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NATURAL HISTORY NOTE

Recaptured *Myotis brandtii* carried glue-on radio-tag for 10 months: does time from tagging to shedding depend on timing of annual moulting?

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ABSTRACT

The use of radio telemetry has been essential for collecting information about bat biology and ecology. The radio-tag is usually glued on the back of the bat and typically falls off after just over a week. In the present study, we present a case where a radio-tagged *Myotis brandtii* was recaptured with its radio-tag still intact and attached, ten months after initial tagging. At the time of recapture, there was no re-growth of hair under the transmitter. Three other radio-tagged *Myotis mystacinus* were also recaptured after the winter season, but these individuals had shed their radio-tags and showed a complete regrowth of hair. Carrying a non-functional transmitter will cause unnecessary costs for the bat. As the onset of moulting is understudied in general, and differs widely between both species, sexes and sexual status, we propose that researchers should put more effort into recapturing radio-tagged bats before the end of the transmitter's battery life to remove the transmitter. This may be particularly important when the time of tagging does not correspond with the bats' moulting season. More intra- and interspecific information is needed about the timing of moulting in order to minimize negative effects on bats when using glued on radio-tags.

Telemetry studies involving radio-tagging and tracking of bats have been carried out for more than 50 years (see O'Mara et al. 2014). Data collected from such studies have provided knowledge on diurnal roost choice (Michaelsen et al. 2013, Dietz et al. 2018), thermal biology (Jonasson & Willis 2012, Stawski et al. 2014) and spatial movements (Audet 1990, de Jong 1994, Murphy et al. 2012, Ashrafi et al. 2013, Dietz et al. 2018). Telemetry studies can provide essential information on the biology and ecology of bats (Salvarina 2016), which can be useful for conservation purposes. Such information can help to pinpoint essential habitats for conservation based on foraging (Ashrafi et al. 2013) and roosting behaviour in natural (Kurta & Murray 2002, Dietz et al. 2018) and urbanized areas (Vlaschenko et al. 2019). However, from an animal welfare perspective, radio-tagging of individuals can be considered a rather invasive method as bats will be affected not just during the initial capture, but also for an elongated time following their release. Scientists should therefore endeavour to minimize the potential short and long-term impacts on a tagged individual.

The most common method for equipping bats with radio-tags has been to attach the tags onto the bats' back with a medical latex glue (reviewed in O'Mara et al. 2014), but alternative methods – such as stitching on the tags (perforating the skin, Castle et al. 2015) or equipping the bats with small radio-collars (Kronwitter 1988) – have been used in some studies (O'Mara et al. 2014). The main reason for the popularity of the glue-on method is that it is easy to implement and less invasive, especially since it is generally assumed that transmitters will eventually fall off as a result of shedding and regrowth of fur, and thus recapture is not required to remove the tag. O'Mara et al. (2014) found that on average, the glued-on tags stayed attached to a bat for 9.3 days (± 4.6 days), which is, in most cases, much shorter time than the expected battery life for most VHF transmitters available for studying small bats (O'Mara et al. 2014). Unfortunately, few articles have reported 1) whether the radio-tag was removed by the bat itself or by the researchers, and 2) under what circumstances bats lost the radio-tag (e.g., during roosting or foraging). Additionally, few studies include information about the presence or absence of injuries or regrowth of hair were the radio-tag has previously been attached.

To the best of our knowledge, the longest duration, for which a radio-transmitter remained attached to a bat, was 159 days (Berg 2012). Two *Myotis myotis* were fitted with radio-tags (PicoPip Ag392, BioTrack, 0.98 g) in October 2011, using medical latex glue (Sauer-Hautkleber 50.01, Manfred Sauer GmbH, Lobbach, Germany), and recaptured the following March, thus following hibernation. Instead of removing hair from the back, the radio-tags were glued to the skin that appeared where the hair was arranged to each

side. The transmitters had left minor scaring on the backs (Berg 2012, Berg pers. comm.).

In another study, a *Myotis lucifugus* was fitted with a transmitter (BD-2NT, Holohil Systems Ltd, Carp, ON, Canada; mass 0.80 g), with a latex-based adhesive (Osto-bond, Montreal Ostomy, Vaudreuil, QC, Canada), which increased the bats weight with 7.3%. It was recaptured 92 days later with the radio-tag still attached. As the bat was initially radio-tagged in late November 2009, it too hibernated with its transmitter attached (Jonasson & Willis 2012, see Fig. 3).

