Partial baldness in relation to reproduction in pond bats in the Netherlands

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Abstract: Temporary bald spots in mammals are usually related to moult. Alternatively, they may be a sign of bad health, or a side effect of hormones. Pond bats (*Myotis dasycneme*) commonly show partial baldness. Using data from more than 2,200 pond bats, captured between 2003 and 2008, we investigate the possible social, ecological and physiological factors involved in this phenomenon. A large proportion of pond bats were partly bald during a short period of the year, mainly between mid-May and the first week of August. Hair loss was observed in just a small area on the back of the bat, between the shoulder blades. These bald spots were much more common among females than males. The occurrence of baldness was temporally correlated with the nursing period of females. To test the generality of these patterns we studied animals from museum collections and photographs of roosting animals taken during the past two decades. While these data remain anecdotal, the position of the bald spots and the timing of appearance are consistent with those found in this study.

Keywords: pond bat, *Myotis dasycneme,* partial baldness, bald spot, hormones, reproduction, parasites, fungi, nutrition deficiencies, moult.

Introduction

Temporary hair loss in relation to moult is a common phenomenon in mammals. Most mammals change their coat every year and some have two different types of hair: a dense winter fur and a lighter summer fur. Most moults can be classified in one of two groups: dorsad and diffuse. Dorsad moult is a uniform sequence of replacement and diffuse moult is characterised by an irregular and blotchy pattern of replacement (Rowsemitt et al. 1975). Other causes for temporary hair loss can be bad health or a side effect of hormones that may be adaptive or selectively neutral.

Excessive loss of fur, caused by bad health, occurs frequently in many bat species (Keller 1994, Butchkoski & Hassinger 2002, Ter Hofstede et al. 2004, Pederson 2006, Wolters 2006). Fur loss can be caused by external parasites (e.g. bat flies, Streblidae and Nycteribiidae) or skin-growing fungi (dermatohpytes) or *Demodex* mites (small mites which live in hair follicles). In captivity, bats' hair loss can also be due to nutritional deficiencies, poor hygiene, improper housing, injury or low humidity (Wilson 1988).

Reproductive hormones have effects on various aspects of hair growth and moult in mammals and some of these effects may be adaptive (Fraser & Nay 1953, Johnson 1958). For example, in rabbits hormones regulate the loosening of hair from the ventrum and inner thighs. This process occurs from the day of parturition until 3-4 days into lactation. Rabbits pluck these hairs and use them for nest building (González-Mariscal et al. 2003). Hormonal change is known to have side effects on hair loss / retention. For example, humans show a change of hair structure that is related to reproduction (Ohnemus et al.

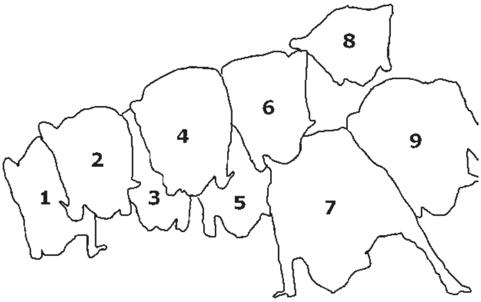


Figure 1. Photograph of roosting pond bats from the church loft in Berlikum, summer 2005. The bald spots can be seen between the shoulder blades. In each individual the bald spot is similarly shaped. Left: Most of the individuals in the photograph can be distinguished by age (juvenile and adult). Individuals with obvious bald spots are: 1 (juv), 2 (juv), 3 (juv), 4 (ad), 6 (juv), 8 (juv). Individuals which might be losing their hairs are: 7 (ad), 9 (ad). Individual 5 (ad) has no bald spot. *Photograph: Zomer Bruijn.*

2006). A change of hormone levels, especially oestrogen, during pregnancy causes hair that under normal conditions would have fallen out to be retained and new hairs to change structure. When hormone levels return to normal after child birth these retained hairs fall out and hair structure changes back to normal. Presumably, such changes have no particular function, but are a selectively neutral pleiotropic effect.

In 2002, during our first year of study on pond bats (*Myotis dasycneme*), we noticed that a large proportion of bats we captured showed bald spots during a short period of the year. The current literature contains no observations on this phenomenon but, due to its inconspicuous nature, it could have been overlooked in the past. We therefore investigated several historical records to check if the occurrence of these bald spots is a recent phenomenon.

