Mem. Inst. Oswaldo Cruz, Rio de Janeiro, Vol. *84* (4):515-526, out./dez. 1989

PREVALENCE OF AVIAN HAEMATOZOA IN SÃO PAULO STATE, BRAZIL

C. B. WOODWORTH-LYNAS, J. R. CAINES & G. F. BENNETT

International Reference Centre for Avian Haematozoa, Department of Biology, Memorial University of Newfoundland, St. John's, NF Canada, A1B 3X9

The blood parasites of 15,574 birds representing 266 species of 43 families from primarily three areas in São Paulo State, Brazil were examined for haematozoa. Only 1240 (8.0% of 121 species of 32 families were infected with blood parasites. This prevalence was similar to that reported in a previous study. Species of Haemoproteus *were the most commonly encountered haematozoans (38.9%), followed by microfilaria (30.7%),* Trypanosoma *(13.7%),* Plasmodium *(7.5%) and* Leucocytozoon *(0.8%). Prevalence of parasitism was significantly different between the three major areas sampled. It was shown that this was due in part to differences in the avifaunas at both the familial and species levels. Prevalence varied markedly in only one of the 10 years of the study. Monthly fluctuations in prevalence were largely due to changes in relative proportions of highly-infected and low-infected avian families either between months, or between areas, or a combination of both. Prevalences of both microfilaria and* Trypanosoma *were higher than reported for any other similar survey in the world.*

Key words: avian haematozoa – Brazil – prevalence – seasonal distribution

Bennett & de Souza Lopes (1980) reported species composition, seasonal distribution, host specificity and prevalence of parasitism in a sample of some 3500 birds from São Paulo State (Brazil). Subsequently, a further sample of 12,000 birds became available thus providing a substantially larger and more comprehensive database of approximately 15,500 birds. A long-term study of this magnitude would serve to greatly broaden the findings of the earlier study by increasing the potential to reveal patterns in prevalence of infection. The 1980 study suggested that differences in prevalences of haematozoa among three locations sampled might result, in part, from differences in their avifaunas. Variations in abundances of particular avian species or families could affect the prevalences of infection in an area because of host-related factors such as susceptibility to infection. The current study, because of its greatly expanded sample size was able to investigate, at both the familial and specific levels, where and how differences in avifauna affected the calculation of prevalences of infection.

Supported by an infrastructure grant to the third author by the Natural Sciences and Engineering Council of Canada.

Received May 26, 1989.
Accepted September 15, 1989.

MATERIALS AND METHODS

Birds were collected during the years 1966-1975 in nine areas of the State of São Paulo, Brazil (Itapetininga, Casa Grande, Guaratuba, Iguape, Zoológica, Registro, Peruíbe, Itanhaém and Piedade). The majority of birds were sampled on a monthly basis at Itapetininga (23°40'S, 48°05'W), an area of open fields and rivers surrounded by gallery forests; Casa Grande (23°40'S, 45°55'W), a highly humid region near the Atlantic Ocean at an altitude of 800 m and covered by extensive primary forest; and Guaratuba (23°45'S, 45°55'W), a sealevel region covered by extensive forests which are continuous with those of Casa Grande. Quantitative habitat measurements were not available to the authors.

Birds were captured using Japanese mist nets (ATX type with 36 mm mesh), identified, banded and released after a blood sample was taken from the brachial vein. Blood smears were fixed in 100% methanol and stained with Leishman's or Giemsa's stain. The smears were then sent to the International Reference Centre for Avian Haematozoa (IRCAH) for examination and identification of the parasites to species. Recapture information was insufficient for analysis. Representative slides are deposited in the collection of the IRCAH. Avian taxon-

omy used in the current study follows that of Clements (1978) to allow comparisons with the study by Bennett & de Souza Lopes (1980). In all instances, the current study also includes those data previously reported by Bennett & de Souza Lopes (1980). Parasite taxonomy follows that of Bennett et al., 1982 and Bennett & Peirce, 1988.

Similarities of the avifauna at both the familial and specific levels in the three study areas were computed using the Coefficient of Community (Pielou, 1974): $CC = 200\ S_{xy}/S_x + S_y$, where S_{xy} is the number of families (species) common to both samples, and S_x and S_y are the number of families (species) found in samples X and Y, respectively. The limits of CC are $0 < CC < 100$, with the values expressed as percent similarity. When the two samples have no taxa in common, CC = 0%, when taxa are identical, CC = 100%. Prevalences of infection were compared by t-tests for equality of two percentages using arcsine transformation of the data (Sokal & Rohlf, 1969).

RESULTS AND DISCUSSION

A total of 15,574 (1980 – 3,449) birds of 266 (1980 – 195) species, representing 43 (1980 – 33) families, were examined for haematozoa. Only 1240 (8.0%) of 121 species representing 32 families harboured one or more blood parasites. These data (Table I) confirm the low prevalence of avian haematozoa recorded by Bennett & de Souza Lopes (1980) and by others elsewhere in the region (Bennett & Borrero, 1976; Gabaldon et al., 1974, 1975; White et al., 1978), all of which are at variance with the considerably higher prevalence of avian haematozoa recorded in North America (Greiner et al., 1975).

A comparison of the overall prevalence of avian haematozoa (i. e. the number of infected birds divided by the total number of birds examined) between the 1980 report and the current study (Table II) indicated little change with the incorporation of the larger sample. The 1980 figures are given in brackets. The percent prevalence was 8.0 (7.8) with the total parasite infections being 1,343 (284). The parasite index, which is defined as the number of parasite infections per infected bird, was calculated at 1.09 (1.06) confirming figures determined by Bennett & de Souza Lopes in 1980.

The proportions of the total infections due to each parasite genus were* *Haemoproteus* 38.9 (42.3), *Leucocytozoon* 0.82 (0.01), microfilaria 30.7 (31.3), *Plasmodium* 7.5 (14.1), *Trypanosoma* 13.7 (10.2) and "other" genera, (which include *Atoxoplasma* sp., *Babesia* sp., *Hepatozoon* sp., *Lankesterella* sp., and as yet unidentifiable parasites) 8.3 (2.2). For *Haemoproteus*, *Leucocytozoon*, microfilaria and trypanosomes these proportions were not significantly different between 1980 and the current study ($t = 1.0$, $t = 2.5$, $t = 0.2$, $t = 1.7$, respectively, $p > 0.01$). The lower proportion of the total infections formed by *Plasmodium* as compared with 1980 figures ($t = 3.3$, $p < 0.01$) was due to the inclusion of large numbers of bird species from this region which were only rarely infected with *Plasmodium*. The significantly higher proportion in the "other" category ($t = 4.4$, $p < 0.01$) was largely due to a large increase in captures of *Stelgidopteryx ruficollis* (Hirundinidae) infected with *Hepatozoon atticorae*.

