Further Observations on the Blood Parasites of Birds in Uganda

Authors: Valkiūnas, Gediminas, Sehgal, Ravinder N. M., Iezhova, Tatjana A., and Smith, Thomas B.

Source: Journal of Wildlife Diseases, 41(3) : 580-587

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-41.3.580

Journal of Wildlife Diseases, 41(3), 2005, pp. 580–587

Further Observations on the Blood Parasites of Birds in Uganda

Gediminas Valkiūnas,[1,3,5] **Ravinder N. M. Sehgal,**[2,3] **Tatjana A. Iezhova,**[1] **and Thomas B. Smith**[3,4] [1] Institute of Ecology, Vilnius University, Akademijos 2, Vilnius 21, LT-08412, Lithuania; [2] Department of Biology, San Francisco State University, 1600 Holloway Ave., San Francisco, California, 94132, USA; [3] Center for Tropical Research, Institute of the Environment, University of California, Los Angeles, 1365 Hershey Hall, P.O. Box 95 1496, Los Angeles, California 90095-1496, USA; [4] Department of Ecology and Evolutionary Biology, University of California, Los Angeles, California 90095-1606, USA; [5] Corresponding author (email: gedvalk@ekoi.lt)

ABSTRACT: Birds from three National Parks (Bwindi Impenetrable, Kibale, and Queen Elizabeth) in western Uganda were surveyed during the dry season in July 2003 and investigated for hematozoa by microscopic examination of stained blood films. Of 307 birds examined, representing 68 species of 15 families and four orders, 61.9% were found to be infected with blood parasites. Species of *Haemoproteus* (15.3% prevalence), *Plasmodium* (20.5%), *Leucocytozoon* (40.1%), *Trypanosoma* (11.4%), *Hepatozoon* (2.6%), *Atoxoplasma* (0.3%), and microfilariae (3.9%) were recorded. Except for *Haemoproteus* spp. infections, the overall prevalence of hematozoa belonging to all genera was significantly higher in this study than was previously reported in Uganda. Thirty-six species of birds were examined for blood parasites for the first time and 112 new host-parasite associations were identified. Eighty-one were at the generic and 31 at the specific level of the hematozoa. *Hepatozoon* and *Atoxoplasma* spp. were detected for the first time in Uganda.

Key words: *Atoxoplasma,* avian hematozoa, *Haemoproteus, Hepatozoon, Leucocytozoon,* microfilariae, *Plasmodium, Trypanosoma,* Uganda.

Although numerous surveys have been conducted on the hematozoa of sub-Saharan African birds (Bennett et al., 1992a; Valkiūnas, 2005), some areas of the Ethiopian zoogeographical region remain insufficiently studied. Relatively little is known about blood parasites of wild birds from Uganda, a country of particular interest because of its diverse endemic avifauna that is threatened by severe deforestation (Sekercioglu, 2002). Hoare (1932) sampled 17 bird species in Uganda and reported a *Plasmodium* sp. infection in only one specimen of the common stonechat (*Saxicola torquata*). Two extensive studies were carried out on blood parasites of wild birds on the Entebbe Peninsula (EP) in Uganda (Bennett et al., 1974, 1977). Of 1,998 birds investigated, 31% were found to be infected with blood parasites. Interestingly, *Haemoproteus* spp. represented 91% of all detected infections of hemosporidian parasites. The prevalences of infections of birds with species of *Plasmodium, Leucocytozoon, Trypanosoma,* and microfilariae were recorded to be less than 2% for the representatives of each genus. However, these blood parasites are common in other countries of sub-Saharan Africa (Bennett et al., 1992a). Dranzoa et al. (1999) reported an unidentified species of *Haemoproteus* (76% prevalence) and *Plasmodium* (29%) in the rock pigeon (*Columba livia*) in Kampala. The distribution of avian blood parasites in other regions of Uganda has not yet been investigated. Our objectives here were to further study the avian hematozoa of Uganda by providing the first documentation on the occurrence and peculiarities of distribution of these parasites in western regions of this country.

