THE DADIA–LEFKIMI–SOUFLI FOREST NATIONAL PARK, GREECE: BIODIVERSITY, MANAGEMENT AND CONSERVATION

Edited by
Giorgos Catsadorakis and Hans Källander

Illustrations by
Paschalis Dougalis

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Editors:

Giorgos Catsadorakis,
P.O. Box 403,
Dadia,
GR-68 400 Soufli,
GREECE
doncats@otenet.gr
g.catsadorakis@wwf.gr

Hans Källander,
Villavägen 6,
SE-240 35 Harlösa,
SWEDEN

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Bats (Mammalia: Chiroptera): species diversity, distribution and abundance

Eleni Papadatou

The diversity, distribution and abundance of bats in the Dadia–Lefkimi–Soufli Forest National Park were recorded in 2003 and 2004 and additional data collected in 2002 and 2005. Bats were captured at roosts and over seasonal streams and artificial pools. Echolocation call recordings were also used. Visual observations at underground roosts (caves and mines) were made in winter. Six species were recorded for the first time in the park: *Rhinolophus mehelyi*, *Myotis daubentonii*, *M. mystacinus bulgaricus*, *Nyctalus lasiopterus*, *Pipistrellus pygmaeus* and *Tadarida teniotis*. Three of these (*M. daubentonii*, *N. lasiopterus* and *P. pygmaeus*) constituted first records for Thrace. Five species are classified as Vulnerable and five as Lower Risk Near Threatened according to the IUCN Red List of Threatened Species (2006). The seasonal and between-year use of underground roosts and seasonal fluctuations in diversity and abundance of cave-dwelling bats are described. The findings are discussed in relation to other sites outside the park and to conservation.

Keywords: Bats, Greece, Dadia National Park, bat conservation

Introduction

Bats are the second largest mammalian order in the world after rodents, accounting for more than 20% of all extant mammals with approximately 1,100 species described to date (Simmons 2005). The order has been traditionally divided into two sub-orders, the Megachiroptera (megabats) and the Microchiroptera (microbats), based primarily on morphological characters (Neuweiler 2000) and the latter's use of ultrasound. However, recent phylogenetic studies based on molecular techniques suggest that the order Chiroptera should be divided into two different suborders, the Yinpterochiroptera (megabats and the microbat superfamily Rhinolophoidea) and the Yangochiroptera (all other microbat families) (Teeling et al. 2005). Megabats are the Old World fruit bats and are found in Africa, tropical Asia and Indo-Australasia, whereas microbats are found throughout the globe except Antarctica (Altringham 1996).

There are approximately 42 species of microbats in Europe (Dietz et al. 2007). These belong to three of the largest bat families: Vespertilionidae (10 genera, 36 species), Rhinolophidae (one genus, five species) and Molossidae (one genus, one species), though recent molecular evidence suggests a new family for the genus *Miniopterus* previously in the Vespertilionidae (Miniopteridae; Eick et al. 2005), containing one species currently recognised in Europe (Appleton et al. 2004). Almost 85% of the European species have been found in Greece (33 species; Hanák et al. 2001, O. von Helversen, pers. comm.): 27 of the family Vespertilionidae, all five species of the family Rhinolophidae, and the European Free-tailed Bat *Tadarida teniotis* (Molossidae). Although bats are one of the major groups of the mammal fauna of Greece, very little work on their ecology has been done and even less published, yet the ecology, and therefore conservation priorities, of Greek bats are possibly quite different from those in other parts of Europe where most of the work has been done. In general, species with a Mediterranean distribution have been studied very little in comparison with bats in the northwest of the continent.

Although bats constitute an important component of the mammal fauna worldwide, there is considerable evidence that bat populations in many parts of the world are in decline. Several species have recently gone extinct (Altringham 1996). The main threats to the bats

are fragmentation, degradation and destruction of their foraging habitat and natural roost sites (e.g. loss of tree roosts through forest clearings, exploitation of caves for tourist attraction), roost disturbance, and deliberate persecution related to their false public image (Altringham 2003). Knowledge of their ecology (e.g. roosting and foraging requirements, habitat preferences etc.) and population size estimates are essential for appropriate and effective conservation action to ensure their long-term survival and welfare. However, ecological research needs to be based on basic biological records: it is necessary to know what species there are, how many there are, where they live and when.

The Dadia–Lefkimi–Soufli Forest National Park (DNP) is an area of outstanding biodiversity, in particular for birds of prey, but also for other groups of animals, such as reptiles, orthoptera and butterflies (Adamakopoulos et al. 1995, Grill and Cleary 2003, Kati et al. 2004, Grill et al., this volume). This high diversity is also reflected in its bat fauna. Eighteen species had been recorded by previous researchers in the park (Adamakopoulos et al. 1995, Hanák et al. 2001, Ivanova 2000, Ivanova and Gueorguieva 2004).