The proportions of the infections which were microfilaria and trypanosomes were, as in 1980, far higher than in previous surveys of the Neotropic, Nearctic or southeastern Asian regions. Sixty-five percent of microfilarial infections were in the Turdidae and Thraupidae, although these families comprise only 25% of the total sample. If these birds are excluded from the calculations, the proportion of microfilaria infections compared to the total infections decreases to 17.6%. This figure is still significantly higher than in the Neotropical ($t = 5.1$, $p < 0.01$), Nearctic ($t = 9.9$, $p < 0.01$) or southeastern Asian region ($t = 5.9$, $p < 0.01$). It is possible that the rates of microfilaria and trypanosome transmission in São Paulo State are higher than in the other regions because (i) the particular bird species involved are more susceptible to these parasites, (ii) the vectors involved are more efficient or (iii) there is a combination of both factors.

Bennett & de Souza Lopes (1980) suggested that habitat related factors were responsible for differences in prevalences among the three areas, since, testing of the Coefficient of Community (CC) indicated that all three areas had a "good" commonality of host families. Similar testing of the larger samples in this study indicated that Itapetininga and Guaratuba had a CC of 85.3% for host families and 64.1% for host species, Itapetininga and Casa Grande had

a CC of 65.2% for families and 59.1% for species and Guaratuba and Casa Grande had a CC of 71.2% for families and 56.9% for species. The degrees of similarity among families of birds were virtually identical to those in 1980. Despite the CC indices, it is readily apparent that the three areas differ in the numbers of individuals of each family present (Table III). Additionally, the abundance of particular species within the families often varies from area to area. Prevalences of infection might be expected to differ as both the avian family and species levels through various interactions of the host-vector-parasite relationship (Greiner et al., 1975). Varying abundances of species and/or families among areas, especially if disproportionate, could obviously be reflected in different prevalences, even when values of CC show a high degree of commonality among areas.

In the present study the prevalence of parasitism (Table IV) was significantly higher at Guaratuba than at Itapetininga ($t = 8.5$, $p < 0.01$), which was in turn significantly higher than at Casa Grande ($t = 7.4$, $p < 0.01$). These differences can be explained partly by differences among the avifaunas of the three areas. For example, of 191 infected thraupids at Guaratuba, 40 birds occurred in species which were not captured in the other areas. The prevalence of haematozoa in *Tangara seledon* was 67.2% at Guaratuba, but this species was captured in very low numbers at Casa Grande ($N = 12$) and not at all at Itapetininga. The situation is further obscured by the presence at Itapetininga of species such as *Zonotrichia capensis* which has a high prevalence of infection. Additionally fifty of the 55 infected *Columba talpacoti* were caught at Itapetininga. However, only 5% of the total captures of this species was caught in the other 2 areas (12 of 251).

The higher prevalence of haematozoa at Guaratuba can not be explained solely by differences in the avifauna among the three sites since species that were captured at all three sites in large numbers had significantly different prevalences of infection. For example, the prevalence of infection in *Tachyphonus coronatus* was 16.2% for Guaratuba, 3.8% for Itapetininga ($t = 5.7$, $p < 0.01$) and 2.6% for Casa Grande ($t = 4.7$, $p < 0.01$). In addition the prevalence of infection in *Thraupis sayaca* was 44.4% ($N = 36$) at Guaratuba but only 12.0% at Itapetininga where the sample size was much higher ($N = 300$). It appears, therefore, that the rates of transmission are higher at Guaratuba suggesting a higher vector efficiency in the area, possibly through increased density. A study of the vectors would, therefore, be best conducted at this location.

The majority of avian families showed equal or higher prevalences of infection at Guaratuba compared to Itapetininga and Casa Grande, with the exception of three families where the prevalences were higher at Itapetininga – the Columbidae, Conopophagidae and the Fringillidae. This was due, largely, to the capture at Itapetininga of large numbers of a single species of each of these families. For example, 120 of the 540 total captures of *Zonotrichia capensis* (Fringillidae) at Itapetininga were infected compared to 1 of the 5 total captures at the other 2 areas combined. Thirty-eight of a total of 240 *Conophaga lineata* (Conopophagidae) were infected at Itapetininga while only 2 of 7 and 11 of 117 were infected at Guaratuba and Casa Grande, respectively.

A comparison of the prevalences of infection for the most highly infected families between 1980 and the current report indicates differences in three families. Prevalence of infection in the Vireonidae increased from 19.4% to 36.0% ($t = 2.7$, $p < 0.01$) while prevalence of infection in the Fringillidae decreased from 15.9% to 10.3% ($t = 2.8$, $p < 0.01$). Among the vireonids the difference is due to a large increase in the captures of *Vireo olivaceus*. This species is commonly infected with *Haemoproteus vireonis*, (Guaratuba 51 of 79 captures, Itapetininga 34 of 76 captures, Casa Grande 7 of 17 captures). Among the fringillids the decrease in the prevalence of infection was due mainly to the large increase in the captures of uninfected *Haplospiza unicolor* (1980 – 3 infected of 20, current – 8 infected of 364) and *Saltator similis* (1980 – 6 infected of 33, current – 6 infected of 100).

Bennett & de Souza Lopes (1980) found little variation in prevalence from year to year. The recalculated prevalences between 1967 to 1972 remained virtually unchanged, despite the large increase in sample size. Prevalences for 1966-1975, based on the expanded sample, are given in Table V.