Between 12 July and 25 July 2003 (the dry season), blood smears of 307 birds (55 males, 52 females, and 200 of unidentified sex) of 68 species belonging to 15 families and four orders were collected for the presence of blood parasites (Table 1). All birds sampled are known to be year-round residents. Among these birds were 18 specimens of <1 yr old (young birds), 288 specimens of >1 yr old (adult birds), and one specimen of unidentified age. The sex and age of each bird was determined according to Stevenson and Fanshawe (2002). Birds were caught with mist nets between daybreak (6:00 AM) and dusk (5:00 PM). They were ringed, bled, and released. None of them were recaptured. The blood was taken by puncturing the brachial vein. Three

blood films were prepared from each bird. Blood films were air dried within 5–10 sec after their preparation. In humid environments, we used a battery-operated fan to aid in the drying of the blood films. Slides were fixed in methanol in the field and then stained with Giemsa in the laboratory. Blood films were examined for 10–15 min at low magnification (400×) and then at least 100 fields were studied at high magnification (1,000×). Intensity of infection was estimated as a percentage by actual counting of the number of parasites per 1,000 red blood cells or per 10,000 red blood cells if infections were light (i.e., <0.1%), as recommended by Godfrey et al. (1987). Species of *Trypanosoma* and hemosporidian parasites were identified according to the reviews by Baker (1976) and Valkiūnas (2005), in which illustrations of all species of parasites mentioned in this article are given.

Sampling sites included 1) Bwindi Impenetrable National Park (BINP) (1°3.5′S, 29°46.5′E; 2,340 m above sea level, n=123), 2) Kibale National Park (KNP) (0°34.7′N, 30°21.3′E; 1,580 m, n=159), and 3) Queen Elizabeth National Park (QENP) (0°17.8′S, 30°3.0′E; 1,000 m, n=25).

In BINP, the study site situated along a mountain ridge consisted of dense, moist, evergreen, montane forest close to mountain marshes and secondary growth vegetation along permanent small, clean streams. The annual mean temperature range is 7–15 C minimum to 20–27 C maximum; annual precipitation lies in the range 1,130–2,390 mm. In KNP, the study site was moist evergreen forest with permanent small, clean streams. The forest is a mixture of pure forest stands and successional grassland, swamp forests, and secondary forests. The mean annual precipitation is approximately 1,740 mm. The annual mean temperature ranges between 16.2 C and 23.3 C. In QENP, the study site was located on a peninsular separating the Kazinga Channel from Lake Edward. The habitat was a mixture of open dry grassland and small patches of secondary bushes. Permanent streams were not present. The mean annual precipitation is approximately 1,000 mm. The annual mean temperature ranges between 18.0 C and 28.0 C (Sekercioglu, 2002; Zhou et al., 2004).

Prevalences of infections were compared by Yates corrected χ^2 test. A $P \leq 0.05$ was considered significant.

The overall prevalence of blood parasites was 61.9% (Table 1). Species of *Haemoproteus, Plasmodium, Leucocytozoon, Trypanosoma, Hepatozoon, Atoxoplasma,* and microfilariae were recorded. A number of the infections (40.5% of all positive birds) were mixed infections with parasites from two to four genera present in the infected birds. Over 80% of all recorded infections were light (<0.1%) and could be regarded as chronic. There was no significant difference in the prevalence or intensity of hematozoa between males or females or between young or adult birds.

Identification of species of hemosporidians was possible when the intensity of infection was >0.01% and when fully grown parasites were present in blood films. Fifteen species of hematozoa were identified (Table 2). Representative blood slides were deposited in the Institute of Ecology, Vilnius University, Vilnius, Lithuania.

The overall prevalence of blood parasites was high at each study site (Table 3). It is worth noting that species of *Leucocytozoon* were not seen and species of *Plasmodium* and *Trypanosoma* were not prevalent in QENP, but these parasites were frequently recorded in both BINP and KNP. This is probably because the former is much drier and has no permanent streams and thus limits mosquito (Culicidae) activity and habitat for immature simuliid flies (Simuliidae). The mosquitoes and simuliid flies are vectors of avian *Plasmodium* and *Leucocytozoon* spp., respectively (Valkiūnas, 2005). These blood-sucking dipterans also transmit avian trypanosomes (Baker, 1976).

Only sample sizes of the yellow-whis-

TABLE 1. Occurrence of hematozoa in birds from Uganda, July 2003.

