Acta Protozool. (2001) 40: 281 - 289

ACTA
PROTOZOOLOGICA

Haemosporida of Birds of Prey and Owls from Germany

Oliver KRONE[1], Jürgen PRIEMER[1], Jürgen STREICH[1], Paul SÖMMER[2], Torsten LANGGEMACH[3] and Olaf LESSOW [4]

[1] Institute for Zoo and Wildlife Research, Berlin; [2] Brandenburg State Institution for Large Protected Areas, Nature Centre Woblitz, Himmelpfort; [3] Brandenburg State Environmental Agency, Bird Conservation Centre, Buckow; [4] NABU Bird Station Leiferde, Leiferde, Germany

Summary. A total of 1149 free-living birds of prey from Germany were examined for blood parasites. The prevalence of infection was 11% (adult birds 18%, immature birds 16%, nestlings 4%). Among the Falconiformes 11% of 976 birds were infected, and 13% of 173 Strigiformes. Out of 17 falconiform species nine were infected with blood parasites whereas the Eurasian buzzard (*Buteo buteo*) had the highest prevalence for haematozoa; i.e. *Leucocytozoon toddi* (31%), the highest prevalence (25%) for *Haemoproteus* sp. was found in the hobby (*Falco subbuteo*). Eight species of owls were examined for blood parasites; the tawny owl (*Strix aluco*) had the highest prevalence with *Haemoproteus syrnii* (22%). In the one pygmy owl (*Glaucidium passerinum*) examined *Trypanosoma avium* and *Plasmodium (Giovannolaia) fallax* were detected. The white-tailed sea eagle (*Haliaeetus albicilla*) was found to be a host of *L. toddi* for the first time. Differences in the prevalence of blood parasites were found in the seasons and age classes of the birds but not between birds admitted to a rehabilitation centre or samples in the wild, the sexes, bird orders and the regions.

Key words: Falconiformes, Haematozoa, *Haemoproteus, Leucocytozoon*, Plasmodiidae, raptors, Strigiformes.

INTRODUCTION

Blood parasites were first described by Danilewsky in 1885 when he examined blood of Accipitridae, Laniidae and Corvidae. Since then avian haemosporidians have been recorded in about 68% of avian species examined and these have been found to be cosmopolitan (Atkinson and Van Riper III 1991). Bennett *et al.* (1994) listed 72 bird families in which *Haemoproteus*, *Leucocytozoon* or *Hepatozoon* were described. Most species of *Haemoproteus* and *Leucocytozoon* are relatively host-specific and restricted to bird species of the same family (Fallis *et al.* 1974, Atkinson 1986). This is in contrast to species of avian *Plasmodium*, which have a much broader host specific and occur in several avian families by changing their character (Bennett *et al.* 1982).

Since the first extensive study on the life cycle of *Haemoproteus tinnunculi* originated from Germany (Wasielewski and Wülker 1918), no systematic study on the prevalence and intensity of blood parasites from Falconiformes and Strigiformes from this country was conducted. Scattered information on blood parasites in raptors from Germany are found in the literature: Koch (1899) found hobby (*F. subbuteo*) nestlings taken from a nest near Berlin were heavily infected

Address for correspondence: Oliver Krone, Institute for Zoo and Wildlife Research, Postfach 601103, D-10252, Berlin, Germany; Fax: +49 (0) 30 51 26104; E-mail: krone@izw-berlin.de

with *Haemoproteus* sp. Mayer (1911) described *Haemoproteus* sp. in 2 of 3 tawny owls (*Strix aluco*) from Lübeck. Information on *Leucocytozoon* spp. is not reliable due to possible confusion with *Trypanosoma* spp. in the early studies of haematozoan research (Schaudin 1904; Mayer 1910, 1911; Moldovan 1913).

This study considers the prevalence and intensity of the genera *Haemoproteus*, *Leucocytozoon* and *Plasmodium*, in falconiform and strigiform birds from Germany.

MATERIALS AND METHODS

The birds examined in this study from 1996-2000 were wild birds admitted to rehabilitation centres sampled during the first two days after admission or birds sampled during ringing. Birds originated from mainly three different locations in Germany: Baden-Württemberg (BW) (47°50' to 49°25' N, 8°50' to 9°75' E), Lower Saxony (LS) (52°00' to 53°00' N, 9°50' to 11°00' E) and Berlin-Brandenburg (BB) (52°00' to 53°25' N, 11°50' to 14°50' E). Twenty-five different species of raptors in 5 families were subject to this study (Table 2). Identification of the bird species and the age categories was based on the descriptions by Baker (1993), Forsman (1999) and Glutz von Blotzheim (1971). The ageing of the pulli was performed by using the descriptions of Heinroth and Heinroth (1927) and the tables of growth for the falconiformes (Bijlsma 1997). A total of 976 blood smears from falconiform and 173 from strigiform birds were examined for the presence of blood parasites.

