The effect of an indirect anthelmintic treatment on parasites and breeding success of free-living pheasants *Phasianus colchicus*

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Abstract

In Great Britain free-living common pheasants *Phasianus colchicus* are often managed at high densities owing to their popularity as a quarry species. They are prone to infection by a range of parasite species including *Heterakis gallinarum*, *Capillaria* spp. and *Syngamus trachea*. In 1995 the efficacy of an indirect anthelmintic technique for controlling parasitic worm burdens of pheasants was determined in a pilot study on a shooting estate in the south of England. Between 2000 and 2003 a large-scale field experiment was conducted on nine estates in eastern England to determine the effect of the technique on parasite burden and pheasant breeding success. In the absence of anthelmintic treatment worm burdens increased rapidly through March and April, whereas birds given anthelmintic-treated grain had lower worm burdens during the same period. The breeding success of pheasants was significantly higher on plots provided with anthelmintic treatment, although no long-term increases in population densities were observed. The burdens of the most common parasite *H. gallinarum* were significantly lower in pheasants from treatment plots six weeks after the anthelmintic treatment had ceased, but spring treatment did not influence parasite burden in the following winter.

Introduction

Common pheasants *Phasianus colchicus* are prone to high levels of parasitic infection (Draycott *et al.*, 2000; Millán *et al.*, 2002). In Britain, the most common helminths that infect pheasants are the gastrointestinal worms *Heterakis gallinarum*, *Capillaria* spp., and the tracheal worm *Syngamus trachea* (Draycott *et al.*, 2002). Pheasants are the primary host of *H. gallinarum* (Lund & Chute, 1974) and experimental work with *H. gallinarum* by Tompkins *et al.* (1999, 2000) suggests that pheasants can act as a reservoir of infection for other species including grey partridges *Perdix perdix*.

Transmission of these parasites is via an infective egg stage which can be ingested directly by ingesting soil or faecal particles or indirectly via soil-feeding organisms including earthworms (Soulsby, 1982; Beer, 1988). Recent studies have shown that helminth parasites can have negative effects on survival in juvenile pheasants (Millán

et al., 2002), and on survival of adult hens during incubation (Woodburn, 1999).

In Britain the common pheasant is the most widely distributed and abundant gamebird (Tapper, 1999). Over the last 40 years stocks of wild game (pheasants and grey partridges) have declined significantly on farmland owing to agricultural intensification (Potts, 1980; Campbell *et al.*, 1997). Concurrent with this has been an increased demand for game shooting (Tapper, 1999), to the extent that today approximately 12 million pheasants are harvested each year in Britain (Tapper, 1999). To sustain this high level of harvest, around 25 million hand-reared juveniles are released each year on farms and estates throughout the British countryside (Tapper, 1999). The majority of these birds are released at 6–8 weeks of age into open-topped pens in woodlands each summer by game managers to increase numbers of birds available for shooting the following winter (Draycott *et al.*, 2002). During the weeks following release the pheasants acclimatize to their new environment and gradually disperse from the pens into the surrounding countryside (Sage *et al.*, 2005). On game shooting estates pheasants are released at densities of approximately 250 birds km^{-2} (Aebischer, 2003) at a stocking density of around 1800

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birds per ha of release pen (Sage *et al.*, 2005). Pheasants are provided with supplementary food via feed hoppers and feed rides in woodlands and in specially planted game crops which provide both nutrition and suitable holding areas for pheasants prior to shooting (Draycott *et al.*, 1998). Pheasants in and around release pens are vulnerable to parasitic infection. Similarly, intensively managed wild pheasant populations can reach densities of around $150 \, km^{-2}$ in the autumn (Draycott, 2006) and are also susceptible to relatively high levels of parasite infection (Draycott *et al.*, 2002).

Over-winter mortality of released pheasants in Britain is approximately 80% (Turner & Sage, 2004) but because large numbers are released, many pheasants survive to the beginning of the breeding season. However, the breeding success of these birds is often poor (Hill & Robertson, 1988; Leif, 1994; Hoodless *et al.*, 1999).