TABLE I

Haematozoa of birds collected in São Paulo State, Brazil, 1966-1975. These data include those previously published by Bennett & de Souza Lopes (1980)

	Total	Infected birds	[a]H.	[a]P.	[a]T.	[a]M.	[b]O.
ACCIPITRIDAE							
Harpagus bidentatus	2	2				2	
[c]Negative birds (3 species)	8						
Total:	10	2				2	
ALCEDINIDAE							
Chloroceryle americana	84	2				1	1
[c]Negative birds (4 species)	29						
Total:	113	2				1	1
APODIDAE							
Chaetura andrei	88	3	1			1	1
Chaetura cinereiventris	58	1				1	
Total:	146	4	1			2	1
BUCCONIDAE							
Malacoptila striata	17	12				5	7
Notharchus macrorhynchos	2	2				1	1
Nystalus chacuru	27	3	1				2
Total:	46	17	1			6	10
COEREBIDAE							
Chlorophanes spiza	32	10			1	9	
Coereba flaveola	275	6			2	4	
Dacnis cayana	67	10	5	1	2	6	1
Total:	374	26	5	1	5	19	1
COLUMBIDAE							
Columbina talpacoti	251	55	53				2
Geotrygon montana	68	6	6				
[c]Negative birds (4 species)	67						
Total:	386	61	59				2
CONOPOPHAGIDAE							
Conophaga lineata	368	52	3	14	21		19
Conophaga melanops	39	6			3	2	2
Total:	407	58	3	14	24	2	21
COTINGIDAE							
Pachyramphus marginatus	2	1			1		
Pachyramphus polychopterus	31	14	6		7	8	2
Platypsaris rufus	53	35	31		3	5	
Tityra cayana	1	1			1		
[c]Negative birds (3 species)	5						
Total:	92	51	37		12	13	2
CUCULIDAE							
Crotophaga ani	16	1					1
[c]Negative birds (6 species)	22						
Total:	38	1					1
CYCLARHIDAE							
Cyclarhis gujanensis	56	7			1	6	
DENDROCOLAPTIDAE							
Campylorhamphus trochilirostris	46	2	1		1		
Dendrocincla fuliginosa	132	9		2		3	5
Dendrocolaptes platyrostris	47	3	1		2		
Lepidocolaptes fuscus	246	9		1	1	5	2

	Total	Infected birds	[a]H.	[a]P.	[a]T.	[a]M.	[b]O.
Sittasomus griseicapillus	156	4					4
[c]Negative birds (2 species)	20						
Total:	647	27	2	3	4	8	11
FALCONIDAE							
Micrastur ruficollis	13	1	1				
FORMICARIIDAE							
Chamaeza ruficauda	12	1				1	
Drymophila malura	27	2			1	1	
Drymophila squamata	22	2				2	
Dysithammus mentalis	207	17	3	5	11		1
Formicarius colma	25	5		2		1	2
Grallaria varia	20	2		1	1		
Hylopezus ochroleucus	2	1	1				
Myrmeciza squamosa	66	4			1	4	1
Myrmotherula gularis	62	5		1	3	1	
Pyriglena leucoptera	193	23	5	2	15	1	3
Thamnophilus caerulescens	145	6			4		2
Thamnophilus ruficapillus	54	1				1	
[c]Negative birds (9 species)	55						
Total:	890	69	9	11	36	12	9
FRINGILLIDAE							
Ammodramus humeralis	37	1	1				
Arremon taciturnis	34	1	1				
Carduelis magellanica	39	1		1			
Haplospiza unicolor	364	8	6		1		2
Pitylus fuliginosus	7	3				3	
Saltator similis	100	6				6	
Sporophila plumbea	6	1			1		
Tiaris fuliginosa	34	2	1	1			
Volatina jacarina	90	2				1	1
Zonotrichia capensis	572	128	107	28	2	11	4
[c]Negative birds (6 species)	234						
Total:	1517	153	116	30	4	21	7
FURNARIIDAE							
Automolus leucophthalmus	261	11	2		7	1	1
Cichlocolaptes leucophrys	26	1			1		
Lochmias nematura	104	6	2			3	2
Philydor atricapillus	64	4	1			3	
Synallaxis ruficapilla	91	3			1	1	1
Syndactyla rufosuperciliata	125	5		1	3	1	1
Xenops minutus	61	4				4	
[c]Negative birds (10 species)	244						
Total:	976	34	5	1	12	13	5
HIRUNDINIDAE							
Alpochelidon fucata	11	1					1
Notiochelidon tibialis	8	1					1
Stelgidopteryx ruficollis	221	28	1			2	26
[c]Negative birds (1 species)	5						
Total:	245	30	1			2	28
ICTERIDAE							
Molothrus bonariensis	30	3	3				
[c]Negative birds (4 species)	59						
Total:	89	3	3				
MIMIDAE							
Mimus saturninus	28	1		1			

	Total	Infected birds	[a]H.	[a]P.	[a]T.	[a]M.	[b]O.
PARULIDAE							
Basileuterus hypoleucus	89	1		1			
Geothlypis aequinoctialis	116	3				3	
Parula pitiayumi	28	2				1	2
[c]Negative birds (3 species)	163						
Total:	396	6		1		4	2
PICIDAE							
Celeus flavescens	14	1	1				
Piculus aurulentus	6	1	1				
Picumnus temminckii	99	2				1	1
[c]Negative birds (4 species)	18						
Total:	137	4	2			1	1
PIPRIDAE							
Chiroxiphia caudata	932	10	3	1	1	4	1
Manacus manacus	247	2			1	1	
Neopelma aurifrons	147	1		1			
Schiffornis virescens	254	6			5		1
[c]Negative birds (2 species)	80						
Total:	1660	19	3	2	7	5	2
PLOCEIDAE							
Passer domesticus	108	3		3			
RALLIDAE							
Laterallus melanophaius	3	1				1	
[c]Negative birds (3 species)	6						
Total:	9	1				1	
RAMPHASTIDAE							
Selenidera maculirostris	3	1				1	
[c]Negative birds (1 species)	2						
Total:	5	1				1	
STRIGIDAE							
Otus choliba	13	4	4	1			
[c]Negative birds (2 species)	3						
Total:	16	4	4	1			
THRAUPIDAE							
Euphonia pectoralis	137	11	2			9	
Euphonia violacea	141	6	6				
Habia rubica	103	3				3	
Hermithraupis ruficapilla	3	1	1				
Pipraeidea melanonota	25	5	4	1			1
Ramphocelus bresilius	153	18			1	16	1
Schistochlamys ruficapillus	41	2				2	
Tachyphonus coronatus	841	84	5	2	10	68	1
Tachyphonus cristatus	22	1			1		
Tangara cayana	113	7			3	3	1
Tangara cyanocephala	18	8	8				
Tangara desmaresti	32	13	11	1	1		
Tangara seledon	73	43	29	1	3	15	
Thraupis cyanoptera	62	10	10				
Thraupis ornata	1	1	1			1	
Thraupis palmarum	29	20	21			3	1
Thraupis sayaca	345	56	52		1	6	2
Trichothraupis melanops	326	6	1	2	1	2	
[c]Negative birds (8 species)	23						
Total:	2488	295	151	7	21	128	7
TINAMIDAE							
Crypturellus parvirostris	5	1				1	

