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Korrespondenzadresse:
majda-globokar@idexx.com

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IDEXX Laboratories, Ludwigsburg, Germany[1]
Clinic for Birds, Reptiles, Amphibians and Fish, Justus Liebig University Giessen, Giessen, Germany[2]
Wildlife Park and Raptor Center Hellenthal, Hellenthal, Germany[3]

Occurrence of endoparasites in captive birds between 2005 to 2011 as determined by faecal flotation and review of literature

Vorkommen von Endoparasiten in Kotproben von Vögeln in Menschenobhut aus Laboreinsendungen zwischen 2005 und 2011 nach Untersuchung mittels Flotationsverfahren und Überblick über die spezifische Literatur

Majda Globokar[1], Dominik Fischer[2, 3], Nikola Pantchev[1]

Summary

Between 2005 and 2011, a total of 10 356 faecal samples of avian species submitted by veterinarians to a diagnostic laboratory were examined parasitologically using a qualitative faecal flotation technique. The aim of this study was to evaluate a large number of faecal samples of birds in captivity under standardized laboratory conditions and to outline and compare the most prevalent parasites in various groups of birds. The samples derived from Columbiformes (n = 2235), Psittaciformes (n = 1886), Galliformes (n = 1330), Passeriformes (n = 398), Anseriformes (n = 337), Accipitriformes and Falconiformes (n = 204), Strigiformes (n = 51), Struthioniformes (n = 48), Ciconiiformes (n = 25), Gruiformes (n = 19), Bucerotiformes (n = 17), Sphenisciformes (n = 16), Pelecaniformes (n = 11), Phoenicopteriformes (n = 7), Charadriiformes (n = 3), Musophagiformes (n = 2), Apodiformes (n = 2), Cuculiformes (n = 1), Coraciiformes (n = 1), Piciformes (n=1) and unspecified bird species (n = 3762). Samples were examined by a conventional flotation method (flotation solution $ZnCl_2$/NaCl with a specific gravity of 1.3). Overall, 3463 out of 10 356 bird samples revealed parasitic stages (33.4%; CI = 32.5–34.4%). Coccidia (mainly *Eimeria* spp./*Isospora* spp./*Caryospora* spp.), *Capillaria* spp., ascarids (mainly *Ascaridia* spp./*Porrocaecum* spp.), *Heterakis* spp., *Trichostronyglus* spp. and *Amidostomum* spp. were the most frequently identified parasites. However, the various bird species differed considerably in terms of their spectrum of endoparasites and the occurrence of parasitic pathogens in the faeces. Examinations of avian faeces may be performed by faecal flotation technique to detect a great number of different endoparasites. The knowledge about the species-specific parasite spectra and the occurrences of endoparasites in avian species is important to interpret an individual diagnosis and to initiate specific therapy and control strategies.

Keywords: Coccidia, nematodes, bird, helminths, coproscopy

Zusammenfassung

Zwischen 2005 und 2011 wurden 10 356 von Tierärzten eingesandte Kotproben von Vögeln in einem Diagnostiklabor parasitologisch mittels eines qualitativen Flotationsverfahrens untersucht und ausgewertet. Das Ziel dieser Studie war es, eine große Anzahl von Kotproben von Vögeln in Menschenobhut unter standardisierten Laborbedingungen zu bewerten und die am meisten verbreiteten Parasiten in verschiedenen Vogelgruppen darzustellen und zu vergleichen. Dabei stammten 2235 Proben von Tauben (Columbiformes), 1886 von Papageien und Sittichen (Psittaciformes), 1330 von Hühnervögeln (Galliformes), 398 von Sperlingsvögeln (Passeriformes), 337 von Gänsevögeln (Anseriformes), 204 von Greifvögeln (Accipitriformes und Falconiformes), 51 von Eulen (Strigiformes), 48 von Laufvögeln (Struthioniformes), 25 von Schreitvögeln (Ciconiiformes), 19 von Kranichvögeln (Gruiformes), 17 von Hornvogelartigen (Bucerotiformes), 16 von Pinguinen (Sphenisciformes), 11 von Ruderfüßern (Pelecaniformes), 7 von Flamingos (Phoenicopteriformes), 3 von Regenpfeiferartigen (Charadriiformes), 2

von Turakos (Musophagiformes) und Seglervögeln (Apodiformes), jeweils 1 von Kuckucksvögeln (Cuculiformes), Rackenvögeln (Coraciiformes) und Spechtvögeln (Piciformes) und 3762 von vorberichtlich nicht weiter spezifizierten Vogelarten. Zur parasitologischen Untersuchung wurde ein konventionelles Flotationsverfahren (Flotationslösung $ZnCl_2$/NaCl mit einem spezifischen Gewicht von 1.3) durchgeführt. Insgesamt zeigten 3463 von 10 356 Vogelproben parasitäre Stadien (33,4%; CI = 32,5–34,4%). Folgende Parasiten wurden häufig nachgewiesen: Kokzidien (v.a. *Eimeria* spp./*Isospora* spp./*Caryospora* spp.), *Capillaria* spp., Askariden (v.a. *Ascaridia* spp./*Porrocaecum* spp.), *Heterakis* spp., *Trichostrongylus* spp. und *Amidostomum* spp.. Das Parasitenspektrum und das Vorkommen parasitärer Erreger im Kot der verschiedenen Vogelarten varriierten teils erheblich voneinander. Das Flotationsverfahren eignet sich um Vogelkotproben auf viele verschiedene Endoparasiten zu untersuchen. Das Wissen über das artspezifische Parasitenspektrum und Vorkommen ist wichtig, um eine gezielte Untersuchung zu veranlassen und in der Folge eine spezifische Therapie und Bekämpfungsstrategie einleiten zu können.