Many factors have been implicated as contributing to the poor breeding success of pheasants including their susceptibility to high levels of endoparasitic infection (Woodburn, 1999; Draycott *et al.*, 2000, 2002). Woodburn (1999) found that direct dosing of released pheasants with an anthelmintic increased their breeding success to levels comparable with wild pheasants. Direct and indirect anthelmintic treatments have been shown to improve breeding success in red grouse, *Lagopus lagopus scoticus* (Hudson *et al.*, 1992; Newborn & Foster, 2002).

The aims of this study are to: (i) evaluate the success of an indirect anthelmintic treatment on parasite burdens in free-living pheasants in the breeding season; (ii) determine the effect of the anthelmintic treatment on the breeding success and density of pheasants; and (iii) determine the effect of the anthelmintic treatment on exposure of pheasants to parasites.

Materials and methods

Pilot study

In spring 1995 a trial was conducted to determine the efficacy of a technique to reduce the parasitic worm burden of free-living pheasants on a 400-ha mixed arable and livestock farm in Dorset, UK (50°58′N, 1°58′W). An anthelmintic product in powder form containing the drug flubendazole (proprietary name Flubenvet®, Janssen Animal Health, UK) was used. Flubendazole is a broad-spectrum anthelmintic for oral administration, and is active against mature and immature stages and eggs of nematodes and cestodes of the gastrointestinal tract and trachea. Wheat grain was coated with the anthelmintic and placed in feed hoppers in suitable pheasant habitat on one half of the farm during the month of April. On the other half of the farm, which was separated by a 500 m buffer zone, further hoppers were provided in suitable pheasant habitat which contained wheat grain only. This was considered to be a suitable technique for adminis-tering the drug as pheasants have been shown to feed readily and frequently on wheat from feed hoppers in spring (Draycott *et al.*, 1998). The provision of sup-plementary wheat to pheasants in spring enables pheasants to maintain body condition through nesting (Draycott *et al.*, 1998) and can increase breeding success (Draycott *et al.*, 2005).

To assess the efficacy of the anthelmintic treatment, under licence from English Nature (the Government Wildlife Agency, Licence no. SB:13:95), between 3–5 male and 3–5 female pheasants from each half of the study area were humanely dispatched before and after the treatment by cervical dislocation. This resulted in a sample of 15 birds at the end of March and 18 at the end of April. Caecal worm burdens were assessed following the method described in Doster & Goater (1997) and the trachea was examined for the presence of the gape worm, *S. trachea*.

Multi-site trial

From 2000 to 2003 in eastern England a large-scale field experiment on nine sites was conducted to determine the effect of a spring anthelmintic treatment on the breeding success of pheasants. All sites were in the north west area of Norfolk (52°49′N, 0°30′E). All the sites were large shooting estates and were broadly similar in land-use type. Arable crops were the dominant land use with crops including winter and spring cereals, sugarbeet, seed rape and root vegetables. The landscape on each farm also contained mixed and broadleaved woodlands and a network of hedgerows and shelterbelts. Active pheasant management took place on all estates. On some sites, management was primarily concerned with wild stocks of pheasants, while on others management was concen-trated on released birds.

On each site two independent study plots were selected, each approximately 300 ha in size and geographically separated by at least 1 km. In 2000 a baseline treatment was provided whereby wild and free-living released pheasants were given Flubenvet®-treated wheat grain in feed hoppers from early February until the end of April in all 18 plots. This was an attempt to achieve a reasonably constant baseline infection level between plots within each estate prior to the main experimental phase. Hoppers were provided primarily in winter holding areas including woodlands and game cover plots but also in breeding territories including woodland edges and hedgerows. One plot on each site was randomly assigned to act as the experimental plot for the period 2001–2003 and anthelmintic-treated grain was provided from the beginning of February until mid March. Treated grain was provided in feeding locations which birds had used throughout the winter, thereby ensuring that birds began to consume the grain immediately. The aim of the dosing strategy was to maximize the proportion of pheasants that consumed the anthelmintic before they established stable breeding territories in the wider countryside in late March and April (Robertson *et al.*, 1993). On the remaining plots on each farm untreated grain was provided for the same period. In all other respects, game management was identical between treatment and control plots. From December to January each year between 3 and 10 pheasants were collected from shoot days from treatment and control plots to assess winter parasite burdens. However, due to the method of driven pheasant shooting in Britain, whereby a team of beaters draw-in pheasants from large areas of farmland and woodland before flushing them over a line of standing guns (Carroll *et al.*, 1997) it was not always possible to be certain that shot

birds had originated from our treatment and control plots. Therefore, we only included in the analyses shot pheasants from drives where the drive was known to cover land restricted to each individual study plot and not any of the surrounding area.