Samples were taken from the brachial vein. Blood films were air dried, fixed in absolute methanol and stained with Giemsa´s solution for 40 minutes. The scanning time was 10 min for every blood smear examined. They were scanned at x25 for 0.5 min, x100 for 1,5 min, x200 for 2 min, and x400 for 6 min. The oil immersion (x1000) was only used when the blood smear contained parasites. Measurements were performed with a Zeiss Axioplan microscope attached *via* a video camera to a PC with AnalysisPro 2.1 as software. Intensities of parasites were calculated by counting them in fields of 300-400 erythrocytes in 10 fields.

Species identification was based on the descriptions by Peirce *et al.* (1990) for *Haemoproteus brachiatus, H. tinnunculi, H. elani* and *H. nisis*, but for *H. buteonis* by Valkiűnas (1997), and by Bishop and Bennett (1989) of strigiform birds; for *Leucocytozoon* of Falconiformes by Greiner and Kocan (1977) and of Strigiformes by Bennett *et al.* (1993), for *Plasmodium* by Garnham (1966). *Trypanosoma avium* from the pygmy owl (*Glaucidium passerinum*) was described previously by Krone (1996).

The age (three classes: nestling, immature bird, adult bird), sex, origin (seven regions), order (Falconiformes or Strigiformes), bird species (25 species), and a possible injury or disease (birds admitted to rehabilitation centres) were regarded as variables potentially influencing its parasite burden (two categories: infected/not infected). Logistic regression (Hosmer and Lemeshow 1989) was used in order to analyse the effect of multiple variables on the parasite load. Categorical variables were compared by means of chi-square test or Fisher's exact test. Adjusted standardised residuals were used to identify the categories responsible for a significant chi-square test (Everitt 1977). Standardised residuals beyond ± 1.96 indicate a significant deviation from the expected values. The McNemar test (Bortz *et al.* 1990) served to compare prevalences for samples with related parasite information. A potential trend for the prevalences of the age classes was tested using Pfanzagl's trend test (Bortz *et al.* 1990). The significance level was generally set to $\alpha = 0.05$. All statistical calculations were performed using the SPSS 9.0 software.

RESULTS

A total of 11% (n=1149; 95% CI: 10, 13) of blood smears from birds of prey were positive for haematozoa. A similar prevalence was found in Falconiformes (n=976, 11%; 9, 13) and Strigiformes (n=173, 13%; 8, 19). The nestlings (pulli) had the lowest, whereas adult birds had the highest prevalences.

Of 17 hawk species examined, 9 were found to be infected with haemoparasites (Table 1). In comparison only 3 of 8 owl species examined were infected (Table 2).

No haematozoa were found in the osprey (*Pandion haliaetus*, pulli n=40, immature n=5, adult n=28), honey buzzard (*Pernis apivorus*, n=13), black kite (*Milvus migrans*, n=11), marsh harrier (*Circus aeruginosus,* pulli n=16, immature n=6, adult n=4), hen harrier (*Circus cyaneus,* n=1), montagu´s harrier (*Circus pygargus*, pulli n=31), merlin (*Falco columbarius*, n=1) and peregrine falcon (*Falco peregrinus,* pulli n=36, immature n=1, adult n=7).

No blood parasites were found in the barn owl (*Tyto alba*, pulli n=25, immature n=6, adult n=31), Tengmalm´s owl (*Aegolius funereus*, n=1), short-eared owl (*Asio flammeus*, n=1), little owl (*Athene noctua,* n=1) and eagle owl (*Bubo bubo,* n=8).

The hawks were mainly infected with *Leucocytozoon toddi* (9.5%, n=976) and only a few with *Haemoproteus* spp. (1.9%, n=976) while an equal number of owls were infected with *L. ziemanni* (10.4%, n=173) and *H. syrnii* (9.2%, n=173). *Plasmodium fallax* and *Trypanosoma avium* were only detected in the single pygmy owl examined. Measurements of the blood parasites are presented from infected birds in which large numbers of haemoparasites were found (Table 3).

A logistic regression was performed using the age, order, origin, season, and the admission to a rehabilitation centre as independent and the infection state as dependent variable. The sex was known only for 547 out of 1149 birds. Therefore, the influence of sex was separately tested, in order to use the full data set in the

Table 1. Prevalences and intensities of blood parasites in Falconiformes. ad. - adult, immat. - immature, max - maximal value, min - minimal value, n - sample size, pull. - pulli, SD - standard deviation, x - mean

