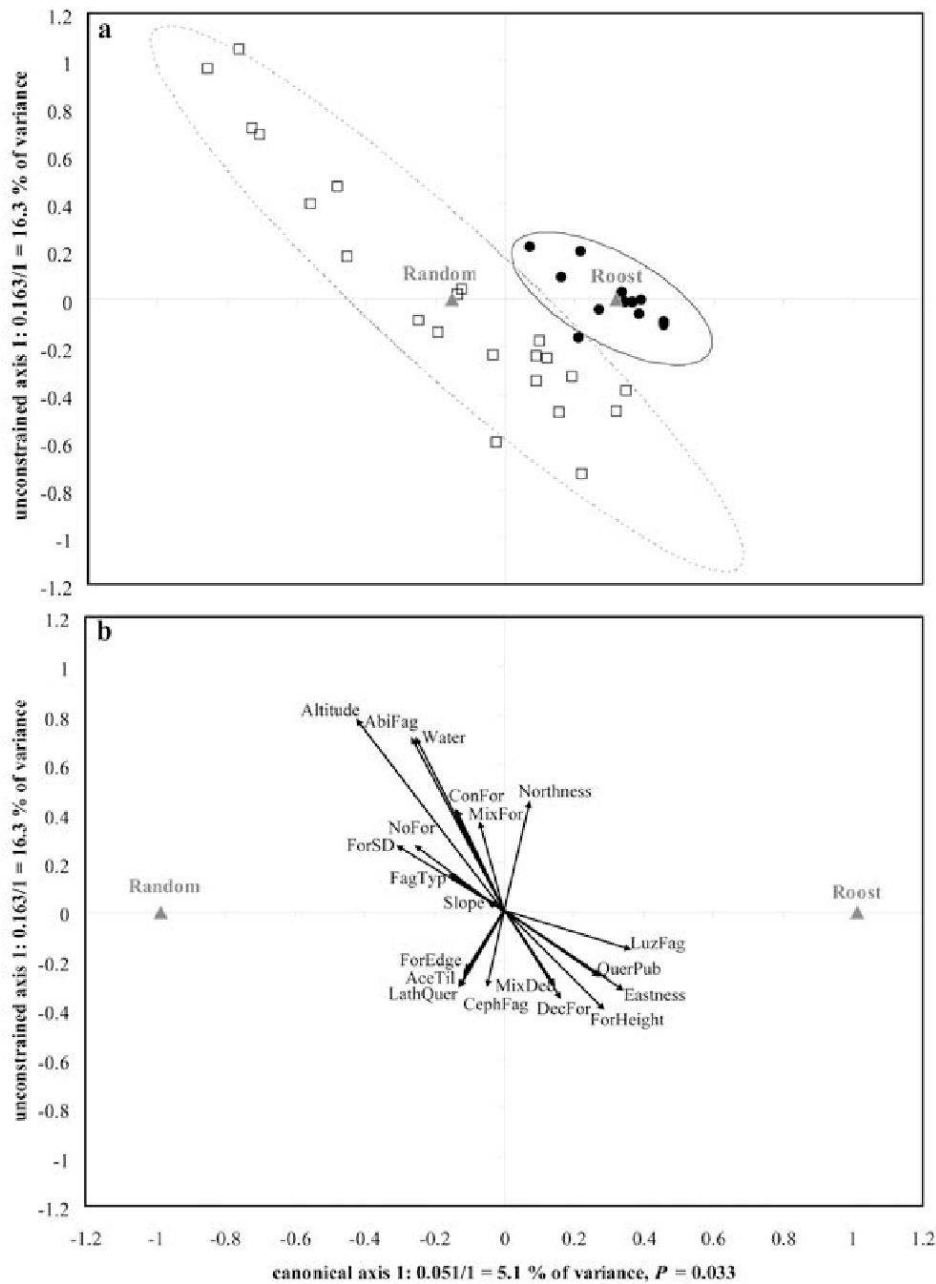
Figure 1a-b. Roost site selection according to RDA. (a) biplot sites and regressors (bat utilisation). (b) biplot of environmental features and regressors. Axis 1 (canonical) accounts significantly for 5.1 % of variance. Constraining categories: Roost = roost plot,, Random = random plot. Constrained categories: QuerPub = Quercion pubescenti-petraeae,, LathQuer = Lathyro nigri-Quercetum,, AceTil = Aceri-Tilietum,, LuzFag = Luzulo-Fagenion,, CephFag = Cephalanthero-Fagenion,, FagTyp = Fagion sylvaticae typicum ConFor = coniferous forest (90-100 % of conifers),, MixCon = mixed forest dominated by conifers (50-90 % of conifers),, MixDec = mixed forest dominated by deciduous (10-50 % of conifers),, DecFor = deciduous forest (0-10 % of conifers),, NoFor = no forest,, ForHeight = mean forest height,, ForSD = standard deviation of forest height,, Altitude = mean altitude,, Slope = mean slope,, Northness = north-south direction,, Eastness = east-west direction,, Water = mean distance to pond or river,, ForEdge = mean distance to the forest edges,, • = roost trees,, □ = random trees, ▯ = 90 % confident ellipse of roost trees, ▯ = 90 % confident ellipse of random trees.