Parasite uptake trial

Unlike the pilot study, we were not able to directly measure the efficacy of the anthelmintic treatment on parasite burdens of pheasants in the multi-site study as this would have necessitated the killing of a large number free-living birds in the breeding season to obtain a reliable estimate of parasite burdens. However, in April 2003 approximately two weeks after the annual Flubenvet treatment had been completed, a trial was conducted to determine the effect of anthelmintic treatment on the uptake of parasites from the environment. On six of nine original sites the uptake of parasites was compared in each of the two plot types by using parasite-free female pheasants held in pens.

Within each of the 12 plots an area was selected to erect a 3.05 m × 3.05 m pheasant holding pen. Areas preferred by pheasants and past congregation points, such as feed rides, woodland edge or near release pens were criteria for siting these experimental pens. In each pen, 12 tagged, numbered female pheasants were placed at random from a captive game-farm flock. All birds had received anthelmintic treatment up to the day they were placed in pens, but before placing birds in pens 13 birds were sacrificed at the outset to assess baseline worm burdens.

The pens were checked daily and wheat grain was scattered on the ground inside the pen to encourage pecking and scratching in the soil. Water was freely available and pens were moved to fresh ground twice a week. Pens in the treated area were visited before control pens at each site each day and boots were disinfected after leaving each pen. After 30 days pheasants were humanely sacrificed by cervical dislocation, and worms in the crop, caeca and trachea were collected, identified and counted (Doster & Goater, 1997; Draycott et al., 2000).

Methods for game counts

In late August and September, after the harvest of annual crops, counts of all adults and juveniles were made in each plot to estimate densities and breeding success, as previously described by Draycott et al. (2005). This involved surveying all fields and woodland edges in the plots with binoculars from a four-wheel-drive vehicle during the two hours after dawn or before dusk. Counts were restricted to days when there was no rain and little or no wind. Densities were determined as the maximum of three counts in each plot and estimates of the relative breeding success were calculated (Draycott et al., 2005). These counts were compared between plot type to investigate the hypothesis that treatment affected breeding success.

Statistical analyses

Statistical analyses were conducted using the software package Systat 9.0 (SPSS, 1999). Where necessary, parasite and game count data were transformed to normalize the distribution and standardize the variance. The $\log_{10}(n + 1)$ transformation was used for game and parasite counts and the angular transformation ($\arcsin\sqrt{p}$) for percentage data. Treatment was applied at the plot level, therefore all analyses of parasite and game counts were based on mean values for each plot. Analyses were conducted using paired 't' tests paired by site. Pheasant breeding success was estimated as the mean young to adult hen ratio across the years for each plot. Due to differences in starting densities of birds between plots, and because density in year 1 (t) may influence density in year t + 1 etc., the mean rate of change over consecutive pairs of years was calculated as follows: (density in t + 1) – (density in t)/(density in t) to obtain a measure of average annual change per plot. These figures were used to determine the effect of anthelmintic treatment on pheasant densities.

Results

Pilot study

In March, prior to treatment, parasite burdens in pheasants were comparable in the two plots (table 1). The number of H. gallinarum and Capillaria spp. increased in male and female pheasants in the control plot between March and April (table 1). In contrast, on the treatment plot, parasite numbers were lower in April than in March. There was a clear trend for increasing worm burdens in the control plot between March and April and a trend for a decline in burdens on the treatment plot suggesting that the anthelmintic treatment was successful in reducing parasite burdens.