Species	n	*Leucocytozoon*	*Haemoproteus*	*Leuco. + Haemo.*
Accipiter gentilis	227	21 (9%)	1	1 (0.4 %)
pull.	185	13		
intensity x (min-max) SD		1.43 (0.1-5) 1.65		
immat.	17	4		
intensity x (min-max) SD		0.33 (0.2-0.5) 0.13		
ad.	25	3	1	1
intensity x (min-max) SD		0.52 (0.05-1.4) 0.77	0.05%	
Accipiter nisus	132	7 (5 %)		
pull.	68			
immat.	20	3		
intensity x (min-max) SD		0.23 (0.05-0.4) 0.16		
ad.	44	4		
intensity x (min-max) SD		0.1 (0.05-0.2) 0.04		
Aquila pomarina	20	1		
pull.	9			
ad.	11	1		
intensity		0.05%		
Buteo buteo	189	59 (31%)	9 (5%)	3 (2 %)
pull.	15	2		
intensity x (min-max) SD		0.23 (0.1-0.35) 0.18		
immat.	62	14	5	1
intensity x (min-max) SD		1.29 (0.05-13.5) 3.32	1.35 (0.05-3.1) 1.1	
ad.	112	43	4	2
intensity x (min-max) SD		0.39 (0.05-8.9) 1.38	1.44 (0.35-2.15) 0.8	
Buteo lagopus	7	1		
immat.	3	1		
intensity		0.10%		
ad.	4			
Falco subbuteo	28		7	
pull.	3			
immat.	1			
ad.	24		7	
intensity x (min-max) SD			2.31 (0.05-6.6) 2.24	
Falco tinnunculus	136	1	3	
pull.	14			
immat.	48	1	1	
intensity		0.05%	2.75%	
ad.	74		2	
intensity x (min-max) SD			1.28 (0.95-1.6) 0.46	
Haliaeetus albicilla	15	1		
pull.	4	1		
intensity		0.45%		
immat.	3			
ad.	8			
Milvus milvus	24	2		
pull.	13	2		
intensity x (min-max) SD		1.7 (0.9-2.5) 1.13		
immat.	2			
ad.	9			

multiple analysis. No significant differences in the infection state of the sexes occurred (Fisher's exact test, P=0.358, n=547). The logistic regression revealed significant differences between the age classes (P<0.001, n=1146) and the seasons (P<0.001, n=1146), but not for the bird orders (p=0.365, n=1146), rehabilitation station (P=0.483, n=1149), and the regions (p=0.162, n=1146). For a more detailed analysis, the significant variables were subsequently tested using chi-square and standardised residuals. Seasonal differences were confirmed (chi-square test, p<0.001, n=1149), whereat the infection rate is below average in summer (standardised

Table 2. Prevalences and intensities of blood parasites in Strigiformes; for abbreviations see Table 1

Species	n	*Leucocytozoon*	*Haemoproteus*	*Leuco.* + *Haemo.*	other
Asio otus	25	1			
pull.	4	1			
intensity		0.40%			
immat.	1				
ad.	20				
Glaucidium passerinum	1				*T. avium*
ad.	1				*P.fallax*
intensity					0.15%
Strix aluco	73	16 (21.9%)	17 (23.3%)	12 (16.4%)	
pull.	33	1			
intensity		0.05%			
immat.	11	2	2	1	
intensity m (min-max) SD		0.2 (0.05-0.35) 0.21	12.2 (0.15-24.25) 17		
ad.	29	13	15	11	
intensity m (min-max) SD		0.35 (0.05-0.8) 0.28	9.22 (0.15-34.4) 9.5		

