MEDWIN PUBLISHERS
Committed to Create Value for Researchers

International Journal of Zoology and Animal Biology
ISSN: 2639-216X

History of the Study of Avian Haemosporidian Parasites in A Neotropical Country: Venezuela

Romero J[1] and Silva-Iturriza A[2]*

[1]Chair of Research Project and Research Work Profa, Faculty of Health Sciences (FCS), University of Carabobo, Venezuela

[2]Laboratory of Transdisciplinary Ecology for Human Wellbeing, Venezuelan Institute for Scientific Research (IVIC), Venezuela

Mini Review

Volume 6 Issue 2

Received Date: February 09, 2023

Published Date: March 09, 2023

DOI: 10.23880/izab-16000452

***Corresponding author:** Adriana Silva-Iturriza, Laboratory of Transdisciplinary Ecology for Human Wellbeing. Ecology Center, Venezuelan Institute for Scientific Research (IVIC), Caracas, Venezuela, Email: silvaiturriza@gmail.com

Abstract

Venezuela has a remarkable presence of endemic birds from the Neotropical region. Therefore, the study of avian haemosporidian parasites (*Plasmodium, Haemoproteus, Leucocytozoon*) in Venezuela should be a priority task for conservation projects, as well as for understanding adaptive processes of the parasite-host-vector triad. The objective of this mini-review is to rescue the most relevant contributions of the study of these parasites in Venezuela and the potentialities derived from them. The greatest contribution reported so far comes from a series of parasitological diagnoses in birds carried out from 1972 to 1990. From these studies, a blood smear collection of wild and captive birds infected with haemosporidian parasites was created (approximately 23000 blood smear), describing 15 species of these parasites. This extensive collection of blood smears could be used as source material to answer many questions, such as the large-scale spatiotemporal distribution patterns of avian haemosporidian parasites in Venezuela.

Keywords: *Plasmodium; Haemoproteus; Leucocytozoon*; Endemism; Bird

Introduction

The most studied avian haemosporidian parasites (phylum Apicomplexa, order Haemosporida) belong to the genera *Plasmodium*, *Haemoproteus* and *Leucocytozoon* [1-3]. The transmission of these parasites depends on dipteran vectors that present certain specificity in terms of the bird species on which they feed and, therefore, the species to which they transmit the infection [4,5]. The adaptation of these parasites to each colonized host and vector has grouped them into several subgenera according to host and vector characteristics [5,6]. When and how often haemosporidian parasites pass from birds to mammals remain a matter of debate [7]. Despite taxonomic differences among all haemosporidian parasites, their development and transmission cycle are similar in several aspects. The study of haemosporidian parasites in a manageable hosts such as birds has been very useful to understand several aspects of their infection process in less manageable hosts such as humans [8].

The study of avian haemosporidian parasites in Venezuela arose as a consequence of the study of the haemosporidian parasites species that cause human malaria: *Plasmodium falciparum, P. vivax, P. malariae, P. ovale, P. knowlesi*. Several researchers collaborated in the fight against human malaria, starting with the research group of Dr. Arnoldo Gabaldón, who were looking for a model organism to study various aspects of *Plasmodium* parasites. They began with monkeys, without any success; later and following the lead of other researchers who had found birds infected with *Plasmodium*, Dr. Gabaldón decided to use birds as a model organism [5,9]. During this time, a collection of blood smears from both wild and captive birds infected with haemosporidian parasites was created; this collection has 221 original records and 22,989 replicates in experimental models, from the 1970s to the 1990s [10].

This mini-review aims to rescue the most relevant contributions on the study of avian haemosporidian parasites in Venezuela and the potentialities derived from them.

