Acta Theriologica 50 (2): 161–166, 2005.
PL ISSN 0001–7051

Winter mortality rates of bats inhabiting man-made shelters (northern Poland)

Ireneusz RUCZYŃSKI, Iwona RUCZYŃSKA and Krzysztof KASPRZYK

Ruczyński I., Ruczyńska I. and Kasprzyk K. 2005. Winter mortality rates of bats inhabiting man-made shelters (northern Poland). Acta Theriologica 50: 161–166.

Non-predator and non-accidental mortality rates of bats inside the city of Toruń's fortification system (northern Poland) were studied over winter periods from 1995 to 2000. The bats were counted and dead bats collected at 1-month intervals from October to April. In total, thirty four dead bats were found. The percentage of dead individuals of the surveyed bats was low: *Myotis daubentonii* (0.6%), *M. nattereri* (0.4%), *Plecotus auritus* (0.4%), *M. myotis* (0.1%), and zero for *Barbastella barbastellus*. There was no clear difference in the species ratio of the observed and dead bats. The percentage of the dead to surveyed bats was lower in November (0.07%) and December (0.07%), and higher in September (3.3%) and April (1.3%). Temperature explained 84% of variation of the differences in mortality rates. Observations suggest that non-predator and non-accidental mortality inside the fortifications was extremely low and non-linearly correlated with the ambient temperature measured outside the fortifications.

Mammal Research Institute, Polish Academy of Sciences, Białowieża, Poland, e-mail: iruczyns@bison.zbs.bialowieza.pl (IR, IR); Department of Vertebrates Zoology, Institute of Ecology and Environment Protection, Nicholas Copernicus University, Toruń, Poland (KK)

Key words: Chiroptera, bats, hibernation, temperature, casualties

Introduction

Bats are small, long-living animals, with low fecundity (Barclay and Harder 2003). Low reproductive rates result in a slow population growth. The inability of a population to recover from population crashes increases the risk of local extinctions (Racey and Entwistle 2000). Therefore the knowledge about mortality factors is important for understanding the population dynamics of bats.

The comparative analysis of life span in bats reveals that longevity is influenced by reproductive rate, tendency to hibernate, body mass and use of cave roosts (Wilkinson and South 2002). Hibernating bats have prolonged lifespan compared with those not hibernating. Prolonged lifespan can be caused by lower predator and famine mortality (Wilkinson and South 2002). Increasing longevity can be also explained by disposable soma theory (Kirkwood and Austad 2000) and a restricted intake of calories (Kirk 2001, Lin *et al.* 2002). Calorie restricted animals shift resources to somatic maintenance rather than to reproduction (Shanley and Kirkwood 2000), which can reduce the accumulation of oxidative damage (Austad 1997) and prolong the life of animals.

During hibernation, bats are exposed to various mortality factors, such as: predation (eg Romanowski and Lesiński 1988, Bogdanowicz 1994, Radzicki *et al.* 1999), human disturbance (Thomas 1995), adverse weather conditions (Ryberg 1947, Davis and Hitchcock 1965, Speakman and Rowland 1999), and accidents (Gilette and Kimbrough 1970). In temperate zones the effects of such factors are highly variable and often unpredictable (Tuttle and Stevenson 1982). Unfortunately, there is a lack of quantitative information to estimate the significance of particular factors. Survival probability is mainly based on capture/recapture models, and is not very useful in estimating the role of mortality factors. This method is time consuming, requires handling of bats, and causes temporal disturbance of these animals. In this paper we propose to focus on measuring non-predator and non-accidental mortality inside hibernacula, by systematic collection of dead animals and comparing frequencies of deaths with the number of live bats. Limiting the observation to hibernacula (like fortifications or caves) allows for the comparison of mortality in different types of shelters, in different regions. Untill now such results have not been published due to the small number of detected dead bats.

