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Low incidence of leg and foot injuries in colour-ringed Marsh Tits *Poecile palustris*

Richard K Broughton

Centre for Ecology and Hydrology, Benson Lane, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB, UK

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Email: rbrou@ceh.ac.uk

Abstract

Marking birds with individually identifiable metal leg-rings (bands) is a common research tool, and the additional use of plastic colour-rings has facilitated numerous studies of bird ecology, yet there is limited information for the impact of these methods on individuals and populations. Despite generally being considered to have a negligible effect upon birds, recent literature shows that leg rings can cause injuries to some passerines. This creates an ethical problem and may also bias research results by influencing individual behaviour and survival.

The incidence of leg injuries was monitored on colour-ringed and unringed Marsh Tits over 12 years. The overall incidence of permanent injury did not differ between ringed and unringed birds, but six out of 404 colour-ringed birds (1.5%) carried a leg or foot injury, which was significantly greater than the background rate (0.2%) among 515 unringed birds. However, some injuries on ringed birds were temporary and/or may have been unrelated to the rings, although one fatality and two serious injuries were recorded, probably resulting from colour-rings becoming caught on thorns or other objects. Although ring-related injuries were very rare, it is recommended that ringers studying Marsh Tits try to minimise the number of rings on each leg.

INTRODUCTION

Ringing (banding) birds with metal rings bearing a unique indentifying code and return address has revolutionised ornithology since its introduction more than a century ago (Greenwood 2009, Birkhead et al. 2014). While ringing and the associated capture and handling is considered to be generally safe for most birds (Calvo & Furness 1992, Spotswood et al. 2012), the method has some limitations. Primary among these is the general requirement to recapture or otherwise handle (e.g. after death) an individual bird in order to read the ring.

Colour-ringing has become the most widely used method of identifying individuals in the field, and involves additional coloured plastic or anodised metal rings being fitted to the legs, which can then be recorded by sight at a reasonable distance (Sharp 2009, Newton 2014). Colour-ringing greatly increases the scope and capability of ringing studies to describe the movements, social relationships and ecology of individuals and populations, and has been used on a large number of species since the 1930s. Although colour-ringing is recognised to carry a risk of potential injury for some groups of birds, such as waders (Reed & Oring 1993), the technique is considered suitable for most small passerines (Calvo & Furness 1992). However, there has also been a growing focus on the potential hazards for this latter group, from an ethical perspective but also with regards to the possible data bias that may be introduced through ring-related effects on behaviour (Burley et al. 1982, Johnsen et al. 1997, Weiss & Cristol 1999) or reduced survival due to injury (e.g. Sedgwick & Klus 1997, Splittgerber & Clarke 2006, Pierce et al. 2007, Griesser et al. 2012).

In a review of the causes of ring-related leg injuries in birds, particularly passerines, Griesser et al. (2012) reported three problems related to plastic (PVC or celluloid) colour-rings in some species: (1) inflammations caused by material accumulating under the ring, (2) contact inflammations caused by rings touching the foot, and (3) toes becoming trapped in partly unwound flat-band colour-rings. Split colour-rings, where the plastic meets at butted edges, appear somewhat safer for passerines than overlapped flat-band colour-rings, and where injuries have occurred these have been due to an inappropriate design of the ring in relation

to the birds' physiology and/or behaviour (Griesser et al. 2012). For example, colour-rings which were too small and carried a slight static charge caused spider webs and debris to accumulate around them and inflame the legs of Purple-crowned Fairy Wrens *Malurus coronatus* (Griesser et al. 2012) and Bell Miners *Manorina melanophrys* (Splittgerber & Clarke 2006). In addition, abrasion of plastic rings on the foot caused inflammation and infection in Willow *Empidonax traillii* (Sedgwick & Klus 1997) Spotted *Muscicapa striata* and Pied Flycatchers *Ficedula hypoleuca* (Pierce et al. 2007), resulting in permanent crippling due to loss or necrosis of the foot.

For the tits (Paridae), one of the most intensively studied groups of wild birds in the World (Otter 2007), there are no published reports of negative effects or injuries resulting from colour-ringing (Calvo & Furness 1992, Griesser et al. 2012). This suggests that colour-ringing may be essentially safe for this group, at least for those species of Eurasian and American tits which have been the subject of long-term study, such as the Great Tit *Parus major*, Blue Tit *Cyanistes caeruleus*, Black-capped Chickadee *Poecile atricapillus*, Marsh Tit *Poecile palustris* and Willow Tit *Poecile montana* (Perrins 1979, Smith 1991, Otter 2007).

