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A preliminary investigation into the endoparasite load of the European hedgehog (*Erinaceus europaeus*) in Ireland

Abstract: The European hedgehog is strictly protected in the Republic of Ireland but has been little studied. Carcasses, such as road kill casualties, can provide valuable information on population demographics, parasite load and general body condition. This study aimed to examine the species of endoparasites present in hedgehogs, their prevalence and intensities and whether differences occurred depending on the age and sex of the hedgehog. Carcasses were collected and examined from around Ireland, over a 3-year period. In 21 of the 23 hedgehogs examined, endoparasites were identified. The nematode species, *Crenosoma triatum* and *Capillaria erinacei* were both positively identified. *C. striatium* was confined to the lungs, whereas *C. erinacei* was the most prevalent (87%) endoparasite and occurred in the stomach and intestines. There was a significantly higher load of *Crenosoma striatum* observed in male hedgehogs compared to females, but no significant difference was observed in the intensity of *C. erinacei* between the sexes. In all tissues, a greater mean endoparasite load was observed in male hedgehogs. Sex differences in exposure or immunity to parasitism could be related to the males' larger home range and the effects of oestrogen levels on immunity.

Keywords: *Capillaria erinacei*; *Crenosoma striatum*; *Erinaceus europaeus*; Ireland; prevalence.

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Introduction

Numerous species of helminths have been described from hedgehogs of several species (Reeve 1994). In the UK, Gaglio et al. (2010) observed that parasite prevalence was 91% in 74 European hedgehogs (*Erinaceus europaeus*, Linnaeus, 1758) obtained from wildlife hospitals, and a total of six helminth species were isolated. The most prevalent parasite was *Crenosoma striatum* (Zeder, 1800) in the lungs, and the most abundant was *Capillaria* spp. in the stomach and small intestine (Gaglio et al. 2010). Similarly, Mayeed et al. (1989) found that, of 35 hedgehogs, 40% had *Crenosoma* only, 14% *Capillaria* only and 46% had both. Boag and Fowler (1988) detected a prevalence of 77% for *C. striatum* and 85% for *C. erinacei* (Rudolphi, 1793), whereas Bunnell (2002) observed that 11% of hedgehogs were infected by *C. striatum*. Pfäffle (2010) revealed that intestinal *Capillaria* spp. infections have a negative effect on body condition, both in the European and New Zealand hedgehog populations, causing a major effect on morbidity and also, potentially, on the survival of their hedgehog hosts, especially in times of increased stress or energy demand, such as the breeding season or hibernation.

The ova and larvae of *Capillaria* may be ingested directly or via the consumption of earthworms (Mayeed et al. 1989). Infection by *Crenosoma striatum* is transmitted via a molluscan intermediate host (Lämmler and Saupe 1968). Therefore, well-fed hedgehogs may accumulate higher parasite burdens, and older individuals, although generally in better condition, may also be more heavily infected with parasites (Gaglio et al. 2010). This may be related to changes in prey selection with age, as Dickman (1988) observed that young hedgehogs sample prey from the entire spectrum of prey types, whereas older hedgehogs specialize in the same narrow range of prey, eating more large prey such as molluscs. The consumption of these intermediate hosts of parasites would therefore make adults more susceptible to infection.

We know that male hedgehogs range further than females (Morris 1969, Reeve 1981, Riber 2006, Haigh 2011), particularly during the breeding season. Therefore they would be expected to come into contact with a greater number of intermediate hosts and have a higher prevalence of endoparasites than females. However, a greater home range has not always been observed to result in a greater endoparasite load (Wilson et al. 2003). In studies by Hillegass et al. (2008), male Cape ground squirrels

(*Xerus inauris*, Zimmerman, 1780) carried three times as many ectoparasites as females, but females harbored nearly three times as many endoparasites as males. We aimed to investigate whether sex differences occurred in hedgehogs.

During a study of the ecology of Irish rural hedgehogs, a number of road-killed hedgehogs were collected. As of yet, there are no data on the helminth fauna of Irish hedgehogs. This study provided the opportunity to examine the presence and prevalence of commonly occurring hedgehog endoparasite species in Ireland. Furthermore, we predict that parasite loads increase with age and that male hedgehogs have a greater parasite load than females.

Materials and methods

During the period of March 2008 to February 2011, 146 hedgehogs were collected from around Ireland. The majority of these carcasses were collected in the southern counties around Cork (67%). A further 31% were collected in the western counties, and 2% were collected in the east of Ireland. Of the carcasses collected, 93% of these carcasses were collected as road kill and so were not all in adequate condition. Therefore, it was not always possible to examine all of the organs for each individual, resulting in differences in sample sizes. Hedgehog carcasses were sexed and weighed using digital scales (Harvard Apparatus, Kent, UK). For 21 of these individuals, age was verified by examination of the periosteal lines of the jaw bone. When the condition of the carcass did not render this adequate (n=2), individuals were considered to be juveniles if they satisfied the following criteria: weight <600 g; hind foot length <3.6 cm, jaw length <4.5 cm, body length <16 cm (Haigh et al. 2013a); and the presence of growing spines.