Main Contributions of the Study of Avian Haemosporidian Parasites In Venezuela

The greatest contribution reported so far comes from the bird parasitological censuses carried out from 1972 to 1990 by Dr. Arnoldo Gabaldón and collaborators. During the first year of the study, 3498 birds were evaluated, finding that the Venezuelan avifauna is largely composed by endemic species to the Neotropical region. This finding made these researchers believed that the haemosporidian parasites identified in the country may be the product of an evolutionary process of the *Mutatis mutandis* type, which must have originated parasites species specific to the Neotropical region, since their hosts are geographically isolated species [5]. By 1974, 8565 birds were evaluated, identifying simple and mixed infections by the genera *Plasmodium* and *Haemoproteus* [11]. Subsequently, the characterization of neotropical haemosporidian parasites began, and in this context, *Plasmodium* (Novyella) *juxtanucleare* was reported and characterized for the first time in Venezuela [12]. In 1976, they reported *Plasmodium (Haemamoeba) lutzi* describing their exoerythrocytic forms [13]. The following year (1977), they detailed the erythrocytic and exoerythrocytic cycle of a new species of avian malarial parasite, *Plasmodium (Haemamoeba) tejerai*, which was found in a domestic turkey (*Meleagris gallipavo*) [14]. In 1978, they described a subspecies of *Haemoproteus rotundus* under the name *H. r. ortalidum*, a parasite found in *Ortalis ruficauda* (Galliformes: Cracidae), endemic bird to Venezuela and to some of the Lesser Antilles [15]. In the 1972-1990 time series, 12 *Plasmodium*, 2 *Haemoproteus* and 1 *Leucocytozoon* species were morphologically characterized [5].

After this great research effort, monitoring of haemosporidian parasites in birds decreased at the national level until the first decade of the 2000s, when these studies were resumed and several works published [16-18]. More recently, Valera and collaborators evaluated 262 birds of the family Columbidae sampled during 2012-2015 in 10 localities of Venezuela with characteristics of migratory passage and reserve of importance for birds, finding by microscopic examination a prevalence of 64% for *Haemoproteus* and 40.5% for *Plasmodium* [19]. Finally, we cite the work done by Sanz, et al. [20], who through amplification and sequencing of a mitochondrial barcode (cytb), evaluated the frequency of avian haemosporidian parasites in 366 birds belonging to 23 species from Margarita and Coche islands, Venezuela; reporting a frequency of these parasites more than double in subspecies of birds endemic to Margarita Island (endemic = 7.3% vs. non-endemic = 3.1%, N = 342), but this difference was not significantly different. These and other contributions are summarized in Table 1.

Parasite species	***Bird Host species***	**Reference**
Plasmodium (Haemamoeba) relictum	*Euphonia violacea (Thraupidae) Notiochelidon cyanoleuca (Hirundinidae)*	[21]
Plasmodium (Haemamoeba) relictum	*Coryphospingus pileatus (Fringillidae)*	[22]
Plasmodium (Haemamoeba) cathemerium	*Quiscalus lugubris, Agelaius icterocephalus (Icteridae)*	[23]
Plasmodium (Huffia) elongatum	*Columba livia (Columbidae)*	[24]
Plasmodium (Novyella) vaughani	*Zonotrichia capensis (Emberizidae)*	[25]
Plasmodium (Novyella) vaughani	*Psarocolius viridis, Quiscalus lugubris (Icteridae)Tachyphonus rufus (Thraupidae)*	[22]
Plasmodium (Giovannolaia) circumflexum	*Chlorophonia cyanea (Fringillidae), Tangara gyrola (Thraupidae)*	[22]
Plasmodium (Novyella) nucleophilum	*Cyanocorax olivaceus (Corvidae)*	[22]
Plasmodium (Haemamoeba) lutzi	*Aramides cajanea cajanea (Rallidae)*	[13]
Plasmodium (Novyella) juxtanucleare	*Gallus gallus (Phasianidae)*	[24,25]
Plasmodium (Novyella) columbae	*Columba livia (Columbidae)*	[26]
*Plasmodium (Giovannolaia) gabaldoni**	*Cairina moschata (Anatidae)*	[22]