However, an absence of reported evidence of harm is not conclusive, as there appears to have been no systematic study to confirm whether colour-ringing carries a significant risk of injury or reduced survival in tits. Indeed, the tits could be considered as potentially vulnerable to leg injuries when wearing multiple rings, due to their acrobatic foraging behaviour, including hanging upside down (Perrins 1979, Smith 1991). This may cause frequent movement of the rings and repeated friction against the tibio-tarsal joint and feet, which was noted by Griesser et al. (2012) as a risk factor for ring-related leg injuries in Brown Thornbills *Acanthiza pusilla*.

In this paper, 12 years of colour-ringing, handling and observation data were used to assess rates of ring-related leg and foot injuries in Marsh Tits, during a long-term population study. Marsh Tits are ideal for such an assessment, due to their highly sedentary and non-migratory behaviour within limited home-ranges, enabling repeated observation of known individuals over a relatively long period of time (months and years; Broughton 2012). The

physiology, ecology and behaviour of Marsh Tits also overlaps with many other Eurasian and North American tits and chickadees, being a cavity-nester (and partial-excavator) which inhabits a range of mixed and deciduous woodland, where it forages throughout the vegetation profile from the tops of canopy trees down to the ground (Broughton & Hinsley 2015). As such, results for the Marsh Tit could also be more widely indicative of this important model group in ecological studies.

METHODS

The Marsh Tit population at Monks Wood National Nature Reserve (52° 24' N, 0° 14' W), and neighbouring woods (within 3 km) in Cambridgeshire, eastern England, have been studied intensively since 2003, to better understand the species' population ecology and habitat selection (Broughton & Hinsley 2015). The Marsh Tit population in the study area numbered up to 90 pairs in spring (Broughton 2012).

Between 2003 and 2014, 515 full-grown (adult and juvenile) Marsh Tits and 685 nestlings were ringed with a British Trust for Ornithology (BTO) magnesium-aluminium alloy ring on one leg and two plastic (celluloid and/or PVC) colour-rings on the opposite leg. This total also included 94 full-grown birds which were fitted with a third colour-ring above the alloy ring. Colour-rings were supplied by A. C. Hughes (Middlesex, UK). Nestlings were ringed during May each year, and full-grown birds were caught during January-April and July-November using cage-traps baited with sunflower seeds.

On average, 73 (range: 18-114) full-grown individuals were handled each year, including 30 (range: 7-70) which had been ringed at least two months previously ('re-traps'), and 43 (range: 11-83) new individuals, which were ringed before release. The re-traps included 165 birds ringed as nestlings during a previous breeding season. In total, 680 individuals were handled as full-grown birds, including 281 birds handled more than once. Birds were aged and sexed according to Broughton et al. (2008).

Systematic records were made of any leg/foot injuries or abnormalities observed on ringed and unringed birds, including crippled or missing claws, toes or feet. In addition to birds

141 examined during capture and handling, any injuries to ringed birds observed in the field were
142 also recorded during spring (March-June). In this period, an average of 48 colour-ringed
143 birds (range: 16-62, total: 338 individuals) were located each year by searching and using
144 playback (songs and calls played on an mp3 player), in order to map breeding territories.
145 Territory occupants were identified by their colour-rings, using binoculars, and followed for
146 extensive periods (from 30 mins to 4 hours) in order to record movements, territorial
147 behaviour, pairings and nesting attempts (Broughton et al. 2011). During these observations,
148 which were made at a typical range of 3-20 m, the birds' legs were carefully scrutinised to
149 confirm the position and colour of the colour-rings, for identification purposes. Any obvious
150 injuries to the legs were also recorded (e.g. a missing leg or foot, or a crippled or lame leg
151 without normal function).
152
153 Analysis
154 The annual and overall incidence of leg injuries was calculated separately as a percentage
155 of the unringed individuals that were handled, and of the ringed birds that were handled or
156 observed in the field. This allowed comparison of the injury rate among ringed birds against
157 a 'background' level of leg injuries among unringed birds, using Fisher's exact test in Minitab
158 16 (Minitab Inc., State College, Pennsylvania). As all ringed adults were visually assessed
159 for injuries in the field in spring, immediately prior to or during nesting, the time in which they
160 could acquire new injuries before being captured or observed later in the year was similar to
161 that for juvenile birds ringed as nestlings in the same breeding period (i.e. since May/June).
162 As such, and because there was no basis for presuming that foraging behaviour would differ
163 between age classes, adults and juveniles were treated the same in analyses. To compare
164 our results with other studies, we calculated the 'hazard index' proposed by Griesser et al.
165 (2012), which scores injuries to individuals according to their severity and divides the sum
166 score by the number of individuals ringed and exposed to injury. In this index, injuries are
167 scored as follows: part of leg inflamed = 1 hazard point, whole leg inflamed = 2, toe loss = 5,
168 foot/leg deformed but functional = 10, foot loss or crippled leg = 20, leg loss = 50 (Griesser

