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45 years of bat study and conservation in Nietoperek bat reserve (Western Poland)

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45 Jahre Fledermausforschung und Fledermausschutz im Fledermausschutzgebiet Nietoperek (West-Polen)

Abstract

The 100 km long Międzyrzecz Fortified Front, Ostwall or Festungsfront im Oder-Warthe Bogen, is located between the rivers Odra in the south and Warta in the north and was built by Germany in 1934 – 1944. The Central Sector "Wysoka" (Zentralabschnitt or Abschnitt Hochwalde), starting south of Staropole, and ending on the lake Kursko, only ca. 15 km long, was to have a concentration of fortifications. It is a system of concrete tunnels with a total length of ca. 32 km situated 20-30 m underground. The axis of the underground system called the "main road" has a narrow gauge railway and runs from north to south and includes 10 wider "railway stations" (Bahnhof), which allowed small electric trains to pass in opposite directions. The smaller side corridors connect the main road to above ground bunkers (Panzerwerk) situated on the eastern part of the fortification system. Currently the access for bats into the underground system is through 25 surface bunkers, through two drainage corridors located on the northern and southern ends of the tunnel system, and also via two ventilation shafts and a 1.43 km long side corridor ("Wysoka corridor", named after the nearest village) sloping upwards from the main corridor to the surface. The major part of the system has a stable microclimate, but a dynamic microclimate is found near the entrances of the system and in the Wysoka corridor. The drainage system of the underground was destroyed after the war, which resulted in flooding of parts of the northern tunnels while drying out the southern part of the system. The underground system provides a wide range of temperature and relative humidity (0 – 10°C and 40 – 100% respectively) for hibernating bats. The value of the underground system for bats was first discovered in 1974 by late Dr. Zbigniew Urbańczyk, Elżbieta Bagrowska-Urbańczyk, Prof. Wiesław Bogdanowicz and others. They started systematic studies of bats in 1975 and published the first short paper in 1976 (see the

selected literature below). So far 12 species have been found hibernating there and one more (the northern bat, *Eptesicus nilssonii*) regularly roosts in much cooler stand alone bunkers not connected with the underground system. According to the data of the EUROBATS Agreement it is ranked in top 10 largest hibernation sites in Europe. The numbers of hibernating bats exceeds 39 000 individuals in some years. In 2007 the Central Sector "Wysoka" (52°25'N, 15°32' E) with the surrounding surface area of 7377.37 ha became protected as Natura 2000 site PLH080003 "Nietoperek". Ringing data collected by bat ringing center (Fledermausmarkierungszentrale Dresden) evidenced that bats migrate to "Nietoperek" from the large area of Central European Lowlands. The longest migration distances of bats from eastern part of Germany to "Nietoperek" are 257 km for *Myotis daubentonii*, 226.7 km for *M. myotis* and 242.1 km for *M. brandtii*. The role of "Nietoperek" for bats is the best shown by the estimation of minimum area of migration of the bats, mainly greater mouse-eared bat (*Myotis myotis*), to that hibernation site. The minimal convex polygon (MCP) based on the recaptured individuals was estimated as at least 17 000 km^2 and covers large part of Land Brandenburg, Mecklemburg-Vorpommern, Sachsen-Anhalt and also western Poland (Lubuskie, Wielkopolskie and Zachodniopomorskie Voyvodeships). For these reasons, the protection of bats in the relatively small area of "Nietoperek" is of key importance for conservation of the population of at least nine species of bats in Central Europe. "Nietoperek" combines the best preserved military fortification system in Europe with a large bat hibernation site and its surrounding well preserved natural habitats, under protection of the European Ecological Network Natura 2000. This place is also a good example of international co-operation in bat conservation and its current favourable conservation status was established as a result of endeavours of bat workers from Poland, Germany, UK, Belgium, Holland and other EU countries. In this article we present the results of the bat monitoring programme carried out in "Nietoperek" since 1999, and also projects on the selection of microclimatic conditions by bats and the changes of microclimatic conditions underground, probably caused by global warming (the "logger project"), "White Nose Syndrome" study, a swarming project, predation by martens and raccoon on hibernating bats, a preliminary summer study, and finally projects on bat friendly tourist use of "Nietoperek", that will hopefully lead to a balance between bat conservation and increasing tourism in the fortifications.

Key words

bats, Nietoperek, Natura 2000, bat conservation, climate change

Zusammenfassung

Die 100 Kilometer lange Międzyrzecz-Festungs-Front, Ostwall oder Festungsfront im Oder-Warthe Bogen genannt, liegt zwischen der Oder im Süden und der Warthe im Norden und wurde 1934 - 1944 unter deutscher Besatzung erbaut. Der zentrale Sektor „Wysoka" (Zentralabschnitt oder Abschnitt Hochwalde), der südlich von Staropole beginnt und am nur ca. 15 km langen Kursko-See endet, sollte besonders mit Festungsobjekten versehen werden. Es handelt sich um ein System von Beton-Eisenbahntunneln mit einer Gesamtlänge von ca. 32 km in 20-30 m Tiefe. Die Achse des unterirdischen Systems „Hauptstraße" hat eine Schmalspurbahn und verläuft von Nord nach Süd und umfasst 10 breitere Bahnhöfe, die es kleinen Elektrozügen ermöglichten, in entgegengesetzte Richtungen zu fahren. Die kleineren Seitengänge verbinden die Hauptstraße mit oberirdischen Bunkern (Panzerwerk) im östlichen Teil des Befestigungssystems. Derzeit erfolgt der Zugang für Fledermäuse in das unterirdische System über 25 oberirdische Bunker, über zwei Entwässerungskorridore am

Fig. 1: Bunker PzW 716 – one of the entrances to the main underground system of „Nietoperek“ bat reserve.

Abb. 1: Bunker PzW 716 - einer der Eingänge zum unterirdischen Hauptsystem des Fledermausreservats “Nietoperek” (Foto: Jens Rydell).

nördlichen und südlichen Ende des Tunnelsystems sowie über zwei Lüftungsschächte und einen 1,43 km langen Seitenkorridor („Wysoka-Korridor“, benannt nach dem nächstgelegenen Dorf), der vom Hauptkorridor nach oben verläuft. Der größte Teil des Systems hat ein stabiles Mikroklima, aber ein dynamisches Mikroklima findet sich in der Nähe der Eingänge des Systems und im Wysoka-Korridor. Das Entwässerungssystem des Untergrundes wurde nach dem Krieg zerstört, was zu einer Überschwemmung des nördlichen Teils der Tunnel führte, während der südliche Teil ausgetrocknet ist.

Die untertägigen Bereiche bieten einen weiten Temperatur- und Luftfeuchtigkeitsbereich (0 - 10°C und 40 - 100%) für überwinternde Fledermäuse. Bisher wurden dort 12 Arten im Winterschlaf gefunden und eine weitere Art (Nordfledermaus, *Eptesicus nilssonii*) schläft regelmäßig in viel kühleren, eigenständigen Bunkern, die nicht mit dem Hauptsystem verbunden sind. Nach den Daten des EUROBATS-Abkommens rangiert das Nietoperek-Schutzgebiet unter den Top 10 der größten Überwinterungsgebiete Europas. Die Zahl der im Winterschlaf befindlichen Fledermäuse übersteigt in einigen Jahren 39 000 Individuen.

Im Jahr 2007 wurde der Zentralsektor „Wysoka“ (52°25‘N, 15°32‘ E) mit einer Fläche von 7.377,37 ha als Natura 2000-Gebiet PLH080003 „Nietoperek“ geschützt. Die von der Fledermausmarkierungszentrale (Dresden) erhobenen Ringdaten belegen, dass viele Fledermäuse aus dem großen Gebiet der mitteleuropäischen Tiefebene nach „Nietoperek“ wandern. Die längsten Wanderwege von Fledermäusen aus Ostdeutschland nach „Nietoperek“ betragen 257 km für *Myotis daubentonii*, 226,7 km für *M. myotis* und 242,1 km für *M. brandtii*. Die Bedeutung von „Nietoperek“ für die Fledermäuse ist am besten durch die Schätzung der minimalen Migrationsfläche der Fledermäuse dargestellt, hier hauptsächlich die des Großen Mausohrs (*Myotis myotis*). Das sogenannte Minimal-Convex-Polygon (MCP), das auf den wiedergefangenen Individuen basiert, wurde auf mindestens 17 000 km^2 geschätzt und umfasst einen großen Teil des Landes Brandenburg, Mecklenburg-Vorpommern,

Fig. 2: Underground railway station „Bahnhof Nord“ in Boryszyńska Loop in southern part of the underground system.

