Universitat de Vic
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Bat assemblages in the Nietoperek bat reserve (Western Poland) and their conservation strategies

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Vic, Setembre de 2014

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1. INTRODUCTION:

During autumn and winter, there is a significant decrease of insect densities that reduces the food supply for insectivorous bats from temperate zones. In the cold season of the year, bats do not have enough energy to cover the high energetic cost of flight and increased cost of thermoregulation at low ambient temperature (Griffin 1986, Speakman & Racey 1991, Speakman 1997). To avoid this loss of energy bats migrate in late summer and autumn either to areas where warm climate and presence of insects make foraging possible, or to underground places where they can hibernate reducing energy demands (Davis & Hitchock 1965, Strelkov 1969, Petit 1998, Harmata & Haensel 1996, Steffens et al. 2004).

Nietoperek bat reserve, situated in Western Poland, is one of the largest bat hibernation sites in European Union and the largest in that country (Tab.1). The main part of Nietoperek are an underground corridors of the abandoned fortification of the Międzyrzecz Fortified Front (MFF). The MFF was built by the Germans in the 1930s and during the World War II. The total length of the underground corridors is ca. 32 km. Also there are the remains of the defend line called “dragon teeth”, originally built to stop the pass of the tanks, it is an important linear corridor for bats to commute from undergrounds to foraging areas (Woźniak 1996). After the war, the MFF were deserted and became a bat hibernaculum.

Actually Nietoperek is the eighth largest bats hibernation site in Europe by “EUROBATS”.

Table 1. The largest wintering bats in Europe by “EUROBATS”. (Source: http://www.eurobats.org/activities/intersessional_working_groups/underground_sites, Modified, Kokurewicz 2013).

Lp.	Kraj	Nazwa stanowiska	Maksymalna liczebność nietoperzy
1.	Rumunia	Sura Mare Cave	81,134
2.	Francja	11003	70,000
3.	Słowacja	Erňa	58,049
4.	Bułgaria	Devetashkata cave	45,503
5.	Bułgaria	Parnitsite cave	42,410
6.	Rumunia	Huda lui Papara cave	40,329
7.	Chorwacja	Trbušnjak špliija	39,000
8.	**Polska**	**MRU, Nietoperek**	**37,693 (12.01.2008 r.)**

Finally Nietoperek bat reserve is also important because bats migrate there for hibernation from places located in eastern Germany. *Myotis daubentonii* flies 257 km, *Myotis brandtii* 242,1 km and *Myotis myotis* 226,7 km to reach the MFF undergrounds. (Fig.1) (Rogowska & Kokurewicz 2007, Kokurewicz 2013).

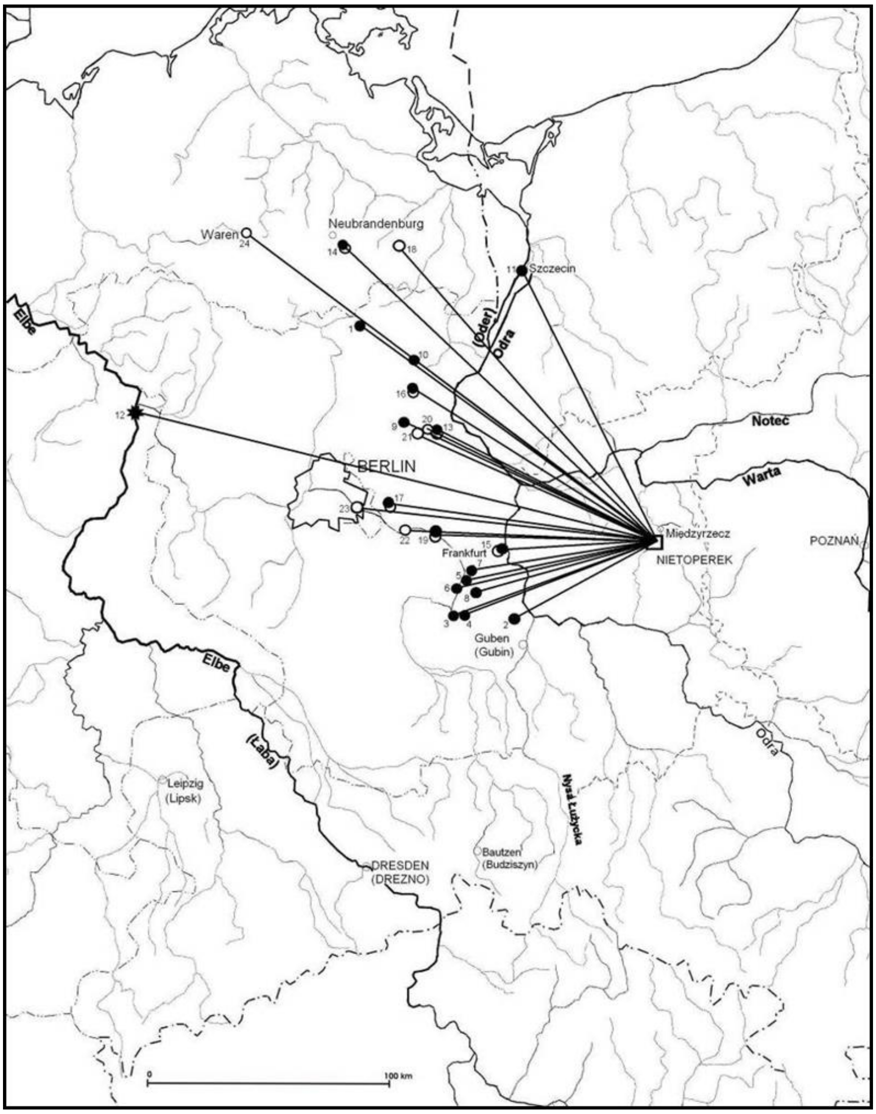

Figure 1. Migrations of mouse-eared bat (*Myotis myotis*) (circles) and Brandt's bat (*Myotis brandtii*) (asterisk) from Germany to Natura 2000 site Nietoperek in the years 1975 – 2009 (Harmata & Haensel 1996) - white circles , own data T. Kokurewicz – black circles, Kokurewicz et al. 2013).

Till now, 12 hibernating species have been found in Nietoperek bat reserve: Greater mouse-eared bat (*Myotis myotis*, Daubenton's bat (*Myotis daubentonii*, Natterer's bat (*Myotis nattereri*, Barbastelle bat (*Barbastella barbastellus*, Brown long-eared bat (*Plecotus auritus*, Grey long-eared bat (*Plecotus austriacus*, Whiskered bat (*Myotis mystacinus*, Brandt's bat (*Myotis brandtii*, Pond bat (*Myotis dasycneme*, the Bechstein's bat (*Myotis bechsteinii*, Serotine bat (*Eptesicus serotinus*, Common pipistrelle (*Pipistrellus pipistrellus*. The maximal number of hibernating bats was recorded in

Nietoperek on 12th January 2008 and exceeded 37.693 individuals (Kokurewicz et al. 2013).

The history of protection of bats in Nietoperek I started very early. In 1980, approximately 30% of the surface area of corridors became protected under the Nietoperek bats reserve. To increase the protection of that unique site in 1998 all the underground corridors became protected as bat reserve Nietoperek II. This new reserve contained also the fortress plots on the surface, to protect the bats entrances to the undergrounds. In 2004 Poland joined the European Union and according to EU Habitat Directive it was necessary to create the Natura 2000 Network. Finally, in November 2007 both bat reserves and the area surface surrounding them were included into the Natura 2000 site called Nietoperek (area code: PLH080003) covering a total area of 7.377,37 ha (Fig.2). The target of protection in MFF are only four bats species i.e. *Myotis myotis*, *Barbastella barbastellus*, *Myotis dasycneme*, *Myotis bechsteinii* which are included in Appendix II of the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) which are legal basis of European Natura 2000 Network.

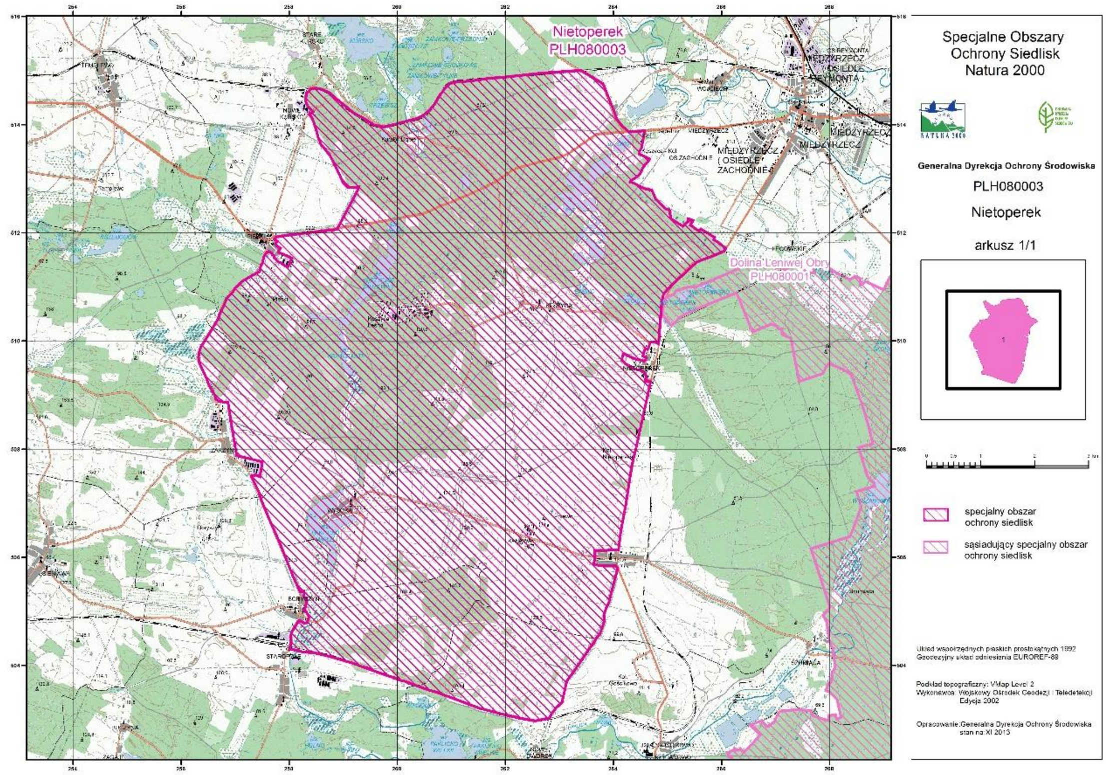

Figure 2. Natura 2000 site PLH080003 Nietoperek (Source: http://www.miedzyrzecz.biz/NATURA-2000/NATURA-2000.htm)

Due to the very large bat numbers hibernating in Nietoperek it is possible to study bat assemblages and its changes in course of hibernation season based on statistically significant samples.

The Międzyrzecz Fortified Front is also important for its historical point of view so many people visit the undergrounds. There is a tourist business working there that offers guided tours and the number of visitors has increased since the latest 1980s (Fig.3). Unfortunately it's well-known that hibernating bats are sensitive to both tactile and nontactile human disturbance (Thomas 1995). According to that it become necessary to compromise between the underground tourism and bat conservation. It could only be done on scientific bases, so the systematic study on bat numbers and species composition of bat assemblages are required. Due to increasing human impact on bats in Nietoperek is important to elaborate conservation strategies to protect this internationally important hibernacula.

Figure 3. View of the bunker PzW 717 usually used as winter tourism entrance to the underground system (Photo by Laura Torrent).