Schlüsselwörter: Kokzidien, Nematoden, Vogel, Helminthen, Koproskopie

Introduction

There are several parasites adapted to avian species and individual birds may be infected with different parasites at the same time. Therefore, parasite species and their relevance to the host may differ between avian species. Uptake of infectious parasite oocysts and eggs does not always lead to an infection and a parasitism is not always associated with clinical disease (Papini et al., 2012). However, certain avian parasitic nematodes are known to cause clinical disease. They are most frequently found in the gastrointestinal tract. Some species prefer other organs and organ systems, such as the air sacs, trachea or sinuses (e.g. *Syngamus trachea, Serratospiculum* spp., *Cyathostoma* spp. (Campbell, 1935; Borgsteede and Okulewicz, 2001).

In captive birds, parasitic nematodes and other endoparasites such as coccidia must be monitored carefully. The reinfection rate of parasites with a direct life-cycle is higher in captive birds compared to free-ranging conspecifics, which can lead to a higher parasite load and increased severity of disease (Hurst et al., 1979; Sasseville et al., 1988; Lierz et al., 2010). The exposure to accumulated infective parasitic stages such as eggs, larvae or coccidian oocysts, especially if combined with stress (e.g. overcrowding inside aviaries) and poor husbandry conditions (e.g. poor hygiene) may lead to clinical diseases (Pantchev, 2008).

Examination of faecal and sputum samples allows for the identification of several endoparasites in birds. Sampling faeces over several days (e.g. a three day collective sample) is advisable, as some stages of certain parasites (e.g. coccidia) are shed intermittently (Pees, 2008). The results of parasitological examinations must always be interpreted together with the case history and the sample quality. In this regard, older faecal samples may be contaminated by free-living nematodes which could be considered as pseudoparasites. Moreover, in carnivorous birds, stages of protozoa and helminths of prey animals (e.g. rodents) may be detected in faecal samples following intestinal passage, which are regarded as so-called "spurious" parasites (Papini et al., 2012). To reveal the true host species of unidentified oocysts or eggs, faecal examination of carnivorous birds should be repeated two or three days after the last feed of potentially infected prey species.

The aim of this study was to evaluate a large number of faecal samples of captive birds under standardized laboratory conditions by means of faecal flotation. Moreover, the diagnostic procedure and the occurrence of the detected parasites were reviewed, in order to support veterinary colleagues in treatment of birds with endoparasites.

Material and Methods

A total of 10 356 avian faecal samples were submitted to a veterinary diagnostic laboratory in Germany (IDEXX Laboratories, Ludwigsburg) from 2005 to 2011. The following sample numbers per year were submitted: 1430 in 2005, 1327 in 2006, 1424 in 2007, 1511 in 2008, 1598 in 2009, 1577 in 2010 and 1489 in 2011.The samples originated mainly from Germany (n = 9270) and from other European countries: Austria (n = 545), Denmark (n=56), France (n = 27), Hungary (n = 20), Italy (n = 37), Luxemburg (n = 58), Malta (n = 3), The Netherlands (n = 287), Norway (n = 7), Poland (n = 10), Spain (n = 33) and Sweden (n = 3). Samples were submitted from veterinarians requesting the routine parasitological examination run by the laboratory. Because of the retrospective nature of the study, no data were available regarding age, sex, husbandry or previous antiparasitic treatment. The reasons for the sample submission were presumed to be gastrointestinal or general disorders of the patients, intended prophylaxis measures, routine monitoring of the flock, potential endangering of persons in the household by zoonotic agents or were unknown. Approximately 20% of the veterinarians clearly indicated diarrhoea as the reason for submission.

