



Plastic colour rings and the incidence of leg injury in flycatchers (Muscicapidae, Monarchidae)

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Studies of birds involving colour ringing can provide much detailed information concerning bird movements and behaviour without the need for recapture. However, a fundamental premise of colour ringing, and indeed all ringing studies, is that the rings applied should neither cause harm to the birds concerned nor alter their behaviour or survival. Colour rings have been used safely for many studies on a wide range of species, and problems are rarely reported. Here, we report on problems associated with colour-ringing several species of flycatcher, and discuss the nature and extent of the issue. Unacceptable levels of leg injury were reported when flycatchers were ringed using either celluloid or PVC colour rings, particularly when the colour ring was proximal to the foot. In the light of our evidence, we would urge those considering embarking upon colour-ringing projects involving flycatchers to consider using anodised aluminium colour rings and to avoid the use of plastic colour rings.

Techniques involving the catching and marking of birds and the subsequent monitoring of marked individuals have been safely and successfully used for many years to provide information on the movement, population dynamics and behavioural ecology of a wide range of species. As ringing (banding) techniques have developed, they have been widely deployed to help identify causes of population decline, thus informing targeted population recovery programmes, including conservation efforts for threatened species. Colour ringing (using plastic or metal coloured rings) is a particularly useful technique, as it allows individuals to be recognised without the need for recapture, vastly increasing the potential for monitoring bird movements and behaviour (Evans 1997, Burton 2001, Hole *et al* 2002, Field & Anderson 2004, Salewski *et al* 2007, but see Calvo & Furness 1992).

Although certain species may respond adversely to capture and handling (eg haemorrhaging in finches, Redfern & Clark 2001, and leg cramp in waders, Bainbridge 1975), ringing has fortunately been shown to carry an extremely low risk of injury (Marion & Shamis 1977, Redfern & Clark 2001), and little or no effect on subsequent return rates, even in intensively studied populations (Perkins *et al* 2004, Cresswell *et al* 2007). When injuries do occur, it is usually possible to identify a specific cause. For instance, in some species, injury may be caused by the specific structure (Common Tern *Sterna hirundo*, Nisbet

1991) and/or behaviour (North Island Robins *Petroica longipes*, Berggren & Low 2004) of the species under study. Alternatively, injury may be caused by the use of rings of an inappropriate size. If the ring is too large, or opens up after being fitted, it may slip over the foot, resulting in injury to the tarso-metatarsal joint or the foot. If it is too small (Gratto-Trevor 1994), or becomes constricted because of accumulated mud (Amat 1999), ice (MacDonald 1961) or faecal matter (Henckel 1976) around it, injury or even foot loss may result from the restriction of blood flow.

Most published evidence of injury resulting from leg ringing concerns metal rings. The incidence of injury caused by coloured plastic rings in passerines is less often reported. Sedgwick & Klus (1997) described injury resulting from a ringing programme of Willow Flycatchers *Empidonax traillii*, which involved problems with coloured plastic rings being used in combination with metal rings. More recently, Splittgerber & Clarke (2006) identified ring-related injuries in colour-ringed Bell Miners *Manorina melanophrys*. Here we report on injuries to the legs of several species of flycatchers fitted with both metal and plastic colour rings. We consider possible reasons for the injuries and recommend strategies to minimise the risk.

METHODS

Evidence for this paper was gathered from a number of ongoing studies involving different flycatcher species from

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widespread geographical locations. In all cases, the plastic colour rings used were split celluloid or Darvic (PVC) obtained from A.C. Hughes Ltd, Hampton Hill, Middlesex, UK. The size used was XF, height 4 mm, internal diameter 2.3 mm. Numbered anodised colour rings used in these studies were of the same dimensions as XF plastic rings and were also obtained from A.C. Hughes Ltd.

