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Review

Current Knowledge of Helminths of Wild Birds in Ecuador

Patricio D. Carrera-Játiva [1,2,*] **and Gustavo Jiménez-Uzcátegui** [3]

1. Escuela de Graduados, Facultad de Ciencias Veterinarias, Universidad Austral de Chile, 5110566 Valdivia, Chile
2. Carrera de Medicina Veterinaria, Facultad Agropecuaria y de Recursos Naturales Renovables, Universidad Nacional de Loja, 110110 Loja, Ecuador
3. Charles Darwin Research Station, Charles Darwin Foundation, Puerto Ayora, 200101 Galápagos, Ecuador; gustavo.jimenez@fcdarwin.org.ec

* Correspondence: patricio.carrera.j@gmail.com

Simple Summary: In the present review, information about parasitic helminths (Platyhelminthes, Nematoda, and Acanthocephala) of wild birds in Ecuador is presented based on a PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) systematic search. Data were obtained from ten scientific articles, eight undergraduate theses, and one doctoral dissertation, published between 1966 to 2022. Forty helminth taxa were recorded, and information about the host species, site of infection, and location are provided. This review serves as a compendium for future ecological and epidemiological studies on helminths in wild birds from Ecuador.

Abstract: Parasitic helminths are diverse in wild birds globally, but knowledge about helminths in Ecuadorian avifauna is still fragmentary. In the present review, records about helminths (Platyhelminthes, Nematoda, and Acanthocephala) in Ecuadorian wild birds is presented. A systematic search was carried out using the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) guideline to compile and summarize the available literature on helminths in wild birds in Ecuador. Data were obtained from ten scientific articles, eight undergraduate theses, and one doctoral dissertation, published between 1966 to 2022. Forty helminth taxa were recorded and information about the host species, site of infection, and location are provided. Nematodes of the genus *Ascaridia* Dujardin, 1844 were the helminth taxa with the greatest number of records in birds, parasitizing 16 avian species. Also, the Rock Dove (*Columba livia*; Gmelin, 1789) was the avian species with the greater number of helminth records (n = 11). This review serves as a compendium for future ecological and epidemiological studies on helminths in wild birds in Ecuador and South America.

Keywords: parasites; Nematoda; Cestoda; Trematoda; Acathocephala; avifauna

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Citation: Carrera-Játiva, P.D.; Jiménez-Uzcátegui, G. Current Knowledge of Helminths of Wild Birds in Ecuador. *Birds* **2024**, *5*, 102–114. https://doi.org/10.3390/birds5010007

Academic Editor: Jukka Jokimäki

Received: 22 December 2023
Revised: 29 January 2024
Accepted: 30 January 2024
Published: 2 February 2024

1. Introduction

Parasitic helminths are metazoan (i.e., multicellular) organisms classified in three phyla: Platyhelminthes (class Cestoda and Trematoda), Nematoda, and Syndermata: Acanthocephala [1,2]. The global diversity of helminths in vertebrates is immense, with an estimation of approximately 10,000 to 350,000 described extant species that use vertebrate animals as hosts, of which 80–90% are still unknown and thus undescribed [3,4]. From these data, 16% (24,144) of helminth species are estimated to be bird-specific [4].

Helminths play significant epidemiological and ecological roles in ecosystems. Helminths exhibit different kinds of life cycles; for example, some nematodes and certain cestodes (e.g., *Hymenolepis nana*) exhibit direct life cycles that require a single host to develop sexual maturity [1,5]. In contrast, most cestodes, trematodes, acanthocephalans, and some nematodes show complex life cycles with several hosts [1,6,7]. In hosts, helminths can have effects at individual and population levels. They can produce a variety of pathological conditions in individuals, which can range from mild and subclinical alterations such as a reduction in body condition, host survival, and reproduction to more severe impacts including tissue damage, bleeding, and mortality [1,8,9]. In the ecological context, helminths (mainly those highly host specific) play a key role in ecosystems' functioning since they have been demonstrated to cyclically regulate populations [10–12]. In this sense, some helminth infections, especially those low-host-specific and directly transmitted, may pose a threat to endangered avian populations living in altered environmental conditions and/or in individuals with other concomitant infections (e.g., bacteria, viruses) [13–15]. This is the reason why there is an increasing interest in understanding changes in helminth community structures and infection rates in wildlife living in natural and human-altered habitats [16–18].

Ecuador is considered one of the most biodiverse countries on Earth [19]. Mainland Ecuador is located over two of the five biodiversity hotspots in South America, including the Tropical Andes and the Tumbes-Chocó-Magdalena Corridor [19]. Also, the Galápagos Islands, part of the Republic of Ecuador and located 600 miles from mainland, exhibit a large number of endemic species, given its particular volcanic origin and the confluence of oceanic currents [20,21]. Diversity of birds amounts to approximately 1600 species in mainland Ecuador and 169 species in the Galápagos Islands [21,22].

Although there has been an increasing interest in detecting and surveying emergent and re-emergent pathogens and parasites in Ecuadorian avifauna (e.g., virus, bacteria, fungi, protozoa, and arthropods), knowledge of the diversity of helminths in wild birds in Ecuador is still very limited [14,23–26]; particularly, a summarizing review on helminths in wild birds in Ecuador has not yet been published. Limited information on helminths in Ecuadorian wild birds has precluded further analyses on their regional or global distribution, host specificity, and cross-species transmission. Furthermore, given that natural environments are being increasingly modified by human-induced activities, a better understanding on the presence of helminths in wild birds located in high diversity countries such as in Ecuador is essential to assessing the potential impact of habitat alteration on avian and public health. Therefore, the aim of the present study is to revise the available information on helminths recorded in wild birds in Ecuador. These data will serve as a baseline for future epidemiological and ecological studies of parasites in wild birds in Ecuador and South America.

