

PREVALENCE AND INTENSITY OF INTESTINAL  
PARASITATION IN A WILD POPULATION OF NESTLING  
EURASIAN KESTREL *FALCO TINNUNCULUS*

PREVALENCIA E INTENSIDAD DE PARASITACIÓN  
EN UNA POBLACIÓN SILVESTRE DE VOLANTONES DE  
CERNÍCALO VULGAR *FALCO TINNUNCULUS*

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Parasites are strong evolutionary forces as they often reduce the host's fitness (Clayton and Moore, 1997; Rigby and Moret, 2000) and the impact of parasites on host reproduction and survival has been demonstrated in different studies (Merino and Potti, 1995; Richner *et al.*, 1995; Nordling *et al.*, 1998; Stjernman *et al.*, 2004). Parasites can also influence maternal allocation (Tschirren *et al.*, 2005) or maternal effort could mediate the parasite abundance in nestlings (Merino *et al.*, 1996), suggesting that parasites can affect individual quality and hence, the quality of the offsprings.

However, studies of host-parasite relationships in wild birds have been mainly limited to blood parasites or ectoparasites (e.g., Merino and Potti, 1995; Korpimäki *et al.*, 1995; Dawson and Bortolotti, 1997; Wiehn *et al.*, 1997; Fitze *et al.*, 2004; Scheuerlein and Ricklefs, 2004). Nonetheless, different studies have suggested that intestinal parasites could have a strong influence on their host's healthiness and physiology (Hõrak *et al.*, 2000; Brawner *et al.*, 2000; McGraw and Hill, 2000; Hõrak *et al.*, 2004). For example, it has been shown that coccidian parasites may constrain carotenoid ab-

sorption (Hõrak *et al.*, 2004), a lipid-soluble hydrocarbon and powerful immunostimulant and antioxidant (Blount *et al.*, 2000; Blount *et al.*, 2003). Carotenoids are also widely used by animals as red and yellow pigments shown in feathers and fleshy ornaments (Olson and Owens, 1998; Møller *et al.*, 2000), being one of the most familiar criteria for mate choice (Hill and McGraw, 2006). Thus, among intestinal parasites the association between coccidian intestinal parasites and their avian hosts in wild conditions seems especially promising. Coccidians (Protozoa, Apicomplexa) infect a number of passerine species (Giacomo *et al.*, 1997; McGraw and Hill, 2000). Yet it is well established that wild raptors are host to a wide range of parasite species including coccidian parasites and can exhibit very high levels of infection (Krone, 2002). Most studies on raptors have been carried out in captive birds (Upton *et al.*, 1990; Forbes and Simpson, 1997; although see Krone, 2002), but not in wild birds and less in nestlings where environmental conditions at nestling period are crucial for future survival and development of birds (Metcalfe and Monaghan, 2001). It has been also described

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a sex-dependent likelihood of parasitism in hosts (Potti and Merino 1996), and thus nestling sex was also considered to describe potential parasitism between male and female nestlings.

This study investigates the relationship between Eurasian kestrel (*Falco tinnunculus*) chick growth and the abundance, prevalence and intensity of intestinal coccidiosis by *Caryospora* sp. in two successive years.

The study was carried out in Campo Azávaro region, a mountain grassland in central Spain, during kestrel breeding season in 2001 and 2002. In the study area, kestrels breed in nest-boxes provided (see Fargallo *et al.*, 2001, for more details). Kestrel pairs were monitored to record clutch size, laying date and brood size. As part of other studies carried out at that time, hatching dates of the nestlings were obtained (see for more details Blanco *et al.*, 2003). At the day of hatching, hatchlings were weighed to the nearest 0.25 g. Wing length (nestling size) to the nearest mm and body mass to the nearest 0.5 g were recorded at 25 days of age. Nestling growth was considered as the difference between hatching and nestling mass. Nestling sex was determined by molecular procedures (Fridolfsson and Ellegren, 1999) from a drop of blood. On the same visit faecal samples were collected by placing each chick on clean, single-use cotton square while the other siblings of the brood were measured. It has been shown daily variation in shedding of coccidial oocysts has been described (Brawner and Hill, 1999; Misof, 2004), so we recorded the hour in which each faecal sample was collected. Faecal samples were kept in a field refrigerator and analysed within the next 7 days after collection by the zinc sulphate flotation technique and counted in a MacMaster chamber. The same observer (JM) performed all analyses. Oocyst concentration was expressed as oocysts / g of faecal fresh mass. Propagules were identified following Melhorn *et al.* (1992).

