ABANICO VETERINARIO ISSN 2448-6132 abanicoveterinario@gmail.com
abanicoacademico.mx/revistasabanico/index.php/abanico-veterinario
Creative Commons (CC BY-NC 4.0)

Abanico Veterinario. January-December 2022; 12:1-15. http://dx.doi.org/10.21929/abavet2022.4
Research Note. Received:30/06/2021. Accepted:09/01/2022. Published:08/03/2022. Code: e2021-45.
https://www.youtube.com/watch?v=dZJVUgPATc8

Prevalence and blood parasitaemia of Eurasian Collared Doves (*Streptopelia decaocto*) and Mourning Dove (*Zenaida macroura*) in Durango, Mexico

Prevalencia y parasitaemia sanguínea de palomas turcas (*Streptopelia decaocto*) y huilotas (*Zenaida macroura*) en Durango, México

Salazar-Borunda Manuel*[1] ID, Martínez-Guerrero José[1] ID, Martínez-Montoya Juan[2] ID, Vargas-Duarte Andrea[1] ID, Sierra-Franco Daniel[1] ID, Pereda-Solís Martín[1] ID**

[1]Cuerpo académico de fauna silvestre, Facultad de Medicina Veterinaria y Zootecnia, Universidad Juárez del Estado de Durango. Km. 11.5 Carretera Durango-Mezquital, Durango, Durango, México. CP. 34197. [2]Colegio de Postgraduados Campus San Luis Potosí. Salinas de Hidalgo, San Luis Potosí. México, C. P. 78620. *Responsible author: Salazar-Borunda Manuel. **Author for correspondence: Pereda-Solís Martín. E-mail: borunda@ujed.mx, che_hugo1@hotmail.com, fmontoya@colpos.mx, andrea.vargas@ujed.mx, d_sierra@ujed.mx, mepereda@ujed.mx.

Abstract

Blood parasitism in Mexican birds is an impoverished-studied phenomenon, and its presence in many species of birds is unknown. In this study, the prevalence and parasitaemia of hemosporidia were compared in the breeding (wet) and non-breeding (dry) seasons in the Eurasian collared doves (*Streptopelia decaocto*) and Mourning ones (*Zenaida macroura*) in northern Mexico. The blood of 40 birds of each species collected between 2013 and 2014, was analyzed. The diagnosis of hemoparasites was made by microscopy and Polymerase Chain Reaction (PCR) techniques. The prevalence of hemoparasites was 87.5% (CI 95% = 78.3–93.3). The mean parasitaemia was 7.03 (CI 95% = 5.68–9.04) hemoparasites per 10,000 infected erythrocytes. The prevalence and parasitaemia were higher for *Haemoproteus* sp. than for *Plasmodium* sp and microfilariae. The prevalence rates did not vary between bird species, nor between times of the year. However, seasonality seems to be an important factor in parasitaemia. The species that obtained the highest rates of parasitaemia was *Z. macoura*. More studies are needed to understand the mechanisms that associate parasitaemia in this species with respect to other columbiform species.

Keywords: *Streptopelia decaocto*, *Zenaida macroura*, seasonal variation, *Haemoproteus*, *Plasmodium.*

Resumen

El parasitismo sanguíneo en aves de México es un fenómeno poco estudiado y su presencia en muchas especies de aves es desconocida. En este estudio, se compararon la prevalencia y parasitaemia de hemosporidios en la época reproductiva (húmeda) y no reproductiva (seca) de las palomas turcas (*Streptopelia decaocto*) y huilotas (*Zenaida macroura*) del norte de México. Se analizó la sangre de 40 aves de cada especie, colectadas entre 2013 y 2014. El diagnóstico de hemoparásitos se realizó mediante técnicas de microscopía y reacción en cadena de la polimerasa (PCR). La prevalencia de hemoparásitos fue de 87.5 % (IC 95%=78.3–93.3). La parasitaemia promedio fue de 7.03 (IC 95 %= 5.68–9.04) hemoparásitos por cada 10,000 eritrocitos infectados. La prevalencia y parasitaemia fueron mayores para *Haemoproteus* sp., que en *Plasmodium* sp y microfilarias. Las tasas de prevalencia no variaron entre especies de aves, ni entre épocas del año. No obstante, la estacionalidad parece ser un factor importante en la parasitaemia . La especie que obtuvo mayores tasas de parasitaemia fue *Z. macoura*. Se necesitan más estudios para comprender los mecanismos que asocian la parasitaemia de esta especie con respecto a otras especies de columbiformes.

Palabras clave: *Streptopelia decaocto*, *Zenaida macroura*, variación estacional, *Haemoproteus*, *Plasmodium*.

INTRODUCTION

Exotic species represent a threat to the structure, function and integrity of ecosystems (Ferreira *et al.,* 2021), contribute to the extinction of some species (Rocha *et al.,* 2021) and introduce infectious agents to the colonized environment (Hernandez-Colina *et al.,* 2021). The Eurasian collared dove (STRDEC, *Streptopelia decaocto*) is an invasive species with a wide distribution in North America (eBird, 2021). It is a relatively large bird (Salazar-Borunda *et al.*, 2019), which competes for food and nesting sites with local avifauna (El-Mansi *et al*., 2021; Koenig, 2020) or can transmit diseases to the colonized environment (Stilmmelmayr *et al.*, 2012). In Mexico, Mourning Dove *huilota* (ZENMAC, *Zenaida macroura*) shares habitat with *S. decaocto* (Otis *et al.,* 2020) and represents a model species to study the effects of the exotic species on Mexico's avifauna.

