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Ectoparasite ticks and chewing lice of red-legged partridge, *Alectoris rufa*, in Spain

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Abstract. During the 1992–1993 and 1993–1994 shooting seasons, 212 wild red-legged partridge, *Alectoris rufa* (Galliformes: Phaisanide) were captured in 18 Spanish provinces and examined for chewing lice and ticks. Three tick species and six species of chewing lice were found. Ticks (Acari: Ixodidae) *Haemaphysalis punctata* Canestrini & Fanzago, *Hyalomma lusitanicum* Koch and *Ixodes frontalis* Panzer were found at the lowest prevalence (1.4% overall tick prevalence). The louse (Mallophaga) species, *Goniodes dispar* Burmeister (Goniodidae) (52.8%) and *Cuclotogaster obscurior* Hopkins (Philopteridae) (28.8%) were the most prevalent, while *Goniocotes obscurus* Giebel (Philopteridae) (10.8%), *Menopon pallens* Clay (Menoponidae) (7.5%) and *Menacanthus lyali* Rodriguez *et al.* (Menoponidae) (3.3%) were found at medium to low prevalence. *Columbicola columbae columbae* Linnaeus (Philopteridae) was found at the lowest prevalence (0.5%). The intensity of *C. obscurior* and overall intensity of all lice species were directly related to the environmental mean temperature and the Normalized Difference Vegetation Index (NDVI), whereas intensity of *G. dispar* was directly related to NDVI only. The intensity of *G. dispar*, *C. obscurior*, all louse intensity, and louse species richness were higher in male than female birds. Intensity of each louse species, all louse intensity and louse species richness were inversely associated with the nutritional index. No relationship was observed between bird age and louse intensity or species richness.

Key words. *Alectoris rufa*, Ixodidae, Mallophaga, bird, chewing lice, ectoparasite, tick, Spain.

Introduction

The red-legged partridge (*Alectoris rufa*) is the most important game bird in Spain, with an estimated three million birds of this species being hunted each year throughout the country according to The Ministry of Agriculture, Fisheries and Food. However, the population of this species in the wild has been in continuous decline for several years. Wildlife managers have suggested that this decline can be partly attributed to an increase in the prevalence of parasitic diseases as a result of widespread restocking of the wild population with birds reared on game farms.

Breeding facilities vary considerably among game farms and there are no strict veterinary controls governing hygiene. As a result, gamebirds can be released in poor sanitary condition and may act as parasite vectors or reservoirs of disease (Tompkins *et al.*, 1999). The impact of parasitic diseases on wild red-legged partridge populations is one of the principal focuses of research in Spain (Tarazona *et al.*, 1978; Illescas & Gomez, 1987). The aim of the survey reported here was therefore to carry out the first study of the natural ectoparasitism of chewing lice and ticks in wild red-legged partridge in Spain, and the factors that influence the intensity and distribution of these ectoparasites.

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Materials and methods

Birds were captured by hunters during the shooting seasons (October–January) of 1992–1993 and 1993–1994. A total of 212 partridges from 54 locations spread across 18 Spanish provinces were collected (Fig. 1). Birds were collected immediately after being killed by hunters, sealed in individual plastic bags, frozen, and transferred to the Department of Animal Pathology of Zaragoza University for parasitological examination. In the laboratory, carcasses were weighed on a 500 g Pesola™ precision scale, and left tarsus length was measured using calipers (±0.01 mm). Birds were dissected and sexed by gonadal inspection (51.9% female; 48.1% male). Age classification (4–7 months old and older than one year) was performed by plumage analysis (Calderón, 1983) and indicated that 84.4% of birds were older than one year. All traits were assessed by the same person to avoid introducing systematic errors into the data set.

Prior to dissection, in a first step, chewing lice were removed by thoroughly brushing all of the plumage onto white paper for 2 min. In a second step, the skin and plumage were then inspected visually for 3 min, while gently blowing the feathers. In this inspection, ticks and remaining lice were removed with forceps. All of the collected ectoparasites were stored in 70% ethanol and subsequently the species of each specimen was identified.

