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EFFECTS OF SPATIAL AND HOST VARIABLES ON HEMATOZOA IN WHITE-CROWNED SPARROWS WINTERING IN BAJA CALIFORNIA

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ABSTRACT: A survey of blood parasites was conducted in February 1995 on white-crowned sparrows (*Zonotrichia leucophrys*) wintering in two environmentally different localities of Baja California Sur (Mexico). Blood parasite prevalence was higher in La Purísima (49%) than in San José del Cabo (8%), but there were no differences between ages or sexes within each locality. All haematozoan infections were by *Haemoproteus coatneyi,* except one bird in each site that were positive for *Trypanosoma* sp. We found no evidence for the predicted negative relationship between host body condition and intensity of parasitism. The relatively high prevalence in one site suggests that an increase of hematozoa transmission may occur in that area.

Key words: Blood parasites, effects on body condition, geographical variation, *Haemoproteus coatneyi,* white-crowned sparrow, *Zonotrichia leucophrys.*

INTRODUCTION

Information on prevalence and geographic distribution of parasites is required because it can potentially provide insights into the evolutionary distribution of these organisms in different hosts under contrasting environmental conditions (Tella et al., 1999). Despite an increasing interest on the geographical variation of avian blood parasitism (Bennett et al., 1995; Blanco et al., 1997; Bosch et al., 1997; Sol, 2000), much basic information is needed regarding the epizootiology of haematozoans for many species and geographical areas. Within North America, information on avian blood parasites exists for extensive areas (Bennett et al., 1982). Several of the host species sampled in these areas were migratory birds with wintering grounds in southern tropical and subtropical regions where potential vectors and infections by blood parasites are probably different (Møller, 1998).

Although haematozoan infections are rarely fatal (but see van Riper et al., 1986; Atkinson et al., 1995), they may temporarily cause listlessness and loss of condition that indirectly may decrease survival rates and breeding success of their avian hosts (Bennett et al., 1993; Yornicks and Atkinson, 2000). Blood parasites can be acquired during the breeding or wintering periods and during migration (Atkinson and van Riper, 1991; Super and van Riper, 1995). The impact on the host's fitness on those parasites acquired under particular environmental conditions remains unknown for most migratory species. In general, blood parasites could be considered as a further factor affecting the survival and future breeding prospects of migratory birds, especially in species which are not confronted commonly with blood parasites, but which eventually can be parasitized by highly virulent parasites (Warner, 1968; Bennett et al., 1993). Therefore, the study of prevalence and intensity of infection of different haematozoans in breeding and wintering areas may be of interest to understand the role of parasites in the ecology and conservation of migratory species (Scott, 1988).

Birds have been sampled for blood parasites in Northern California (USA; Super and van Riper, 1995), but nothing is known about the prevalence and intensity of infection by blood parasites on resident and wintering birds at southern adjacent areas such as the Peninsula of Baja California. Here, we present the result of a survey of blood parasites on white-crowned sparrows (*Zonotrichia leucophrys*) wintering in two localities of Baja California Sur. This is, to our knowledge, the first sampling for avian haematozoa in this area. Herein, we also compared body condition of hosts captured in our two study localities, and assessed whether the condition of host was correlated with the intensity of infection by blood parasites.

MATERIALS AND METHODS

During February 1995 data on white-crowned sparrows and their haematozoan parasites were collected in two localities of Baja California Sur separated by about 600 km. La Purísíma (26°11′N, 112°04′W) study area is a linear 30 km long oasis with fresh water and abundant riparian vegetation dominated by palms (*Washingtonia* sp., *Phoenix datilifera*) and surrounded by sarcocaulescent scrub desert, with 111 mm annual rainfall and an annual mean temperature of 22.8 C. San José del Cabo (23°03′, 109°41′W) is a brackish estuary surrounded by scarce riparian vegetation and wide intensively cultivated fields (rainfall 335 mm, temperature 23.6 C). The study areas were described in detail elsewhere (Rodríguez-Estrella, 1997).

White-crowned sparrows were caught in mistnets from sunset to dawn and were released where caught after data collection. We distinguished age (first-year or adult) and sex of birds following criteria detailed in Fugle and Rothstein (1985) and Pyle et al. (1987). All birds were banded, weighed (to the nearest 0.1 g), measured for wing length at maximum chord to the nearest 1 mm, and scored for fat accumulation by using an index ranging from 0 to 5 following Gosler (1996) criteria.

