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Marking birds is a vital tool for determining survival, habitat-use patterns, and movements. For galliform species, metal leg bands and radio-transmitters are widely used marking techniques. While commonly used on adult birds, leg banding and radio-marking of galliform chicks are not commonly employed. During a two-year study to evaluate survival, dispersal, and habitat-use of released four-week old ring-necked pheasants *Phasianus colchicus*, we sought to mark chicks in a manner that allowed us to track them post-release and recognize them if harvested as adults. Our objectives were to evaluate the efficacy of four banding techniques: 1) standard bands for adult ring-necked pheasants [no. 6 aluminum butt-end bands], 2) colored plastic spiral leg bands commonly used for banding poultry, 3) no. 6 bands and plastic spiral leg bands to prevent the aluminum bands from slipping off, and 4) cotton-filled no. 6 bands to prevent bands from slipping off and allow growth of the tarsus. We also evaluated two radio-transmitter attachment methods: gluing or suturing transmitters on the back of four-week-old chicks. The no. 6 bands did not stay attached to the birds due to the bands being too large, and plastic spiral bands commonly caused constriction of the legs, possibly crippling birds. However, using cotton filled leg-bands was a reliable method for marking pheasant chicks. Although gluing has been used successfully as a radio-transmitter attachment method in other studies, in our study it largely failed given that few radio-transmitters remained attached beyond two days. Suturing was an effective method (90% of the transmitters remained attached until death or expected life of the battery) for attaching radio-transmitters to ring-necked pheasant chicks. Our field study has revealed promising approaches and we suggest that a captive study should now evaluate the possible sub-lethal effects (e.g. growth rates, body condition, transmitter retention times) of these attachment methods.

Marking birds is a vital tool for determining their survival, habitat-use patterns, movements, cause-specific mortality, and brood mixing. For galliform species, metal leg bands and radio-transmitters are widely used marking techniques. Both of these techniques are commonly used to mark adult galliform birds. However, as the size and mass of radio-transmitters has decreased, radio-transmitters have also been used in studies of galliform chicks (Riley et al. 1998, Spears et al. 2005, Gregg et al. 2007).

Attachment of metal leg bands and radio-transmitters to galliform chicks are not without issues. Although metal leg bands are largely considered a safe and effective method for marking birds, leg injuries may occur if wrong sized bands are used or if bands are improperly attached (Reed and Oring 1993, Gratto-Trevor 1994, Splittgerber and Clarke 2005). For some galliform chicks e.g. northern bobwhite *Colinus virginainus*, leg banding may be impractical because of the chick's rapid growth and a considerable size difference in the tarso–metatarsus length between adults and chicks (Carver et al. 1999). For example, bands determined to be the appropriate size for chicks may constrict the leg as the chick grows, whereas adult-sized bands may slip off the chick's leg. Because of these problems, patagial tags have frequently been used to mark galliform chicks (Hannon et al. 1990, Carver et al. 1999). However, recovery rates for patagial tags, unlike leg bands, may be lower because tags may not be visible when birds are recovered as adults (e.g. by hunters during the hunting season).

One of the problems with radio-telemetry is the potential impact of the attachment method on survival and behavior of radio-marked birds (Fuller et al. 2005). Consequently, it is imperative that researchers minimize potential impacts from the attachment method such that the animal's welfare is not compromised and the data collected are unbiased. Moreover, success of an attachment method will depend on the species, age of the bird, habitat type, and life history characteristics. A variety of attachment methods have been used to attach radio-transmitters to galliform chicks and other precocial species; radio-transmitters have been attached by gluing to the back (Dobony 2000, Göth and Jones 2001), using backpacks (Hubbard et al. 1998) and

necklaces (Dobony 2000), subcutaneous implantation (Ewing et al. 1994, Hubbard et al. 1998, Gregg et al. 2007), prongs and sutures (Mauser and Jarvis 1991, Amundson and Arnold 2010), and suturing (Burkepile et al. 2002). Some of these techniques had limitations that made them unsuitable for some galliform chicks and age classes. For example, backpacks and harnesses may be unsuitable because they may restrict blood flow and suppress growth (Hubbard et al. 1998), while implantation is an invasive technique that must be conducted in a sterile environment and typically requires the supervision of a veterinarian (Korschgen et al. 1996). Suturing with prongs is less invasive than full implantation, but still requires the subcutaneous implantation of an anchor or prong that may make the chick susceptible to infection (Mauser and Jarvis 1991). Gluing has been successfully used to attach transmitters to Australian brush-turkeys *Alectura lathami* chicks (Göth and Jones 2001) and wild turkey *Meleagris gallopavo* poults (Spears et al. 2002), and suturing has been successfully used to attach transmitters to greater sage-grouse *Centrocercus urophasianus* chicks (Burkepile et al. 2002), wild turkey poults (Bowman et al. 2002), and northern bobwhite and chukar *Alectoris chukar* chicks (Dreitz et al. 2011).