Multi-site trial – winter parasite burdens

In 2000, the baseline year, there were no differences in the prevalence of H. gallinarum ($t_6 = 1.26$, $P = 0.26$) or Capillaria spp. ($t_6 = 2.13$, $P = 0.08$) in pheasants collected on shooting days from treatment and control plots. There were also no differences in worm intensities between treatment and control plots H. gallinarum ($t_6 = 0.41$, $P = 0.69$) or Capillaria spp. ($t_6 = 0.08$, $P = 0.94$) (table 2). During the experimental phase in 2001–2003, the prevalence and intensity of H. gallinarum were not significantly different between treatment and control plots (prevalence: $t_7 = 0.39$, $P = 0.71$, intensity: $t_7 = 0.16$, $P = 0.88$). Similarly, there were no differences in the prevalence or intensity of Capillaria spp. between treatment and control plots (prevalence: $t_7 = 0.08$, $P = 0.94$, intensity: $t_7 = 0.85$, $P = 0.43$). There was no evidence of S. trachea infection in any birds in winter.

Parasite uptake trial

Analyses of 13 birds culled prior to being placed in pens revealed the absence of parasites. After 30 days exposure all culled birds were infected with at least one parasite species. There were no differences in the proportion of birds infected with H. gallinarum ($t_5 = 0.52$, $P = 0.63$), Capillaria spp. ($t_5 = 0.002$, $P = 0.99$) or S. trachea ($t_5 = 0.445$, $P = 0.68$) between treatment and control plots (table 3).

Table 1. Changes in worm burdens in male and female pheasants on anthelmintic-treated and untreated areas of a pheasant shooting estate in Dorset, England in 1995.

	Males						Females					
	Treatment plot			Control plot			Treatment plot			Control plot		
	March	April	Change[a]	March	April	Change	March	April	Change	March	April	Change
Adult *Heterakis gallinarum*	27.3 ± 13.9	0.6 ± 0.4	−26.7	19.3 ± 4.5	152.7 ± 120.7	133.4	6.0 ± 3.3	4.2 ± 3.5	−1.8	11.8 ± 4.5	37.0 ± 19.6	25.2
Immature *H. gallinarum*	14.0 ± 7.0	0	−14	16.3 ± 13.3	27.7 ± 10.4	11.4	14.3 ± 6.3	15.0 ± 14.8	0.7	2.0 ± 1.2	114.0 ± 38.9	112.0
Capillaria spp.	8.7 ± 5.4	0.2 ± 0.2	−8.5	3.8 ± 1.6	6.7 ± 3.7	2.9	6.8 ± 3.4	2.0 ± 1.8	−4.8	6.5 ± 3.3	8.2 ± 3.1	1.7

[a] Change = April − March worm burdens; (−) indicates a reduction in worm burden.

However, pheasants from the treatment plots had significantly lower burdens of *H. gallinarum* than pheasants from control plots ($t_5 = -2.80$, $P = 0.038$) (table 3). There were no differences in burdens of *Capillaria* spp. ($t_5 = 1.16$, $P = 0.30$) or *S. trachea* ($t_5 = 0.64$, $P = 0.55$) between treatment and control plots.

Pheasant breeding success

In 2000, there were no differences in the ratio of young:hens (treatment plots (mean ± SE): 2.0 ± 0.5:1, control plots: 2.3 ± 0.3:1, $t_7 = -0.39$, $P = 0.706$) or the overall ratio of young:old (treatment plots: 0.9 ± 0.2:1, control plots: 1.0 ± 0.2, $t_7 = -0.190$, $P = 0.855$) between treatment and control plots. However, during 2001–2003 the mean young:hen ratio was significantly higher in the treatment plots (treatment plots: 6.9 ± 0.5:1, control plots: 5.0 ± 0.7:1, $t_8 = 2.86$, $P = 0.021$) and on average 25% more young were observed each year in treatment plots (fig. 1). There were no significant differences in the average annual rate of change in pheasant numbers between treatment and control plots (males: $t_6 = -1.04$, $P = 0.34$, females: $t_6 = 0.45$, $P = 0.67$, young: $t_6 = 1.37$, $P = 0.22$).

