Veterinary Parasitology 228 (2016) 1–5

Contents lists available at ScienceDirect

Veterinary Parasitology

journal homepage: www.elsevier.com/locate/vetpar

Research paper

Body condition is negatively associated with infection with *Syngamus trachea* in the ring-necked pheasant (*Phasianus colchicus*)

O.J. Gethings[a,*], R.B. Sage[b], E.R. Morgan[c], S.R. Leather[a]

[a] Department of Crop & Environment Sciences, Harper Adams University, Edgmond, Newport, TF10 8NB, UK
[b] Game & Wildlife Conservation Trust, Burgate Manor, Fordingbridge, SP6 1EF, UK
[c] University of Bristol, School of Veterinary Sciences, Langford House, Langford, North Somerset, BS40 5DU, UK

ARTICLE INFO

Article history:
Received 26 May 2016
Received in revised form 29 July 2016
Accepted 4 August 2016

Keywords:
Phasianus colchicus
Pheasant
Body condition
Gapeworm
Syngamus trachea
Reproduction

ABSTRACT

The role that parasites play in regulating animal populations is debated, however recent research hints at their pervasiveness among free-living animal populations. Parasites exert both direct and indirect effects on host populations, and can act to regulate populations. The Ring-necked pheasant is an important game-bird species in the UK, and large numbers of birds are released annually. The impact of the ubiquitous tracheal nematode, *Syngamus trachea* on pheasant populations through effects on host condition was assessed on two pheasant estates in the south west of England. Pheasants infected with *S. trachea* demonstrated a significant reduction in host condition compared with uninfected controls, with as few as one pair of worms per bird. Although there was no difference in worm burden between sexes, analysis of regression slopes revealed there was a significant difference between sexes in the magnitude of the effect of increasing worm burden on host condition, with detectable effects observed in hosts with one and three pairs of worms for males and females respectively. The observed reductions in host condition in birds with even sub-clinical infections could be the cause of poor reproductive success and survival of pheasants post-release.

1. Introduction

Parasites are well known to play an important role in regulating host population dynamics (Tompkins and Begon, 1999; Irvine et al., 2006; Dunn et al., 2012; Watson, 2013; Granoth-Wilding et al., 2005), although there has been some debate as to the relative importance of predators compared with parasites (Irvine, 2006; Moss and Watson, 2001). Recent research however, has demonstrated that parasites are as, if not more, important than predators in regulating host populations (Watson, 2013). Parasites can have direct impacts on host populations through increases in morbidity and mortality, and they can also indirectly affect host populations through reductions in fecundity (Hudson, 1986; Granoth-Wilding et al., 2005; Dunn et al., 2012). Despite this, very little published research exists on the effects of parasite species on condition and host population dynamics in the ring-necked pheasant. One of the few studies by Draycott et al. (2002) assessed the effects of *Syngamus trachea* and *Heterakis gallinarum* on pheasant populations and concluded that infection with these species did not negatively affect host body condition. One major issue with this study is that body condition was assessed in April, whereas the infectious stages of *S. trachea*, and therefore infection pressure do not reach their peak until around June/July (Gethings et al., 2015). A similar issue was observed by Irvine et al. (2006). Previous studies failed to find any effect of gastrointestinal nematodes on host condition in Reindeer populations in the High Arctic, however Irvine et al. (2006), through the use of delayed-release anthelmintic boluses, demonstrated reductions in host fitness in winter. Reindeer populations were sampled previously when populations were more accessible, which highlights the importance of timing research protocols to account for seasonal dynamics in the transmission of parasites, and therefore any parasite-mediated effects.

Reproductive success of released ring-necked pheasants is generally poor compared with their 'wild' counterparts (Leif, 1994), but it is currently unclear as to why this is the case (Leif, 1994; Draycott et al., 2000; Millán et al., 2002; Draycott et al., 2006; Villanúa et al., 2006). A number of factors such as increased parasitic worm infections and reduced food availability/quality are believed to be major components governing life-history traits in game birds (Hudson et al., 1992). *Syngamus trachea*, for example, is a parasitic-tracheal nematode that commonly affects managed pheasant and poultry populations. Morbidity rates are generally very high, par-

* Corresponding author.
E-mail address: owengethings@hotmail.co.uk (O.J. Gethings).

http://dx.doi.org/10.1016/j.vetpar.2016.08.007
0304-4017/

ticularly when birds are managed under high stocking densities and when proper sanitary measures are not incorporated into management programs (Gethings et al., 2015). There is marked pathology associated with syngamosis (Fernando et al., 1971; Nevarez et al., 2002; Atkinson et al., 2008) and mortality rates of affected birds can be as high as 80% (Wójcik et al., 1999). Experimental infections with *S. trachea* have demonstrated negative associations between larval challenge and weight gain and condition. Hwang (1964) experimentally infected turkey poults with varying numbers of *S. trachea*-infected earthworms to observe their effect on weight gain and packed cell volume (PCV). Significant differences were identified in weight gain between birds infected with an average of 0.2 worms ($n = 10$) compared with an average of 55 worms ($n = 55$), with the heavily infected group gaining an average of 51 g compared with 1482 g for the lightly infected group (Hwang, 1964). This significant effect on weight gain and condition could potentially influence fecundity directly through parasite-mediated competition for resources or indirectly if the host invests more resources into mounting an immune response (Delahay et al., 1995; Shutler et al., 2012). Indeed, Draycott et al. (2006) demonstrated increased breeding success in pheasants treated with Flubendazole, which suggests a possible relationship between fecundity and parasitic infection in the ring-necked pheasant.