An index of nutritional status was calculated as the residual of a linear regression of $\log_{10}$-transformed body mass on $\log_{10}$-transformed tarsus length ($R^2 = 0.18$; $P < 0.001$, d.f. = 210). This index is a measure of relative body mass corrected for differences in structural body size, and has been used in several bird species (Johnson *et al.*, 1985; Blem, 1990). Nevertheless, this index covaried with age class and year, so the effects of these factors were removed by means of an ANCOVA ($R^2 = 0.45$; $P < 0.001$; d.f. = 207) and the residuals used as an index independent of age and year.

Each of the 54 localities included in the survey was characterized by means of two bioclimatic indexes: yearly mean temperature on the soil surface and yearly mean NDVI (Normalized Difference Vegetation Index), which is directly correlated to environmental humidity (Tucker *et al.*, 1981). These data were obtained from time series data on land applications, remotely sensed by the Advanced Very High Resolution Radiometer (AVHRR) of the National Oceanic and Atmospheric Administration (NOAA) (Kidwell, 1991).

The variation of intensity of ectoparasites across habitat variables delineated by host age, sex, index of nutritional status and bioclimatic parameters of each locality was tested using Generalized Linear Models (GzLM) of factorial regressions. Interactions of second grade between all predictor variables were introduced in the initial model, and a backward elimination procedure was used to obtain the final model. The analyses were performed by means of the empirical estimation of a negative binomial error based on Poisson errors (Wilson & Grenfell, 1997) and controlling the effects of the year. Tests were carried out for intensity of each louse species, all louse intensity and number of louse species found in every infected host.

Parasitological terms are used following the recommendations of the *ad hoc* committee of the American Society of Parasitologists (Margolis *et al.*, 1982).

Results

The ectoparasites found on the collected partridges comprised three tick species and six species of chewing lice

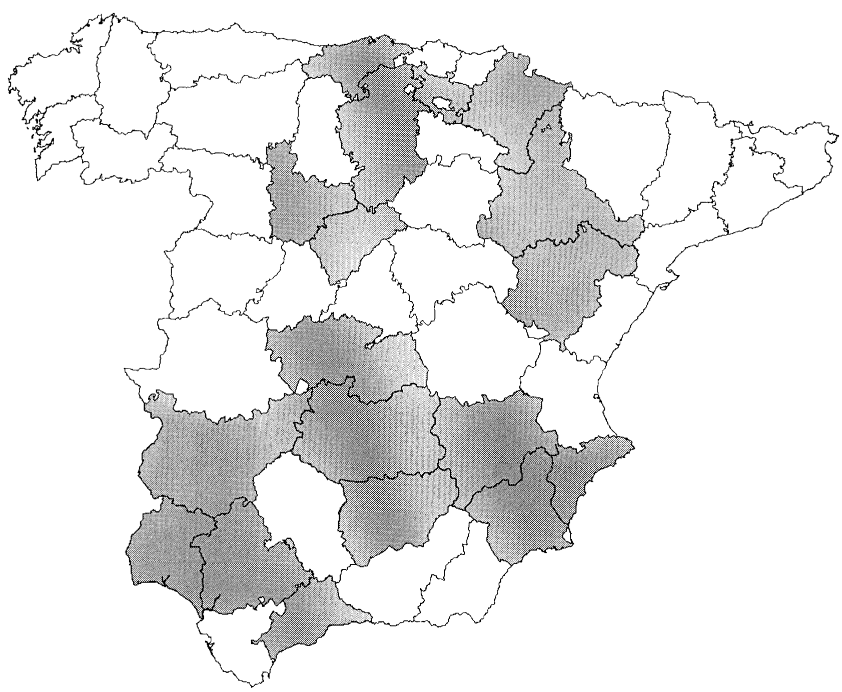

Fig. 1. Provinces of Spain (in grey) where wild red partridge populations were sampled.

(Table 1). Total prevalence (1.4%) and intensity of ticks were very low, because each tick species (*Haemaphysalis punctata* Canestrini & Fanzago, *Hyalomma lusitanicum* Koch and *Ixodes frontalis* Panzer) was represented by only a single specimen and each of these specimens was found on a different partridge. Hence, no further analysis of the ticks was performed.

The lice assemblage consisted of six species of chewing lice (Mallophaga): *Goniodes dispar* Burmeister, *Cuclotogaster obscurior* Hopkins, *Menacanthus lyali* Rodriguez *et al.*, *Goniocotes obscurus* Giebel, *Menopon pallens* Clay and *Columbicola columbae columbae* Linnaeus. Approximately 58% of birds were parasitized by at least one louse species, with the highest intensity of infestation on a single bird being 203 lice.