Although the introduction of exotic diseases is a complex phenomenon and multiple etiological agents may be involved (Hawkins, 2021; Martínez-Pérez *et al*., 2021), hemoparasites have been widely distributed among birds (White *et al.,* 1978; Starkloff *et al*., 2021). This group of microorganisms is transmitted by dipteran insects such as mosquitoes, hypobossids and simulids and include the genera *Haemoproteus*, *Plasmodium*, *Leucocytozoon*, *Falissia*, *Garnia* (Valkiūnas & Iezhova, 2018), Trypanosoma (Ham-Dueñas *et al*., 2017) and microfilariae (Noden *et al*., 2021.

When infecting birds, hemoparasites can cause acute or chronic clinical signs. In the acute presentation, the host develops a high parasitaemia associated with systemic phenomena generated by exoerythrocytic and intraerythrocytic forms (microgametocytes, macrogametocytes and meronts). The chronic phase instead, occurs days or weeks after infection, when infected birds experience low parasitaemia and mild clinical impacts that can last for years with seasonal relapses (Valkiūnas & Iezhova, 2017). Although common in bird populations (Palinauskas *et al.,* 2011) they are sometimes fatal (Cardona *et al.,* 2002; Yoshimoto *et al.,* 2021), especially when introduced (Warner, 1968).

In terms of prevalence, hemoparasites vary between ecological regions (Loiseau *et al.*, 2012), seasons of the year (DeBrock *et al.,* 2021) or depending on vector response to climatic fluctuations (Wood *et al.*, 2007). Knowledge of the hemoparasitic prevalence of an exotic and a native species will enrich the biological knowledge of this ecological interaction. Therefore, the objective of this study was to determine and compare the hemoparasitic prevalence between collared doves and mourning doves in Durango municipality, Mexico, during two seasons of the year.

MATERIAL AND METHODS

The study area corresponds to the localities from "José Refugio Salcido" (23.97 N, -104.51 W), "Praxedis Guerrero Nuevo" (23.94 N; -104.56 W) and "La Purísima" (23.96 N; -104.57 W) from Durango municipality, Mexico. Blood samples (500 µl) were extracted from STRDEC (n= 40) and ZENMAC (n= 40), during the breeding (spring-summer, 2014) and non-breeding (autumn-winter, 2013) seasons under the protection of scientific collection permit SGPA/DGVS/12294/13.

Blood collection

Two blood smears were taken from each bird, which were dried at room temperature (2 min) and fixed with 100% methanol (3 min). Once dried, they were wrapped in paper to avoid direct contact between them, and subsequently stained with a Giemsa solution (pH 7.0-7.2 at 18-20 °C for 1 h; Santiago-Alarcón & Carbó-Ramírez, 2015). From the collected blood, 100 µl were deposited in a sterile Eppendorf tube with buffer solution (100 mM Tris HCl, pH 8.0, 100 mM EDTA, 10 mM NaCl, 0.5 % SDS; Longmire *et al.,* 1988) to keep it frozen (- 20 °C) until molecular analysis.

Molecular analysis

The presence and absence of hemoparasites was determined by polymerase chain reaction (PCR) targeting a 479 base pair region of the cytochrome b gene (Hellgren *et al.,* 2004). DNA extraction was performed following the DNeasy blood & Tissue® protocol (Quiagen, 2021). PCR was performed with 100 ng of GA, 10 mM Tris-HCl (pH 8.3), 50 mM KCl, 3.0 mM MgCl, 0.4 mM deoxynucleotide triphosphate, 5 µl Q buffer and 0.5 µl Taq. Amplification was performed from the oligonucleotides HaemNFI-HaemNR3 (Hellgren *et al.,* 2004) and HaemF-HaemR2 (Bensch *et al.*, 2000). The products of that reaction were deposited inside an electrophoresis chamber (25 mA, 25 min) together with 0.01 µg/µL TrackIt™ and SYBR® for observation in an ultraviolet light photo-documentation chamber (ImageQuant LAS 4000, 6 s exposure).

Microscopic analysis

To confirm the presence or absence of parasitic structures, blood smears were examined at high dry (40 ×, 30 min) and wet (100 ×, 30 min) magnification for at least 100 fields using a binocular light microscope (Carl Zeiss®, Primo Star model). Parasite identification, limited to genus level, was performed following the criteria of Valkiūnas and Iezhova (2018). The prevalence of hemoparasites was estimated by the ratio of infected birds to the total number of sampled individuals.

To determine hemoparasite parasitaemia, the observed parasitic elements were counted by counting 10 000 host red blood cells (Godfrey *et al.,* 1987).

Statistical analysis

Prevalence, mean parasitaemia and their respective 95% confidence intervals were calculated with Quantitative Parasitology QPweb (Reiczigel *et al*., 2020). Estimation of prevalence as for parasitaemia, was based on 5 000 bootstrap replicates, with the

Sterne method for binomial prevalence data (Rózsa *et al*., 2000; Ham-Dueñas *et al*., 2017; Reiczigel *et al*., 2019). Prevalence and parasitaemia indices were compared between parasitic genera (*Haemoproteus* sp. vs. *Plasmodium* sp.). Prevalence was analyzed by Chi-square analysis and parasitaemia with a generalized linear model (GLM), using the negative binomial distribution.