*Plasmodium (Haemamoeba) tejerai**	*Meleagris gallopavo (Phasianidae)*	[14]
*Plasmodium (Novyella) bertii**	*Aramides cajanea (Rallidae)*	[27]
*Haemoproteus ortalidum**	*Ortalis ruficauda (Cracidae)*	[15]
*Haemoproteus cracidarum**	*Ortalis ruficauda (Cracidae)*	[28]
Leucocytozoon sp.	*Columba livia (Columbidae)*	[5]
Plasmodium sp.	*Pipreola formosa (Cotinginae) Atlapetes semirufua, Zonotrichia capensis (Emberizidae) Grallaricula loricata (Formicariidae) Basileuterus griseiceps, Parkesia noveboracensis (Parulidea) Pyrrhura hoematotis (Psittacidae) Dysithammus mentalis (Thamnophilidae) Euphonia xanthogaster, Tangara arthus (Thraupidae) Platycichla flavipes, Turdus olivater (Turdidae) Sternoclyta cyanopectus (Trochilidae) Henicorhina leucophrys (Troglodytidae)*	[16]
Haemoproteus sp.	*Pipreola formosa (Cotinginae) Atlapetes semirufua, A. schistaceus, Buarremon torquatus, Zonotrichia capensis (Emberizidae) Myrmotherula schisticolor (Thamnophilidae)Anisognathus lacrymosus, Chlorospingus cyanea, Diglossa venezuelensis, Dubusia taeniata, Tangara cyanicollis, T. guttata, T. gyrola (Thraupidae) Turdus olivater, T. serranus (Turdidae)*	[16]
Plasmodium sp.	*Mimus gilvus (Mimidae) Sublegatus arenarum (Tyrannidae) Cardinalis phoeniceus (Cardinalidae) Thraupis glaucocolpa (Thraupidae) Icterus nigrogularis (Icteridae) Dendroplex picus (Furnariidae) Sublegatus arenarum (Tyrannidae)*	[17]
Haemoproteus sp.	*Cardinalis phoeniceus (Cardinalidae) Icterus nigrogularis (Icteridae) Melanerpes rubricapillus (Picidae) Eupsittula pertinax (Psittacidae) Dendroplex picus (Furnariidae) Sakesphorus canadensis, Formicivora intermedia (Thamnop hilidae) Cardinalis phoeniceus (Cardinalidae) Tiaris bicolor, Thraupis glaucocolpa, Coryphospingus pileatus, Saltator coerulescens (Thraupidae) Mimus gilvus (Mimidae)*	[17]
Plasmodium sp.	*Formicarius analis, Chamaeza campanisona (Formicariidae)*	[18]
Haemoproteus sp.	*Geotrygon linearis (Columbidae) Chlorospingus ophthalmicus (Thraupidae)*	[18]
Leucocytozoon sp.	*Parkesia noveboracensis (Parulidae)*	[18]
Plasmodium haemamoeba lutzi	*Mimus gilvus (Mimidae)*	[29]
Haemoproteus cracidarum	*Columbina squammata (Columbidae)*	[29]
Haemoproteus ortalidum	*Columbina squammata (Columbidae)*	[29]
Plasmodium sp.	*Zenaida auriculata, Columbina squammata (Columbidae) Mimus gilvus (Mimidae) Melanospiza bicolor, Sporophila intermedia, Thraupis episcopus (Thraupidae) Icterus nigrogularis, Quiscalus lugubris, Molothrus bonariensis (Icteridae)*	[29]
Haemoproteus sp.	*Columbina squammata, Columbina passerina (Columbidae)*	[29]
Haemoproteus spp.	*Columbina minuta, C. passerina, C. squammata, C. talpacoti, Leptotila verreauxi Zenaida auriculata (Columbidae)*	[19]
Plasmodium spp.	*Columbina minuta, C. passerina, C. squammata, C. talpacoti, Leptotila verreauxi, Zenaida auriculata (Columbidae)*	[19]