Abb. 2: Untergrund „Bahnhof Nord“ in der Boryszyńska Schleife im südlichen Teil des Untergrund-Systems (Foto: Peter Suchánek)

Sachsen-Anhalt und auch Westpolen (Lubuskie, Wielkopolskie und Zachodniopomorskie Voyvodeships). Aus diesen Gründen ist der Schutz von Fledermäusen im relativ kleinen Gebiet von „Nietoperek“ von wichtiger Bedeutung für die Erhaltung der Population von mindestens neun Fledermausarten in Mitteleuropa. „Nietoperek“ vereint das besterhaltene militärische Befestigungssystem Europas mit einem großen Fledermauswinterschlafgebiet und gut erhaltenen natürlichen Lebensräumen, die im europäischen ökologischen Netzwerk Natura 2000 geschützt sind. Dieser Ort ist auch ein gutes Beispiel für die internationale Zusammenarbeit beim Fledermausschutz und sein derzeit günstiger Erhaltungszustand wurde durch die Bemühungen von Fledermausschützern aus Polen, Deutschland, Großbritannien, Belgien, Holland und vielen anderen EU-Ländern geschaffen. In diesem Artikel stellen wir die Ergebnisse des Fledermausmonitoring-Programms vor, das seit 1999 in „Nietoperek“ durchgeführt wurde. Außerdem stellen wir verschiedene Forschungsschwerpunkte vor, wie die mikroklimatischen Veränderungen im unterirdischen Quartier aufgrund der Erderwärmung (sog. „Loggerprojekt“), die Studie „White Nose Syndrome“, das Schwärmprojekt, der Einfluss von Mardern und Waschbären auf überwinterndende Fledermäuse, die vorläufige Sommerstudie und schließlich die Projekte zur fledermausfreundlichen touristischen Nutzung von “Nietoperek”, die es hoffentlich ermöglichen werden, das Gleichgewicht zwischen dem Schutz der Fledermäuse und der zunehmenden touristischen Nutzung der Festungsanlagen zu finden.

Schlüsselwörter

Fledermäuse, Nietoperek, Natura 2000, Fledermausschutz, Klimawandel

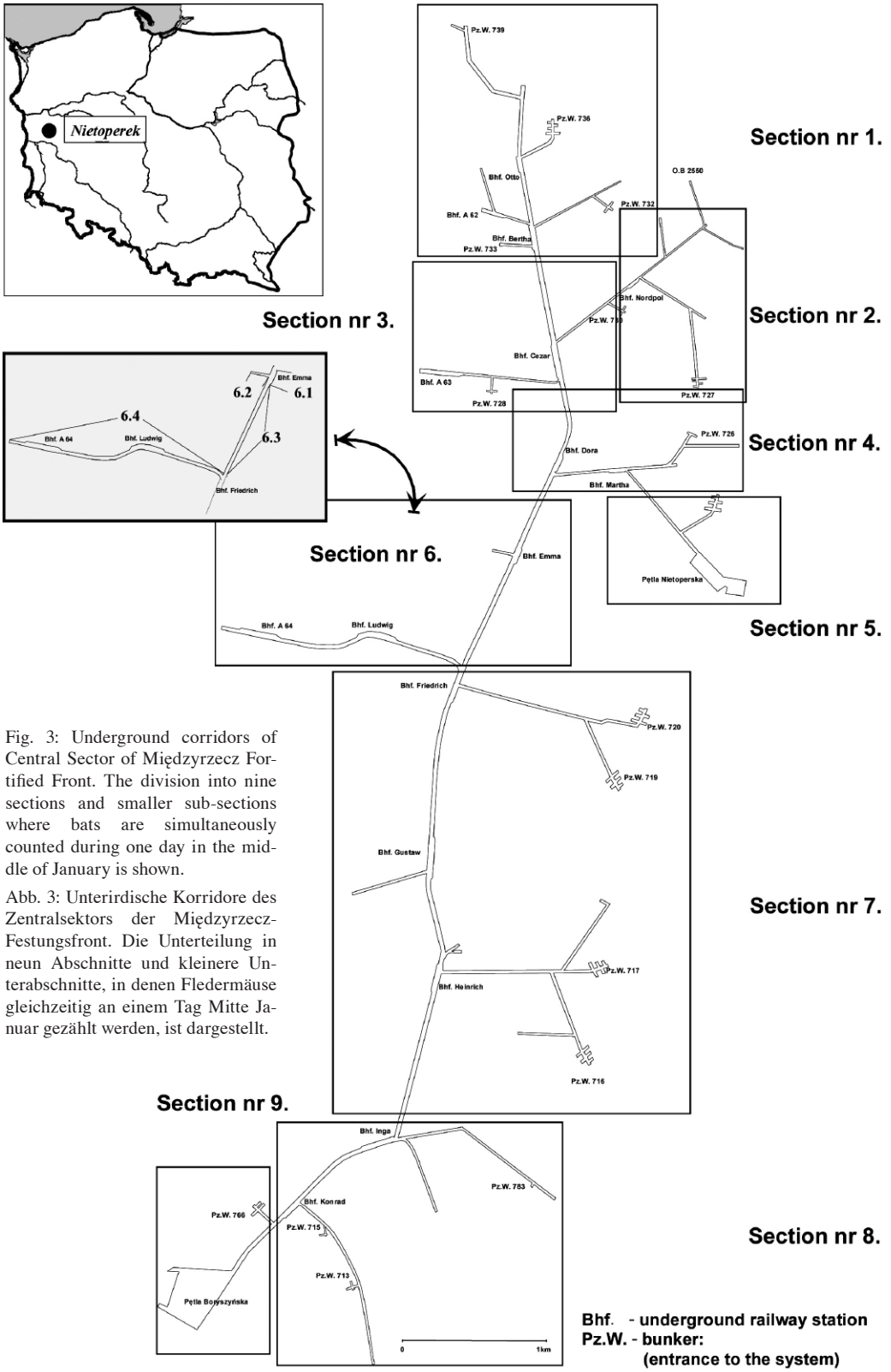

Fig. 3: Underground corridors of Central Sector of Międzyrzecz Fortified Front. The division into nine sections and smaller sub-sections where bats are simultaneously counted during one day in the middle of January is shown.

Abb. 3: Unterirdische Korridore des Zentralsektors der Międzyrzecz-Festungsfront. Die Unterteilung in neun Abschnitte und kleinere Unterabschnitte, in denen Fledermäuse gleichzeitig an einem Tag Mitte Januar gezählt werden, ist dargestellt.

Introduction

Międzyrzecz Fortified Front (MFF) (52°25'N, 15°32' E) situated in Lubuskie Voyvodeship in Western Poland, where "Nietoperek" bat reserve is located, is recognised as one of the largest bat hibernation sites in the European Union. According to the data of the EUROBATS Agreement it is ranked in top 10 largest hibernation sites in Europe. The numbers of hibernating bats is really amazing, exceeding 39 000 individuals in some years. So far 12 bat species have been found hibernating in the 32 km long labyrinth of so called "main underground system" and one more (the northern bat, *Eptesicus nilssonii*) regularly roosts in much cooler stand alone bunkers not connected with it.