In the present paper, we report on the recapture of a female *Myotis brandtii*, with a glue-on radio-tag 306 days after the initial tagging. This is by far the longest documented period, for which a glued-on radio-tag has stayed attached to a free-ranging bat.

In order to study the spatial movement and habitat use by *M. brandtii* and *M. mystacinus*, bats were captured with mist-nets at different capture locations on several occasions throughout the summer. Some of the captured individuals were fitted with a radio-tag, which was glued on the back of the bat below the scapula with a medical latex glue (Sauer-Hautkleber 50.01, Manfred Sauer GmbH, Lobbach, Germany). Before the radio-tag was glued on, the fur was trimmed short so that the tag would attach to the skin rather than to the hair. Neighbouring hair were glued on top of the transmitter to strengthen the attachment.

The female bat was one of 56 female *M. brandtii* and 111 *M. mystacinus* captures within the study area in Nittedal municipality, Viken county, Norway (Eldegard et al. unpublished data) during the summer months (June, July and August) of 2018. The study area is situated in a valley characterized by the main river, Nitelva, running southwards down the valley, surrounded by agricultural areas, small deciduous forest patches and small settlements, particularly on the west side of the valley. At higher elevations along the sides of the valley, the landscape is dominated by continuous coniferous forest that is used for timber production. As part of an ongoing study (van der Kooij et al. in prep) to recognize individual bats by their wing structure (see Amelon et al. 2017), each wing was photographed in a standardized way.

On the 14th of August 2018, a female *M. brandtii*, (weight 6.4 g, forearm length 35.0 mm), with no signs of recent reproduction and with deformed ear tips (Fig. 1), was captured next to a small pond in a coniferous forest. The bat was fitted with a radio-tag (PIP4, BioTrack, 0.31 g), which added 5.8 % to its body weight, which is in line with previous recommendations (O'Mara et al. 2014). After tagging, it was tracked continuously for 11 days, which exceeded the expected battery life of the radio-tag (estimated battery life: 8.4 days).

On the 17th of June 2019, a radio-tagged female *M. brandtii* was captured next to a farmhouse approximately 1.1 km west of the small pond. The recaptured bat had deformed ear tips, and the pattern of the collagen-elastin bundles revealed that this was the same individual as the one tagged in 2018 (Fig. 1 and 2). The recapture site was situated between one of the female bats' autumn roosts,

Fig. 1 - Deformed eartips of recaptured bat in 2018 (left) and 2019 (right).

Fig. 2 - Wing photos of the recaptured bat in 2018 (MbraF189, upper) and 2019 (MbraF284, lower).

Fig. 3 - Pictures of the recaptured bat's back shortly after the radio-tag had fallen off (left) on July 7th 2019 and upon recapture (right) on July 16th 2019.

her main foraging area from the previous year (Eldegard et al. unpublished data), and a known colony of *M. brandtii* (Siljedal 2018).

When recaptured the bat weighed 5.6 g and was pregnant. It showed no signs of injury related to the radio-tag. However, the bat carried a relatively large amount of ectoparasites, and showed scars which originated from parasites and irritated/swollen bloodvessels. (Fig. 2).

Pending the transmitter to fall off, the bat was kept in captivity and placed in a flight cage with heated roosts (van der Kooij 2007), where it was hand fed daily. After the transmitter fell off, there were no visible signs of regrowth of fur on, and around the previous attachment point (Fig. 3). Subsequently, the bat was released on the same location as it was captured the same summer. On the 16th July 2019, the same bat was captured for the third time at the same pond as where it was captured and radio-tagged during the previous year. At this second recapture, a new layer of fur had started to grow back on the spot where the radio-tag

Table 1 - WingID refers to the numbers assigned to the photographed wing-pairs at the radio-tagging (Tagging) and at the subsequent recapture date(s). Fur regrowth is the level of regrowth after the transmitter had fallen off. None = bare skin on the back. Short = hair shorter than the surrounding hair. Full = hair indistinguishable from surrounding hair. * The only bat which was recaptured twice after being radio-tagged.