The aims of the study were:

1. To show the changes in number of each species in the course of hibernation season (from October to April) for the three analysed winter seasons (2011/2012, 2012/2013 and 2013/2014). Due to fluctuations in numbers recorded by previous authors (Bagrowska-Urbańczyk & Urbańczyk 1983; Hejduk & Radzicki 1996; Kokurewicz et al. 1996; Kozakiewicz & Strzałka 1996) and my own field study it is difficult to find the proper period of winter monitoring of bats. As a result of my analysis it could be possible to suggest the deadlines for monitoring of different bat species to obtain the

maximal population numbers. This data could be possibly applied to other bat hibernation sites;

2. To describe bat assemblages, their numbers and intra- and inter seasonal (within the seasonal and between seasons) changes in the two surveyed sections 7 and 8 during the last three winter seasons. The results could be useful for nature conservancy authorities to take the decision to make this parts of undergrounds available for winter tourism or not;
3. To find out a possible negative impact of tourism on hibernating bats in the underground. It is interesting and important because subsections (7.9.1, 7.9.2 and 7.8) were available for tourism during last three winter seasons. Bats are highly protected in Europe, they are included in Annex II and IV of the Habitat Directive and so its disturbance during a crucial period, such as hibernation, could be fatal for them. Finally the results could lead to propose improvements for their conservation in parts of Nietoperek under increasing tourism pressure.

2. MATERIALS AND METHODS:

Study area

Międzyrzecz Fortified Front is situated in the macroregion of the Lubuskie Lake District, Western part of Poland, halfway between Poznań and Berlin. Specifically Lubuskie Lake District is on the border between two mesoregions: Bruzda Zbąszyńska, with its main axis of the Obra River, and the Łagowskie Lake District situated between the Obra and Odra Rivers (Świerkosz 1996).

Bruzda Zbąszyńska is a wide depression extending along the Obra River, which originated as a result of postglacial erosion processes and Łagowskie Lake District is characteristic for its high hills (even up to 277 m), formed of Tertiary and Quaternary deposits, and numerous, long and narrow, postglacial lakes. Also, small fragments in the surroundings of the MFF are occupied by marshy and boggy soils. The latter form in places where the process of becoming marshy has been suddenly stopped as a result of decreasing ground water level (e.g. mismanaged drainage). The western border of the area was based on the series of lakes and canals extending between Boryszyn and Lake Pieski. The complex includes several postglacial lakes (partly with shoreline changed by the fortifications), canals between Wysoka and Krzewie lake, as well as Struga Jeziorna stream (called also Pieski Potok). In addition between Nietoperek and Kęszyca on one hand and Międzyrzecz on the other, there is a whole complex of fish ponds whose fauna and flora constitute a valuable addition to the surroundings of the MFF (Świerkosz 1996).

Climate

The climate of Ziemia Lubuska is among the warmest and most humid regions in Poland. This results from a strong effect of oceanic air masses, mainly from the Atlantic Ocean, that make the climate milder: cooling it down in the summer and bringing an air warmer than that coming from the interior of Euroasia in the winter. Thanks to this, the mean annual temperature amounts to 7,9 °C (Gorzów Wielkopolski) to 8,2 °C (Słubice). In Ziemia Lubuska the vegetation season it amounts on an average to 220 days. The frost-free period, very important for agriculture and gardening, lasts 160-170 days. The annual precipitation in Ziemia Lubuska depends on many local factors. It is lower in river valleys (up to 536mm in the Odra River valley near Słubice), and higher (even up to 630mm, of which 425mm between April and October) on the moraine hills of the Łagowskie Lake District (Świerkosz 1996).

Vegetation

The vegetation cover of the surroundings of the MFF has been strongly transformed, since the area has remained under human impact for hundreds of years. The forest felling, agriculture, grazing and, finally, modern military technology, have all contributed to the absence of natural, primeval plant communities. As many as 393 species of higher plants have been recorded from the entire surroundings of the MFF; some of them are rare or protected in Poland (Świerkosz 1996).

Fauna

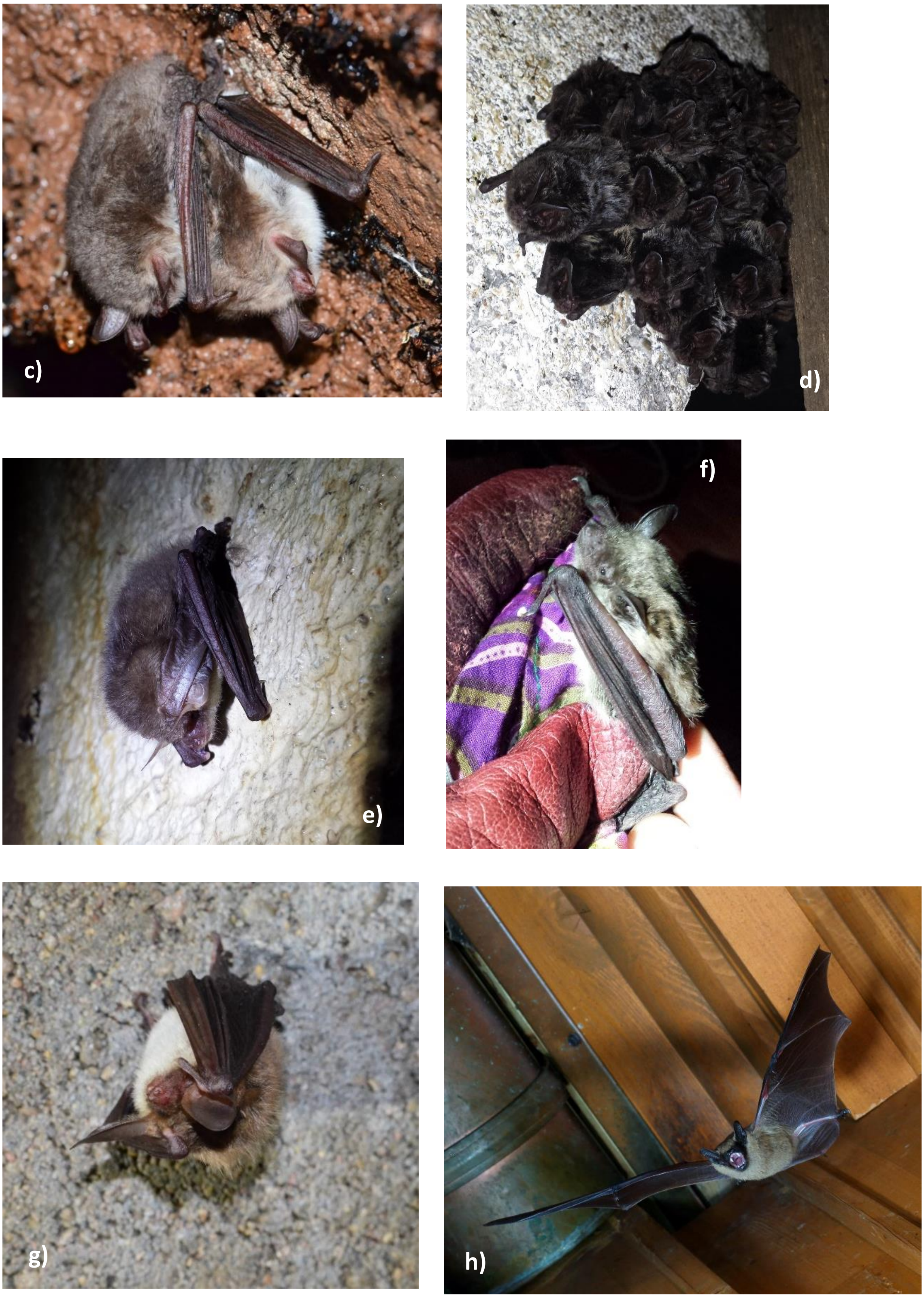

Figure 4. Hibernating bat species in Nietoperek: a) *M. myotis*, b) M. *daubentonii*, c) *M. nattereri,* d) *B. barbastellus*, e) *P. auritus*, f) *M. dasycneme*, g) *M. bechsteinii* and h) *E. serotinus* (Photos **a**, **b**, **c** and **g** by Jordi Camprodon; **d**, **e** and **f** by Laura Torrent; and **h** by Jens Rydell).

Nietoperek bat reserve is also important for other animals besides bats (Fig.4). Two species of mammals; beaver (*Castor fiber*) and otter (*Lutra lutra*) live in the area and both are listed in Annex II of the Habitats Directive. The presence of otters (droppings, footprints) were reported in 4 places. Due to the shyness of the species the abundance is probably a bit higher. It can be estimated at no more than 5-8 individuals. Also 13 species of birds listed in Annex I of the Directive 79/409/CEE were found in 2009, furthermore one of them, white-tailed eagle (*Haliaeetus albicilla*) was breeding in the area. Furthermore European fire-bellied toad (*Bombina bombina*), also included in the Annex II of the Habitats Directive, was found in Natura 2000 site Nietoperek. (Andrzejczak et al. 2009). Finally in Nietoperek Natura 2000 site two species of martens (*Martes martes* and *Martes foina*) have been found above and underground. Thanks to DNA analysis of the scats collected in the tunnels the foraging of both species on hibernating bats have been discovered (Power et al. 2012).

Data collection

For monitoring of bat numbers started in 1999 the system was divided in 9 main sections (Fig.5). The study have been undertaken in the sections 7 and 8 (Fig.6a-b) where the tourist trails are situated.

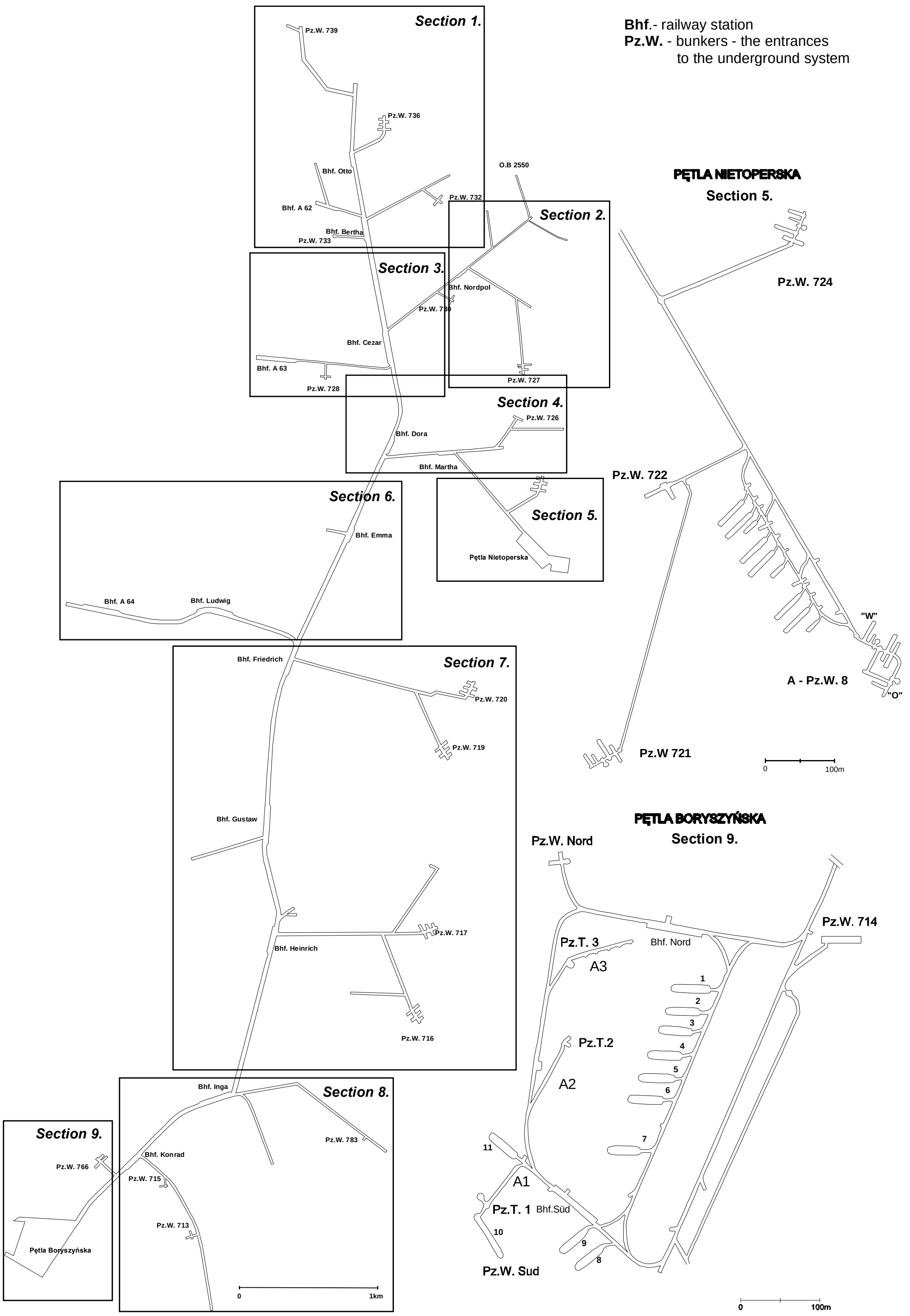

Figure 5. Division of the underground tunnels of MFF, ca. 32km, into sections (1-9). The present division was implemented for every monitoring study carried out in the middle of January from 1999 to present.