Ringing data collected by Bat Ringing Centre (Fledermausmarkierungszentrale, Dresden) has provided evidence that bats migrate to "Nietoperek" from the large area of Central European Lowlands. Interestingly, in Europe the usual direction of autumn migration is from NE to SW, but due to the presence of underground complex of tunnels in western Poland, some bats migrate opposite way, i.e. NE, SE or E, to spend winter in the underground, providing them with a wide range of temperature and relative humidity (0 – 10°C and 40 – 100%). The longest migration distances of bats from eastern part of Germany to "Nietoperek" are 257 km for *Myotis daubentonii*, 226.7 km for *M. myotis* and 242.1 km for tiny *M. brandtii* (Fig. 4). The role of "Nietoperek" for the bats is best shown by an estimation of the minimum area of migration by bats, mainly greater mouse-eared bat (*Myotis myotis*), to that hibernation site. The minimal convex polygon (MCP) based on the recaptured individuals was estimated as at least 17 000 km^2 and covers large part of Land Brandenburg, Mecklemburg-Vorpommern, Sachsen-Anhalt and also western Poland (Lubuskie, Wielkopolskie and Zachodniopomorskie Voyvodeships). For these reasons, the protection of bats in the relatively small area of "Nietoperek" is of key importance for conservation of the population of at least nine species of bats in Central Europe.

"Nietoperek" is unique and remarkable in many ways. It merges the best preserved military fortification system in Europe, built by Germany before and during World War II, with a large bat hibernation site and its surrounding well preserved natural habitats, under protection of the European Ecological Network Natura 2000.

This place is also a good example of international co-operation in bat conservation, and its current favourable conservation status was established as a result of endeavours of bat workers not only from Poland, but also from Germany, UK, Belgium, The Netherlands and other EU countries.

In this article we will briefly present the results of bat monitoring programme carried out in "Nietoperek" since 1999, and a range of projects on: the changes in microclimatic conditions underground probably caused by global warming (the "logger project"), "White Nose Syndrome" study, a swarming project, predation by martens and raccoon on hibernating bats, a preliminary summer study, and finally projects on bat friendly tourism in "Nietoperek", that will hopefully lead to a balance between the bat conservation and increasing tourist use of the fortifications.

History of construction of the Międzyrzecz Fortified Front

After World War I Germany assumed France to be the first enemy in the possible next war and started to think about preventing a costly war on two fronts. As early as in 1933 fortifications were built in Eastern Prussia, Pomerania and Silesia, but the most important strategic area, the so called "Route to Berlin", still remained at the planning stage. Because the ultimate concept of fortifying the Berlin direction had still not been completed, it was decided to provisionally close the so called "Lubuska Gateway" with the Line of Obstacles Nischlitz (now Niesłysz) - Obra River, which was built during 1934-1935. In May 1935 the ultimate design of the fortifications that would close the "Lubuska Gateway" was completed, based on the concept of a Fortified Front. The 100 km long Międzyrzecz Fortified Front (MFF), Ostwall or Festungsfront im Oder-Warthe Bogen,

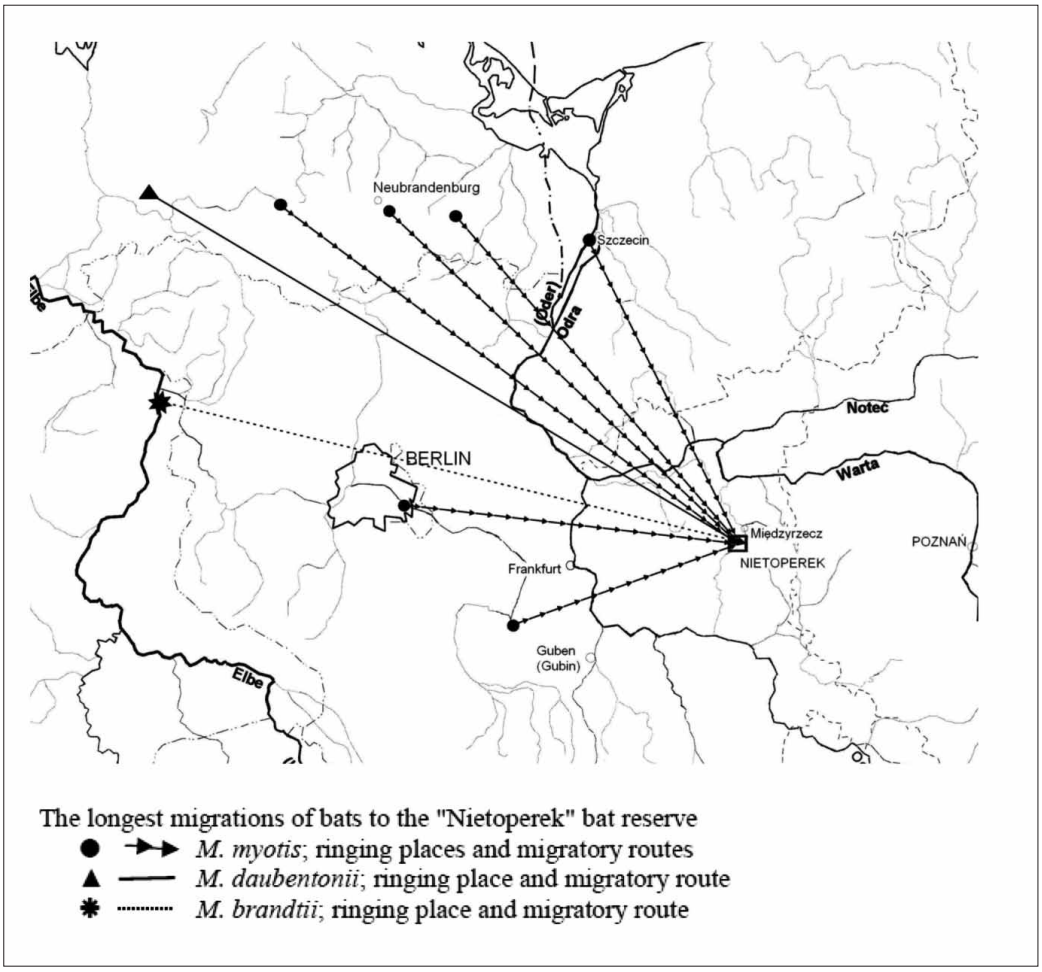

Fig. 4: The longest migrations of bats to the „Nietoperek“ bat reserve (after Rogowska and Kokurewicz 2007).

Abb. 4: Die längsten Wanderungen von Fledermäusen in das Fledermausreservat “Nietoperek” (nach Rogowska und Kokurewicz 2007).

was located between the rivers Odra in the south and Warta in the north and was built in 1934 – 1944. The Central Sector “Wysoka” (Zentralabschnitt or Abschnitt Hochwalde), starting south of Staropole, and ending on lake Kursko, only c. 15 km long, was to have a concentration of fortifications. It is a system of concrete tunnels with a total length of ca. 32 km situated 20-30 m underground (Fig. 2). The axis of the underground system, called the “main road”, has a narrow gauge railway. It runs from north to south and includes 10 wider “railway stations” (Bahnhof), which allowed small electric trains to pass in opposite directions. The smaller side corridors connect the main road to above ground bunkers (Panzerwerk) situated on the eastern part of the fortification system (Fig. 3).

The defensive system had no part in the offensive war, so after September 1939 work was gradually abandoned in the Międzyrzecz Fortified Front, and as a result only ca. 25-30% of the planned fortifications was built. In autumn 1940 the RAF (Royal Air Force) began a programme of bombing Germany, the armaments industry being one of its main targets. Because of that, in mid 1943, some of the production of aircraft engine parts by the “Daimler” company was moved to the underground of Central Sector “Wysoka”.

In 1943/1944, when the Soviet Army took the initiative on the eastern front, the Międzyrzecz

Fortified Front rose in importance. In 1944 preparatory work in the MFF started, providing it with field fortifications, especially armoured vehicle and anti-infantry obstacles, concrete "dragon's teeth" and trenches situated in front of them. On January 12th 1945, the eastern front moved from the Vistula River and in the evening January 29th Russian 1st Tank Army arrived in front of the main fortification line of the Central Sector "Wysoka". The night of 29/30 January 1945 was dark and cloudy. The Russian engineers removed the obstacles blocking the road in Kaława and the Russian tanks led by Major A. KARABANOV moved in a column towards Wysoka which they reached before 23:00. The first exchange of fire took place around Panzerwerk 775, when the Russians tried to pass Wysoka and lake Paklicko Małe from the north. Through to January 31st the Soviet army formed a uniform, continuous front east of the Międzyrzecz Fortified Front, but in the evening of January 31st the German troops began their retreat from battle positions. The defence of the MFF lasted only three days, but this, however, should not be deprecated, because the fortifications were only ca. 30% complete, manned with weak military personnel, who were surprised by the sudden shift of the Red Army front. The three-day delay and subsequent reduction of the impetus of the Soviet attack, had the result that the Soviet Army, with enormous effort and great cost, had to restart its final offensive on Berlin.