63
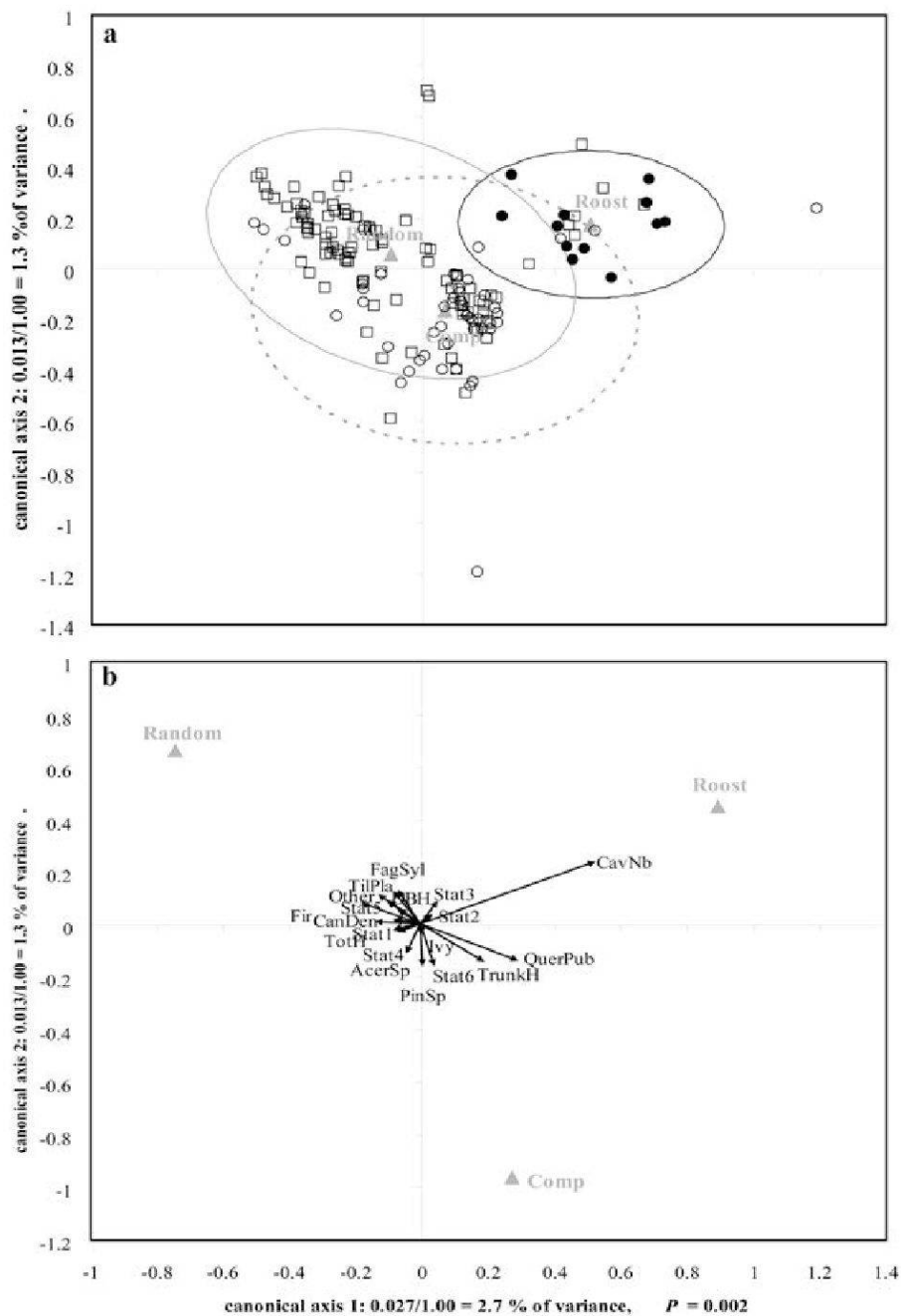
Figure 2a-b. Roost trees selection according to RDA. (a) biplot trees and regressors (bat utilisation). (b) biplot of trees characteristics and regressors. Axes 1 and 2 (canonical) accounted significantly for 3.9 % of variance. Constraining categories: Roost = roost trees; Comp = companion trees; Random = random trees. Constrained categories: Stat1 = decay stage 1; Stat2 = decay stage 2; Stat3 = decay stage 3; Stat4 = decay stage 4; Stat5 = decay stage 5; Stat6 = decay stage 6; DBH = diameter at breast height; TotH = total height; TrunkH = trunk height; CanDen = canopy density; CavNb = cavity number; Ivy = presence of ivy; Fir = *Abies alba, Picea abies, Larix decidua*; AcerSp = *Acer sp.*; FagSyl = *Fagus sylvatica*; PinSp = *Pinus sp.*; QuerSp = *Quercus sp.*; TilPla = *Tilia platiphyllos*; Other = other trees species; • = roost trees; o = companion trees; □ = random trees; – = 90 % confident ellipse of roost trees; - - = 90 % confident ellipse of companion trees; – = 90 % confident ellipse of random trees.