To understand the cause or function of the bald spots (also referred to in this paper as partial baldness) we investigated all the bats we captured between 2003 and 2008 and described possible causal factors such as parasite load, body condition, sex, sexual maturity and reproductive status. By comparing descriptions of marked individuals we could

Figure 2. A pond bat captured in Reeuwijk, Zuid-Holland, August 2007. Between the shoulder blades a typical regrowth pattern can be seen, the darker hairs growing from the centre outwards. Left: Line drawing of the outline of the regrowth pattern.*Photograph: René Janssen.*

identify if individuals became partially bald in two or more successive years. We were also interested in the spatial and temporal patterns of the occurrence of these bald spots and took observations of pond bats in several Dutch provinces between April and September in each year.

Material and methods

Captures and measurements

During six years of study, between 2003 and 2008, the authors and bat volunteers captured pond bats in several locations in the Netherlands between April and September. These bats were mostly captured on their commuting routes using mistnets (Haarsma & van Alphen 2009a). In addition, pond bats were captured in spring and autumn while they were swarming in front of their hibernacula in the provinces of Gelderland, Limburg and Zuid-Holland.

Each individual was handled and described by the first named author using the Dutch protocol for the assessment of reproductive status, age and health of bats (Haarsma 2008, Haarsma & van Alphen 2009b). Sometimes, for ethical reasons (e.g. a highly pregnant female, large number of bats) handling time was shortened and some characteristics were not recorded. Standard biometric measurements were taken from every bat (forearm length and weight) as well as sex and reproductive status. Based on the fusion of phalangeal epiphyses, descriptions of male testes and epidydimes and of female abdomen and nipples, bats were classified into three maturity groups: juvenile, sexual immature animals and sexual mature animals. Females were grouped into three reproductive groups: not reproductive, nursing and pregnant. In addition the presence or absence of parasites on the wing membrane and in the fur was recorded.

The hairstyle of each bat was categorised into three groups: 1. normal (absence of bald spots), 2. visible bald spot and 3. regrowth of hair. The location of bald spots (on the back, around the umbilicus or other location) was also noted. The typical shape and location of the bald spots can be seen in figure 1. Regrowth was easy to distinguish because the under fur, which has a grey colour, grows back first, followed later by the top fur. The hairs typically regrow from the centre outwards (figure 2). To investigate the factors influencing the phenomenon of partial baldness, we clustered the hairstyles into two groups: absence of bald spots (normal hairstyle) and presence of bald spots (visible bald spot and individuals with regrowth).

Approximately 75% of the population were marked with a ring and fitted with a transponder. We avoided marking the entire population, because of the risk of damage or injuries from the marking methods. By recapturing marked individuals, we could monitor how quickly hairs regrew and whether individuals showed partial baldness in successive trapping sessions.

Investigation of historical records

All the pond bats within the collection of the National Museum of Natural History (Naturalis) were investigated for signs of bald spots. These included 19 dried stuffed specimens (8 females and 11 males) and 87 specimens preserved in alcohol (21 males and 57 females captured in winter, 7 males and 2 females captured in summer). All of these had been collected in the Netherlands between 1917 and 2002. The hairstyle of each animal was recorded.

Mr. Z. Bruijn investigated his collection of photos of roosting pond bats from church lofts in Berlikum and Tjerkwerd (in the province of Friesland). These were taken annually between 1999 and 2006, with an initial photo session from the early 1990s. Although these pictures were not taken for this purpose, the bald spots can be distinguished in the photos as pond bats always hang with their bellies against objects and their backs visible (figure 1).

Statistical analysis

Binary logistic regression was used to compare the binary dependent variable (presence/absence of bald spots) with categorical independent variables such as sex, province, parasite load, sexual maturity and reproductive status of females. As a measure for body condition index we took the unstandardised residual of the linear relation between forearm length and body weight (Kaňuch et al. 2005, Vázquez-Morón et al. 2008). A Kruskal Wallis test for independent samples was used to compare the frequency of bald spots over the five research years. Statistical analyses were carried out using SPSS V15.

