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Bats hibernating in stand-alone bunkers of the Międzyrzecki Fortified Front in the years 2005–2012

Witold Grzywiński[1*], Jan S. Boratyński[2*], Jakub Górecki[3], Radosław Jaros[4], Maurycy Ignaczak[4], Barbara Karwowska[3], Anna Kmiecik[3], Paweł Kmiecik[3], Maciej Łochyński[4], Katarzyna Malak[3], Krzysztof Polowy[3], Marta Wieczorek[3] & Grzegorz Wojtaszyn[4]

[1] *Poznań University of Life Sciences*, *Department of Forest Utilization*, *Wojska Polskiego 71A*, *PL–60-684 Poznań*, *Poland*; *witold.grzywinski@up.poznan.pl*
[2] *Nicolaus Copernicus University*, *Department of Animal Physiology*, *Lwowska 1*, *PL–87-100 Toruń*, *Poland*; *jan.boratynski@gmail.com*
[3] *Poznań University of Life Sciences*, *Theriological Student Association*, *Wojska Polskiego 85*, *PL–60-625 Poznań*, *Poland*
[4] *The Polish Society for Nature Protection Salamandra*, *Stolarska 7/3*, *PL–60-788 Poznań*, *Poland*; **corresponding authors*

Abstract: The paper presents the results of winter bat censuses in stand-alone bunkers of the Międzyrzecki Fortified Front (MFF) not connected with the central part of the underground system of corridors and stations in western Poland. During the years 2005–2012, altogether 47 objects were checked. At least 12 bat species (3536 determined individuals) hibernated in stand-alone bunkers: *Myotis myotis*, *M. nattereri*, *M. bechsteinii*, *M. daubentonii*, *M. dasycneme*, *M. brandtii* or *M. mystacinus*, *Eptesicus serotinus*, *E. nilssonii*, *Pipistrellus pipistrellus* sensu lato, *Plecotus auritus*, *P. austriacus* and *Barbastella barbastellus*. *M. nattereri*, *M. daubentonii*, *B. barbastellus*, *P. auritus* and *M. myotis* were dominant in species composition (in total 94.4%) and occurred in a great number of structures (17–38). *M. dasycneme* and *M. bechsteinii* were definitely less numerous (in total 4.4%) and occurred in a smaller number of bunkers (7–11). *E. serotinus*, *E. nilssonii*, *P. austriacus* and *Pipistrellus pipistrellus* s. l. represented only 1.4% of all bats recorded and usually occurred in a smaller number of bunkers (4–5). Most of bats species found in stand-alone bunkers were more numerous in the middle part of MFF near the Central System. The number of species and number of individuals were higher in the deep multilevel bunkers located in forested areas. In contrast, in bunkers located in open areas, only the species characterized by wide climatic tolerance such as *B. barbastellus* and *P. auritus* were found.

Poland, Chiroptera, fauna, hibernation

Introduction

The Międzyrzecki Fortified Front (MFF) is one of the largest bat hibernacula in Central Europe (Urbańczyk 1989, 1990). It consists of an underground system of corridors and stations (named Central System) and a formation of stand-alone bunkers not connected with them. In 1980, the Central System of MFF became protected as the Nietoperek Reserve – the main aim of which is protection of hibernating bats and their winter habitats.

Species composition and numbers of individuals in that approx. 30 m deep system of underground corridors were studied in detail and published (Bagrowska-Urbańczyk & Urbanczyk 1983, Urbańczyk 1989, 1990). The authors reported 11 bat species wintering in the Central System: *Myotis myotis*, *M. nattereri*, *M. bechsteinii*, *M. daubentonii*, *M. dasycneme*, *M. brandtii*, *M. mystacinus*, *Barbastella barbastellus*, *Plecotus auritus*, *Eptesicus serotinus* and *Pipistrellus*

pipistrellus sensu lato. On the other hand, published information on bat species composition and abundance in stand-alone bunkers of MFF not connected to the Central System is sparse. The only available information concerns distribution of rare species such as *M. dasycneme* (Ciechanowski et al. 2007), several new winter roosts (Szkudlarek et al. 2001, Warchałowski et al. 2008) and autumn swarming activities of bats (Łupicki et al. 2001). Based on a winter survey in selected bunkers, Szkudlarek et al. (2001) reported only 5 bat species: *M. nattereri*, *M. bechsteinii*, *M. daubentonii*, *M. dasycneme* and *E. nilssonii*.