Faecal samples (approximately 3–4 g) were examined by a conventional flotation method (according to Melhorn et al., 1993). The flotation solution was prepared by mixing 800 ml distilled water, 210 g NaCl (>99.9%; Roth, Karlsruhe, Germany) and 220 g ZnCl2 (>97%; Roth, Karlsruhe, Germany) and adjusting the specific gravity to 1.3 with a density hydrometer. Each sample was homogenized thoroughly on a vortexer in 50 ml preparation tubes (with sealing cap) with approx. 15 ml of the zinc chloride/sodium chloride solution. The suspension was sieved through a strainer into a 12 ml

TABLE 1: *Parasite occurrence (in %) within the Psittaciformes (n = 1886 in total)*

			Number of positive samples (Percent occurence [%]) and 95%-Confidence Interval					
Scientific name	**Common name**	**No. examined**	***Isospora***	***Eimeria***	***Capillaria***	***Ascaridia***	***Syngamus***	***tapeworm***
Psittaciformes (unspecified)	Parrots	260	1 (0.4) 0–2.1	–	44 (16.9) 12.6–22	8 (3.1) 1.3–6	–	–
Nymphicus hollandicus	Cockatiel	209	3 (1.4) 0.3–4.1	–	1 (0.5) 0–2.6	5 (2.4) 0.8–5.5	–	–
Cacatua	Cockatoo	75	1 (1.3) 0–7.2	1 (1.3) 0–7.2	–	2 (2.7) 0.3–9.3	–	–
Melopsittacus undulatus	Budgerigar	759	1 (0.1) 0–0.7	–	1 (0.1) 0–0.7	11 (1.4) 0.7–2.6	–	–
Psittacula eupatria	Alexandrine Parakeet	2	1 (50) 1.3–98.7	–	1 (50) 1.3–98.7	1 (50) 1.3–98.7	–	–
Psephotus varius	Mulga Parrot	1	–	–	–	1 (100) 2.5–100	–	–
Eunymphicus cornutus	Horned Parakeet	4	–	–	–	1 (25) 0.6–80.6	–	–
Lathamus discolor	Swift Parrot	2	–	–	–	2 (100) 15.8–100	–	–
Platycercus eximius	Eastern Rosella	16	–	–	–	2 (12.5) 1.6–38.3	–	–
Platycercus elegans	Crimson Rosella	5	–	–	–	1 (20) 0.5–71.6	–	–
Psephotus dissimilis	Hooded Parrot	1	–	–	–	1 (100) 2.5–100	–	–
Aprosmictus erythropterus	Red–winged Parrot	2	–	–	–	1 (50) 1.3–98.7	–	–
Barnardius zonarius	Port Lincoln Parrot	1	–	–	1 (100) 2.5–100	–	–	–
Cyanoramphus novaezelandiae	Red–fronted Parakeet	23	–	–	–	1 (4.3) 0.1–21.9	–	–
Agapornis	Lovebird	47	–	1 (2.1) 0.1–11.3	2 (4.3) 0.5–14.5	–	–	–
Loriinae	Lories	6	–	–	1 (16.7) 0.4–64.1	–	–	–
Ara	Macaw	68	–	–	1 (1.5) 0–7.9	2 (2.9) 0.4–10.2	–	–
Bolborhynchus lineola	Catherine Parakeet	2	–	–	–	1 (50) 1.3–98.7	–	–
Forpus	Parrotlet	4	–	–	1 (25) 0.6–80.6	–	–	–
Amazona	Amazon Parrots	85	–	–	1 (1.2) 0–6.4	4 (4.7) 1.3–11.6	–	–
Amazona aestiva	Blue–fronted Parrot	30	–	–	–	3 (10) 2.1–26.5	–	–
Amazona pretrei	Red–spectacled Amazon	1	–	–	1 (100) 2.5–100	–	–	–
Psittacus erithacus	African Gray Parrot	259	1 (0.4) 0–2.1	–	–	–	1 (0.4) 0–2.1	1 (0.4)* 0–2.1
Poicephalus senegalus	Senegal Parrot	18	–	–	3 (16.7) 3.6–41.4	2 (11.1) 1.4–34.7	–	–
Nestor	Kea	6	–	–	3 (50) 11.8–88.2	–	–	–

* based on egg morphology classified as *Triuterina* sp.

centrifuge tube, filled and centrifuged for 8–10 min at 300 g. Afterwards the tube was filled with flotation solution to form a convex meniscus at the top. Ten minutes later a coverslip was placed carefully in contact with the meniscus, lifted off and placed on a glass slide for microscopic examination. The cover glass was analyzed at 100x magnification in a meandering pattern. Suspicious structures were confirmed at a higher magnification. Parasite stages found (eggs and/or oocysts) were recorded and classified according to genus, including coccidia oocysts/sporocysts (*Isospora, Eimeria, Caryospora, Sarcocystis),* nematode eggs (*Syngamus, Cyathostoma, Capillaria, Ascaridia, Porrocaecum, Heterakis, Trichostrongylus, Amidostomum, Libyostrongylus/Codiostomum, Deletrocephalus)* and tapeworm eggs *(Raillietina, Davainea, Choanotaenia, Triuterina, Passerilepis)* according to Beck and Pantchev (2012). Occurrence and 95% confidence intervals (CI) of parasite genera were calculated. Data were evaluated using the program Excel (Microsoft Excel 97–2003, Microsoft Corporation, Redmond, USA).

Results

A total of, 3463 out of 10 356 faecal samples revealed parasitic stages by faecal flotation (33.4%; CI = 32.5–34.4%), but occurrence as well as spectrum of detected parasites varied with regards to different bird groups.

