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Negative consequences of forearm bands that are too small for bats

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INTRODUCTION

Marking of animals so that they are individually identifiable is essential to the study of population biology (e.g., population structure and dynamics, home range use and habitat selection, dispersion and migration — McCallum, 2000). Adverse effects of the marking method should not bias such investigations and avoiding negative effects of marking is usually a tacit assumption (Godfrey *et al*., 2003). However, possible negative effects of marking are manifold including, in the short term, disturbances which may change the natural behaviour or activity, and in the long term, disturbances which may lead to a reduced fitness and an enhanced mortality.

Thousands of bats have been individually marked for decades to unravel the elusive ecology of these nocturnal mammals (e.g., Allen, 1921; Steffens *et al*., 2004). Recent literature points at negative effects of marking methods on the animals and on the results derived from the investigations (Baker *et al*., 2001; Dietz *et al*., 2006). We believe recognising problems in marking bats is important for sound science. Results derived from individuals that are not representative of the population are of limited scientific value for generalization.

In this short note we contribute to the knowledge on marking problems by reporting observed injury rates by forearm bands in an endangered, medium sized insectivorous bat, the Leisler's bat *Nyctalus leisleri*. We derive recommendations for choosing a suitable forearm band size for a relevant species.

MATERIALS AND METHODS

Between 2000 and 2004, we marked Leisler's bats *N. leisleri* with forearm bands (Zambelli *et al*., 2008) to assess the effect of the restoration of traditionally managed chestnut orchards in Southern Switzerland, which are the winter sites from where the species migrates to the reproduction roosts in North-Eastern Europe (Hoch *et al*., 2005; Spada *et al*., 2008). *Nyctalus leisleri* is IUCN red listed as lower risk/near threatened (IUCN, 2007) but it is considered endangered or vulnerable in several European countries (Hutson *et al*., 2001).

We used forearm bands (split metal rings) of two different diameters (alloy 2.9 mm and 2.4 mm, measured as the longest inner diameter when nearly closed, type narrow, produced by Porzana Ltd, Icklesham, East Sussex, UK). These ring sizes were delivered by the Natural History Museum in Geneva, the official authority in Switzerland for the distribution of forearm bands. The marking technique was in accordance with the national regulations (BVET and BAFU 2004) and marking was licensed by the responsible department (Ufficio della natura e del paesaggio, Bellinzona). The bats were examined, weighed, and marked by one experienced person. It was ensured that the bands still could move loosely on the forearm and the ring gap did not allow the radius bone to slip through it. After the first injured bats were found, the forearm bands were removed from all individuals displaying evidence of band-related injuries. Difference in injury rates were analysed by randomised χ^2-tests by Actus (Estabrook and Estabrook, 1989). No evidence was found that the gender of bats has an influence on injury rate and gender is therefore not reported in the results. In November 2004 we ceased marking but we continued controlling the bats until December 2006.

RESULTS

Frequency of Problems

We ringed 377 *N. leisleri*, of which 349 were ringed with 2.9 mm forearm bands and 28 with

TABLE 1. Number of *N. leisleri* marked and recaptured and frequency of problems observed in relation to forearm band (diameter in mm), *n* indicates number of individuals

Forearm band	Marked	Recaptured		Injured[1, 2]		No problem[1, 3]	
	n	*n*	%	*n*	%	*n*	%
2.4 mm	28	10	35.7	4	40.0	3	30.0
2.9 mm	349	187	53.6	18	9.6	167	89.3
Total	377	197	52.3	22	11.2	170	86.3

[1] — In relation to individuals recaptured
[2] — Five cases not categorized which showed signs of emerging problems
[3] — The forearm band was moving loose and no injuries were visible

2.4 mm forearm bands. In the reporting period of 6.5 years, 52.3% of the marked bats were recaptured (75 once, 122 between twice and 30 times) after a median period of 19 months (range 1 to 59 months). In total, we had 671 recaptures and every recaptured individual was controlled an average of 3.4 times (Table 1).

Overall 86.3% of the 197 recaptured bats had no visible problems with the forearm bands (Table 1), although 62% of these were recaptured two or more times. However, we found injuries caused by forearm bands in 22 individuals (11.2% of recaptures). 4 cases were related to bands with the small diameter of 2.4 mm (40% of the forearm bands of this diameter) while 18 were with bands of the larger diameter of 2.9 mm (9.6% of the forearm bands of this diameter, $\chi^2 = 5.68$, $P = 0.016$). In five additional cases (three of 2.4 mm, 2 of 2.9 mm) the forearm bands were removed because of evidence of emerging problems.