The year season effect and species were assessed by generalized linear mixed models (GLMM, Paterson & Lello, 2003,), using logistic regression for hemosporidia prevalence and negative binomial distribution for parasitaemia . These analyses were implemented using the "MASS" package (Venables & Ripley, 2002) in R version 4.0.5 (R Core Team, 2021).

RESULTS

Of the 80 pigeons tested for hemoparasites with PCR, 70 were infected (87.5 %, 95% CI=78.3-93.3). Prevalence rates ranged from 80-100 % and the parasite gene was amplified at a higher rate during the non-breeding season (Table 1).

Table 1. Percentage of birds infected with hemoparasites, diagnosed morphologically and through amplification of the mitochondrial parasitic cytochrome B gene in Durango, Mexico

Species	Morphological diagnosis	
	Reproductive*	Non-reproductive **
ZENMAC	14 $_{n}$, 70 % $_{P}$, 47.5–86.0 $_{IC}$	19 $_{n}$, 95 % $_{P}$, 75.6–99.7 $_{IC}$
STRDEC	13 $_{n}$, 65 % $_{P}$, 42.4–83.3 $_{IC}$	14 $_{n}$, 70 % $_{P}$, 47.5–86.0 $_{IC}$
Species	**Diagnóstico molecular**	
	Reproductive*	Non-reproductive **
ZENMAC	17 $_{n}$, 85 % $_{P}$, 62.8–95.8 $_{IC}$	20 $_{n}$, 100 % $_{P}$, 83.3–100 $_{IC}$
STRDEC	16 $_{n}$, 80 % $_{P}$,57.6–92.9 $_{IC}$	17 $_{n}$, 85% $_{P}$, 62.8–95.8 $_{IC}$

ZENMAC *Zenaida macroura*, STRDEC *Streptopelia decaocto*, n Number of infected birds, *P* Prevalence, 95% confidence interval *CI*, *Spring-Summer 2014, **Fall-Winter 2013

Although most infections were diagnosed by both methods, microscopic analysis reflected lower prevalences. Most of the positive samples had single hemosporidia infections. However, one bird of each species showed co-infection between *Haemoproteus* sp. and microfilariae.

The prevalence of hemoparasites detected by light microscopy was 75.0 % (60 birds, 95 % CI= 64.4-83.4) and identified on average 7.03 (95 % CI= 5.68-9.04) hemoparasites per 10,000 infected erythrocytes. The percentage prevalence and average parasitaemia for each species, hemoparasite taxa and season are shown in Table 2.

Parasite structures were identified at different evolutionary stages. Macro- and microgametocytes for Haemoproteus sp., meronts for Plasmodium sp. and larval stages of filariae were detected (Figure 1). *Haemoproteus* sp. infections were higher than *Plasmodium* sp. infections (prevalence: $X^2 = 1.14$, df = 1, $P = 0.02$, parasitaemia : $F = 508.80$, P = 0.001).

Table 2. Percentage prevalence of hemoparasites and average parasitaemia in *Streptopelia decaocto* and *Zenaida macroura* during the breeding and non-breeding season in Durango, Mexico

Group	Infected birds	n	Prevalence% (CI 95%)	Parasitaemia[1] average (CI 95%)
STRDEC	27	40	67.5 (51.3–80.2)	4.0 (3.1–5.2)
ZENMAC	33	40	82.5 (67.7–91.6)	9.4 (7.4–12.8)
Haemoproteus sp.	55	80	68.8 (57.5–78.3)	6.3 (5.0–8.17)
Plasmodium sp.	17	80	21.2 (13.6–31.8)	2.6 (1.9–3.4)
Microfilarias	4	80	5.0 (1.7–12.3)	3.0 (1.0–4.7)
Reproductive*	27	40	67.5 (51.3–80.2)	5.15 (3.8–7.4)
Non-reproductive **	33	40	82.5 (67.7–91.6)	8.58 (6.67–11.9)

[1] Number of parasitic elements in 10 000 red blood cells quantified, n Total samples, 95% confidence interval CI, *STRDEC* collared dove, *ZENMAC* mourning dove, *Spring-Summer 2014, **Fall-Winter 2013

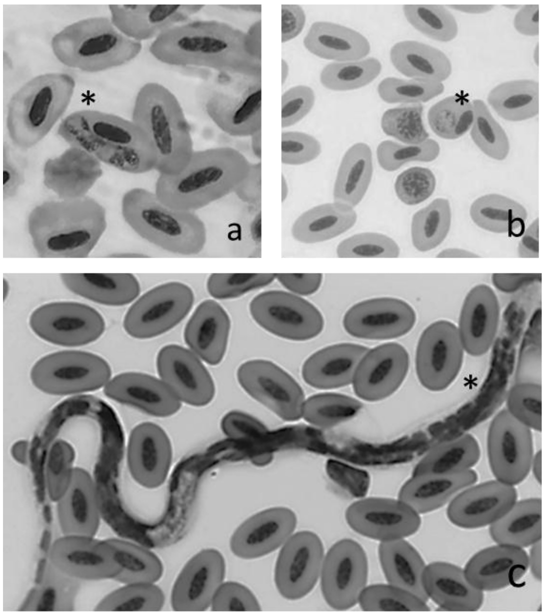

Figura 1. Photomicrographs of blood smears from columbiform birds naturally parasitized by hemoparasites (*). a. *Haemoproteus* **sp., b.** *Plasmodium* **and c.** Microfilariae **(c);** Giemsa**, 100 x**

Generalized linear mixed models revealed that parasitaemia varied between species and time of year (F= 337.8, P= 0.001). The GLMM fit explaining parasitaemia was moderate (R^2 = 0.89). Parasitaemia was higher during the non-breeding season, especially in ZENMAC (Table 2). Finally, the effect of species (*P*= 0.18) and season (*P*= 0.50) on prevalence rates were not significant.