We hypothesise that non-predator and non-accidental mortality inside the fortifications caused by a disease, parasites, or starvation is low, as predicted by the disposable soma theory (Kirkwood and Austad 2000), restricted calorie intake (Shanley and Kirkwood 2000), and correlated with the ambient temperature. Thus, the aim of the study was to find out whether non-predator and non-accidental mortality rates of bats inside the fortifications varied throughout the September to April period, and if they were dependent on the ambient temperature measured outside the fortifications.

Material and methods

The study was conducted in the city of Toruń (approx. 200 000 inhabitants), located in northern Poland (53°01'N, 18°35'E). The investigation area consisted of five systems of Prussian military fortifications dating back to the 19th century. The fortifications surround the city and in many places are overgrown by trees. Shelter is provided for the bats in a system of corridors and large quarters, some of which are well-protected from weather conditions, others only partly. One system of the quarters was regularly flooded by water, while others were dry or flooded temporarily. The bats stayed on the walls, in choked ventilation canals, within holes in the walls, crevices, and metal pipes.

The bats were counted in the fortifications at 1-month intervals from October to March, from 1995/1996 to 1999/2000. In the years 1995/1996 and 1996/1997, inspections were also performed in September and April. The period from September to April will be further referred as the winter or cold season. The period from November to March was recognized as a hibernal period, preceded by a pre-hibernal and followed by a post-hibernal period (estimation from Lesiński 1986, Kokurewicz 2004). The same parts of a given hibernaculum were inspected. In total, during the five study periods, each fortification system was visited 15 to 31 times. The bats that may have died in the previous winter were excluded from the analysis.

Live bats species were identified and counted without handling. Only individuals that did not hang in a natural position, hung in the same position on two consecutive controls and dried out, or when their fur had changed its colour were handled (all controlled bats were dead). All the dead bats which were not found in water or did not bear any visible injuries attributable to predators or other accidents were taken for post-mortem analyses, however, cause of death were not investigated in detail. The age of the bats was estimated on the base of canines' tooth wear: sub-adults – lack of wear, adults – slight detritions or a complete lack of enamel.

Mortality rates were estimated for the 5 most common bat species for the months during the study period (September–April). Test *G* was used for estimating differences in the species ratio of the living and dead bats (Sokal and Rohlf 1981). The data concerning the ambient temperature were provided by the Meteorological Station in Toruń.

Results

On average 64.2 (SE ± 33.9) bats were observed inside each fortification system during the 5 study periods. Eight species of bats were found: *Myotis nattereri* (40.4%) and *M. daubentonii* (34.3%) dominated, *M. myotis* (11.5%), *Plecotus auritus* (7.6%) and *Barbastella barbastellus* (5.8%) were less common (Fig. 1), *Eptesicus serotinus*, *E. nilsonii* and *M. brandtii*/*M. mystacinus* were found sporadically (< 0.5% of bats).

During the research thirty four dead bats were found: *M. daubentonii* (17), *M. nattereri* (13), *P. auritus* (2), *M. myotis* (1), and 1 unidentified specimen. Among the 28 bats whose age was estimated, 21 were adults and 7 sub-adults. On average 0.3 of a dead bat per fortification system on one inspection was detected: *M. daubentonii* 0.13, *M. nattereri* 0.10, *M. myotis* 0.01, and *P. auritus* 0.02 (Fig. 1). Dead bats of *B. barbastellus* were not found. Differences in the species ratio of the observed and dead bats were insignificant ($G = 9.3$, df = 4, $p = 0.05$).

The percentage of the dead individuals to the surveyed bats, calculated as a mean number of the observed (live and dead) and dead bats during all inspections, was low for all species: *M. daubentonii* (0.6%), *M. nattereri* (0.4%), *P. auritus* (0.4%), and *M. myotis* (0.1%).