Type of Problems

We observed four principal types of injuries: 1) Ingrown: in 9 individuals scar tissue had grown over parts of the band and the forearm band was partially embedded into the flesh (Fig. 1A). 2) Swelling of the forearm: in 12 cases the forearm bands provoked an inflammation (Fig. 1B). Possibly the bats had closed their own bands by biting themselves in response to being disturbed by the bands, which consequently hampered blood flow and resulted in dying tissue distal from the forearm band. 3) Perforation of wing membrane: in one individual the band had turned around and perforated the patagium (Fig. 1C). 4) Scraped and rubbed areas of the breast skin, at the zone of contact between breast and forearms when they are folded up during rest, was found in varying extents in some individuals with ingrown forearm bands, possibly as a related effect (Fig. 1D).

DISCUSSION

In this short note, we report a non negligible frequency of 11.2% of bat recaptures which, sometimes only after years, showed problems associated with forearm bands. No problems were observed in the majority of the marked bats.

Although the use of the smallest bands was stopped after the first recaptures with injuries, it became obvious that the injury rate was much higher with the smaller bands than with the larger ones. This indicates that the applied forearm band sizes are most probably the reason of the problems. The marking authority in Switzerland had suggested both band sizes as appropriate. However, in a white paper published later by Eurobats (2003), researchers from all over Europe made recommendations for band sizes, including the suggestion to use band sizes of 3.5 or even 4.2 mm for the study

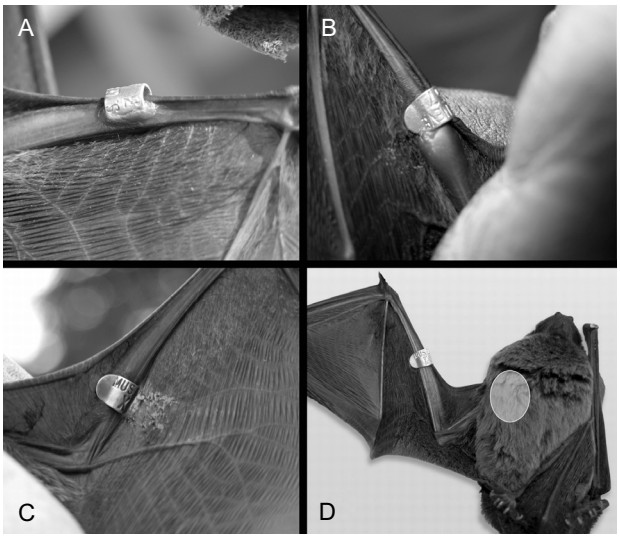

FIG. 1. Typology of four problems caused by small forearm bands in 22 *N. leisleri* out of 197 marked bats recaptured. A — ingrown, B — swelling, C — perforation, D — scraped zone on skin (location is marked by ellipse)

species *N. leisleri*. A scatter plot of forearm size (as proxy for forearm thickness) by recommended forearm band diameter shows the general, and not surprising, relationship: the larger a bat, the larger the recommended band size (Fig. 2). However, there are some important deviations from the marked trend line: one case considers our study species *N. leisleri*. Both of the forearm band diameters recommended by Eurobats are larger then those suggested by the regression line and they are much larger then the bands used in our study (Fig. 2). Furthermore there are some recommendations which lie clearly below the regression line (see arrows in Fig. 2). They may all be subject to problems after marking, as happened in our study, and the application of these forearm bands should be evaluated carefully. Additionally there are recommended band sizes which are much above the trend line, thus they are possibly too large for a given forearm size.

We should remember that most of the recaptured bats (86%) in our study did not show any problems with the applied forearm bands. In the others, problems arose with time lags of between one and 59 months. Therefore we assume that problems were initiated by a sporadic event (e.g., some dirtying). This seems to be favoured by relatively small bands, as there are only few observations of similar problems when larger bands have been applied (W. Schorcht, personal communication).

The optimal type of forearm band depends on several factors, including the wing morphology. The Rhinolophid species with a prolonged propatagium, for example, are especially prone to problems when small wing bands are used (Dietz *et al*., 2006). Long-term marking in greater horseshoe bats (Ransome, 1990) revealed few problems, suggesting that they require rather oversized bands, so that the free movement of the forearm band is guaranteed (Bontadina *et al*., 2006).