64

roost trees only. 'Trunk height' and 'decay stage 6 (dead tree)' were significantly and positively correlated with the companion trees only whereas 'other tree species' and 'fir group species' (*Abies alba, Picea abies, Larix decidua*) were negatively correlated to random trees.

Roost trees vs. random trees

The second RDA compared only roost against random trees. A significant difference in overall tree features was found between the two groups (Monte Carlo test on first canonical axis, F-ratio = 4.498, P = 0.002, 1000 permutations), but only 4 % of the variance was explained by the tree categories (fig. 3a). The number of cavities and the species 'Oaks (*Quercus spp.*)' contributed to partition the tree types (significant positive correlation with roost trees) (fig. 3b).

Roost trees vs. companion trees

Finally, we compared roost with companion trees through the third RDA. Both tree categories differed significantly (Monte Carlo test on first canonical axis, F-ratio = 2.406, P = 0.012, 1000 permutations), but only 4 % of the tree features' variance was group-specific (fig. 4a). The number of cavities was the only tree feature, which was significantly correlated to roost trees (fig. 4b).

### DISCUSSION

Roosting behaviour

As several other tree-dwelling bats (e.g.: VONHOF & BARCLAY, 1996; SEDGELEY & O'DONNELL, 1999; RUSSO *et al.*, 2004), *Myotis bechsteinii* switches roost frequently. We observed roost switching in early June before births and in August when juveniles could fly. During these periods, bats used the same roost only during two consecutive days. These results were similar to those of

KERTH & KÖNIG (1996) who found in Germany that Bechstein bats switched roost every day and that one colony could use up to 24 different roosts in a single season. The last three individuals we tracked used seven roosts within two weeks. However, the French colony studied by BARATAUD *et al.* (2005) didn't show the same behaviour: during the entire season, the bats used only eight roosts, showing a higher fidelity to their roosts. We also observed such a high fidelity in two lactating females, which were staying in the same roost during respectively 10 and 16 continuous days. As the rearing of the pup requires more energy, the lactating females could reduce energetic costs by staying in the same roost during longer periods. The roost switching observed by KERTH & KÖNIG (1996) during the lactation could be due to the less favourable thermal and/or hygrometric conditions in the bat-boxes where their observations took place. Pregnant and lactating females could thus show different behaviour and roost selection as they must face higher energetic costs than non-reproductive ones and must additionally provide for pup's needs. However, KERTH & KÖNIG (1999) showed that non-lactating females roost frequently with reproductive ones, suggesting cooperative behaviours and improved social thermoregulation in the roost.