During a two-year study that evaluated the survival, dispersal, and habitat-use of ring-necked pheasant *Phasianus colchicus* chicks released at four weeks old from a device called a Surrogator (Wildlife Management Technologies, Wichita, KS, USA; <http://wildlifemanagementtechnologies.com >) (hereafter, surrogator), we sought to mark chicks such that they could be tracked post-release and recognized if harvested as adults. The surrogator is a chick-rearing system designed for the purpose of captive raising gamebird chicks to 4–5 weeks of age prior to release (Surrogator 2013, Thacker et al. 2016). As a self-contained unit which can be stationed and deployed in the field, the surrogator serves as a food and water delivery system while simultaneously protecting chicks from unfavorable environmental conditions (Surrogator 2013, Thacker et al. 2016). Therefore, our objectives were to evaluate the efficacy of four banding techniques: 1) standard bands for adult ring-necked pheasants [no. 6 aluminum butt-end bands], 2) colored plastic spiral leg bands commonly used for banding poultry, 3) no. 6 bands and plastic spiral leg bands to prevent the aluminum bands from slipping off, and 4) cotton-filled no. 6 bands to prevent bands from slipping off and allow growth of the tarsus. We also evaluated two radio-transmitter attachment methods: gluing or suturing transmitters on the back of four-week-old chicks.

Material and methods

Our study was conducted from early June to early January 2009 and 2010 on four Conservation Reserve Program (CRP) fields in Kiowa County, south–central Kansas, USA. The mean size of fields was 103 ha (range of 65–161 ha). Fields occur as close as 20 m to as far as 3.2 km from one another. In 2009, food plot strips were planted on the fields; however, these were not replanted in 2010. The fields had prescribed burns performed on them previously, but not in recent years (J. Johnson, Wildlife Management Technologies, pers. comm.).

Leg banding

In 2009, we initially banded 60 chicks using no. 6 aluminum butt-end leg bands (National Band and Tag Co., Newport, KY) prior to release from the surrogator. All chicks included in this study were obtained from Birds of Brilliance Gamebird Farm, Milford, KS. Leg bands were individually numbered and contained contact information for birds recovered off the study site. Because bands slipped off the chicks, we modified our banding technique by placing a plastic spiral band (QC Supply, Schuyler, NE) below the no. 6 band to secure the aluminum band to the leg (Fig. 1). We banded 373 chicks using the combination of spiral and aluminum bands. We additionally banded 257 chicks exclusively with the plastic spiral bands.

In 2010, we further modified our banding technique by using no. 6 bands that had pieces of sterile hydrophilic (i.e. 100% absorbent) cotton glued to the inside of the band (Fig. 2). To attach the cotton, we applied a small amount of Loctite super glue to the inside of a band and then attached the cotton (~0.065 g of cotton) to the glue (i.e. one cotton ball could adequately fill 5–6 bands). Prior to use, we allowed the glue to dry for at least 3–4 h and we checked all bands to determine if the cotton was attached securely or if the band had been overfilled with cotton. We banded 352 chicks with the cotton-filled bands. If the band contained too much cotton to allow the band to fit on a chick's leg, we removed small amounts until the band fit securely, but did not pinch the leg.

Attachment of radio-transmitters

In 2009, we attached 2.05-g radio-transmitters (Holohil Systems Ltd., Carp, ON) to 84 pheasant chicks by several gluing techniques (Table 1). All techniques initially involved roughening the underside of the transmitter with sandpaper to enhance adhesion (Bowman et al. 2002), moving feathers on the bird's back away to expose bare skin, applying glue to the back of a transmitter, and pressing the transmitter firmly onto the skin. The transmitter was then held in place for 3–5 min until the glue dried. We tested three types of adhesive: rubber cement [Elmer's Products Inc.], Loctite Super Gel [Henkel Corp.] and Super Glue [Super Glue

Figure 1. Aluminum band and plastic spiral affixed to a ring-necked pheasant chick during summer 2009, Kiowa County, KS, USA.