Bird species and family	No. examined	No. infected	No. of birds infected[a]						
			H	P	L	T	M	He	A
Columbidae									
Columba arquatrix[bc]	1	1			1[d]				
Turtur tympanistria	1	1	1						
Total	2	2	1		1				
Cuculidae									
Chrysococcyx cupreus	1	1			1[d]		1[d]		
Estrildidae									
Cryptospiza jacksoni[b]	3	2			2		2[d]		
Lonchura bicolor	3	2	1					1[d]	
Nigrita canicapilla	1	1			1[d]		1[d]		
Total	7	5	1		3		3	1	
Indicatoridae									
Indicator pumilio[bc]	3	1			1[d]				
Laniidae									
Laniarius luehderi[bc]	1	1			1[d]	1[d]			
Lybiidae									
Pogoniulus coryphaeus[bc]	2	1			1[d]				
Muscicapidae									
Alethe poliocephala[bc]	3	1	1[d]	1[d]	1[d]				
Alethe poliophyrs[bc]	2	1			1[d]		1[d]		
Batis diops[bc]	2	2			2[d]				
Muscicapa aquatica[bc]	2	1	1[d]						
Muscicapa comitata[bc]	1	1		1[d]	1[d]				
Neocossyphus poensis[bc]	2	1							1[d]
Pogonocichla stellata[b]	2	1	1[d]						
Total	14	8	3	2	5		1		1
Nectarinidae									
Cinnyris erythrocerca[bc]	2	1					1[d]		
Cinnyris minulla[bc]	3	2	1[d]	1[d]	1[d]				
Cinnyris preussi[bc]	5	4	4[d]			1[d]			
Cyanomitra alinae[bc]	18	14	12[d]	5[d]	10[d]	3[d]			
Hedydipna collaris	2	2		2	1	1	1[d]		
Nectarinia olivacea	29	24	6	13	10	8			
Nectarinia verticalis	5	4		4[d]	1[d]		1[d]		
Total	64	51	23	25	23	13	3		
Ploceidae									
Malimbus rubricollis[bc]	1	1	1[d]		1[d]				
Ploceus alienus[bc]	1	1		1[d]	1[d]				
Ploceus melanocephalus[b]	2	2	2						
Ploceus pelzelni	11	4	3	1[d]					
Quelea quelea	1	1	1						
Total	16	9	7	2	2				
Pycnonotidae									
Andropadus gracilis[b]	1	1		1[d]	1				
Andropadus latirostris	67	52		16[d]	46[d]	13[d]		6[d]	
Andropadus nigroceps[bc]	4	4	2[d]	1[d]	4[d]	1[d]			
Andropadus virens	24	16		1	15		1		
Bleda syndactyla[bc]	4	2		1[d]		1[d]			
Phyllastrephus cabanisi[b]	3	2			2[d]				
Phyllastrephus flavostriatus[bc]	1	1		1[d]					
Phyllastrephus hypochloris[bc]	3	3	1[d]	2[d]	3[d]				
Total	107	81	3	23	71	15	1	6	

TABLE 1. Continued.

Bird species and family	No. examined	No. infected	No. of birds infected[a]						
			H	P	L	T	M	He	A
Sturnidae									
Onychognathus tenuirostris[bc]	4	3		1[d]	1[d]	1[d]	2[d]		
Syliviidae									
Apalis personata[bc]	3	3		1[d]		2[d]			
Bradypterus cinnamomeus[bc]	2	2		2[d]				1[d]	
Camaroptera brachyura	2	1				1[d]			
Chloropeta similis[bc]	1	1	1[d]			1[d]			
Cisticola chubbi[bc]	10	1			1[d]				
Prinia bairdii[b]	3	2		2[d]					
Sylvietta leucophrys[bc]	2	1		1[d]					
Total	23	11	1	6	1	4		1	
Timaliidae									
Illadopsis fulvescens	2	2			1[d]	1[d]			
Illadopsis pyrrhoptera	4	2		1[d]	1[d]		1[d]		
Illadopsis rufipennis	6	4	1[d]	2[d]	2[d]				
Pseudoalcippe abyssinica	3	3	3[d]		3[d]				
Total	15	11	4	3	7	1	1		
Zosteropidae									
Zosterops senegalensis	5	5	4	1	5				
Uninfected species[e]	43								
Grand total	307	190	47	63	123	35	12	8	1
Prevalence (%)		61.9	15.3	20.5	40.1	11.4	3.9	2.6	0.3

[a] H = *Haemoproteus* spp.; P = *Plasmodium* spp.; L = *Leucocytozoon* spp.; T = *Trypanosoma* spp.; M = microfilaria; He = *Hepatozoon* spp.; A = *Atoxoplasma* spp.

[b] First time species examined in Uganda.

[c] First time species examined for blood parasites.

[d] New host record.