Three Generalized Linear Mixed Models (GLMMIX) were performed in SAS software

to assess variation prevalence (presence *vs.* absence), intensity and abundance of infection. In the first model, binomial error structure and a logit link function were used and the second and third models were fitted to a Poisson distribution of errors and log function. As potential explanatory variables, year and nestling sex (factors), laying date, nestling mass, size and growth (continuous) were included. The "hour of sampling" was also considered in order to control for potential bias in oocysts excretion during the day. This variable was coded into three equal periods according to the overall range of variation of the two years (1 or morning: from 8:30 to 12:30; 2 or mid-day: from 12:30 to 17:00; 3 or evening: from 17:00 to 20:55), following Martínez-Padilla (2006). Only nests that were occupied by kestrels one of each year were included. To examine the variation of nestling growth in relation to parasites, General Linear Mixed Models (GLMM) were used in which nestling growth was included as response variable and the rest of variables described above as explanatory variables. In both GLMM and GLMMIX models, 'nest' was considered as random term to overcome the problem of pseudoreplication due to used chicks within broods and including all the interactions between the variables considered. In each model, some of the explanatory variables may co-vary, so they were fitted to the observed data following a forward stepwise procedure. The significance of the remaining variables was tested again until no additional variable or interaction reached significance.

Faeces from 71 kestrel chicks ( $n = 24$  in 2001;  $n = 47$  in 2002) from 41 different nests ( $n = 15$  in 2001;  $n = 26$  in 2002) from a total population of 117 nestlings (60.7 %) were analysed. *Caryospora* sp. oocysts were found in 42 nestlings (59.2 %) of the faecal samples. Mean abundance of *Caryospora* sp. oocysts was 2991.3 oocysts / g of faecal fresh mass (range 0 to 23646), and mean of intensity was 5168.3 (range 27 to 23646).

TABLE 1

GLIMMIX models with prevalence (presence vs. absence), abundance and intensity of parasitation in Eurasian kestrel nestlings. Negative binomial error and log link function were used when prevalence was analysed and Poisson error and log function were used when intensity and abundance of *Caryospora* infection was analysed. Other potentially influencing interactions between the variables were not significant ( $P > 0.345$ ).

[Modelo GLIMMIX con la prevalencia (presencia vs. ausencia), abundancia e intensidad de parasitación en los volatones de cernícalo vulgar como variables dependientes. Para la prevalencia se usó una distribución binomial negativa para los errores y una función “log-link”. Para la intensidad y abundancia de *Caryospora* se usó una distribución de Poisson para los errores y una función log. Las interacciones no mostradas fueron no significativas ( $P > 0.345$ ).]

Response term	Explanatory term	Rejected term	F	df	P
Prevalence		Nestling mass	1.03	1,38	0.315
		Year	1.37	1,37	0.249
		Laying date	0.64	1,36	0.427
		Nestling size	0.35	1,35	0.540
		Nestling sex	0.24	1,33	0.630
		Nestling growth	0.25	1.32	0.623
Intensity	Year		5.24	1,19	0.001
		Nestling growth	3.51	1,18	0.067
		Nestling sex	3.40	1,17	0.080
		Laying date	2.99	1,16	0.110
		Nestling mass	1.10	1,15	0.312
		Nestling size	1.08	1,14	0.395
Abundance	Year		20.2	1,38.0	0.002
		Nestling sex	3.32	1,33.6	0.086
		Nestling mass	1.87	1,33.7	0.141
		Laying date	0.52	1,34.0	0.473
		Nestling growth	0.25	1,28.4	0.620
		Nestling size	0.03	1,29.4	0.870

Neither prevalence, abundance nor intensity of infection were affected by the time of the day the faeces were sampled (GLMMIX, all  $P > 0.624$ ). Thus, time of the day was not considered in analyses. Any of the explanatory variables considered were related to the prevalence of coccidia infection (Table 1). Only year was related to intensity and abundance of *Caryospora* infection (Table 1). Intensity and

abundance were higher in 2002 (intensity:  $4286.2 \pm 6806.9$ ; abundance:  $7006.05 \pm 1538.7$ ) than in 2001 (intensity:  $455.6 \pm 849.1$ , abundance:  $1032.07 \pm 2479.7$ ).