Having captured and manned the MFF, the Red Army started to investigate the system and to dismantle and remove all that was valuable, especially armaments, technical equipment, such as electrical equipment, pumps, compressors and ventilation devices. Later on, the bunkers also served as an experimental artillery shooting area used for testing the efficiency of new projectile designs. The most obvious traces of these can be seen today on the armoured cupolas of Pz.W 717 in the village Pniewo. After that, partial or complete destruction of the bunkers began, using high explosives, in order to deprive them of any future battle value.

At the end of the 1940s, after the majority of the Soviet army left the MFF, uncontrolled dismantling of the remnants of equipment began, especially in the Sector "Wysoka". Remaining factory machinery and carriages of electric trains were removed. Pipework, both of steel and concrete, were dismantled; water, electrical, telephone and other installations were destroyed. From 1953 to 1957 the Polish Armed Forces manned the underground system of the Central Sector of MFF and the destruction and looting were finally stopped. The bunkers were cleared, the damaged entrances bricked up, an inventory was made, and preservation work was done, for example painting the walls of chambers and corridors, and some metal structures. However, since 1956 in the northern part of Sector "Wysoka" the Soviet occupiers of Poland had a military base in Kęszyca Leśna (Waldkainscht), with access to the underground tunnels. The base was finally abandoned in 1993. Meeting fully equipped Soviet soldiers, and the presence of radar installations on bunker PzW 730 was one of the first, and somewhat traumatic experiences when in 1984 TOMASZ KOKUREWICZ started his work on bats in "Nietoperek". The presence of the Soviet military base resulted in stopping all local economic development. However this had a positive impact on return to nature of the "Nietoperek" area.

In July 1983 the Polish State Atomic Agency developed plans to locate a radioactive materials dump in the MFF underground, but fortunately that secret plan became known to the local community. From the beginning of 1985 the situation was at a stalemate, because the authorities remained indifferent to the numerous individual and collective protests. On February 1986 a formal ecological group was founded in Międzyrzecz collecting arguments against the location of the radioactive dump in the underground. The struggle to save Sector "Wysoka" and its inhabitants – the bats – continued till August 1988 and the after two years the result was a victory to the "ecologists".

It is worthwhile mentioning that the name of "Nietoperek", that means "little bat" in Polish is a remarkable coincidence. In 1945 Poland's borders were re-drawn by the allies and effectively the whole country was shifted westwards. This meant that Poles inhabiting the current western part of Ukraine had to leave

and settle down in the eastern part of Germany that was "given" to Poland as a compensation for the lost territories in the east. The same happened to Germans who had to move their homes to the west. Thanks to this operation invented and implemented by Joseph Stalin with the help of a new Polish government totally in his control, the area of Nietoperek unexpectedly appeared 70 km inside Poland, and in consequence all the villages which had German names had to be renamed in Polish. Sometimes the new name was a simple translation, so the village "Hochwalde" (high wood) became Wysoka (high in Polish), other names were just "Polish-ised" including the village "Kalau" that has become Kaława and village "Nipter" became Nietoperek.

The beginning of bat study and conservation

The value of the underground system for bats was first discovered in 1974 by biologists from the Adam Mickiewicz University in Poznań – the late Dr. Zbigniew Urbańczyk, his wife Elżbieta Bagrowska-Urbańczyk, Prof. Wiesław Bogdanowicz and others. They started systematic studies on bats in 1975 and published the first short paper in 1976 (see the list of selected literature below). In those "pioneering times" the Polish bat community was very small, but all its members somehow became involved in protecting "Nietoperek" against the plans to site the underground radioactive dump there. It is worth to mention the involvement of those late academics from the Polish bat community in that action – Adam Krzanowski and Wincenty Harmata from Kraków.

In 1980 due to the great efforts of Dr. Zbigniew Urbańczyk, approximately 30% of the tunnels (2.5 ha) became protected as the "Nietoperek" bat reserve. Due to his endeavours, supported by Prof. Bronisław W. Wołoszyn, founder of the Chiropterological Information Centre Polish Academy of Sciences in Kraków (CIC), who organised few visits to the bat reserve for chiropterologists from abroad, the entrances to the underground were for first closed in 1991 by "bat friendly" gates.

In 1998, during the preparation of the first management plan for "Nietoperek" by the National Foundation for Environmental Protection from Warsaw, the extension of the bat reserve by 48.27 ha was made to protect the remaining 70% of the underground, and the surface "fortresses" with the bunkers and bat entrances to the tunnels situated in them.

Before joining the European Union by Poland in May 2004 the draft plan for Natura 2000 network had to be established. Unfortunately, the government version of the Natura 2000 site "Nietoperek" prepared "ad hoc" in autumn 2003 designed for protection only 1 474.8 ha of land situated above the underground fortifications and did not include the stand alone bunkers and bat foraging areas. As a result of collective action undertaken together by government experts (whose remarks were not included in the draft version of Natura 2000 site), and NGO's, a "Shadow List" for the Natura 2000 network was prepared in 2004 and sent to the European Commission. Finally, in 2007 the underground system plus the surrounding surface area of 7.377.37 ha became protected as Natura 2000 site PLH080003 "Nietoperek". Its targets for protection are bat species: greater mouse-eared bat (*Myotis myotis*), pond bat (*M. dasycneme*), Bechstein's bat (*M. bechsteinii*) and the western barbastelle (*Barbastella barbastellus*) listed in Annex II of the EC Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora. These species all hibernate in Nietoperek in large numbers.

Currently the access for bats to the underground system is through 25 surface bunkers (Fig. 1), through two drainage corridors located on the northern and southern ends of the tunnel system, and also via two ventilation shafts and a 1.43 km long side corridor ("Wysoka corridor", named after the nearby village) sloping upwards from the main corridor to the surface. On a number of occasions there have been discussions with German bat friends about installing an automatic infra-red beam system to count the bats emerging from "Nietoperek" in spring. Unfortunately due to large number of

the entrances to be monitored and the need of protection of the equipment from theft for long periods the idea has been postponed that for now, but it is hoped that it may be possible in future.

The major part of the system has a stable microclimate, but a dynamic microclimate is found near the entrances of the system and in the Wysoka corridor. The drainage system of the underground was destroyed after the war, which resulted in flooding of the northern part of the tunnels (sections 1–6, see Fig. 3) while drying out the southern part (sections 8 and 9).

Bat monitoring program

Main fortification system

It is uncertain exactly when bats began to colonise the underground. In our opinion the colonization of the Central Sector of MFF by bats commenced shortly after the tunnel administration by the Polish Army ended in 1957, and that after nearly half a century the increase in number of some species reflects the real change in the numbers of hibernating bats, and that immigration to that man-made hibernation site does not reflect bat population trends.

The winter bat censuses in „Nietoperek" were first time established by Dr. Zbigniew Urbańczyk in the period of 1985 – 1995. They were organized in different months of winter season and lasted from 2 to 4 days. In 1999, after a break of four years, they were re-established and until now have been carried out by the Wrocław University of Environmental and Life Sciences. In the years 1999 – 2004 the census was biannual, and since 2005 the census has been annual. Considering the sensitivity of bats to non-tactile human disturbance, the high energy costs of non-spontaneous arousals from torpor (Thomas 1990) and the fact that activity of the awakened bats is higher than normal for 2.5–8.5 h after observers enter the underground (Thomas 1995), censuses are carried out in a single day of 8 hours from sunrise to sunset. Because of species specific variation in their dates of arrival to and departure from Nietoperek for hibernation, censuses are carried out in the middle of January when all species are present. By strictly following this protocol every year, results are comparable and it is possible to avoid errors from repeated counting of active individuals which may change roost sites underground. Additionally, it is good for the bats because minimises their disturbance during the census. To survey 32 km of the tunnels within eight hours, the underground system was divided into nine sections and each of them into smaller sub-sections (Fig. 3). Bats are counted simultaneously by 65 – 70 bat workers divided into nine groups, one for each section. To obtain fully comparable results in consecutive years the census protocol requires that the census is carried out by observers with previous bat counting experience in particular sub-sections. In order to ensure the comparability of results by reducing possible human error the results of two censuses (in 2014 and 2015) carried out by another team of bat workers is excluded from our analysis. The monitoring protocol used by that team, involving smaller number of bat observers with limited experience of bat censuses in "Nietoperek" is considered as being inconsistent with other years (Fig. 6).