DISCUSSION

The hypothesis that prevalence rates differ significantly between bird species and between seasons was not supported by the data. This means that the phenomenon of parasitism is common in both bird species.

The prevalence value recorded is higher than some values reported in Mexico (Reinoso-Pérez *et al*., 2016; Ham-Dueñas *et al*., 2017; Villalva-Pasillas *et al*., 2020). However, these results should not be surprising because the response towards blood parasitism depends on factors associated with seasonality, immunology or host behavior, as reported in similar studies in passerine (Lee *et al*., 2006; Dubiec *et al*., 2016) and columbiform birds (Schumm *et al.,* 2021).

The influence of such variables on blood parasites is monitored in long-term studies, and generally do not reflect significant differences between prevalences over several years (Bensch *et al.,* 2007; Dubiec *et al.,* 2016). In this sense, although the patterns observed in this study can be considered reliable, they should be monitored in the same region over time.

On the other hand, the results of this study support the hypothesis that parasitaemia varies between species and seasons. The reasons why the amount of hemoparasites was significantly higher in ZENMAC may be associated with differences in the distribution of both birds or with characteristics of vectors and parasites themselves (Reinoso-Pérez *et al.,* 2016). Fokis *et al*. (2008), reported a lower incidence of hemoparasites in birds of urban habits and, although both species come to share habitat (Green *et al*., 2020), the ZENMAC captured for this study were distributed towards more open areas, with adjacent water bodies, probably with more vectors (Lega *et al*., 2017; Lynton-Jenkins *et al.,* 2020) and with higher contagion probability (Hellard *et al.,* 2016). The influence of season (breeding) on parasitaemia could be considered normal, coinciding with the vector breeding season (Inumaru *et al.,* 2021) and hormonal events relevant to the resolution of parasitaemia by the avian host (Deviche & Parris, 2006).

Although regional differences may exist, *Haemoproteus* is the most common hemoparasitic genus in birds, followed by *Plasmodium* and *Leucocytozoon* (*Carlson et al., 2013*; Heym *et al.*, 2019). This pattern was observed in this study with the exception of the genus *Leucocytozoon*, whose absence could be associated with the altitudinal and climatic characteristics of the study site that restrict mosquito abundance and parasite development in these vectors (Borji *et al.*, 2011; Nath *et al.*, 2014). The results show the study site having a sufficient number of vectors capable of transmitting hemoparasites in both bird species (Valkiūnas & Iezhova, 2018; Inumaru *et al.,* 2021).

Works analyzing parasitaemia are limited (Huang *et al.*, 2020) and associate this parameter with the damage generated by the parasite to the host (Knowles *et al*., 2010; Muriel, 2020). To our knowledge, there is no study examining blood parasitaemia in the species sampled in this study. However, the quantified parasitaemia rates were lower than those reported in columbiformes from South Africa (Nebel *et al.*, 2020), Canary Islands (Foronda *et al.,* 2004) and India (Gupta *et al.,* 2011), whose adverse effects on hosts depended on factors such as bird immunity or food availability (Chagas *et al.,* 2016). Likewise, it should be considered that under normal circumstances, the *Haemoproteus* and *Plasmodium* genera only cause health problems when the host is cured by stress events, immunosuppression (Valkiūnas & Iezhova, 2017) or when introduced into non-native communities (Yoshimoto *et al.,* 2021), therefore, these phenomena should be ruled out in these species.

In Mexico, studies reporting microfilariae in birds are scarce and their impact on the host is believed to be not very severe (Yanga *et al.,* 2011). Although it was the least observed parasite, the calculated prevalences exceed those reported by similar studies in Mexico (Clark & Swinehart, 1969; Villalva-Pasillas *et al*., 2020). However, the future development of hemoparasites should be monitored and the possible effects on columbiform communities should be determined, especially in the scenario of global change, since the increase in temperature and anthropogenic changes in land use could provide new opportunities for the transmission of these microorganisms to poultry communities.

It should be noted that in this study were used two analyses (molecular and microscopic) to assess hemoparasite prevalence as accurately as possible. These two approaches led to discrepancies between analyses, determining a lower prevalence in blood smear counts. This event is consistent with previous studies in columbiformes, where the prevalences of microscopic and molecular analysis were different (Dunn *et al*., 2017; Tavassoli *et al.,* 2018).

Birds whose blood had absence of parasitic structures, but were PCR positive, could be having a slight parasitaemia with few gametocytes, sporozoites or parasite remnants that interrupted their development (Valkiūnas & Iezhova, 2017). The molecular method instead, relied on the detection of the parasite gene, but does not reveal whether the parasites have had or will develop into a successful infection (Chagas *et al.,* 2016; Valkiūnas & Iezhova, 2017).

CONCLUSION

Blood parasitism was observed in birds of both species, mainly by the genus *Haemoproteus* spp. Parasitaemia was higher in *Z. macroura* during the breeding season and therefore, seasonality should be an important variable to consider in studies involving parasitism in this species. This study contributes to the understanding of the diversity of hemoparasites infecting wild birds of the order Columbiformes in Durango, Mexico. Although we were unable to determine the cause of differences in calculated parasitaemia, this study provides baseline information for monitoring bird populations at the study sites or possible future changes in parasite ranges and diversity.