[e] Uninfected species (number of individuals examined): Estrildidae: *Estrilda quartinia*[bc] (2), *Lagonosticta senegala*[b] (2); Indicatoridae: *Indicator exils*[bc] (4); Lybiidae: *Gymnobucco bonapartei*[bc] (1), *Pogoniulus bilineatus* (1); Muscicapidae: *Cossypha heuglini* (2), *Cossypha polioptera*[bc] (1), *Dyaphorophyia jamesoni*[bc] (1), *Sheppardia aequatorialis*[bc] (1); Picidae: *Campethera caroli*[b] (1), *Campethera nivosa* (3); Poloceidae: *Ploceus heuglini*[bc] (1), *Ploceus intermedius*[b] (1); Sylviidae: *Apalis ruwenzorii*[bc] (4), *Bathmocercus rufus*[bc] (5), *Camaroptera chloronota* (1), *Hylia prasina*[b] (3), *Prinia leucopogon* (8); Nectarinidae: *Cinnyris regia*[bc] (1).

kered greenbul (*Andropadus latirostris*) were large enough to compare prevalences of blood parasites in the same avian host between different study sites. There was no significant difference in the overall prevalence of blood parasites between BINP (86%) or KNP (73%). Species of *Haemoproteus*, *Atoxoplasma*, and microfilariae were not found in this species at either study site. There was no difference discernable in the prevalence of *Plasmodium* spp., *Leucocytozoon* spp., and *Hepatozoon* spp. infections in the yellow-whiskered greenbul between BINP or KNP. Only *Trypanosoma* spp. were significantly more prevalent in BINP (36%) than in KNP (11%) ($P<0.05$). The similarity of the hematozoan infection prevalences in the same avian host at these national parks probably indicates similarity in vector ecology, which warrants further investigation.

Sample sizes of the little greenbul (*Andropadus virens*) and olive sunbird (*Nectarinia olivacea*) were sufficient to compare prevalences of blood parasites in different species of avian hosts at the same study sites. There was no significant difference in the overall prevalence of infection and the prevalence of *Leucocytozoon*

TABLE 2. Occurrence of hematozoa in Ugandan birds by species, July 2003.

Bird species and family	Parasite species	Accession number of the representative blood slide
Columbidae		
Columba arquatrix	*Leucocytozoon marchouxi*[ab]	7033 NS
Turtur tympanistria	*Haemoproteus turtur*[b]	6639 NS
Estrildidae		
Cryptospiza jacksoni	*L. fringillinarum*[ab]	7190 NS
Lonchura bicolor	*H. beckeri*[b]	7034 NS
Laniidae		
Laniarius luehderi	*L. fringillinarum*[ab]	6643 NS
Muscicapidae		
Alethe poliocephala	*H. minutus*[ab]	6746 NS
Muscicapa aquatica	*H. balmorali*[a]	6927 NS
Pogonicichla stellata	*H. balmorali*[ab]	6991 NS
Nectarinidae		
Cyanomitra alinae	*Plasmodium rouxi*[ab]	7335 NS
	L. dubreuili[ab]	7151 NS
	L. fringillinarum[ab]	6975 NS
	L. majoris[ab]	7335 NS
	Trypanosoma everetti	6957 NS
Hedydipna collaris	*L. majoris*[b]	6410 NS
Ploceidae		
Malimbus rubricollis	*L. majoris*[ab]	6463 NS
Ploceus alienus	*L. majoris*[ab]	7231 NS
Ploceus pelzelni	*H. queleae*	6903 NS
Pycnonotidae		
Andropadus latirostris	*L. fringillinarum*[b]	7016 NS
	L. majoris[b]	6319 NS
	T. avium[b]	6386 NS
	T. everetti[b]	6983 NS
Andropadus nigroceps	*P. circumflexum*[ab]	7383 NS
	L. fringillinarum[ab]	7148 NS
	L. majoris[ab]	7092 NS
	T. avium[ab]	7139 NS
	T. everetti[ab]	7106 NS
Andropadus virens	*L. fringillinarum*[b]	6557 NS
	L. majoris[b]	6312 NS
Bleda syndactyla	*T. everetti*	6565 NS
Sylviidae		
Chloropeta similis	*H. belopolskyi*[ab]	6950 NS
	T. avium[ab]	6950 NS
Cisticola chubbi	*L. fringillinarum*[ab]	6962 NS
Timaliidae		
Illadopsis pyrrhoptera	*P. rouxi*[ab]	7222 NS
Illadopsis rufipennis	*L. majoris*[ab]	6619 NS
Pseudoalcippe abyssinica	*L. majoris*[ab]	7216 NS
Zosteropidae		
Zosterops senegalensis	*H. killangoi*	7083 NS

[a] First time parasite recorded in Uganda.
[b] New host record.