Black-naped Monarch *Hypothymis azurea*, Thailand

Work was carried out as part of a long-term study monitoring bird populations and ecology on the 30 ha Mo-singto permanent forest plot, Khao Yai National Park, Nakhon Nayok Province (14° 26'N 101° 22'E). The plot was situated in mature, seasonally wet evergreen forest at 723–817 m elevation (Brockelman 1998). During 2003–04 a total of 20 adults and 12 nestlings were ringed. Adults were ringed with a single aluminium ring as issued by the British Trust for Ornithology (BTO) Ringing Scheme (size AA, height 5.5 mm, internal diameter 2.0 mm) on one leg and two plastic rings on the other. Nestlings were ringed with a single plastic ring on one leg and one or two plastic rings on the other leg. The plastic rings used were a mixture of both celluloid and Darvic, and were not sealed. During 2005 nine adults and three nestlings were ringed with only one anodised ring on each leg. Anodised aluminium rings (equivalent to BTO size AA), provided by Porzana Ltd, Icklesham, E Sussex (but anodised locally), were also used, thus increasing the available colour combinations. Birds retrapped from 2005 onwards had their plastic rings removed and those without injuries were fitted with anodised rings. Although problems with availability of small-sized plastic rings resulted in birds being fitted with plastic rings of a larger internal diameter than the BTO-issued aluminium rings, they did not slip off nor restrict the foot, nor could they move above the inter-tarsal joint.

Madagascar Paradise-flycatcher *Terpsiphone mutata*, Madagascar

Work was carried out as part of an intensive research programme looking at ornamentation and symmetry. The research was based in the Bealoka Reserve, southern Madagascar (23° 75'S 46° 15'E). The 120 ha reserve covers an area of dry gallery forest along the Mandraré River. Between June 1993 and June 1994, 106 birds were ringed using three rings in combination (metal above plastic on one leg, one plastic ring only on the other). The metal rings were split aluminium rings of size 01 provided by the Australasian Bird and Bat Banding Scheme (ABBBS), height 6 mm, internal diameter 2.2 mm. The plastic rings were celluloid and were all sealed using acetone. In August 1996 ringing recommenced using a different method, replacing the ABBBS metal ring with anodised metal

rings. This reduced the overall height of the rings on the leg carrying two rings from 10 mm to 8 mm, leaving more of the tarsus (length about 13 mm) uncovered. These rings were made from slightly thicker material and appeared less sharp at the edges than the ABBBS-issued rings. Birds captured between August and November 1996 were fitted with either a single metal ring on one leg and a single plastic ring on the other ($n = 21$), or with a single metal ring on one leg and two plastic rings on the other ($n = 70$). From July 1997 only anodised coloured metal rings were used, with a single ring fitted on each leg. However, since this provided too few combinations, starting in October 1997, single-colour plastic rings were cut in half so that they were only 2 mm in height, and these were used in a combination in which a metal ring was used on one leg, and a cut-down plastic ring over a metal ring on the other. Since July 1997 a total of 256 adults and 860 nestlings have been ringed with this method.

Spotted Flycatcher *Muscicapa striata*, United Kingdom

Work was carried out as part of an intensive three-year autecological study. The study area, centred on Aveton Gifford in the South Hams area of Devon, (50° 18'N 3° 50'W), covered c 3,200 ha of which c 2,670 ha was farmland, 160 ha woodland and 111 ha villages and rural gardens. Fifty adult birds were fitted with combinations of metal rings (size A, height 5.5 mm, internal diameter 2.3 mm) supplied by the BTO ringing scheme, and Darvic (PVC) colour rings, in 2004 and 2005. The Darvic colour rings were not sealed, but all were checked for correct closure. Two colour rings were applied to the left leg, with the BTO metal and colour ring on the right leg, the colour ring being placed in both proximal and distal locations over the course of the study. In 2006, 22 adult birds were marked with a single anodised aluminium colour ring on one leg, and a BTO metal ring on the other.

Pied Flycatcher *Ficedula hypoleuca* and Black-headed Paradise-flycatcher *Terpsiphone rufiventer*, Ivory Coast

Work was carried out as part of a joint project of the Institute for Avian Research, Vogelwarte Helgoland, in Wilhelmshaven, Germany, and the Max-Planck Institute for Ornithology, Vogelwarte Radolfzell, in Radolfzell, Germany, investigating the wintering ecology of Palearctic passerine migrants in Africa. It was performed in the Comoé National Park in northeastern Ivory Coast (8° 45'N 3° 49'W). Pied Flycatchers ($n = 115$) were fitted with one or two colour rings (celluloid) on one leg, with a metal (diameter 2.3 mm) and a colour ring on the other leg. Additionally, 58 Paradise-flycatchers were fitted with one or two (celluloid) colour rings, but were not ringed with

a metal ring. The colour rings were not sealed. When a colour ring was used together with a metal ring the colour ring was always distal to the foot.