This chapter reports results on the diversity, distribution, abundance and status of bat species occurring in the DNP, from studies conducted between 2002 and 2005. It also provides information on the seasonal and between-year fluctuations of cave-dwelling bats in particular. This knowledge is essential as a baseline for further ecological surveys and research on bat species in the area and can be integrated in conservation and management plans by the park authorities to ensure adequate protection of these threatened animals.

Methods

Data on the bat fauna of the park were obtained from captures at roosts (author and C. Dietz unpubl. data, Puechmaille 2004, Papadatou et al. 2008a) and at foraging and drinking sites (author and C. Dietz unpubl. data, Angell 2003, Palmer 2004, Papadatou et al. 2008b). Data were also obtained from echolocation call recordings from bats at foraging and drinking sites, as well as at street lamps in villages (for a detailed description of the method, see Papadatou et al. 2008b). Roosts were primarily examined at underground sites (caves and mines; Fig. 1), as only two other roosts were found in the DNP during this study: one *Nyctalus noctula* roost in a crevice under a bridge and one *Pipistrellus pipistrellus* roost at the nursery school in Dadia village. No other roosts were known. Thus, the majority of bats except cave-dwelling species were captured at seasonal streams and artificial pools that are used regularly for foraging and drinking (Fig. 2).

There are eight known underground sites in the park, five of which were found to host bat assemblages during this study: three disused chromium mines and two volcanic caves (Fig. 1) (Ivanova 2000, Hanák et al. 2001, this study). The mine in the Katrantzides area (Fig. 1) had not been studied prior to this research. In addition, there are caves and mines near the park that are used regularly by bats (Iliopoulou-Georgudaki 1977, Ivanova 2000, Hanák et al. 2001, pers. obs.). A number of these sites were explored over the course of this study (Fig. 1). Six underground sites were finally surveyed in a systematic way, from April through to October in 2003 and 2004. Kirki mine was visited once, Kamila cave twice and Didimoticho cave three times during these years (pers. obs. and C. Dietz, pers. comm.). Additional data were collected in autumn 2002 and in summer 2005 (Papadatou 2006). Roosting sites still accessible in December and January were visited in order to check for hibernating bats. Only findings from sites inside the park are reported in this chapter.

Roost captures were made on a regular basis, with time intervals between captures at any one roost ranging between 10 and 14 days, except maternity colonies that were only visited once a month to minimise disturbance. Only one site was visited on any given night. Bats were captured at roost entrances during evening emergence using a harp trap and/or mist-nets. Bats were removed immediately from the trap or net, placed in cloth bags, and processed and released within two hours of capture. Samples of captured bats were assumed to reflect species composition, colony structure and relative abundance of bats within roosts.

Bats were also captured over different sections of seasonal streams and at artificial pools used for fire prevention within the boundaries of the park (Fig. 2) with the use of mist-nets in spring and summer 2003 and 2004. Nets were placed approximately 30 min before sunset, but they were opened only when most bird activity had ceased and were removed when most bat activity had ceased, usually three to four hours after sunset.

Captured animals were identified to species; their sex, age and reproductive condition were assessed and their weight and forearm length measured. Three age categories were identified, juveniles, immatures and adults (Papadatou et al. 2008a). Juveniles were defined as bats with unfused phalangeal epiphyses (Anthony 1988). Immature bats were individuals with no sign of

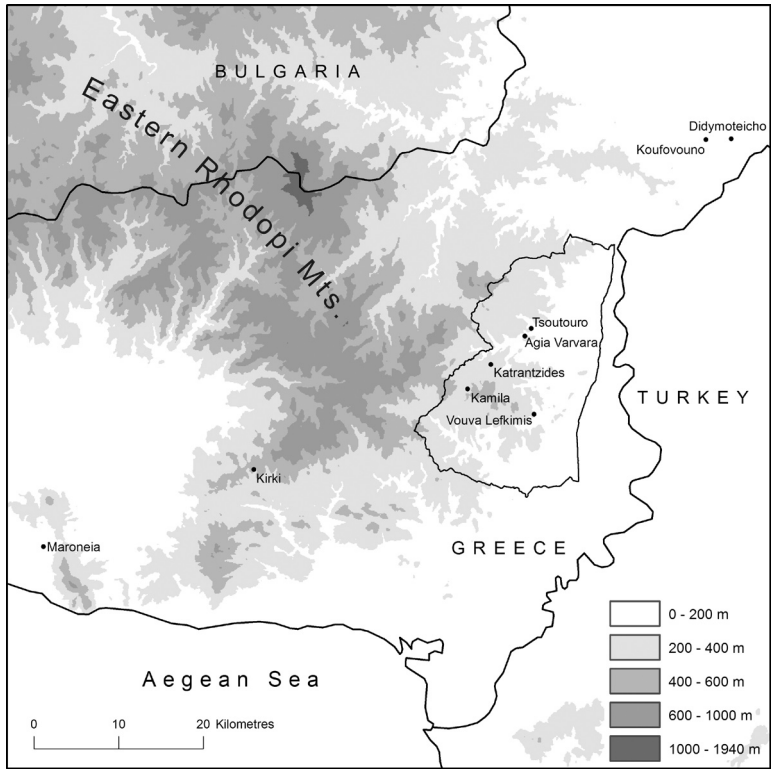

Fig. 1. The Dadia–Lefkimi–Soufli Forest National Park and study roosts. Only underground sites are indicated. Some sites outside the boundaries of the park known to host bat assemblages were also explored during this study. Caves: Maronia, Voùva Lefkimis, Kamila, Koufovouno, Didimoticho. Mines: Kirki, Agia Varvara, Tsoutouro, Katrantzides. Maronia, Koufovouno and Didimoticho are named after the villages nearest to the caves.