ACKNOWLEDGMENTS

Thanks to the University Juárez of Durango State and the Autonomous University of Nuevo León for their support for the completion of this work and to the reviewers whose comments substantially enriched this work.

CITED LITERATURE

BENSCH S, Stjernman M, Hasselquist D, Örjan Ö, Hannson B, Westerdahl H, Torres-Pinheiro R. 2000. Host specificity in avian blood parasites: a study of *Plasmodium* and *Haemoproteus* mitochondrial DNA amplified from birds. *Proceedings of the Royal Society*. 267(1452):1583–1589. ISSN: 0370-1662.
https://doi.org/10.1098/rspb.2000.1181

BENSCH S, Waldenström J, Jonzen N,Westerdahl H, Hansson B, Sejberg D, Hasselquist D. 2007. Temporal dynamics and diversity of avian malaria parasites in a single host species. *Journal of Animal Ecology.* 76(1):112–122. ISSN: 1365-2656. https://doi.org/10.1111/j.1365-2656.2006.01176.x

BORJI H, Moghaddas E, Razmi G, Heidarpour M, Mohri M, Azad M. 2011. Prevalence of pigeon haemosporidians and effect of infection on biochemical factors in Iran. *Journal of Parasitic Diseases*. 35: 199-201. ISSN: 0971-7196.
https://doi.org/10.1007/s12639-011-0056-1

CARDONA CJ, Ihejirika A, McClellan L. 2002. *Haemoproteus lophortyx* infection in bobwhite quail. *Avian Dissease*. 46(1):249–255. ISSN: 1090-2449.
https://doi.org/10.1637/0005-2086(2002)046[0249:hliibq]2.0.co;2

CARLSON J, Martínez-Gómez JE, Valkiūnas G, Loiseau C, Bell DA, Sehgal RN. 2013. Diversity and phylogenetic relationships of hemosporidian parasites in birds of Socorro Island,México and their role in the re-introduction of the Socorro Dove (*Zenaida graysoni*). *Journal of Parasitology.* 99(2):270–276. ISSN: 0022-3395.
https://doi.org/10.1645/GE-3206.1

CHAGAS CRF, de Oliveira-Guimarães L, Monteiro EF, Valkiūnas G, Katayama MV, Santos SV, Guida FJV, Simões RF, Kirchgatter K. 2016. Hemosporidian parasites of free-living birds in the São Paulo Zoo, Brazil. *Parasitology Research*. 115:1443–1452. ISSN: 1432-1955. https://doi.org/10.1007/s00436-015-4878-0

CLARK, GW, Swinehart, B. 1969. Avian haematozoa from the offshore islands of northern Mexico. *Bulletin of the Wildlife Disease Association.* 5(2):111-112. ISSN: 0098373x. https://bioone.org/journalArticle/Download?fullDOI=10.7589/0090-3558-5.2.111

DEBROCK S, Cohen E, Balasubramanian S, Marra PP, Hamer SA. 2021. Characterization of the *Plasmodium* and *Haemoproteus* parasite community in temperate-tropical birds during spring migration. *International Journal for Parasitology: Parasites and Wildlife*. 15:12–21. ISSN: 22132244.
https://doi.org/10.1016/j.ijppaw.2021.03.013

DEVICHE P., Parris J. 2006. Testosterone Treatment to Free-Ranging Male Dark-Eyed Juncos (*Junco Hyemalis*) Exacerbates Hemoparasitic Infection. *The Auk.* 123(2):548–562. ISSN: 2732-4613. https://doi.org/10.1093/auk/123.2.548

DUBIEC A, Podmoka E, Zagalska-Neubauer M, Drobniak SM, Arct A, Gustafsson L, Cichoń M .2016. Differential prevalence and diversity of haemosporidian parasites in two sympatric closely related non-migratory passerines. *Parasitology.* 143:1320–1329. ISSN: 0031-1820. https://doi.org/10.1017/S0031182016000779

DUNN JC, Stockdale JE, Bradford EL, McCubbin A, Morris AJ, Grice PV, Goodman SJ, Hamer KC. 2017. High rates of infection by blood parasites during the nestling phase in UK Columbids with notes on ecological associations. *Parasitology*. 144(5):622–628. ISSN: 0031-1820. https://doi.org/10.1017/S0031182016002274

EBIRD. 2021. eBird: An online database of bird distribution and abundance. eBird, Cornell Lab of Ornithology, Ithaca, New York. http://www.ebird.org

EL-MANSI AA, El-Bealy EA, Rady A M, Abumandour M A, El-Badry DA. 2021. Macro- and microstructures of the digestive tract in the Eurasian collared dove, Streptopelia decaocto (Frivaldszky 1838): Adaptive interplay between structure and dietary niche. *Microscopy Research and Technique*. ISSN: 1097-0029. https://doi.org/10.1002/jemt.23843

FERREIRA L, Silva-Torres C, Torres J, Venette R. 2021. Potential displacement of the native Tenuisvalvae notata by the invasive Cryptolaemus montrouzieri in South America suggested by differences in climate suitability. *Bulletin of Entomological Research.* 1–11. ISSN: 1475-2670. https://doi.org/10.1017/S000748532100033X

FOKIDIS HB, Greiner EC, Deviche P. 2008. Interspecific variation in avian blood parasites and haematology associated with urbanization in a desert habitat. *Journal of Avian Biology*. 39:300–310. ISSN: 1600-048X. https://doi.org/10.1111/j.0908-8857.2008.04248.x