et al. 2012). Therefore, as an example, one crippled leg and one lost toe among 100 birds ringed would generate a total hazard score of 20 + 5 = 25, which is then divided by 100 birds to give a hazard index of 0.25.

RESULTS

In total, six ringed full-grown Marsh Tits were encountered with leg or foot injuries, representing 0.9% of the 680 adult and juvenile birds, or 1.5% of 404 ringed birds which were handled as full-grown re-traps or later observed in the field. The mean annual percentage of ringed birds with a new injury each year was 0.8% (sd = 1.1%, range: 0-2.7%). A single unringed bird was found to be missing two toes, representing 0.2% of 515 individuals and giving a mean annual 'background' injury rate of 0.1% (sd = 0.4%, range: 0-1.2%). Overall, ringed birds were more likely to carry leg or foot injuries than unringed birds (Fisher's exact test, $P = 0.048$).

Five of the six injuries on ringed birds (83%) were on legs bearing two rings, such as two plastic colour-rings (four birds) or a colour-ring above a BTO alloy ring (one bird), with the remaining injury on a leg bearing a single alloy ring. Four of the injured ringed birds (67%) were male, and two were female. Injuries to three of the ringed birds involved temporary lameness, with the bird observed on a single occasion persistently holding up the leg into the plumage, and apparently being unable or unwilling to use it. However, all three birds were later observed with no sign of injury and full function of the leg, from as little as two days later. For the fourth bird, an injury to a leg bearing a single alloy ring concerned a damaged (rigid) hind toe, but the bird's behaviour appeared unaffected. The remaining two birds had serious permanent injuries, including a missing foot and healed fracture to the tarsus on one individual, and on the other a twisted tarsus with a crippled, non-functional foot, presumably resulting from a fractured tarsus. Ringed birds were not significantly more likely to carry a permanent injury than unringed birds (Fisher's exact test, $P = 0.325$).

The time between ringing and the detection of the injury averaged 20 months (sd = 14, range: 0.5-41 months). Of the two birds with serious injuries, one (a male) survived for at

least a further 11 months, during which it successfully defended a territory and was paired with a female, while the other (a female) survived for at least one month after injury, during which it nested but the incubated eggs were destroyed by a predator. The four birds with lesser injuries survived for at least a further 16-42 months. The unringed bird missing two toes survived for at least nine months after being handled and ringed.

In addition to the injuries recorded on live birds, colour-ringing was apparently the direct cause of death of an adult male Marsh Tit found in June 2005. In this case, the colour-rings had become caught on a Blackthorn *Prunus spinosa* shrub, with a thorn passing over the lower colour-ring and through the upper ring (Fig. 1), and the bird being unable to free itself.

Applying the ringing hazard categories and scoring system proposed by Griesser et al. (2012) to the Marsh Tit data, a hazard index of 0.075 was calculated based on the total of 680 colour-ringed birds. On an annual basis, the hazard index varied from 0-0.364, with a 12-year mean of 0.065. In these calculations, the two serious injuries (foot loss and crippled leg/foot) were scored as 20 hazard points, the rigid toe was scored as 'toe loss' at 5 points, and the three temporarily lame birds were scored as 'whole leg inflamed' at 2 points (Griesser et al. 2012). The dead bird was excluded from these calculations, as Griesser et al. (2012) included no scoring system for fatalities. However, including the dead bird in the most severe category (leg loss, 50 points) gave an overall hazard index of 0.149. For full-grown birds that were unringed at the initial handling, the overall hazard index was calculated as 0.002, or an annual mean of 0.005 (range = 0-0.062).