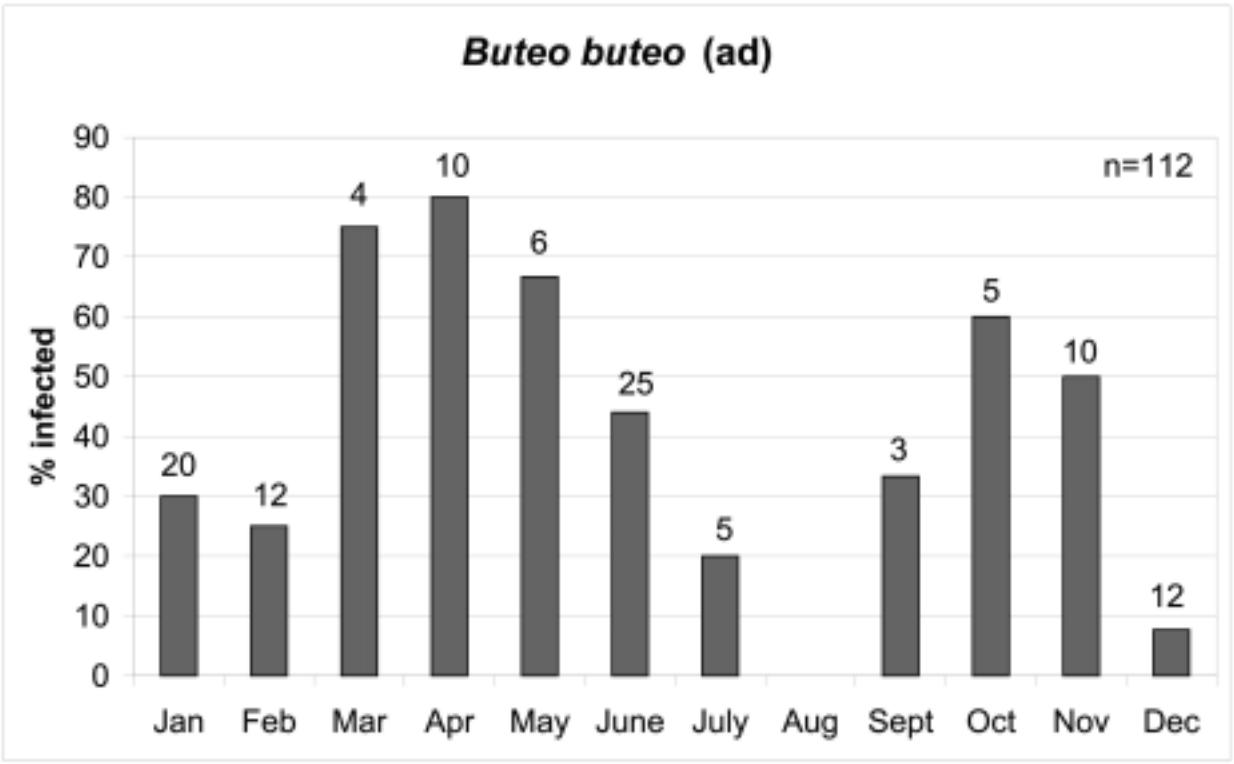

Fig. 1. Prevalence of blood parasites in adult Eurasian buzzards over the year (numbers above the bars are birds examined)

residual SR=-4.4) and above average in spring (SR=2.7) and autumn (SR=3.5). Differences between the age classes were also confirmed (chi-square test, $p<0.001$, n=1149) with pulli (SR=-7.2) showing a below-average infection rate as opposed to immature (SR=3.0) and adult birds (SR=5.0). A trend was detected (Pfanzagl's test, $P<0.001$, n=1149) demonstrating an increase in the prevalence with increasing age.

Hawks and owls differed in their prevalence for *Haemoproteus* spp. ($P<0.001$, Fisher´s exact test, n=1149) but not for *Leucocytozoon* spp. (P=0.677, Fisher´s exact test, n=1149). The hawks had a signifi-

Table 3. Measurements (mean in μm, standard deviation in parentheses) of *Haemoproteus* spp. found in Falconiformes and Strigiformes; ACGE - *Accipiter gentilis*, BUBT - *Buteo buteo*, FATI - *Falco tinnunculus*, FASU - *Falco subbuteo*, STAL - *Strix aluco*

Host species	ACGE	BUBT	FASU	FATI	STAL
Parasite species	*H. elani*	*H. buteonis*	*H. tinnunculi*	*H. tinnunculi*	*H. syrnii*
Uninfected erythrocyte	n = 20	n = 20	n = 20	n = 20	n = 20
Length	12.73 (0.55)	13.29 (0.97)	11.70 (0.55)	12.80 (0.62)	12.48 (0.66)
Width	7.02 (0.42)	7.02 (0.51)	6.43 (0.43)	6.93 (0.46)	7.37 (0.39)
Area	70.28 (3.84)	75.30 (7.46)	62.69 (3.55)	71.82 (4.45)	74.97 (5.81)
Uninfected erythrocyte nucleus	n = 20	n = 20	n = 20	n = 20	n = 20
Length	6.59 (0.25)	5.83 (0.49)	6.45 (3.89)	6.07 (0.42)	6.01 (0.53)
Width	2.48 (0.18)	2.50 (0.14)	2.34 (0.27)	2.64 (0.20)	3.04 (0.29)
Area	13.76 (1.03)	12.62 (0.93)	12.89 (1.73)	13.83 (1.19)	16.36 (2.22)
% area of erythrocyte	19.58	16.76	20.56	19.26	21.82
Erythrocyte infected by macrogametocyte	n = 20	n = 20	n = 20	n = 20	n = 20
Length	14.09 (0.72)	14.00 (0.89)	13.03 (0.44)	13.05 (0.73)	13.87 (0.99)
Width	7.08 (0.49)	6.98 (0.67)	7.43 (0.24)	7.39 (0.54)	7.43 (0.93)
Area	84.42 (4.88)	81.37 (9.77)	78.55 (5.07)	78.96 (4.75)	87.83 (8.38)
Infected erythrocyte nucleus	n = 20	n = 20	n = 20	n = 20	n = 20
Length	6.13 (0.74)	5.90 (0.64)	6.23 (0.28)	5.40 (0.37)	5.47 (0.64)
Width	2.35 (0.17)	2.54 (0.36)	2.11 (0.33)	2.74 (0.18)	2.94 (0.27)
Area	12.91 (1.22)	13.50 (1.49)	11.93 (0.84)	13.40 (1.08)	14.84 (2.02)
% area of erythrocyte-parasite complex	15.29	16.59	15.19	16.97	16.90
Macrogametocyte	n = 20	n = 20	n = 20	n = 20	n = 20
Length	13.23 (0.57)	15.08 (1.07)	16.40 (0.53)	15.67 (0.47)	15.27 (0.33)
Width	2.60 (0.34)	2.61 (0.16)	4.06 (0.21)	3.92 (0.22)	3.15 (0.27)
Area	53.57 (7.11)	54.51 (6.21)	57.63 (6.01)	55.21 (2.59)	53.42 (5.80)
% area of erythrocyte-parasite complex	63.46	66.69	73.36	69.92	60.82
Macrogametocyte nucleus	n = 20	n = 20	n = 20	n = 20	n = 20
Length	2.76 (0.34)	2.64 (0.17)	3.81 (0.20)	3.75 (0.25)	3.63 (0.43)
Width	2.04 (0.36)	2.14 (0.18)	2.88 (0.33)	2.87 (0.11)	2.19 (0.12)
Area	4.53 (0.91)	4.67 (0.39)	9.14 (0.49)	9.28 (0.46)	5.80 (0.88)
% area of gametocyte	8.46	6.97	15.86	16.81	10.86
Pigment granules	15.15 (1.59)	15.30 (2.03)	22.60 (2.60)	23.90 (2.83)	20.20 (3.71)
Nuclear displacement ratio	0.81 (0.09)	0.83 (0.10)	0.61 (0.09)	0.59 (0.11)	0.61 (0.13)
Erythrocyte infected by microgametocyte	n = 20	n = 20	n = 20	n = 20	n = 20
Length	13.42 (1.05)	14.66 (1.04)	12.96 (0.50)	13.00 (1.00)	14.07 (0.75)
Width	7.11 (0.46)	7.19 (0.34)	7.50 (0.52)	7.67 (0.66)	7.99 (0.50)
Area	79.92 (7.42)	88.03 (7.11)	82.56 (6.24)	80.66 (3.26)	94.11 (7.47)
Infected erythrocyte nucleus	n = 20	n = 20	n = 20	n = 20	n = 20
Length	6.38 (0.62)	5.81 (0.49)	6.19 (0.37)	5.78 (0.30)	5.62 (0.44)
Width	2.34 (0.25)	2.45 (0.25)	2.12 (0.19)	2.62 (0.21)	2.79 (0.24)
Area	12.66 (1.38)	12.59 (1.29)	12.54 (1.27)	13.70 (0.68)	14.25 (1.68)
% area of erythrocyte-parasite complex	15.84	14.30	15.19	16.98	15.14
Microgametocyte	n = 20	n = 20	n = 20	n = 20	n = 20
Length	16.26 (2.34)	15.92 (0.79)	14.62 (0.67)	15.32 (0.63)	15.38 (0.36)
Width	3.16 (0.16)	3.19 (0.31)	4.24 (0.31)	4.28 (0.44)	2.96 (0.35)
Area	55.37 (3.14)	57.72 (3.11)	60.11 (3.02)	59.77 (5.32)	52.03 (2.32)
% area of erythrocyte-parasite complex	69.28	64.89	72.81	74.10	55.29
Microgametocyte nucleus	n = 20	n = 20	n = 20	n = 20	n = 20
Length	10.17 (1.79)	10.24 (0.47)	9.56 (0.55)	9.57 (0.69)	5.73 (0.41)
Width	2.27 (0.21)	2.61 (0.21)	3.80 (0.30)	4.12 (0.48)	3.23 (0.26)
Area	28.07 (3.10)	29.74 (2.13)	40.40 (1.61)	38.90 (2.08)	15.31 (1.32)
% area of gametocyte	50.70	51.52	67.21	65.08	29.43
Pigment granules	14.70 (2.67)	15.60 (1.56)	21.75 (1.76)	22.15 (2.31)	15.75 (1.73)
Nuclear displacement ratio	0.83 (0.08)	0.85 (0.08)	0.62 (0.12)	0.50 (0.09)	0.69 (0.09)