RESULTS

Injury rates

The rate of injury in colour-ringed individuals was not straightforward to compare, since ringed individuals were sighted with unequal frequency, and many were never resighted. Additionally, injury may not be visible without direct, physical examination of birds in the hand, particularly in the early stages. Where the number of birds resighted or recaptured was known, it was therefore more appropriate to calculate rates of injury from these figures, rather than the total numbers of birds ringed. Overall, injury rates of colour-ringed birds, before any remedial action was taken, ranged from 13.2% to 35.3% (Table 1). Rates of leg injury noticed in unringed birds were much lower, ranging from 0% to approximately 2% (three of approximately 150 unringed individuals, RM unpublished data). Of the 1,295 legs bearing only a metal ring that were checked, only three showed signs of injury. All of the injured Spotted Flycatchers were female ($n = 4$).

Systematic patterns of injury associated with colour rings

In most cases the injury seemed to occur on a leg on which a plastic ring had direct contact with the foot, particularly where there were two rings on the leg (a plastic ring in combination with either another plastic ring or a metal

ring). However, it was not possible to test these data statistically since, during the course of the four studies, different combinations of rings were utilised, some birds were ringed and not resighted and others were seen repeatedly for many years. Additionally, most observations were made incidentally and were not planned within the framework of the respective research projects. A small number of injuries were recorded on legs with only metal rings (Table 1). Injuries occurred with both sealed and unsealed plastic rings.

Onset of injury

For all the species, most individuals developed the injury between six months and two years after ringing. Indeed, many of the individuals later found with injury had been recaptured in the interim and had shown no signs of injury, confirming our belief that injuries were not immediate. Based on census and capture data, onset of injuries in Madagascar Paradise-flycatchers took between seven weeks and six years. When birds were observed in the field with leg injuries, and could be recaptured, rings were removed. These birds recovered well from their injuries, some making a complete recovery and being observed for at least six months after the injury disappeared, with no apparent ill effects.

Description of injuries

Leg damage ranged from an accumulation of shed scales on the tarso-metatarsus ($n = 2$, 3.2% of all injuries), and signs of necrotic skin, through to swellings above and/or below the rings ($n = 53$, 85.5%), and finally to complete amputation of the foot ($n = 7$, 11.3%; Fig 1). All birds were

Table 1. Injury rates of birds colour-ringed in the four studies. For ring combinations, M = metal ring (plain or anodised), C = plastic colour ring. Where figures for resighting are available, the injury rate is calculated from the number of birds resighted; where not recorded (-) the injury rate is the percentage of birds ringed. Species codes used: MAPFL Madagascar Paradise-flycatcher, BLAMO Black-naped Monarch, SPOFL Spotted Flycatcher, PIEFL Pied Flycatcher, BLPFL Black-headed Paradise-flycatcher.

Species	Year(s)	Ring combination		Number of birds		Total no. of injuries observed for ring combination		Rate (%)
		Leg 1	Leg 2	Ringed	Resighted	Leg 1	Leg 2	
MAPFL	93–94	C	M/C	106	–	3	11	13.2
MAPFL	96	C	M	21	–	3	0	14.3
MAPFL	96	C/C	M	70	–	19	0	27.1
MAPFL	97–04	M	C/M	1,116	–	3	10	1.2
BLAMO	03–04	C/C	M	20	17	6	0	35.3
BLAMO	05	M	M	12	6	0	0	0
SPOFL	04–05	C/C	M/C	50	24	3	1	16.7
SPOFL	06	M	M	22	–	0	0	0
PIEFL	94–98	C/C	C/M	115	21	2	0	9.5
BLPFL	94–98	C/C	–	58	6	1	–	16.7

in an otherwise healthy condition, with no apparent loss of body condition. In most individuals, a large swelling formed over the foot, underneath and inside the ring, similar in appearance to avian pox swellings (RM, pers obs). The ring constrained the growth of the swelling, which led to deformation and subsequent loss of the foot. The usual site for the swelling was around the 'ankle' (tarso-metatarsal joint), below the lower colour ring and proximal to the foot, although there was also some lesser swelling between the rings and above rings distal to the foot. It seems likely that all early stages of leg injury would have developed into the more serious injuries had the rings not been removed.