In 2235 samples from Columbiformes, occurrences of 62.5% (CI = 60.5–64.5%) for *Eimeria* oocysts, 24.8% (CI = 23.0–26.6%) for *Capillaria* eggs, 16.6% (CI = 15.0–18.2%) for *Ascaridia* eggs and 0.4% (CI = 0.2–0.8%; n = 10) for *Trichostrongylus* eggs were identified. One pigeon shed *Syngamus* sp. eggs.

In the 1886 specimens from psittacines, 0.4% (CI = 0.2–0.8%) *Isospora* oocysts, 0.1% (CI = 0–0.4%) *Eimeria* oocysts, 3.2% (CI = 2.5–4.1%) *Capillaria* eggs and 2.6% (CI = 1.9–3.4%) *Ascaridia* eggs were detected, along with a single sample containing tapeworm (*Triuterina* sp.) and another containing *Syngamus* sp. eggs (Fig. 1A). The detailed results of the Psittaciformes are listed in Table 1.

In 1330 samples from Galliformes the following occurrences were calculated: *Isospora* oocysts 1.2% (CI = 0.7–1.9%), *Eimeria* oocysts 53.9% (CI = 51.2–56.6%) (Fig. 1C), *Capillaria* eggs 38.3% (CI = 35.7–41%) (Fig. 1B, C), *Ascaridia* eggs 31.2% (CI = 28.7–33.8%) (Fig. 1B), *Trichostrongylus* eggs 2.3% (CI = 1.5–3.2%), tapeworm eggs (*Choanotaenia/Davainea* 0.2% (CI = 0–0.2%; Fig. 1D, E), *Heterakis* eggs 7.0% (CI = 5.7–8.5%) (Fig. 1B), *Syngamus* eggs 0.5% (CI = 0.2–1.1%) and *Cyathostoma* eggs 0.2% (CI = 0–0.7%). The precise results of the Galliformes are listed in Table 2. *Amidostomum* eggs were found in one sample from a peafowl. Spirurid eggs were detected in one sample from a common quail (data not shown; Fig. 1F).

In 398 samples from Passeriformes 18.1% (CI = 14.4–22.2%) *Isospora* oocysts (Fig. 2A), 3.5% (CI = 1.9–5.8%) *Eimeria* oocysts, 5.3% (CI = 3.3–8.0%) *Capillaria* eggs, 0.5% (CI = 0.1–1.8%) *Ascaridia* eggs, 0.5% (CI = 0.1–1.8%) *Cyathostoma* eggs, 2.5% (CI = 1.2–4.6%) *Syngamus* eggs, 1.3% (CI = 0.4–2.9%) *Raillietina* eggs, 5.5% (CI = 3.5–8.2%) *Porrocaecum* eggs (Fig. 2B) and 1.0% tape-

