Research Note

Reducing Tick Burdens on Chicks by Treating Breeding Female Grouse with Permethrin

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ABSTRACT Ticks are important arthropod vectors of diseases of human, livestock, and wildlife hosts. In the United Kingdom, the sheep tick (*Ixodes ricinus*) is increasingly recognised as a main limiting factor of red grouse (*Lagopus lagopus*) populations, a game bird of high economic value. We evaluated the effectiveness of a new practical technique that could help managers reduce negative impacts of ticks on young grouse. In a replicated field experiment, we treated breeding females with leg bands impregnated with permethrin, a slow-releasing potent acaracide. We found that treatment reduced tick burdens on young chicks. Because this treatment is easily applied, it offers a new practical management tool to tackle problems caused by ticks in game bird populations. (JOURNAL OF WILDLIFE MANAGEMENT 72(2):000–000; 2008)

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Ixodid ticks are important arthropod vectors of diseases that cause mortality and morbidity to livestock and wildlife hosts with annual costs of losses and control amounting to billions of dollars worldwide (Sonenshine and Mather 1994). In the United Kingdom, the sheep tick (*Ixodes ricinus*) is the only species of major economic and pathogenic importance, as the principal vector of pathogens such as Lyme disease and Louping ill virus (LIV). Of particular interest is the role that the sheep tick may have in the decline of red grouse (*Lagopus lagopus*) populations, a species of high economic importance and key to the conservation of heather moorland habitats (Hudson 1986). Tick infestations of red grouse chicks (aged 1–40 d) have increased 6-fold between 1985 and 2003 in the Scottish uplands (Kirby et al. 2004). Failure of grouse populations to respond on moors where best management practices have been implemented has been attributed by managers to poor recruitment due to high chick mortality because of tick infestation and the associated transmission of LIV (Hudson et al. 1995, Laurenson et al. 2003).

Louping ill virus has been reported as a major cause of mortality in wild red grouse and is transmitted by the sheep tick during feeding (Reid et al. 1978, 1980; Hudson et al. 1997). Ticks follow a 3-host life-cycle, with the larva, nymph, and adult feeding from different vertebrate hosts such as red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), sheep (*Ovis aries*), and mountain hare (*Lepus timidus*; Jones et al. 1997, Norman et al. 1999, Laurenson et al. 2000). Management solutions to tick problems have so far mainly targeted these alternative hosts (see Wilson et al. 1988, Hudson et al. 1995, Gilbert et al. 2001, Laurenson et al. 2003). Tick control methods also can be applied to grouse. Directly treating chicks with acaricide can be beneficial, but no appropriate acaricide application method has been found for chicks (Laurenson et al. 1997). Moreover, direct treatment of chicks would not provide a practical management solution, given the considerable effort required to locate, catch, and treat grouse chicks on a large scale. An alternative option could be treating females for the benefit of their chicks. As part of standard grouse management, female red grouse are often routinely caught and dosed with anthelminthic to reduce infection by a nematode, the caecal threadworm (*Trichostrongylus tenuis*), which is well-known to reduce grouse productivity (Hudson 1986, Hudson et al. 1992, Redpath et al. 2006). Thus, an acaricide treatment applied to females, if effective, could similarly be used on a large scale.

We evaluated potential benefits of treating female red grouse with leg bands impregnated with pernethrin, a potent slow-releasing acaracide, to protect their chicks from ticks (Deblinger and Rimmer 1991, Burridge et al. 2003, Solberg et al. 2003). The acaracide is passed onto females when leg bands rub on feathers and leg skin, providing a topical and a systemic treatment (circulated via blood) that protects females from ticks. Acaracide treatment should also help protect chicks from ticks: 1) by reducing tick numbers on females, thus minimizing transmission to chicks, and 2) by passing acaracide to chicks when brooded by females (when in close contact, chicks would also rub against the female's leg band and feathers and receive the acaracide treatment). We expected young chicks from treated females to have fewer ticks, and thus greater survival, than chicks from control females.