DISCUSSION

The rate of leg injuries detected on colour-ringed Marsh Tits was very low on an annual and overall basis. Ringed birds were significantly more likely to carry injuries than unringed birds, but the incidence of permanent injuries was very low and essentially no different from that in unringed birds. Nevertheless, it seems probable that colour-rings were the direct cause of at least some of these permanent injuries, particularly where two rings were fitted on a single leg.

The mechanism for the more serious leg injuries among ringed birds, notably the crippled leg and/or foot amputation observed in two individuals, was suggested by the discovery of the dead Marsh Tit caught by its rings on a thorn. It seems probable that the two sub-lethal serious injuries had happened in similar circumstances, but the birds were able to struggle free after incurring the injury (apparently a fractured tarsus in both cases, between or around the position of the rings). Nevertheless, both birds seemingly adapted to the injury, and showed normal breeding and territorial behaviour, similar to a male Wilson's Warbler (*Wilsonia pusilla*) which also adapted after a ring-related foot amputation (Gilbert & Kwon 2001).

The temporary lameness observed on three other birds could also have been due to the colour-rings becoming caught on thorns or other objects, with the birds suffering a leg strain when struggling free. However, these apparent cases of temporary injury appeared to have no lasting consequences, and the birds recovered quickly (one within just two days), and all survived for more than a year afterwards.

The type of serious injury to Marsh Tits in this study has not previously been reported among passerines in two reviews of ring-related problems (Calvo & Furness 1992, Griesser et al. 2012). It is possible that the injuries to Marsh Tits in this population may reflect habitat-specific factors, such as the abundance of very thorny Blackthorn shrubs at this site, and the moderate attractiveness of this vegetation to foraging Marsh Tits (Carpenter 2008, Broughton & Hinsley 2015). Behaviour-related differences in injury rates were observed in Brown Thornbills by Griesser et al. (2012), with Tasmanian birds being injured by plastic rings more frequently than those on the Australian mainland, due to their different use of habitat.

It was impossible to quantify or estimate the number of Marsh Tits which may have become trapped on e.g. thorns by their rings and died without detection, as such birds were unlikely to have been discovered by chance, and would also be quickly scavenged by other animals. Yet such deaths were assumed to have been extremely rare, and have no effect on the Marsh Tit population overall. This is because adult survival was relatively constant over time

and similar to other populations across Europe (Broughton & Hinsley 2015), whereas a decrease over time would be expected if ringing were an ongoing cause of cumulative mortality. Similarly, the rate of nest losses was low in our study population, and similar to national sampling by the BTO's Nest Record Scheme, where the great majority of breeding birds would have been unringed (Broughton et al. 2011). This indicates that ringed adults were not becoming trapped by their rings on vegetation while breeding, leading to greater nest losses. In addition, during extensive radio-tracking of thirteen birds during winter (Broughton et al. 2014), no individuals were recorded becoming trapped by their rings on vegetation, and no other ring-related problems were observed.

In their exhaustive review, Calvo & Furness (1992) concluded that all methods of marking birds can have adverse consequences for some individuals. Single metal rings fitted on one leg are by far the most common method of marking birds, and any negative effects of this technique were considered to be negligible for the vast majority of small passerines, although problems were reported in a few cases. These included injury or loss of a leg in tits and finches due to ice accumulating around the ring (Dunbar 1959, MacDonald 1961). More recently, metal rings that were fitted too tightly on the tarsus were the cause of leg injuries, including total loss of function, in Great Tits and some other small passerines in Britain (but particularly Yellowhammer *Emberiza citrinella*) (Kew 2014). This necessitated a change in the recommended ring sizes for these species. However, no such problems with metal rings were apparent among the Marsh Tits in the current study. Only one bird was recorded with an injury to a leg bearing a single BTO alloy ring, this being a rigid hind toe, but it seems improbable that such an injury could be caused by the ring. Indeed, the unringed Marsh Tit with two missing toes shows that such relatively minor injuries can occur naturally.