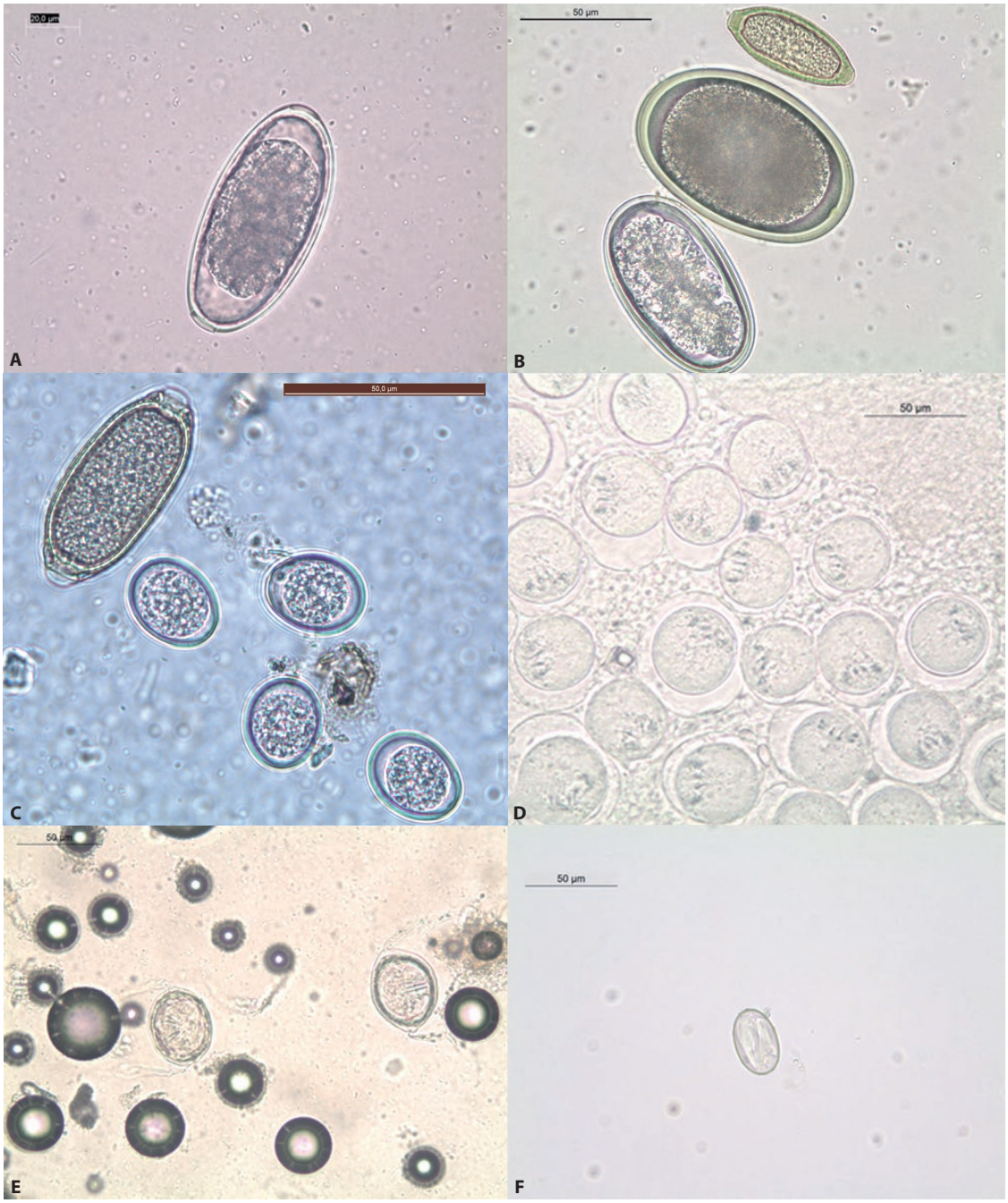

FIGURE 1: *A: Syngamus egg, African Grey Parrot, B: Capillaria (top), Ascaridia (center) and Heterakis (bottom) eggs, Rock Partridge; C: Capillaria egg and four Eimeria oocysts, Pheasant; D: Davainea eggs, Chicken; E: Choanotaenia eggs, Chicken; F: Spirurid egg, Common Quail (A-F: scale bar= 50 µm)*

worm eggs (*Choanotaenia*/*Passerilepis*/one unspecified) were detected (Tab. 3).

In 337 samples from Anseriformes parasite occurrences were: *Isospora* oocysts 1.8% (CI = 0.7–3.8%), *Eimeria* oocysts 7.4% (CI = 4.9–10.8%), *Capillaria* eggs 14.8% (CI = 11.2–19.1%), *Ascaridia* eggs 4.7% (CI = 2.7–7.6%), *Trichostrongylus* eggs and *Cyathostoma* eggs 1.8% (CI = 0.7–3.8%), *Syngamus* eggs 1.2% (CI = 0.3–3.0%) and *Amidostomum* eggs 8.3% (CI = 5.6–11.8%) (Fig. 2C). In one sample from a goose spirurid eggs were detected (Tab. 4).

In a total of 204 samples from raptors (Falconiformes and Accipitriformes) 1.0% (CI = 0.1–3.5%) *Eimeria* oocysts, 11.8% (CI = 7.7–17.0%) *Caryospora* oocysts (Fig. 2D), 9.3% (CI = 5.7–14.2%) *Capillaria* eggs, 1.0% each (CI = 0.1–3.5%) of *Ascaridia* eggs and *Cyathostoma* eggs, and 2.0% (CI = 0.5–4.9%) *Porrocaecum* eggs were identified (Tab. 5). In one faecal sample of an Eurasian sparrow hawk (*Accipiter nisus*) spirurid eggs and *Sarcocystis* sp. oocysts were found. *Isospora* oocysts were detected in one sample from a hawk (*Accipiter*) (data not shown).

In 51 samples from Strigiformes 15.7% (CI = 7.0–28.6%) *Eimeria* oocysts, 5.9% (CI = 1.2–16.2%) *Caryospora* oocysts, 11.8% (CI = 4.4–23.9%) *Capillaria* eggs and 2.0% (CI = 0–10.4%) *Syngamus* eggs were encountered (Tab. 6).