Lungs were initially preserved in 70% alcohol and investigated by histological methods. However, this proved unsuccessful, and lungs were then treated in the same manner as the intestines and stomach. At the time of dissection, the intestines, stomach and lungs were removed and refrozen until they were processed. Endoparasites were sampled using a direct examination of the gut and lung contents as well as the organs themselves. Sections were obtained from all four regions (top section of cranial lobe, outer section of cranial lobe, longitudinal section of middle lobe and horizontal section of inner middle lobe).

The digestive tracts were defrosted and cut open and divided into stomach (n=17) and intestines (n=22). The stomach, lungs and intestines were washed through a 250-µm and 150-µm sieve. The contents of each sieve were separated and washed using 70% alcohol and placed into sterile labelled containers. The samples were examined using a Nikon SMZ645 stereoscopic microscope and identified using the descriptions of Lapage (1956), Davis and Anderson (1971) and Barutzki et al. (1987).

Data analysis

When means are provided, they are followed by the ± standard error (SE), unless otherwise stated. Tests for normality were performed using the Brodgar software package, version 2.6.3, for univariate and multivariate analysis and multivariate time series analysis. PASW Statistics, version 17 was used for all further statistical analysis.

Results

The lungs, stomach and intestines were examined in 23 individuals (10♀, 13♂) (16 adults and 7 juveniles). *Crenosoma striatum* and *Capillaria erinacei* were both positively identified. Male hedgehogs had significantly higher *C. striatum* counts than females (t=1.19, df=21, p=0.023). There was no significant difference between the sexes in the case of *C. erinacei* (t=0.436, df=21, p=0.164). In all cases, the mean number of each helminth species per organ was higher in males than in females (Table 1). With the exception of *C. erinacei* in 1-year-old females, *C. erinacei* and *C. striatum* numbers were higher in males than in females among all age classes (Figures 1 and 2).

Although *Crenosoma striatum* was confined to the lungs, *Capillaria erinacei* was the most prevalent

Table 1 The mean (±SE) number of endoparasites observed in each sex and tissue.

Tissue	*Crenosoma striatum*	*Capillaria erinacei*	*Capillaria erinacei*
	Lungs	Stomach	Intestines
Females (mean±SE)	4±1.03 (n=2)	6.78±0.30 (n=9)	2.13±0.16 (n=9)
Males (mean±SE)	16.4±0.98 (n=5)	23.5±0.75 (n=8)	6.8±0.26 (n=13)

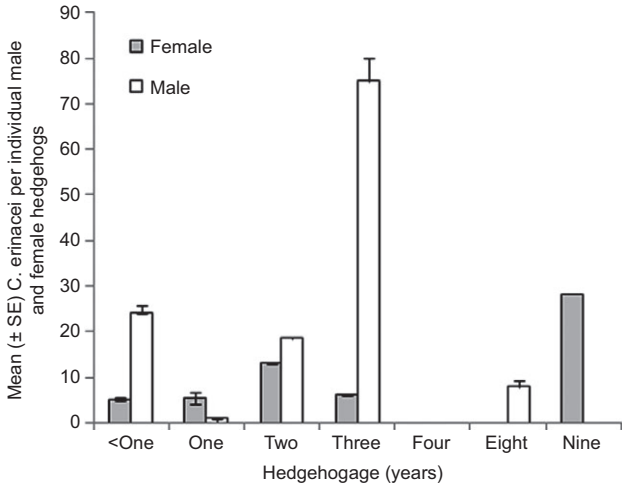

Figure 1 The mean (±SE) number of *Capillaria erinacei* per individual male and female hedgehogs that were aged using the dentary bone.

endoparasite with prevalences of 88% in the stomach and 86% in the intestines (Table 2). In only two cases (adult ♂) were no parasites were found, whereas 158 *C. erinacei* were found in the stomach and intestines of one adult male.

Of 17 stomachs examined, *Capillaria erinacei* was found in all but two hedgehogs, with a mean of 16.6 (±0.30) per individual (Table 2). In 22 intestines examined, *C. erinacei* was found in all but three. Seven lungs were examined, and *Crenosoma striatum* was found in all of them, with a maximum of 59 in one adult male (Table 2).

There was no significant correlation between the parasite load and the age of the individual hedgehog (Spearman rank: R_s=0.120, n=21, p>0.05). The greatest number of *Capillaria erinacei* were observed in males (n=2) who had survived three hibernations (Figure 1). The highest number of *Crenosoma striatum* were detected in males (n=2) who had survived two hibernations (Figure 2).