	Total	Infected birds	[a]H.	[a]P.	[a]T.	[a]M.	[b]O.
[c]Negative birds (2 species)	10						
Total:	15	1				1	
TROCHILIDAE							
Colibri serrirostris	1	1	1				
[c]Negative birds (5 species)	33						
Total:	34	1	1				
TROGLODYTIDAE							
Thryothorus longirostris	47	6		1		5	
Troglodytes musculus	52	1				1	
[c]Negative birds (1 species)	16						
Total:	115	7		1		6	
TURDIDAE							
Platycichla flavipes	198	47	2		1	44	
Turdus albicollis	442	81	7	2	27	53	1
Turdus amaurochalinus	214	20	5	2		13	
Turdus leucomelas	86	14	2	5		6	2
Turdus rufiventris	397	40	4	6	5	24	1
[c]Negative birds (1 species)	1						
Total:	1338	202	20	15	33	140	4
TYRANNIDAE							
Cnemotriccus fuscatus	41	1	1				
Elaenia mesoleuca	184	2	1	1			
Empidonax eureli	169	1	1				
Empidonomus varius	23	6	1		1	3	1
Hemitriccus diops	31	1				1	
Myiobius atricaudus	100	1					1
Myiobius barbatus	23	1					1
Myiophobus fasciatus	149	2				1	1
Myiodynastes maculatus	48	2		1	1		
Myiozetetes similis	10	2			1	1	
Oreotriccus griseocapillus	3	1			1		
Phyllomyias fasciatus	72	2	1			1	
Pipromorpha rufiventris	542	3			1	2	
Pitangus sulphuratus	36	4			3	1	
Platyrinchus mystaceus	340	12		2	8	1	2
Serpophaga subcristata	16	1				1	
Sublegatus modestus	10	1				1	
Tyrannus melancholicus	73	8	3	1	5	1	1
[c]Negative birds (36 species)	939						
Total:	2809	51	8	5	21	14	7
VIREONIDAE							
Hylophilus poicilotus	87	1					1
Vireo olivaceus	186	97	91	5	4	4	
Total:	273	98	91	5	4	4	1
[c]Negative birds from other families	98						
Grand Total:	15574	1240	523	101	184	412	123

[a] *H.* = *Haemoproteus*: *H. borgesi*, **H. bucconis*, *H. syrnii*, *H. columbae*, *H. fallisi*, **H. formicarius*, *H. fringillae*, **H. furnarius*, *H. orizivorae*, *H. ortalidium*, **H. souzalopesi*, *H. trochili*, **H. tyranni*, **H. vireonis*.
P. = *Plasmodium*: *P. nucleophilum*, *P. pinotti*, *P. polare*, *P. relictum*, *P. rouxi*, *P. vaughani*.
T. = *Trypanosoma*: *T. avium*, *T. calmettei*, *T. corvi*, *T. paddae*.
M. = microfilaria.

[b] Includes *Atoxoplasma* sp., *Babesia* sp., *Hepatozoon* sp., *Lankesterella* sp., *Leucocytozoon dubreuili*, *L. fringillae* and *L. hirundinis*.

* New parasite species described from this collection and summarized by Bennett and Peirce (1988).

[c]*Negative birds:* ACCIPITRIDAE: *Accipiter superciliosus* (1), *A. striatus* (2), *Buteo magnirostris* (5); ALCEDINIDAE: *Ceryle torquata* (1), *Chloroceryle amazona* (3), *C. inda* (14), *C. aenea* (11); ANATIDAE: *Anser anser* (1), *Dendrocygna viduata* (10), *Anas platyrhynchos* (11); ARDEIDAE: *Ardea cocoi* (1), *Butoroides striatus* (2); CAPRIMULGIDAE: *Lurocalis semitorquatus* (16), *Nyctidromus albicollis* (1), *Nyctiphrynus ocellatus* (3), *Hydropsalis brasiliana* (1); *Eleothreptus anomalus* (1); CHARADRIIDAE: *Vanellus chilensis* (1); COLUMBIDAE: *Columba plumbea* (2), *Claravis pretiosa* (3), *Leptotila verreauxi* (48), *L. rufaxilla* (14); PSITTACIDAE: *Pyrrhura frontalis* (5), *Forpus passerinus* (4), *Brotogeris tirica* (8), *B. versicolurus* (1), *Pionus maximiliani* (3), *Triclaria malachitacea* (1); CORVIDAE: *Cyanocorax cristatellus* (1); COTINGIDAE: *Laniisoma elegans* (1), *Pachyramphus viridis* (2), *Procnias nudicollis* (2); CUCULIDAE: *Coccyzus euleri* (1), *C. melacoryphus* (2), *Piaya cayana* (6), *Guira guira* (2), *Tapera naevia* (5), *Dromococcyx pavoninus* (6); DENDROCOLAPTIDAE: *Xiphocolaptes albicollis* (18), *Lepidocolaptes squamatus* (1); FORMICARIIDAE: *Batara cinerea* (6), *Mackenziaena leachii* (4), *Thamnophilus schistaceus* (1), *Drymophila ferruginea* (1), *D. ochropyga* (4), *Dysithamnus xanthopterus* (3), *Herpsilochmus rufimarginatus* (4), *Chamaeza campanisona* (7), *Myrmotherula unicolor* (24); FRINGILLIDAE: *Sporophila caerulescens* (190), *S. leucoptera* (1), *Sicalis flaveola* (9), *Coryphospingus cucullatus* (2), *Emberizoides herbicola* (28), *Donacospiza albifrons* (4); FURNARIIDAE: *Furnarius rufus* (38), *Synallaxis frontalis* (22), *S. spixi* (14), *Phacellodomus erythrophthalmus* (3), *Anabazenops fuscus* (13), *Anabarcerthia amauurotis* (40), *Philydor rufus* (8), *Heliobletus contaminatus* (24), *Xenops rutilans* (5), *Sclerurus scansor* (77); HIRUNDINIDAE: *Notiochelidon cyanoleuca* (5); ICTERIDAE: *Cacicus haemorrhous* (46), *Gnorimopsar chopi* (7), *Icterus cayanensis* (3), *Pseudoleistes guirahuro* (3); PARULIDAE: *Basileuterus culicivorus* (69), *B. leucoblepharus* (52), *Phaeothlypis rivularis* (41); PHASIANIDAE: *Gallus gallus* (17); PICIDAE: *Picumnus cirratus* (1), *Colaptes campestris* (3), *Chrysoptilus melanochloros* (8), *Venilornis spilogaster* (6); PIPRIDAE: *Ilicura militaris* (77), *Piprites chloris* (2); RALLIDAE: *Aramides cajanea* (3), *Laterallus viridus* (1), *Micropygia schomburgkii* (2); RAMPHASTIDAE: *Ramphastos vitellinus* (2); RHINOCRYPTIDAE: *Merulaxis ater* (2); SCOLOPACIDAE: *Tringa flaviceps* (1); STRIGIDAE: *Glaucidium brasilianum* (1), *Speotyto cunicularia* (2); TERSINIDAE: *Tersina viridis* (1); THRAUPIDAE: *Chlorophanes spiza* (3), *Chlorophonia cyanea* (1), *Euphonia plumbea* (1), *Orthogonys chloricterus* (5), *Hermithraupis guira* (4), *Thlypopsis sordida* (7), *Neothraupis fasciata* (1), *Schistochlamys melanopis* (4); TINAMIDAE: *Crypturellus noctivagus* (1), *C. obsoletus* (9); TROCHILIDAE: *Ramphodon naevius* (25), *Glaucis hirsuta* (1), *Phaethornis eurynome* (2), *Anthracothorax nigricollis* (1), *Clytolaema rubricauda* (4); TROGLODYTIDAE: *Troglodytes aedon* (16); TROGONIDAE: *Trogon rufus* (3); TURDIDAE: *Turdus nigriceps* (1); TYRANNIDAE: *Atilla rufus* (57), *Pseudatilla phoenicurus* (16), *Rhytipterna simplex* (6), *Xolmis cinerea* (2), *Gubernetes yetapa* (7), *Knipolegus cyanirostris* (2), *Muscipipra vetuia* (1), *Pyrocephalus rubinus* (1), *Satrapa icterophrys* (19), *Sirystes sibilator* (1), *Muscivora tyrannus* (15), *Legatus leucophaius* (7), *Myiozetetes cayanensis* (13), *Myiarchus tyrannulus* (10), *M. swainsoni* (16), *Contopus cinereus* (3), *Onychorhynchus coronatus* (2), *Platyrinchus platyrhynchos* (6), *P. leucoryphus* (6), *Tolmomyias sulphurescens* (41), *Todirostrum poliocephalum* (2), *T. fumifrons* (1), *T. plumbeiceps* (4), *Idioptilon nidipendulum* (5), *I. orbitatum* (1), *Phylloscartes ventralis* (22), *P. oustaleti* (6), *Elaenia flavogaster* (76), *E. parvirostris* (10), *E. cristata* (100), *E. chiriquensis* (152), *E. obscura* (188), *Camptostoma obsoletum* (39), *Xanthomyias virescens* (31), *Phyllomyias griseiceps* (1), *Leptopogon amaurocephalus* (50).