Roosts of Bechstein bats were located close to their foraging grounds; more than 50 % were found within a radius of 0.6 km from the nearest foraging area. The different roosts used by the three bats belonging to the same colony were close to each other (maximal distance = 0.5 km). Our results are thus in accordance with those of WOLZ (1986). Tree-dwelling bats exhibit fidelity to a particular site rather than to any particular tree. Roost switching requires actually energy to the bats and in order to minimize this cost, they select roost trees within small areas (VONHOF & BARCLAY, 1996).

Our observations on colony size, although from a limited roost sample, are compa-
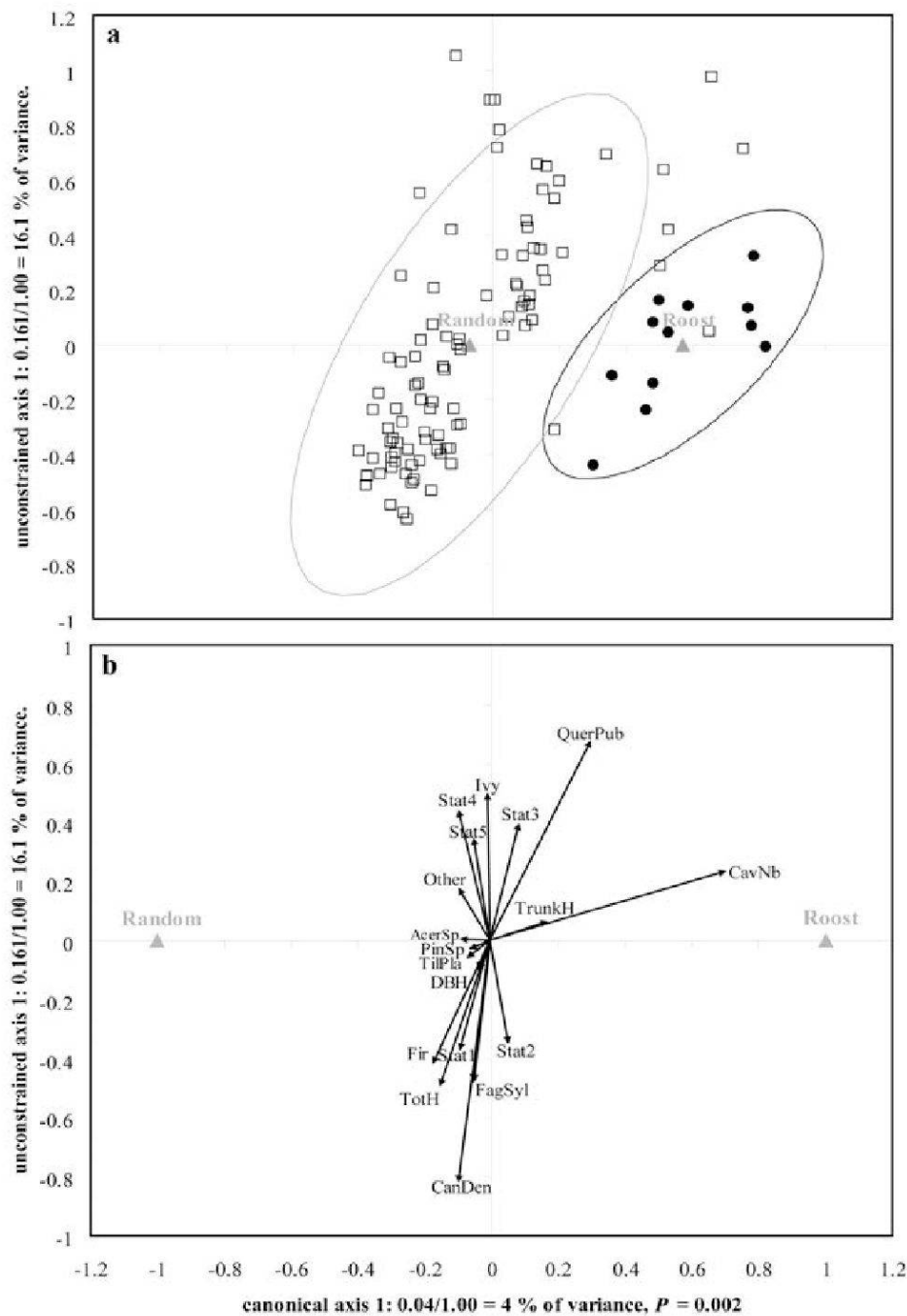
Figure 3a-b Roost trees vs. random trees selection according to RDA. (a) biplot trees and regressors (bat utilisation). (b) biplot of trees characteristics and regressors. Axes 1 (canonical) accounted significantly for 4 % of variance. Constraining categories: Roost = roost trees; Random = random trees. Constrained categories: Stat1 = decay stage 1; Stat2 = decay stage 2; Stat3 = decay stage 3; Stat4 = decay stage 4; Stat5 = decay stage 5; Stat6 = decay stage 6; DBH = diameter at breast height; TotH = total height; TrunkH = trunk height; CanDen = canopy density; CavNb = cavity number; Ivy = presence of ivy; AbiAlb = *Abies alba*; AcerSp = *Acer sp.*; FagSyl = *Fagus sylvatica*; PinSp = *Pinus sp.*; QuerSp = *Quercus sp.*; TilPla = *Tilia platiphyllos*; Other = other trees species; • = roost trees; □ = random trees; – = 90 % confident ellipse of roost trees; – = 90 % confident ellipse of random trees.