Haemoproteus (Parahaemoproteus) sp.	*Columbina squammata (Columbidae) Hypnelus ruficollis stoicus (Psittacidae) Mimus gilvus (Mimidae) Thamnophilus doliatus (Thamnophilidae) Cardinalis phoeniceus (Cardinalidae) Icterus nigrogularis helioeides, Icterus icterus (Icteridae)*	[20]
Haemoproteus (Haemoproteus) sp.	*Leptotila verreauxi (Columbidae)*	[20]
Plasmodium sp.	*Columbina passerina (Columbidae)*	[20]
Leucocytozoon sp.	*Setophaga striata (Parulidae)*	[20]

*Parasite species describe for the first time.

Table 1. Studies of avian haemosporidian parasites in Venezuela from 1916 to 2021.

Potentialities in Venezuela for the Study of Avian Haemosporidian Parasites

The geological history of Venezuela, together with the research trajectory carried out in the region, make this South American country an interesting and priority region for the study of avian haemosporidian parasites. In this context, it is important to point out that the South American region was separated from Africa at the latest during the Jurassic period, about 150 million years ago, when the class Aves had barely differentiated. Then, during the Eocene (about 50 million years ago) it joined Central America. Later, during the Miocene (about 20 million years ago) this large island joined North America. Therefore, the Neotropical avifauna has practically no influence from the Ethiopic or Australasian Regions, having probably only influence from the Palearctic Region through the Nearctic [5]. It is very likely that this geographic isolation greatly contributed to the speciation of birds [30], also producing a marked repercussion in the speciation of the haemosporidian hosted by them. Recently, a meta-analysis conducted in the tropical Andean region reveals that areas of avian endemism are associated with a differential spatial distribution of haemosporidian diversity [31]. In the context of the global crisis of biodiversity loss, it is important to establish species rarity and endemism as fundamental criteria for conservation [32]. Therefore, given the large proportion of Neotropical endemic birds in Venezuela, this should be a priority country for studies aimed at understanding the consequences of these parasites on the functionality and behavior of the birds which host them [33], to understand how the structure of the bird community influences the exploitation strategy followed by haemosporidian parasites [34], to understand the socio-environmental factors that modulate their transmission among other interesting studies that could be developed in Venezuela [35,36].

Conclusions

The great value of the avifauna in the Neotropical region makes it a priority area for the study of haemosporidian parasites. The presence in Venezuela of endemic birds to the Neotropical region, plus the extensive collection of blood smears of birds infected with haemosporidian parasites collected in Venezuela, are compelling reasons to continue these studies in the country. It is recommended to genetically characterize the most representative specimens of the collection, as well as to continue with the annual avian monitoring with the respective parasitological examinations.

Acknowledgements

The present study was supported by the Autonomous Service Institute of Higher Studies “Dr. Arnoldo Gabaldón” (IAE) and by the Venezuelan Institute for Scientific Research (project number 1365). Noemí Chacón, Mariela López-Gasca, Juan Carlos Freites and an anonymous reviewer made relevant comments to improve the original manuscript.

References

1. Barrow LN, Bauernfeind SM, Cruz PA, Williamson JL, Wiley DL, et al. (2021) Detecting turnover among complex communities using null models: a case study with sky-island haemosporidian parasites. Oecologia 195(2): 435-451.

2. Miranda-Paez A, Chalkowski K, Zohdy S, Willoughby JR (2022) Management of avian malaria in populations of high conservation concern. Parasites and Vectors 15: 208.

3. Nourani L, Aliabadian M, Mirshamsi O, Djadid ND (2022) Prevalence of co-infection and genetic diversity of avian haemosporidian parasites in two rehabilitation facilities in Iran: implications for the conservation of captive raptors. Ecology and Evolution 22: 114.

4. Hellgren O, Bensch S, Malmqvist B (2008) Bird hosts, blood parasites and their vectors-associations uncovered by molecular analyses of blackfly blood meals. Molecular Ecology 17(6): 1605-1613.