Results

Historical records

None of the specimens from the Naturalis collection showed signs of partial baldness, with the exception of one stuffed animal from Russia, collected on 16 August 1989 in Nizhni Chir (RNHM reg. no 37172). The size and coloration of the nipples indicate this was a lactating female. Between her shoulder

Table 1. The presence (+) and absence (-) of partial baldness on photos, slides and videos taken from the churches of Tjerkwerd and Berlikum.Years in which no photos were taken are marked with a ?.

Year	Tjerkwerd	Berlikum
Early 1990s	+	+
1999	+	?
2000	+	+
2001	-	?
2002	?	?
2003	+	?
2004	+	?
2005	?	+

blades the typical regrowth pattern of the partial baldness described in this article could be distinguished (figure 3).

Examination of the historical photographs from Berlikum and Tjerkwerd showed that the phenomenon was present in the early 1990s (table 1). Between 1999 and 2005 in all years, except 2002, pond bats with bald spots were present in one or both of the churches. The photos were not taken systematically so no other conclusions could be drawn from these pictures.

Animals captured between 2003 and 2008

Between 2003 and 2008 we captured and described 627 male and 1592 female pond bats (531 and 1233 individuals respectively). Of these animals a total of 404 males (76.1%) and 927 females (75.2%) were individually marked. For the analyses in this paper all 2219 descriptions of individual bats were used.

Sex, sexual maturity, parasites and body condition

Almost all observed bald spots were located on the back of the bat, between the shoulder blades (the three exceptions were located around the navel and the nipples). The presence or absence of partial baldness was scored for all the captured bats (figure 4). Partial baldness was more common in female pond bats than in males (table 2, P=0.000). Partial baldness was related to sexual maturity (table 2, P=0.000). 27.9% of the females from the sampled population showed signs of partial baldness. Partial baldness was not evenly distributed between the female maturity groups: it was found in 44.1% of the juveniles, 2.9% of the sexual immature individuals and 36.3% of those that were sexual matures. The male population also showed shows signs of partial baldness (15.4%), but the juvenile age group was the only group with a relative high frequency of bald spots (41.1%). The other maturity groups had a low percentage of individuals with bald spots: sexual immature males (3.2%) and sexual mature ones (1.9%).

Although the majority (88.7%) of pond bats captured for this study had at least some parasites, no relation between the number of parasites and partial baldness was found (table 2, P=0.810). The presence of bald spots was also not related to the body condition index (table 2, P=0.401).

Table 2. Results of binary logistic regression between the dependent variable 'partial baldness' (presence/absence of bald spots) and several categorical independent variables. Significant relations with the dependent variable are marked with an asterisk.

	Wald statistic	df	Significance
Sexual maturity	77.57	2	0.000*
Sex	88.18	1	0.000*
Body condition	0.652	1	0.401
Parasite load	0.3016	1	0.810
Province	50.00	8	0.000*
Reproductive status of females	144.96	2	0.000*

Figure 3. Female pond bat from Russia, collected on the 16th August 1989 (RNMH reg nr 37172). Between the shoulder blades a hair regrowth pattern can be distinguished. This pattern is only observed in animals which previously showed bald spots. *Photograph: Hein van Grouw.*

Spatial patterns

Approximately three quarters of the total sample of pond bats used in this research were captured in Zuid-Holland. The majority of the remainder were captured in the provinces of Overijssel, Friesland, Utrecht and Noord-Holland (table 3). The occurrence of bald spots in pond bats was more common in some provinces than in others (table 2, *P*=0.000). The highest percentage of individuals with bald spots was found in Utrecht (50.6% females and 18.5% males).

Temporal patterns

In all the research years (2003-2008) the timing of partial baldness occurred in a similar manner (table 4). The first bald spots were noticed around mid-May (week 19). During week 24 (second week of June) the highest number of individuals showed signs of partial baldness, and the last individuals with bald spots were observed around week 32 (first week of August). The first signs of regrowth were found in the second week of June (week 24). During week 29 (mid-July) the highest number of individuals showed signs of regrowth. By the beginning of August (week 35) no more signs of partial baldness or regrowth were found.