Blood samples were taken from the brachial vein and smeared on microscope slides, air-dried, fixed with absolute ethanol and stained with Giemsa. Once a slide was mounted, half a smear was chosen at random and scanned at 200× looking for extraerythrocytic protozoans. Intraerythrocytic parasites were quantified under oil at 1,000× by counting the number of parasites per 2,000 erythrocytes (Godfrey et al., 1987). Prevalence was defined as the proportion of hosts with slide-positive infections (Margolis et al., 1982).

We used generalized linear models (GLM) (Crawley, 1993) to derive a mathematical description of (1) blood parasites prevalence, (2) intensity of infection by blood parasites, and (3) host body mass. We used GLM modeling to assess simultaneously which explanatory variables and/or their interactions better explain the original deviance of the data set. Generalized linear models allows for the use of other error functions when the normal distribution is not applicable, as is common in the study of parasites that show an aggregated distribution. We fitted each explanatory variable to the observed data following a modification of the traditional forward stepwise procedure that conducts, through the principle of parsimony, the most minimal adequate model able to describe the data set (Tella et al., 1999). We explored possible non-linear data distribution before conducting the analyses utilizing GLIM software (Baker and Nelder, 1978).

For the analysis of prevalence, we used the presence (1) or absence (0) of *Haemoproteus coatneyi* as the response variable, and locality of capture, age and sex of birds as the explanatory variables. Thus, we considered a binomial distribution of errors and a logistic link (equivalent to a logistic regression). For the analysis of intensity of infection, we considered the number of infected erythrocytes per 2,000 erythrocytes as the response variable and age, sex, site of capture, structural size (wing length), and two measures of physiological condition (body mass and fat scores) as explanatory variables. Because intensity of infection shows an aggregated distribution ($k = 0.1613$), where the variance (6.41) is substantially greater than the mean (1.29), we conducted a GLM analysis with negative binomial error and the logarithm as its natural link function following Crawley (1993). To assess for differences in host condition, we considered body mass as the response variable and age, sex, site of capture, structural size (wing length), fat scores, and abundance of blood parasites as explanatory ones. In this case, we used a normal distribution of errors and an identity link (equivalent to multiple regression). In this GLM we tested for differences in body mass between and within areas while controlling for the effects of other potentially influencing variables and their interactions. Because not all data were collected for all birds sample sizes varied slightly among analyses. All P-values refers to two-tailed tests.

RESULTS

Haematozoan prevalence varied from 49% in La Purísima ($n = 35$) to 8% in San

TABLE 1. Generalized Linear Model for prevalence of blood parasites on white-crowned sparrows (n = 73) wintering in Baja California Sur (Mexico) using binomial error and logistic link (total deviance = 85.73).

Variable	Parameter estimated	SE
Constant	−0.057	0.027
Locality	−2.400	0.690
Residual deviance	69.48	
df	71	

José del Cabo (n = 38). All haematozoan infections were by *H. coatneyi,* except one bird in each site that had also a *Trypanosoma* sp. infection. Positive slides were deposited in the collection of the Museo Nacional de Ciencias Naturales, Madrid, Spain (accession numbers: MNCN 35.02/5, MNCN 35.02/6, MNCN 33.03/5).

We obtained a final model that accounted for 19% of the original deviance of prevalence and did not show data overdispersion (mean deviance = 0.98). The only variable included was locality of capture (Table 1); no effects of age and sex, or its interaction were included in the model ($P < 0.001$; Table 1).

The intensity of haematozoan infections varied from 1 to 40 parasites per 2,000 erythrocytes (mean ± SE = 7.9 ± 2.6/2000 erythrocytes, n = 20). There were no differences between ages or sexes in the intensity of infection either between areas or within areas, and it was not related to size and condition of the hosts (all $P < 0.05$), although the low sample sizes of infected individuals may preclude finding differences (mean ± SE intensity of infection/2,000 erythrocytes, La Purísima: first-year male = 8.8 ± 9.4, n = 6; first-year female = 0.4, n = 1; adult male: 8.6 ± 15.7, n = 5; adult female = 10.8 ± 11.2, n = 5; San José del Cabo: first-year male = 2.0, n = 1; adult female = 3.0 ± 1.0, n = 2; all first-year females and adult males were uninfected). In fact, the GLM did not include any variable explaining a significant fraction of the original deviance (32.381, df = 19).