Figure 2. A cotton-filled band affixed to leg of a ring-necked pheasant chick during summer 2010, Kiowa County, KS, USA.

Figure 3. Radio-transmitter suture attachment to a ring-necked pheasant chick during summer 2010, Kiowa County, KS, USA.

Corp.] for attachment directly to the chicks as well as the effectiveness of attaching the radio-transmitter to a piece of gauze that was glued to the back of chicks. We used rubber cement and Loctite Super Gel for evaluating use of gauze to attach radio-transmitters.

In 2010, we used a suturing technique to attach radio-transmitters to 58 chicks following Burkepile et al. (2002) (Fig. 3). Photos of this technique being used on greater sage-grouse chicks are provided in Burkepile et al. (2002), Gregg et al. (2007; Fig. 1), and for ring-necked pheasant chicks in this study (Fig. 3). We used the same radio-transmitters as were used for testing the gluing except that the radio-transmitters had been retrofitted with eyeholes at each end (Fig. 3). We attached a radio-transmitter to a chick by inserting an 18 gauge hypodermic needle through the skin between the scapulae, perpendicular to the dorsal midline. The suture (3-0 chromic gut sutures) was then fed through the tip of the needle to the other side. The needle was then withdrawn, leaving the suture in place. This process was repeated below the first suture using the transmitter for determination of appropriate placement. After both sutures were inserted, we tied the transmitter into place using two square knots for each suture. We then snipped loose ends and applied super glue to the knots for further hold. This procedure was approved by the Oklahoma State Univ. Animal Care and Use Committee (protocol no. AG-09-9).

Table 1. Summary of sample sizes (n) obtained among attachment type and attachment technique for each year of the study, 2009–2010, Kiowa County, KS, USA.

Attachment type	Year	Attachment technique	n
Band or spiral	2009	band only	60
	2009	band and spiral	373
	2009	spiral only	257
	2010	cotton-filled band	352
Radio-transmitter	2009	rubber cement	27
	2009	Super Gel	19
	2009	Super Glue	17
	2009	Super Glue and gauze	17
	2009	Super Gel and gauze	20
	2010	Suture	58

We monitored each radio-marked bird at least three times a week until the transmitter detached or ceased functioning or the fate of the chick was known. If the transmitter was found detached without evidence that the bird had died, it was considered an attachment failure.

Results

Aluminum leg band only

The no. 6 aluminum bands typically did not remain attached to the chicks' legs; we lost at least 50% of bands after banding (i.e. we recovered bands that slipped off the chick's legs from the release site). A maximum of 50% of the bands still remained on the chicks' legs after they were released from the surrogator. Only one of the 'band only' (n = 60) birds was recovered later during the study; the bird was killed after colliding with a vehicle shortly before hunting season.

Aluminum leg band and plastic spiral band

We did not observe any initial band losses from this technique (i.e. no bands were observed on the ground at or near the release site); however, we encountered other issues. Immediately evident was a 'jingling' sound made by the aluminum band colliding with the plastic band. In the weeks after release, we also observed several of the banded birds limping. Nearly all of the birds recovered showed signs that their leg had been constricted by the plastic band. The band recovery rate for this technique was 1.9% (n = 6). One of the birds was harvested during the hunting season in 2010, and that bird also exhibited signs of constriction.

Plastic spiral band only

Similar to the aluminum band plus plastic spiral band method, we did not observe any initial band losses from this technique. The band recovery rate for these birds was 1.6% (n = 5), and all these birds exhibited signs of band constriction on the tarso-metatarus. The least severe case of constriction was a depression in the leg where the band was

Figure 4. Evidence of constriction on a harvested male ring-necked pheasant caused by a plastic spiral leg band during winter 2009 in Kiowa County, KS, USA.

located (Fig. 4), while in the most severe case, the tissue of the leg had grown around the band.

