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Research paper

Spatial and seasonal variation of avian malaria infections in five different land use types within a Neotropical montane forest matrix

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HIGHLIGHTS

- We studied haemosporidian parasites at different land use types and seasons.
- Prevalence and parasitaemia increased in the urban forest.
- Prevalence and parasitaemia increased during the rainy season.
- Land use intensity and urbanization reduces seasonal fluctuations in parasite transmission.

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ABSTRACT

Seasonality as well as habitat destruction can alter host-parasite interactions. The montane cloud forest of Veracruz State in Mexico has been transformed into agro-ecosystems and cities. The aim of this study was to determine how ecological parameters of avian malaria parasites responded to five different land use types (i.e., well-preserved cloud forest, periurban forest, urban forest, coffee plantation, and cattle field) and to seasonality. We used microscopy and PCR methods to determine prevalence, parasitaemia, and aggregation of haemosporidians infecting the widespread chestnut-capped brush finch (*Arremon brunneinucha*). We performed PCA and cluster analyses to determine vegetation structure and similarity, and to investigate how relevant vegetation variables are associated with parasitological parameters. All haemosporidian infections in chestnut-capped brush finches belonged to *Haemoproteus* and *Plasmodium* species. Prevalence and parasitaemia of avian malaria were higher during the rainy season, while aggregation remained similar. Both prevalence and parasitaemia were higher in the urban forest. Prevalence was lower in the well-preserved cloud forest during the dry season. Parasitaemia was negatively associated to bush cover. Our results suggest that an increase in land use intensity reduces seasonal fluctuations in parasite transmission, and that infections are more frequent and more severe for birds inhabiting urban environments.

1. Introduction

Environmental changes such as deforestation, habitat fragmentation, and land use change may alter host-parasite interactions (Ostfeld, Keesing, & Eviner, 2008). These changes may facilitate outbreaks of emergent and/or re-emergent diseases having detrimental effects on host populations and communities (Daszak, Cunningham, & Hyatt, 2001; McCallum, 2008; Tylianakis, Didham, Bascompte, & Wardle, 2008). For example, due to habitat destruction, the fungus *Batrachochytrium dendrobatidis* has been able to expand and increase in incidence causing amphibian population reductions and extinctions in many places around the world (Daszak, Cunningham, & Hyatt, 2003).

Besides habitat characteristics, seasonality is an important factor in the transmission of vector-borne diseases because vectors are very sensitive to local climatic conditions (Hess et al., 2001). Many studies have reported higher prevalence of Haemosporida parasites during the warm and rainy months of the year because precipitation and temperature allow the development of blood sucking insects that can act as vectors (e.g. Cosgrove, Wood, Day, & Sheldon, 2008; Hay et al., 2000). Higher temperatures, to some upper limit, allow a faster completion of the parasite's life cycle

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within the vector (Santiago-Alarcon, Palinauskas, & Schaefer, 2012), which increases the probability of transmission.

The majority of ecological studies on Haemosporida in wildlife comparing parasitological parameters between host populations focus on parasite prevalence, and in some cases parasitaemia is also considered. However, a third parameter commonly used with macroparasites, aggregation (see Shaw & Dobson, 1995), has not traditionally been used with haemosporidians. We decided to include this parameter in our study in order to have a better understanding of the host-parasite dynamics in our system. In nature, parasites present an aggregated distribution among its host populations, meaning that most of the hosts present none or a few parasites, while only a few hosts have the majority of parasites. Therefore, the distribution of parasites in host populations is statistically represented by a negative binomial distribution, which responds to such natural aggregation (i.e., overdispersion in statistical terms) of parasites on hosts (Wilson & Grenfell, 1997).

Only a few studies have compared the prevalence of haemosporidian parasites infecting bird populations at undisturbed versus modified habitats, showing opposite trends depending on the parasite and the host species under study. In Cameroon, Chasar et al. (2009) reported higher prevalence of avian parasites of the genera *Haemoproteus* and *Leucocytozoon* in undisturbed sites, and higher prevalence of *Plasmodium* species in disturbed locations. In contrast, Bonneaud et al. (2009) recorded elevated *Plasmodium* prevalence in undisturbed tropical forests. Loiseau et al. (2010) studied the prevalence, parasitaemia, and co-infections of haemosporidians in two bird species in sites with different tree cover, temperature, and precipitation in Africa. They found higher prevalence of *Plasmodium* species in the Olive Sunbird (*Cyanomitra olivacea*) at the site with more tree cover and higher precipitation. However, the Yellow-whiskered Greenbul (*Andropadus latirostris*) showed similar prevalence across all sites. Moreover, the two bird species showed opposite parasitaemia patterns, higher in the Olive Sunbird at the site with the least disturbance and higher in the Yellow-whiskered Greenbul at the most disturbed site. Evans et al. (2009) reported a higher prevalence of *Haemoproteus* and *Plasmodium* parasites in the majority of rural areas compared to their urban counterpart across different cities in Europe. In contrast, Belo, Pinheiro, Reis, Ricklefs, and Braga (2011) found higher prevalence of parasites of the genera *Plasmodium* and *Haemoproteus* in an urban site in comparison with a preserved and transition areas. Hence, there is no clear relationship between land use type and prevalence of Haemosporida parasites. This is probably due to the fact that haemosporidian parasites of different genera are transmitted by different Diptera families, and vector life cycles are differentially influenced by microclimatic conditions; thus, local instead of regional factors mostly govern ecological dynamics of these host-parasite systems (e.g., Knowles, Wood, Alves, & Sheldon, 2014). Also, the differential response of each host species to disturbance and their ability to eliminate infections could explain these contrasting results.