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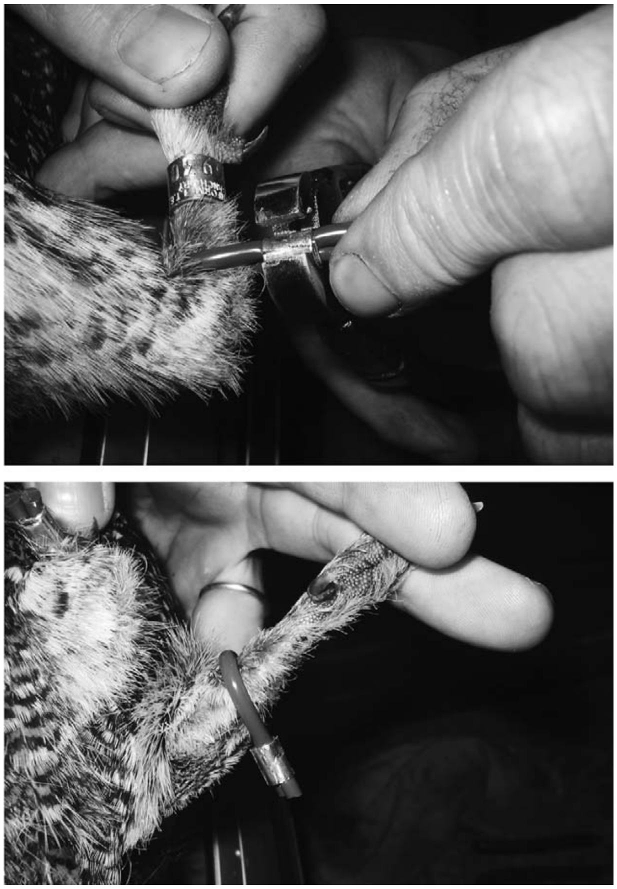

Figure 1. a) Permethrin band being clipped and b) once fitted onto the leg of a female red grouse (photos by F. Mougeot). Tullybeagles, Scotland, March 2005.

STUDY AREA

We conducted our experiment in northeast Scotland in 2005 on 2 grouse moors, Forest of Birse, Aberdeenshire (hereafter moor 1) and Tullybeagles, Perthshire (moor 2). Both sites had similar vegetation (heather [*Calluna vulgaris*]-dominated moorland) and physical features. Both moors were managed for grouse, with gamekeepers conducting parasite and predator control and heather-burning to improve the habitat for grouse (see Hudson 1986).

METHODS

In spring (18 Mar–6 Apr), we caught 60 females (20 on moor 1 and 40 on moor 2) at night by lamping and netting them (Hudson 1986). We ringed, fitted with an individual radiotag (TW3 necklace; Biotrack, Dorset, United Kingdom), and randomly assigned each female to either the control group or treatment group, which entailed treatment with 2 permethrin leg bands (one on each leg; see Fig. 1). Permethrin is a Pyrethroid synthetic chemical that functions as a neurotoxin and is a potent acaracide often used for tick control (Deblinger and Rimmer 1991, Burridge et al. 2003, Solberg et al. 2003). Leg bands were 4 cm long and 4 mm in diameter, and their microstructure allowed a slow release of permethrin for $\geq$3 months. Leg bands were an extruded polyvinyl chloride (PVC) matrix, which exuded permethrin by a diffusion process. Because release of permethrin was a function of concentration gradient within the polymer, release is exponential rather than linear over time. For the leg bands that we used, the daily release (mg/d) was approximated as $1.47 \times T^{-1/2}$, where time (T) is expressed in days postattachment. Therefore release rate for each leg band declined from 1.47 mg per day to 0.27 mg per day and 0.19 mg per day after 30 days and 60 days, respectively. Given that the incubation period is 31 days (Hudson 1986), we estimated from capture dates and laying dates that females were treated, on average, 60 days before their young hatched. We folded leg bands around the tarso-metatarsus part of the leg, in the area where metal identity rings are normally fitted, and clipped them using a metal tag (Fig. 1 a,b). On moor 2, we gave control females either no leg band ($n = 10$) or 2 leg bands (one on each foot; similar to the ones used on treated F) without permethrin ($n = 9$), to evaluate possible adverse effects of the leg band on females and chicks. On moor 1 control females received no leg bands. We dosed all females with an anthelminthic (Levamisol; Nilverm Gold^{TM}, Schering-Plough Animal Health, Welwyn Garden City, United Kingdom), a treatment effective at reducing infection by caecal threadworms (*Trichostrongylus tenuis*), a nematode well-known for its negative effects on grouse condition and productivity (Hudson 1986, Hudson et al. 1992, Mougeot et al. 2005, Redpath et al. 2006). Treatment with an anthelminthic allowed us to standardise females for this possible source of variation. All procedures were conducted under a United Kingdom Home Office licence (PPL80/1438).