Table 4. Prevalences of *Leucocytozoon* and *Haemoproteus* and number of birds examined in different regions of Europe (L - *Leucocytozoon,* H - *Haemoproteus)*

	Peirce and Marquiss (1983)	Mikaelian and Bayol (1991)	Peirce *et al*. (1983)		Sacchi and Prigioni (1984)	Svobodová and Votýpka (1998)	Kučera (1981a)
Region	Scotland	France	Britain	Spain	Italy	Czech Republic	Europe (literature review)
birds of prey (number of species)	60% (6) n = 235	31% (14) n = 150	20.3% (17) n = 54	14.2% (12) n = 28	21.9% (15) n = 114		
falconiform birds	60% (L,H) n = 229	35% (L,H) n = 83	2 (L,H) n = 33	3 (L,H) n = 25	22% (L,H) n = 91	24% (L) n = 459 9.3% (H) n = 495	2.5% (L) n = 334 53.1% (H) n = 178
strigiform birds	3 (L,H) n = 6	30% (L,H) n = 67	9 (L,H) n = 21	1 (L,H) n = 3	22% (L,H) n = 23		9.9% (L) n = 162 22.6% (H) n = 178
A. nisus	67% (L) 16% (H) n = 195	1 (H) n = 4	2 (L) 1 (H) n = 2		3 (L) n = 7	29% (L) 12% (H) n = 308	
B. buteo	2 (L) n = 3	46% (L) 61% (H) n = 26	0 (L,H) n = 3	1 (L,H) n = 9	9 (L) n = 39	38% (L) 9% (H) n = 99	
F. tinnunculus	0 (L,H) n = 6	20% (H) n = 35	0 (L,H) n = 12	0 (L,H) n = 1	1 (L) 5 (H) n = 20	0 (L) 1.5% (H) n = 66	
F. peregrinus	0 (L,H) n = 25		0 (L,H) n = 3	0 (L,H) n = 2			
F. subbuteo		2 (H) n = 4					
S. aluco	3 (L) 0 (H) n = 4	14% (L) 50% (H) n = 22	6 (L) 2 (H) n = 12		2 (L) 1 (H) n = 7		
A. otus	0 (L,H) n = 2	45% (H) 1 8% (L) n = 11	0 (L,H) n = 1		0 (L,H) n = 6		
T. alba		0 (L,H) n = 17	0 (L,H) n = 1	0 (L,H) n = 2	0 (L,H) n = 5		

cantly higher prevalence for *L. toddi* than for *H. elani* (P<0.001, McNemar test, n=976), whereas no differences could be found between prevalences of different blood parasites within the owls (P<0.754, McNemar test, n=173).