To test for differences in host body mass depending on age, sex, site, structural size and intensity of parasitism, we fitted a GLM in which we controlled for each explanatory variable and their interactions. We obtained a GLM model which accounted for 50.8% of the original deviance in body mass (Table 2), of which wing length explains 70% (Table 2). All variables in the final model entered at $P < 0.002$: wing length, age, fat scores and sex (Table 2). There were no significant effects due to the locality of capture or the intensity of blood parasites. The final model thus showed that host body mass was higher in adult than juveniles, in males than females, and that it increased as did fat scores (Table 2). Because of the significant differences in prevalence between capture sites, we also conducted a GLM considering only infected birds and obtained a final model that accounted for 61% of the original deviance (110.95, df = 19). The only variable included was sex (constant: pa-

TABLE 2. Generalized Linear Model for body mass of white-crowned sparrows (n = 72) wintering in Baja California Sur (Mexico) using normal error and identity link (total deviance = 378.56).

Variable	Parameter estimated	SE	P	Explained deviance (%)
Constant	10.760	7.693		
Wing length	0.158	0.105	< 0.0001	70.3
Age	1.537	0.451	< 0.0001	11.6
Fat scores	0.775	0.246	< 0.0001	11.3
Sex	1.552	0.715	< 0.002	6.8
Residual deviance	186.25			
df	67			

rameter estimate = 23.910, SE = 0.477, sex: parameter estimate = 3.646, SE = 0.712, $P < 0.0001$). This indicates that in the sample of infected hosts, the sex of hosts was the only variable that explained body mass variation, males being heavier than females.

DISCUSSION

We found a geographical difference in the prevalence of infection by *H. coatneyi* in white-crowned sparrows wintering in Baja California Sur. Different environments may promote differences in the presence and activity of potential vectors (Figuerola, 1999; Sol et al., 2000), and also possibly the development of blood parasites in their vectors (Atkinson and van Riper, 1991). Therefore, the difference in prevalence between areas may be promoted by the contrasting environmental conditions affecting the ability of hosts to cope with infections produced in the wintering or the breeding areas, respectively. The presence of infections in 49% of birds in one area during the season when infections usually occurs at lower intensities (Allander and Sundberg, 1997) point out that the transmission of hematozoa may occur in the area (see also Super and van Riper, 1995). Alternatively, a different origin of the birds sampled in the two wintering sites may be the cause of the prevalence difference.

The immune response to parasites may vary in effectiveness depending on gender and during the host's life cycle (Allander and Sundberg, 1997; Sol et al., 2000). Age and gender differences in nutritional or environmental stress may affect susceptibility to blood parasites, but in turn, favorable environmental conditions may produce the situation that birds in good physiological condition may be better able to cope with blood parasites infections (Merino et al., 1996). We found that white-crowned sparrows did not differ in prevalence and intensity of blood parasite infection depending on age or sex. In addition, we found no difference in body condition and fat scores between the two sites, nor a negative relationship between individual body mass or levels of fat reserves and intensity of infection. Therefore, the geographical difference in haematozoan prevalence, and the individual variation in haematozoan infections within areas, can not be related to different host body condition between or within areas.

In conclusion, the geographical difference in prevalence of infection of blood parasites may be caused by different factors affecting both the vectors and the hosts, and also the probability of infection in the breeding or wintering areas of migratory species. We cannot clearly discern the role of environmental effects on the host or the vectors because we lack information about the identity and abundance of the latter in the two areas, although hypoboscid flies, which are potential vectors (Atkinson and Van Riper, 1991; Sol et al., 2000), were not present in the birds sampled (G. Blanco, unpubl. data; see also Tella et al., 2000). However, blood parasites appear not to be a main cause or effect of poor body condition or reduced levels of fat reserves in the two wintering populations of white-crowned sparrows studied. This result, together with the lack of differences in host body condition between areas, support the hypothesis of a habitat effect.

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