Bunkers

After the census in the main fortification system there was, in the early years, difficulty with counts of bats in the surrounding bunkers. In fact, since there was no obligation to count bats there, the bunkers were visited only occasionally. Since 2007, thanks to the initiative of Fons Bongers from Holland this part of the work is carried out mainly by the Dutch and Belgians teams organised by him. Our friends from these countries have much experience in counting the bats in many smaller structures in Belgium and Holland. The accuracy of the bat census in bunkers developed by the Dutch-Belgian team was illustrated when the same bunkers were counted during two consecutive years by the other team of bat workers. It appeared that in all 14 bunkers they recorded ca. 150 bats of all species per year, which could

Fig. 5: The largest cluster of greater mouse-eared bat (*M. myotis*) recorded in March 2018.
Abb. 5: Das größte Cluster von Großen Mausohren (M. *myotis*), aufgenommen im März 2018 (Foto: Jasja Dekker).

mean a decline by 50% compared with the previous results recorded by Fons and his team. However, in the following four years, when the bunkers were once again counted by Dutch-Belgian teams, the numbers returned to ca. 300 bats.

Methods for bat counting

During the both censuses bats are visually identified to species without being handled. Whiskered bat and Brandt's bat which cannot be identified to species level with certainty without handling are recorded as a species pair (*M. mystacinus*/*M. brandtii*). Large clusters of mouse-eared bats (Fig. 5) and barbastelles are photographed using digital cameras and the number of individuals is determined later from photographs viewed on laptop computer screens. Portable aluminum ladders are used to assist identification of bats hibernating high on the walls and ceilings, while mirrors are used to identify bats roosting in crevices or behind metal bars and other construction elements. Individual bats identified only to genus constitute on average less than 0.25% of the total number of all those counted.

Results of the bat monitoring programme

We found out that all bat species hibernating in "Nietoperek" increased in number from 1999 by an average rate of 530 individuals per year. The reason for that is a significant increase in *M. myotis* numbers. This species has become dominant in the multi-species bat colony. In the 1980s and early 1990s the dominant species was *M. daubentonii,* but since then it has steadily declined in number for reasons that are not clear (Fig. 6). Interestingly, in the past Daubenton's bats frequently hibernated in big clusters (Urbańczyk, 1989; Urbańczyk, 1991*a*, 1991*b*), reaching up to 103 individuals (Kokurewicz, 1990, 1999), while during our annual winter censuses only smaller clusters have been recorded. Some hypotheses explaining that phenomenon have been already pro-

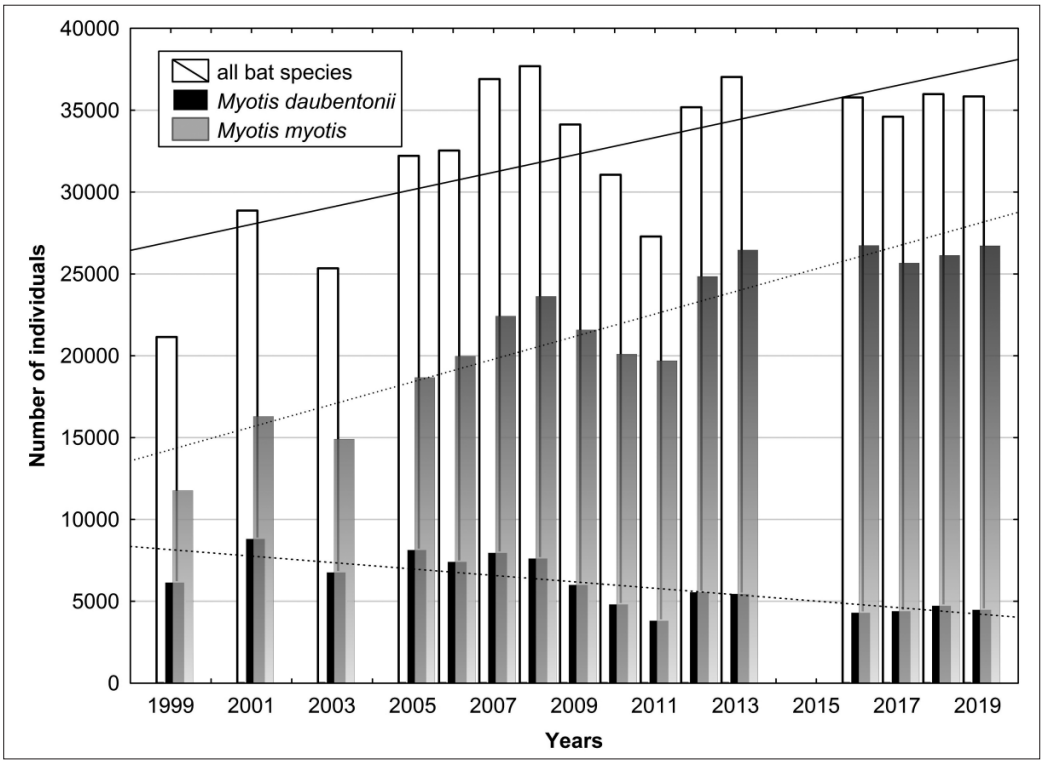

Fig. 6: Population trends of all bat species, greater mouse-eared bat (*M. myotis*) and Daubenton's bat (*M. daubentonii*) hibernation in Nietoperek bat reserve from 1999 to 2019. The trend for greater mouse-eared bat (*M. myotis*) was converted from non-linear to linear for better comparisons with the other trends.

Abb. 6: Populationstrends aller Fledermausarten, Winterschlaf des Großen Mausohrs (*M. myotis*) und der Wasserfledermaus (*M. daubentonii*) im Fledermausreservat Nietoperek von 1999 bis 2019. Der Trend der Großen Mausohren (*M. myotis*) wurde zur besseren Vergleichbarkeit mit den anderen Trends von nichtlinear auf linear konvertiert.

posed (T. Kokurewicz, in preparation) and will be tested during future field studies. Generally, in our study period, the number of individuals of thermophilic species, choosing high temperatures during hibernation (i.e. *M. myotis*, *M. nattereri*, *M. dasycneme* and *M. bechsteinii*) seems to increase, while the psychrophilic species, preferring low hibernation temperatures, (i.e. *B. barbastellus*, *P. auritus* and the species pair *M. mystacinus*/*M. brandtii*) are declining. We hypothesise that these trends are likely caused by global climate change. It is possible that the psychrophilic species are moving from the deeper underground that is becoming relatively too warm, to hibernate in less insulated cooler locations. However this possible explanation needs proof both from statistical analysis and from future field studies.

We must keep in mind that the bat monitoring programme based on a coherent methodology started in "Nietoperek" only 21 years ago and only now, when the trends have finally "stabilised", it has become possible to summarise and publish our results.

Other projects

From a conservation point of view the main and most important study carried out in "Nietoperek" is monitoring of the long-term changes in numbers of the hibernating bat populations. Primarily, based on these results we will be able to estimate their conservation status, particularly for the four species mentioned in Annex II of the Habitat Directive. The aim is also to recognize the threats to these populations and to initiate appropriate conservation measures. However, for better understanding and interpretation of the results, since 1999 other projects have been introduced.

"Logger project"

The project entitled: "Structure characteristics, temperature regimes and roost site selection in bats hibernating in the Nietoperek bat reserve (Poland)" is led by Ralf Gyselings, Dr. Luc De Bruyn and Dr. Lucinda Kirkpatrick. So far, most of published data concerning the microclimatic conditions chosen by hibernating bats were based on single measurements, and not including seasonal effects. In September 2017 both in the main underground system and in the stand alone bunkers we installed large number of loggers to constantly monitor the temperature and relative humidity throughout the year. Since the winter season 2017/2018, in addition to January censuses, the bats have also been counted in November and March, in five of nine sections of the underground (Fig. 3), in order to combine the microclimatic data with bat numbers and species composition. The model that was developed as a result of this study is being used to gain more insight in the selection of microclimatic conditions by bats throughout the season, to investigate the effect of climate change on the bat hibernacula. It will also assist the appropriate conservation and management of hibernation sites and enable better understanding and interpretation of population trends of bats in "Nietoperek" since 1999.