2. Materials and Methods

2.1. Database Search

A systematic search was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) declaration guidelines [27]. Publications were searched in several online databases (Google Scholar Database (n = 2170) [28]; PMC PubMed Central® (n = 124) [29]; Web of Science Core Collection (n = 7) [30]; and, Scopus Database (n = 2) [31]) with the following topic search terms: ("birds" AND "Ecuador", AND "parasites" AND "helminths"). Additionally, terms in Spanish (i.e., "parasitos" AND "aves" AND "silvestres", AND "Ecuador") were searched in the Google Scholar database (n = 1820) [28] (see Figure 1).

Also, helminth records in birds were searched in the online repository of the Charles Darwin Foundation—Galapagos Species Checklist Datazone [32]. In this database, the categories Platyhelminths (marine; terrestrial), Nematoda (marine), and Pathogens and Parasites were inspected.

2.2. Study Selection

Studies were selected using the following inclusion criteria: reports in English or Spanish Language; papers that report wild bird birds as hosts either in captive or free-ranging conditions; reports that investigated helminth parasites of birds at least to class taxonomic level; studies carried out in mainland Ecuador or in the Galapagos Islands. Given the limited literature on this topic, information included were from both peer-review manuscripts and postgraduate and undergraduate dissertations.

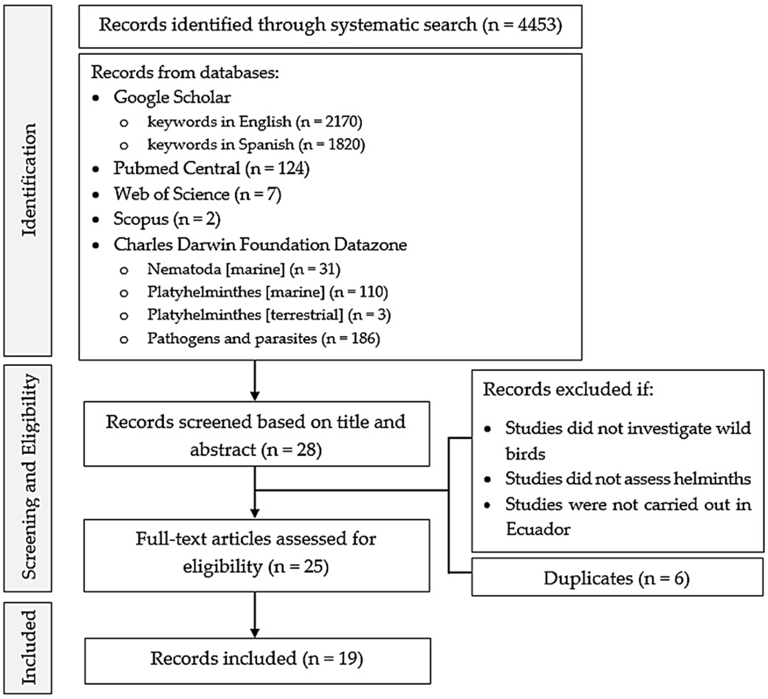

Figure 1. Simplified illustration of the record selection flow diagram following the PRISMA systematic search.

2.3. Data Extractions and Synthesis

For each study, extracted data included information about year of publication, reference (authors, year, journal title, volume, issue, pages), helminth species, avian host species, type of wild bird (captive or free-ranging), methods used for detection, site in host, and geographical location of the study. Bird taxonomy was standardized according to the South American Classification Committee (SACC) [33] and the IUCN list [34]. Parasite names were standardized using the WoRMS database [35] and the Global Biodiversity Information Facility [36]. Additionally, we obtained information about the host geographical scope (i.e., endemic) according to the IUCN threatened species Red List [34], and the conservation status of each avian species was obtained from the IUCN Ecuadorian Red List of Threatened Species [37] and Global IUCN [34].

3. Results

3.1. Publications

Of the 4453 academic documents that were retrieved from databases, nineteen studies included selected information on helminths in Ecuadorean wild birds, which consisted of ten scientific articles [38–47], eight undergraduate theses [48–55], and one doctoral dissertation [56] (Figure 1). The reviewed literature was published between 1966 to 2022, most of which (i.e., fourteen studies) was carried out between 2010 to 2022, and only five publications were available before 2009. In addition, 10 documents were available in Spanish, and 9 records were in English.

3.2. Helminth Taxa

Forty helminth taxa were identified in wild birds in Ecuador. Helminth taxa comprised two phyla, 28 (70%) of which belonged to Platyhelminthes (i.e., 21 parasite taxa were Trematoda, and seven taxa were Cestoda), and 12 (30%) were Nematoda. Parasite records included 17 nominal species, 17 taxa identified to the genus level, and 6 taxa identified to family or phylum levels. Nematodes of the genus *Ascaridia* spp. (Dujardin, 1844) were the helminths with the greatest number of records in birds, parasitizing 16 avian species. Records of helminths in wild birds in Ecuador are shown in Table 1.

Table 1. Checklist of helminths recorded in wild birds in Ecuador.