TABLE II

Comparison of the prevalence and parasite frequency of avian haematozoa

	Brazil 1980	Brazil current	[a]Neotropic	[b]Nearctic	[c]SE Asia
Total birds examined	3449	15574	35555	57026	55289
Total infected birds	268	1240	3743	21048	9026
Percent prevalence	7.8	8.0	10.5	36.9	16.3
Total parasite infections	284	1343	4107	27771	9827
Parasite index	1.06	1.09	1.10	1.32	1.10
Percent parasite frequency of total parasite infections					
Haemoproteus	42.3	39.0	63.8	40.0	63.2
Leucocytozoon	0.01	0.82	0.01	36.3	14.9
Microfilaria	31.3	30.7	10.7	6.4	10.2
Plasmodium	14.1	7.5	16.3	7.9	4.3
Trypanosoma	10.2	13.7	4.8	8.1	1.2
[d]Other	2.2	8.3			

[a] White et al., 1978.
[b] Greiner et al., 1975.
[c] McClure et al., 1978.
[d] Includes *Atoxoplasma* sp., *Babesia* sp., *Hepatozoon* sp., *Lankesterella* sp., and as yet unidentifiable parasites.

TABLE III

Prevalence of avian haematozoa by bird family in three regions of São Paulo State. (N)

Family	Overall prevalence	Itapetininga	Guaratuba	Casa Grande
Accipitridae	20.0 (10)	0.0 (7)	66.7 (3)	–
Alcedinidae	1.8 (112)	2.7 (37)	1.3 (75)	–
Apodidae	2.7 (146)	–	2.7 (146)	–
Ardeidae	0.0 (3)	0.0 (2)	0.0 (1)	–
Bucconidae	37.2 (43)	8.3 (24)	73.7 (19)	–
Caprimulgidae	0.0 (21)	0.0 (5)	0.0 (16)	–
Coerebidae	7.1 (364)	1.0 (97)	9.5 (264)	0.0 (3)
Columbidae	15.4 (376)	18.8 (277)	8.3 (36)	4.8 (63)
Conopophagidae	13.8 (399)	15.8 (240)	13.9 (36)	9.8 (123)
Corvidae	0.0 (1)	0.0 (1)	–	–
Cotingidae	55.4 (92)	30.0 (30)	71.4 (56)	33.3 (6)
Cuculidae	2.9 (34)	0.0 (21)	7.7 (13)	–
Cyclarhidae	12.7 (55)	15.9 (44)	0.0 (2)	0.0 (9)
Dendrocolaptidae	4.2 (639)	4.0 (149)	9.0 (199)	1.0 (291)
Falconidae	7.7 (13)	25.0 (4)	–	0.0 (9)
Formicariidae	7.6 (853)	8.5 (317)	9.5 (148)	6.2 (388)
Fringillidae	10.5 (1377)	13.8 (992)	3.7 (82)	1.6 (303)
Furnariidae	3.6 (953)	4.4 (504)	7.3 (151)	0.3 (298)
Hirundinidae	11.6 (242)	10.0 (60)	12.1 (182)	–
Icteridae	4.6 (86)	10.0 (40)	0.0 (46)	–
Mimidae	3.6 (28)	3.6 (28)	–	–
Parulidae	1.6 (376)	1.5 (206)	2.9 (105)	0.0 (65)
Picidae	3.0 (131)	0.0 (66)	6.8 (59)	0.0 (6)
Pipridae	1.2 (1625)	1.5 (524)	1.6 (369)	0.7 (732)
Ploceidae	16.7 (6)	16.7 (6)	–	–
Psittacidae	0.0 (22)	–	0.0 (21)	0.0 (1)
Rallidae	12.5 (8)	14.3 (7)	0.0 (1)	–
Ramphastidae	20.0 (5)	–	20.0 (5)	–
Rhinocryptidae	0.0 (2)	–	–	0.0 (2)
Strigidae	25.0 (16)	15.4 (13)	100.0 (2)	0.0 (1)
Tersinidae	0.0 (1)	–	0.0 (1)	–
Thraupidae	11.6 (2439)	6.4 (905)	18.6 (1028)	6.7 (506)
Tinamidae	6.7 (15)	20.0 (5)	0.0 (1)	0.0 (9)
Trochilidae	3.8 (26)	33.3 (3)	0.0 (18)	0.0 (5)
Troglodytidae	6.9 (102)	0.0 (29)	9.7 (72)	0.0 (1)
Trogonidae	0.0 (3)	–	0.0 (1)	0.0 (2)
Turdidae	15.0 (1315)	12.4 (598)	16.7 (384)	17.7 (333)
Tyrannidae	1.9 (2766)	1.4 (1525)	4.5 (507)	0.9 (734)
Vireonidae	36.0 (258)	29.2 (120)	64.6 (79)	11.9 (59)