sexual maturity in the autumn as indicated from past or present reproductive activity (Papadatou et al. 2008a). Reproductive status of adult females was judged by palpation of their abdomen prior to parturition (pregnant) and the size and condition of their nipples. Lactation was indicated by enlarged bare nipples. Females with visible nipples several weeks after parturition were classified as parous. Females without visible nipples or with hair grown over them during the reproductive period were classified as nulli-parous, which means that they

Fig. 2. (a) Seasonal stream (Diavolorema), and (b) concrete cistern (artificial pool) used for providing water to fire-fighting water carriers in the park. Natural and artificial pools are used in summer by large numbers of bats for drinking and foraging.

were not reproductively active. Reproductive status of adult males was judged by examining their testes and epidydimes. Swollen testes and epidydimes indicated reproductively active bats.

Bat species in the park: distribution, abundance and status

During this study, six species were added to the park's list (shown in bold below), which now includes 24 species, i.e. about 72% of all bat species found in Greece:

1. Greater Horseshoe Bat *Rhinolophus ferrumequinum*
2. Lesser Horseshoe Bat *R. hipposideros*
3. Mediterranean Horseshoe Bat *R. euryale*
4. Blasius's Horseshoe Bat *R. blasii*
5. **Mehely's Horseshoe Bat *R. mehelyi***
6. **Daubenton's Bat *Myotis daubentonii***
7. Long-fingered Bat *M. capaccinii*
8. **Whiskered Bat *M. mystacinus bulgaricus***
9. Geoffroy's Bat *M. emarginatus*
10. Bechstein's Bat *M. bechsteinii*
11. Greater Mouse-eared Bat *M. myotis*
12. Lesser Mouse-eared Bat *M. blythii*
13. Noctule *Nyctalus noctula*
14. Leisler's Bat *N. leisleri*
15. **Greater Noctule *N. lasiopterus***
16. Serotine *Eptesicus serotinus*
17. Pipistrelle Bat *Pipistrellus pipistrellus*
18. **Soprano Pipistrelle *P. pygmaeus***
19. Nathusius Pipistrelle *P. nathusii*
20. Kuhl's Pipistrelle *P. kuhlii*
21. Savi's Pipistrelle *Hypsugo savii*
22. Grey Long-eared Bat *Plecotus austriacus*
23. Schreiber's Bat *Miniopterus schreibersii*
24. **European Free-tailed Bat *Tadarida teniotis***

M. daubentonii, *N. lasiopterus* and *P. pygmaeus* were recorded for the first time in the whole region of Thrace. *Myotis nattereri* was additionally caught once at Koufovouno cave (Fig. 1), but was never caught within the boundaries of the park and, hence, is not included in the list. *T. teniotis* was not captured, but its presence was confirmed through audible calls and sound recordings (Papadatou et al. 2008b).

Table 1 summarises the number of bats caught and locations where captured, as well as their status in the park. The status could not be confirmed for all species present. Because *M. capaccinii* was the principal study species of Papadatou (2006), many other bats captured at underground sites were immediately released without being counted in 2003, so that their numbers may be under-estimated. However, these numbers still reflect their relative abundance, when combined with visual observations within the roosts. Table 2 shows species and total number of individuals per species caught at each of the underground sites in the park (Fig. 1) during the study period. Because the total number of bats caught may depend on the number of visits at any one roosting site, the average, the minimum and the maximum number of captured bats per night and site (except Kamila cave) were calculated (Table 3).

Bats and underground sites

Among roosting sites, Tsoutouro and Katrantzides mines appear to be most heavily used by bats, followed by Lefkimi cave (Vouva) and Ag. Varvara mine (Tables 2 and 3). However, Katrantzides mine was only used in mid spring, late summer and autumn, most probably by bats moving between their winter and summer quarters and for mating (Papadatou et al. 2008a). In contrast, Tsoutouro was used throughout the period of study both by maternity colonies and bats moving between summer and winter roosts. The large mean and standard deviation (SD) at Katrantzides mine (Table 3) is due to the large number of transient *Miniopterus schreibersii* caught in spring 2004 (1066 individuals on 14 April and 299 on 24 April; Puechmaille 2004). If these numbers are removed from the samples, mean (SD) drops to 26 (25.5) and the maximum to 92. Despite the fact that Ag.Varvara may be used throughout the year, it is the site hosting the lowest number of bats on average (Table 3). Overall, V. Lefkimis was used by the largest number of species (13), followed by Tsoutouro (12), Ag. Varvara (9) and Katrantzides mines (7) and Kamila cave (1) (Table 2). However, most *Eptesicus serotinus, Pipistrellus pipistrellus, P. pygmaeus* and *Hypsugo savii* did not emerge from these roosts but were rather visiting them during the night.