In May, we located nests by radiotracking females and we recorded clutch size. We measured length and width of each egg with a calliper (nearest 0.1 mm) and weighed eggs with an electronic balance (nearest 0.1 g). We determined hatch dates (nearest 2 d) from egg density or from direct observations of hatching during nest visits (see Seivwright 2004). We counted ticks on females upon the first (Mar–Apr) and last capture (Oct, see below). We used head tick counts, which were shown to reliably estimate tick infection levels in grouse chicks (Laurenson et al. 1997, Kirby 2003, Kirby et al. 2004).

We located broods by radiotracking females, and we used trained pointer dogs to find and catch chicks (we found most but not all chicks on a given brood visit). We located each brood 2–4 times when chicks were between 1–30 days old. Older chicks flush when disturbed and could not be caught easily. Upon first capture, we individually tagged each chick using a numbered patagial metal tag and counted ticks on the chick's head by carefully inspecting the area around the eye, comb, and base of the beak.

In June, we recorded brood size when chicks were 1 month old by radiotracking and lamping females at night and by counting young from a close distance without flushing them. From 5 October to 14 October, we recaptured females, and we released them after retrieving radiotags and leg bands.

We used SAS 8.01 (SAS Institute, Inc., Cary, NC) for all analyses. We fitted dependent variables to models using the

Table 1. Effects of site, chick age (d), treatment (control F or F treated with permethrin leg bands), and interactions on number of ticks per chick. We conducted the experiment on red grouse, March–June 2005, in northeast Scotland. We fitted counts of ticks to the model with a Poisson error distribution. We included female identity and chick identity as random effects to account for the nonindependence of chicks within a brood and for repeated measures on some chicks.

Effect	df	*F*-value	$P > F$
Site	1,11	1.56	0.238
Chick age	1,11	31.12	0.001
Treatment	1,11	7.01	0.023
Chick age × treatment	1,11	14.75	0.003
Treatment × site	1,11	0.03	0.867
Chick age × site	1,11	0.58	0.463
Chick age × treatment × site	1,11	0.16	0.695

following error distributions: 1) hatch date—normal error distribution, 2) counts of eggs, chicks and ticks per chick—Poisson error distribution, and 3) survival probability of females—binomial error distribution. For tick-count analyses, we used generalized linear mixed models (GLIMMIX, SAS Institute, Inc. 2001) that included female identity (brood) and chick identity as random effects, to account for the nonindependence of chicks from the same brood and for repeated measures on some chicks (Elston et al. 2001). All tests were 2-tailed and we express all data as means ± standard deviation.