In order to analyse potential differences between the species, the subsequent analysis was restricted to adult birds of those species with at least 20 adult animals in the sample. A difference was found among adult birds of the species: *A. gentilis, A. nisus, B. buteo, F. subbuteo,*

F. tinnunculus, P. haliaetus concerning the infection rates with *Haemoproteus* spp. (P<0.001, chi-square test, n=299). The hobby was infected above average (SR=6.2).

Adult hawks (*A. gentilis, A. nisus, B. buteo, F. subbuteo, F. tinnunculus, P. haliaetus*) parasitised by *L. toddi* differed significantly in the species' prevalences (P<0.001, chi-square test, n=299). The Eurasian buzzard was most frequently parasitised (SR=7.2) compared to all others and the hobby (SR=-2.2), kestrel (SR=-4.3), and osprey (SR=-2.4) were infected below average.

More detailed analysis was done on the Eurasian buzzard for which sufficient data were available. A logistic regression test revealed differences between the seasons (P<0.001, n=189) but not between the age classes (P=0.108, n=189), rehabilitation stations (P=0.790, n=189), and between the regions (P=0.168, n=189). The seasonal differences were confirmed by a subsequent analysis (chi-square test, P=0.001, n=189), with an above-average infection rate in spring (SR=3.3) and a below-average infection rate in winter (SR=-3.2). A bias could be suspected because of the inclusion of pullis in the spring. However, the same analysis restricted to the adult buzzards revealed the same results (chi-square test, P=0.003, n=112, SR (spring)=3.0, SR (winter)=-3.3).

A seasonal change in prevalence was found. Peaks of infection occurring in both spring and autumn are shown in Fig. 1. Of all adult Eurasian buzzards examined, 38% were infected with *L. toddi* and only 4% with *H. buteonis* (n=112).

No differences could be found between the sexes of Eurasian buzzards (Fisher's exact test, P=0.185, n=44).

From the nestlings (pulli) sampled, the minimum age of infection with *Leucozytozoon toddi* in the goshawk (*Accipiter gentilis*, n=13) was 17 days, in the red kite (*Milvus milvus*, n=13) 24 days, in the Eurasian buzzard (n=14) 36 days, white-tailed sea eagle (n=4) 40 days and with *Leucozytozoon ziemanni* in the tawny owl (n=33) 15 days.

DISCUSSION

Prevalences of blood parasites in European birds of prey varied considerably, depending on bird species, geographic region (Table 4) and season.

The prevalences for *Plasmodium* spp. in birds of prey are generally low. Kučera (1981b) found a prevalence of 2.3% in Strigiformes (n=178), but did not diagnose the parasite in Falconiformes (n=333). In this survey only the pygmy owl was infected with *P. fallax*.

The low prevalence of *Haemoproteus* spp. in hawks (1.9%, n=976) in this study might be explained due to the different abundance of the vectors in the habitats of hawks and owls or due to a possible difference in susceptibility. The low prevalence of 5.3% with *L. toddi* in sparrow-hawks (n=132) in this survey could be a result of the choice of the breeding area, which often consists of young coniferous trees in a dry habitat, which is less suitable for vectors.

Wiehn *et al.* (1999) found a significantly higher prevalence of *Haemoproteus* spp. in females than in males during the nestling period in common kestrels from Finland in one of three years of investigations, whereas no differences between the sexes could be found in this study.

The differences in the prevalence of blood parasites between age classes are consistent with results by Ashford *et al.* (1990).

Parasitaemic intensities of *H. tinnunculi* in American kestrels (*Falco sparverius*) increased during the nestling cycle in females, indicating that blood parasitism, immunity and kestrel reproduction are interrelated and are possibly linked allocation of metabolizable energy in the host (Apanius 1993). The youngest birds of prey infected with blood parasites were nestlings of sparrow-hawks in Scotland infected with *L. toddi* at an age of 14 days (Peirce and Marquiss 1983). Only a few white-tailed sea eagles (*Haliaeetus albicilla*) had previously been examined for haematozoa, with all being negative (Nikitin and Artemenko 1927, Peirce 1980). This study showed for the first time that the white-tailed sea eagle could be infected with *L. toddi*. The bird was 40 days old. Stuht *et al.* (1999) found the youngest nestling of a bald eagle (*Haliaeetus leucocephalus*) to be infected with *L. toddi* at an age of 25 days.