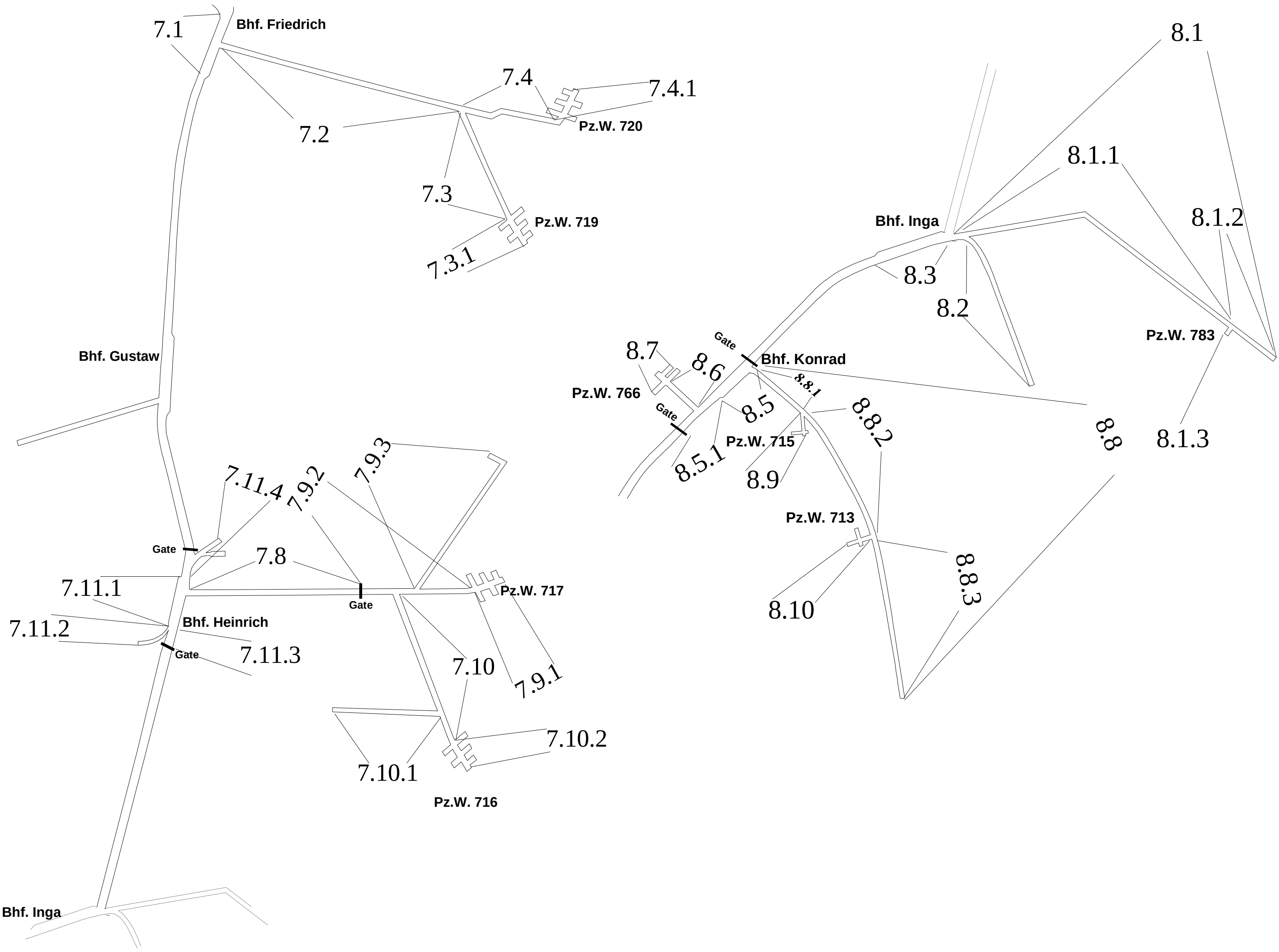

Figure 6a-6b. Parts of the undergrounds from sections 7 and 8 with the division into subsections surveyed every month in the winter seasons 2011/12 -2013/14. *Bhf.* – railway station.

Under the license issued by County Nature Conservancy Management in Gorzów Wielkopolski tourist were allowed to see in winter parts of the undergrounds included following our division of subsections: 7.9.1, 7.9.2 and 7.8.

The censuses were done every month from October to April. The surveys of sections 7 (Fig.6a) and 8 (Fig.6b) have been done during Saturdays. The data form the first two winter seasons (2010/11 and 2011/12) were available for my final project and have been collected by the team from Wrocław University of Environmental and Life Sciences leaded by Dr. Tomasz Kokurewicz. The team was composed of PhD and MSc students from Wrocław and Gdańsk Universities and also of students from Students Mammal Society of Wrocław University and volunteers interested in bats. During my first inspection I was trained on bats identification which made possible for me to collect data by myself from October 2013 to April 2014. Altogether data from 18 inspections were analysed in this project. Data used for my project were collected at: 14.10.2011; 11.11.2011; 17.12.2011; 14.01.2012; 11.02.2012; 10.03.2012; 1.04.2012; 20.10.2012; 17.11.2012; 15.12.2012; 12.01.2013; 16.02.2013; 16.03.2013; 06.04.2013; 12.10.2013; 09.11.2013; 07.12.2013; 17.01.2014; 26.02.2014; 15.03.2014; 05.04.2014.

Due to the protection of bats the study, which cause the disturbance of hibernating animals, have been done under the license issued by County Nature Conservancy Management (Regionalna Dyrekcja Ochrony Środowiska w Gorzowie Wielkopolskim) in Gorzów Wielkopolski (license numbers WPN-I.6205.4.An.Al , WPN-I-604.1.2014.AI and WPN-I-6205.13.2014.AI).

Every month we were surveying undergrounds by two groups of people one for each section. The groups were composed of at least two people, i.e. expert in bats identification and the person recoding the bats numbers in the standard table provided (Tab.2).

We intended to disturb the bats as less as possible during the data collection so we wanted to restrict the time at less hours possible. Due to that during this last winter season inspections we have had different number of people coming each month, usually from 10 to 15. Everybody was perfectly aware of that fact so we worked as fast as possible. We usually went to the underground at 10 am in the morning and finished about 15 – 16 pm. The inspections lasted 5-6 hours depending on the bat and people numbers.

Once inside the tunnels the way to proceed was went to the end of the subsection and start counting form there. We divided the tunnel and each person count a half of it as they keep moving forward. The information about the location of individual bats, the number of them and the presence, size and number of clusters, defined as groups of 5 or more hibernating bats with body contact, was noted. In case of big clusters to minimise the error we have taken a picture and counting bats from it. We implemented a way of writing down clusters information; we write the species found inside the cluster between brackets. For that reason we had to look closely the clusters because bats of different species might mixt each other.

Identification of bat species was done based on morphological characteristics like body size, length and shape of the ear and tragus, size of the foot compared to the rest of the body, and appearance and colour of the muzzle (Pucek 1981, Wołoszyn 2001 and Dietz & von Helversen 2004). In case of doubt, if it's not possible to see enough parts of its body to identify we declared it "Indeterminate". It is very difficult and unsure to distinguish between whiskered bat (*Myotis mystacinus*) and Brandt's bat (*Myotis brandtii*) without handling them. Due to that both species were treated jointly as a group.

The external features of bats were examined by use of headlamps *Peztl* model and hand torches Cree LEDs 1300 lumens. Extra new batteries are also needed in case of drain the old ones. The hand torches are very useful because made possible to identify species hibernating in the railway station ceilings, 5 m high (Fig.7).

Figure 7. Underground tunnels with a high situated cluster of greater mouse-eared bat (*Myotis myotis*) (Photo by Jens Rydell).

Our license did not cover handling bats and due to that we were not allowed to touch them so we made pictures of the rings. With this pictures we could read the numbers and send the information to Dr. Urlich Zöphel & Dipl. Biol. Dagmar Brockmann from Bat Ringing Centre in Dreseden (Germany) (Fledermausmarkierungszentrale, Dresden).

Furthermore some bats hide inside holes and crevices where we were not able to look so we used an endoscope or an extensible little mirror (Fig.8).

Figure 8. Endoscope (left) and extensive mirror (right) used during the survey (Photos by Jordi Camprodon).

During the inspections we used maps of section 7 and 8 (Fig. 6a-6b) to oriented correctly and to know in which subsection of the underground we were recording bat numbers. The teams write down the number of bats per species they count in each subsection and at the end of the day they summarise all data in the tables in Excel (Tab.2).

Table 2. Standard table used to record the results during the census in control areas 7 and 8 in Natura 2000 site Nietoperek.

	M.myo	*M.dau*	*M.nat*	*B.ba*	*P.au*	*M.ms/ M.br*	*M.bc*	*M.ds*	*E.sr*	*Indet*	*Number of bats on subsections*	*Clusters*
7.1												
7.2												
7.3												
Suma												

Ring numbers:

Remarks:

Acronyms of scientific bat names used:

M.myo - Myotis myotis; M.dau – M. daubentonii; M.nat – M. nattereri; B.ba. - Barbastella barbastellus; P.au - Plecotus auritus; M.ms/M.br – M. mystacinus& M. brandtii; M.bc – M.bechsteinii; M.ds – M. dasycneme; E.sr - Eptesicus serotinus; Indet. – Not determined (bat species)

Climatic data

The mean temperatures during the observations were taken from weather station in Zielona Góra - a city situated 66km away from Nietoperek bat reserve (Tab.3) (Source: http://www.wunderground.com/history/airport/EPZG/2014/1/1/MonthlyHistory.html?req_city=NA&req_state=NA&req_statename=NA).

Table 3. Mean temperatures in Zielona Góra from October 2011 to April 2014.

Winter season	October	November	December	January	February	March	April	Mean temperatures (°C)
2011/2012	10	4	4	1	-3	6	9	4,42
2012/2013	8	4	-2	-2	-1	-3	8	1,71
2013/2014	10	4	2	2	3	6	11	5,43

3. RESULTS

3.1. Bat species community in Nietoperek

This three species were the most numerous censed during this winter seasons analysed. The results indicate a significant increase of numbers of *M.myotis* and stabilize numbers for *M. daubentonii* and *M.nattereri* (Fig.9).