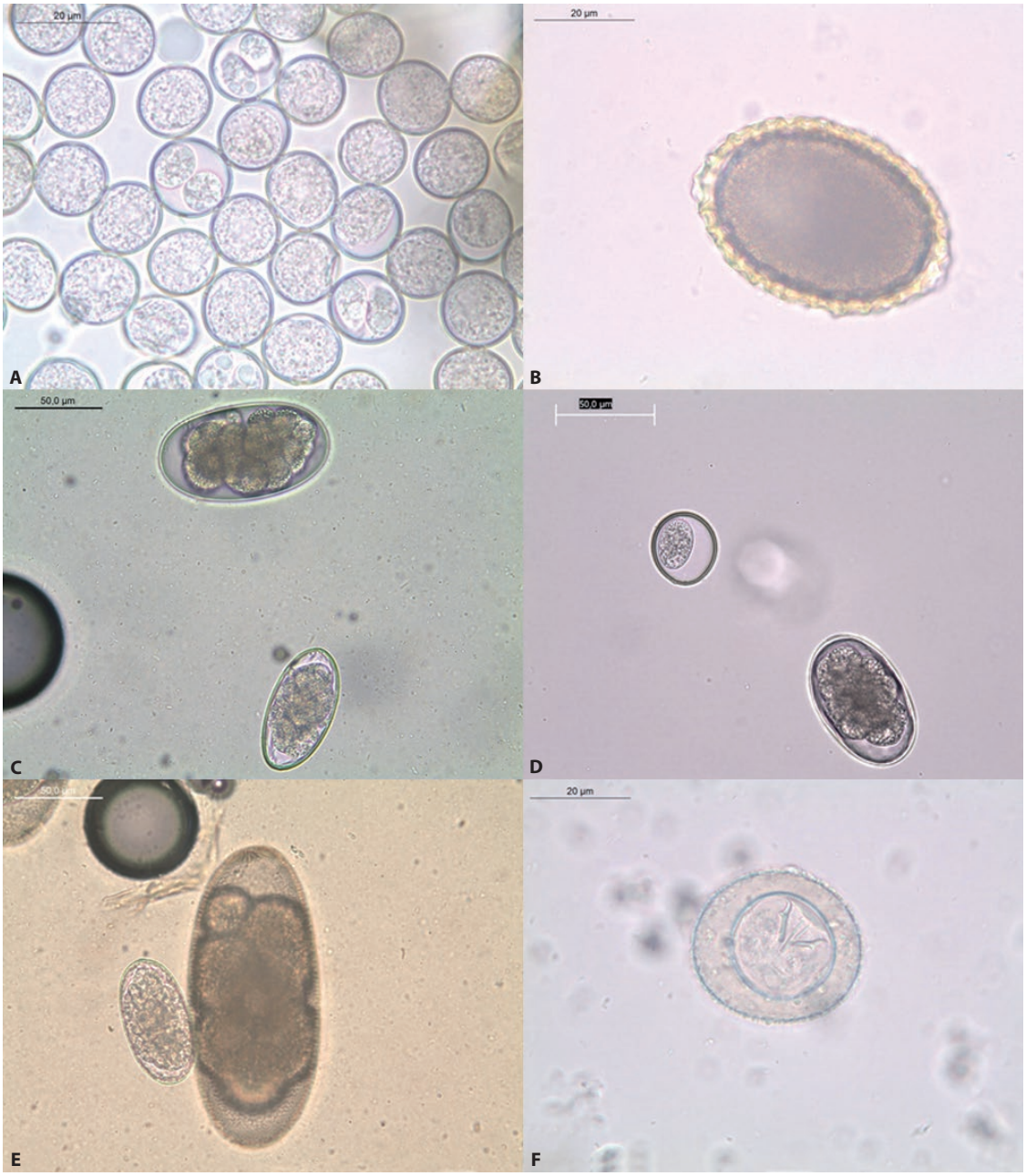

FIGURE 2: *A: Isospora oocysts, Canary; B: Porrocaecum egg, Eurasian Blackbird; C: Amidostomum egg (top) and Trichostrongylus egg (bottom), Goose; D: Caryospora oocyst (at the left) and Cyathostoma egg (at the right), Falcon; E: Strongyle-type egg (Libyostrongylus/Codiostomum spp. at the left) and Deletrocephalus egg (at the right), Rhea; F: Raillietina egg, unspecified bird (A, B, F: scale bar= 20 µm; C, D, E: scale bar= 50 µm)*

In 48 specimens from Struthioniformes occurrences of protozoa and nematodes were: *Isospora* oocysts 2.1% (CI = 0.1–11.1%), *Eimeria* oocysts 6.3% (CI = 7.0–28.6%), *Capillaria* eggs 10.4% (CI = 3.5–22.7%), *Libyostrongylus/Codiostomum* eggs 12.5% (CI = 4.7–25.2%) and *Deletrocephalus* eggs 6.3% (CI = 1.3–17.2%) (Fig. 2E; Tab. 7).

From Ciconiiformes 25 specimens were examined. *Eimeria* oocysts, *Capillaria* eggs and *Ascaridia* eggs were detected in one sample of storks (n=21), respectively. In one sample from a Northern Bald Ibis (n = 4) *Trichostrongylus* eggs were found.

In 19 samples from Gruiformes (and specifically cranes; n = 17), three were positive for *Eimeria* oocysts (17.7%; CI = 3.8–43.4%) and four for *Capillaria* eggs (23.5%; CI = 6.8–49.9%). In one of two tested Bustard specimens *Capillaria* eggs were observed.

Positive cases from Charadriiformes (n = 3) included one sample from a Pied Avocet (n = 1) with *Eimeria* oocysts and *Capillaria* eggs, and one sample from Gull (n = 2) with *Capillaria* eggs.

Additionally, in one sample from a turaco, belonging to the Musophagiformes, *Eimeria* oocysts were detected.