Female reproductive status

Females with a swollen abdomen, which was taken as a sign of pregnancy, were captured from mid-April (week 15) onwards, with peak densities in week 20 (mid-May) (figure 5). The graph shows a dip in week 19 as we tried to avoid capturing pregnant females. Swollen mammae and bald areas around the mammae, which were taken as a sign of nursing, were observed from the second week of May (week 19), with a peak in week 25 (mid-June).

The peak in partial baldness correlated with the peak in nursing (figure 5). The occurrence of bald spots in adults females was sig-

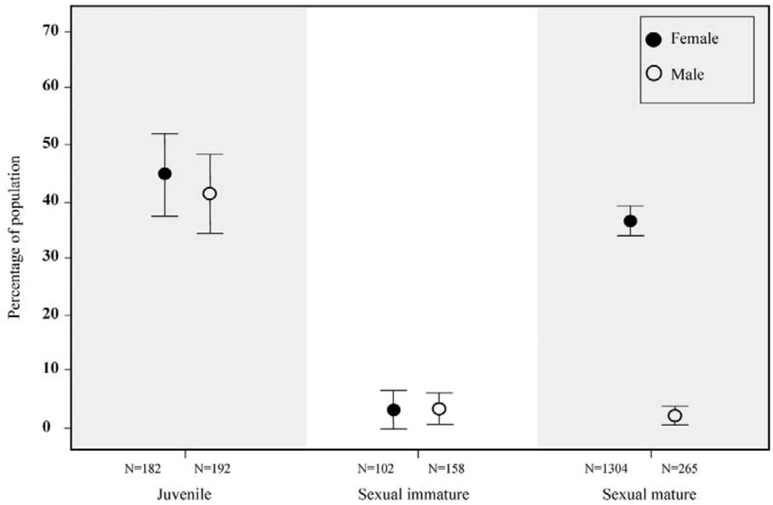


Figure 4. Percentage of the population with signs of partial baldness for three maturity groups (juvenile, sexual immature and sexual mature). The males and females are represented by open and shaded circles, respectively. The error bars show the 95% confidence interval for the mean.

Table 3. The number of individuals captured on commuting routes in different provinces and the percentage of this sample showing signs of partial baldness.

	Females		Males	
Province	*n*	%	*n*	%
Friesland	119	47.1	46	10.8
Overijssel	149	14.1	13	7.7
Flevoland	17	29.4	14	7.1
Utrecht	89	50.6	27	18.5
Noord-Holland	93	16.2	46	13.0
Zuid-Holland	1098	37.8	400	17.7
Gelderland	16	0	39	0
Limburg	11	0	39	0
Zeeland	0	0	3	0
Total	1592		627	

Table 4. The first, peak and last observation of partial baldness and regrowth between 2003 and 2008 (expressed as week number).

	Partial baldness			Regrowth		
Year	First observation	Peak	Last observation	First observation	Peak	Last observation
2003	22	24	32	24	28	31
2004	19	25	30	25	29	33
2005	20	24	30	24	29	31
2006	21	24	30	24	29	34
2007	21	25	31	25	28	33
2008	19	24	29	25	29	29

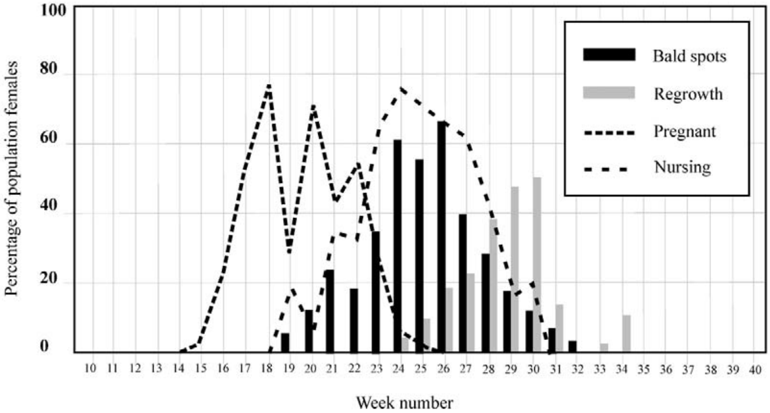


Figure 5. Percentage of the female population showing bald spots or the typical dark hairs which indicate regrowth of a former bald spot per week. The figure also shows the timing of reproductive status of females: pregnant and nursing are indicated as a percentage of the population.

nificantly correlated to reproductive status of females (table 2, *P*=0.000).