Cotton-filled aluminum bands

We observed no initial losses with the cotton-filled bands, and there were no apparent leg constriction problems as occurred with the spiral bands. Upon examination of recovered mortalities, we observed that the cotton had compressed such that the bands were relatively loose, but secure on the leg. The cotton also began to degrade and slowly fall from the band as the birds grew as evident by the fact that all the bands of recovered birds, except for two birds, contained no cotton or only negligible amounts of cotton. For the other two recovered birds, the cotton had compressed to a solid mass that caused noticeable irritation to the skin of the leg, but the constriction issue that occurred with the spiral bands was not observed. A total of 52 pheasants with cotton-filled bands were recovered during the hunting season for a recovery rate of 16.1%.

Gluing radio-transmitters

Using rubber cement, the mean number of days the radio-transmitter remained attached was 3.9 ± 0.81 (SE) (n = 27). Retention time estimates were based on transmitters recovered that had no evidence of predation and/or scavenging. Radio-transmitters attached by rubber cement remained attached to chicks for 1–18 days and 82% of the radio-transmitters detached from chicks within seven days. Loctite Super Gel (n = 19) had a retention rate of 1.6 days ± 0.33. All radio-transmitters attached with Loctite Super Gel detached within seven days. Radio-transmitters attached by Super Glue (n = 17) had a retention rate of 2.2 days ± 0.26, and all radio-transmitters detached within seven days. Use of glue and gauze attached to the chicks had similar results as gluing the radio-transmitter directly to the skin. Both rubber cement (n = 17) and Super Gel (n = 20) attached to gauze resulted in all transmitters detaching within 1–2 days of attachment. We suspended efforts for attachment methods that exhibited very poor retention because it was clear that these methods were mostly ineffective and thus sample sizes for radio-transmitter attachment methods were uneven among methods.

Suturing radio-transmitters

Ninety percent of the sutured radio-transmitters (n = 58) remained attached to the chicks until death or the expected life of the battery (i.e. 84 days). Sutures failed to secure transmitters on six chicks. Radio-transmitters remained attached for 18–84 days. Although we did not recapture chicks for later examination, there appeared to be no issues with the suturing technique. Observations of chicks in the field and examination of recovered deceased chicks (n = 35) indicated no infection or inflammation of suture sites. Additionally, we did not observe any chicks with impaired mobility caused by the radio-transmitters.

Discussion

Leg banding

The use of adult size no. 6 aluminum leg bands alone was not an effective technique for marking ring-necked pheasant chicks, as ≥ 50% of the bands slipped off immediately after release and only one was recovered. The use of plastic spiral leg bands was also not effective. As evidenced by the band constriction of the legs observed on harvested birds and the low band returns, it is possible that the plastic bands led to the death of many birds from causes such as infection or an increased susceptibility to predation. Another factor with the plastic leg bands that could have further decreased band return rates is that hunters that harvested any birds off site could not report the birds unless they were aware of the study. While this possibly biased our band return rates at a lower rate, it is unlikely that many more birds were harvested off site and not reported since we did observe a low return rate on research fields and the band constriction was observed on all harvested birds.

Using cotton-filled leg bands was an effective technique for marking ring-necked pheasant chicks. Compared to the other marking techniques, the band recovery rate for cotton-filled bands was considerably greater (16% versus 1%), and there were no adverse effects from the bands as occurred with the plastic spiral bands (i.e. constriction of the legs) or loss of bands from slippage. The two cases of skin irritation that were observed were assumed to come from a relatively large amount of cotton remaining in the bands, however, the irritation appeared minor and did not seem to have affected the bird's overall condition. In all other cases, the cotton had either come out completely or a small remnant was left in the band.

Currently, it is rare for upland gamebird chicks to be banded at a young age. This is in contrast with waterfowl in which specialized plasticine-filled bands are frequently used to band ducklings (Blums et al. 1999, Amundson and Arnold 2010). The ability to band gamebird chicks could result in more accurate dispersal and survival data being collected. To our knowledge, the use of cotton-filled bands is a novel technique that appears to be a safe and effective

method for banding pheasant chicks. Based on our results, this technique also shows promise for use on other precocial chicks.