Helminth Species	Diagnostic Method [1]	Site in Host [2]	Host Species		Location	Ref.
			Name	IUCN Status [3]		
Cestoda						
Hymenolepididae						
Hymenolepis nana (Siebold, 1852)	Flot.	GI	Dusky-legged Guan (*Penelope obscura)* Temminck, 1815 [Cracidae; Galliformes]	VU	Pastaza	[53]
Hymenolepis sp. (Weinland, 1858)	Flot.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	LC	Azuay	[41]
	Flot.	GI	Crested Guan (*Penelope purpurascens*) Wagler, 1830 [Cracidae; Galliformes]	VU	Pastaza	[53]
Taeniidae						
Taenia sp. (Linnaeus, 1758)	Flot.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	LC	Azuay	[41]
Tetrabothriidae						
Tetrabothrius sp. (Rudolphi, 1819)	Flot. and McM	GI	Waved Albatross (*Phoebastria irrorata*) Salvin, 1883 [Diomedeidae; Procellariiformes]	CR	Galápagos	[39]
Gen. nov. Cestoda gen. sp	Flot.	GI	Galápagos Penguin (*Spheniscus mendiculus*) Sundevall, 1871 [Spheniscidae; Sphenisciformes] ‡	EN	Galápagos	[42]
Davaineidae						
Raillietina sp, (Fuhrmann, 1920)	Flot.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	LC	Azuay	[41]
Diphyllobothriidae						
Dibothriocephalus sp. [syn. *Diphyllobothrium*] (Linnaeus, 1758) (Lühe, 1899)	Flot.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	LC	Azuay	[41]
Nematoda						
Acuariidae						
Dispharynx sp. (Railliet, Henry and Sisoff, 1912)	Nec.	-	Dark-billed Cuckoo (*Coccyzus melacoryphus*) Vieillot, 1817 [Cuculidae; Cuculiformes]	NE	Galápagos	[38]
	Nec.	Prov.	Smooth-billed Ani (*Crotophaga* ani) Linnaeus, 1758 [Cuculidae; Cuculiformes]	LC	Galápagos	[38]
	Nec.	Prov.	Yellow Warbler (*Setophaga petechia aureola*) Linnaeus, 1766 [Parulidae; Passeriformes] ‡	LC	Galápagos	[38]
Anisakidae						
Contracaecum sp. (Railliet and Henry, 1912)	Nec.	Prov.	Cattle Egret (*Bubulcus ibis*) Linnaeus, 1758 [Ardeidae; Pelecaniformes]	LC	Galápagos	[38]
	Flot.	GI	Flightless Cormorant (*Phalacrocorax harrisi*) Rothschild, 1898 [Phalacrocoracidae; Suliformes] ‡	VU	Galápagos	[42]
	Nec.	Prov.	Paint-billed Crake (*Mustelirallus erythrops*) Sclater, 1867 [Rallidae; Gruiformes]	LC	Galápagos	[38]
	Nec.	Prov.	Yellow-crowned Night-Heron (*Nyctanassa violácea pauper*) Linnaeus, 1758 [Ardeidae; Pelecaniformes]	VU	Galápagos	[38]
	Nec.	Prov.	Brown Pelican (*Pelecanus occidentalis urinator*) Wetmore, 1945 [Pelecanidae; Pelecaniformes] ‡	LC	Galápagos	[38]
	Flot.	GI	Waved Albatross (*Phoebastria irrorata*) Salvin, 1883 [Diomedeidae; Procellariiformes] ‡	CR	Galápagos	[39]
	Flot.	GI	Galápagos Penguin (*Spheniscus mendiculus*) Sundevall, 1871 [Spheniscidae; Sphenisciformes] ‡	EN	Galápagos	[42]
Ascaridiidae						
Ascaridia sp. (Dujardin, 1844)	Flot.	GI	Horned screamer (*Anhima cornuta*) Linnaeus, 1766 [Anhimidae; Anseriformes]	LC	Tungurahua	[52]
	Flot. and McM	GI	Woodpecker Finch (*Camarhynchus pallidus*) Sclater and Salvin, 1870 [Thraupidae; Passeriformes] ‡	VU	Galápagos	[55]
	Flot.	GI	Southern Screamer (*Chauna torquata*) Oken, 1816 [Anhimidae; Anseriformes]	LC	Tungurahua	[52]
	Nec. and McM.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	NE	Pichincha	[48]
	Flot.	GI	White-throated Screech-Owl (*Megascops albogularis*) Cassin, 1850 [Strigidae; Strigiformes]	LC	Tungurahua	[52]
	Flot.	GI	Band-tailed Pigeon (*Patagioenas fasciata*) Say, 1823 [Columbidae; Columbiformes]	LC	Tungurahua	[52]
	Flot.	GI	Common Peafowl (* *Pavo cristatus*) Linnaeus, 1758 [Phasianidae; Galliformes]	LC	Tungurahua	[52]
	Flot.	GI	Carunculated Caracara (*Phalcoboenus carunculatus*) Des Murs, 1853 [Falconidae; Falconiformes]	LC	Tungurahua	[52]
	Flot.	GI	King Vulture (*Sarcoramphus papa*) Linnaeus, 1758 [Cathartidae; Cathartiformes]	NT	Tungurahua	[52]
	Flot.	GI	Andean Condor (*Vultur gryphus*) Linnaeus, 1758 [Cathartidae; Cathartiformes]	EN	Tungurahua	[52]
	Flot.	GI	Orange-winged Parrot (*Amazona amazónica*) Linnaeus, 1766 [Psittacidae; Psittaciformes]	LC	Guayas	[54]
	Flot.	GI	Red-lored Parrot (*Amazona autumnalis*) Linnaeus, 1758 [Psittacidae; Psittaciformes]	EN	Guayas	[54]
	Flot.	GI	Red-masked Parakeet (*Psittacara erythrogenys*) Lesson, 1844 [Psittacidae; Psittaciformes] ‡	NT	Guayas	[54]
	Flot.	GI	Anatidae (Vigors, 1825) [Anseriformes]	-	Loja	[49]
	Flot.	GI	*Anser* spp. (Brisson, 1760) [Anatidae; Anseriformes]	-	Loja	[49]
	Flot.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	LC	Azuay	[41]