"White Nose Syndrome" study

In 2014 the fungus *Pseudogymnoascus destructans*, the causative agent of "White Nose Syndrome", was first recorded in "Nietoperek" (Kokurewicz *et al*. 2016). Taking into account the constant and significant decline of hibernating population of *M. daubentonii* (Fig. 6) we began to worry if the presence of the parasitic fungus could be the cause. In September 2014 during the 13th European Bat Research Symposium in *Šibenik* (Croatia), the «Nietoperek team» invited Prof. Jiří Pikula (University of Veterinary and Pharmaceutical Sciences in Brno, Czech Republic) and Dr. Jan Zukal (Masaryk University and Institute of Vertebrate Biology, Czech Academy of Sciences, Brno, Czech Republic) with their research groups to study this problem in "Nietoperek. In our opinion, supported by a few years of study (Martínková et al., 2018), *P. destructans* cannot be treated as the factor responsible for that decline. Interestingly, the greater mouse-eared bat (*M. myotis*), that is increasing in number, showed the highest rate of infection. Analysis of blood parameters showed blood homeostasis disruption in heavily infected individuals, i.e. having more than 300 skin lesions caused by *P. destructans* on both wings. These greater mouse-eared bats generally survive *P. destructans* invasion, but were found to have body surface temperatures lower by 2°C. Because of that, conservation measures should minimise additional stress factors, such as human disturbance, to conserve the fat reserves of hibernating *M. myotis* bats (Bandouchova *et al*. 2018). Some other results may be found in Open Access publications listed in the literature review at the end of the article.

Swarming study

Studying swarming behaviour in "Nietoperek" had been considered for many years, but it would have remained at the planning stage without Dr. Anita Glover, who previously studied this phenomenon in the UK and in other European countries, and during one of the January censuses organized the project with Justyna Błeszнowska, Ewa Kwasiborska and Tomek Marszałek – at the time new MSc students at Wrocław University of Environmental and Life Sciences. The study was carried out in 2014 and 2015 from August to the beginning of October near two entrances to the main fortification system and included a total of 32 nights of mist netting. In total, 3.265 bats from 13 species were caught, marked by fur clipping, sexed, aged, weighed, forearm length measured, and reproductive status recorded. In both netting sites no re-trapped individuals were recorded, indicating an almost nightly change of population at the swarming sites. On average 144 Bechstein's bats were caught per swarming season, while the largest number recorded hibernating underground has been only 48 individuals. This result is consistent with the other

study done in Europe, and suggests either "Nietoperek" is a stopover during migration, or there is a significant underestimation of wintering population of the species. Based on the largest number of individuals caught, the highest activity for *B.barbastellus* and *M.bechsteinii* was recorded in the first half of September, while for *M.nattereri* and *P.auritus* numbers peaked later in that month. In Daubenton's bat and mouse-eared bat numbers two separate activity peaks were observed, which could indicate the presence of local populations (from nearby maternity roosts), and also migratory populations (from eastern part of Germany) swarming at different times (Błesznowska et al. 2017). It would be very interesting to follow this up using genetic analysis and possibly estimate gene flow between these populations. We are very grateful to volunteers from the UK for valuable assistance in that project.

Bat-friendly tourist use of "Nietoperek" fortifications

The main problem for bat conservation in "Nietoperek" is the increase in tourism underground. On one hand the Międzyrzecz Fortified Front is the well known and the best preserved WWII military fortification system in Europe, that attracts an interest of historians, fans of fortifications and ordinary tourists, but on the other hand it is one of the largest bat hibernation sites in the EU protected as Natura 2000 site.

At present the tunnels are closed for tourists from October 15th to April 15th, to protect the hibernating bats. The only exception is bunker 717 in Pniewo and the 1 km long corridor leading from it to underground railway station "Bahnhof Heinrich" on the "main road", open for tourism all year.

However, the growing interest of domestic and foreign tourists in the "Nietoperek" underground may result in the extension and modernisation of underground tourist routes. This includes draining, painting walls and additional lighting in the underground tourist routes in Pniewo (Międzyrzecz Community) and in Boryszyn (Lubrza Community) in the near future. It is obvious that these activities are a threat to hibernating bats, but on the other hand, the development of tourism is an important element of economic development of the region.

We believe that this fundamental conflict of interest must be resolved only through negotiations with local communities, Międzyrzecz and Lubrza, who are the owners of the underground system. The local people and local authorities need to understand and accept the conservation measures we are implementing to protect "our bats" in order to make an agreement effective and permanent.

For that reason we are in contact with local communities, discussing with them the need for protection of "the common natural heritage of united Europe", the legal status of endangered species and their role in keeping the equilibrium in semi-natural ecosystems, with special emphasis on the "environmental services" provided by bats to pest control in agriculture and forestry.

To increase the effectiveness of bat conservation and for better communication with local communities, not only from the University level, in April 2018 we registered the NGO called Society for Nature Conservation "Nietoperek" (top.nietoperek@gmail.com; https://www.facebook.com/TOPNietoperek).

The growth in tourism poses new challenges for organizations and institutions responsible for protecting this unique bat hibernation site, particularly because our knowledge about the use of it by bats outside the hibernation period remains very limited.

The first studies on the negative impact of tourist movement on bats hibernating in "Nietoperek" were done by Laura Torrent who, as an ERASMUS student, did her "Final Project" at Wrocław University of Environmental and Life Sciences. Her study undertaken in the part of the tunnels visited by tourists in winter proved the negative effect of human disturbance, illustrated by an average 23% decline of total bat numbers during three consecutive winter seasons (Torrent 2014).

Another example of good practice in that field was the study done in the 4 km long section of the tunnels from April 8th to October 14th 2017, involving 10 one-day controls, ai-

med at an estimate of the use of the tunnels outside hibernation season. We observed a large increase in the number of bats between September and October (22nd September - 317 bats; 14th October - 2007 bats). Based on our observations we suggested advancing the date for closing the tunnels, outside the established tourist trails, by one month (i.e. changing from 15th October to 15th September), which would be beneficial for bats as it would offer protection during the period of autumn swarming and preparation for hibernation. The date for the start of tourism in the whole underground system of 15th April appeared to be acceptable (Apoznański et al. 2018), but we still need more research aimed at bat conservation to be done in "Nietoperek".

Apart from legal and organized tourism, the Central Sector of Międzyrzecz Fortified Front is intensively used by fans of fortifications, some of them still searching for lost treasures and militaria. Such people break into the system and damage the bat gates to visit this place illegally in winter. Their activity causes alteration of water conditions, draining the underground and weakening the structure of the corridors. Thanks to the activity of local communities, especially Mr Leszek Lisiecki – the Director of the Museum of Fortifications and Bats in Pniewo (Międzyrzecz Community) – and Ms Beata Studzińska (Lubrza Community) the intensity of illegal activity is declining, but legally they should be considered as destruction of winter habitats of protected bat species and should be successfully prosecuted by the forces of law.

Predation by martens and raccoon on hibernating bats

The predation by martens on bats hibernating in "Nietoperek" was discovered by Dr. Zbigniew Urbańczyk in 1981. The first systematic study of this problem was done by John Power from the Waterford Institute of Technology (Ireland), by use of non-invasive genetic monitoring based on scats collected in and around the underground system. The research proved the predation of both marten species i.e. pine marten (*Martes martes*) and stone marten (*M. foina*) on hibernating bats (Power 2015).

During the last winter two bat censuses we found two raccoons (*Procyon lotor*) resting underground and started a small project to study this possible new threat to hibernating bats. The study was led by Santiago Perea Arroyo from Complutense University of Madrid, who did his traineeship under ERASMUS+ in Wrocław University of Environmental and Life Sciences. This year we collected raccoon scat samples for genetic analysis and put trail cameras in 18 locations to investigate the distribution of this invasive species in the Natura 2000 site "Nietoperek" outside hibernation season.