Similarly, other studies have demonstrated significant negative parasite-mediated effects on host fitness. Many of these associations are however, correlational, and it is often difficult to disentangle cause and effect in the parasite-host relationship. Tompkins et al. (2000), demonstrated a negative relationship between the caecal nematode *H. gallinarum* and body condition in partridges. More relevant perhaps, is the negative association identified between *H. gallinarum* and body mass, breast muscle mass and cloacal fat in ring-necked pheasants (Sage et al., 2002).

The aim of the present study was to evaluate what effect, if any, significant infections with the nematode, *Syngamus trachea* have on pheasant body condition under natural circumstances.

2. Materials and method

2.1. Study sites

Two pheasant estates were selected in the South West of England due to regular problems with clinical syngamosis, as reported by managers. Site 1 was located approximately at grid reference ST 97502 39837 and consisted of seven release pens. Site 2 was situated approximately at grid reference SU 17769 30326 and similarly consisted of seven release pens. Both sites release ~15,000 birds annually, undertake thorough predator control measures and provide supplementary grain via feed hoppers. Anthelmintic treatment (Flubendazole – at manufacturers dosage recommendations) ceased after birds were released in June 2015. Sites were matched in order to ensure that any effects on body condition would be parasite-mediated and not a result of intra/inter specific competition for food resources or other environmental factors.

2.2. Carcass recovery

One hundred and eighty adult pheasants were recovered following release from June 2015 through April of 2016. Birds were recovered by professional game managers, either as part of crop-protection programs or were shot during the shooting season. Pheasants were either shot whilst flying, or occasionally found dead upon the estate ($n = 4$). Carcasses that had been scavenged were not included in the analysis and recovered birds were examined for non-parasite related disease that could influence the results. Carcasses were processed immediately upon recovery and assessed for the presence of *S. trachea, Ascaridia galli* and *H. gallinarum* by dissection of the trachea, gastrointestinal tract and abdominal cavity and caeca respectively. Other nematode species were recorded but were not differentiated by species, as they were too few in number. In two instances, severely emaciated pheasants with bulbous, fluid-filled intestines consistent with clinical hexamitiasis and confirmed by the presence of motile protozoa on wet slide preparation were recovered. These birds were excluded from the analyses as they were found to be free of nematode infection, but are mentioned in the discussion.

2.3. Worm recovery and body condition assessment

Adult pheasants were weighed to the nearest 0.1 g using a digital weighing scales and tarsal length was measured using a digital calliper with accuracy to 0.01 mm. A body condition index was then obtained by dividing body mass by tarsal length (Yom-Tov, 2001), which controlled for body size.

2.4. Statistical analysis

To determine whether the data were aggregated, adult worm counts were compared with an estimated Poisson distribution ($\mu = \sigma^2$) with n − 1 d.f. using the chi.sq test function in R available in the MASS package. Data were then compared with both an estimated Poisson and a Negative Binomial distribution using the fitdistr function (fitdistrplus package) and goodness of fit was assessed using Maximum Likelihood Estimation using AIC as a determinant. As the number of factors in each model were equal, the model with the lowest AIC score was considered a better fit. All data were analysed using *R* for Macintosh. The effect of parasite burden on host body condition was assessed using ordinary least-squares regression using $\log(n+1)$ transformed parasite count data. Though the inclusion of the four dead-found birds could be a potential confounder, there was no change in model accuracy when they were excluded. Non-constant error variance was assessed using the Breusch-Pagan test and 'ratio' data were transformed to the appropriate power transformation ($y\hat{0}.15$). The transformed data were then assessed for non-constant error variance, which confirmed that the power transformation was successful ($x^2 = 0.54$, $df = 1$, $p = 0.51$). Differences in parasite burden between sexes (including zero counts) were assessed using Welch's *t*-test for unequal samples.

3. Results

3.1. Prevalence of S. trachea—pheasants

Parasite count data were significantly different from the estimated Poisson distribution ($x^2 = 2175$, d.f = 153, $p = < 0.001$) and comparison of models demonstrated the data were aggregated, and consistent with the negative binomial distribution ($x^2 = 4.87$, d.f = 3, $p = 0.18$). The overall prevalence of *S. trachea* within this study population was 33%, with 32% of males ($n = 148$, $n = 48$ infected) and 38% of females ($n = 32$, $n = 12$ infected) being infected with at least 1 pair of worms. Males had a mean (±SEM) worm burden of 3.01 ± 0.54, and females had a mean (±SEM) worm burden of 4.78 ± 1.68, however no significant differences were found between sexes in mean worm burden ($t^{35.78} = -1.26$, $p = 0.21$).

3.2. Effect of S. trachea on body condition

Worm burden and the associated effects on pheasant body condition are presented in Tables 1 and 2. The regression of log parasite burden on body condition revealed a significant inverse