RESULTS

Neither clutch size, hatch date, nor brood size at hatching differed between treated and control females (GLMs controlling for site: clutch size: $F_{1,43} = 0.02$, $P = 0.88$; hatch date: $F_{1,46} = 0.00$, $P = 0.96$; hatch brood size: $F_{1,46} = 0.26$, $P = 0.61$). Mean (± SD) breeding parameters were the following: clutch size: 9.5 ± 1.7 ($n = 47$); hatch date: 28 May ± 6 days ($n = 50$); hatch brood size: 8.4 ± 2.9 ($n = 50$). We observed no relaying after breeding failure. Upon first capture, (18 Mar–6 Apr), 11.6% of females ($n = 60$) had ticks (1 tick each). Upon recapture (5–14 Oct), none of the treated females had ticks ($n = 14$) and 13.3% of control females had ticks (1 tick each; $n = 15$).

We found that the treatment applied to females had a significant effect on number of ticks per chick (Table 1; Fig. 2). Tick numbers increased with chick age, reaching a maximum of approximately 13 ticks per chick when chicks were 1 month old, but we did not observe the increase in ticks in chicks from treated females, in which number of ticks remained <1.5 ticks per chick until ≥1 month of age. Treatment effects appeared similar in both study sites (nonsignificant: treatment × site, chick age × site, and chick age × treatment × site interactions; Table 1). Because hatching date did not differ between control and treated females, we obtained similar results when using sampling date instead of chick age (GLIMMIX: Date: $F_{1,12} = 40.52$, $P < 0.001$; Treatment: $F_{1,12} = 12.30$, $P = 0.004$; Date × Treatment: $F_{1,12} = 13.29$, $P = 0.003$). Maximum observed tick infection levels occurred around 22 June and were almost 10 times higher in chicks from control females (21.8

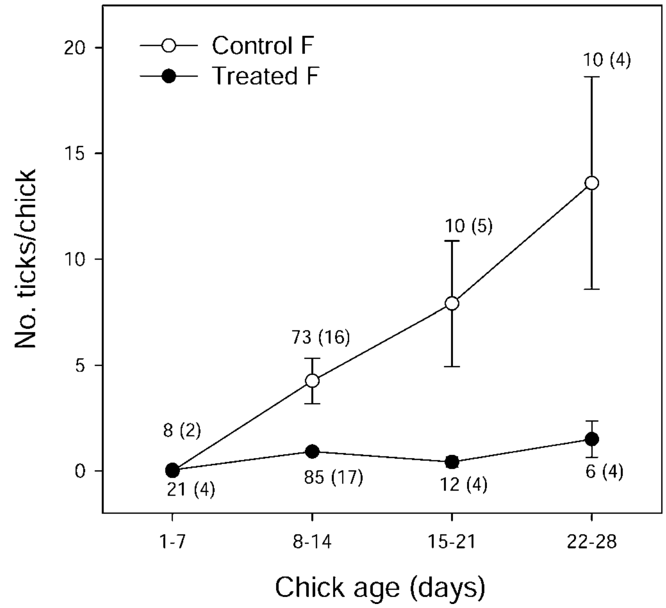

Figure 2. Mean (±SE) number of ticks per chick according to chick age and to female permethrin treatment (control F: white dots; F with permethrin leg bands: black dots), March–June 2005, northeast Scotland. Sample sizes above and below bars refers to number of red grouse chicks (no brackets) and number of broods (in brackets), respectively.

ticks/chick) than in chicks from treated females (2.4 ticks/chick).

Brood size at 1 month did not differ between treated and control females (GLM controlling for site effect: $F_{1,39} = 0.00$, $P = 0.96$; control: 3.0 ± 2.7, $n = 21$; treated: 3.2 ± 2.7, $n = 21$ [$\bar{x}$ ± SD]). Treated females survived as well (70.9% survival, $n = 31$) as control females (75.9%, $n = 29$) during the study (Mar–Jun; GENMOD: model controlling for site $F_{1,57} = 0.21$, $P = 0.65$).