The pattern described in figure 5 occurred in all the years of the study period. There was some variation in the timing of the first and last observations (table 4). In 2004 and 2008 the first signs of bald spots were observed in week 19, which is one week earlier than average. The pattern of regrowth that year corresponded with previous years. In 2006 the last signs of regrowth were observed in week 34, which is one week later than average. The difference between the years was not significant (χ^2=4, df=5, *P*=0.406).

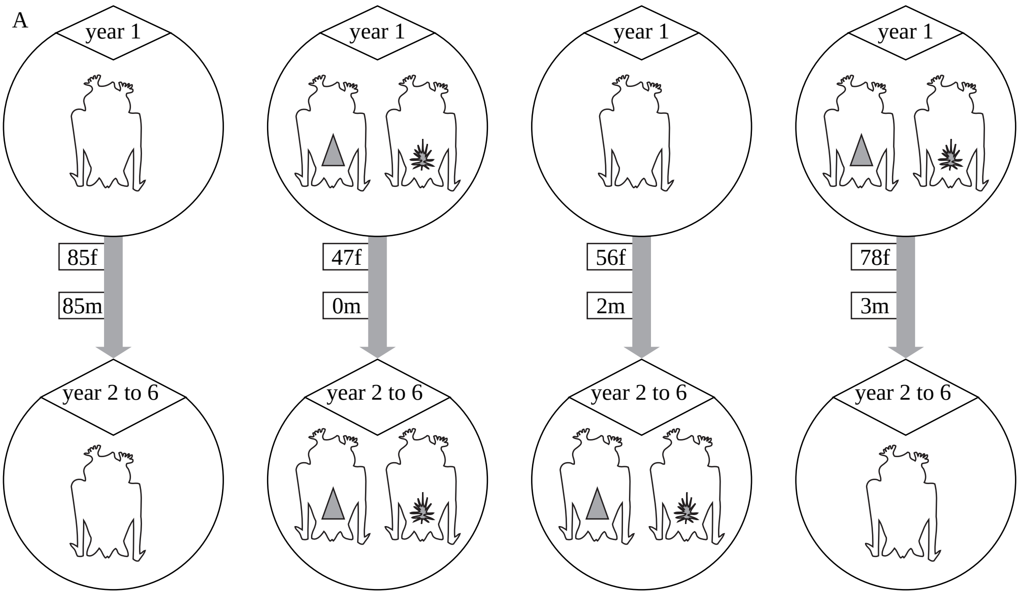
298 individuals (216 females, 82 males) were captured, described and assessed for the presence or absence of bald spots more than once. Several individuals were recaptured in the same season, some in different years, others were recaptured in both. In total we used 137 recapture sightings (99 females and 38 males) of pond bats captured within one season (figure 6B) and 356 recapture sightings (266 females and 90 males) of bats captured in two different years (figure 6A). Some bats were observed with the same hairstyle (normal, bald spots present or regrowth), some had different hairstyles. Partial baldness is a recurrent, rather than a one-off, characteristic (at least among females): 17.7% of the recaptured females that once had bald spots, were observed with partial baldness the next year and 29.3% of these females were recaptured without showing signs of bald spots. None of the males, on the other hand, became partially bald in two successive years. 94.5% of the males did not show any bald spots over the years.

We observed 53 individuals (49 females and 4 males) that lost and regrew their hair during one summer season. 44.4% of the recaptured females and 86.8% of the recaptured males were observed more than twice during one season without bald spots.

Partial baldness was not observed during hibernation, according to annual observations of approximately 300 pond bats in hibernacula in several parts of the Netherlands (A.-J. Haarsma, unpublished results). During the pond bat swarming season (between week 33 and week 37, Janssen et al. 2008) no pond bats with bald spots were captured.