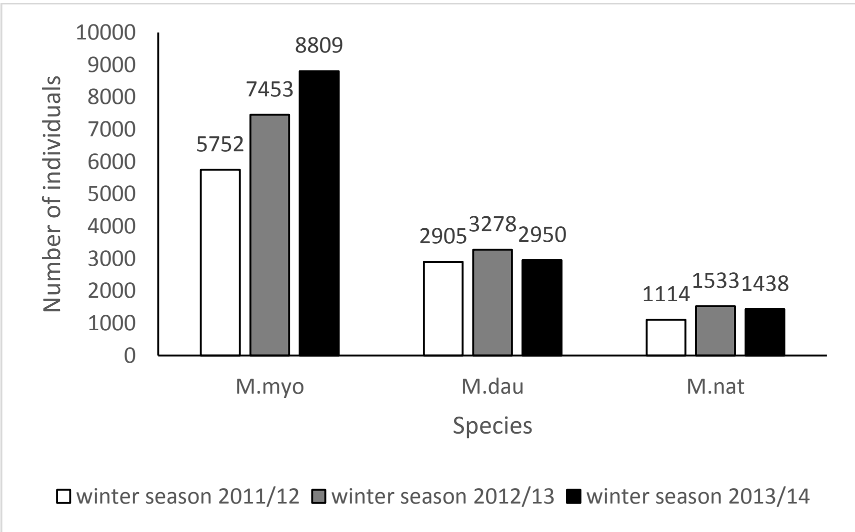

Figure 9.The numbers of *Myotis myotis*, *M. daubentonii* and *M.nattereri* in control areas 7 and 8 in Natura 2000 site Nietoperek in the three consecutive winter seasons.

There is a significant decreasing of numbers of this two species, half of the individuals have been found, during the winter season 2013/14. The milder winter could be the reason for this decline (Fig.10).

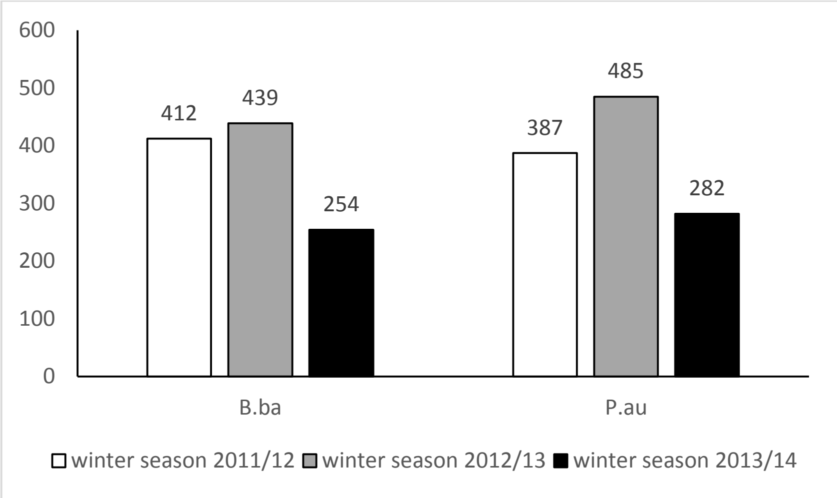

Figure 10. The numbers of *Barbastella barbastellus* and *Plecotus auritus* in control areas 7 and 8 in Natura 2000 site Nietoperek in the three consecutive winter seasons.

The numbers of these species showed in Fig. 11 indicate the maximal numbers recorded of 49 individuals of Bechstein's bat and the less numerous for Serotine bat with 4 individuals (Tab.4). Due to the big fluctuations in number of bats during the three winter seasons analysed of these less numerous species it is very difficult or impossible to estimate any trends. Must be mentioned that *Myotis bechsteinii* it is a very rare species in Poland and in EU so the sample size will always be small.

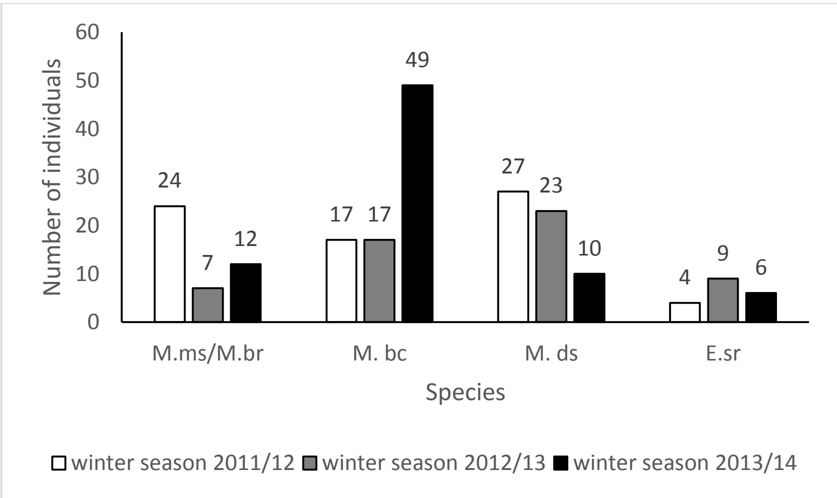

Figure 11. The numbers of *Myotis mystacinus* & *Myotis brandtii*; *Myotis bechsteinii*, *Myotis dasycneme* and *Eptesicus serotinus* in control areas 7 and 8 in Natura 2000 site Nietoperek in the three consecutive winter seasons.

Table 4. Total numbers of individuals per species recorded in three consecutive winter seasons 2011/2012 – 2013/2014.

	M.myo	*M.dau*	*M.nat*	*B.ba*	*P.au*	*M.ms/M.br*	*M.bc*	*M.ds*	*E.sr*	Indet.
W. season 2011/12	5752	2905	1114	412	387	24	17	27	4	66
W. season 2012/13	7453	3278	1533	439	485	7	17	23	9	63
W. season 2013/14	8809	2950	1438	254	282	12	49	10	6	43

3.2. Intra-seasonal changes in bat numbers

The bat numbers in the studied sections (7 and 8) keeps increasing constantly from October to November (season 2012/13) or December (2013/14), were it reached the maximal numbers and later constantly decreased till April. In the first winter season (2011/12) the maximal number of all bat species was recorded in December (2146 individuals), in the second season in November (2597 individuals) and in the third season in December again (3200 individuals). The results showed the same pattern of number changes in every season but the largest number was reached in different month, twice in December and once in November. Furthermore during three analyzed seasons the constant increase of total bat numbers recorded in all months (from 10708 ind. in the first to 13854 ind. in the last winter season) was recorded (Fig.12). Monthly numbers used for this graph are included into Annex I.

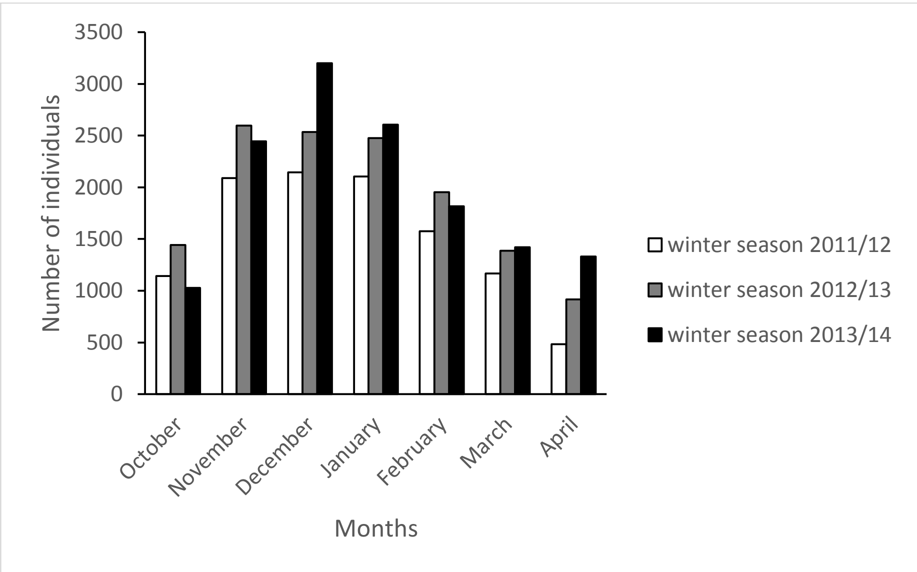

Figure 12. Total bats numbers in control areas 7 and 8 in Natura 2000 site Nietoperek in three consecutive winter seasons 2011/2012 – 2013/2014.

The number of individuals of *Myotis myots* rises constantly from October to November (season 2011/12) or December (2013/14) and then slowly decrees till April (2011/12). A significant decreasing of individuals in the second season from 1557 ind. in November to 1277 ind. in December was visible. Then on January the numbers slightly increased (1310 ind.) again for starting constantly declining till April. The third season was very atypical because the number of bats increased till December, then slowly declined till February (1087 ind.) and finally in March and April they increased again (1073 and 1310 respectively). The maximal numbers of season 2011/12 and 2012/13 were in November (1235 and 1557 ind. respectively). On the other hand for season 2013/14 this highest numbers were noted in December (1839 ind.) (Fig.13).

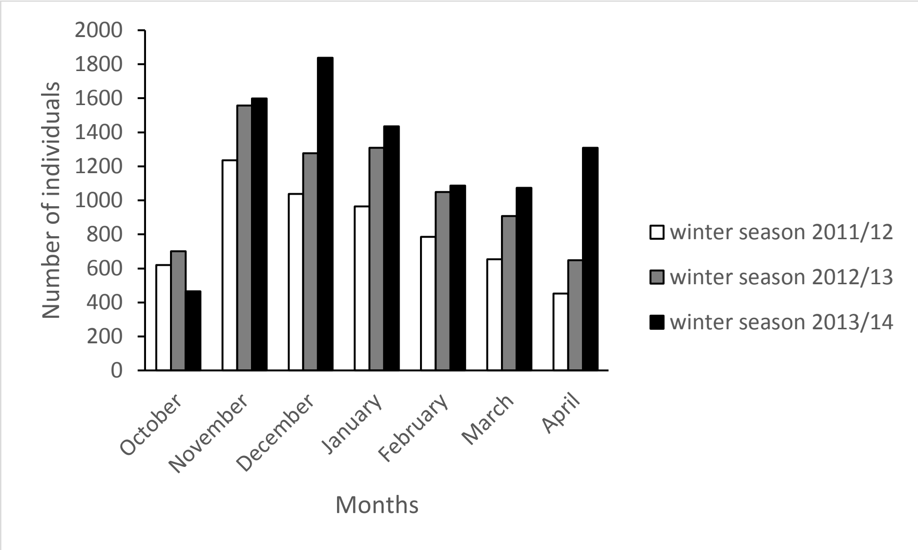

Figure 13. Number of individuals of Greater mouse-eared bat (*Myotis myotis*) in control areas 7 and 8 in Natura 2000 site Nietoperek in three consecutive winter seasons 2011/2012 – 2013/2014.

The number of individuals of *Myotis daubentonii* increases from October to November and then slowly decrees till April. This patron is followed in the three consecutive winter seasons analysed. In the first winter season the maximal number of bats was 673 individuals, the second 720 individuals and the last one 640 individuals. The December (2013/14) has 3 more individuals than November which could be caused by an error of counting them in a cluster (Fig.14).