WingID	Tagging	Recapture	Second recapture	Fur regrowth
MmysF003/013	05.06.2018	11.06.2018	-	None
MmysF074/106	24.06.2018	11.07.2018	-	None
MmysF070/130	24.06.2018	16.07.2018	-	None
MmysF110/200	11.07.2018	20.08.2018	-	Unknown
MbraF035/181	13.06.2018	04.08.2018	-	Full
MbraF093/163	03.07.2018	21.07.2018	-	Short
MmysF024/283	12.06.2018	05.07.2019	-	Full
MmysF108/232	11.07.2018	09.06.2019	-	Full
MmysF140/254	17.07.2018	20.06.2019	-	Full
MbraF189/248/307*	14.08.2018	17.06.2019	16.07.2019	None/Short

had been attached (Fig. 3), indicating that its annual moult occurred in July.

In the present study, only one out of 10 radio-tagged female *M. brandtii* lost their radio-tag before the battery expired (Table 1), or before the field crew stopped radio-tracking the bat (Eldegard et al. unpublished data). It had lost its radio-tag in the roost. The 10 radio-tagged *M. brandtii* weighed on average 6.5 g (±1.0 g), and the radio-tag added on average 5.8% (±0.7%) to their bodyweight %). Each bat was tracked for an average of 7.4 days (±3.6 days). In contrast, the 12 radio-tagged female *M. mystacinus* weighed on average 5.7 g (±0.9 g), and the radio-tags added 6.5% (±1.0%) to their bodyweight, and the tags remained attached for only 5.7 days (± 2.9 days) before they dropped off. Eight out of the 12 *M. mystacinus* were confirmed to have lost their radio-tag. Seven of these were lost inside roosts, whereas one was lost while foraging. Four *M. mystacinus* were recaptured later in the summer. The first that was recaptured had only carried its radio-tag for three nights before it was lost. The radio-tag had caused a minor scar on the otherwise bare skin patch. Two of the remaining *M. mystacinus* were recaptured in mid-July, 17 and 22 days after being radio-tagged. No new fur had grown where the radio-tag had been. The fourth *M. mystacinus* was recaptured in mid-August, 39 days after being radio-tagged. Unfortunately, whether or not the bat had started to moult at that time was not noted. In contrast, one *M. brandtii* was recaptured in the second half of July, 13 days after being radio-tagged. This bat had dark pigmentation on the underside of its skin (see Tiunov & Makarikova 2007, Fraser et al. 2013), and it had already started to grow a new layer of fur. Its time of moulting corresponds with the one recaptured with its radio-tag still attached (Table 1). Additionally, another *M. brandtii* was recaptured 52 days after being radio-tagged. When recaptured at the beginning of August 2018, the bat had gone through a complete moult.

In the summer of 2019, three of the 12 *M. mystacinus* that were radio-tagged in 2018 were recaptured in the same study area. None of them showed any visible signs of previous radio-tagging (Table 1). The recaptures were verified by means of wing photo ID (Amelon et al. 2017).

A documented period of 306 days for a radio-tag to be attached to a bat, is both considerably longer than the average longevity of glued-on transmitters (O'Mara et al. 2014) and much longer than previously reported in literature, irrespective of method of attachment. To date, few telemetry studies have been published on *M. brandtii*. Dense & Rahmel (2002) studied nine female *M. brandtii* individuals in which the radio-tags lasted 1-7 days. Berge (2007) studied the habitat use of 11 *M. brandtii* individuals in which the radio-tags had a lifespan of 4-11 days (average: 8 days), but some transmitters still emitted signals when the tracking was ended. Similarly, the radio-tags attached to the morphometrically similar *M. mystacinus* had a lifespan of 6-14 days (average: 9.4 days, Berge 2007).

Based on the few observations on difference in shedding time of the radio-tag and the observed pattern of regrowth we propose that *M. brandtii* may moult earlier than *M. mystacinus*. This is supported by the fact that all *M. mystacinus* recaptured in June and July the following year, had a fully regrown fur (Table 1). Whereas the *M. brandtii* recaptured had not. Additionally, *M. brandtii* swarms earlier than *M. mystacinus* (Parsons et al. 2003, Meschede & Rudolph 2004, Šuba et al. 2008), thus indicating a different annual cycle which may also include a different moulting time.