We studied the Chestnut-capped Brush Finch (*Arremon brunneinucha*), which is a widely distributed Neotropical resident bird (from central Mexico to Peru). This bird can be found in thick undergrowth of dense humid evergreen and pine-evergreen forests, adjacent second growth vegetation, and thickets in altitudes from 900 to 3500 m asl. They are understory birds that feed on a variety of insects from the ground, the underside of leaves, and fruits from low bushes (Stiles & Skutch, 2007). It nests in bushes and trees below 2 m from the ground. Breeding season is during the months of May and August (del Hoyo, Elliot, & Christie, 2011; Howell & Webb, 1995; Rising, 2011). There are no studies about the dispersal capacity of this species, but its flights are short and usually avoid open spaces (del Hoyo et al., 2011). According to our data, all of the recaptures from two adjacent sites occurred where birds were first captured, giving support to the low dispersal capacity of this understory bird. The Chestnut-capped Brush Finch has been reported to host one species of haemosporidian parasite, *Haemoproteus coatneyi*, which is a generalist parasite that infects at least 19 other passeriform bird species (Valkiūnas, 2005). Recently, this bird species was reported to harbor infections by lineages of the genera *Plasmodium*, *Leucocytozoon*, and *Trypanosoma* (González et al., 2014).

Here, we studied the variation of haemosporidian infections (prevalence, parasitaemia, and aggregation) in five different land use types and two seasons for two consecutive years within a region originally dominated by montane cloud forest, located in central Veracruz, Mexico. The land use types considered for this study were: preserved cloud forest, urban forest, periurban forest, shade coffee plantation and cattle field. The abundance of Chestnut-capped Brush Finches is higher in habitats with abundant leaf litter and bush cover, which could increase the probability of transmission of haemosporidians because of optimal conditions for the development of some vectors. Therefore, we expected to find higher prevalence of Haemosporida parasites in areas where the vegetation structure has a well-developed understory layer compared to sites with an open understory. When hosts are located in sub-optimal conditions, there are higher costs when infection occurs because there is a trade-off between using limited resources to combat the infection or to do body maintenance and compete for territories (e.g. Lüdtke et al., 2013). Hence, we expected an increase in parasitaemia and a decrease in aggregation in the coffee plantation and urban forest, where habitat characteristics (i.e. open understory due to tillage and pesticide use in coffee plantations; pollution, encroachment, and predators in urban areas) may not be optimal for the Chestnut-capped Brush Finch. Finally, the montane cloud forest is a seasonal habitat with a clearly defined cold period (late November to late April), where vector activity and abundance is reduced (Abella-Medrano, Ibáñez-Bernal, MacGregor-Fors, & Santiago-Alarcon, 2015). Therefore, we expect to find a lower prevalence in all sites during this season compared to the warmer and rainy period of the year (May–October).

2. Methods

2.1. Study area

The study area is located in central Veracruz, Mexico, where the original vegetation was montane cloud forest. The sampling sites are located in the municipalities of Xalapa, Coatepec, Xico, and San Andrés Tlalnelhuayocan. The region is comprised of a landscape matrix of shade coffee plantations, cattle fields, second growth vegetation, montane cloud forest patches, and human settlements that are rapidly expanding (Williams-Linera, 2012). Mean annual rainfall is 1492 mm, with a minimum of 44.8 mm in December and a maximum of 273.4 mm in June. Mean annual temperature is 18 °C, with a maximum mean temperature of 20.4 °C in May and a minimum of 14.9 °C in January. The original vegetation, described by Rzedowski (1978) as montane cloud forest, has been heavily fragmented and there are a few isolated remnants within an agricultural matrix composed mostly of shade coffee plantations (Tolome, 1993; Williams-Linera, 1993). We sampled five sites, each one with a different land use type: 1) preserved cloud forest, 2) urban forest, 3) periurban forest, 4) shade coffee plantation, and 5) cattle field (Fig. 1).

The studied preserved cloud forest (19°27′15″N, 97°00′28″W; 1300–1500 m asl; 77 ha) is immersed in a matrix composed by shade coffee plantations and other fragments of cloud forest. This site presents a floristic composition similar to other fragments of cloud forest in the region (García-De la Cruz, Olivares-López,