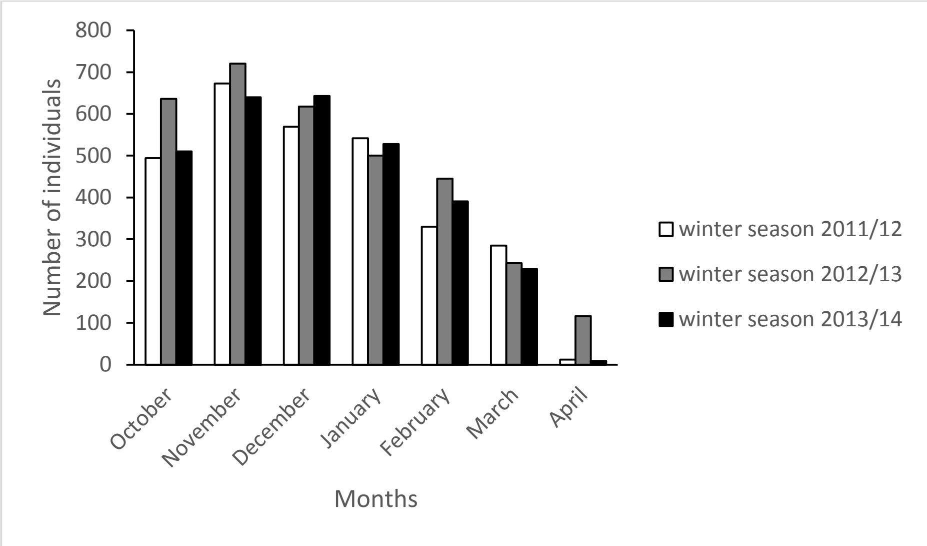

Figure 14. Number of individuals of Daubenton's bat (*Myotis daubentonii*) in control areas 7 and 8 in Natura 2000 site Nietoperek in three consecutive winter seasons 2011/2012 – 2013/2014.

The numbers of *Myotis nattereir* increases constantly from October to December and then decrees till April. This patron is followed for the three winter seasons. Maximal numbers of all winter seasons were in December (325 individuals in 2011/12, 388 ind. 2012/13 and 500 ind. 2013/14) (Fig.15).

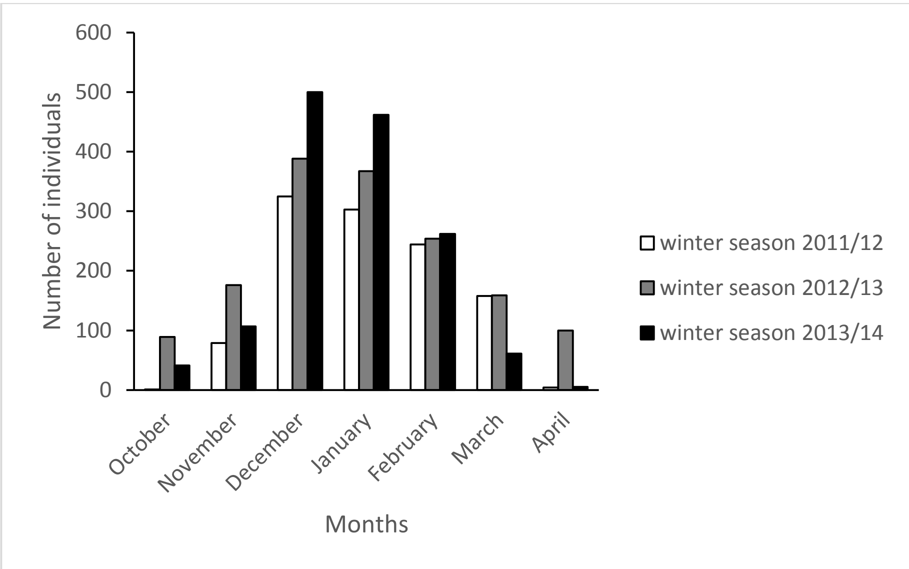

Figure 15. Number of individuals of Natterer's bat (*Myotis nattereri*) in control areas 7 and 8 in Natura 2000 site Nietoperek in three consecutive winter seasons 2011/2012 – 2013/2014.

Numbers of *Barbastella barbastellus* in winter seasons 2011/12 and 2012/13 increases slowly from October to January and then decrees till April. Season 2013/14 was atypical and less bats were censed. Maximal numbers were in January for the two first seasons (151 individuals and 142 ind. respectively). Third season maximal numbers were in December with 92 individuals which were 4 bats more censed than in January (88 ind.) (Fig.16).

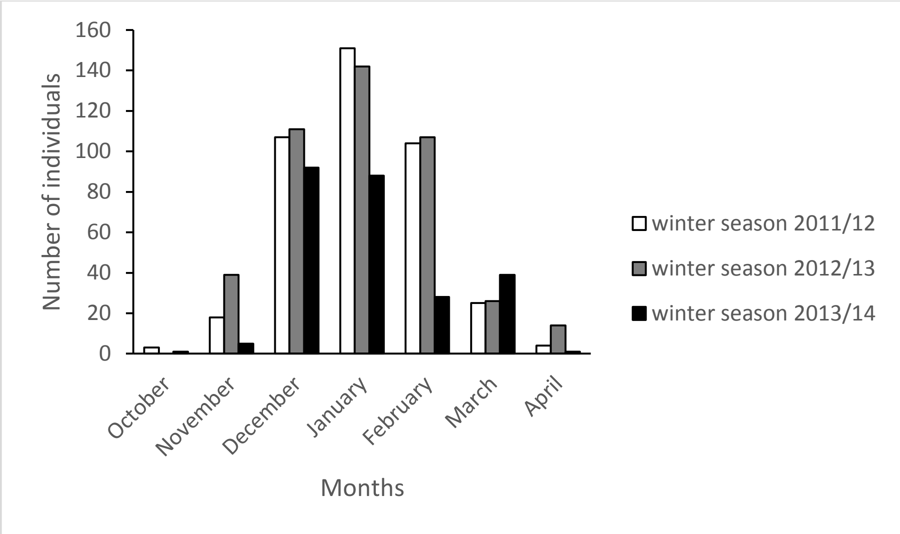

Figure 16. Number of individuals of Western barbastelle (*Barbastella barbastellus*) in control areas 7 and 8 in Natura 2000 site Nietoperek in three consecutive winter seasons 2011/2012 – 2013/2014.

The numbers of *Plecotus auritus* increases from October to January (seasons 2011/12 and 2012/13) or December (season 2013/14) were they reach the maximum, and then slowly decrees till April. Maximal numbers were 120 individuals (2011/12) and 138 ind. (2012/13) in January and 99 ind. (2013/14) in December. The first and the last month there are few of them, less than 20 individuals (Fig.17).

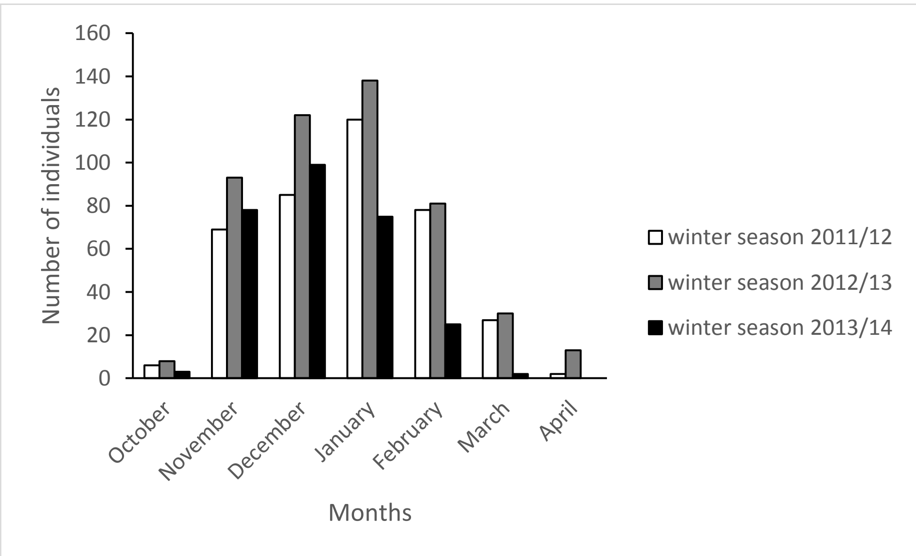

Figure 17. Number of individuals of Brown long-eared bat (*Plecotus auritus*) in control areas 7 and 8 in Natura 2000 site Nietoperek in three consecutive winter seasons 2011/2012 – 2013/2014.

The numbers in winter season 2011/12 are more or less constant, from 3 to 1 individuals, every month with the exception of January were 9 individuals were recorded. In 2012/13 the numbers were constant of 1 individual from October to December or 2 ind. from March to April excepting January and February were no one was found. The season 2013/14 a maximum of 4 individuals were found in October, 3 individuals during November and December and 1 individual in January and March. The month February and April no bats were found (Fig.18). In my opinion the number of recorded individuals was not large enough to determine the pattern, during winter season, of this two species.

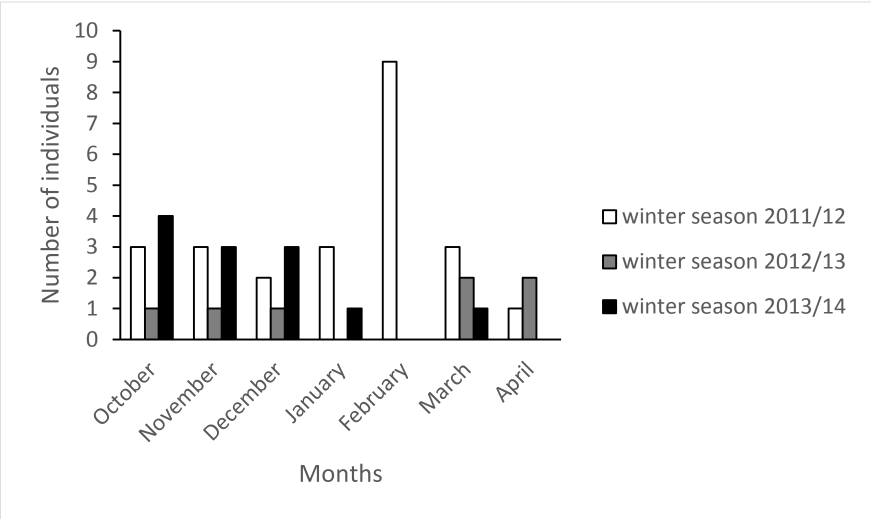

Figure 18. Number of individuals of Whiskered bat (*Myotis mystacinus*) / Brandt's bat (*Myotis brandtii*) in control areas 7 and 8 in Natura 2000 site Nietoperek in three consecutive winter seasons 2011/2012 – 2013/2014.

In winter season 2011/12 the numbers of *Myotis bechsteinii* increases from December to January and decreases till April, in season 2012/13 it keeps constant since October, between 1 and 2 individuals, till March and finally decrease in April. In winter season 2013/14 numbers increase from October to January and then decrease till March/April (same numbers). Maximal number of individuals were in January, 7 individuals in 2011/12 and 12 ind. in 2013/14, and March 5 individuals in 2012/13. It is possible to see the pattern of this species in winter seasons 2011/12 and 2013/14; slowly increases since October, reaches the maximum in January and decreases to March were it keeps constant till April (Fig.19).

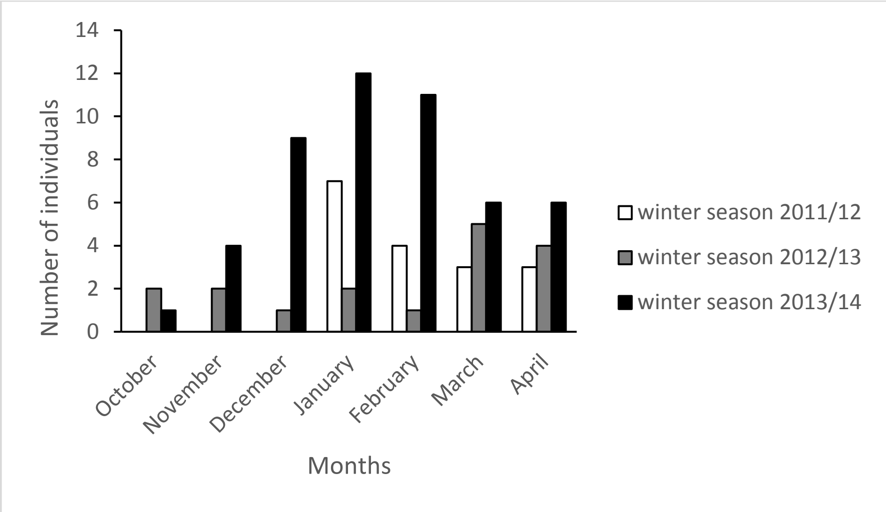

Figure 19. Number of individuals of Bechstein's bat (*Myotis bechsteinii*) in control areas 7 and 8 in Natura 2000 site Nietoperek in three consecutive winter seasons 2011/2012 – 2013/2014.