The purpose of this study is to supplement information about bat species composition and abundance in stand-alone bunkers not connected to the Central System of the Międzyrzecki Fortified Front. An attempt to analyze bat species composition and number of individuals in relation to different types of bunkers and their surroundings and conservation priorities was undertaken.

Material and Methods

Description of the study site

The Międzyrzecki Fortified Front (MFF) is situated in the Lubuskie province and Wielkopolsko-Kujawskie Lakeland in western Poland. The studied bunkers are located between the Odra and Warta rivers. The most southern bunker is located near the Brody village (52° 04' N, 15° 23' E) and the most northern one near the Skwierzyna town (52° 34' N, 15° 25' E). All objects of MFF were built of concrete in the 1930s and during the World War II (Jurga & Kędryna 2006). MFF comprises the Central System (underground system of corridors and stations approx. 32 km long) and stand-alone bunkers (named 'Panzerwerks') not connected to it.

During the years 2005–2012, winter censuses of bats were conducted in 47 underground objects not connected to the Central System of MFF. Most of them (45) are military bunkers and shelters. A labour camp canteen near the Wysoka village and a basement in an old mill at the Staropole village were also surveyed.

The aforementioned bunkers were characterized by different degrees of preservation, size (volume), structure and surroundings. For the purpose of the study, the bunkers were divided into the following categories: small (12 to 500 m^3), medium (501 to 1000 m^3) and large (more than 1000 m^3) based on their volume, and into: slightly or heavily damaged based on the degree of preservation (100–50% and less than 49% of preservation, respectively) (Jurga & Kędryna 2006). In addition, classification according to the surroundings of the bunkers (forest or open area) and their spatial structure (one- or multi-level) was also used.

Bat surveys

Bat surveys were conducted in 47 stand-alone bunkers during the winter seasons of 2005–2012. The censuses were usually carried out once a year in February. Only in the year 2006, the main survey was done in December. During the study period, additional checks were carried out in December 2005 and March 2006. All observations were performed in the daytime. Individual bats were determined to species without handling them. When necessary, a hand mirror or binoculars were used. Bat identification was done considering morphological characteristics such as body size, length and shape of ear and tragus, appearance and color of muzzle (Dietz & Helversen 2004).

Data analysis

The species dominance (D%) was calculated on the basis of the total number of individuals identified to species during all checks and in all bunkers. The percentage of utilization of bunkers (U%) was calculated for each species as a ratio of the number of bunkers occupied by a particular species to all bunkers where bats were recorded. Species constancy index (C_{index}) within the studied bat fauna was calculated as the ratio of the number of checks where a particular species was found to the number of all checks in the particular bunker. The C_{index} was calculated separately for 30 bunkers where censuses were conducted for more than 3 winter seasons.

The Analysis of Deviance in Generalized Linear Models (GLM) for Count Data (Crawley 2007) was used to examine the impact of bunker surroundings (forest or open area), their spatial structure (one-level or multi-level), size (small, medium or large) and degree of damage (low or heavy) on the number of species present and the maximum number of determined individuals. The Quasi-Poisson and Poisson error distribution for the number of individuals and the number of species were used, respectively. The model was simplified by rejecting insignificant interactions. Relationship between the number of species and all predictors was computed for 42 bunkers with known volume, number of levels, degree of preservation and surroundings. All statistical analyses were done in the R program (R 2011). Species abbreviations used in the paper follow Wołoszyn (1992): MYM – *Myotis myotis*, MYN – *M. nattereri*, MBE – *M. bechsteinii*, MDA – *M.*

daubentonii, MDS – *M. dasycneme*, MYB/MYS – *M. brandtii* or *M. mystacinus*, ESE – *Eptesicus serotinus*, ENI – *E. nilssonii*, PIP s.l. – *Pipistrellus pipistrellus* sensu lato, PAR – *Plecotus auritus*, PAS – *P. austriacus*, BAR – *Barbastella barbastellus*.

Results

During eight years of the study, altogether 42 out of 47 checked objects were found to be used as hibernacula by bats. At least 12 bat species (3536 determined individuals) hibernated in stand--alone bunkers. *M. nattereri*, *M. daubentonii*, *B. barbastellus*, *P. auritus* and *M. myotis* were dominant in species composition (in total 94.4%) and occurred in most of structures (between 17 and 38). *M. dasycneme* and *M. bechsteinii* were definitely less numerous (in total 4.4%) and occurred in a smaller number of bunkerss (7–11). *E. serotinus*, *E. nilssonii*, *P. austriacus* and *Pipistrellus pipistrellus* s. l. represented only 1.4% of all bats recorded and usually occurred in a smaller number of bunkers (4–5). The 28 records of *E. serotinus* were made in as many as 16 bunkers. *M. brandtii/mystacinus* was noticed only once (Table 1).