All sites except Katrantzides mine hosted nursery colonies of at least two species, but not in all years of study. Tsoutouro was used by a mixed-species maternity colony in 2003 and partly in 2004. Additional captures in summer 2005 showed that it was not used by nursery colonies (only a few non-reproductive individuals were captured in June 2005). Ag. Varvara was used by a mixed-species maternity colony in 2004 and 2005, by a low number of non-reproductive individuals in summer 2003. Lefkimi cave (Vouva) was used by nursery colonies in both 2003 and 2004 (it was not visited in 2005), but the species alternated. In 2003, colonies consisted

Table 1. List of bat species captured between October 2002 and October 2004 in the Dadia–Lefkimi–Soufli Forest National Park: total number of individuals caught (N), location and status. A number of *M. capaccinii* captured in 2005 are not included in the table. Location includes roosting sites, seasonal streams and artificial (fire) pools within the boundaries of the park. Question marks (?) mean that more data are needed to confirm the species status. *T. teniotis* was not captured, but its presence was confirmed through audible calls and sound recordings. Sources: own unpubl. data, Angell (2003), C. & I. Dietz (unpubl.), Palmer (2004), Puechmaille (2004).

	Species	N	Location	Status
	Rhinolophidae			
1	*Rhinolophus ferrumequinum*	45	R	MAT?, TRS?, HBN
2	*Rhinolophus hipposideros*	5	R	UNK
3	*Rhinolophus euryale*	456	R	BR, MAT, TRS?
4	*Rhinolophus mehelyi*	20	R	TRS?
5	*Rhinolophus blasii*	4	R, S	UNK
	Vespertilionidae			
6	*Myotis capaccinii*	2,050	R, S	BR, MAT, TRS
7	*Myotis daubentonii*	33	S	MM, BR?
8	*Myotis mystacinus bulgaricus*	4	S, A	BR
9	*Myotis emarginatus*	231	R, S, A	BR, TRS
10	*Myotis bechsteinii*	8	S, A	BR
11	*Myotis myotis*	7	R	BR?
12	*Myotis blythii*	512	R, S	BR, MAT, TRS?
13	*Nyctalus lasiopterus*	1	S	UNK
14	*Nyctalus noctula*	62	R, S, A	BR?, MM, TRS?
15	*Nyctalus leisleri*	21	S, A	MM, TRS?
16	*Eptesicus serotinus*	71	R, S, A	BR
17	*Pipistrellus pipistrellus*	20	R, S, A	BR
18	*Pipistrellus pygmaeus*	112	S, A	BR, MM
19	*Pipistrellus nathusii*	3	S, A	UNK
20	*Pipistrellus kuhlii*	8	S, A	BR
21	*Hypsugo savii*	206	R, S, A	BR
22	*Plecotus austriacus*	12	R, S, A	BR, MM?
23	*Miniopterus schreibersii*	2,814	R, A	BR, MAT, TRS
	Molossidae			
24	*Tadarida teniotis*	–		UNK
	Total	6,713		

R = Roost; S = Seasonal streams used by bats for foraging/drinking; A = Artificial (fire) pools used for foraging/drinking; BR = breeding, MM = mostly males, MAT = mating, TRS = transient, HBN = hibernating, UNK = unknown.

mainly of *Rhinolophus euryale* and *Myotis emarginatus*. In May 2004, a large colony of *M. emarginatus* totalling up to 3,000 individuals used the cave, most of which were pregnant females. However, by June they had abandoned the site giving place to a maternity colony of *M. capaccinii* numbering approximately 100 individuals. By August 2004 almost all bats had left the site. A few reproductive females, some adult males and/or juveniles of other species (*Myotis myotis*, *M. blythii*, *Hypsugo savii*, *Eptesicus serotinus*, *Miniopterus schreibersii*) were also captured at this cave in both years.

These findings show that long-term observations can reveal different types of roost use and species diversity between years. Ivanova (2000) described Ag. Varvara as a temporary roost, and Tsoutouro and Lefkimi (Vouva) as maternity roosts, but these observations were made

Table 2. Total number of bats captured at underground sites in the Dadia–Lefkimi–Soufli Forest National Park in 2002, 2003 and 2004 (see text for details). *Eptesicus serotinus, Pipistrellus pipistrellus, P. pygmaeus* and *Hypsugo savii* were almost all juveniles caught in late summer and/or autumn at these sites with the exception of Lefkimi cave (Vouva), where *E. serotinus* and *H. savii* formed small colonies in summer 2003. Sources: own unpubl. data, C. & I. Dietz (unpubl.), Puechmaille (2004).