The injuries mainly hampered the bird's ability to perch comfortably, and individuals with injuries characteristically fluttered for balance when descending onto a perch. Several birds nevertheless managed to breed successfully despite having damaged or amputated legs. It is not believed that injured birds had higher resighting probabilities, since data reported here were collected during the course of intensive research projects involving the location of all birds within a specific area.

DISCUSSION

Data presented here on colour-marked flycatchers suggest that plastic colour rings were more likely to cause infection or injury than metal rings, particularly when proximal to the foot or when two rings were fitted to the same leg. Although injuries were recorded in birds ringed only with metal rings, we believe that this was comparable to the incidence of injury recorded in unringed birds (RM unpublished data) and we thus remain convinced that it was the colour rings which were problematic, not the metal rings. Similar conclusions have been reached by others reporting comparable injuries (Sedgwick & Klus 1997, Splittgerber & Clarke 2006). Sedgwick & Klus (1997) proposed that leg injuries in ringed Willow Flycatchers were caused by irritation of the tarsus, due to friction

between the leg and sharp edges on the plastic colour rings. Continued irritation may lead to infection, swelling and ultimately amputation. Splittgerber & Clarke (2006) suggested that the main factors influencing the chance of injury were the smoothness of the internal surface of the ring (plastic rings being more pitted and generally rougher than metal rings) and the material from which it was made (plastic generating more static electricity than metal). They went on to suggest that both factors affected the likelihood that tarsal scales shed from the leg would accumulate inside the ring and that smooth surfaces decreased the probability of scales adhering to the ring, while materials such as plastic increased the probability of adherence. Therefore, Splittgerber & Clarke (2006) concluded that injuries were more likely to develop in rings that were a closer fit. The close fitting of rings is, however, unlikely to be a factor with flycatchers. In the species studied and reported on here, the tarsus is relatively narrow in proportion to the internal diameter of the colour ring, and the 'ankle' is very thin compared to that of most other passerines. During the course of the Black-naped Monarch research, birds were fitted with plastic rings of a larger size than the metal rings and that were a looser fit, yet they still suffered a high rate of injuries. Significantly, this is contrary to the findings of Splittgerber & Clarke (2006) who found leg injuries in Bell Miners which had colour rings that were of a tighter fit than the metal rings. This therefore suggests that the injuries are more likely caused by the material than by the size of the ring. During 2003–05, a total of 123 individuals of five other species were fitted with the same size and combination of rings as the Black-naped Monarchs. Forty-three of these, including five returning Palearctic migrants, were recaptured and examined in the hand but none showed any sign of leg injury.

Birds moult tarsal scales on a regular basis (Storer 1952), but whether this occurs as a continual process or annually under the influence of endocrine cycles is unknown. Whitaker (1957) reported that Lark Sparrows *Chondestes grammacus* use the secretions from the uropygial gland to oil their tarsal scales, and Elder (1954) reported that when



Figure 1. Photographs showing the types and various stages of injuries encountered, from a) injury visible in field on right leg below the white plastic ring, b) early stages of leg injury (colour rings removed from left leg) through to c) extreme injury resulting in amputation of the foot.

the uropygial gland of ducks was experimentally removed, skin on the legs became cracked and dry. Because rings hamper access to the scales, it is possible that they make regular maintenance and oiling of tarsal scales more difficult, and this may increase the rate at which scales are shed. Furthermore, *in vitro* experiments have reported that secretions from the uropygial gland inhibit bacterial growth (Bandyopadhyay & Bhattacharyya 1996, Jacob *et al* 1997, Law-Brown 2001). If this were the case *in vivo*, reduced opportunities for preening and oiling of metatarsal scales due to the presence of rings may mean that the scales are less often exposed to both the moisturising and the anti-bacterial properties of preen oil. This might compound any problem of scale build-up inside the rings and increase the chances of leg injury through subsequent infection. In the case of flycatchers, the addition of more than one ring to what is a relatively short tarsus will leave little room for the rings to slide up and down the leg. However, it is interesting that we also observed leg injuries in unringed birds (albeit at much lower frequency), which may also suggest that colour rings may have increased the occurrence of a naturally occurring infection.