Barbastella barbastellus, *Plecotus auritus*, *Myotis nattereri*, *M. daubentonii*, *M. myotis* had a high C_{index} (between 0.52–0.75) and were constant elements of bat fauna of the bunkers. *Myotis dasycneme* (C_{index} 0.42) was classified as a sub-constant element, whereas *Myotis bechsteinii*, *Eptesicus serotinus*, *E. nilssonii* and *Plecotus austriacus* as accessory species with C_{index} between 0.16–0.28. The low C_{index} values for only few observations of *Pipistrellus pipistrellus* s. l. and *Myotis brandtii / M. mystacinus* (under 0.12) qualify them as accidental species (Fig. 1).

Most of bat species found in stand-alone bunkers were more numerous in the middle part of MFF near the Central System. Only *B. barbastellus* and *P. auritus* were observed in similar numbers in the middle and southern parts of MFF. Very rare species such as *E. nilssonii*, *M. mystacinus / M. brandtii* and *Pipistrellus pipistrellus* s. l. were seen only in the middle part of MFF (Table 2).

Significant interactions between individual predictors (parameters of the bunkers and their surroundings) were not found. Then the simplification of the models was done by rejecting all interactions and testing only their main effects. Both the number of species and the maximum number of individuals in bunkers were higher in forested than in open areas (Tables 3, 4). Additionally, the number of individuals and bat species was lower in the smallest bunkers (Tables 3, 4).

Table 1. The total number of individuals (NI), the number of bunkers used by bats (NB), species dominance (D%) and the relative use of the bunkers by particular species (U%) in 42 bunkers with bats in the years 2005–2012

bat species	NI	NB	D%	U%
Myotis nattereri	970	34	27.4	81.0
Myotis daubentonii	814	31	23.0	73.8
Barbastella barbastellus	611	38	17.3	90.5
Plecotus auritus	513	36	14.5	85.7
Myotis myotis	432	17	12.2	40.5
Myotis dasycneme	77	7	2.2	16.7
Myotis bechsteinii	69	11	2.0	26.2
Eptesicus serotinus	28	16	0.8	38.1
Eptesicus nilssonii	9	4	0.3	9.5
Plecotus austriacus	7	5	0.2	11.9
Pipistrellus pipistrellus s. l.	5	4	0.1	9.5
Myotis mystacinus group	1	1	0.0	2.4

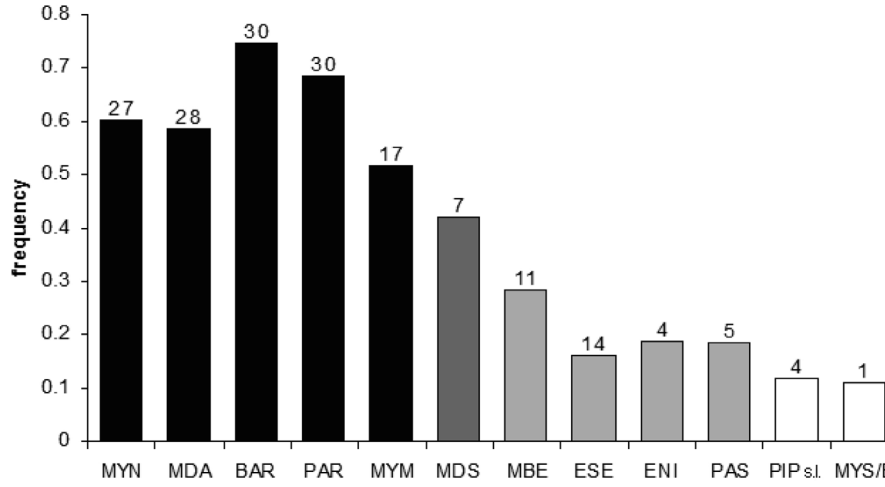

Fig. 1. Mean constancy index of the occurrence of bat species in 30 bunkers checked at least 4 times during the years 2005–2012. Black – constant species, dark-grey – sub-constant species, light-grey – accessory species, white – accidental species. Numbers above bars indicate the number of bunkers used by the species.