	Site					
Species	Tsoutouro	Ag. Varvara	Katrantzides	Kamila	V. Lefkimis	Total
Rhinolophus ferrumequinum	12	27	2	–	3	45
R. hipposideros	2	–	3	–	–	5
R. euryale	270	57	108	–	21	456
R. mehelyi	20	–	–	–	–	20
R. blasii	–	1	–	–	3	4
Myotis capaccinii	1,148	227	134	–	120	1,629
Myotis emarginatus	123	17	30	–	48	218
M. myotis	2	–	–	–	5	7
M. blythii	367	129	–	–	8	506
Eptesicus serotinus	1	–	–	–	32	33
Pipistrellus pipistrellus	1	–	–	–	4	5
P. pygmaeus	3	–	1	–	1	5
Hypsugo savii	–	1	–	–	17	18
Plecotus austriacus	–	1	–	3	4	8
Miniopterus schreibersii	1,164	149	1,468	–	28	2,809
Total	3,113	608	1,750	3	294	**5,768**

over a shorter period at a specific time of year. An even longer-term study could potentially reveal whether Katrantzides is also used by nursery colonies. A colony consisting of up to 100 female and juvenile *Rhinolophus euryale* used the site in late summer 2003 and 2004, but not earlier in the year, which means that they had bred elsewhere.

Although Ivanova (2000) found six species in Kamila cave (*Rhinolophus ferrumequinum, Myotis emarginatus, Eptesicus serotinus, Pipistrellus pipistrellus, Hypsugo savii* and *Plecotus austriacus*), only *P. austriacus* was found in this study. This difference may be due to the different timing of our visits. The cave was visited by Ivanova in July 1997, but it was visited by the author in October 2003. A day visit was also made in June 2002, but no bats were observed. The cave showed signs of heavy use by bats in the past (piles of old droppings on the cave floor). The cave may have been abandoned by the majority of bats, or it may be used temporarily by certain species at specific times of year.

All five European *Rhinolophus* species were found in the park, which is particularly important given the size of the area and the species' conservation status. In particular, *R. euryale* and *R. mehelyi* are classified as Vulnerable and *R. ferrumequinum* and *R. blasii* are classified as Lower Risk Near Threatened in the IUCN Red List of Threatened Species (2006). For comparison, Furman and Ozgul (2004) found four species of *Rhinolophus* in a total of 32 underground sites in the Turkish part of Thrace, but only one individual of *R. mehelyi* was encountered. *R. ferrumequinum* used our sites mainly in spring and autumn. A few individuals were caught in summer, but none of the adults were reproductively active and no juveniles were found. Clusters of up to 10 individuals were observed hibernating in Ag. Varvara, Tsoutouro and Katrantzides mines. *R. euryale* was the only among the five species that formed large nursery colonies in the park (Table 1), but it had abandoned all sites by winter. Pregnant females of *R. mehelyi* were present in spring, but there was no evidence of maternity colonies in summer. A few male and female individuals were caught in summer and autumn. *R. hipposideros* and *R. blasii* were occasional visitors, with generally small numbers captured (Tables 1 and 2). One *R. mehelyi* and one *R. hipposideros* were observed hibernating in Katrantzides mine in January 2005.

Miniopterus schreibersii was the most abundant species among cave-dwelling bats (Tables 1 and 2), as also

Table 3. Mean (SD), minimum, maximum and median number of bats captured per capture occasion and number of capture occasions (N) at each roosting site between October 2002 and October 2004 (Katrantzides mine: October 2003–October 2004). Sources: own unpubl. data, Puechmaille (2004).

Site	Mean (SD)	Min	Max	Median	N
Tsoutouro	100 (138.3)	2	742	62	34
Ag. Varvara	21 (35.2)	1	173	8	31
Katrantzides	103 (263.0)	1	1107	21	18
Lefkimi (Vouva)	32 (18.5)	3	55	31	9

reported in other studies (e.g. Dwyer 1966, Furman and Ozgul 2004), and it is one of the most common species in Greece (Hanák et al. 2001). This bat formed small maternity colonies (a few tens or hundreds of individuals) in the park in 2004 (Tsoutouro and Ag. Varvara mines), but not in 2003. It formed large maternity colonies counting several thousand individuals and was found in large numbers throughout the year in underground sites outside the park (Fig. 1), such as Maronia cave (Paragamian et al. 2004). It used the park's sites mainly in spring and autumn when moving between its winter and summer roosts.

The second most abundant species was *Myotis capaccinii* (Tables 1 and 2). The species is typically closely associated with *Miniopterus schreibersii, Rhinolophus ferrumequinum, R. euryale, R. mehelyi, M. emarginatus* and *Myotis blythii* (Spitzenberger and von Helversen 2001). In the park, colonies consisted of some or occasionally all of these. *M. capaccinii* formed either mixed or single-species nursery colonies of up to a few hundred individuals in all years of study. It did not hibernate in any of the study sites, but a few individuals were found in winter. The species also used these sites in transit (Papadatou et al. 2008a). Diavolorema, the seasonal stream near Tsoutouro and Ag.Varvara mines, was regularly used for foraging by the colonies roosting in these mines (data from recaptures of ringed bats; Papadatou et al. 2008a). *M. capaccinii* is a vulnerable species according to the IUCN Red List.