Calvo & Furness (1992) reported no evidence of negative effects of colour-rings on small passerines. However, like our results, more recent evidence from studies on flycatchers (Sedgwick & Klus 1997, Pierce et al. 2007) and other small passerines (Griesser et al. 2012) indicates that colour-ringing can indeed result in leg injuries to birds in some circumstances, and can occasionally lead to death. Nevertheless, the impact on the Marsh Tit population

281 appeared negligible, with only six injuries (and one death) observed over 12 years from
282 1,200 birds ringed. This compares with 11 injuries observed from 791 (1.4%) Purple-
283 crowned Fairy Wrens over a six-month period, and injuries to nine of 314 (3%) Brown
284 Thornbills over a two-year period (Griesser et al. 2012). However, the ringing hazard index
285 for Marsh Tits (0.075) was intermediate between that for the Purple-crowned Fairy Wrens
286 (0.11) and Siberian Jays *Perisoreus infaustus* (0.04) reported by Griesser et al. (2012), but
287 substantially lower than that for Brown Thornbills (0.3).
288 Reducing the risk of injuries to Marsh Tits (and similar species) resulting from colour-rings
289 becoming caught on thorns or similar may be possible, but would likely introduce new risks.
290 Gluing or cementing together the two colour-rings, to create a single longer structure, would
291 prevent thorns becoming caught between them, but would then limit movement of the rings
292 and prevent the bird from preening the tarsus, perhaps leading to infection as detritus
293 accumulated next to the leg. This could create new problems, such as the necrosis and leg
294 injuries seen on Bell Miners by Splittgerber & Clarke 2006, and also Purple-crowned Fairy
295 Wrens and Brown Thornbills by Griesser et al. (2012). Furthermore, cementing or gluing
296 rings increases handling times in the field and carries the risk of accidents, such as the rings
297 being glued to the bird's leg (Hartley et al. 2011).
298 Limiting colour-ringing to a single ring per leg would be impractical for most studies, with too
299 few colour combinations to enable individual identification in a species where both sexes
300 appear virtually identical. However, unless strictly necessary, avoiding the fitting of two rings
301 on both legs (e.g. a third colour-ring next to the alloy ring) seems prudent in reducing the risk
302 of the type of injuries recorded in this study. Use of only two colour-rings, placed together on
303 either leg, is likely to provide sufficient combinations for most Marsh Tit studies. For
304 example, at Monks Wood more than 500 usable combinations are based on 18 different
305 colour-rings (single colour and striped rings), which are also 're-cycled' after several years
306 without observation or where death of the original bird is known.
307 Field observation of a colour-ringed Willow Tit with a crippled leg (which bore two colour-
308 rings) at a site in Berkshire in 2015 (R. Broughton & M. Maziarz, pers. obs.), shows that

post-ringing injuries can also occur in species related to Marsh Tits. The injury appeared very similar to that observed in the female Marsh Tit described above (non-functional foot, misaligned tarsus), possibly highlighting the need for evaluation of the frequency of injuries in other tit species.

While the colour-ringing of Marsh Tits in this population appears to have had a negative impact on a small number of individuals, and caused the death of at least one bird, marking of these birds has enabled extensive study of Marsh Tit ecology, leading to significant gains in the understanding of the species' serious population decline in Britain (Broughton 2012, Broughton & Hinsley 2015). As such, the conservation benefits to British Marsh Tits as a whole are likely to far outweigh the negative consequences of ringing for a very small number of birds, particularly as the majority of injuries detected were temporary or minor in nature. Therefore, the conservation and welfare case for colour-ringing studies of Marsh Tits, and of scientific ringing in general, appears highly justified (Anderson & Green 2009, Newton 2014).

In summary, for small passerines such as the Marsh Tit, no marking technique can be considered to be completely without risk to the individual bird, including the very common methods of ringing with metal and/or plastic rings. The results for Marsh Tits demonstrate that serious injuries and death of birds can occur in typical ringing studies, although they are rare. Weighed against the wealth of scientific information gathered during such research, which can have a direct application to species conservation (e.g. Broughton 2012, Broughton & Hinsley 2015), such a rate of mortality or sub-lethal injury may be considered acceptable. However, researchers must be vigilant for welfare issues resulting from study methods and the use of colour-rings, and ensure that marking studies and procedures are fully justified on a scientific basis, are adequately planned and resourced, and that methods of monitoring, reporting and resolving problems are in place (Anderson & Green 2009, Griesser et al. 2012).

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Figure 1. Leg of a Marsh Tit, showing colour-rings caught on a Blackthorn thorn, leading to the bird's death.