Table 1. *Cont.*

Helmint Species	Diagnostic Method [1]	Site in Host [2]	Host Species		Location	Ref.
			Name	IUCN Status [3]		
Ascaridia columbae (Gmelin, 1790)	Flot. and McM.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	NE	Loja	[43]
Ascaridia galli (Schrank, 1788)	Flot. and McM.	GI	Slate-colored Coot (*Fulica ardesiaca*) Tschudi, 1843 [Rallidae; Gruiformes]	LC	Chimborazo	[50]
	Flot.	GI	Slate-colored Coot (*Fulica ardesiaca*) Tschudi, 1843 [Rallidae; Gruiformes]	LC	Imbabura	[51]
	Flot.	GI	Neotropic Cormorant (*Phalacrocorax brasilianus*) Gmelin, 1789 [Phalacrocoracidae; Suliformes]	LC	Imbabura	[51]
Heterakis gallinarum (Gmelin, 1790)	Flot. and McM.	GI	Slate-colored Coot (*Fulica ardesiaca*) Tschudi, 1843 [Rallidae; Gruiformes]	LC	Chimborazo	[50]
	Flot.	GI	Slate-colored Coot (*Fulica ardesiaca*) Tschudi, 1843 [Rallidae; Gruiformes]	LC	Imbabura	[51]
	Flot.	GI	Neotropic Cormorant (*Phalacrocorax brasilianus*) Gmelin, 1789 [Phalacrocoracidae; Suliformes]	LC	Imbabura	[51]
Heterakis sp. (Schrank, 1790)	Flot.	GI	Anatidae (Vigors, 1825) [Anseriformes]	-	Loja	[49]
Capillariidae						
Capillaria sp. (Zeder, 1800)	Flot.	GI	Scarlet Macaw (*Ara macao*) Linnaeus, 1758 [Psittacidae; Psittaciformes]	NT	Tungurahua	[52]
	Flot. and McM.	GI	Woodpecker Finch (*Camarhynchus pallidu*) Sclater and Salvin, 1870 (Thraupidae; Passeriformes] ‡	VU	Galápagos	[55]
	Nec. and McM.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	LC	Pichincha	[48]
	Flot. and McM.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	LC	Loja	[43]
	Flot. and McM.	GI	Slate-colored Coot (*Fulica ardesiaca*) Tschudi, 1843 [Rallidae; Gruiformes]	LC	Chimborazo	[50]
	Flot.	GI	Slate-colored Coot (*Fulica ardesiaca*) Tschudi, 1843 [Rallidae; Gruiformes]	LC	Imbabura	[51]
	Flot.	GI	Common Peafowl (* *Pavo cristatus*) Linnaeus, 1758 [Phasianidae; Galliformes]	LC	Tungurahua	[52]
	Flot.	GI	Neotropic Cormorant (*Phalacrocorax brasilianus*) Gmelin, 1789 [Phalacrocoracidae; Suliformes]	LC	Imbabura	[51]
	Flot.	GI	Carunculated Caracara (*Phalcoboenus carunculatus*) Des Murs, 1853 [Falconidae; Falconiformes]	LC	Tungurahua	[52]
	Flot.	GI	Anatidae (Vigors, 1825) [Anseriformes]	-	Loja	[49]
	Flot.	GI	*Anser* spp. (Brisson, 1760) [Anatidae; Anseriformes]	-	Loja	[49]
Onchocercidae						
fam *Onchocercidae* gen. sp. (Chabaud and Anderson, 1959)	Mic. and mol.	B.	Flightless Cormorant (*Phalacrocorax harrisi*) Rothschild, 1898 [Phalacrocoracidae; Suliformes]	VU	Galápagos	[40,46]
	Mic. and mol.	B.	Galápagos Penguin (*Spheniscus mendiculus*) Sundevall, 1871 [Spheniscidae; Sphenisciformes] ‡	EN	Galápagos	[40,46]
Strongyloidea						
superfam *Strongyloidea* gen. sp (Baird, 1853)	Flot.	GI	Anatidae (Vigors, 1825) [Anseriformes]	-	Loja	[49]
	Flot.	GI	*Anser* spp. (Brisson, 1760) [Anatidae; Anseriformes]	-	Loja	[49]
	Flot.	GI	*Cygnus* spp. (Bechstein 1803) [Anatidae; Anseriformes]	-	Loja	[49]
Strongyloididae						
Strongyloides sp. (Grassi, 1879)	Flot.	GI	Red-lored Parrot (*Amazona autumnalis*) Linnaeus, 1758 [Psittacidae; Psittaciformes]	EN	Guayas	[54]
	Flot.	GI	Mealy Parrot (*Amazona farinosa*) Boddaert, 1783 [Psittacidae; Psittaciformes]	NT	Guayas	[54]
Trichuridae						
Trichuris sp. (Roederer, 1761)	Flot.	GI	Chestnut-fronted Macaw *(Ara severus*) Linnaeus, 1758 [Psittacidae; Psittaciformes]	LC	Tungurahua	[52]
	Flot.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	LC	Azuay	[41]
Trematoda						
Brachylaimidae						
fam *Brachylaimidae* Gen. sp. (Joyeux and Foley, 1930)	Nec.	Int.	Black-faced Antthrush (*Formicarius analis*) d'Orbigny and Lafresnaye, 1837 [Formicariidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	Int.	Rufous-capped Antthrush (*Formicarius colma*) Boddaert, 17832 [Formicariidae; Passeriformes]	LC	Sucumbios	[44]
Cyclocoelidae						
Cyclocoelum obscurum (Leidy, 1887)	Nec.	AS.	Pectoral Sandpiper (*Calidris melanotos*) Vieillot, 1819 [Scolopacidae; Charadriiformes]	NE	Sucumbios	[56]
	Nec.	AS.	*Tringa solitaria* (Wilson, 1813) (Wilson, 18132) Solitary Sandpiper [Scolopacidae; Charadriiformes]	NE	Sucumbios	[56]
Cyclocoelum (Haematotrephus) tringae (Brandes 1892)	Nec.	AS.	Pectoral Sandpiper (*Calidris melanotos*) Vieillot, 1819 [Scolopacidae; Charadriiformes]	NE	Sucumbios	[56]
Selfcoelum brasilianum (Stossich, 1903)	Nec.	AS.	Solitary Sandpiper (*Tringa solitaria*) Wilson, 1913 [Scolopacidae; Charadriiformes]	NE	Sucumbios	[56]
Bothrigaster variolaris (Fuhrmann, 1904)	Nec. and mol.	AS. and L.	Snail Kite (*Rostrhamus sociabilis*) Vieillot, 1817 [Accipitridae; Accipitriformes]	LC	Guayas	[47]