Although the number of individuals was higher in multi-level bunkers (Table 3), their vertical construction did not affect species composition (Table 4).

Discussion

At least 12 species of bats hibernate in stand-alone bunkers of MFF not connected to central system, which means 48% of bat species occurring in Poland and more than 70% within the Wielkopolsko-Kujawskie Lakeland (Sachanowicz et al. 2006). The potential number of bat species hibernating in those bunkers may be higher because individuals from the genus *Pipistrellus* were determined only as *Pipistrellus pipistrellus* sensu lato. Similarly, *M. mystacinus* and *M. brandtii* were treated as *M. brandtii/mystacinus* without species identification.

The described bat species composition in stand-alone bunkers seems to be similar to that found in the underground of the Central System of MFF. The exception is *M. myotis* which is dominant in the Central System (Bagrowska-Urbańczyk & Urbanczyk 1983, Urbańczyk 1989, 1990) but is less frequently in stand-alone bunkers.

M. nattereri and *M. daubentonii* were the most numerous species but *B. barbastellus* and *P. auritus* occurred in a larger number of bunkers (Tables 1, 2). Among the recorded species, *E. nilssonii* is noteworthy. The small proportion of this species in winter roosts is similar in different areas of Poland (Lesiński 2001, Lesiński et al. 2004, Sachanowicz 2007). Only occasionally it is found in larger numbers, for example in Gierłoż bunkers in the Mazury Lakeland (Fuszara et al. 2003) and is dominant only in northern Poland (Marzec 2003). *Eptesicus nilssonii* was recorded only in 4 bunkers in the maximum number of 2 individuals. It is worth to mention that this species was not found in the main underground Central System of MFF.

Furthermore, it is very interesting that *M. dasycneme* (Fig. 2), which is considered a vulnerable species (Hutson et. al. 2001), was found in a relatively large number of 18 individuals during one

Table 2. Maximum numbers of bats in the studied bunkers of MFF in the years 2005–2012. For the bat acronyms see Material and Methods

bunker	MYN	MYM	MDA	MDS	MBE	MYS/B	PAR	BAR	ESE	ENI	PAS	PIP sl
North												
Pz. W 863–865 tunnel	61	9	27	2			2	1	1			
Pz. W 817	3						1	1				
Pz. W 814	4	5	6				2	7				
Pz. W 811			1				1		2			
Pz. W 805								2				
Pz. W 782	2							2				
Middle												
Pz. W 775	1							1				
Pz.W 773	2	1	1		1		2	19		1		1
Pz. W 772	12	1	6	1	1		3	12	2	1		1
Pz. W 761	7		8	1			5	7	1			
Pz. W 754–757	18	25	12	1	1		8	6	1			
Pz. W 750	6	1	2		1		3	3	1			2
Pz. W 748	5		1		1		2	2				1
Pz. W 746	2		1				2	2				
MG. St. u Pak.U 755	2	1	1				4	1				
MG. St. u Pak.U 745	2						1	1				
Pz. W 743	19	17	33	5	1		16	4	2	1		
Pz. W 741	34	6	33	12	9		11	12	1	2		
Pz. W 712	28	3	19		1		3	7	1			
Pz. W 708	25	16	23		1	1	7	16	1		1	
Staropole mill basement							2					
technical tunnel in Wysoka	1		1					5				
labour canteen in Wysoka	17	1	3				4	13				
Anti-aircraft shelter in Wysoka	19	6	7		3		2	15				
Weir 714							1	1			1	
Pz. W 706	3		1				6	2				
Pz. W 703	7		5				5	3				
Pz. W 702	6		6				4	7			1	
Pz. W 701	2	1	5				2	6			1	
Pz. W 671							2	2				
South												
Pz. W 669	8		6	1			4	5	1			
Pz. W 657	7	1	2				6	6	1			
Pz. W 646			1				4	3	1			
Pz. W 631			1				4	5	1			
Pz. W 630	1		1				14	6	3			
Pz. W 625	4	3	2		1		8	5				
Pz. W 623	1						3					
Pz. W 601									1			
Pz. W 598	2	3	1				8	12			1	
Pz. W 594	1							1				
Pz. W 589	1		1				2	4				

census (19–20 February 2005). In contrast, in a large hibernaculum such as the Central System of MFF, *M. dasycneme* was recorded in the maximum number of 21 individuals (Ciechanowski et al. 2007). Additionally, this species appears in all winter seasons and seems to be a constant component of the fauna of stand-alone bunkers of MFF (Fig. 1). It shows the importance of stand-