Hence, as the *M. brandtii* we recaptured was tagged in mid-August 2018, it may have been tagged after its moult. Hence, the lack of fur growth beneath the transmitter may have impaired its ability to remove the radio-tag. Although the moulting pattern of *M. brandtii* has been studied previously (Gauckler & Kraus 1970, Ohlendorf et al. 2002, Heise & Blohm 2013), no information on the onset of moulting has been published.

Kurta & Murray (2002) recaptured 12 *Myotis sodalis* that had previously been radio-tagged. Within three weeks after attaching the radio-tag, one recaptured bat had a naked patch below the scapula where the tag had previously been attached. In contrast, another radio-tagged bat recaptured 10 months later had grown a new layer of fur over the previous tag position, with shorter hairs than the

surrounding fur. Kurta & Murray (2002) suggested that, as moulting presumably occurs in July and August, bats tagged in this time-period will have less regrowth of fur in the year-of-tagging, compared to bats tagged earlier in the summer; i.e. before the moulting period.

Information about the seasonal moulting of bat fur is scarce in the scientific literature (see Fraser et al. 2013). Gebhard & Bogdanowicz (2004) studied the moulting process in *Nyctalus noctula* in Switzerland. By the onset of spermatogenesis at the end of June, males and non-reproductive females started their moult and finished it by the end of July. The reproductive females started their moult when their offspring were weaned at the end of July/beginning of August. The juveniles had their first moult in August. In Russia, female *Nyctalus noctula* also started to moult after lactation, but here it started as early as June/July (Ilyin 1990 in Gebhard & Bogdanowicz 2004). Similar patterns have also been observed by others (Quay 1970 in Olsson & Barnard 2009).

Alagaili et al. (2011) studied moulting patterns by capturing 577 *Pipistrellus kuhlii* over one year in Saudi Arabia. By inspecting each bat, they found that the time of moulting varied substantially between individuals and ranged from late April to September, but with the majority occurring in July, after the females had completed the weaning of newborn pups. In contrast, Tiunov & Makarikova (2007) discovered that female *Myotis petax* moulted in July, the period in which they are most energetically stressed through giving birth and lactating. Similarly, Voigt et al. (2016) evaluated the moulting of *Pipistrellus nathusii* and concluded that moulting started in the second half of May. Bats that had parts of their fur removed in the last part of July, August and September, showed no signs of regrowth in the following spring (Voigt et al. 2016).

The combination of the energy-demanding processes of moulting and lactation at the same time is presumably more prevalent at northern latitudes as bats have to rely on insects that occur in seasonal outbreaks, such as mayflies (Tiunov & Makarikova 2007), during the relatively short summer and prepare for hibernation (Alagaili et al. 2011) or migration (Voigt et al. 2016, Lehnert et al. 2018). In contrast, bats at lower latitudes can benefit from a longer season, which means they have a wider window of time in which moulting is possible (Alagaili et al. 2011). Though there have been several recently published studies exploring the diet of *M. brandtii* and *M. mystacinus* during the maternity season (Berge 2007, Roswag et al. 2019, Vesterinen et al. 2019), these studies lack a temporal scale that would make it possible to understand how energy demands during the different stages of the maternity season are reflected in the diet of these bats.

It has been suggested that naked patches in the fur of *Nyctalus noctula* caused by glued on radio-tags do not regrow in autumn and that due to the impaired insolation properties, this may cause severe loss of energy during hibernation (Gebhard & Bogdanowicz 2004, referring to unpublished data collected by J. Gebhard). Similarly, although the increased parasite load and the relatively low bodyweight of the recaptured *M. brandtii* described in our study is merely anecdotal information, we cannot rule out the possibility that these observations were associated with the extra load of carrying a radio-tag and the deficit of hair on the back.

Given the findings reported in our study and the overall lack of data, we would like to emphasize that future studies should put more effort into recapturing radio-tagged bats, either close to the end of the battery life-time, or after the bats have lost their radio-tags (to assess potential injuries). Additionally, future studies should assess hair growth to better understand moulting in bats. Furthermore, one should evaluate the benefits of hair removal carefully, as well as the use of radio-tags on bats after moult and before hibernation.

Data availability: Individual wing photos of all recaptures may be made available on request.

Declarations of interest: None

Ethical approval: all applicable institutional and/or national guidelines for the care and use of animals were followed.

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