Conclusion

The results show that partial baldness in pond bats is not a recent phenomenon. Historical evidence of this was found from both the Naturalis specimens and the photographic



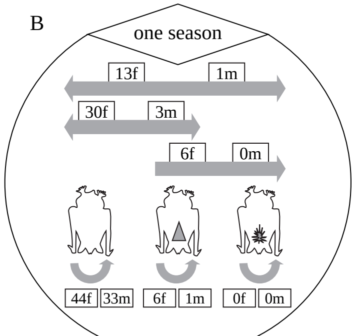


Figure 6. An overview of observations of pond bats recorded in two different years (A) or twice or more within one year (B). Three different hairstyles are schematically presented: bald spots absent ( ), bald spots present ( ) and regrowth ( ). The number of observations for each arrow are given for males (m) and females (f). Over the years, pond bats may develop bald spots or bald spots may disappear, or bats with bald spots may develop regrowth. A particular hair condition (not bald, bald or regrowth) may also remain unchanged.

archive of Z. Bruijn. The photographs from Tjerkwerd and Berlikum indicated that the phenomenon has existed in the Netherlands at least since the early 1990s. Based on geographic evidence from Russia, we hypothesise the phenomenon also occurs in other European counties. Recently, during a fieldtrip in northern Germany with local bat workers, we witnessed evidence for this hypothesis: in this part of Germany bald spots have frequently been observed since 2004 (A. Seebens & F. Gloza-Rausch, personal communication).

Partial baldness is found across the Netherlands. Bald spots were observed among bats captured in the provinces of Noord-Holland, Zuid-Holland, Friesland, Overijssel and Utrecht. In spring and autumn partial baldness did not occur in areas without maternity roosts, such as the provinces of Gelderland and Limburg.

Bald spots in pond bats always occurred in the same part of the body, between the shoulder blades. The results show that partial baldness in pond bats can be an annually recurrent phenomenon, occurring mostly in juveniles and females, and that it is linked with reproduction in females. The onset of partial baldness in female pond bats was around mid-May and hair regrowth started around mid-June. Partial baldness was not observed in hibernating bats, indicating this regrowth is completed at least before winter and that partial baldness is not found the whole year round. We conclude that partial baldness in pond bats is not a sign of bad health and is not related to body condition.

Discussion

Our results do not provide a decisive answer about the functional factors that influence partial baldness in pond bats. Here we give an overview of hypothetical causes. These can be classified into three groups: bad health, a neutral (non-adaptive) side effect of hormones, and an adaptive side effect related to reproduction.

Bad health

Several external factors may be responsible for hair loss in pond bats: external parasites (e.g. bat flies), skin-growing fungi, *Demodex* mites, nutritional deficiencies, poor hygiene, improper housing, injury, low humidity and moult. The fact that bald spots are restricted to a small area on the back of the bats may be explained by their grooming behaviour. Bats are able to clean their bodies very thoroughly, except for a small area on their backs, which is difficult to reach. So, while they can get rid of parasites, skin growing fungi and *Demodex* mites from most of their body, it is possible that part of their back remains infected and becomes bald. The results of this study, however strongly suggest that baldness is not a sign of bad health. We found no relation between body condition or parasite load and partial baldness. Furthermore, bad health would not account for the sex difference in the incidence of partial baldness and the occurrence of bald spots could not be predicted to be site-specific or restricted to a particular time of year.

A neutral (non-adaptive) side effect of hormones

The temporal pattern in adult females seems indicative of a hormonal effect. Both male and female juveniles develop bald spots in their early stages of life. We hypothesise that offspring of balding females acquire these hormones through their mother's milk and this leads them to develop bald spots themselves. There could be several hormones involved, possibly including reproductive hormones like oestrogen and aggression-inducing hormones (testosterone). During a short period of the year pond bats, especially those with young, need to be very aggressive because of high competition for food. During this research we did not notice any signs of aggressiveness among pond bats in summer. Signs of aggressiveness are found regularly in male pond bats during the mating season when bite marks in the ears and wings are visible (A.-J. Haarsma, personal observation). While this indicates aggression towards each other, it does not indicate partial baldness.

A second hypothetical neutral side effect is linked to the behaviour of animals in the roost. In the second week of May the number of individuals in the maternity roost increases, due to the birth of young. Individuals tend to form clusters (figure 1) and many sit on top of each other. This behaviour could result in physical damage, especially when the nails of the thumbs lay on the backs of other individuals. However, it seems very unlikely that this would result in similarly shaped bald spots and that it would only affect reproducing individuals (not all individuals reproduce each year: about 30% of the sexual mature females within a roost do not reproduce in any particular year; A.-J. Haarsma, unpublished data).