FORONDA P, Valladares B, Rivera-Medina JA, Figueruelo E, Abreu N, Casanova JC. 2004. Parasites of Columba livia (Aves: Columbiformes) in Tenerife (Canary Islands) and their role in the conservation biology of the Laurel pigeons. *Parasite*. 11(3):311–316. ISSN: 1776-1042. https://doi.org/10.1051/parasite/2004113311

GODFREY RD, Fedynich AM, Pence DB. 1987. Quantification of hematozoa in blood smears. *Journal of Wildlife Disease*. 23:558–565. ISSN: 0090-3558. https://doi.org/10.7589/0090-3558-23.4.558

GREEN AW, Sofaer HR, Otis DL, Van Lanen NJ. 2020. Co-Occurrence and Occupancy of Mourning Doves and Eurasian Collared-Doves. *The Journal of Wildlife Management*. 84(4):775-785. ISSN: 1937-2817. https://doi.org/10.1002/jwmg.21835

GUPTA DK, Jahan N, Gupta N. 2011. New records of *Haemoproteus* and *Plasmodium* (Sporozoa: Haemosporida) of rock pigeon (*Columba livia*) in India. *Journal of Parasitic Diseases*. 35:155–168. ISSN: 0975-0703. https://doi.org/10.1007/s12639-011-0044-5

HAM-DUEÑAS, JG., Chapa-Vargas L, Stracey CM, Huber-Sannwald E. 2017. Haemosporidian prevalence and parasitaemia in the Black-throated sparrow (Amphispiza bilineata) in central-Mexican dryland habitats. *Parasitology Research*. 116: 2527–2537. ISSN: 1432-1955. https://doi.org/10.1007/s00436-017-5562-3

HAWKINS S, Garner MM, Hartup BK. 2021. Neoplasia in captive cranes. *Journal of Zoo and Wildlife Medicine.* 52(2):689–697. ISSN: 1937-2825. https://doi.org/10.1638/2020-0180

HELLARD E, Cumming GS, Caron A, Coe E, Peters JL. 2016. Testing epidemiological functional groups as predictors of avian haemosporidia patterns in southern Africa. *Ecosphere*. 7(4):1–17. ISSN: 2150-8925. https://doi.org/10.1002/ecs2.1225

HELLGREN O, Waldenstrom J, Bensch S. 2004. A new PCR assay for simultaneous studies of *Leucocytozoon*, *Plasmodium*, and *Haemoproteus* from avian blood. *Journal of Parasitology*. 90(4):797–802. ISSN: 0022-3395. https://doi.org/10.1645/ge-184r1

HERNANDEZ-COLINA A., Gonzalez-Olvera M, Lomax E, Townsend F, Maddox A, Hesson JC, Sherlock K, Ward D, Eckley L, Vercoe M, Lopez J, Baylis M. 2021. Blood-feeding ecology of mosquitoes in two zoological gardens in the United Kingdom. *Parasites Vectors*. 14(249). ISSN: 1756-3305. https://doi.org/10.1186/s13071-021-04735-0

HEYM EC, Kampen H, Krone O, Schäfer M, Werner D. 2019. Molecular detection of vector-borne pathogens from mosquitoes collected in two zoological gardens in Germany. *Parasitology Research*. 118(3):2097–2105. ISSN: 1432-1955. https://doi.org/10.1007/s00436-019-06327-5

HUANG X, Huang D, Liang Y, Zhang L, Yang G, Peng Y, Deng W, Dong L. 2020. A new protocol for absolute quantification of haemosporidian parasites in raptors and comparison with current assays. *Parasites Vectors*. 13:354. ISSN: 1756-3305. https://doi.org/10.1186/s13071-020-04195-y

INUMARU M, Yamada A, Shimizu M, Ono A, Horinouchi M, Shimamoto T, Tsuda Y, Murata K, Sato Y. 2021. Vector incrimination and transmission of avian malaria at an aquarium in Japan: mismatch in parasite composition between mosquitoes and penguins. *Malaria Journal*. 20(136). ISSN: 14752875. https://doi.org/10.1186/s12936-021-03669-3

KNOWLES SCL, Palinauskas V, Sheldon BC. 2010. Chronic malaria infections increase family inequalities and reduce parental fitness: experimental evidence from a wild bird population. *Journal of Evolutionary Biology*. 23(3):557–569. ISSN: 1420-9101. https://doi.org/10.1111/j.1420-9101.2009.01920.x

KOENIG WD. 2020. What are the competitive effects of invasive species? Forty years of the Eurasian collared-dove in North America. Biological Invasions. 22:3645–3652. ISSN: 1573-1464. https://doi.org/10.1007/s10530-020-02350-1

LEE KA, Martin LB, Hasselquist D, Ricklefs RE, Wikelski M. 2006. Contrasting adaptive immune defenses and blood parasite prevalence in closely related Passer sparrows. *Oecologia*. 150:383–392. ISSN: 1432-1939. https://doi.org/10.1007/s00442-006-0537-6

LEGA J, Brown HE, Barrera R. 2017. *Aedes aegypti* (Diptera: Culicidae) abundance model improved with relative humidity and precipitation-driven egg hatching. *Journal of medical entomology*. ISSN: 00222585. 54(5):1375-1384. https://doi.org/10.1093/jme/tjx077