TABLE 2: *Parasite occurrence (in %) within the Galliformes (n = 1330 in total)*

			Number of positive samples (Percent occurence [%]) and 95%-Confidence Interval								
Scientific name	**Common name**	**No. exam.**	***Isospora***	***Eimeria***	***Capillaria***	***Ascaridia***	***Trichostrongylus***	***Heterakis***	***Syngamus***	***Cyathostoma***	***tapeworm***
Gallus	Chicken	1127	12 (1.1) 0.6–1.9	629 (55.8) 52.9–58.7	431 (38.2) 35.4–41.2	381 (33.8) 31.0–36.7	21 (1.9) 1.2–2.8	84 (7.5) 6.0–9.1	3 (0.3) 0.1–0.8	2 (0.2) 0–0.6	2 (0.2)* 0–0.6
Pavo	Peafowl	69	2 (2.9) 0.4–10.1	40 (58) 45.5–69.8	36 (52.2) 39.8–64.4	16 (23.2) 13.9–34.9	2 (2.9) 0.4–10.1	2 (2.9) 0.4–10.1	1 (1.4) 0–7.8	1 (1.4) 0–7.8	
Meleagris	Turkey	52	1 (1.9) 0–10.3	19 (36.5) 23.6–51	15 (28.8) 17.1–43.1	7 (13.5) 5.6–25.8	7 (13.5) 5.6–25.8	2 (3.8) 0.5–13.2	2 (3.8) 0.5–13.2	–	
Coturnix coturnix	Common Quail	31	–	13 (41.9) 24.5–60.9	7 (22.6) 9.6–41.1	2 (6.5) 0.8–21.4	–	–	1 (3.2) 0.1–16.7	1 (3.2) 0.1–16.7	
Phasianidae	Pheasant	29	1 (3.4) 0.1–17.8	4 (13.8) 3.9–31.7	10 (34.5) 17.9–54.3	8 (28) 12.7–47.2	–	3 (10.3) 2.2–27.4	1 (3.4) 0.1–17.8	–	
Tetrao urogallus	Eurasian Capercaillie	20	–	11 (55) 31.5–76.9	10 (50) 27.2–72.8	1 (5) 0.1–24.9	–	2 (10) 1.2–31.7	–	–	
Tetrao tetrix	Black Grouse	2	–	1 (50) 1.3–98.7	1 (50) 1.3–98.7	–	–	–	–	–	

* based on egg and proglottid morphology classified as *Choanotaenia* sp. and *Davainea* sp.

By microscopic examination of 3762 samples from birds of unknown species the following occurrences and confidence intervals were identified: *Isospora* oocysts 1.2% (CI = 0.9–1.6%; n = 45), *Eimeria* oocysts 15.0% (CI = 14.0–16.4%; n = 571), *Capillaria* eggs 6.0% (CI = 5.4–7.0%; n = 231), *Ascaridia* eggs 5.5% (CI = 4.8–6.3%; n = 207), *Heterakis* eggs 0.2% (CI = 0.1–0.5%; n = 9), *Trichostrongylus* and tapeworm eggs (unspecified) 0.1% (CI = 0–0.2%; n = 3). In this group, spirurid, *Syngamus* sp. and *Raillietina* sp. eggs were each found in single sample (Fig. 2F).

Discussion

Microscopic examination of faecal flotations in over ten thousand samples revealed a high occurrence of parasitic infections in avian species. Reviewing the literature, few prevalence data of parasites in domestic fowl and in free-ranging populations are available from different bird orders (Kutzer et al., 1980; Ssenyonga, 1982; Krone, 2000; Lierz et al., 2002; Zhang et al., 2008). Current study data are based upon samples from different bird groups derived from several European countries. As the genera and species of parasites and their occurrences differed considerably between the various avian groups and families, the detection of parasites will be discussed separately for each bird group. Further research is necessary to identify the factors (such as season or geographic location) that influence incidence of parasitic infection in captive birds.