M. emarginatus is another vulnerable species and was caught in relatively large numbers in the park (Tables 1 and 2). The species formed a maternity colony in V. Lefkimis cave in 2003. Except a few individuals captured in summers 2003 and 2004 at other roosts, as well as at natural and artificial pools (Fig. 2), the majority of bats were transient females observed and captured at roosts in spring. None were found in the autumn or winter months.

Myotis myotis was one of the rarest bats found in the park during the course of this study (Tables 1 and 2), although it is mentioned as a fairly common bat in mainland Greece (Hanák et al. 2001). Except Maronia cave (Fig. 1) where it formed a large maternity colony (Paragamian et al. 2004), it was found in relatively small numbers in other sites outside the park. Only a few pregnant females were captured in Lefkimi cave (Vouva) in May 2003. The species is among those classified as Lower Risk Near Threatened in the IUCN Red List. In contrast, its sibling species *M. blythii* was the third most common bat in the Park, following *Miniopterus schreibersii* and *Myotis capaccinii* (Tables 1 and 2). It formed maternity colonies in Tsoutouro and Ag. Varvara mines numbering up to a few hundred individuals. Few bats of this species used Lefkimis cave (Vouva) and none were found in Katrantzides mine (Table 2). Maternity colonies started forming in late spring in both 2003 and 2004 and had dispersed by late summer, when they were replaced by reproductively active males. *M. blythii* appears to be a fairly common species both in mainland Greece and the islands (Hanák et al. 2001).

Apart from the three *Plecotus austriacus* found roosting together in Kamila cave, all other individuals were single captures on separate dates. The species may typically be found roosting singly in underground sites, but it may form larger colonies in buildings and other types of roosts (Schober and Grimmberger 1989). Most bats were adult males, except two adult females caught in Kamila and one lactating female caught on a seasonal stream (Diavolorema) in August 2003. One juvenile female was also captured in Diavolorema in July 2004, suggesting that the species may be breeding in the park. The species appears to be rather rare in the area (Table 1).

Seasonal change in diversity and abundance of cave-dwelling bats

There was a considerable difference in species diversity and abundance across seasons (Fig. 3), as discussed earlier. In particular, five species (*R. euryale, M. capaccinii,*

M. emarginatus, M. blythii and *M. schreibersii*) exhibited large seasonal fluctuations. These fluctuations in diversity and abundance suggest differential use of sites across seasons, as also suggested in other studies of cave-dwelling species (e.g. Furman and Ozgul 2002, 2004). These bats must use other sites either within or outside the boundaries of the park. Recaptures of ringed bats between Koufovouno cave and the park's underground roosts provide evidence for this (Papadatou et al. 2008a).

Other species

The most common among non cave-dwelling species in the samples was *Hypsugo savii,* followed by *Pipistrellus pygmaeus, Eptesicus serotinus, Nyctalus noctula* and *Myotis daubentonii*, even when only samples from natural and artificial pools were included, i.e. excluding individuals captured at roosts. *N. leisleri* and *P. pipistrellus* were less common, followed by *Myotis bechsteinii* and *P. kuhlii.* The rarest bats were *M. mystacinus bulgaricus, P. nathusii* and *N. lasiopterus* (Table 1). Fig. 4 shows the distribution of natural and artificial pools where bats were captured and Table 4 shows species captured at each of these sites.

Hypsugo savii used artificial pools regularly for drinking and foraging (C. Dietz and own unpublished data, Angell 2003, Palmer 2004). Most bats captured in early to mid summer in both 2003 and 2004 were reproductive females (pregnant and lactating), indicating that these bats form large maternity colonies in the forest. The species roosts in trees and crevices on rocks (Schober and Grimmberger 1989). Maternity colonies dispersed in late summer, as only a few juvenile individuals were captured by then.

Pipistrellus pipistrellus and *P. pygmaeus* are the two smallest European bats and morphologically very similar. Although from capture data *P. pipistrellus* appeared to be less common than *P. pygmaeus* (Table 1), the former species was very common at street lamps in villages where its echolocation calls were regularly recorded and identified using its species-specific social calls (Barlow and Jones 1997, Papadatou et al. 2008b). The ecology of *P. pygmaeus* has not yet been systematically studied, but this bat appears to be closely associated with riparian habitats and woodland (e.g. Russo and Jones 2003), which may explain its higher capture rates. *P. pipistrellus*

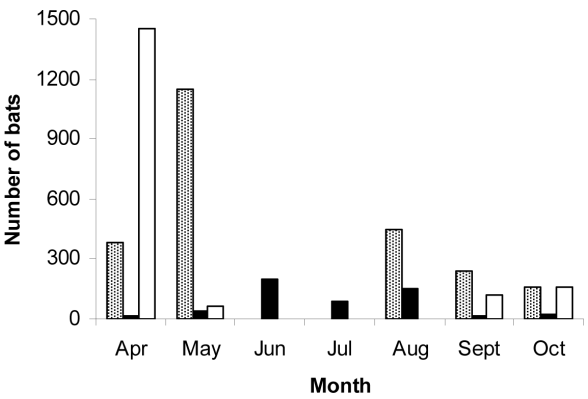

Fig. 3. Seasonal fluctuations of cave-dwelling bats at three underground sites in the DNP in 2004, expressed as total number of bats captured per month; ■ : Tsoutouro, ■ : Ag. Varvara, ❑ : Katrantzides. Numbers for all species are combined. Sources: own unpubl. data, C. and I. Dietz unpubl., and Puechmaille (2004).