66
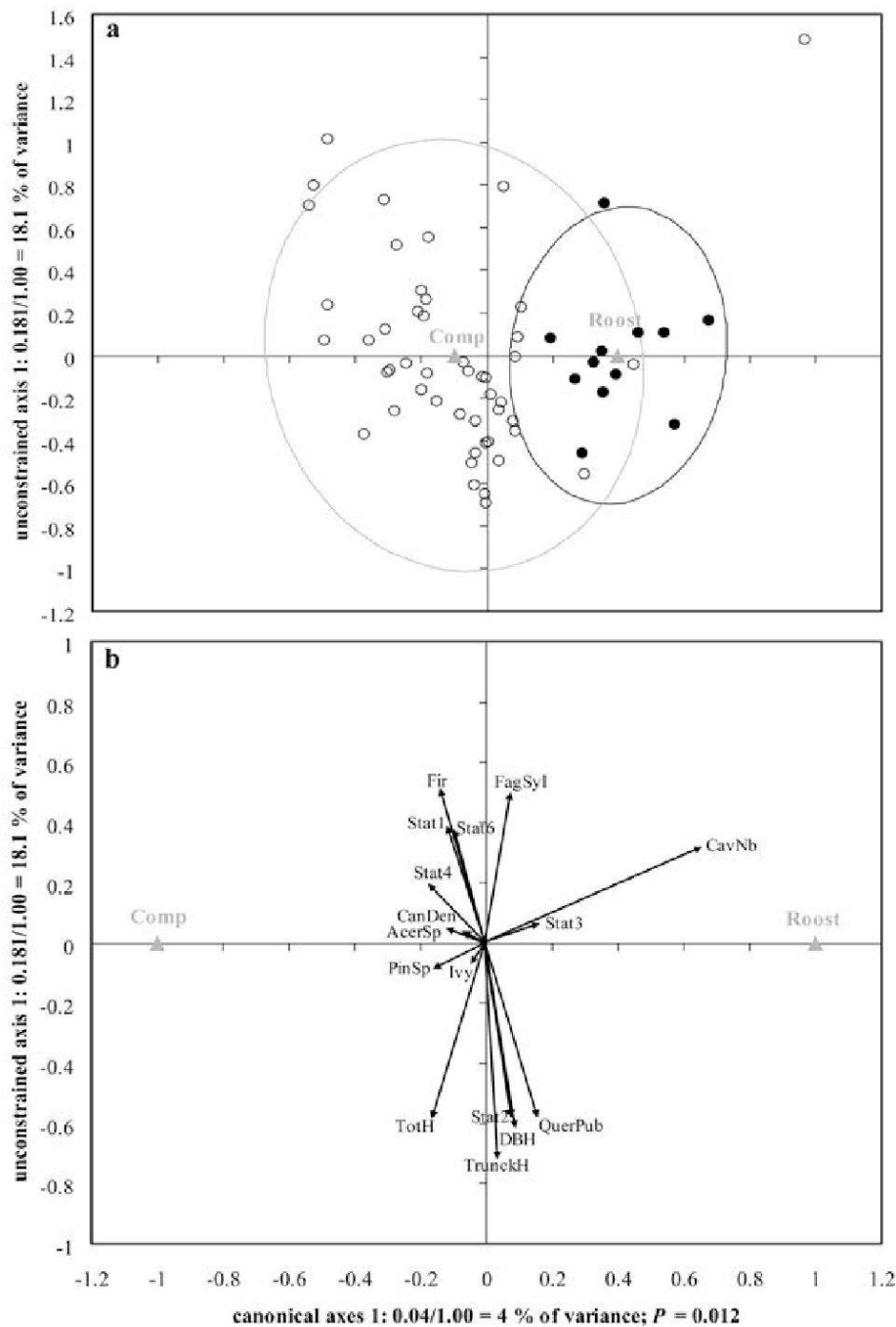
Figure 4a-b Roost trees vs. companion trees selection according to RDA. (a) biplot trees and regressors (bat utilisation). (b) biplot of trees characteristics and regressors. Axes 1 (canonical) accounted significantly for 4 % of variance. Constraining categories: Roost = roost trees; Comp = companion trees. Constrained categories: Stat1 = decay stage 1; Stat2 = decay stage 2; Stat3 = decay stage 3; Stat4 = decay stage 4; Stat5 = decay stage 5; Stat6 = decay stage 6; DBH = diameter at breast height; TotH = total height; TrunkH = trunk height; CanDen = canopy density; CavNb = cavity number; Ivy = presence of ivy; Fir = *Abies alba*, *Picea abies*, *Larix decidua*; AcerSp = *Acer sp.*; FagSyl = *Fagus sylvatica*; PinSp = *Pinus sp.*; QuerSp = *Quercus sp.*; TilPla = *Tilia platiphyllos*; Other = other trees species; • = roost trees; o = companion trees; – = 90 % confident ellipse of roost trees; – = 90 % confident ellipse of companion trees.