Discussion

The results of the pilot study suggest that administering an anthelmintic to both male and female pheasants by means of supplementary grain in spring was effective in reducing parasitic worm burden in free-living pheasants. There was a marked rise in worm burden in 'untreated' (control) birds between the end of March and the end of April, and a corresponding decrease in worm burden in the 'treated' group in response to eating the anthelmintic feed. The timing of this increase in the level of infection in the control group may coincide with increased earthworm and other invertebrate activity, triggered by environmental changes, such as humidity and warmer soil temperatures. Since infective eggs and larvae can be indirectly transmitted to pheasant hosts through the ingestion of these invertebrates, an increase in invertebrate activity may have increased the availability of infective stages to the pheasants at that time (Clapham, 1934, 1950).

In addition, the resistance of pheasants to parasites may have been reduced due to elevated levels of sex hormones and stress associated with the breeding season. Testosterone is known to have a suppressive effect on the immune system of many animals, including birds (Alexander & Simson, 1988). The high levels needed to produce good secondary sexual characteristics are often associated with an individual's lowered ability to control infection (Hillgarth & Wingfield, 1997). On the 'treated' area the anthelmintic may have had both a direct detrimental effect on the parasites themselves, and an indirect boosting effect on the immune response of the host. Acting simultaneously, the result would be a reduction in worm burden in the pheasant, as observed in the pilot study.

Birds used in the parasite uptake trial, although parasite-free, were not naïve birds, hence it is likely they had previously been exposed to infection and had

Table 2. The prevalence (%) and intensity of infection (plot mean ± SE worms bird^{-1}) of *Heterakis gallinarum* and *Capillaria* spp. in pheasants collected on shooting days in December or January in Norfolk, England in treatment and control plots in 2000–2003.

| | *H. gallinarum* | | | | *Capillaria* spp. | | | |
| | Treatment | | Control | | Treatment | | Control | |
	n	Mean	n	Mean	n	Mean	n	Mean
Prevalence of infection (%)								
Baseline phase (2000)	7	79.4 ± 4.0	7	86.6 ± 5.3	7	69.0 ± 5.9	7	54.0 ± 5.8
Experimental phase (2001—2003)	8	86.5 ± 8.1	8	92.0 ± 3.2	8	51.1 ± 7.5	8	49.5 ± 10.1
Intensity of infection								
Baseline phase (2000)	7	14.8 ± 3.0	7	14.1 ± 3.8	7	5.0 ± 0.7	7	5.7 ± 1.5
Experimental phase (2001–2003)	8	25.4 ± 7.7	8	25.3 ± 6.8	8	5.6 ± 1.4	8	6.1 ± 1.1

n = number of plots.

some degree of acquired resistance to parasites (Lund, 1967). Hence, after 30 days exposure it is likely that worm burdens in naïve birds would have been higher than in the birds we used. All parasites found in pheasants would have originated from eggs picked up by pheasants from either the soil or faeces while foraging on the ground or from consuming invertebrates acting as intermediate hosts. All birds were infected with at least one parasite species. The high prevalence of parasites (table 3) demonstrates that pheasants are highly susceptible to infection in areas where they congregate at high densities such as feeding points and in releasing and holding woods. Parasite eggs can remain viable in the soil for several months (Lund, 1960) and it is likely that there is a 'carry over' from one year to the next when birds are released or concentrated in the same locations year on year (Draycott *et al.*, 2000). Burdens of *H. gallinarum* were lower than those reported by Draycott *et al.* (2000), where the average burden was over 80 worms bird^{-1}. Pheasants were culled after 30 days, which is the approximate time for *H. gallinarum* to reach maturity (Tompkins & Hudson, 1999). Considering there is a negligible worm mortality for a further 20 days, (Tompkins & Hudson, 1999) it is likely that the burdens observed in the present study would have been higher if birds had been exposed for a longer period.

Although there were no differences in the prevalence of parasite species between birds in treatment and control plots, the intensity of infection of *H. gallinarum* was lower in birds in the treatment plots (table 3). The present results indicate that this difference was due to a reduction in the environmental worm burden in the treatment plots. This may have been a short-term reduction caused by the spring treatment which had ceased immediately prior to the parasite uptake experiment resulting in fewer fresh active larvae being deposited by pheasants. Alternatively, the annual treatment over the period of the four-year trial could have caused a long-term reduction in environmental worm burdens.