The first winter season had a maximum of 6 individuals in February, the second season had the maximal number in April (5 individuals) and the third season had a maximum of 3 bats in February again (Fig.20). The results are insufficient for seeing this bats pattern during winter season.

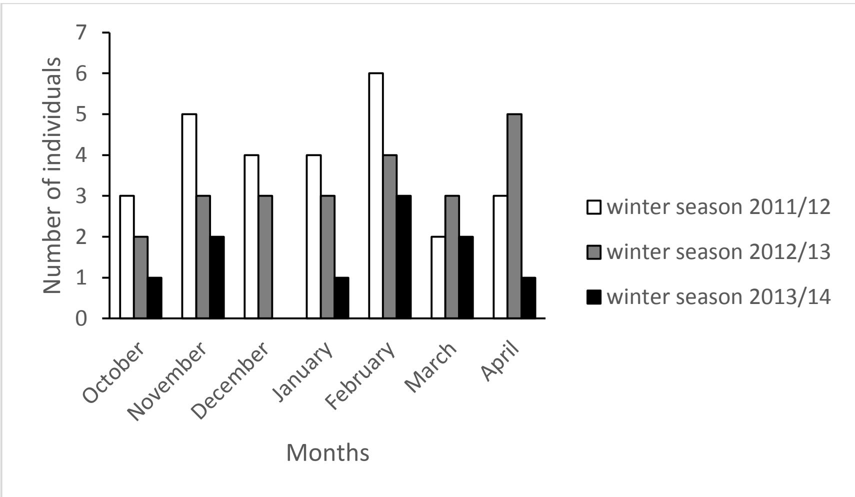

Figure 20. Number of individuals of Pond bat (*Myotis dasycneme*) in control areas 7 and 8 in Natura 2000 site Nietoperek in three consecutive winter seasons 2011/2012 – 2013/2014.

Numbers of *Eptesicus serotinus* in 2011/12 were 1 individual November, December, February and March, in January and April no individuals were found. Season 2012/13 had a maximum of 2 individuals in November, March and April and 1 individual from December to February. Season 2013/13 had 2 individuals in February, 1 individual in

October, November, January and March and zero in December and April (Fig.21). This bats censed were probably the same individuals each month. The population of Serotine bats in Nietoperek is too small to describe the dynamics of this species during winter season.

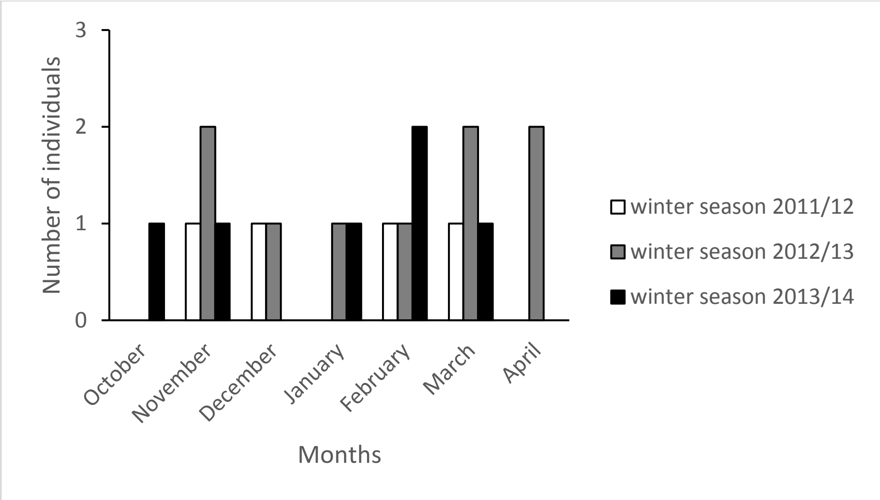

Figure 21. Number of individuals of Serotine bat (*Eptesicus serotinus*) in control areas 7 and 8 in Natura 2000 site Nietoperek in three consecutive winter seasons 2011/2012 – 2013/2014.

3.3. Tourist subsections

The subsections visited by the tourists are: 7.9.1, 7.9.2 and 7.8. Number of bats in this subsection decreased slowly from winter season 2011/12 with 113 individuals to winter season 2013/14 with 84 individuals. The subsection 7.9.1. was the first to be opened for winter tourism, entrance bunker PzW 717, in 2009 which involved painting the walls, putting lights and drying wet areas besides the constant noise and disturbance by people. There was not presence of *Myoits myotis*, *Barbastella barbastellus*, *Myotis mystacinus*/ *brandtii*, *Myotis dasycneme* and *Eptesicus serotinus*. The number of *Myotis nattereri* was the biggest one but decreased from 83 individuals in the first to 56 in third winter season. *Myotis daubentonii* numbers kept more or less constant around 18 individuals and 6 individuals of *Plecotus auritus* were found in the first and third winter season and 1 in the second. Three individuals of the high protected *Myotis bechsteinii* were found the first winter season and one the second and the third. (Fig.22 and Tab.5).

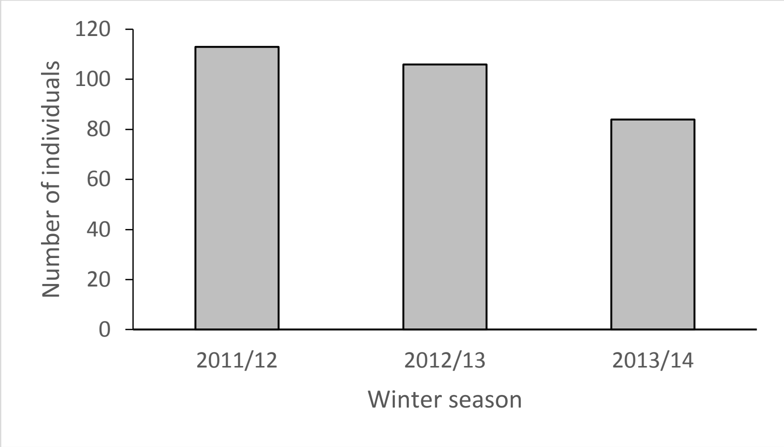

Figure 22. Number of bats in subsection 7.9.1. during three consecutive winter seasons (2011/12-2013/14) in Natura 2000 site Nietoperek.

Table 5. Number of individuals per species in subsection 7.9.1. each winter season.

Winter season	*M.myo*	*M.dau*	*M.nat*	*Ba*	*P.au*	*M.ms/M.br*	*M.bc*	*M.ds*	*E. sr*
2011/12	0	19	83	0	6	0	3	0	0
2012/13	0	15	89	0	1	0	1	0	0
2013/14	0	20	56	0	6	0	1	0	0

Numbers of bats in this subsection decrease from 53 individuals to 20 ind. in seasons 2011/12 and 2013/14 respectably. The subsection was available for winter tourism in 2012. The most numerous species found in this subsection was *M. daubentonii* with 29 individuals in the first season and 9 in the third. The number of *M. myotis* was 18 individuals in the first winter season and 7 in the third. The number of *M. nattereri* kept constant with 3 bats every season. A maximum of 3 individuals of *P. auritus* were recorded in the second season. Finally, there was presence of 1 individual of *M. bechsteinii* and 2 of *M. dasycneme* in the first winter season, the third season none of this species was found (Fig.23).

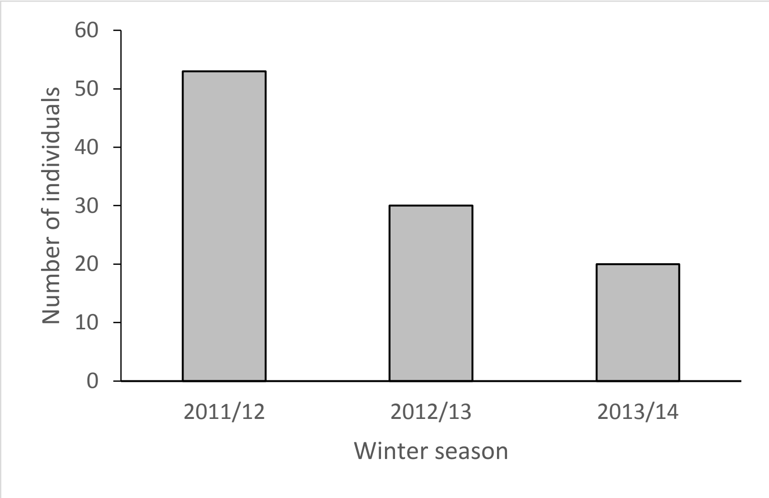

Figure 23. Number of bats in subsection 7.9.2. during three consecutive winter seasons (2011/12-2013/14) in Natura 2000 site Nietoperek.

Table 6. Number of individuals per species in subsection 7.9.2. each winter season.

Winter season	*M.myo*	*M.dau*	*M.nat*	*Ba*	*P.au*	*M.ms/M.br*	*M.bc*	*M.ds*	*E. sr*
2011/12	18	29	3	0	0	0	1	2	0
2012/13	9	13	3	0	3	0	1	1	0
2013/14	7	9	3	0	1	0	0	0	0

Bats numbers increase from 568 individuals in 2011/12 to 641 ind. in 2013/14 and then decrease to 476 ind. in 2013/14. This subsection it is not open to winter tourism but it is connected to the subsection 7.9.2. where people go across (Fig.24).

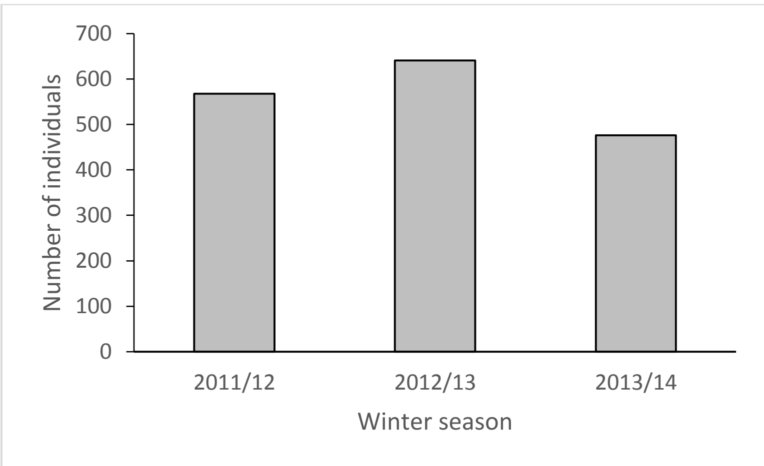

Figure 24. Number of bats in subsection 7.9.3. during three consecutive winter seasons (2011/12-2013/14) in Natura 2000 site Nietoperek.

Numbers of bats in subsection 7.10 decrease from 61 individuals the first winter season to 43 the second season. The third winter season had 43 individuals. This subsection it is not available for winter tourism but the tunnel is connected to subsection 7.9.2. which it is visited. The third winter season it was noticed a repainting of the walls and the installation of lights along the corridor (Fig.25).