In virtually all families where numbers were sufficiently large, the 1973 prevalence was higher than other years. This remains true for both highly-infected families such as the Turdidae, Thraupidae and Columbidae and also for low-infected families such as the Tyrannidae. For many of the low-infected families, a substantial proportion of their total infected birds were caught in 1973. Therefore, the differences in the 1973 prevalences were due to factors peculiar to that year rather than to the numbers of birds caught or the particular community compositions. These factors may well be associated with climatic changes. However, we have been unable to obtain detailed meteorological information for the specific areas.

The prevalences of trypanosomes and microfilaria are the major contributors to the increase in the overall prevalence for all areas combined in 1973. For example, for the highly-infected families Turdidae and Thraupidae, the 1973 contributions to total trypanosomes (over all years) were 72% and 53%, respectively, and microfilaria 24% and 24%, respectively. For the low-infected family Tyrannidae, 62% of trypa-

TABLE IV

Prevalence of avian haematozoa in São Paulo State, Brazil, 1966-1975

Region	Total	Infected birds	[a]*H.*	[a]*P.*	[a]*T.*	[a]M.	[b]O.
Guaratuba	4128	515	190	14	59	232	58
Percent infected		12.5	4.6	0.3	1.4	5.6	1.4
Itapetininga	6886	520	245	69	83	108	43
Percent infected		7.5	3.6	1.0	1.2	1.6	0.6
Casa Grande	3952	162	51	12	34	61	15
Percent infected		4.1	1.3	0.3	0.9	1.5	0.4
Other areas	608	46	20	4	8	12	5
Percent infected		7.6	3.3	0.7	1.3	2.0	0.8
Total	15574	1243	506	99	184	413	121
Overall prevalence			3.2	0.6	1.2	2.7	0.8

[a] *H.* = *Haemoproteus*, *P.* = *Plasmodium*, *T.* = *Trypanosoma*, M. = microfilaria.
[b] Includes *Atoxoplasma*, *Babesia*, *Hepatozoon*, *Lankesterella*, *Leucocytozoon* and as yet unidentifiable parasites.

TABLE V

Yearly distribution of avian haematozoa in three regions of São Paulo State, 1966-1975. Prevalences of infection are given in parentheses

Year	Total	Infected birds	% Infected	[a]*H.*	[a]*P.*	[a]*T.*	[a]M.
1966	175	19	10.9	6 (3.4)	1 (0.6)	2 (1.1)	12 (6.9)
1967	1596	97	6.1	54 (3.4)	9 (0.6)	6 (0.4)	23 (1.4)
1968	1314	96	7.3	39 (3.0)	19 (1.4)	3 (0.2)	31 (2.4)
1969	1858	116	6.2	58 (3.1)	15 (0.8)	6 (0.3)	35 (1.9)
1970	1651	111	6.7	51 (3.1)	12 (0.7)	13 (0.8)	31 (1.9)
1971	2220	164	7.4	77 (3.5)	7 (0.3)	25 (1.1)	56 (2.5)
1972	1863	180	9.7	63 (3.4)	12 (0.6)	28 (1.5)	74 (4.0)
1973	2279	288	12.6	85 (3.7)	15 (0.7)	83 (3.6)	88 (3.9)
1974	1107	63	5.7	30 (2.7)	2 (0.2)	4 (0.4)	25 (2.3)
1975	899	63	7.0	23 (2.6)	3 (0.3)	6 (0.7)	26 (2.9)
Total	14962	1197	8.0	486 (3.2)	95 (0.6)	176 (1.2)	401 (2.7)

[a] *H.* = *Haemoproteus*, *P.* = *Plasmodium*, *T.* = *Trypanosoma*, M. = microfilaria.

nosome infections and 43% of microfilaria infections were found in birds captured in 1973.

Prevalences of parasitism were examined on a monthly basis (Table VI, Fig. 1). It was determined that fluctuations between months were due to several factors. Turdids and thraupids appear to be the major contributors to the fluctuations in the overall monthly prevalences. (Figs 2, 3). Many fluctuations were due to changes in the relative proportions of highly-infected and low-infected families either between the months or between the areas or a combination of both. For example, wherever and whenever vireonids and cotingids occurred in large enough numbers they increase the overall prevalence. In October and December the increased number of vireonids and cotingids are responsible for the increased prevalences in Guaratuba and Itapetininga. The overall prevalences for the month of June were low as found by Bennett & de Souza Lopes (1980). It appears likely that the lowered prevalence was a reflection of a reduction in the number of birds captured in June and/or reduction of vector potential by climatic factors as suggested by Bennett & de Souza Lopes (1980).

TABLE VI

Monthly distribution of avian haematozoa in three regions of São Paulo State, Brazil, 1966-1975

Month	Total	Infected	% Infected	[a]*H.*	[a]*P.*	[a]*T.*	[a]M.
Jan	1148	118	10.3	51 (4.4)	3 (0.3)	12 (1.0)	30 (2.6)
Feb	1311	91	6.9	34 (2.6)	21 (1.6)	13 (1.0)	24 (1.8)
Mar	1335	75	5.6	27 (2.0)	9 (0.7)	15 (1.1)	20 (1.5)
Apr	1717	133	7.8	44 (2.6)	16 (0.9)	21 (1.2)	47 (2.7)
May	836	57	6.8	13 (1.6)	4 (0.5)	16 (1.9)	23 (2.8)
Jun	789	29	3.7	10 (1.3)	3 (0.4)	8 (1.0)	7 (0.9)
Jul	1322	108	8.2	32 (2.4)	9 (0.7)	15 (1.1)	56 (4.2)
Aug	1195	106	8.9	32 (2.7)	11 (0.9)	20 (1.7)	37 (3.1)
Sep	1250	84	6.7	38 (3.0)	4 (0.3)	13 (1.0)	29 (2.3)
Oct	1677	167	10.0	84 (5.0)	9 (0.5)	19 (1.1)	49 (2.9)
Nov	959	62	6.5	30 (3.1)	2 (0.2)	7 (0.7)	18 (1.9)
Dec	1423	167	11.7	91 (6.4)	4 (0.3)	17 (1.2)	61 (4.3)
Total	14962	1197	8.0	486 (3.2)	95 (0.6)	176 (1.2)	401 (2.7)

[a] *H.* = *Haemoproteus*, *P.* = *Plasmodium*, *T.* = *Trypanosoma*, M. = microfilaria.