Mean burdens of *H. gallinarum* in pheasants collected during the shooting season (table 2) were higher than those reported by Robertson & Hillgarth (1993) and Woodburn (1999) who reported mean worm burdens of 7.0 and 6.0 per bird respectively. The prevalence and intensity of *H. gallinarum* and *Capillaria* spp. did not differ between treatment and control plots. This is perhaps not surprising considering birds were collected 8–9 months after treatment had ceased. Also, a significant proportion of birds were likely to be juveniles released onto the estate in the summer representing a new potential source of infection.

The mechanism responsible for improved breeding success cannot be identified as no measures were made of clutch size or hatching success of pheasants in treatment and control plots. Newborn & Foster (2002) noted that grouse with reduced worm burdens had a higher breeding success than untreated birds even though

Table 3. The prevalence (%) and intensity of infection (plot mean ± SE worms bird^{-1}) of three nematode species in penned female pheasants in April 2003 in treatment and control plots.

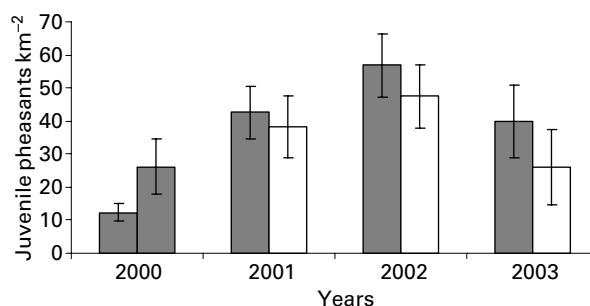| | Treatment | | Control | |
	n	Mean ± SE	n	Mean ± SE
Prevalence of infection (%)				
Heterakis gallinarum	6	98.2 ± 1.9	6	96.5 ± 2.2
Capillaria spp.	6	61.8 ± 4.0	6	57.6 ± 11.2
Syngamus trachea	6	11.9 ± 5.2	6	9.3 ± 4.7
Intensity of infection				
H. gallinarum	6	27.0 ± 8.6	6	40.2 ± 11.5
Capillaria spp.	6	4.7 ± 0.7	6	3.0 ± 0.4
S. trachea	6	1.3 ± 0.3	6	1.2 ± 0.2

n = number of plots.

Fig. 1. Mean ± SE number of juvenile pheasants observed in treatment (■) and control (□) plots in autumn 2000–2003; all plots were treated in 2000.

there were no differences in clutch size or hatching success. They postulated that higher levels of chick survival were due to the improved brood-rearing ability of treated females. It is possible that differences in productivity in the present study are also related to an improved maternal ability or improved survival in the nesting season. Hudson *et al.* (1992) showed that red grouse treated with an anthelmintic were less vulnerable to predation than untreated birds. Similarly, Woodburn (1999) found that treatment with an anthelmintic improved survival of hen pheasants during nesting. Both authors hypothesized that this may be due to reduced scent emission by birds with reduced parasite burdens. In the present study, data on the survival of females during nesting were not collected, although no differences were found in the annual rate of change in the density of females. There were also no differences in the annual rate of change of males or juveniles, implying that treatment did not have a long-term effect on pheasant densities. This is perhaps not surprising considering that there was an annual release of pheasants on the majority of sites and shooting took place on all sites each year.

In conclusion, managed pheasant populations in Britain are subject to levels of infection with helminth parasites that are sufficient to suppress their breeding performance. The present results indicate that the provision of anthelmintic-treated grain in spring can reduce parasite burdens in pheasants to levels that can lead to improved breeding success. However, any benefits conferred by this treatment are likely to be short-term. Therefore, treatment of parasites is likely to be most effective if used in conjunction with other important parasite management strategies such as reducing the densities of birds released, moving the location of woodland release pens every few years and regularly moving feeding stations. Management of parasites in free-living pheasants in order to improve their breeding potential should be undertaken in conjunction with other important game management techniques such as efficient predation control and the provision of suitable nesting and brood rearing habitats (Draycott *et al.*, 2005).

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