Cheke *et al.* (1976) detected a seasonal variation in the prevalence of blood parasites in wild birds from England, with a peak in May. Kučera (1981b) revealed two significant peaks in the prevalence of *Haemoproteus* spp., one in May and another in September. For *Leucocytozoon* he only found a peak in spring (Kučera 1981a). He attributed the spring peak to an increase of sexual hormones during the breeding and rearing of young. It was suggested that the autumn peak

was due to a high proportion of young birds in the population with acute infections due to incomplete immunity. Research on raptors during their breeding period revealed a "spring relapse" of haemoparasites in the blood of adult birds, facilitating the infection of the youngsters in the nest by an insect vector (Ashford *et al.* 1990). As this study shows there is an increase of infection in Eurasian buzzards during spring and autumn (Fig. 1). The peak in spring reflects the so called "spring relapse" and the peak in autumn is consistent with the idea of Peirce (1989) that relapses with increased parasitaemia may occur, that are triggered by hormonal activity during breeding, migration or stress. Migrating birds of prey, mainly steppe buzzards (*Buteo buteo vulpinus*) sampled in Israel had a high prevalence (64%) of blood parasites (Cooper *et al.* 1993).

Measurements of *H. elani* from the goshawk, *H. buteonis* from the Eurasian buzzard and *H. tinnunculi* from the hobby and common kestrel are lower than given by Peirce *et al.* (1990). These and the lower dimensions of *H. syrnii* from the tawny owl compared to the results of Bishop and Bennett (1989) can probably be explained due to smaller erythrocytes measured in this study containing smaller parasites. In addition results presented in Table 3 indicate a broader range for *Haemoproteus* than given by Peirce *et al.* (1990) and Bishop and Bennett (1989). We followed the separation of the species *H. elani* and *H. buteonis* on the basis of morphological characteristics indicated by Valkiű`nas (1997). A cross-transmission experiment would be applicable to proof the species separation.

Acknowledgements. We are grateful to the "Deutscher Falkenorden" for supporting this study financially. We would like to thank R. Altenkamp, D. Haas, A. Hallau, N. Kenntner, P. Lepom, B.-U. Meyburg, C. Rohde, W. Scheller, D. Schmidt and M. Streitz for their co-operative work in collecting blood smears and providing us with back ground information about the sampled birds. We are also grateful to M.A. Peirce for verification of species identification and constructive advises, to M. East for reading the manuscript and to K. Ernst for her technical assistance.

REFERENCES

Apanius V. (1993) Blood parasitism, immunity and reproduction in American kestrels (*Falco sparverius*). In: Biology and Conservation of Small Falcons, (Eds. M. K. Nicholls and R. Clarke). Proceedings of the Hawk and owl Trust Conference, London, 117-125

Ashford R. W., Wyllie I., Newton I. (1990) *Leucocytozoon toddi* in British sparrowhawks *Accipiter nisus*: observations on the dynamics of infection. *J. Nat. Hist.* **24:** 1101-1107

Atkinson C. T. (1986) Host specificity and morphometric variation of *Haemoproteus meleagridis* Levine, 1961 (Protozoa: Haemosporina) in gallinaceous birds. *Can. J. Zool.* **64:** 2634-2638

Atkinson C. T., Van Riper III C. (1991) Pathogenicity and epizootiology of avian haematozoa: *Plasmodium*, *Leucocytozoon*, and *Haemoproteus*. In: Bird-parasite Interaction, (Eds. J. E. Loye and M. Zuk). Oxford University Press, New York, 19-48

Baker K. (1993) Identification Guide to European Non-passeriformes. BTO Guide 24, Norfolk

Bennett G. F., Whiteway M., Woodworth-Lynas C. B. (1982) A host-parasite catalogue of the avian haematozoa. Occasional papers in biology, No. 5, Memorial University of Newfoundland

Bennett G. F., Earlé R. A., Peirce M. A. (1993) The Leucocytozoidae of South African birds. The Falconiformes and Strigiformes. *Ostrich* **64:** 67-72

Bennett G. F., Peirce M. A., Earlé R. A. (1994) An annotated checklist of the valid avian species of *Haemoproteus*, *Leucocytozoon* (Apicomplexa: Haemosporida) and *Hepatozoon* (Apicomplexa: Haemogregarinidae). *Syst. Parasitol*. **29:** 61-73

Bijlsma R. G. (1997) Handleiding veldonderzoek Roofvogels. KNNV Uitgeverij, Utrecht

Bishop M. A., Bennett G. F. (1989) The haemoproteids of the avian order Strigiformes. *Can. J. Zool*. **67:** 2676-2684

Bortz J., Lienert G. A., Boehnke K. (1990) Verteilungsfreie Methoden in der Biostatistik. Springer, Berlin, Germany

Cheke R. A., Hassall M., Peirce M. A. (1976) Blood parasites of British birds and notes an their seasonal occurrence at two rural sites in England. *J. Wildl. Dis*. **12:** 133-138

Cooper J. E., Gorney-Labinger E., Ion F. (1993) Parasitological and other studies on migrating raptors. In: Raptor Biomedicine, (Eds. P. T. Redig, J. E. Cooper, J. D. Remple and B. Hunter). University of Minnesota Press, Minneapolis, 28-31