67

rable to other studies (WOLZ, 1986; KERTH, 1998; BARATAUD et al., 2005) and confirm the small size of maternity colonies. These high roost-switching behaviour and small colonies size are central strategy of forest dwelling bats, which prevent predation and competition and keep a low parasites' level in the close habitat of a tree's cavity by these behaviours.

Myotis bechsteinii roosting preferences

Myotis bechsteinii selected roosts on the basis of landscape, forest composition and tree characteristics. All bechstein bats' roosts found during the season 2005 were localized in mature deciduous forest at low altitude (< 650 m.s.l.). The Bechstein bat is generally considered as a thermophilous bat species (BAAGØE 2001). In our study, the tagged bats actually searched for the more thermophilous roost sites on the south-east-facing slope. This topographic situation permits the storage of heat during the day in order to improve breeding conditions.

The different studies conducted in Germany (MESCHEDE & HELLER, 2003) show that *Myotis bechsteinii* selects always roost site within large clump of dense forest. FUHRMANN & GODMANN (in MESCHEDE & HELLER, 2003) have shown that roost sites are in natural tree cavities, but never close to the forest edge. FITZSIMONS et al. (2002) realised similar observations on a British maternity colony studied with radio-tracking method. In our study, we didn't have seen any effect of the distance to the forest edge. However, the colony studied by BARATAUD et al. (2005) occupied roosts in fragmented landscape composed by intensive woodland, farmland, orchard, tree line and settlement, i.e. never far from forest edges. In fact, this species seems to be sufficiently plastic enough to adapt different preferences according with environments present in areas studies.

In diversified woodland, *Myotis bechsteinii* avoid conifers plantations (MESCHEDE & HELLER, 2003). Our results were gone in the same way (fig. 1). Conifer avoidance could be explained by too low solar radiation (very high canopy closure) and thus poor climatic conditions or by lower food availability. The presence of conifers around some roost plots was principally attributed to the pines and in particular to the black pine *Pinus nigra*. This species was largely planted during the second part of XIXth century and the beginning of the XXth century in the most xeric areas to compensate for the over-exploitation of oaks. It covers yet large parts of climacic thermophilous forest. *Myotis bechsteinii* preferred to roost in dry mesophilous or in thermophilous forests (*Luzulo-Fagenion, Cephalanthero-Fagenion* and *Quercion pubescenti-petraeae*). These forests usually provide low economic profitability (small trees, low density) and are associated with extensive management (DELARZE et al., 1998). However, they offer very high biodiversity, mainly because of optimal solar radiation. Anyway, eight out of 12 roosts were localized in an area with special management policy for biodiversity. This is in accordance with BOYE & DIETZ (2005) who concluded that Bechstein bats prefers low-density oaks tree stands compared to dense beech stands for its maternity roosts.