Attaching radio-transmitters

We determined that gluing radio-transmitters to ring-necked pheasant chicks was ineffective. During our study, nearly all the radio-transmitters detached within seven days of attachment. Our results with glues and gels are similar to other studies that used liquid glues and gels to attach radio-transmitters to northern bobwhite and chukar *Alectoris chukar* chicks (Dreitz et al. 2011) and ruffed grouse chicks *Bonasa umbellus* (Dobony 2000). Both studies reported only a few radio-transmitters remained attached beyond 3–5 days. However, other studies have reported successful attachment of radio-transmitters to galliform chicks. Bowman et al. (2002) and Spears et al. (2002) both reported that gluing was an effective technique for attaching radio-transmitters to wild turkey poults; radio-transmitters remained attached for 20 days in the case of the Spears et al. (2002) study and 28 days in the case of the Bowman et al. (2002) study. Similarly, Göth and Jones (2001) reported that Australian brush-turkey chicks retain glued radio-transmitters for 21–28 days. Unlike our study which was conducted under field conditions, the Bowman et al. (2002) study was conducted using captive birds which may have facilitated higher retention rates because the birds were not regularly traveling through dense vegetation that could detach a radio-transmitter. It is also possible that differences in habitat conditions could explain the higher retention rates for Spears et al. (2002) and Göth and Jones (2001) compared to our study. Both of these studies were conducted in different habitats than our study and with species that would likely spend more time in less dense habitats than occurred in our study.

Several reasons could account for the failure of gluing in our study. The first is the chemical natures of the glues might have been inappropriate for this type of use, as some glues are advertised to bind more effectively to specific substances. However, Superglue, or chemically similar glues, has been used in other successful studies (Johnson et al. 1991, Bowman et al. 2002, Spears et al. 2002). Second, the radio-transmitters may more easily detach because the chicks are rapidly growing and molting feathers. We attempted to glue to bare skin, but feathers were occasionally entrapped in the glue. If the feather was molted or otherwise lost, it might have affected the attachment of the radio-transmitter by weakening the glue's bond to the bird. Finally, the habitat that the chicks used was typically dense stands of perennial grasses. With the birds constantly brushing against stiff grasses that may have pushed and pried the radio-transmitter, the bond may have constantly been under strain, which eventually could have led to attachment failure.

Suturing is a more invasive technique than gluing, but it is still a comparatively benign technique compared to implantation or the addition of prongs to the transmitter. The suturing technique worked well during our study. While it was more difficult to perform, once perfected, it was completed in approximately the same amount of time required for the gluing technique (approximately 5–10 min). This technique has been successfully used on other galliform chicks (Bowman et al. 2002, Burkepile et al. 2002, Dahlgren et al. 2010, Dreitz et al. 2011). Suturing is less invasive than other techniques such as subcutaneous implants or the prong-and-suture technique, can be rapidly performed in the field, and has relatively high retention rates (nearly 90% retention in our study). However, future research involving captive studies could be effective at addressing the possible long-term effects of high retention associated with suturing relative to bird fitness and infection risk. Although, the technique was effective for retaining radio-transmitters on four-week old ring-necked pheasant chicks, but for younger pheasant chicks the technique may be less effective because of smaller surface area available on the back for attachment (Dreitz et al. 2011).

We did not note any deaths attributed to handling or radio-transmitter attachment, but it is possible that some deaths caused by handling or radio-transmitter attachment could have occurred. In six cases, it was not possible to determine if mortality was due to predation or from another source that had been subsequently scavenged. Moreover, it is also possible that sub-lethal effects of transmitters went undocumented and may have contributed to mortalities by handicapping the birds such that they may be more susceptible to predation or other mortality factors (Guthery and Lusk 2004, Abbott et al. 2005, Barron et al. 2010). Moreover, Venturato et al. 2009 found that increased transmitter weight of radio collars caused reduced survival in ring-necked pheasants and hypothesized that these effects were likely due to increase energy expenditure, reduced mobility or agility, or greater susceptibility to predation. Our mean survival rate for pheasant chicks over the 12-week monitoring period was 0.08 ± 0.06 (Thacker et al. 2016), which may suggest possible handicapping effects from attachment of the radio-transmitters.

Our field study has revealed promising approaches, and we suggest that a study in captivity is appropriate and needed to evaluate the most promising methods. A captive study can, for example, examine sub-lethal effects that may influence growth rates or body condition. Specifically, comparing chick weight and survival over time could elucidate the effects of different attachment methods and also discern retention times with much greater certainty (Mateo-Moriones et al. 2012). Nevertheless, our study provides insight into the efficacy of various banding and radio-transmitter attachment methods for young galliforms which, heretofore, has been and understudied aspect of gamebird and avian research.

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