The mean number of the observed bats increased through the study period, September (15.0, SE ± 4.3), January (77.5 ± 9.0), and was the highest in February (76.1 ± 11.3). The figure was still high in March (64.4 ± 12.0) but dropped hereafter and was at its lowest in April (33.2 ± 10.1; Fig. 2). The mean number of the detected dead bats was high in September (0.5, ± 0.3), dropping in October (0.25 ± 0.14), and was the lowest in November (0.05 ± 0.05) and December (0.05 ± 0.05). From January the mean number of these dead bats slowly grew till the end of the study period and was the highest in March (0.6 ± 0.2) and April (0.4 ± 0.4). The percentage of the dead to surveyed bats, calculated as a mean number of the dead bats to a mean number of the observed bats during re-

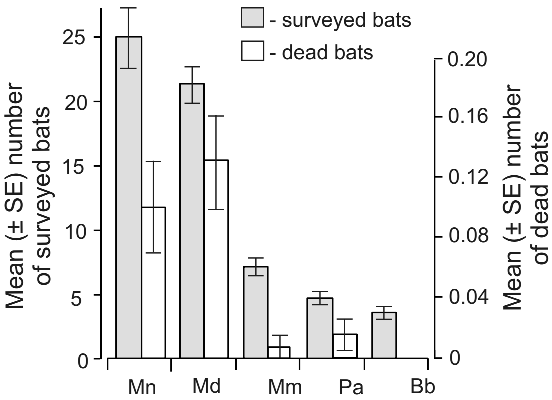

Fig. 1. Mean number (± SE) of observed and dead bats of the respective species during controls (totally 5 winters). Mn – *M. nattereri*, Md – *M. daubentonii*, Mm – *M. myotis*, Pa – *P. auritus*, Bb – *B. barbastellus*.

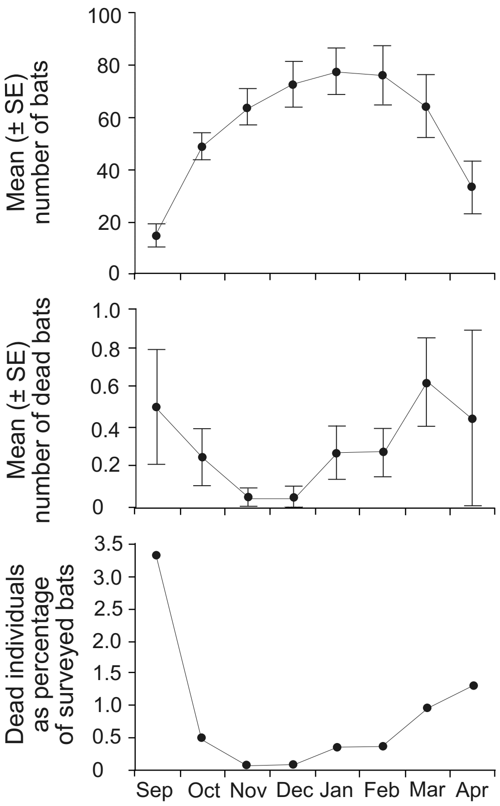

Fig. 2. Variation in numbers of bats and mortality rate during the hibernation period (totally 5 winter seasons).

spective visits, was at its highest in September (3.3%), lower in October (0.5%) dropping in November (0.07%) and December (0.07%), and increased again from January (0.3%) to its highest in April (1.3%) (Fig. 2). Mortality was positively correlated with the mean temperature measured outside the hibernation site of the respective month for the five study periods. Regression explained 84% of variation in mortality rates ($Y = 0.032\,x^2 - 0.120x + 0.206$, $n = 8$, $R^2 = 0.84$, $p < 0.05$).

Discussion

Our results indicate that *M. daubentonii*, *M. nattereri*, and *P. auritus* may be more exposed to mortality inside the fortifications than *M. myotis* and *B. barbastellus*, however the differences were statistically insignificant. Reasons for the observed tendency are not clear. Bats hibernating in the fortifications can switch hides and change microclimatic conditions due to changes in the external weather conditions or their energy reserves (Bogdanowicz and Urbańczyk 1983, Valenciuc 1989, Jurczyszyn and Bajarczyk 2001, Kokurewicz 2004). This enables for the bats to choose an optimal temperature. Possibly the quality of hides available in the fortifications are more suitable for *M. myotis* and *B. barbastellus* than M. *daubentonii*, *M. nattereri*, and *P. auritus*.