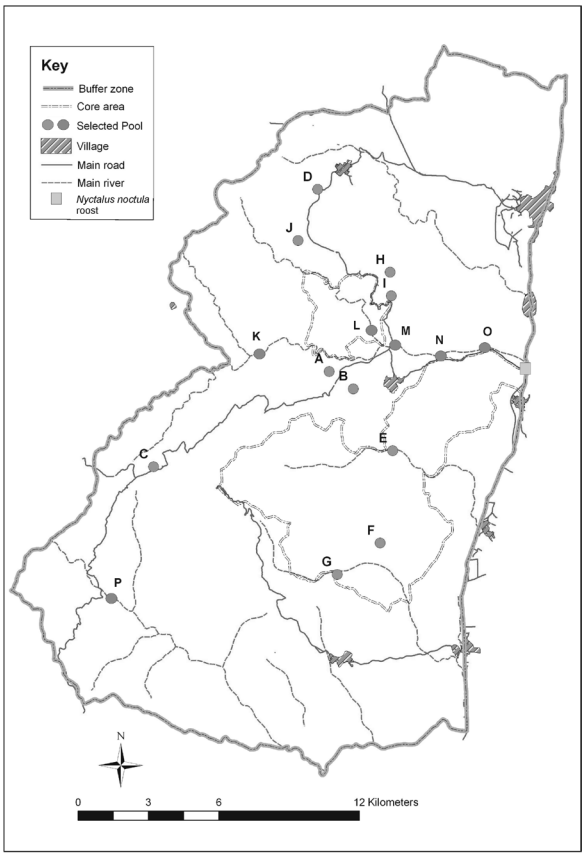

Fig. 4. Distribution of natural and artificial pools in the DNP selected for bat captures. Also shown is a *Nyctalus noctula* roost; A – J: artificial (fire) pools; K – P: natural pools (sections at seasonal streams). No bats were captured at pools E, H and J. Locations at seasonal streams where there was no capture success are not shown.

Table 4. Bat species and capture locations in the Dadia–Lefkimi–Soufli Forest National Park; A – J: artificial (fire) pools; K – P: natural pools (sections at seasonal streams). See distribution of locations in Fig. 3.

	Species	Location
1	*Rhinolophus blasii*	M
2	*Myotis daubentonii*	M, N, O
3	*M. mystacinus bulgaricus*	B,F, N, O
4	*M. emarginatus*	A, B, C, L, M, N
5	*M. bechsteinii*	A, B, C, P
6	*M. blythii*	K, L, M, N
7	*Nyctalus noctula*	A, C, L, M, N
8	*N. leisleri*	B, C, M, N, P
9	*N. lasiopterus*	N
10	*Eptesicus serotinus*	A, B, C, G, K, M, N, O
11	*Pipistrellus pipistrellus*	B, D, I, M, N, O
12	*P. pygmaeus*	A, B, C, I, K, M, N, O
13	*P. nathusii*	B, M
14	*P. kuhlii*	A, B, M, N
15	*Hypsugo savii*	A, B, C, D, F, I, M, N, P
16	*Plecotus austriacus*	A, M
17	*Miniopterus schreibersii*	B, C, N

breeds in the park, as most individuals caught were juveniles and reproductive females. In addition, a *P. pipistrellus* maternity colony was found roosting at the nursery school of Dadia village in 2005, where 45 emerging individuals were counted. The majority of *P. pygmaeus* captured were adult males, though some juvenile individuals were also found, suggesting that this species may also breed in the area.

Eptesicus serotinus breeds in the park (Table 1), as the majority of bats captured were reproductive females and juveniles. It is one of the most common species in Greece (Hanák et al. 2001). Most *M. daubentonii* were adult males. Only four out the 33 captured individuals (Table 1) were juveniles and only one out of four adult females was reproductive (pregnant), which suggests that, if the species breeds in the park, it may not form large maternity colonies. Of the few *M. bechsteinii* found (Table 1), one was a lactating female and one was a juvenile, indicating that the species breeds in the area; all the rest were adult males. This bat is also classified as Vulnerable in the IUCN Red List and appears to have a patchy distribution in Greece (Hanák et al. 2001). *M. mystacinus bulgaricus* (Mayer et al. 2007) is one of the rarest species and breeds in the park, as three out of the four individuals captured (Table 1) were reproductive females.