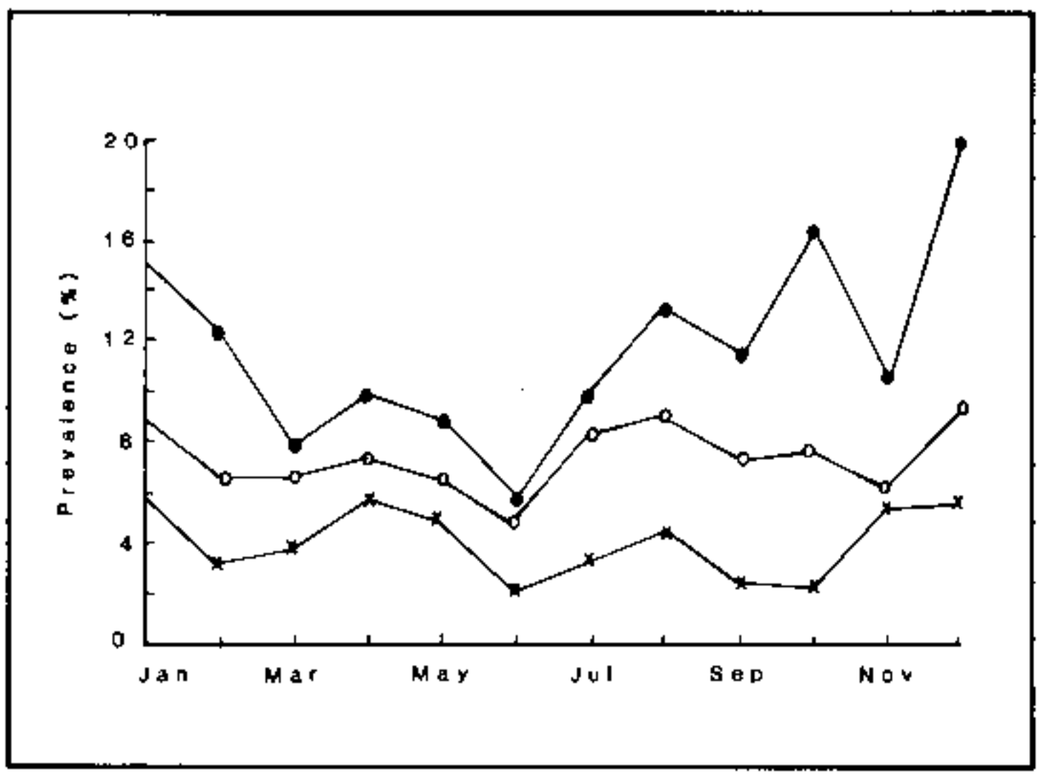

Fig. 1: monthly prevalences of haematozoa at 3 areas of São Paulo State, 1966-1975. – ● – Itapetininga; – ○ – Guaratuba; – x – Casa Grande.

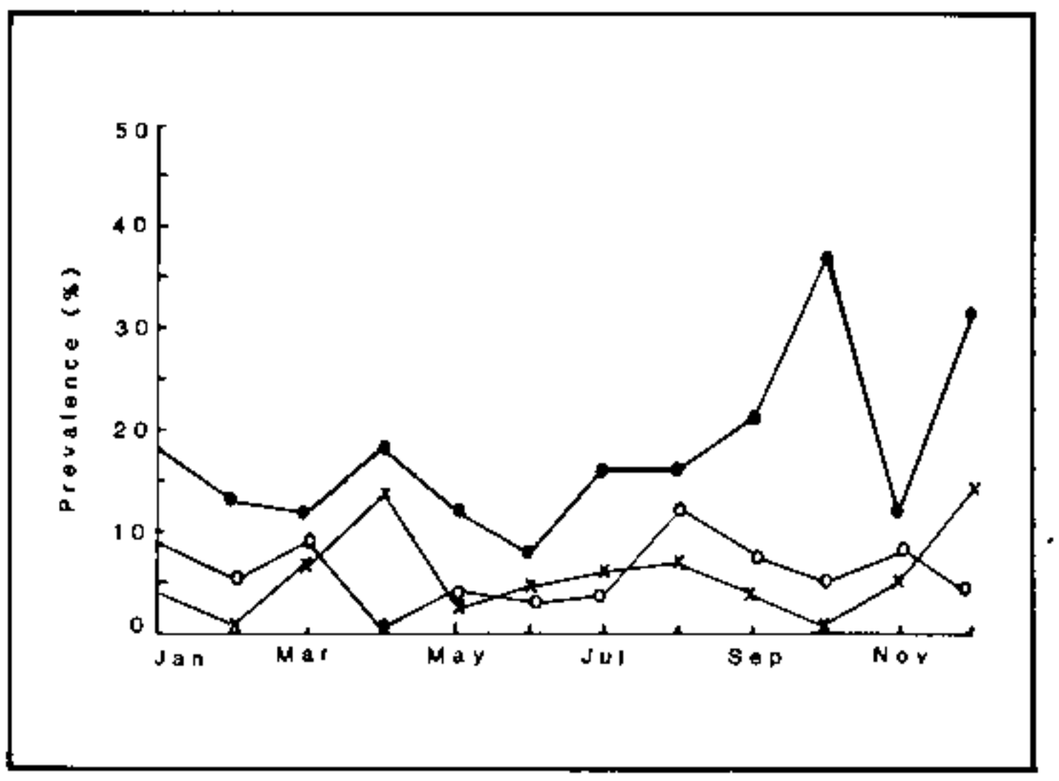

Fig. 3: monthly prevalences of haematozoa in the avian family Thraupidae at 3 areas of São Paulo State, 1966-1975. – ● – Itapetininga; – ○ – Guaratuba; – x – Casa Grande.