Table 1. *Cont.*

Helminth Species	Diagnostic Method [1]	Site in Host [2]	Host Species: Name	Host Species: IUCN Status [3]	Location	Ref.
Dicrocoeliidae						
Lubens lubens (Braun, 1901)	Nec.	-	White-cheeked Antbird (*Gymnopithys leucaspis*) Sclater, 1855 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB	Common Scale-backed Antbird (*Willisornis poecilinotus*) Cabanis, 1847 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB, Liv.	Reddish-winged Bare-eye (*Phlegopsis erythroptera*) Gould, 1855 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	BD.	Spot-winged Antshrike (*Pygiptila stellaris*) Spix, 1825 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	BD.	Dusky-throated Antshrike (*Thamnomanes ardesiacus*) Sclater and Salvin, 1868 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
Zonorchis meyeri (Vercammen-Grandjean, 1966)	Nec.	GB	Galápagos Rail (*Laterallus* sp.) (* *spilonota*) Gould, 1841 [Rallidae; Gruiformes] ‡	VU	Galápagos	[45]
Zonorchis delectans (Braun, 1901)	Nec.	GA, Liv.	Fasciated Antshrike (*Cymbilaimus lineatus*) Leach, 1814 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	BD, Liv.	Ornate Stipplethroat (*Epinecrophylla ornate*) Sclater, 1853 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB	White-cheeked Antbird (*Gymnopithys leucaspis*) Sclater, 1855 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	Kid.	Guianan Warbling-Antbird (* *Hypocnemis cantator*) Boddaert, 1783 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB	Plumbeous Antbird (* *Myrmelastes hyperythrus*) Sclater, 1855 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	BD, GB	Black-faced Antbird (*Myrmoborus myotherinus*) Spix, 1825 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB	White-flanked Antwren (*Myrmotherula axillaris*) Vieillot, 1817 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB, Liv.	Plain-throated Antwren (*Isleria hauxwelli*) Sclater, 1857 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB, Liv., BD	Slaty Antwren (*Myrmotherula schisticolor*) Lawrence, 1865 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB	Reddish-winged Bare-eye (*Phlegopsis erythroptera*) Gould, 1855 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB, Liv.	Black-spotted Bare-eye (*Phlegopsis nigromaculata*) d'Orbigny and Lafresnaye, 1837 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB, Liv.	Spot-winged Antbird (*Myrmelastes leucostigma*) Pelzeln, 1868 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB	Dusky-throated Antshrike (*Thamnomanes ardesiacus*) Sclater and Salvin, 1868 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB, Kid.	Cinereous Antshrike (*Thamnomanes caesius*) Temminck, 1820 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
Brachylecithum rarum (Travassos 1944)	Nec.	Liv.	Striated Antthrush (*Chamaeza nobilis*) Gould, 1855 [Formicariidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	Liv.	Black-faced Antthrush (*Formicarius analis*) d'Orbigny and Lafresnaye, 1837 [Formicariidae; Passeriformes]	LC	Sucumbios	[44]
Fasciolidae						
Fasciola sp. (Linnaeus, 1758)	Flot.	GI	Rock Dove (*Columba livia*) Gmelin, 1789 [Columbidae; Columbiformes]	LC	Azuay	[41]
Heterophidae						
fam *Heterophyidae* Gen. sp. (Odhner, 1914)	Flot.	GI	Flightless Cormorant (*Phalacrocorax harrisi*) Rothschild, 1898 [Phalacrocoracidae; Suliformes] ‡	VU	Galápagos	[42]
Diplostomidae						
Neodiplostomum sp. (Railliet, 1919)	Nec.	-	Sooty Antbird (*Hafferia fortis*) Sclater and Salvin, 1868 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
Neodiplostomum ellipticum (Brandes, 1888)	Nec.	GI	White-cheeked Antbird (*Gymnopithys leucaspis*) Sclater, 1855 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
Echinostomatidae						
fam *Echinostomatidae* gen. sp. (Looss, 1899)	Nec.	Kid.	Plumbeous Antbird (* *Myrmelastes hyperythrus*) Sclater, 1855 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
Eucotylidae						
Tanaisia bragai (Santos, 1934)	Nec.	Kid.	Black-faced Antthrush (*Formicarius analis*) d'Orbigny and Lafresnaye, 1837 [Formicariidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	Kid.	Undulated Antshrike (*Frederickena unduliger*) Pelzeln, 1868 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.		White-cheeked Antbird (*Gymnopithys leucaspis*) Sclater, 1855 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	Kid.	Spot-backed Antbird (*Hylophylax naevius*) Gmelin, 1789 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
Tanaisia fedtschenkoi (Skrjabin, 1924)	Nec.	Kid.	Pectoral Sandpiper (*Calidris melanotos*) Vieillot, 1819 [Scolopacidae; Charadriiformes]	NE	Sucumbios	[56]
	Nec.	Kid.	Solitary Sandpiper (*Tringa solitaria*) Wilson, 1813 [Scolopacidae; Charadriiformes]	NE	Sucumbios	[56]