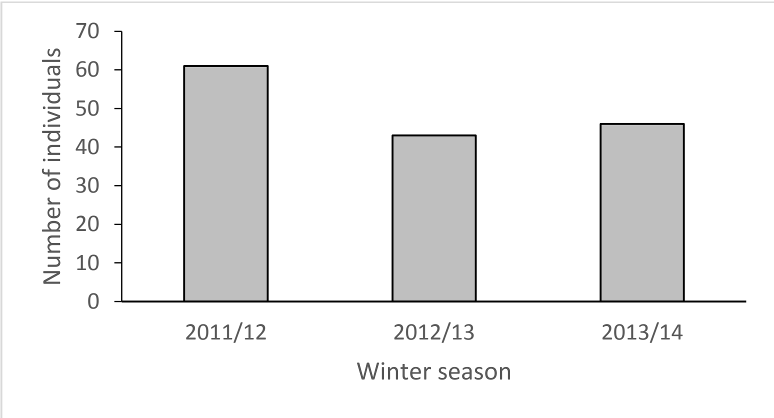

Figure 25. Number of bats in subsection 7.10. during three consecutive winter seasons (2011/12-2013/14) in Natura 2000 site Nietoperek.

The number of bats in this subsection increase from 56 individuals (2011/12) to 67 ind. (2013/14). The most numerous species was *M. myotis* that increased from 26 individuals in the first season to 45 in the third. The number of *M. daubentonii* kept stable with a mean of 22 individuals per season. Only one *M. nattereri* was recorded in this subsection. Three individuals of *B. barbastellus* were found the first season and a maximum of 10 individuals of *P. auritus* in the second season. The subsection was opened to winter tourism in 2012 and for the moment no light is present in it. In near future it is expected a decrease of number of bats in this subsection caused by tourism pressure. The bat numbers there should be carefully monitored in next winter seasons (Fig.26).

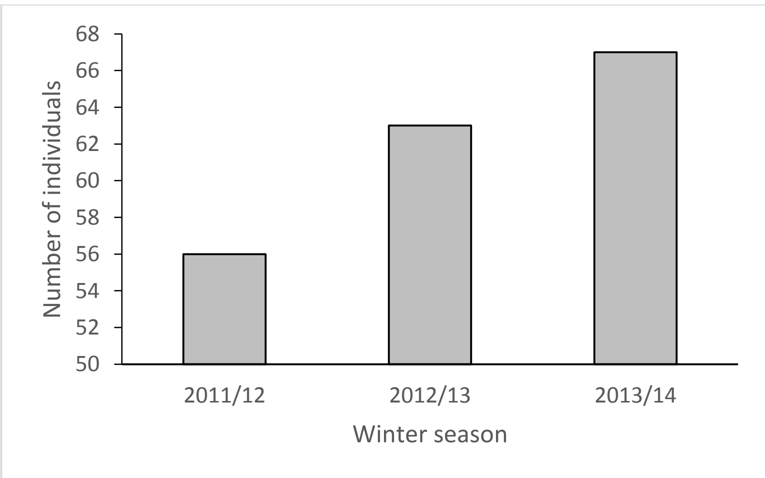

Figure 26. Number of bats in subsection 7.8. during three consecutive winter seasons (2011/12-2013/14) in Natura 2000 site Nietoperek.

Table 7. Number of individuals per species in subsection 7.8. each winter season.

Winter season	*M.myo*	*M.dau*	*M.nat*	*Ba*	*P.au*	*M.ms/M.br*	*M.bc*	*M.ds*	*E. sr*
2011/12	26	24	1	3	1	0	0	0	0
2012/13	29	22	0	1	10	0	0	0	0
2013/14	45	20	0	0	2	0	0	0	0

Number of bats decrease from 250 individuals (2011/12) to 105 ind. (2012/13) and then increase to 142 ind. (2013/14). This subsection is a small part of the main railway that connects all the bunkers and it is not visited by tourists (Fig.27).

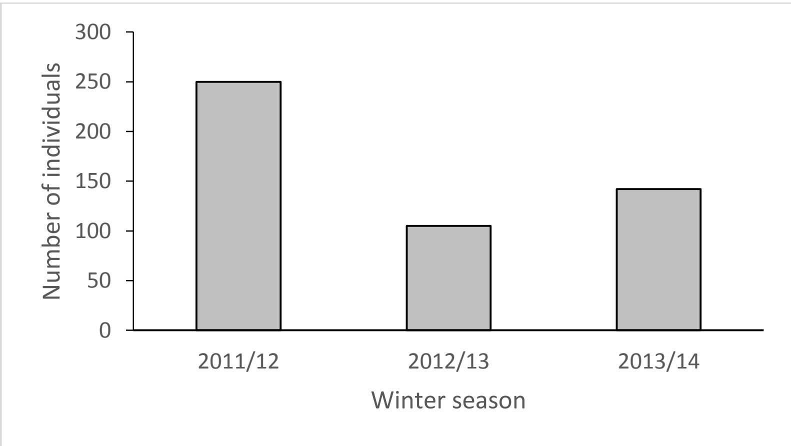

Figure 27. Number of bats in subsection 7.11.1. during three consecutive winter seasons (2011/12-2013/14) in Natura 2000 site Nietoperek.

4. DISSCUSSION

The results in the graph of total bat numbers (Fig.12) showed the same pattern of number changes in the three consecutive analyzed winter seasons; constantly increasing from October to January (1975/76) or December (1976/77) and decreasing till April, described by Bagrowska-Urbańczyk & Urbańczyk (1983) in one corridor (1,5 km long) in Nietoperek (Section 6 see Fig.5).

Starting from 1999 the main census is taking place in the middle of January. The reason was that it is the coldest month in the Polish winter and we could expect the largest numbers of bats. Results from the season (2011/12 and 2012/13) shows that for *Myotis* *myoits* the best month for estimation of maximal population number should be done in November instead of January (Fig.13). My conclusion do not match with the one described by Bagrowska-Urbańczyk & Urbańczyk (1983); they saw that population of *M. myotis* was bigger in January of 1976 and April of 1977. This differences could be because my studied area was larger, ca. 13,5km, and his was 3km. Another explanation could be the constant increasing of *M.myotis* population in Nietoperek. Since 1976, maximum of 249 individuals, the numbers of this species has continued increasing till 2014, maximum of 1839 individuals.

In the third season (2013/14) was observed a completely different pattern of dynamics with a peak in April (Fig.13). This result was caused by increase of number of *M. myotis* in subsecrtion 7.2 (Fig.6a) where bats increased from 196 individuals in March to 853 ind. in April. The subsection 7.2 is a very wet corridor, partly flooded by water and connected with two bunker entrances (PzW 719 and PzW 720 - see Annex I, part B, Fig.2a). In the end of hibernation bats are choosing places with high relative humidity to minimize the water body loss during arousals from hibernation torpor (Boratyński et al. 2012). Additionally this place make possible for bats to leave undergrounds for foraging which starts in April. In conclusion this peak in April is an artifact probably caused by *M. myotis* (Fig.28) movements from other parts of the system to subsection 7.2 because of better environmental conditions with high relative humidity and also for the vicinity to the entrances.

Figure 28. Greater mouse-eared bat (*Myotis myotis*) the biggest bat found hibernating in Nietoperek (Photo by Jordi Camprodon).

Myotis daubentonii hibernates in high numbers in undergrounds of Central and Eastern Europe (Strelkow 1971, Haitlinger 1976, Bogdanowicz 1983, Degn 1987) and it prefers large undergrounds (Bagrowska-Ubrańczyk & Ubrańczyk 1983). Nietoperek bat reserve fits perfectly in this hibernation site descriptions. Data from the Szachownica Cave (Central Poland) indicate an upward trend of *M. daubentonii* populations which was reported earlier from other countries: Netherlands (Daan 1980), Czechoslovakia (Bárta et al. 1981, Červeny & Bürger 1990), Germany (von Helversen et al. 1987, Weinreich & Oude Voshaar 1992) and also from the hole Poland (Urbańczyk 1989, Kokurewicz 1995). Recently this trend has been less marked, at least in Poland, in areas situated near Warsaw and Bialystok (200–300 km NE from the Szachownica Cave) (Fuszara et al. 2010). Number of *M. daubentonii* have been reduced from 17000 individuals in 1991 to ca. 7000 ind. in 2005 in Nietoperek bat reserve (Sachanowicz and Ciechanowski 2005) . In other European countries, on the other hand, the numbers of Daubenton's bat have been rising since 1993 to 2011 and the general trend was described as moderate increase (European bat population trends 2013). The maximal number recorded in Nietoperek was 3278 individuals during winter season 2012/13 which it is less bats compared with data from two previous authors cited (Tab.4). In conclusion, our graph do not show this decline because we only have the data for three winter seasons, but we know that exists comparing data analysed from 1991 to 2014. Furthermore for estimation of maximal population number of this species we suggest that the best month for do it is November.

M. daubentonii feed on non-biting midges (Diptera: *Chironomidae*) (Kokurewicz 1995). This Chironomid larvae feed on organic matter which cumulates in sediments and the imaginal stage lasts from several hours to a few days. The time of emergence of non-biting midges depends on many factors but it is almost completely inhibited during periods of rain and cold (Sjoeberg & Danell 1982). Species belonging to Chironomini usually emerge at dusk or at night. The pollution of waters by organic matter in cities and the channelization seems to be the ideal situations for chironomids to emerge. The eutrophication of surface waters causes more favourable trophic conditions and therefore more individuals of *M. daubentonii* can reach sexual maturity in the first year of life (Kokurewicz & Bartmańska 1992). The recent purifying of waters in Poland, due to EU regulations, might causes a less eutrophication of this areas and due to that non-biting midges population have been decreasing (Kokurewicz 1995). This could be a good hypothesis worth to keep investigating as one of the factors that have influenced negatively on *M. daubentonii* population causing a decline of this species in Poland since 1991. On the other hand Fuszara et al. (2010) do not suppose that this decline was caused by a decrease in the abundance of this insect or other prey, but if the downward trend continues, such hypothesis may become worth investigating. However it is known that in other parts of the country we have a slight upward trend of *M. daubentonii* population in Szachownica Cave (central Poland) till 2010 (Lesiński et al. 2011). That could indicate that this correlation it is not as strong as it seems and that more studies should be carried on in this species.

Probably the best way to clarify this situation would be a study of the local summer activity of the species. Its results could show if the decrease in the number of hibernating bats is caused by some individuals choosing other winter roosts or if the local population is actually declining (Fuszara et al. 2010).
The predation of martens (*Martes martes* and *M. foina*) could be another explanation for *M. daubentonii* decline in Nietoperek. During my study I noticed that the species which hibernates in the lowest height, sometimes less than one meter, was *M. daubentonii*. This fact makes this species more prone on predation by martens (Kokurewicz 2004, Power et al. 2012).
Finally, the presence of *Geomyces destructans* (= *Pseudogymnoascus destructans*) the fungi responsible of White Nose Syndrome (WNS) have been detected in Nietoperek in winter season 2013/14 (Kokurewicz, Matkowski, Ogórek & Pusz. In preparation). White-nose syndrome (WNS) is an emergent disease of hibernating bats that has spread from the northeastern to the central United States at an alarming rate. This fungi comes from Europe where bats are immune to it. Since the winter of 2007-2008, millions of insect-eating bats in 25 states and 5 Canadian provinces have died from this disease. The disease is named for the white fungus that infects skin of the muzzle, ears and wings of hibernating bats. In April 2014, WNS was confirmed in Michigan and Wisconsin (Source: National Wildlife Health Center http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/, Modified).
The study made in years 2010-2012 by use of standard protocol of sampling of fungi from bat's muzzles by Scotch tape and examining the spores under the microscope did not prove the existence of WNS in Nietoperek. The presence of the fungus do not strictly implicates that is causing WNS. This problem is interesting and requires more detailed study focus on this single species *M. daubentonii*.