LOISEAU C, Harrigan RJ, Cornel AJ, Guers SL, Dodge M, Marzec T, Carlson JS, Seppi B, Ravinder NM. 2012. First Evidence and Predictions of *Plasmodium* Transmission in Alaskan Bird Populations. *Plos One.* ISSN: 1932-6203. https://dx.doi.org/10.1371%2Fjournal.pone.0044729

LONGMIRE JL, Lewis AK, Brown NC, Buckingham JM, Clark LM, Jones MD, Meincke LJ, Meyne J, Ratliff RL, Ray FA, Wagner RP, Moyzis RK. 1988. Isolation and molecular characterization of a highly polymorphic centromeric tandem repeat in the family Falconidae. *Genomics.* 2(1):14–24. ISSN: 0888-7543. https://doi.org/10.1016/0888-7543(88)90104-8

LYNTON-JENKINS JG, Bründl AC, Cauchoix M, Lejeune LA, Sallé L, Thiney AC, Russell AF, Chaine AS, Bonneaud C. 2020. Contrasting the seasonal and elevational prevalence of generalist avian haemosporidia in co-occurring host species. *Ecology and evolution*. 10(12):6097–6111. ISSN: 2045-7758. https://doi.org/10.1002/ece3.6355

MARTÍNEZ-PÉREZ P, Hyndman TH, Fleming PA, Vaz PK, Ficorilli NP, Wilks CR. 2021. A widespread novel gammaherpesvirus in apparently healthy wild quokkas (*Setonix brachyurus*): a threatened and endemic wallaby of western Australia. *Journal of Zoo and Wildlife Medicine.* 52(2):592–603. ISSN: 1937-2825. https://doi.org/10.1638/2020-0029

MURIEL, J. 2020. Evaluación ecofisiológica de las infecciones por hemosporidios sanguíneos en aves. *Ecosistemas.* 29(2):1979. ISSN: ISSN 1697-2473. https://doi.org/10.7818/ECOS.1979

NATH T, Bhuiyan M, Alam M. 2014. A study on the presence of leucocytozoonosis in pigeon and chicken of hilly districts of Bangladesh. *Biological Sciences and Pharmaceutical Research*. 2(2): 13–18. ISSN: 2350-1588. https://journalissues.org/ibspr/wp-content/uploads/sites/6/2014/02/Nath-et-al.pdf

NEBEL C, Harl J, Pajot A, Weissenböck H, Amar A, Sumasgutner P. 2020. High prevalence and genetic diversity of *Haemoproteus columbae* (Haemosporida: Haemoproteidae) in feral pigeons Columba livia in Cape Town, South Africa. *Parasitology Research*. 119:447–463. ISSN: 1432-1955. https://doi.org/10.1007/s00436-019-06558-6

NODEN, BH, Bradt, DL, Sanders, JD. 2021. Mosquito-borne parasites in the Great Plains: searching for vectors of nematodes and avian malaria parasites. *Acta Tropica*. 213:105735. ISSN:0001-706X. https://doi.org/10.1016/j.actatropica.2020.105735

OTIS DL, Schulz JH, Miller D, Mirarchi RE, Baskett TS. 2020. Mourning Dove (*Zenaida macroura*), version 1.0. En Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.moudov.01

PALINAUSKAS V, Valkunias G, Bolshakov CV, Bensch S. 2011. *Plasmodium relictum* (lineage SGS1) and *Plasmodium ashfordi* (lineage GRW2): The effects of the co-infection on experimentally infected passerine birds. *Experimental Parasitology*. 127(2):527–33. ISSN: 00144894. https://doi.org/10.1016/j.exppara.2010.10.007

PATERSON S, Lello J .2003. Mixed models: getting the best use of parasitological data. *Trends in Parasitology*. 19:370–375. ISSN: 1471-5007. https://doi.org/10.1016/s1471-4922(03)00149-1

QUIAGEN. 2021. DNeasy Blood & Tissue Kits Handbook. https://www.qiagen.com/us/resources/resourcedetail?id=68f29296-5a9f-40fa-8b3d-1c148d0b3030&lang=en

R CORE TEAM (4.0.5). 2021. [Software]. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/

REICZIGEL J, Marozzi M, Fábián I, Rózsa L. 2019. Biostatistics for parasitologists – a primer to Quantitative Parasitology. *Trends in Parasitology*. 35(4)277–281. ISSN: 1471-5007. https://doi.org/10.1016/j.pt.2019.01.003

REINOSO-PÉREZ MT, Canales-Delgadillo JC, Chapa-Vargas L, Riego-Ruiz L .2016. Haemosporidian parasite prevalence, parasitaemia , and diversity in three resident bird species at a shrubland dominated landscape of the Mexican highland plateau. *Parasites Vectors.* 9:307. ISSN: 1756-3305.
https://doi.org/10.1186/s13071-016-1569-3

ROCHA SL, Guimarães JP, Barbosa De Oliveira, CY, Nader C. 2021. Current status of Brazilian scientific production on non-native species. *Ethology Ecology & Evolution.* ISSN: 0394-9370. https://doi.org/10.1080/03949370.2020.1870570

RÓZSA L, Reiczigel J, Majoros G. 2000. Quantifying parasites in samples of hosts. *Journal of Parasitology*. 86:228–232. ISSN: 0022-3395. https://doi.org/10.1645/0022-3395(2000)086[0228:qpisoh]2.0.co;2