We observed four types of injuries caused by the forearm bands. The wing perforation injury did not obviously negatively affect the health status of the bat. However, it is most probable that the health – and as a consequence eventually also the fitness – of the affected individuals may be seriously influenced by the observed inflammation and irritation of the skin and the tissue. Although no mortality could be directly attributed to the observed forearm band problems, we have to consider that the number of injuries may be underestimated because very severe

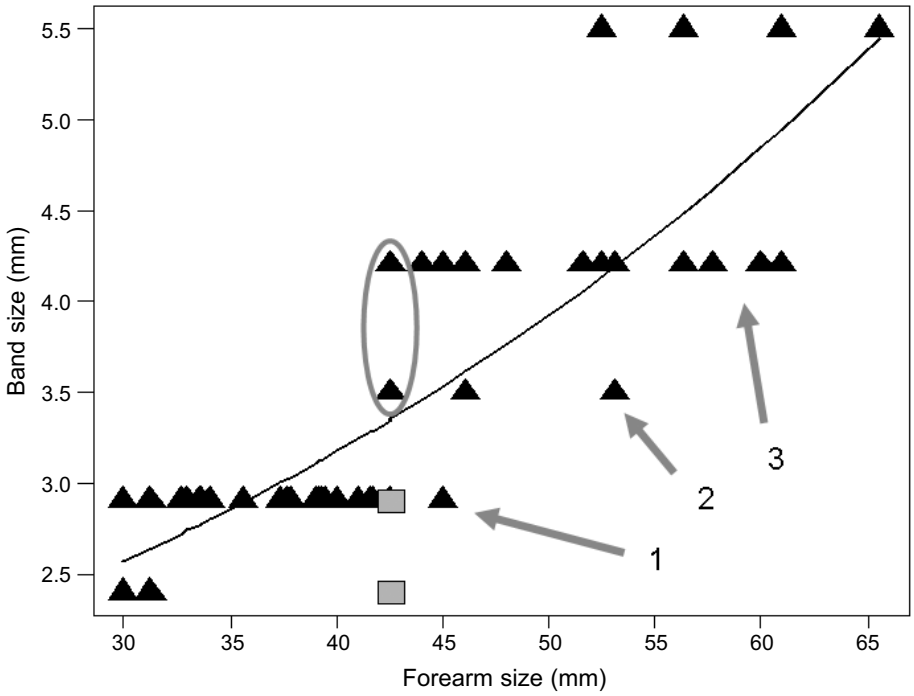

FIG. 2. Forearm band sizes recommended by experts (n = 44) in relation to mean forearm size of 35 European bat species (Eurobats, 2003). Our population study with *N. leisleri* started with bands of 2.4 and 2.9 mm diameter (marked as grey squares), the Eurobats recommendations for this species, released three years afterwards, are marked with circle. The arrows indicate questionable recommendations when compared with a trend line fitting the recommended forearm band diameters (y) to the forearm size (x) [$\ln(y) = 0.310 + 0.021x$]: 1 = *Miniopterus schreibersii*, 2 = *Nyctalus noctula*, 3 = bat species with forearm size ≥ 57 mm and recommended band size of 4.2 mm

damages may cause flight problems or even lead to the death of the individual. Such bats can not be recaptured and are not included in the statistics.

Conclusions and Practical Implications

The observed frequency and type of problems question the bat worker's competence in the public perception. They are a serious animal welfare issue and, coupled with the possibility of hampered behaviour and negative effects on individual fitness or even an increased additional mortality, they may contribute to biased estimates of vital parameters revealed in mark-recapture studies.

Alerted by possible negative effects of marking methods, it is essential to evaluate available methods in order to minimize the possible impacts. It is important that researchers report not only positive but also negative experiences of their work. We suggest that advice is sought from experts with long-term experience in ringing the relevant species. The experiences from marking various species in the field should be compiled internationally and provided to all researchers. Such guidelines (e.g., Eurobats, 2003; Russo *et al*., 2007) are essential tools, which should be regularly updated and strictly applied. Alternative marking methods, e.g., implanted pit tags, should be included in evaluations.

For species where no practical experience is available, a simple regression line as presented in figure 2 may help to select an appropriate forearm band size. Additionally, genus or species-specific characters should also be taken in consideration. In cases of doubts we recommend to give slightly larger bands priority to smaller ones.

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