Danilewsky B. (1885) Zur Parasitologie des Blutes. *Biol. Zentrabl.* **5:** 529-537

Everitt B. S. (1977) The Analysis of Contingency Tables. Chapman and Hall, London

Fallis A. M., Desser S. S., Kahn R. A. (1974) On species of *Leucocytozoon*. *Adv. Parasitol*. **12:** 1-67

Forsman D. (1999) The Raptors of Europe and the Middle East. T&AD Poyser, London

Garnham P. C. C. (1966) Malaria Parasites and other Haemosporidia. Blackwell Scientific Publications, Oxford

Glutz v. Blotzheim U. N. (Eds.) (1971) Handbuch der Vögel Mitteleuropas. Band 4 Falconiformes. Akademische Verlagsgesellschaft, Frankfurt am Main

Greiner E. C., Kocan A. A. (1977) *Leucozytozoon* (Haemosporida; Leucozytozoidae) of the Falconiformes. *Can. J. Zool.* **55:** 761-770

Heinroth O., Heinroth M. (1927) Die Vögel Mitteleuropas. Band II. Hugo Bermühler Verlag, Berlin

Hosmer D. W., Lemeshow S. (1989) Applied Logistic Regression. John Wiley & Sons, N. Y.

Koch R. (1899) Über die Entwicklung der Malariaparasiten. *Z. Hyg. Infektionskr.* **32:** 1-24 (I-IV)

Krone O. (1996) The pygmy owl (*Glaucidium passerinum*) as a new host for the rare haematozoon *Trypanosoma avium*. *Appl. Parasitol*. **37:** 300-301

Kučera J. (1981a) Blood parasites of birds in central Europe. 2. Leucocytozoon. *Folia Parasitol*. **28:** 193-203

Kučera J. (1981b) Blood parasites of birds in central Europe. 3. Plasmodium and Haemoproteus. *Folia Parasitol*. **28:** 303-312

Mayer M. (1910) Über die Entwicklung von Halteridium. *Arch. Schiffs. Tropenhyg*. **14:** 197-202

Mayer M. (1911) Über ein Halteridium und Leucocytozoon des Waldkauzes und deren Weiterentwicklung in Stechmücken. *Arch. Protistenkd*. **21:** 232-254

Mikaelian I., Bayol P. (1991) Blood Protozoa found in birds of prey undergoing rehabilitation. *Point Vet*. **22:** 857-860

Moldovan J. (1913) Über die Entwicklung von *Leukozytozoon ziemanni*. *Zentbl. Bak. Parasit. Infektionskr*. **71:** 66-69

Nikitin S. A., Artemenko W. D. (1927) Protozoa in the blood of vertebrates of the Southern Ukraine. *Russ. Zh. Trop. Med*. **5:** 654-664 (in Russian)

Peirce M. A. (1980) Haematozoa of British birds: post-mortem and clinical findings. *Bull. Br. Ornithiol. Club* **100:** 158-160

Peirce M. A. (1989) The significance of avian haematozoa in conservation strategies. In: Diseases and threatened birds, (Ed. J. E. Cooper). ICBP Technical Publication No. 10, Cambridge 69-78

Peirce M. A., Marquiss M. (1983) Haematozoa of British birds. VII. Haematozoa of raptors in Scotland with a description of *Haemoproteus nisi* sp. nov. from the sparrow-hawk (*Accipiter nisus*) *J. Nat. Hist*. **17:** 813-821

Peirce M. A., Greenwood A. G., Cooper J. E. (1983) Haematozoa of raptors and other birds from Britain, Spain and the United Arab Emirates. *Avian Pathol*. **12:** 447-459

Peirce M. A., Bennett G. F., Bishop M. (1990) The Haemoproteus of the avian order Falconiformes. *J. Nat. Hist*. **24:** 1091-1100

Sacchi L., Prigioni C. (1984) Occurrence of *Leucocytozoon* and *Heamoproteus* (Apicomplexa, Haemosporina) in Falconiformes and Strigiformes of Italy. *Ann. Parasitol. Hum. Comp*. **59:** 219-226

Schaudin F. (1904) Generations- und Wirtswechsel bei Trypanosoma und Spirochaete. *Arb. K. GesundhAmt.* **20:** 387-439

Stuht J. N., Bowerman W. W., Best D. A. (1999) Leucocytozoonosis in nestling Bald Eagles in Michigan and Minnesota. *J. Wild. Dis*. **35:** 608-612

Svobodová M., Votýpka J. (1998) Occurrence of blood protists in raptors (Falconiformes). *Buteo* **10:** 51-56 (in Czech)

Valkiűnas G. (1997) Bird haemosporida. *Acta Zool. Lituanica*, 3-5 (monograph)

Wasielewski T., Wülker G. (1918) Die *Haemoproteus*-Infektion des Turmfalken. *Arch. Schiffs. Tropenhyg*. **22:** 3-100, I-IV

Wiehn J., Korpimäki E., Pen I. (1999) Haematozoan infections in the Eurasian kestrel: effects of fluctuating food supply and experimental manipulation of parental effort. *Oikos* **84:** 87-98

Received on 30th January, 2001; accepted on 18th July, 2001