TABLE 3. Occurrence of blood parasites in birds from three national parks in Uganda, July 2003.

National park	No. examined	No. infected	No. of birds infected[a]						
			H	P	L	T	M	He	A
Bwindi Impenetrable National Park	123	80 (65.0)[b]	29 (23.6)	19 (15.4)	54 (43.9)	17 (13.8)	8 (6.5)	3 (2.4)	0
Kibale National Park	159	100 (62.9)	11 (6.9)	43 (27.0)	69 (43.4)	17 (10.7)	3 (1.9)	5 (3.1)	1 (0.6)
Queen Elizabeth National Park	25	10 (40)	7 (28)	1 (4)	0	1 (4)	1 (4)	0	0

[a] H = *Haemoproteus* spp.; P = *Plasmodium* spp.; L = *Leucocytozoon* spp.; T = *Trypanosoma* spp.; M = microfilaria; He = *Hepatozoon* spp.; A = *Atoxoplasma* spp.
[b] Percentage of positive birds is given in parentheses.

spp. and microfilarial infections between these bird species in KNP. The species of *Haemoproteus, Plasmodium,* and *Trypanosoma* were significantly more prevalent in the olive sunbird than in the little greenbul at this study site ($P=0.05$, $P<0.01$, and $P<0.05$, respectively). It is probable that the olive sunbird is an attractive host for vectors of these hematozoa.

The overall prevalence of hematozoa in this study was two times greater than had been formerly recorded in wild birds from the EP in southern Uganda (Bennett et al., 1974, 1977). We recorded a significantly greater prevalence of infection in western Uganda than had been previously detected around EP for *Plasmodium* spp. (1% prevalence was detected around the EP), *Leucocytozoon* spp. (2%), and *Trypanosoma* spp. (1%). However, the overall prevalence of *Haemoproteus* spp. infection was greater at EP (28%) than in our sites.

We sampled birds only during the dry season, whereas Bennett et al. (1974, 1977) sampled birds throughout the year over a period of 6 years. They found no significant differences in the overall prevalence of hematozoan infections in birds collected during wet and dry seasons or in different years. Thus, the prevalence of blood parasites in birds collected around EP was relatively stable. Therefore, the differences in prevalence of hematozoa around EP and in western Uganda during this study probably cannot be explained by differences due to the season of investigation. These differences are perhaps due to differences in the transmission of hematozoa in these different regions of Uganda.

There is presently no published information regarding the vectors that transmit the avian blood parasites of Uganda. In addition, few studies have reported on the vectors of the blood parasites of birds in sub-Saharan Africa (Fallis et al., 1973; Crewe, 1975; Huchzermeyer, 1993). The limited information concerning the insect vectors in Africa remains one of the main obstacles to understanding the dynamics of transmission of avian blood parasites in Uganda.

According to Bennett et al. (1974, 1977) and this study, blood parasites are present in birds at all study sites in Uganda. Because the resident year-round birds were infected at each study site, it is probable that the transmission of representatives of all recorded genera of blood parasites takes place throughout the country.

Atoxoplasma and *Hepatozoon* spp. have been frequently recorded in birds all over the world, including African countries (Levine, 1982; Bennett et al., 1992b). These parasites are reported for the first time in Ugandan birds in this study. Six of the eight recorded *Hepatozoon* spp. infections were found in the yellow-whiskered greenbul (Table 1). Because *Hepatozoon* spp. are transmitted among avian hosts by means of eating infected arthropods (Bennett et al., 1992b), investigations on the feeding behavior of the yellow-whiskered greenbul may be helpful to elucidate a

possible invertebrate host of *Hepatozoon* spp. in Uganda.

In all, 36 species of birds (Table 1) were examined for hematozoa for the first time and 46 for the first time in Uganda during this study (Bennett et al., 1974, 1977, 1992a; Valkiūnas, 2005). Twelve new host records for *Haemoproteus* spp., 20 for *Plasmodium* spp., 25 for *Leucocytozoon* spp., 11 for *Trypanosoma* spp., three for *Hepatozoon* spp., one for *Atoxoplasma* spp., and nine for microfilariae are reported in this study (Table 1).