Adaptive side effect related to reproduction

The reproductive success of pond bats depends on a female bat's ability to produce milk.

Good milk production ensures that a female can wean her single young faster, giving the young more time to prepare for hibernation. Researchers discovered that energy export during lactation is limited by the ability of mothers to dissipate body heat (the heat dissipation limit hypothesis, Król & Speakman 2003). The mothers need to lose the additional heat produced in processing food and producing milk. In support of this hypothesis nest building mammals select nests based on their insulative value, not only to reduce heat loss in cold conditions but also to dissipate heat during warm periods (Guillemette et al. 2009). Pond bats do not often move between different roosts and are not able to change the construction of their roost. Temperatures within a maternity roost remain relatively stable (Voûte 1972). Partial baldness may therefore be an adaptation to enhance milk production.

Another hypothetical explanation for partial baldness in pond bats is that it is a trade-off, where resources needed for the maintenance of hairs are allocated to other functions, such as lactation or acquiring brown tissue. There are, however, no studies to support this hypothesis. Pond bats are a migrating species, travelling between 70 and 350 kilometres each year between summer and winter roosts (Haarsma 2009). It is possible that changing the most important body hairs first gives animals that leave the maternity roost relatively early in the year (the reproductive females) a head start during the moult, which would otherwise take place during migration.

The third hypothetical explanation for partial baldness in pond bats is associated with olfactory communication. Many species of bats secrete substances, for reasons such as mate recognition, territory marking, offspring recognition and sexual selection. Scent glands are located on different parts of a bat's body, including the face, ears, neck, chest, shoulders and genital area. Scent glands in bats can be very inconspicuous and only visible during a short period of each year (Nassar et al. 2008). Although the bald spots did not excrete an odour perceivable by humans, they might have an olfactory function.

Further studies

Further studies are required to assess whether partial baldness in this species has an adaptive function. In this respect, comparative studies with other bat species would be useful. Species that are naturally partial bald, such as the Neotropical bat *Pteronotus davyi*, would be of special interest. This species is permanently hairless on its back, which is caused by the dorsal side of the wing membranes meeting in the middle of the back (Bonaccorso et al. 1992). Experiments in a laboratory setting are needed to distinguish between the different hypotheses: for example, by temporally preventing bats from cleaning themselves with their tongues and hind feet. Equally, reproductive hormones could be administered to captive, non pregnant females. If bald spots really are an effect of hormones, such manipulation should induce baldness. The temperature in maternity roosts might also be of influence and gathering data about temperature fluctuations in roosts, such as church lofts might lead to new insights into this hypothesis.

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Samenvatting

Het voorkomen van kale plekken in relatie tot reproductie bij de meervleermuis

Kale plekken in de vacht van zoogdieren worden meestal veroorzaakt door rui. In sommige gevallen kunnen kale plekken veroorzaakt worden door ziekte of een bij-effect zijn van hormonen. Meervleermuizen (*Myotis dasycneme*) vertonen vaak opvallende kale plekken op de rug. Aan de hand van data van meer dan 2200 gevangen meervleermuizen tussen 2003 en 2008 hebben we de mogelijke sociale, ecologische en fysiologische oorzaken achter dit fenomeen onderzocht. Het merendeel van de gevangen meervleermuizen vertoonde kale plekken in een korte periode van het jaar, meestal tussen midden mei en de eerste week van augustus. De kale plekken bevonden zich in een duidelijk afgebakend gebied op de rug van de vleermuizen, tussen de schouderbladen. Vrouwtjes vertoonden vaker kale plekken dan mannetjes. De aanwezigheid van kale plekken is duidelijk gerelateerd aan de zoogperiode van vrouwtjes. We hebben onderzocht hoe recent het door ons waargenomen patroon is. Hiervoor hebben we onze patronen vergeleken met de Naturalis-museumcollectie en met archieffoto's van rustende meervleermuizen op kerkzolders. Ondanks het feit dat vroegere waarnemingen van kale plekken alleen door toeval verzameld zijn, is de positie van de kale plek en het patroon van verschijnen door het jaar heen, gelijk aan de resultaten van huidige onderzoek.

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