Summer study

The number, roosts and foraging areas of bats in "Nietoperek" area in summer are still poorly investigated. A radio tracking study conducted in 2008–2010 showed that female *M. myotis* from a breeding colony located in a bunker A2 (in the southern part of the underground system) travelled 14 km NW to forage in mature beech woodlands in acid lowland beech woodland (*Luzulo pilosae-Fagetum*, Natura 2000 code: 9110-1) in Natura 2000 site "Buczyny Łagowsko-Sulęcińskie" (Andrzejczak et al. 2009, Kiczyńska et al. 2010, Apoznański *et al*. in preparation). During this study we found foraging by this species in dry Scots pine (*Pinus silvestris*) forests (*Cladonio-Pinetum*), and also in dry mature pine plantations without undergrowth (Wawrocka, 2011), which is consistent with another study showing the ability of this species to forage in coniferous forests (Zahn et al. 2004). These results demonstrate ecological plasticity of this species, possibly one of the reasons for the significant increase observed in winter in the underground. Lubuskie Voyvodeship, where "Nietoperek" is situated, has the highest level of afforestation in Poland (49.3%, comparing to 29.5% average for the country), a factor favouring forest species like *M. myotis*. Indeed, in churches in Skwierzyna, Sulechów and Otyń in Lubuskie Voyvodeship there are large maternity colonies of this species, protected as Natura 2000

sites. Recently, in riparian woodlands (*Fraxino-Alnetum*, Natura 2000 code: 91E0-3) near the underground we caught lactating females of western barbastelle (Apoznański et al. in preparation). This was the first breeding record of this species for "Nietoperek". In addition, a pregnant female Leisler's bat (*Nyctalus leisleri*) previously caught only once in the Lubuskie Voyvodeship (Apoznański, Kokurewicz 2018). These preliminary observations indicate the need for further summer projects in "Nietoperek" to supplement the data accumulated over the years during winter and autumn study.

While our research in "Nietoperek" has yielded a great amount of valuable information on its bats, there is a constant awareness of the necessity for conservation, and the need to minimise the impact of any research on this internationally important multi-species bat colony. All our research activity is licensed by regional and/or national nature conservation authorities, and some research is further sanctioned after consultation with the Local Ethical Commission in Wrocław. Finally, while much has been discovered so far during years of observation and study in "Nietoperek", there is clearly yet more to be understood, and consequently the need for more research projects in future.

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Literatur

Andrzejczak W., Batycki A., Kasprzak A., Kokurewicz T., Matraj M., Rusiński M., Świerkosz K., Wylęgała P., Weigle A. & Kaim, K. (2009): Documentation of the Management Plan of the Natura 2000 site „Nietoperek" (PLH080003). National Foundation for Environmental Protection, Warszawa [In Polish].

Apoznański, G., Kokurewicz, T., Rusiński, M. & Górska, M. (2018): Changes in bat number in the undergrounds of Natura 2000 PLH 080003 „Nietoperek" outside hibernation season and problems related with conservation of the largest hibernation site of those mammals in Poland. Przegląd Przyrodniczy, **29** (3) 47–55 [In Polish with English summ.].

Apoznański, G. & Kokurewicz, T. (2018): New breeding record of Leisler's bat *Nyctalus leisleri* (*Kuhl,* 1817) in Lubuskie province. Parki Narodowe i Rezerwaty Przyrody, **37** (3) 93–97 [In Polish with English summ.].

Bagrowska, E. & Urbańczyk, Z. (1976): The station of Bechstein's bat *Myotis bechsteini* (Kuhl) in the Lubuskie lake district. Przegląd Zoologiczny, **20** 367-369. [In Polish with English & Russ. summ.].

Bagrowska-Urbańczyk, E. & Urbańczyk, Z. (1983): Structure and dynamics of a winter colony of bats. Acta Theriologica, **28** 183-196.

Bandouchova, H., Bartonička, T., Berkova, H., Brichta, J., Kokurewicz, T., Kovacova, V., Linhart, P., Piacek, V., Pikula, J., Zahradníková, A. Jr. & Zukal, J. (2018): Alterations in the health of hibernating bats under pathogen pressure. Scientific Reports, **8** 6067. DOI:10.1038/s41598-018-24461-5.

Błeszynowska, J., Kwasiborska, E., Marszałek, T., Kokurewicz, T., Glover, A., Haddow, J. & Apoznański, G. (2017): Changes in numbers and reproductive status of bats during swarming in Natura 2000 site PLH080003 "Nietoperek", Poland. Pp. 57, *in* Abstract book of the 14th European Bat Research Symposium - EBRS 2017, 1-5 August 2017. Donostia, The Basque Country.

Boratyński, J., Rusiński, M., Kokurewicz, T., Bereszyński, A. & Wojciechowski, M. S. (2012): Clustering behavior in wintering greater mouse-eared bats *Myotis myotis* - the effect of micro-environmental conditions. Acta Chiropterologica, **4** (2) 417–424.

Boratyński, J. & Kokurewicz, T. (2011): Współwystępowanie gatunków nietoperzy w skupieniach podczas zimowania w podziemiach Centralnego Odcinka Frontu Umocnionego Łuku Odry i Warty. Nietoperze, XII, **1-2**: 23-28 [In Polish with English summ.].

De Bruyn, L., Kokurewicz, T., Gyselings, R., Kirkpatrick, L., Glover, A., Schofield, H., Ciechanowski, M., Haddow, J., Schmidt, C., Bongers, F., Willems, W., Rusiński, M., Kliś, T., Apoznański, G., Rachwald, A. & Zapart, A. (2018): Changes in overwintering bat numbers, an effect of global warming? Benelux Congress of Zoology, Brussels, 14-15 December 2018.

Hutterer, R., Ivanova, T., Meyer-Cords, C. & Rodrigues, L. (2005): Bat migrations in Europe: a review of banding data and literature. Naturschutz und Biologische Vielfalt, Bonn **28**:1–176.

Jones, G. & Kokurewicz, T. (1994): Sex and age variation in echolocation calls and flight morphology of Daubenton's bats *Myotis daubentonii*. Mammalia, **58** 41–50.

Jurga, R. M. & Kędryna, A. M. (2000): Festungsfront Oder-Warthe-Bogen. Donjon, Boryszyn, 180 pp.

Kiczyńska, A., Kokurewicz, T., Błaszczyk, M., Horbacz, A., Jaśkiewicz, M., Kieroński, D., Kowalewski, H., M. Rusiński (2010): Expertise on the impact of the A2 motorway on the Natura 2000 site „Nietoperek" on the *Świecko* - Trzciel section (km 1 + 995 - 92 + 533) in the Lubuskie voivodship. National Foundation for Environmental Protection, Warszawa [In Polish].

Kokurewicz, T. (1990): Hibernation of two age classes of *Myotis daubentoni* (Kuhl, 1819) in the nature reserve "Nietoperek" (W Poland) and effect of microclimate on cluster formation. Bat Research News, **31** 43.

Kokurewicz, T. (1999): Hibernation ecology of Daubenton's bat *Myotis daubentonii* (Kuhl, 1817). Ph.D. Thesis, Museum and Institute of Zoology, Polish Academy of Sciences, Warsaw, 141 pp. (in Polish).

Kokurewicz, T. & Bartmańska, J. (1992): Early sexual maturity in males of Daubenton's bat *(Myotis daubentoni* (Kuhl, 1819) (Chiroptera: Vespertilionidae); field observations and histological studies on the genitalia. Myotis, **30** 95-108.

Kokurewicz, T., Bongers, F., Ciechanowski, M., Duvergè, L., Glover, A., Haddow, J., Rachwald, A., Rusiński, M., Schmidt, C., Schofield, H., Wawrocka, K., Willems, W. & Zapart, A. (2014): Bat research and conservation in "Nietoperek" bat reserve (Western Poland). Pp. 93–94, *in* Abstracts of the 13th European Bat Research Symposium, September 01- 05.2014, Šibenik, Croatia.

Kokurewicz, T., Kirkpatrick, L., Glover, A., Haddow, J., Schmidt, C., Schofield, H., Bongers, F., Willems, K. & Apoznański, G. (2017): An influence of climatic factors on numbers of bats hibernating underground – the consequences for methodology of winter monitoring. Pp. 122, *in* Abstracts of the 14th European Bat Research Symposium, EBRS 2017, 1-5 August 2017. Donostia, The Basque Country.