5. Gabaldón A (1998) Malaria Aviaria en un país de la región neotropical Venezuela. Fondo Editorial Interfundaciones.

Caracas, Venezuela pp: 1-344.

6. Pacheco MA, Matta NE, Valkiūnas G, Parker PG, Mello B, et al. (2018) Mode and Rate of Evolution of Haemosporidian Mitochondrial Genomes: Timing the Radiation of Avian Parasites. Molecular Biology and Evolution 35(2): 383-403.

7. Galen SC, Borner J, Martinsen ES, Schaer J, Austin CC, et al. (2018) The polyphyly of *Plasmodium*: comprehensive phylogenetic analyses of the malaria parasites (order Haemosporida) reveal widespread taxonomic confict. The Royal Society Open Science 5: 171780.

8. Valkiūnas G (2005) Avian malaria parasites and other haemosporidia. Florida, USA, CRC Press pp: 1-936.

9. Garnham PCC (1977) A new malaria parasite of pigeons and ducks from Venezuela. Protistologica. 23(1): 113-125.

10. Gabaldon A (2016) Colección de Parásitos Maláricos y otros Haemosporidios en aves. Boletín de Malariología y Salud Ambiental 56(1): 89-90.

11. Gabaldón A (1975) Datos hematológicos e histológicos útiles en el estudio de la malaria aviaria. Boletín Informativo de la Dirección de Malariología y Saneamiento Ambiental 15(5): 161-200.

12. Gabaldón A, Ulloa G, González T (1976) Presencia en Venezuela de *Plasmodium (Novyella) juxtanucleare* Versiani y Gómez, 1941. Boletín Informativo de la Dirección de Malariología y Saneamiento Ambiental 16(1): 3-12.

13. Gabaldón A, Ulloa G (1976) Las formas exoeritrocíticas de *Plasmodium (Haemamoeba) lutzi* Lucena, 1939 y presencia de esta especie en Venezuela. Boletín Informativo de la Dirección de Malariologia y Saneamiento Ambiental 16(4): 299-311.

14. Gabaldón A, Ulloa G (1977) *Plasmodium (Haemamoeba) tejerai* sp. n. del pavo doméstico (*Meleagris gallopavo*) de Venezuela. Boletín Informativo de la Dirección de Malariologia y Saneamiento Ambiental 17(4): 255-273.

15. Gabaldón A, Ulloa G (1978) Subespecie de *Haemoproteus rotundus* Oliger, 1956 (Haemosporina: Haemoproteidae) presente en Venezuela. Boletín Informativo de la Dirección de Malariología y Saneamiento Ambiental 18(3): 165-174.

16. Castillo A (2008) Prevalencia e intensidad de hemoparásitos en aves montanas de Venezuela. In: Escuela de Biología. Universidad Central de Venezuela, Caracas, pp: 1-59.

17. Belo NO, Rodríguez-Ferraro A, Braga EM, Ricklefs RE (2012) Diversity of Avian Haemosporidians in Arid Zones of Northern Venezuela. Parasitology 139(8): 1021-1028.

18. Mijares A, Rosales R, Silva-Iturriza A (2012) Hemosporidian Parasites in Forest Birds from Venezuela: Genetic Lineage Analyses. Avian Diseases 56(3): 583-588.

19. Valera KR, Velásquez LD, Silva-Sánchez CJ, Arevalo CO, Romero-Palmera J (2017) Hemoparásitos en aves Columbidae de Venezuela 2012-2015. Boletín de Malariología y Salud Ambiental LV II (2): 69-79.

20. Sanz V, Mijares A, Rosales R, Silva-Iturriza A (2021) Frequency of avian haemosporidian parasites in birds from Margarita and Coche islands, Venezuela. Ornitología Neotropical 32: 62-67.