Table 1. *Cont.*

Helminth Species	Diagnostic Method [1]	Site in Host [2]	Host Species		Location	Ref.
			Name	IUCN Status [3]		
Leucochloridiidae						
Urotocus fusiformis (McIntosh, 1935)	Nec.	BOF	Striated Antthrush (*Chamaeza nobilis*) Gould, 1855 [Formicariidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GB	Thrush-like Antpitta (*Myrmothera campanisona*) Hermann, 1783 [Grallariidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	BOF	Black-faced Antthrush (*Formicarius analis*) d'Orbigny and Lafresnaye, 1837 [Formicariidae; Passeriformes]	LC	Sucumbios	[44]
Leucochloridium sp. (Carus, 1835)	Nec.	-	Spot-backed Antbird (*Hylophylax naevius*) Gmelin, 1789 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	-	Sooty Antbird (*Hafferia fortis*) Sclater and Salvin, 1868 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	Kid.	Black-faced Antbird (*Myrmoborus myotherinus*) Spix, 1825 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	GI	Plain-throated Antwren (*Isleria hauxwelli*) Sclater, 1857 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
Prosthogonimidae						
Prosthogonimus cuneatus (Rudolphi, 1809)	Nec.	Kid.	Striated Antthrush (*Chamaeza nobilis*) Gould, 1855 [Formicariidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	BOF	White-cheeked Antbird (*Gymnopithys leucaspis*) Sclater, 1855 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	BOF	Spot-winged Antbird (*Myrmelastes leucostigma*) Pelzeln, 1868 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	BOF	Silvered Antbird (*Sclateria naevia*) Gmelin, 1788 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
	Nec.	BOF	Cinereous Antshrike (*Thamnomanes caesius*) Temminck, 1820 [Thamnophilidae; Passeriformes]	LC	Sucumbios	[44]
Renicolidae						
Renicola sp. (Cohn, 1904)	Nec.	Kid.	Dark-billed Cuckoo (*Coccyzus melacoryphus*) Vieillot, 1817 [Cuculidae; Cuculiformes]	NE	Galápagos	[38]
	Nec.	Kid.	Brown Pelican (*Pelecanus occidentalis urinator*) Wetmore, 1945 [Pelecanidae; Pelecaniformes] ‡	LC	Galápagos	[38]
	Nec.	Kid.	Blue-footed Booby (*Sula nebouxii*) Todd, 1948 [Sulidae; Suliformes] ‡	LC	Galápagos	[38]
Strigeidae						
Cardiocephaloides sp. (Sudarikov, 1959)	Flot.	GI	Waved Albatross (*Phoebastria irrorata*) Salvin, 1883 [Diomedeidae; Procellariiformes] ‡	CR	Galápagos	[39]

[1] Diagnostic method: Flot. = Flotation; Flot and McM = Flotation and Mc Master; Nec. = Necropsy; Mic and mol. = Microscopy and molecular; Nec. and mol. = Necropsy and molecular; [2] Site in host: GI = gastrointestinal; Prov. = Proventriculus; B. = Blood; Int. = Intestine; AS = Air sacs; AS and L. = Air sacs and Lungs; GB = Gall bladder; Liv = Liver; BD = Bile duct; Kid = Kidney; BOF = Bursa of Fabricius. [3] Threatened category from ECU-UICN [37], except with * from GLOBAL IUCN [34]: LC = Least concern; VU = Vulnerable; CR = Critically endangered; EN = Endangered; NE = Not evaluated; NT = Near threatened. ‡ = endemic bird species.

No reports included in this review investigated the development and life cycles of helminths in Ecuadorian wild birds. Studies were based on descriptions of the presence of helminths (i.e., adults and developmental stages), but transmission routes were not proven.

3.3. Hosts

Wild avifauna harboring helminths in Ecuador involved 62 bird taxa which included 59 nominal species, 2 taxa identified at genus level, and 1 taxon described at family level (see Table 1). Avian host species belonged to 16 orders and 23 family taxa, in which Thamnophilidae was the most studied, with 21 nominal species. In addition, the Rock Dove (*Columba livia*; Gmelin, 1789) was the species with the greater number of helminth records (n = 11).

Out of the 62 avian taxa with recorded helminths, 10 are classified in the highest threatened category in Ecuador according to the IUCN (see Table 1—IUCN category), from which nine are endemic in Ecuador [i.e., Waved Albatross (*Phoebastria irrorate;* Salvin, 1883), Galápagos Penguin (*Spheniscus mendiculus;* Sundevall, 1871), Yellow Warbler *(Setophaga petechia aureola;* Linnaeus, 1766), Flightless Cormorant (*Phalacrocorax harrisi;* Rothschild, 1898); Brown Pelican (*Pelecanus occidentalis urinator;* Wetmore, 1945), Woodpecker Finch (*Camarhynchus pallidus;* Sclater and Salvin, 1870), Red-masked Parakeet *(Psittacara erythrogenys,* Lesson, 1844), Galápagos Rail *(Laterallus spilonota;* Gould, 1841), andBlue-footed Booby (*Sula nebouxii;* Todd, 1948)] [34,37].

3.4. Sample Size and Prevalence Rates of Infection

The sample size of reviewed studies ranged from 1 to 380 individuals, with prevalence rates between 4% and 100%. In particular, five studies investigated avian helminth infections based on individual casualties or opportunistic captures of free-ranging avifauna, with sample sizes ranging from 1 to 68 individuals, and prevalence rates from 16% to 100% [38,44,45,47,56]. In other records, helminths were evaluated based on population studies in wild conditions, with sample sizes ranging between 16 and 380 individuals [39,40,42,43,46,48,50,51]. In such records, the helminth taxon with the highest prevalence was *Onchocercidae* gen. sp. in the Galápagos Penguin with 42% (n = 298) [40]. Other studies assessed helminth infection in wild birds in captive settings, with sample sizes between 1 and 11 individuals and prevalence rates ranging from 40% to 100% [52–55].

3.5. Methodologies

Most studies (59%; n = 10) evaluated parasitic infections via concentration coprologic methods (i.e., flotation, sedimentation) and identification of developmental parasite stages [39,42,43,49–55]. Four studies (24%) based their diagnostic method on necropsy and identification of adult helminths [38,44,45,56]. Two studies evaluated helminth infection via both analysis of fecal samples and necropsy [41,48]. Only three studies determined helminth species in wild birds via morphological keys and molecular tools (i.e., PCR and nucleotide sequencing) [40,46,47].