Goniodes dispar showed the highest prevalence and abundance, whereas *M. lyali* showed the highest intensity of infestation, with 119 lice counted on one bird (Table 1). *Cuclotogaster obscurior* was found with the second highest prevalence and abundance, whereas *G. obscurus* and *M. pallens* were found at medium values. *Columbicola columbae columbae* was represented in the assemblage by only one specimen.

The final regression models fitted to louse intensity variation (Table 2) showed that the intensity of each louse species and the intensity of all lice were inversely correlated to the nutritional index of the birds. Sex was also a factor associated with louse intensity variation. Male birds had higher intensities of *G. dispar* and *C. obscurior*, and displayed higher overall louse burdens.

Other factors external to the host were related to louse intensity. The intensity of *C. obscurior* infestation and the intensity of infestation by all lice were directly associated with mean temperature, NDVI and their interaction, whereas the intensity of *G. dispar* depended only on NDVI.

Species richness did not vary across physiographical variables, but did vary across host-dependent variables with trends similar to those observed for intensity. This dependence on host-dependent variables arises because male birds and birds with a lower nutritional index were parasitized by a higher number of louse species. Age or interactions between host-dependent factors were not related to the variation of intensity or species richness of lice.

Discussion

All but one of the ectoparasite species found in this survey are known parasites of red-legged partridges in the Iberian Peninsula. The exception is the chewing louse *C. columbae columbae*, which is a specific parasite of pigeons. The presence of this species may be due to natural infestation or, more probably, to accidental contamination from pigeons or restocked partridges. Artificial contamination from other bird species during hunting and storing dead birds was not possible, because carcasses of sampled partridges were sealed in plastic bags a few minutes after they were hunted.

Chewing lice are obligate ectoparasites of birds that complete their entire life-cycle on the body of the host. However, the frequency and mechanisms of dispersal of chewing lice are poorly understood because they can move between individual hosts in several ways: (1) through direct contact of birds or through birds using the same nest or resting place (horizontal transmission) (Darolova *et al.*, 2001), (2) during parental care (vertical transmission) (Murray, 1963) and (3) by phoresy (Keirans, 1975).

Phoresy can be discounted for red-legged partridge because no flies or any other more mobile ectoparasite were detected in this survey. However, little can be inferred from the present results about the mechanisms of lice transmission between partridges. Some authors argue that the transmission of lice to new hosts is largely vertical, from parents to offspring in the nest (Clayton & Tompkins, 1995; Lee & Clayton, 1995), whereas other studies have shown that the transmission in nestling species is horizontal (Hoi *et al.*, 1998; Darolova *et al.*, 2001). Other factors that influence lice transmission are the suitability of a host species, and microhabitat traits on the host such as temperature, humidity and barb diameter of the feathers (Tompkins & Clayton, 1999; Latta & O'Connor, 2001). Although chicks of red-legged partridge leave the nest

Table 1. Prevalence, abundance (±SE) and intensity range of ticks and lice inhabiting the wild red-legged partridges.

	Prevalence (%)	Mean abundance ± SE per bird	Intensity
Ticks			
Haemaphysalis punctata	0.47	0.005 ± 0.005	1
Hyalomma lusitanicum	0.47	0.005 ± 0.005	1
Ixodes frontalis	0.47	0.005 ± 0.005	1
Overall ticks	1.41	0.014 ± 0.008	1
Lice			
Goniodes dispar	52.83	3.87 ± 0.75	1–105
Cuclotogaster obscurior	28.77	1.2 ± 0.26	1–40
Menacanthus lyali	3.3	0.63 ± 0.56	1–119
Goniocotes obscurus	10.85	0.2 ± 0.05	1–8
Menopon pallens	7.55	0.12 ± 0.03	1–4
Columbicola columbae columbae	0.47	0.014 ± 0.008	1
Overall lice	58.02	6.02 ± 1.3	1–203

Table 2. Regression parameters (±SE) and *P*-values of habitat variables (host age, sex and nutritional index and bioclimatic parameters of each locality) significantly associated with variation of intensity of any louse species, overall species and species richness of lice. Host age did not show any significant association, thus it was not included in the table.