Growth was lower in the year of higher prevalence (GLMM, interaction year\*prevalence,  $F_{1,24} = 5.32$ ,  $P = 0.03$ , all other variables and interactions,  $P > 0.12$ ; Fig. 1). In 2002, infected birds grew significantly more

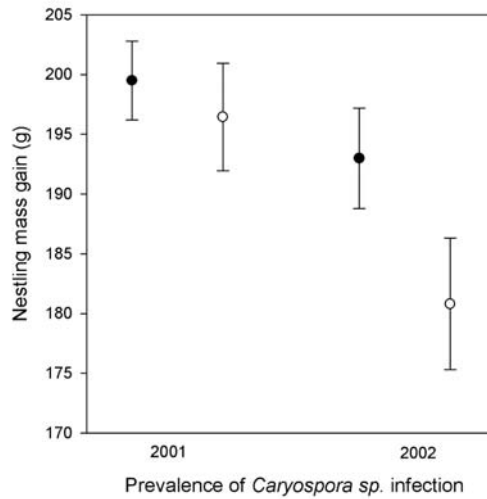


FIG. 1.—Mean  $\pm$  SE of nestling growth in relation to prevalence of *Caryospora* sp. infection in wild Eurasian kestrels. Filled and empty circles denote uninfected and infected birds respectively.

[Crecimiento de los pollos de *Cernicalo vulgar* (media  $\pm$  ES) en relación a la prevalencia de *Caryospora* sp. en la población estudiada. Círculos vacíos y rellenos representan las aves infectadas o no, respectivamente.]

than uninfected ones (GLMM,  $F_{1,10} = 2.24$ ,  $P = 0.01$ ; Fig. 1) but they did not so in 2001 (GLMM,  $F_{1,18} = 5.32$ ,  $P = 0.170$ ).

This is the first study to investigate intestinal parasitism on wild and living raptor nestlings. *Caryospora* was prevalent in about 60 % of kestrel nestlings. Sex-dependent parasite infection was not found, suggesting that at least with coccidian parasites and under this level of prevalence male and female nestling are equally prone to be infected. Neither was there an effect of the time of sampling with oocyst excretion of coccidian found, as previously reported (Brawner and Hill, 1999; Misof, 2004). This result is unexpected and it is speculated that the relationship between parasites and hosts may be altered in nestling birds (Clayton and Moore, 1997). In addition, and only few studies have described daily variation in coccidia oocysts excretion, combined with non-determination of the species of coccidia in this study, a different life cycle in those parasite species

that infect kestrel nestlings might also be suggested. These results may encourage future work about the mechanisms of transmission of intestinal parasites in wild nestling birds.

The lack of relationship between nestling growth and prevalence of *Caryospora* infection in the year when abundance was lower suggests that lower levels of *Caryospora* may not have detectable effects on birds, at least in the considered variables. In other studies of similar host-parasite relationships, parasites may not produce clinical disease unless the host is highly infected or stressed (Oppliger *et al.*, 1996; Oppliger *et al.*, 1998). So, in years of low prevalence, kestrels may cope with basal levels of coccidia infection. However, this relationship appears to be year-dependent, altering the stability of the parasite-host interactions in this kestrel population. The results suggest that the intensity of infection was related negatively to nestling growth only when abundance was higher. A tentative explanation

might be that parasited nestlings might allocate resources to fight against infection, suffering a decreasing in their growth rate (Merino *et al.*, 2000). Alternatively, food shortage may have affected both the growth of chicks and the capacity to keep their coccidian infections under control. However, this is a descriptive study and it is not possible to suggest reliable conclusions

Common voles (*Microtus arvalis*) might act as a paratenic host of coccidian parasites (Volf *et al.*, 2001). This prey represents about 35 % of the total prey biomass captured by kestrels in the study area (Bonald *et al.*, *unpubl. data*). It has been also suggested that Mediterranean lizards (*Lacerta lepida*) can be infected by coccidian parasites (Amo *et al.*, 2005) and they represent 30 % of the kestrel diet in this study area (Fargallo, 1999). Thus, prevalence of intestinal parasites in voles and lizards as their importance as paratenic host of these parasites in wild birds could be a key factor in understanding the variation in coccidian infection in kestrels. Thus, this potential effect may encourage future work on the effects of coccidian parasites on signalling and physiology in wild nestling birds.

**RESUMEN.**—*En este trabajo se estudia el posible efecto de la abundancia, prevalencia e intensidad de coccidiosis por Caryospora sp sobre el crecimiento de los pollos de cernícalo vulgar (Falco tinnunculus). Para ello, se realizó un estudio durante dos años en Campo Azávaro (Segovia). Caryospora presentó una prevalencia de un 60 % en los volantones de cernícalo vulgar. La prevalencia no fue diferente entre machos y hembras de esta especie. Los resultados muestran que la intensidad de infección por coccidios estaba negativamente relacionada con el crecimiento de los pollos cuando la abundancia anual fue baja (2002). Una posible explicación puede ser que los pollos parasitados deben reasignar recursos al vuelo en lugar de asignarlos a una*

*lucha contra la infección, sufriendo una reducción en su tasa de crecimiento. Alternativamente, años con menor disponibilidad de alimento afecta tanto al crecimiento de los pollos como a su capacidad de controlar infecciones de coccidios.*

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