3.6. Location

Records on wild birds harboring helminth species were reported in ten different provinces in Ecuador (Figure 2). The Galápagos Islands represent the province with the greater number of studies, with seven reports (37%) [38–40,42,45,46,55]. In addition, seven studies (37%) described helminth infections in avifauna distributed along the Sierra region, with records in provinces such as Loja (n = 2), Pichincha (n = 1), Azuay (n = 1), Tungurahua (n = 1), Chimborazo (n = 1), and Imbabura (n = 1) [41,43,48–52]. In the coastal region, specifically in the Guayas province, there were two records of helminth infections in wild birds [47,54]. Only three studies were carried out in avifauna distributed in the Amazon region (i.e., Pastaza and Sucumbios provinces) [44,53,56].

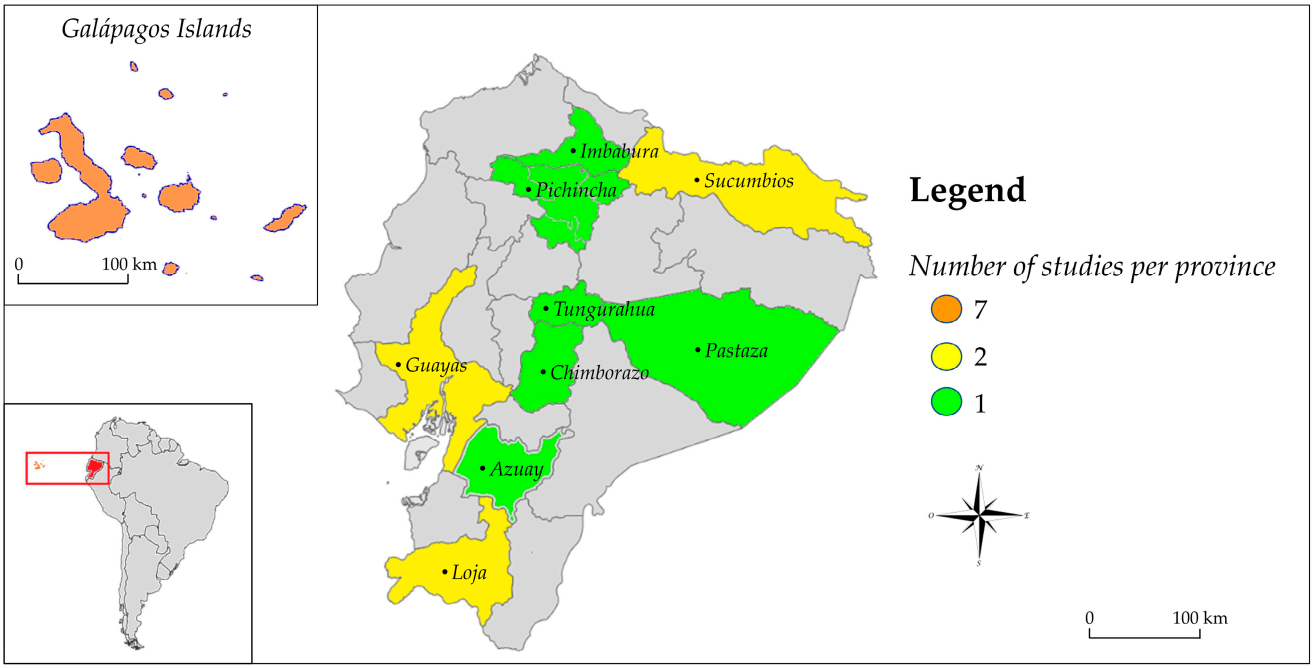

Figure 2. Geographic distribution of 19 studies reporting helminths in wild birds in Ecuador The color red indicates the location of Ecuador in South America. (modified from [57]).

4. Discussion

In this review, the parasitic helminth fauna in Ecuadorian wild birds was summarized based on 19 available academic records. To the best of the authors' knowledge, this is the first compilation on helminths in wild birds in Ecuador, in which 40 helminth taxa were reported, parasitizing 62 avian host species.

The evidence shows that information on the diversity of helminths in Ecuadorian wild birds is very limited, taking into consideration the high avian diversity that is present in Ecuador due to its geographical location [19]. Only 62 birds exhibit helminth records out of 1769 reported Ecuadorian avian species (i.e., 1600 species in mainland Ecuador and 169 species in the Galápagos Islands) [21,22]. In addition, we found only 10 scientific peer-reviewed documents, 9 of which were in English language [38–46]. Almost half of the records were grey literature (i.e., undergraduate and postgraduate theses) [48–56]. This highlights the need for more research on helminths parasitizing wild birds in Ecuador, and future endeavors should aim to present findings through documents that are evaluated via a peer-review process.

In this review, we compiled 40 helminths records in wild birds that comprised 17 nominal species, 17 taxa identified to the genus level, and 6 taxa identified to family or phylum levels. The most reported helminth in avian species was *Ascaridia* spp., and no Acanthocephala was reported. Also, identification of helminths in most studies (i.e., 12 documents) was based on the morphology of their developmental stages (i.e., eggs) via coprological analysis, which preluded their identification at the species taxonomic level [39,41–43,48–55]. In this sense, only three studies confirmed their findings with molecular tools [40,46,47]. Future work should aim to carry out research with more sensitive diagnostic methods, including the recuperation of adult helminths, DNA extraction and amplification, and sequencing (see [47,58]).