	Temperature	NDVI	Temperature × NDVI	Sex	Nutritional index
Goniodes dispar		5.06 ± 1.51		0.81 ± 0.22	−0.78 ± 0.07
	NS	$P < 0.001$	NS	$P < 0.001$	$P < 0.001$
Cuclotogaster obscurior	0.9 ± 0.33	43.72 ± 19.17	2.17 ± 1.08	1.1 ± 0.34	−0.72 ± 0.11
	$P = 0.006$	$P = 0.023$	$P = 0.045$	$P = 0.001$	$P < 0.001$
Menacanthus lyali					−1.61 ± 0.7
	NS	NS	NS	NS	$P = 0.021$
Goniocotes obscurus					−0.56 ± 0.15
	NS	NS	NS	NS	$P < 0.001$
Menopon pallens					−0.67 ± 0.23
	NS	NS	NS	NS	$P = 0.004$
Overall louse intensity	0.51 ± 0.2	28.34 ± 11.9	−1.38 ± 0.69	0.96 ± 0.21	−0.81 ± 0.06
	$P = 0.012$	$P = 0.017$	$P = 0.046$	$P < 0.001$	$P < 0.001$
Species richness				0.2 ± 0.08	− 0.1 ± 0.04
	NS	NS	NS	$P = 0.016$	$P = 0.006$

NS: non-significant association.

a few minutes after hatching, our results suggest that transmission of lice is largely vertical, while family groups remain in their respective breeding areas, and young are acquiring their definitive first adult plumage from the second to the fourth month of age (Clayton & Tompkins, 1995). This hypothesis is supported by the fact that no differences were observed in louse intensity between age classes, although this lack of difference could be due to the small number of young sampled, or to a quick infestation of young from parasitized birds in the winter flocks (Darolova *et al.*, 2001). Winter flocks are formed about four weeks before the start of shooting period, when family groups from adjoining breeding areas join in early autumn.

Mean temperature and NDVI, which is highly correlated with environmental humidity, were associated with louse intensity. Latta & O'Connor (2001) showed that the intensity of a mite species was controlled by specific ecological conditions (e.g. rainfall or humidity), which affected transmission of the mite. Most species of lice depend on the warm, humid conditions near the skin of the host and are unable to survive off the host for more than a few days or hours (Tompkins & Clayton, 1999). Wiles *et al.* (2000) found that changes in the distribution of mites on the wings of the host were driven by microclimatic changes due in part to environmental temperature and humidity. It is therefore possible that both the reproduction traits of lice and their transmission among partridges could be enhanced by higher temperature and/or humidity, because these environmental factors could increase the transmission rate of lice directly from host to host or enhance the survival chances and active dispersal of lice off the host, thereby increasing the infection probability during the use of communal resting or sand-bathing places.

Differences in ectoparasitism, both in intensity of infestation and negative impact on physiological condition between sexes, and the effects of these differences on sexual selection, have been described for other bird species (Kose & Moller, 1999; Kose *et al.*, 1999; Blanco *et al.*, 2001). Nevertheless, no statistically significant association of louse intensity with interaction between sex and nutritional index was found in the present survey. Only higher louse intensity and louse species richness was found in males than in females, but the small degree of sexual dimorphism in red-legged partridges in regard to plumage and body size suggests that the higher louse loads found in males were not due to sexual morphological differences.

Bird lice can have a negative impact on host fitness at high infestation levels (Booth *et al.*, 1993) and ectoparasite infestation costs the bird at least the time spent grooming, which has been shown to depend on parasite load (Clayton, 1991). However, chewing lice are considered to have a low negative impact on their host (Tompkins *et al.*, 1996; Quek *et al.*, 1999; Blanco *et al.*, 2001) and the intensity of their infestations are secondary to the deterioration of host performance caused by disease, poor nutrition or senescence (Moller & De Lope, 1999).

Given that the time devoted to feather cleaning through self-preening, grooming or anting is likely to be important for parasite population regulation (Clayton, 1991; Figuerola, 2000), the higher louse loads (both in terms of intensity and species richness) found in the present survey in males and in birds with lower nutritional index values could be related to behavioural traits. This would explain why male birds, which display greater territorial and competitive behaviour than females, and birds with low values of the nutritional index, due to their poor physiological condition, potentially devote less time to self-maintenance and are parasitized to a greater extent.

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