Although the mechanical causes of injury described above are entirely plausible, they do not help to explain why certain species should be more susceptible to infection and injury. In two of the studies reported here (AP, Thailand, and VS, Ivory Coast), over 1,500 birds of more than 85 species were colour-ringed and observed over the same periods without similar incidence of associated leg injuries. Indeed, despite the widespread use of colour marking, leg injuries have been reported in only a handful of species (Sedgwick & Klus 1997, Dettmann 1999, Splittgerber & Clarke 2006). Splittgerber & Clarke (2006) also highlighted several other (unpublished) cases involving intensive studies of particular species (Helmeted Honeyeater *Lichenostomus melanops*, Leaden Flycatcher *Myiagra rubecula* and thornbills *Acanthiza* spp) where leg injury associated with colour ringing has been reported. Colour rings are widely used by both amateur and professional ornithologists for the study of birds without the need for recapture. Apart from extreme cases of amputation, many of the instances of leg injury reported here were visible only upon direct physical examination of the bird in the hand. It is possible that other instances go unrecorded because the deployment of colour rings makes recapture unnecessary. That some species appear to be more susceptible to injury than others, and that injury does not manifest itself immediately, highlights the requirement for regular monitoring of colour-ringed birds for signs of injury. It may be that there is something in the morphology or behaviour of birds in the Muscicapidae and closely related Monarchidae families (and perhaps even the Tyrannidae flycatchers of the Americas), that causes them to be particularly susceptible to damage by plastic rings. This

could explain the largely anecdotal evidence that a great many other species of birds are colour-ringed apparently with no adverse effects (and see also *eg* Perkins *et al* 2004, Cresswell *et al* 2007). At present, we have no compelling morphological, ecological or behavioural explanation for the prevalence of such injuries in flycatchers.

Sedgwick & Klus (1997) reported that the incidence of leg injury was greater in female Willow Flycatchers than males, and we observed the same pattern in at least one species in this study (Spotted Flycatcher), albeit anecdotally. This apparent sex bias is similarly difficult to explain. Willow and Spotted Flycatchers have similar behavioural traits during breeding, with the females taking a more active role during the breeding season, nest building and incubating, but this offers no obvious explanation of why leg injury rates should be different from those observed in males. Interestingly, there was no observed sex bias to the incidence of injuries in Black-naped Monarchs, a species where males and females tend to take equal roles in the breeding season. Although these observations are supported by only anecdotal evidence, they are perhaps worthy of further study.

Conclusions and recommendations

After substituting anodised metal rings for plastic rings, we recorded no further injuries in either Black-naped Monarchs or Spotted Flycatchers (Table 1), and the incidence of injury in Madagascar Paradise-flycatchers was reduced to a level comparable with that observed in unringed individuals (in the order of two individuals per year in a population of around 200 adults). Clearly, any researcher wishing to commence a colour-ringing study on flycatchers should avoid using plastic colour bands. We recommend the use of single anodised aluminium colour rings in place of either celluloid or PVC (Darvic) plastic rings. Using only a single ring reduces the number of colour combinations available, but Koronkiewicz *et al* (2005) reported a method to overcome this by making striped anodised colour rings. If plastic rings are to be used, we recommend placing them above metal rings (*ie* distal to the foot) and not placing two colour rings together.

It is important to stress again that plastic colour rings have been used in many studies worldwide without incidence of injury, and they remain a useful tool in ecological studies of birds. Occasional accidents and injuries due to handling and ringing may be inevitable but should be kept to a minimum – for ethical reasons, to avoid errors and bias in data collection, and to avoid weakening the populations of rare species. Where an unexpectedly high number of injuries occur, changes to the methods should be implemented immediately and the problem reported promptly to the relevant ringing regulatory authority and/or the ring supplier. Potential effects of

injury may be minimised by detecting injuries at an early stage, recapturing affected individuals and removing rings from the injured leg. Any project targeting a rare species would be wise to undertake preliminary studies on a more common, taxonomically and physically similar species beforehand, to assess the potential problems.

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