In control females on moor 2, female survival probability, hatching success, or brood size at 1 month did not differ between control females with or without leg bands (GENMOD; models controlling for site: survival probability: $F_{1,17} = 0.01$, $P = 0.91$; hatching success: $F_{1,15} = 0.06$, $P = 0.81$; brood size at 1 month: $F_{1,12} = 0.22$; $P = 0.65$). Thus, we had no evidence that leg bands affected female survival, hatching success, or survival of young chicks.

DISCUSSION

In control broods, tick burdens increased with chick age up to a maximum of approximately 13 ticks per chick, similar to what has been found in recent years on most Scottish moors, following increases in tick numbers (Kirby et al. 2004). In contrast, tick burdens remained low (<2 ticks/chick) in chicks from treated females, in which we observed no seasonal or age-related increases, until young were ≥28 days old. Several nonexclusive mechanisms could explain how treatment on females benefited chicks. Although we did not measure tick abundance on females in April–September, it is likely that treated females had fewer ticks than control females, which could have led to reduced exposure for chicks. Chicks would nevertheless have been exposed to questing ticks when moving on the moor, so it is unlikely that differences in tick exposure alone would explain differences in tick burdens of chicks. Another possible explanation for reduced tick burden is that chicks from treated females benefited via maternal effects. Because we treated females before egg-laying, treatment might have influenced the chemical composition of eggs during production (i.e., additional antibodies), which could have subsequently benefited chicks (e.g., Grindstaff et al. 2002). The most likely explanation for reduced tick burden on chicks from treated females is that chicks were protected from ticks by acquiring permethrin by rubbing onto legs bands of females during brooding, which could be confirmed in future studies, for instance by comparing levels of permethrin in the blood of chicks from control and treated females.

By comparing survival and breeding performance of control females with or without leg bands, we evaluated possible negative impacts of leg bands on the grouse. Although our sample size was small, we had no indication that leg bands affected female survival, hatching success, or survival of chicks up to 1 month old. The only side effects we observed from leg bands were swelling of the leg in 3 birds (2 control and 1 treated F), in which the leg band was too tight or tangled with the individual metal ring. We would thus recommend taking care when fitting the leg bands and not using a metal ring together with leg bands (a numbered patagial metal tag could be used instead for individually marking F).

Number of young reared per female red grouse correlates negatively with average numbers of ticks per chick (Reid et al. 1978, Laurenson et al. 2003). Chicks could thus benefit from lower tick burdens in 2 main ways: 1) by minimizing direct impacts such as weakening from anemia, or reduced feeding through swollen eyelids and eye closures (Duncan et al. 1978, Kirby 2003), and 2) by reducing risk of infection by LIV, which increases with tick infection levels (Reid 1975). However, we did not find differences in either hatch brood size or brood size up to 1 month after hatching. Chick losses occurred mainly during the first 2 weeks after hatching and were most likely due to factors other than ticks. Tick burdens might not have been high enough to detect negative direct effects. Prevalence of LIV infection in red grouse increases at an early age coinciding with the seasonal rise in tick abundance (Hudson et al. 1997). However, LIV prevalence in chicks was low (1.4% on moor 1 and 0% on moor 2; Moseley et al. in press) and might not have been a significant cause of mortality on the study areas.

Management Implications

We found that treating female red grouse with a permethrin-impregnated leg band reduced tick burdens on chicks, which provides a new way of reducing tick burdens on chicks that can be easily applied and could help grouse managers solve tick problems. Currently permethrin is licensed for use in domestic birds. In wild game birds there may be issues with treated birds entering the food chain so the administration of permethrin as a routine treatment would need to be subject to licensing procedures (such as those laid down by the Veterinary Medicines directorate in the U.K.). Because permethrin treatment is cheap and grouse are routinely caught in the prebreeding season, adding this protocol into normal management practices is feasible. Treating female red grouse with permethrin on a larger scale could increase chick survival and postbreeding densities, in particular in situations where tick infections and LIV prevalence are high.

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