M. nattereri are reaching the maximal numbers in December and following the same pattern every winter season analysed. Due to that the best month for doing this species census should be in December. Furthermore during this three winter periods the trends of Natterer's bat was stable with total numbers being 1114, 1533 and 1438 respectively. In Nietoperek bat reserve, the largest Polish hibernaculum, the number of wintering Natterer's bats grew by 30% in the period 1985–1989 (Urbańczyk 1989). In this roost the increase continued at least until 2007 at an average rate of 160 individuals per year (T. Kokurewicz, personal communication). Finally the population of this species have shown a similar increasing trend also in other parts of Poland (Fuszara et al. 2010).

The Western barbasetlle (*Barbastella barbastellus*) (Fig.29) is an endangered European bat species protected by European law under the Habitat Directive 92/43/EEC of Annex II. It is listed as 'vulnerable' under the IUCN Red List of Threatened Species. It is a forest-dwelling species and a highly specialised predator of small moths in deciduous or mixed forests and cultivated lands (Hillen et al. 2009).

This species selected similar roost habitats in other study areas across Europe (Dietz et al. 2007). However, the occurrence of the species seems not to depend on a specific forest type (e.g. deciduous, mixed or coniferous forest – Spitzenberger 1993, Steinhauser 2002, Russo et al. 2005, Hillen et al. 2009). Number of *B. barbastellus* in bunkers is affected by outside thermal conditions during the hibernation period. The MFF have areas very destroyed with many openings in it that cause intensive air circulations and temperature changes. Even when the outside temperature increases for a short time in winter, there is only small reflection in change of thermal conditions in bunkers, probably due to a high level of thermal inertia inside the fortifications (Sachanowicz & Zub 2002). Lower temperatures at hibernation sites favour *B. barbastellus*, which prefers cold sites (Harmata 1969, 1973, Urbańczyk 1991, Sachanowicz & Zub 2002), with temperature ranging from -1 °C to 4 °C (Kowalski & Ruprecht 1981, Bogdanowicz & Urbańczyk 1983, Lesiński 1986, Řehák 1992).

Individuals appeared in Nietoperek when mean monthly temperature dropped below 0 °C (during December, January and February) and emerged when the air temperature increased above 0 °C (in March and April – Tab.3). Similar pattern was shown by Kozakiewics & Strzałka (1996) in the cave Dolina Będkowska (Krakow) for *B. barbastellus* and *P. auritus* during winter seasons 1993/94 - 1994/95.

Figure 29. Solitary Western barbasetlle (*Barbastella barbastellus*) in MFF undergrounds (Photo by Laura Torrent).

The number of individuals of Western barbastelle was reduced from 412 individuals in 2011/12 season to 254 ind. in 2013/14 season (Tab.4). This decreasing could be caused by the unusual milder temperatures during this third winter period i.e. mean temperatures of 2 and 3 °C in January and February 2014 respectively (Tab.3). Lesiński et al. (2005) declare that in warmer years, this species is reluctant to come to hibernacula and easily abandons them as soon as temperatures rise in spring. On the other hand, this fluctuations in the number of hibernating Western barbastelles could not be easily attributed to differences in weather conditions (e.g. Fuszara & Fuszara 2002, Fuszara et al. 2002). A further difficulty in interpreting the results is the lack of temperature data from inside the hibernacula (Fuszara et al. 2010). A big compilation of winter season data of monthly bat census and all the temperatures inside and outside Nietoperek should be needed for being able to define if this correlation exists. Furthermore, despite the well protection of MFF, lock entrances and regulation of tourism to the system, human disturbance it is still present, so we cannot exclude the possibility that bats were occasionally bothered from their shelters or were forced to retreat to deep crevices where they could not be censed. This could explain that during the 2013/14 season maximal numbers were in December with 92 individuals which were 4 bats more than the next month (88 ind.) (See Annex I, Part A, Tab.5). This small difference could be caused by their movements, due to the disturbance, to other places or deep cracks or also a human error during the census.
Moreover, Western barbastelle have pointed wings, making them aerial insectivores that are able to forage in open space and at forest edges (Norberg & Rayner 1987, Sierro 1999, Steinhauser 2002). Maximal numbers of this species were concentrated in subsections 8.1.1 and 8.8.2 during December, January and February (Fig.6b and Fig.16). This two subsections are connected with PzW 783 and 713 entrances respectively. The fortress plots are composed of forests, and spacious fields are very near, which are the perfects foraging areas for *B. barbastellus* (Annex I, Part B, Fig.3).

Harmata (1985) proved that the average time in *Plecotus auritus* measured since awakening till the moment it is able to fly was 38 min at 3,5 °C which was the shortest time comparing the results with *Rhinolophus hipposideros* and *Myotis myotis* that needed 52 min at 5,5 °C and 49 min at 3,5 °C respectively. In all three species studied the time of awakening from hibernation depends on air temperature in winter habitat, body temperature and thermopreferendum (Harmata 1985). Brown long-eared bat (*Plecotus auritus*) is also a cold-dwelling species so we suggest that the decreased in number of individuals, from 387 in season 2011/12 to 282 in season 2013/14 (Tab.4), might be for the milder winter temperatures (Tab.3). This species can hibernate in less

isolated buildings or in trees. Due to that, this constant decreasing of individuals since January to March 2014 could be caused by this species migration to bunkers or trees less isolated in the vicinity of the entrances to MFF. Furthermore this species forage in forests (*Plecotus auritus*: Entwistle et al. 1996) close to the vegetation or the ground (Kerth 2009).
Finally we suggest January for doing the census of this two cold-dwelling species - *Barbastella barbastellus* and *Plecotus auritus* – because maximal number were recorded in this month (Fig.16 and Fig.17).

During the winter seasons census to minimize bats disturbance they are not touched, due to that, identification without handling this two species: *Myotis brandtii* and *Myotis mystacinus* it is not possible. *Myotis mystacinus* it probably more frequent in central and southern Poland (Ignaczak et al. 2001, Lesiński & Gwardjan 2001) but seems to be rare everywhere in the country, except of the Tatra Mountains, where it is the most numerous species in cave bat assemblages and its largest hibernacula are located (Piksa 1998, Piksa & Nowak 2000). *Myotis brandtii* seems to be much more numerous in some part of the country than previously thought, particularly in the woodlands of central and eastern Poland (Kowalski et al. 1996, Ignaczak et al. 2001, Sachanowicz & Ruczyński 2001). Also it is known to hibernate in small numbers in several Polish sites (e.g. Furman kiewicz & Furmankiewicz 2002, Szkudlarek et al. 2002).

Bechstein's bats (*Myotis bechsteinii*), like *B. barbastellus*, are among the most threatened European bats and are listed in the European FFH-directive and the IUCN conservation action plan to be of high priority (Hutson et al. 2001, Dietz et al. 2007). Furthermore, despite the small number of individuals censed during this three winter seasons, a maxim of 12 bats in January 2014, it is important to mention that the largest Polish hibernaculum of Bechstein's bats is in Nietoperek bat reserve, where up to 24 individuals were counted (Sachanowicz & Ciechanowski 2005). Due to this reasons it is crucial to keep the protection of Nietoperek bat reserve for the future conservation of *M. bechsteinii* in the region and the whole country.

The population and distribution of Pond bat (*Myoits dasycneme*) in Poland is poorly known. For the moment only in two sites have been found breeding colonies. Many areas that are potentially attractive for breeding populations of pond bat have not yet been surveyed, suggesting that the species in Poland may be much more common and numerous than previously thought (Ciechanowski, Sachanowicz & Kokurewicz, 2007). The presence of this globally vulnerable and nationally endangered species, included in

Appendix II of the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC), increases the value of Nietoperek and the importance of keeping bats protection.

A maximum of 2 individuals of Serotine bat (*Eptesicus serotinus*), probably the same each month, have been found during the three winter season census. This species hibernates in roosts singly or in small numbers which could explain the small number of individuals found in Nietoperek. Serotine bats are one of the most numerous species in summer in Poland (Ruprecht 1983), in winter they are rarely encountered in underground hibernacula (e.g. Jarzembowski et al. 2000, Postawa & Zygmunt 2000, Lesiński et al. 2001b), only locally being more numerous in bunkers (Sachanowicz & Zub 2002). The roosts are usually in fairly cold, dry sites (IUCN: http://www.iucnredlist.org/details/7911/0). In conclusion having few of them in Nietoperek increases the value of the place.
To summarize, we do not have enough individuals of the less common species; *Myotis mystacinus* & *Myotis brandtii*; *Myotis bechsteinii*, *Myotis dasycneme* and *Eptesicus serotinus*, during this three winter seasons in Nietoperek to see the trends that this bat species have within hibernation period.

Subsection 7.9.1 was opened to the winter tourism in 2009 and subsections 7.9.2 and 7.8 in 2012. There have been noticed a decline of 29 individuals in 7.9.1, in subsection 7.9.2 a decline of 33 ind. and in 7.8 an increase of 11 bats between winter season 2011/12 and 2013/14.
Although infrequent and short, arousals represent the largest depletion in energy reserves for bats during the hibernation periods (Thomas and others 1990). Nontactile disturbance associated with human visitation such as noise, light and changes in microclimate, can cause a dramatic increase in bat arousals and flight activity (Olson, Hobson & Pybus 2011). Peak activity of this two American species; Little Brown Myotis (*Myotis lucifugus*) and Northern Myotis (*Myotis septentrionalis*) in the study by Thomas (1995) occurred 1.0 to 7.5 hours after the initial disturbance, when human visitors were no longer present. Thus, even seemingly benign visits to caves may result in substantial energy depletions, possible starvation, or inadequate energy reserves for reproduction the following season (Thomas 1995, Kunz and others 1998).
Olson, Hobson & Pybus (2011) support the hypothesis that reduced disturbance explains, in part, the increase in census results.
Fuszara et al. (2010) declared that adding summer monitoring surveys to the existing winter ones is necessary to get a complete picture of bat population status.

5. CONCLUSIONS

1- Results indicated that the best period for counting maximal numbers of *M. myotis* and *M. daubentonii* is November, for *M. nattereri* is December and for *B. barbastellus* and *P. auritus* is January.
2- The study undertaken in the part visited by tourists in winter (total length of 900 m) proved negative effect caused by human disturbance with 23% decline of total bat numbers. We suggest to consider stopping winter tourism and keeping the actual conditions of the underground without more reforms.
3- *Myotis myotis* population keeps increasing and *Myotis daubentonii* numbers still decreasing every winter season.
4- A significantly decrease during the third season 2013/14 of *Barbastella barbastellus* and *Plecotus auritus* may be caused by milder winter temperatures which allows this species to roost in places less isolated from temperature changes i.e. three holes and/or bunkers.
5- The presence of individuals of *Myotis myotis*, *Barbastella barbastellus*, *Myotis dasycneme* and *Myotis bechsteinii* which are included in Appendix II of the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) increase a lot the importance of keeping the protection of bats in Nietoperek.
6- A constant monitoring of the numbers of bats in winter roosts may help to detect population changes in the future without delay. In the case of a dramatic drop, this may allow more time for the identification of its cause and to give time to increase the level of protection in bat hibernation sites under threat.

6. ACKNOWLEDGEMENTS

I would like to express my deep gratitude to my Polish bat ecologist Dr Tomasz Kokurewicz and my Catalan teacher Dr Jordi Camprodon, my research supervisors and friends, for their dedication and useful critiques and advises of this research work.
I would like to offer my special thanks to all Tomasz's colleagues and students: Dr Alek Rachwald, MSc Katarzyna Kozyra, MSc Dawid Zyskowski, MSc Piotr Piliczewski, MSc Aneta Zapart, MSc Tomasz Kliś, MSc Marcin Rusiński, MSc Grzegorz Apoznański, Ewa Kwasiborska and Tomasz Marszałek. Also assistance provided by Henry Schofield, John Haddow, Christiane Schmidt, Toni Belstedt and Jens Rydell was greatly appreciated.
Finally, I wish to thank my parents for their support and encouragement throughout my project.

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