SALAZAR-BORUNDA MA, Martínez-Guerrero JH, Pereda-Solís ME, Delgado-León T, Sierra-Franco D. 2019. Phenotypic variation in eurasian collared dove (*Streptopelia decaocto* Frivaldszky) in Durango, Mexico. *AgroProductividad*. 12(10). ISSN: 2594-0252. http://dx.doi.org/10.32854/agrop.vi0.1461

SANTIAGO-ALARCÓN D, Carbó-Ramírez P. 2015. Parásitos sanguíneos de malaria y géneros relacionados (Orden: Haemosporida) en aves de México: recomendaciones metodológicas para campo y laboratorio. *Ornitología Neotropical.* 26(1):59–77. ISSN 1075–4377. https://journals.sfu.ca/ornneo/index.php/ornneo/article/view/13

SCHUMM, YR, Bakaloudis D, Barboutis C, Cecere JG, Eraud C, Fischer D, Hering J, Hillerich K, Lormée H, Mader V, Masello JF, Metzger B, Rocha G, Spina F, Quillfeldt, P. 2021. Prevalence and genetic diversity of avian haemosporidian parasites in wild bird species of the order Columbiformes. *Parasitology Research*. 120(4):1405-1420. ISSN: 1432-1955. https://doi.org/10.1007/s00436-021-07053-7

STARKLOFF NC, Turner WC, FitzGerald AM, Oftedal MC, Martinsen ES, Kirchman JJ. 2021. Disentangling the effects of host relatedness and elevation on haemosporidian parasite turnover in a clade of songbirds. *Ecosphere*. 12(5): e03497. ISSN: 2150-8925.
https://doi.org/10.1002/ecs2.3497 https://doi.org/10.1002/ecs2.3497

STILMMELMAYR R, Stefani LM, Thrall MA, Landers K, Revan F, Miller A, Beckstead R, Gerhold R. 2012. Trichomonosis in free-ranging Eurasian collared doves (*Streptopelia decaocto*) and African collared dove hybrids (*Streptopelia risoria*) in the Caribbean and description of ITS -1 region genotypes. *Avian Diseases*. 56(2):451–455. ISSN: 0005-2086. https://doi.org/10.1637/9905-082311-case.1

TAVASSOLI M, Esmaeilnejad B, Malekifard F, Mardani K. 2018. PCR-RFLP detection of Haemoproteus spp. (Haemosporida: Haemoproteidae) in pigeon blood samples from Iran. *Bulgarian Journal of Veterinarian Medicine*. 21(4):429–435. ISSN: 1311-1477. https://doi.org/10.15547/bjvm.2014

VALKIŪNAS G, Iezhova TA. 2017. Exo-erythrocytic development of avian malaria and related haemosporidian parasites. *Malaria Journal.* 16(1):1–24. ISSN: 14752875. https://doi.org/10.1186/s12936-017-1746-7

VALKIŪNAS G, Iezhova TA. 2018. Keys to the avian malaria parasites. *Malaria Journal.* 17(1):1-24. ISSN: 1475-2875. https://doi.org/10.1186/s12936-018-2359-5

VENABLES WN, Ripley BD. 2002. *Modern Applied Statistics with S*, Fourth edition. Springer, New York. ISBN 0-387-95457-0. https://www.stats.ox.ac.uk/pub/MASS4/

VILLALVA-PASILLAS D, Medina JP, Soriano-Vargas E, Martínez-Hernández DA, García-Conejo M, Galindo-Sánchez KP, Sánchez-Jasso JM, Martín-Talavera-Rojas M, Salgado-Miranda C. 2020. Haemoparasites in endemic and non-endemic passerine birds from central Mexico highlands. *International Journal for Parasitology: Parasites and Wildlife*. 11:88–92. ISSN: 2213-2244.
https://doi.org/10.1016/j.ijppaw.2019.12.007

WHITE EM, Greiner EC, Bennett GF, Herman CM. 1978. Distribution of hematozoa of Neotropical birds. *Revista de Biología Tropical*. 1: 43–102. ISSN: 0034-7744.
https://pubmed.ncbi.nlm.nih.gov/108771/

WILEY-BLACKWELL, New York. USA. ISBN: 978-1-444-31619-3. https://www.wiley.com/en-us/Atlas+of+Clinical+Avian+Hematology-p-9781444316193

WOOD MJ, Cosgrove CL, Wilkin TA, Sknowles C, Day KP, Sheldon BC. 2007. Within-population variation in prevalence and lineage distribution of avian malaria in blue tits, *Cyanistes caeruleus*. *Molecular Ecology*. 16(15):3263–3273. ISSN: 0962-1083. https://doi.org/10.1111/j.1365-294x.2007.03362.x

YANGA S, Martinez-Gomez JE, Sehgal RNM, Escalante P, Camacho FC, Bell DA. 2011. A preliminary survey for avian pathogens in Columbiformes birds on Socorro Island, Mexico. *Pacific Conservation Biology*. 17(1):11–20. ISSN: 1038-2097. https://doi.org/10.1071/PC110011

YOSHIMOTO M, Ozawa K, Kondo H, Echigoya Y, Shibuya H, Sato Y, Sehgal RN. 2021. A fatal case of a captive snowy owl (*Bubo scandiacus*) with *Haemoproteus* infection in Japan. *Parasitology Research.* 120(1):277–288. ISSN: 1432-1955. https://doi.org/10.1007/s00436-020-06972-1

Errata Erratum

https://abanicoacademico.mx/revistasabanico-version-nueva/index.php/abanico-veterinario/errata