We observed few differences between roost trees and other available trees. BARCLAY & KURTA (2007) noted that it is difficult to determine which trees are available. In particular, because it is difficult to determine if a tree is not used by bats. However, in the study area, *Myotis bechsteinii* preferred clearly to roost in live oaks with woodpecker holes. This close link to oaks results probably from oaks selection by the woodpecker species (Great and Middle Spotted Woodpecker, *Dendrocopos spp.*: KOSINSKI & WINIECKI, 2004; PASINELLI 2000). Thus, presence of *Myotis bechsteinii* could be directly dependent on the abundance of these birds, which are known to occur in high densities in the study area (MULHAUSER, 2005).

This is supported by the fact that the only difference between roost and companion trees was the presence of cavities in roost trees; other features were similar but obviously not suitable for the bats. The link to tree cavities probably also explains why the majority of European bat species roost in deciduous trees, primarily oaks and beech (Boye & Dietz, 2005). Alive conifers are avoided, because they do not offer suitable cavities, principally due of the production of resin. Only completely dead conifers can be used by species roosting under loose barks, as the barbastelle bat *Barbastella barbastellus* (Steinhauser, 2002; Russo et al., 2004; Jaberg et al., 2006); *Myotis bechsteinii* is known to seldom occupy this kind of roosts (Boye & Dietz, 2005), except in the case of solitary individuals. A colony of *Myotis bechsteinii* was also found in a cavity of a large black locust *Robinia pseudoacacia* in France (Roué, S, pers. comm.).

In Germany, the Bechstein bats are frequent users of bat boxes in hot days, but only natural cavities are occupied during cooler periods (Meschede & Heller, 2003), suggesting that only natural cavities can provide suitable thermic conditions. This is supported by the fact that trees with small stem diameter are only used after the weaning of the juveniles, probably due to low cavity insulation (high thermic loss during the night) insufficient themperature balance for reproduction (Vonhof & Barclay, 1996; Kerth et al., 2001). Boye & Dietz (2005) emphasized that most nursery colonies are found in tree with at least 40 cm stem diameter although other roosts are not uncommon in trees having at least 20 cm diameter at breast height. Our results are in accordance with these observations. Furthermore, in our study, *Myotis bechsteinii* roosted in trees with a low canopy closure and few branches on the trunk. In that way, the cavities, which were usually located in the trunks or in the first branches of the canopy, could profit of high solar radiation and good heat accumulation. The south-facing roost entrances are in agreement with the hypothesis that thermal conditions play an important role in roost selection by female Bechstein's bat. Russo et al. (2004) proposed the same hypothesis for the barbastelle bats *Barbastella barbastellus.* Sedgeley & O'Donnell (2004) concluded that long-tailed bats *Chalinolobus tuberculatus* selected roost trees on the basis of their functional characteristics, number of cavities and their orientations, cavities' structure and cavities' temperature and hygrometry, and not according to tree species. Our results agree with this conclusion.

Management and conservation implications

In our study, excepted one individual, bats travelled less than 1 km from their roost to reach drinking sites and to forage. This would to influence on the consideration about the conservation of this forest species. Harvesting management would not be reduce to the preservation of known roost trees, but it would consider all areas in an radius of 600 meters around known roosts.

The presence of significant breeding population of *Myotis bechsteinii* at our study site was certainly made possible by the preservation of large areas of ancient or extensive managed woodland: protection and extensive exploitation of such areas are probably the most important conservation measure to ensure optimal roosting conditions. Moreover, small maternity colonies and frequent roost switching imply that even a small breeding population require the availability of quite large number of roost. The extensive management plan of woodland at our study site and maintain of an important part of thermophilous deciduous forest are undoubtedly favourable to woodpecker populations which create numerous roosting opportunities for the Bechstein's bat. In roosting areas, mature trees offering cavities and/or low-density canopy (e.g.

injured) should not be logged: when felling operations are necessary, tree cavities should be carefully inspected in advance for the presence of bats. In logged areas, specific management plan preserving a significant portion of mature trees should adopted. As bats frequently switch between different roosts and have a short activity range, preserved mature trees patches should connected to each other (mean distance between patches = 500 m).

Even where one roost was close to a path with cavity entrance directly up to the path, our observations suggest that disturbance to roosting areas should be avoided. Forest roads and trails should limit with *Myotis bechsteinii* roost areas; in nature reserve accessible by visitors, patch of mature woodland should conserve far tourist paths.

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