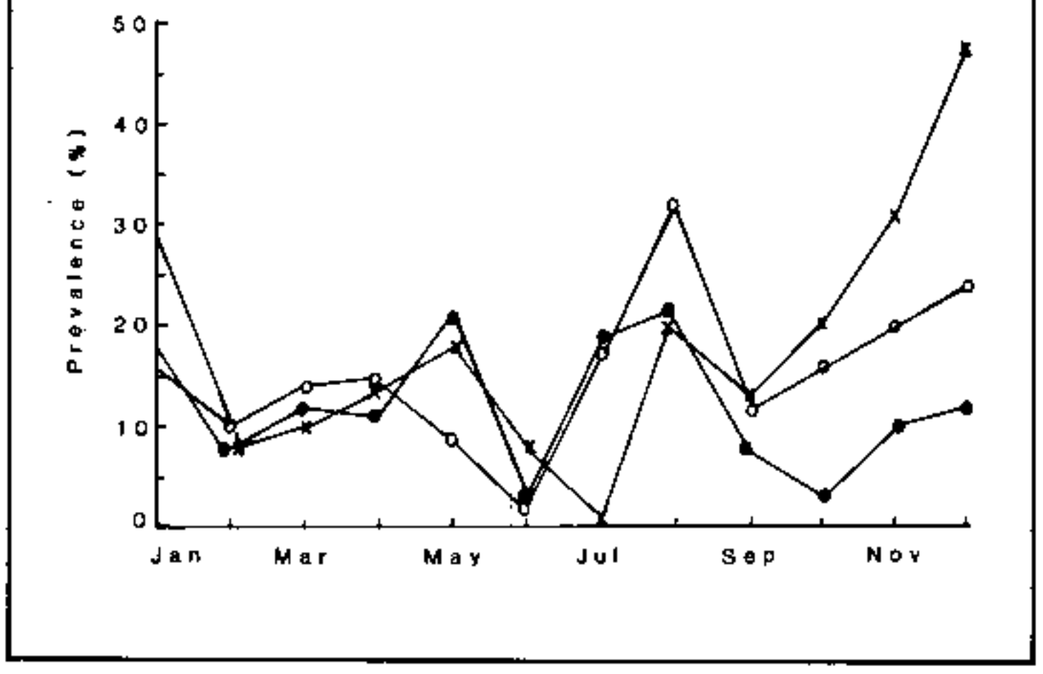

Fig. 2: monthly prevalences of haematozoa in the avian family Turdidae at 3 areas of São Paulo State, 1966-1975. – ● – Itapetininga; – ○ – Guaratuba; – x – Casa Grande.

It is apparent that in any examination of prevalence of parasitism careful consideration must be given to the avifauna involved especially when comparisons are to be made between areas. Prevalence rates calculated for higher taxa should be viewed with caution since variation in prevalences can be considerable at the specific level.

RESUMO

Prevalência de hematozoários de aves do Estado de São Paulo, Brasil – Analisamos o sangue de 15.574 aves que representam 266 espécies entre 43 famílias, para revelar a presença de

hematozoários. Somente 1.240 (8,0%) de 121 espécies entre 32 famílias estavam infectadas com parasitas sanguíneos. Esta prevalência era semelhante àquele relatada em estudos anteriores. Espécies de *Haemoproteus* foram os hematozomas mais comuns encontrados (38,9%), seguidos por microfilária (30,7%) – *Trypanosoma* (13,7%), *Plasmodium* (7,5%) e *Leucocytozoon* (0,8%). A prevalência do parasitismo foi significativamente diferente nas amostras das três áreas maiores. Foi demonstrado que isto se deve em parte às diferenças da avifauna, tanto no que se refere às famílias, como às espécies. A prevalência só variou significativamente num dos anos, durante os dez do estudo. As altas flutuações mensais de prevalência foram devidas a alterações nas proporções relativas das famílias aviárias que apresentaram níveis altos e baixos de infecção, entre os meses ou entre as áreas, ou devido à combinação dos dois fatores. A prevalência da microfilária e do *Trypanosoma* foi maior do que qualquer outra já registrada em trabalhos semelhantes no mundo.

Palavras-chave: hematozoários de aves – Brasil – prevalência – distribuição em relação às estações do ano

ACKNOWLEDGEMENTS

The authors are indebted to Dr Oscar de Souza Lopes for providing the blood films and Mr Emilio Dente who was responsible for much of the collection effort.

REFERENCES

BENNETT, G. F. & BORRERO, J. I. H., 1976. Blood parasites of some birds from Colombia. *J. Wildl. Dis., 12:* 454-458.

BENNETT, G. F. & PEIRCE, M. A., 1988. Morphological form in the avian Haemoproteidae and an annotated checklist of the genus *Haemoproteus* Kruse, 1890. *J. Nat. Hist., 22:* 1683-1696.

BENNETT, G. F. & de SOUZA LOPES, O., 1980. Blood parasites of some birds from São Paulo State, Brazil. *Mem. Inst. Oswaldo Cruz,* Rio de Janeiro, *75:* 117-134.

BENNETT, G. F.; WHITEWAY, M. & WOODWORTH-LYNAS, C., 1982. *A Host-Parasite Catalogue of the Avian Haematozoa.* Memorial University of Newfoundland Occasional Papers in Biology No. 5. 243 p.

CLEMENTS, J. F., 1978. *Birds of the World: A Check List.* Second Edition. The Two Continents Publishing Group, N. Y. 532 p.

GABALDON, A.; ULLOA, G. & GOMEZ DE MONTCOURT, A., 1974. Encuesta sobre malaria aviaria en Venezuela: Resultados del primer año. *Bol. Dir. Malariol. y San. Amb., 19:* 80-103.

GABALDON, A.; ULLOA, G. & GOMEZ DE MONTCOURT, A., 1975. Encuesta sobre malaria aviaria en Venezuela: Resultados del segundo año. *Bol. Dir. Malariol. y San. Amb., 20:* 73-91.

GREINER, E. C.; BENNETT, G. F.; WHITE, E. M. & COOMBS, R. F., 1975. Distribution of the avian haematozoa of North America. *Can. J. Zool., 53:* 1762-1787.

MCCLURE, H. E.; POONSWAD, P.; GREINER, E. C. & LAIRD, M., 1978. *Haematozoa in the birds of eastern and southern Asia.* Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 296 p.

PIELOU, E. C., 1974. *Population and community ecology: principles and methods.* Gordon and Breach, New York. 385 p.

SOKAL, R. R. & ROHLF, F. J., 1969. *Biometry.* W. H. Freeman and Company, San Francisco. 776 p.

WHITE, E. M.; GREINER, E. C.; BENNETT, G. F. & HERMAN, C. M., 1978. Distribution of the haematozoa of Neotropical birds. *Rev. Biol. Trop., 26:* 43-102.