Also, no reports included in this review investigated the development and life cycles of helminths in Ecuadorian wild birds. Some helminths reported in Ecuadorian birds are known to exhibit simple life cycles. These include *Ascaridia columbae Gmelin*, 1790; *Ascaridia galli* Schrank, 1788; *Heterakis gallinarum* Gmelin, 179; *Trichuris* sp. Roederer, 1761; and *Strongyloides* sp. Grassi, 1879 [1,5]. On the other hand, most cestodes (i.e., *Tetrabothrius* sp. Rudolphi, 1819; *Raillietina* sp. Fuhrmann, 1920; *Dibothriocephalus* sp. (syn. *Diphyllobothrium*)

Linnaeus, 1758), digenetic trematodes (e.g., *Prosthogonimus cuneatus* Rudolphi, 1809), and the nematodes, including *Dispharynx* sp. Railliet, Henry and Sisoff, 1912, and *Contracaecum* sp. Railliet and Henry, 1912, are known to exhibit complex life cycles, requiring more than one host to complete their development [1,5–7]. In this sense, helminths with direct life cycles can be acquired via fecal–oral transmission by ingestion of infective larval stages and/or parasitic eggs [1,59,60]. Parasitic larvae of the directly transmitted *Strongyloides* spp. can also infect host by skin penetration [61]. In counterpart, helminths with complex life cycles require the availability of compatible intermediate hosts, which can comprise mostly invertebrates (e.g., earthworms, arthropods, and mollusks), and avian hosts can become infected via trophic transmission or skin-penetration of infective parasitic larval stages [1,6,7]. Insectivorous and omnivorous birds, including some Passeriformes [e.g., the Black-faced Antbird (*Myrmoborus myotherinus;* Spix, 1825)] and Anseriformes [e.g., the mallard (*Anas platyrhynchos;* Linnaeus, 1758) can harbor high diversity of helminths with direct and indirect life cycles [6,7,44,49]. Consequently, more observational and experimental research should be carried out to elucidate and confirm the development and life cycles of helminths in Ecuadorian wild birds in accordance with the foraging strategies of avian species.

Selected records of helminths in wild birds varied in methodology, sample size, and diagnostic methods, which precluded further conclusions on the effects of avian health. In individual (i.e., sample size = 1) and population (i.e., sample size = 16–380) studies, prevalence rates of helminth fauna ranged from 4% to 100%, and hosts were in different kinds of settings (i.e., free-ranging and captive conditions). In this sense, the synanthropic Rock Dove was the species with the greater number of helminth records, and only 10 avian species with recorded helminths were classified in the highest threatened category in Ecuador according to the IUCN [34,37]. As wild birds face several threats including climate change, increasing human interactions, predation by introduced species, and emerging diseases [14], helminths can have negative effects on bird species, especially when hosts are already impacted by such threats [13]. Host immunosuppression may induce helminths to become more pathogenic [9,13,14]. Additionally, birds kept in cages with stressful and overcrowding conditions are more susceptible to increases in rates of parasitic infections, particularly by directly transmitted helminths [13,62,63]. On the other hand, helminths play essential epidemiological and ecological roles in ecosystem functioning by regulating populations [10–12], and helminth diversity is an indicator of the status of natural environments [15,64]. Thus, conducting more research about helminth infections in wild birds, especially in endangered species and free-ranging conditions, is crucial in order to identify whether helminths pose threats to avian conservation, or if it is important to conserve them as part of the country's biodiversity [15].

In addition, research on helminths in wild birds has been geographically biased in Ecuador, in which more studies were carried out in the Galápagos Islands, and only three out of 19 studies were performed in the Amazon region (see Figure 2) [44,53,56]. Considering that Ecuador is comprised of 24 provinces in the four ecoregions (i.e., Coastal, Sierra, Amazon, and the Insular regions), more research on helminths should be carried out in birds distributed through high diversity areas, such as the Tropical Andes, the Tumbes-Chocó-Magdalena Corridor, and the Amazon Region.

Given the limited availability of information on helminths in wild birds in Ecuador, some records in this review were obtained from grey literature (i.e., academic dissertations), as carried out in other baseline reviews elsewhere [65]. In future scientific efforts, confirmation and in-depth descriptions of helminth taxa should be undertaken. Nevertheless, this review offers insights into helminths infecting wild birds in mainland Ecuador and the Galápagos Islands. This compendium essentially serves as a foundational reference for helminth research in avifauna in the country, paving the way for future ecological and epidemiological studies.

5. Conclusions

In this review, records of helminths in wild birds in Ecuador were systematically searched following the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) guidelines in five online databases. There were 19 documents available on helminths in Ecuadorian wild birds, which comprised ten scientific articles, eight undergraduate theses, and one doctoral dissertation published between 1966 to 2022. Forty helminth taxa were presented in 62 bird taxa. In particular, the nematode of the genus *Ascaridia* spp. exhibited the greatest number of records, parasitizing 16 avian species, and the synanthropic Rock Dove was the avian species with the greater number of helminth records. Of reported avifauna harboring helminths, only 10 species were classified in the highest threatened category in Ecuador according to the IUCN. Regarding geographical location, the Galápagos Islands was the province where the greater number of records were carried out, with seven reports. Selected records in this review varied in methodology, sample size, and diagnostic methods, in which most studies were carried out through coprological analyses. This review serves as a compendium for future ecological and epidemiological studies on helminths in wild birds in Ecuador and South America.

Author Contributions: Conceptualization, P.D.C.-J.; methodology, P.D.C.-J.; writing—original draft preparation, P.D.C.-J.; writing—review and editing, P.D.C.-J. and G.J.-U. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Patricio D. Carrera-Játiva gratefully acknowledges ANID Agencia Nacional de Investigación y Desarrollo, Gobierno de Chile, for the Doctoral Fellowship N. 21200220 and the WWF Russell E. Train Fellowship. The authors thank the academic editor and the two anonymous reviewers for their many helpful comments that have improved this manuscript. This publication is contribution number 2604 of the Charles Darwin Foundation for the Galápagos Islands.

Conflicts of Interest: The authors declare no conflicts of interest.

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