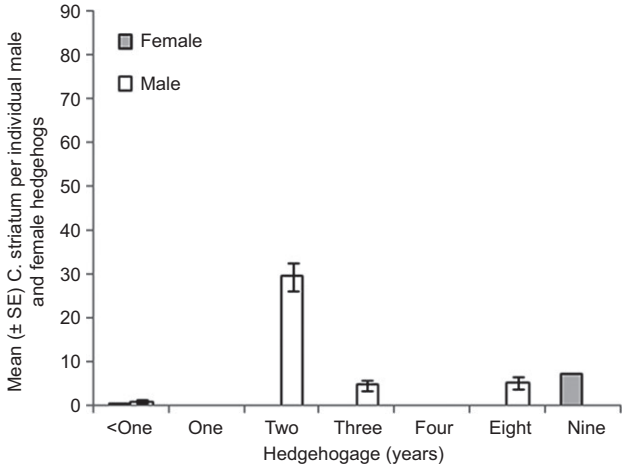

Figure 2 The mean (±SE) number of *Crenosoma striatum* per individual male and female hedgehogs that were aged using the dentary bone.

Discussion

The majority of hedgehogs (n=21) (91%) harbored helminth parasites. This is consistent with the findings of other studies (Boag and Fowler 1988, Mayeed et al. 1989, Gaglio et al. 2010). Although five species of nematode and one trematode were discovered in the Gaglio et al. (2010) study, the presence of only two species of nematode and no trematodes were recorded in the present study.

Hedgehogs in Ireland have been observed to respond to fluctuations in mollusc (a host of *Crenosoma striatum*) numbers, with corresponding shifts in habitat use (Haigh 2011). Obrtel and Holisova (1981) and Wroot (1984) found a clear tendency for hedgehogs to concentrate on a single type of prey at a time and to switch from one prey group to another according to season; therefore, the risk of infection may change seasonally. Dickman (1988) observed that older hedgehogs ate more molluscs, and if this age-related dietary change occurred, it would be expected that older hedgehogs may be more susceptible to infection. There was no significant variation between the age and parasite load of hedgehogs observed in the present study. However, this may be related to the small sample size.

There was no significant sex difference in endoparasite intensity loads in the research of Mayeed et al. (1989) on hedgehogs. However, in the present study, males had a significantly higher intensity of *Crenosoma striatum* than females. Although it was not significant, males also had a greater mean number of *Capillaria erinacei* in the intestines and stomach than females. Bordes et al. (2012) observed in wood mice that, although helminth infection did not differ between the two sexes, females seemed to invest more in immune defense, with increasing risk of parasite diversity, but were potentially more tolerant of parasitic diversity. Similarly, Ponlet et al. (2011) found that female spleen mass in rodents is significantly influenced by the specific species richness of parasites, whereas male spleen mass is influenced by individual mean parasite diversity indices. Equally, the observed differences in this study may represent different immune strategies of male and female hedgehogs. The difference may also be due to the fact that male hedgehogs have a much larger home range than females (Reeve 1981, Kristiansson 1984, Riber 2006, Haigh 2011) and could therefore be expected to have a greater opportunity to become infected, as

Table 2 The occurrence of endoparasites in hedgehogs collected as road kill.

Tissue	*Crenosoma striatum*	*Capillaria erinacei*	*Capillaria erinacei*
	Lungs	Stomach	Intestines
No. of tissues in which parasites were observed	7/7	15/17	19/22
Prevalence (%)	100	88	86
Total	90	249	116
Mean (±SE) abundance	12.8(±0.27)	16.6(±0.30)	5.3(±0.14)
Range	0–59	0–109	0–40

they forage over a wider area than females (Haigh 2011). Hillegass et al. (2008) observed that, in the Cape ground squirrel, females had a greater endoparasite load that they attributed to females having a smaller home range and so a greater opportunity to be re-infected. This may be related to the highly social nature of the Cape ground squirrel, which is not evident among the predominantly solitary hedgehog. Although the home range of adult male hedgehogs overlapped completely and encompassed that of all adult females, females showed little overlap and occupied mutually exclusive areas (Haigh et al. 2013b). This may therefore have increased infection rates in male hedgehogs. Wilson et al. (2003) found that there was no relationship between the mean home range size and parasite prevalence amongst mammals. Schalk and Forbes (1997) observed that a male bias in parasite load was only evident in adult mammals, something that was thought to be due to the fact that oestrogens stimulate immunity, whereas androgens depress immunity.

Hedgehogs are polygynous, and individual males make mating attempts with several females, in some cases during the same night (Kristiansson 1984, Haigh et al. 2012). Zuk and McKean (1996) reported that sex differences in parasite loads were greater in polygynous species, as they are subject to greater sexual selection than monogamous species and the development of secondary sexual characteristics, often characteristic of males with a polygynous mating strategy, are testosterone-dependent. Females had a longer lifespan than males (Haigh et al. 2013a), which may also be a reflection of the males' polygynous mating strategy and larger home range. It is suggested that the larger home range of males and their polygynous mating strategy may also account for the higher endoparasite load observed in male hedgehogs. Further work with a larger sample size of juveniles would be required to explore age variations to a greater extent.

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