The proportion of the dead to live bats was higher in September and October than in November and December. The higher mortality rate in the first month of the study period could be attributed to weak animals that arrive first to the fortifications, where they die quickly. Ransome (1990) also suggests that in October late-born juveniles with low body food reserves leave the sampling sites or die. In Warsaw, in similar structures and climate as Toruń, *M. daubentonii* reaches its maximum weight in September (Lesiński 1986), and reaches its best condition. On the other hand, daily decreases in body weight during the first part of the study period (until mid-November) were more than twice as high as in the remaining period (Lesiński 1986), so energy expenditure is much higher then than during deep hibernation. It is possible that the higher energetic costs of life during the transitory period (pre-hibernal and beginning of hibernation) correlate with the ambient temperature and reduce the survival rate of weak or sick animals. The lowest mortality in November and December suggest that benefits of energy preservation and somatic maintenance one the highest.

The dead bats were also found more often from January onwards and mortality increased until April (post-hibernal period). This might be explained by the weakened physical condition (eg Lesiński 1986, Koteja *et al*. 2001), and be a result of deteriorations of physical functions (eg disease progress). We observed that the mortality rate of bats positively correlated with the mean monthly temperature. Park *et al*. (1999) noted a positive correlation between the number of daily bat passes monitored and cave temperature and an increase in diurnal activity at the end of winter. Because arousal involves high energy consumption (Thomas *et al*. 1990), we believe that most bats die inside the fortifications when the frequency of arousals increases, and as they grow active, because it reduces fat reserves. At this time progressive deterioration of body condition (due to the exhaustion of fat reserves) may also contribute to further problems. Whether the lowest monthly ambient temperatures increased the mortality inside the fortifications is not clear. It seems that the fortifications protect bats well from external weather conditions, and even the lowest ambient temperatures do not or rarely reduce temperatures in the whole fortification below the ones to which bats are adapted.

The presented results show that non-predator and non-accidental mortality (probably caused by a disease, parasites, or starvation) measured inside the fortifications is higher during transitory periods preceding and following the period of deep hibernation, in which mortality was the lowest. The results also indicate that both entering and exiting from hibernation are more risky periods for bats than the period of deeper hibernation. The slowdown of life processes decreases the risk of non-predator and non-accidental mortality per unit time. For endothermic mammals the coldest month of the year usually causes a growth in mortality due to famine or diseases (eg Pucek *et al*. 1993, Jędrzejewska and Jędrzejewski 1998), alternatively bats take advantage of low temperatures by slowing down their life processes and minimizing non-predator and non-accidental mortality.

Acknowledgements: Our thanks go to M. Wojciechowski, E. Szyp, I. Szyp, S. Bonin, J. Trochimiuk for assisting with the census of bats in the fortifications. We are very grateful to B. Jędrzejewska, Z. Pucek, L. Rychlik for comments on earlier drafts of the article, two anonymous reviewers for critical remarks on the manuscript, and S. Prior for language correction.

References

Austad S. N. 1997. Comparative aging and life histories in mammals. Experimental Gerontology 32: 23–38.

Barclay R. M. R. and Harder L. D. 2003. Life histories of bats: Life in the slow lane [In: Bat ecology. T. H. Kunz and M. B. Fenton, eds]. The University of Chicago Press, Chicago and London: 209–253.

Bogdanowicz W. 1994. *Myotis daubentonii*. Mammalian Species 475: 1–9.

Bogdanowicz W. and Urbańczyk Z. 1983. Some ecological aspect of bats hibernating in city of Poznań. Acta Theriologica 24: 371–385.

Davis W. H. and Hitchcock H. B. 1965. Biology and migration of the bat, *Myotis lucifugus*, in New England. Journal of Mammalogy 46: 296–313.