Although few *Pipistrellus kuhlii* were found, the species commonly foraged around street lamps, where its echolocation calls were recorded and identified with the aid of its species-specific social calls (Russo and Jones 1999, Papadatou et al. 2008b). It is thus more common in the park than it appears from captures only. It is closely associated with urban environments because it feeds on insects around street lamps and is a fairly common bat generally in Greece (Hanák et al. 2001). Most captured individuals were reproductive females. *P. kuhlii* is morphologically very similar to *P. nathusii.* Very few *P. nathusii* were captured and although its echolocation calls are also very similar to those of *P. kuhlii* (Kalko and Schnitzler 1993), its species-specific social calls (Barlow and Jones 1996) were never recorded (Papadatou et al. 2008b). This suggests that the species is very rare in the park. All three individuals captured in summer 2003 were adult males.

The majority of *Nyctalus noctula* and *N. leisleri* at seasonal streams and artificial pools (Fig. 2) were males. A roost of male *N. noctula* in a crevice under a bridge was discovered in 2003 (Fig. 3). The roost was used throughout the summer by approximately 65 bats, but this number decreased by mid autumn (data from counts of emerging individuals). However, female individuals of both species were also captured. Four out of five *N. noctula* and six out of seven *N. leisleri* captured on 22 September 2003 at a natural pool were adult females (C. Dietz, unpublished). One pregnant *N. noctula* was also caught in June 2004 (C. Dietz, unpublished) and one female *N. leisleri* in May 2004. *N. noctula* records in the park were more frequent than those of *N. leisleri*, in contrast to the rest of Greece, where the latter species appears to be more frequent (Hanák et al. 2001). However, these records come from a number of different researchers and different times of year. The rarest bat in the park was the largest of all three *Nyctalus* species and one of the largest species in Europe, *N. lasiopterus.* Only one individual was captured in September 2003 (C. Dietz, unpublished), but it escaped before identifying its gender and reproductive condition. Both *N. lasiopterus* and *N. leisleri* are classified as Lower Risk Near Threatened species in the IUCN Red List.

P. nathusii, *N. noctula* and *N. leisleri* are long-distance migrants, which may explain the predominantly male occurrence in the park. In migratory bats, the summer range of males may not overlap with that of females, which may migrate longer distances to form maternity colonies (Strelkov 1969, Fleming and Eby 2003). In

Greece, in summer, usually males of these three species are found, mostly in the northern and mountainous regions of the country (Hanák et al. 2001; O. von Helversen, pers. comm.). Females caught in September 2003 in the park may be individuals migrating to the south of the country to hibernate. However, the pregnant female *N. noctula* suggests the presence of a breeding colony in the area.

Conservation implications and further research

Four of the park's bat species classified as Vulnerable in the IUCN Red List (*Rhinolophus euryale*, *R. mehelyi*, *Myotis capaccinii* and *M. emarginatus*) and two classified as Lower Risk Near Threatened (*Rhinolophus ferrumequinum* and *R. blasii*) are highly dependent on caves. The three mines hosted important populations of some of these species. Artificial roosts may be very important for the survival of bat populations, often substituting lost natural roost sites, such as caves exploited as a tourist attraction. In addition, seasonal and between-year change in bat numbers and diversity implies movement between different roost sites. These movements are related to the bats' different physiological, behavioural and ecological requirements imposed by the different stages of their annual life cycle. Loss of some of these sites may have detrimental effects on their survival. Disused mines should therefore be maintained and their entrances stabilised. The entrance at Tsoutouro mine has already collapsed. Attempts to stabilise Ag.Varvara and Tsoutouro mines had been made in the 1980s by the relevant Greek mining authorities (T. Zanidis, pers. comm.), but no effort has been made since then due to financial constraints.

A large number of bats belonging to 13 species (Table 1) use regularly the concrete cisterns (Fig. 2) for drinking and foraging (C. Dietz and own unpublished data, Angell 2003, Palmer 2004). Summer is a crucial period for the survival of bats, since this is when they form their nursery colonies. However, water sources in the park are limited during the hot and dry summer, especially since uncontrolled pumping of water for irrigation purposes leads to quick drying-out of the seasonal streams (pers. obs.). This means that artificial pools are an essential source for these animals and should be maintained.

In order to better understand the bat fauna of the park, a more systematic survey covering the whole territory of the park is necessary. Capture techniques can be complemented by acoustic surveys, i.e. using echolocation call recordings, since many bats are capable of escaping nets. One very widely used method in such surveys is transects (e.g. Vaughan et al. 1997, Russo and Jones 2003). Acoustic transects should be based on a reference library of known echolocation calls. Such work has already been done in the park (Papadatou et al. 2008b). A systematic search for roosts other than underground sites would also be an important step, e.g. by following bats captured at foraging and drinking sites to their roosts using radio-telemetry techniques. However, the difficult terrain of the park (many densely forested and steep hills, few forest roads) should be taken into account if such efforts are to be made. One first attempt would be to locate such roosts at more accessible places, such as buildings in villages where many bats may roost (e.g. in roof spaces) and other artificial formations such as bridges.

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