Kokurewicz, T., Ogórek, R., Pusz, W. & Matkowski, K. (2016): Bats increase the number of cultivable airborne fungi in the "Nietoperek" bat reserve in Western Poland. Microbial Ecology, **72** (1) 36–48.

Kokurewicz, T., Paszkiewicz, R. & Szkudlarek, R. (1993): Hibernation strategies of five bat species in the "Nietoperek" bat reserve (Western Poland). Str. 28-29, w: Abstracts of the Sixth European Bat Research Symposium, 22-27 August, Evora, Portugal.

Łupicki D. & Cichocki, J. (2008): Occurrence of the bats in area of Międzyrzecz Fortified Region during the summer period. Nietoperze IX, **1** 19-27 [In Polish with English summ.].

Łupicki, D. & Kokurewicz, T. (1995): Jesienna akumulacja tłuszczu nocka rudego (*Myotis daubentonii*) w warunkach naturalnych i laboratoryjnych. Str. 20 w: Streszczenia referatów IX Ogólnopolskiej Konferencji Chiropterologicznej, Zakład Systematyki i Ewolucji Zwierząt PAN w Krakowie, Kraków 25-26 listopada 1995.

Łupicki, D., Szkudlarek, R., Schick, P. & Dudek, I. (2001): The utilisation of underground objects by bats in „Nietoperek" reserves in autumn season. Nietoperze II, **1** 93-101 [In Polish with English summ.].

Martínková, N., Pikula, J., Zukal, J., Kovacova, V., Bandouchova, H., Bartonička, T., Botvinkin, A. D., Brichta, J., Dundarova, H., Kokurewicz, T., Irwin, N. R., Linhart, P., Orlov, O. L., Piacek, V., *Škrabánek*, P., Tiunov, M. P. & Zahradníková, A. Jr. (2018): Hibernation temperature-dependent *Pseudogymnoascus destructans* infection intensity in Palearctic bats. Virulence, **9** (1): 1734–1750. DOI: 10.1080/21505594.2018.1548685.

Ogórek, R., K. Guz-Regner, T. Kokurewicz, E. Baraniok & Kozak, B. (2018): Airborne bacteria cultivated from underground hibernation sites in the Nietoperek bat reserve (Poland). Journal of Cave and Karst Studies, **80** (4) 161–171. DOI: 10.4311/2017MB0124.

Paszkiewicz, R. & Szkudlarek, R. (1996): Predation of martens on bats wintering in the „Nietoperek" Reserve. Pp. 52, *in*: Abstracts of the Seventh European Bat Research Symposium, 12-16 August 1996, Veldhoven, The Netherlands.

Pikula, J., Amelon, S. K., Bandouchova, H., Bartonička, t., Berkova, H., Brichta, J., Hooper, S., Kokurewicz, T., Kolarik, M., Köllner, B., Kovacova, V., Linhart, P., Piacek, V., Turner, G. G., Zukal, J. & Martínková, N. (2017): White-nose syndrome pathology grading in Nearctic and Palearctic bats. PLoS ONE **12** (8) e0180435. https://doi.org/10.1371/journal.pone.0180435.

Power, J. (2015): Non-invasive genetic monitoring of pine marten (*Martes martes*) and stone marten (*Martes foina*) in and around the Nietoperek bat hibernation site, Poland. Ph.D. Thesis, Waterford Institute of Technology, Department of Chemical and Life Sciences, Waterford, 254 pp.

Rogowska, K. & Kokurewicz, T. (2007): The longest migrations of three bat species to the „Nietoperek" bat reserve (Western Poland). Berichte der Naturforschenden Gesellschaft der Oberlausitz, Supplement zu Band **15** 53–60.

Romanowski, J. & Lesiński, G. (1988): Martens are hunting bats. Wszechświat, **89** (9): 210 [In Polish].

Schick, P. (1998): Zimowe żerowanie osobników nocka rudego *Myotis daubentonii* w Międzyrzeckim Rejonie Umocnionym. Str. 32-33, w: Streszczenia referatów XII Ogólnopolskiej Konferencji Chiropterologicznej, Wrocław, 14-15 listopada 1998.

Steffens, R., U. Zöphel, Brockmann, D. (2004): 40th Anniversary Bat Marking Centre Dresden – Evaluation of Methods and Overview of Results. Saxon State Office for Environment and Geology, Dresden, 126 pp.

Szkudlarek R., R. Paszkiewicz., T. Blohm, E. Nowak, Łupicki, D. (2001): Bunkers of Ziemia Lubuska as the bat shelters. Nietoperze 2: 83-92 [In Polish with English summ.].

Thomas, D. W., M. Dorais & Bergeron, J. M. (1990): Winter energy budgets and cost of arousals for hibernating little brown bats, *Myotis lucifugus*. Journal of Mammalogy, **71** 475–479.

Thomas, D. W. (1995): Hibernating bats are sensitive to nontactile human disturbance. Journal of Mammalogy, **76** 940–946.

Torrent, L. (2014): Bat assemblages in the Nietoperek bat reserve (Western Poland) and their conservation strategies. Final Project, Universitat de Vic, 42 pp.

Tryjanowski, P. (1997): Food of the stone marten *(Martes foina)* in Nietoperek Bat Reserve. Zeitschrift für Säugetierkunde, **62** 318-320.

Urbańczyk, Z. (1981): Fledermäuse (Chiroptera) in der Nahrung des Marders (*Martes sp.*). Säugetierkundliche Mitteilungen, **29** 77–79.

Urbańczyk, Z. (1989): Bats of the Międzyrzecz Fortified Front. Przyroda Ziemi Lubuskiej. Muzeum Regionalne w Świebodzinie, Świebodzin [In Polish].

Urbańczyk, Z. (1989). Results of the winter census of bats in Nietoperek 1985-1989. Myotis, **27** 139-145.

Urbańczyk, Z. (1991*a*): Hibernation of *Myotis daubentonii* and *Barbastella barbastellus* in Nietoperek bat reserve. Myotis, **29** 115–120.

Urbańczyk, Z. (1991*b*): Nietoperek Bat Reserve. Przyroda Ziemi Lubuskiej. Lubuski Klub Przyrodników, Świebodzin [In Polish].

Urbańczyk, Z. & Gólski, Z. (1994): Winter bat censuses in Ziemia Lubuska in 1988–1992. Pp 149–157, *in* Winter bat censuses in Poland: 1988-1992. Results and evaluation of effectiveness. (B.W. Wołoszyn, ed.). Publications of Chiropterological Information Center (CIC) ISEZ PAN Kraków [In Polish].

Warchałowski, M., D. Łupicki, J. Cichocki, M. Pietraszko, A. Rusek, A. Zawadzka & Mazur, N. (2013): Wintering bats Chiroptera in selected stand-alone objects of the Fortified Front of the Odra-Warta Arch. Kulon, **18** 139-149 [In Polish].

Wawrocka, K. (2011): Foraging ecology of Mouse–eared bat (*Myotis myotis*) (Borkhausen, 1797) on Natura 2000 site "Nietoperek" (western Poland). MSc thesis, Wrocław University of Environmental and Life Sciences, 53 pp [In Polish].

Wołoszyn, B. W., M. Kowalski, Urbańczyk, Z. (1990): Monitoring of the underground hibernation sites of bats in Poland, winter 1990. Str. 79, w: Abstracts ·of the Fifth European Bat Research Symposium, 20-25 August 1990, Nyborg Strand, Denmark.

Woźniak, C. (1996): History and architecture of the undergrounds of the Międzyrzecki Rejon Umocniony. Pp 78–113, *in* The nature of the Gorzow Voyvodeship. Bat reserve "Nietoperek" (T. Kokurewicz, ed.). Voyvodeship Fund for Environment Protection and Water Management, Gorzów Wielkopolski, 195 pp [In Polish with English and German summ.].

Zahn, A., H. Haselbach & Güttinger, r. (2004): Foraging activity of central European *Myotis myotis* in a landscape dominated by spruce monocultures. Mammalian Biology, **70** 265–270.