Table 3. Relationship between the maximum number of individual bats wintering in stand-alone bunkers and their location, structure, degree of damage and size

	estimate	standard error	t value	p
intercept	0.91	0.70	1.30	*0.20*
forest	1.55	0.51	3.06	*0.004*
multi-level	1.37	0.31	4.45	*<0.000*
low damage	0.17	0.28	0.59	*0.56*
medium size	0.48	0.31	1.56	*0.13*
small size	–1.17	0.52	–2.23	*0.03*

residual deviance: 455.77 on 36 degrees of freedom

-alone bunkers as wintering sites for that species. It is also important that another rare species *M. bechsteinii* (Fig. 3) was recorded twice (27–28 February 2010 and 25 February 2012) in the maximum number of 12 individuals. Both species *M. dasycneme* and *M. bechsteinii* are infrequently found in regional hibernacula and across the country (Sachanowicz et al. 2002, Wojtaszyn et. al 2006, 2008, Ciechanowski et al. 2007).

Most of bat species occurred in large numbers mainly in stand-alone bunkers in the middle part of MFF, which is probably caused by three factors: the depth of multi-level bunkers, the location in forests and the proximity to the Central System of MFF. Multi-level bunkers consisting of 2–4 levels offer a more stable microclimate than one-level objects. It was noticed that the first levels of the bunkers were often frozen, especially in those located in open areas. Among other factors, the deepest bunkers were characterized by a higher number of individuals recorded (Tab. 3).

The location of bunkers in forested areas was the most important factor affecting bat species composition (Table 4) and one of the most important factors for the number of individuals (Tab. 3). Forest cover stabilizes daily variations of temperature above the ground (Lützke 1961) and frost penetration of ground is about twice smaller in forests than in open areas (Raymond 1940). Bunkers located in open areas can have a more changeable microclimate and they are more susceptible to freezing. Lesiński (2009) found higher bat species diversity and frequency in cellars located in forests than in open areas, which was also tested in this study. In bunkers located in open areas, only the species characterized by wide climatic tolerance such as *B. barbastellus* and *P. auritus* which are able to hibernate at a very low ambient temperature (Harmata 1969, 1973, Urbańczyk 1991, Sachanowicz & Zub 2002), were found.

Table 4. Relationship between the number of bat species wintering in stand-alone bunkers and their location, structure, degree of damage and size

	estimate	standard error	t value	p
intercept	1.11	0.31	3.56	*<0.000*
forest	0.48	0.23	2.12	*0.03*
multi-level	0.22	0.17	1.25	*0.21*
small damage	0.17	0.16	1.03	*0.30*
medium size	0.06	0.19	0.31	*0.75*
small size	–0.61	0.24	–2.50	*0.01*

residual deviance: 34.960 on 36 degrees of freedom

Figs. 2, 3. Bats hibernating in the Międzyrzecki Fortified Front. 2 – Pond bat *Myotis dasycneme* (photo by J. S. Boratyński). 3 – Bechstein's bat *Myotis bechsteinii* (photo by W. Grzywiński).

In the study, non-significant interactions between the location of bunkers, the number of their levels and bat species composition and the number of individuals were found. Despite that, the species composition varied in different types of bunkers and their surroundings. The one-level bunkers located in open areas were used by only 3 bat species: *B. barbastellus* (58.3%), *P. auritus* (25.0%) and *M. nattereri* (16.7%). In multi-level bunkers located in open areas 8 bat species were found: *P. auritus* (30.7%), *M. nattereri* (27.8%), *B. barbastellus* (16.6%), *M. daubentonii* (14.8%), *M. myotis* (7.1%), *E. serotinus* (1.8%), *M. bechsteinii* (0.6%) and *M. dasycneme* (0.6%). In contrast to that, in bunkers located in forests, regardless of the number of levels, 11 bat species were noticed.

In stand-alone bunkers of MFF, 4 bat species listed in Annex II of the Habitats Directive were found: *M. myotis*, *M. bechsteinii*, *M. dasycneme* and *B. barbastellus*, which make these objects very important from the bat conservation point of view.

In conclusion, there are two main important requirements to preserve the study sites: protection of deep, multi-level bunkers from tourism during winter periods and preservation of forest cover in the close vicinity of the bunkers.

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