21. Iturbe J, González E (1916) El paludismo de las aves en Venezuela. Vargas 7: 363-369.

22. Gabaldón A, Ulloa G, de Montcourt AG (1974) Encuesta sobre la malaria aviaria en Venezuela: Resultados del primer año. Boletín Informativo de la Dirección de Malariología y Saneamiento Ambiental 14(3-4): 80-103.

23. Gabaldón A, Ulloa G, Zerpa N (1988) *Plasmodium cathemerium*, cepa de Icteridae inoculable a palomas, patos y pavos: sus vectores y utilidad en enseñanza e investigación. Boletín de la Dirección de Malariología y Saneamiento Ambiental 28(3-4): 53-68.

24. Gabaldón A, Ulloa G, de Montcourt AG (1975) Encuesta sobre la malaria aviaria en Venezuela: Resultados del segundo año. Boletín Informativo de la Dirección de Malariología y Saneamiento Ambiental 15(3-4): 73-92.

25. Gabaldón A (1938) Primer informe annual (1937) de la Dirección de Malariología. Boletín del Ministerio de Sanidad y Asistencia Social pp: 139-355.

26. Gabaldón A, Ulloa G (1976) Revalidación y redescripción de *Plasmodium columbae* Carini, 1912. Boletín de la Dirección de Malariología y Saneamiento Ambiental 16(2): 93-106.

27. Gabaldón A, Ulloa G (1981) A new species of the subgenus Novyella (Haemosporina, Plasmodidae) from *Aramides cajanea* (Gruiformes, Rallidae). Parasitological tropics. Kansas Society of Protozoologists pp: 100-105.

28. Bennett GF, Gabaldón A, Ulloa G (1982) Avian Haemoproteidae 17. The Haemoproteids of the avian family Cracidae (Galliformes); The guans, curassows, and Chachalacas. Canadian Journal of Zoology 60(12):

3105-3112.

29. Praderes G (2016) Prevalencia de parásitos malaricos y otros haemosporidios en aves en la estación Planetario Simón Bolívar, Maracaibo estado Zulia. In: Facultad de Ciencias Veterinarias. Universidad Central de Venezuela, Maracay pp: 1-65.

30. Prieto-Torres DA, Rojas-Soto OR, Santiago-Alarcon D, Bonaccorso E, Navarro-Sigüenza AG (2019) Diversity, Endemism, Species Turnover and Relationships among Avifauna of Neotropical Seasonally Dry Forests. Ardeola 66(2): 257-277.

31. Gil-Vargas DL, Sedano-Cruz RE (2019) Genetic variation of avian malaria in the tropical Andes: a relationship with the spatial distribution of hosts. Malaria Journal 18: 129.

32. Burlakova LE, Karatayev AY, Karatayev VA, May ME, Bennett DL, et al. (2011) Endemic species: Contribution to community uniqueness, effect of habitat alteration, and conservation priorities. Biological Conservation 144(1): 155-165.

33. Remacha C, Ramírez Á, Arriero E, Pérez-Tris J (2023) Haemosporidian infections influence risk-taking behaviours in young male blackcaps, Sylvia atricapilla. Animal Behaviour 196: 113-126.

34. Garcia-Longoria L, Muriel J, Magallanes S, Villa-Galarce ZH, Ricopa L, et al. (2021) Diversity and host assemblage of avian haemosporidians in different terrestrial ecoregions of Peru. Current Zoology 1(68): 27-40.

35. Fecchio A, Clarks NJ, Bell JA, Skeen HR, Lutz HL, et al. (2021) Global drivers of avian haemosporidian infections vary across zoogeographical regions. Global Ecology and Biogeography 30: 2393-2406.

36. Vinagre-Izquierdo C, Bodawatta KH, Chmel K, Renelies-Hamilton J, Paul L, et al. (2021) The drivers of avian haemosporidian prevalence in tropical lowland forest of New Guinea in three dimensions. Ecology and Evolution 12: e8497.