Gilette D. D. and Kimbrough J. D. 1970. Chiropteran mortality. [In: About bats: A Chiropteran Biology Symposium. B. H. Slaughter and D. W. Walton, eds]. Southern Methodist University Press, Dallas, Texas: 262–283.

Jędrzejewska B. and Jędrzejewski W. 1998. Predation in vertebrate communities: the Białowieża Primeval Forest as a case study. Springer, Berlin Heidelberg: 1–450.

Jurczyszyn M. and Bajaczyk R. 2001. Departure dynamics of *Myotis daubentonii* (Kuhl, 1817) (Mammalia, Chiroptera) from their hibernaculum. Mammalia 65: 121–130.

Kirk K. L. 2001. Dietary restriction and aging: comparative tests of evolutionary hypotheses. Journal of Gerontology 56: 123–129.

Kirkwood T. B. L. and Austad S. N. 2000. Why do we age? Nature 408: 233–238.

Kokurewicz T. 2004. Sex and age related habitat selection and mass dynamics of Daubenton's bats *Myotis daubentonii* (Kuhl, 1817) hibernating in natural conditions. Acta Chiropterologica 6: 121–144.

Koteja P., Jurczyszyn M. and Wołoszyn B. 2001. Energy balance of hibernating mouse-eared. *Myotis myotis*: a study with a TOBEC instrument. Acta Theriologica 46: 1–12.

Lesiński G. 1986. Ecology of bats hibernating underground in Central Poland. Acta Theriologica 31: 507–521.

Lin S. J., Kaeberlein M., Andalis A. A., Sturtz L. A., Defossez P. A., Culotta V. C., Fink G. R. and Guarente L. 2002. Calorie restriction extends *Saccaromeces cerevisiae* lifespan by increasing respiration. Nature 418: 344–348.

Park K. J., Jones G. and Ransome R. D. 1999. Winter activity of a population of greater horseshoe bats (*Rhinolophus ferrumequinum*). Journal of Zoology, London 248: 419–427.

Pucek Z., Jędrzejewski W., Jędrzejewska B. and Pucek M. 1993. Rodent population dynamics in a primeval deciduous forest (Białowieża National Park) in relation to weather, seed crop, and predation. Acta Theriologica 38: 199–232.

Racey P. A. and Entwistle A. C. 2000. Life history and reproductive strategies of bats. [In: Reproductive biology of bats. Crighton E. G. and P. H. Krutzsch, eds]. Academic Press, New York: 363–414.

Radzicki G., Hejduk J. and Bańbura J. 1999. Tits (*Parus major* and *Parus caeruleus)* preying upon hibernating bats. Ornis Fennica 76: 93–94.

Ransome R. 1990. The natural history of hibernating bats. Christpher Helm, London: 1–235.

Romanowski J. and Lesiński G. 1988. [Martens hunt bats]. Wszechświat 89: 210. [In Polish]

Ryberg O. 1947. Studies on bats and bat parasites. Svensk Natur, Stockholm: 1–329.

Shanley D. P. and Kirkwood T. B. L. 2000. Calorie restriction and aging: a life history analysis. Evolution 54: 740–750.

Sokal R. R. and Rohlf F. J. 1981. Biometry. W. H. Freeman and Company, New York: 1–859.

Speakman J. R. and Rowland A. 1999. Preparing for inactivity: how insectivorous bats deposit a fat store for hibernation. Proceedings of the Nutrition Society 58: 123–131.

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

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

Tuttle M. D. and Stevenson D. E. 1982. Growth and survival of bats [In: Ecology of bats. T. H. Kunz, ed]. Plenum Press, New York: 105–150.

Valenciuc N. 1989. Dynamics of movements of bats inside some shelters. [In: European bat research. V. Hanák, I. Horáček and J. Gaisler, eds]. Charles University Press, Praha: 511–517.

Wilkinson G. S. and South J. M. 2002. Life history, ecology and longevity in bats. Aging Cell 1: 124–131.

Received 8 September 2004, accepted 7 February 2005.

Associate Editor was Andrzej Zalewski.