The diversity of hematozoa recorded in this work is typical for African birds and the most parasitized birds belong to families typically heavily infected in sub-Saharan Africa (Bennett et al., 1992a). The great majority of species of blood parasites recorded in this study (Table 2) are found throughout the Old World (Valkiūnas, 2005). The detection of these parasites in Ugandan birds is thus not unexpected. Further field studies, supplemented by experimental work on vectors, and studies on the epidemiology, virulence, and molecular phylogenetics of the parasites are needed to explain the peculiarities of the distribution of hematozoa and to determine their significance in Uganda and other sub-Saharan countries.

We wish to thank Christine Dranzoa and John Kasenene, Makerere University, Kampala, Uganda, for their advice and help in organizing our work in Uganda. Adam Freedman and Joseph Kamanyire are gratefully acknowledged for help in the field. We are grateful to the Uganda Wildlife Authority for the opportunity to perform this study, which was supported by the NATO Collaborative Linkage Grant and the Lithuanian State Science and Studies Foundation. R.N.M.S. was supported in part by a NIGMS MORE Institutional Research and Academic Career Development Award to UC Davis and San Francisco State University, grant K12GM00679. The research was also supported by the NSF-NIH Ecology of Infectious Diseases Program grant EF-0430146 awarded to R.N.M.S. and T.B.S.

LITERATURE CITED

BAKER, J. R. 1976. Biology of the trypanosomes of birds. *In* Biology of the Kinetoplastida, Vol. 1, W. H. R. Lumsden, and D. A. Evans (eds.). Academic Press, London, UK, pp. 131–174.

BENNETT, G. F., N. O. OKIA, AND M. F. CAMERON. 1974. Avian hematozoa of some Ugandan birds. Journal of Wildlife Diseases 10: 458–465.

———, E. M. WHITE, AND N. A. WILLIAMS. 1977. Additional observations on the blood parasites of Ugandan birds. Journal of Wildlife Diseases 13: 251–257.

———, R. A. EARLÉ, H. DU TOIT, AND F. W. HUCHZERMEYER. 1992a. A host-parasite catalogue of the haematozoa of the sub-Saharan birds. Onderstepoot Journal of Veterinary Research 59: 1–73.

———, ———, AND M. PEIRCE. 1992b. New species of avian *Hepatozoon* (Apicomplexa: Haemogregarinidae) and a re-description of *Hepatozoon neophrontis* (Todd and Wohlbach, 1912) Wenyon, 1926. Systematic Parasitology 23: 183–193.

CREWE, S. M. 1975. Studies on the biology of malaria and other blood parasites of Nigerian birds. PhD Thesis, University of Liverpool, Liverpool, UK, 278 pp.

DRANZOA, C., M. OCAIDO, AND P. KATETE. 1999. The ecto-, gastro-intestinal and haemo-parasites of life pigeons (*Columba livia*) in Kampala, Uganda. Avian Pathology 28: 119–124.

FALLIS, A. M., R. L. JACOBSON, AND J. N. RAYBOULD. 1973. Haematozoa in domestic chickens and guinea fowl in Tanzania and transmission of *Leucocytozoon neavei* and *Leucocytozoon schoutedeni.* Journal of Protozoology 20: 438–442.

GODFREY, R. D., A. M. FEDYNICH, AND D. B. PENCE. 1987. Quantification of hematozoa in blood smears. Journal of Wildlife Diseases 23: 558–565.

HOARE, C. A. 1932. On protozoal blood parasites collected in Uganda. With an account of the life cycle of the crocodile haemogregarine. Parasitology 24: 210–224.

HUCHZERMEYER, F. W. 1993. A host-parasite list of the haematozoa of domestic poultry in sub-Saharan Africa and the isolation of *Plasmodium durae* Herman from turkeys and francolins in South Africa. Onderstepoot Journal of Veterinary Research 60: 15–21.

LEVINE, N. D. 1982. The genus *Atoxoplasma* (Protozoa, Apicomplexa). Journal of Parasitology 68: 719–723.

SEKERCIOGLU, C. H. 2002. Effects of forestry practices on vegetation structure and bird community

of Kibale National Park, Uganda. Biological Conservation 107: 229–240.

STEVENSON, T., AND J. FANSHAWE. 2002. Field guide to the birds of East Africa. T. and A. D. Poyser Ltd, London, UK, 600 pp.

VALKIŪNAS, G. 2005. Avian malaria parasites and other haemosporidia. CRC Press, Boca Raton, Florida, 946 pp.

ZHOU, G., N. MINAKAWA, A. K. GITHEKO, AND G. YAN. 2004. Association between climate variability and malaria epidemics in the East African highlands. Proceedings of the National Academy of Sciences 101: 2375–2380.

Received for publication 6 August 2004.