Columbiformes

The present study demonstrates that parasites are very common in faecal samples from Columbiformes. Previous studies reported lower prevalences (2.5–40.2%) of *Eimeria* oocysts in domestic pigeons than in this survey (Ras-Norynska et al., 2011; Radfar et al., 2012). In contrast Dovč et al. (2004) noted a high prevalence (71.9%) of *Eimeria* oocysts in free-living pigeons. Whether or not and when to initiate anticoccidial treatment is still under discussion. Even if mild infections do not result in clinical signs and may induce individual immunity, coccidia are still considered to be harmful to pigeons, especially if combined with other factors such as stress during the racing season (Pees, 2008). Moreover, high oocyst counts of more than 3000–20 000 oocysts/g faeces were found in flocks with poor performance and body condition (Wallis, 1991). Different *Eimeria* species may vary in their virulence. For example, *Eimeria labbeana, Eimeria columbarum* and *Eimeria columbae* are reported as clinically relevant, especially in young individuals (Balicka-Ramisz and Pilarczyk, 2014). Therefore, anticoccidial therapy may be advisable to treat against certain species of *Eimeria* in pigeons. Regarding nematode infections, higher prevalences (55.6–67.2%) of *Capillaria* eggs have been reported in pigeons previously, compared to the current study (Tanveer et al., 2011; D'Avila et al., 2012). The occurrence of *Ascaridia columbae* eggs (16.6%) in the present study was in agreement with studies conducted in Iran and Brazil, but lower than the prevalences (30–42%) observed in other studies (Mushi et al., 2000; Senlik et al., 2005; Tanveer et al., 2011; Al-Barwari and Saeed, 2012; Taroda et al., 2013). In pigeons, *Capillaria caudinflata* (*syn. Pterothominxs caudinflata, syn. Aonchotheca caudinflata*) and *Capillaria columbae* (*syn. Baruscapillaria obsignata, syn. Capillaria obsignata)* are known to colonize the small intestine, and *C. columbae* additionally the caecum. Some authors believe *Capillaria* spp. to be more pathogenic than ascarids, as they burrow in the bowel wall and suck blood. As few as 50 worms may cause death of adult pigeons (Harper , 1996). The correlation between clinical signs and the number of eggs found in the faeces is rather low (Pees, 2008). Therefore, a specific treatment of nematodes is recommended, independent of faecal egg count results.

Psittaciformes

In general, parasitism of captive parrots in Europe is low. Outdoor aviary birds may be more predisposed to parasitism due to increased access to the ground and potentially to faeces of wild birds (Monks, 2005). This corresponds to a conspicuously low occurrence of coccidia in Psittaciformes compared to other avian orders in this study. The most frequent parasites found in this group were *Capillaria* and *Ascaridia* eggs (3.2% and 2.6%, respectively), though at significant lower rates compared to Columbiformes and Galliformes. Different feeding practices might explain these differences, as parrot food is commonly provided in elevated feeding dishes, while pigeons and chickens may feed from potentially contaminated ground. *Capillaria* eggs had been reported in

TABLE 3: *Parasite occurrence (in %) within the Passeriformes (n = 398 in total)*

			Number of positive samples (Percent occurence [%]) and 95%-Confidence Interval								
Scientific name	**Common name**	**No. exam.**	***Isospora***	***Eimeria***	***Capillaria***	***Ascaridia***	***Porrocaecum***	***Syngamus***	***Cyathostoma***	***Raillietina***	***tapeworm***
Passeriformes (unspecified)	Passerine	5	2 (40) 5.3–85.3	–	–	–	–	–	–	–	–
Serinus canaria forma domestica	Canary	157	18 (11.5) 6.9–17.5	–	–	1 (0.6) 0–3.5	–	–	–	–	–
Serinus serinus	European Serin	3	1 (33.3) 0.8–90.6	–	–	–	–	–	–	–	–
Carduelis carduelis	European Goldfinch	18	6 (33.3) 13.3–59	–	–	–	–	–	–	–	–
Pyrrhula pyrrhula	Eurasian Bullfinch	11	4 (36.4) 10.9–69.2	–	–	–	–	–	–	–	–
Coccothraustes coccothraustes	Hawfinch	1	1 (100) 2.5–100	–	–	–	–	–	–	–	–
Carduelis	Finch	16	–	–	1 (6.3) 0.2–30.2	–	–	–	–	–	–
Taeniopygia guttata	Zebra Finch	15	1 (6.7) 0.2–31.9	–	–	–	–	–	–	–	–
Padda oryzivora	Java Sparrow	3	3 (100) 29.2–100	–	–	–	–	–	–	–	–
Chloebia gouldiae	Gouldian Finch	11	1 (9.1) 0.2–41.3	–	–	–	–	–	–	–	–
Fringilla coelebs	Chaffinch	3	1 (33.3) 0.8–90.6	–	–	–	–	–	–	–	–
Fringilla montifringilla	Brambling	2	1 (50) 1.3–98.7	–	–	–	–	–	–	–	–
Cotinga	Cotinga	13	1 (7,7) 0.2–36	–	–	–	–	–	–	–	–
Cardinalidae	Cardinal	5	2 (40) 5.3–85.3	–	1 (20) 0.5–71.6	–	–	–	–	–	–
Gracula religiosa	Common Hill Myna	39	5 (12,8) 4.3–27.4	–	1 (2,6) 0.1–13.5	–	–	–	–	–	–
Sturnus vulgaris	European Starling	4	1 (25) 0.6–80.6	–	–	–	–	–	–	–	–
Leucopsar rotschildi	Bali Myna	2	1 (50) 1.3–98.7	–	–	–	–	–	–	–	–
Lamprotornis superbus	Superbus Starling	1	–	–	–	–		–	–	–	– 1 (100) * 2.5–100
Turdus	Thrush	1	–	–	1 (100) 2.5–100	–	–	1 (100) 2.5–100	–	–	–
Turdus merula	Eurasian Blackbird	11	2 (18.2) 2.3–51.8	–	2 (18.2) 2.3–51.8	–	1 (9.1) 0.2–41.3	2 (18.2) 2.3–51.8	–	3 (27.3) 6.0–61	
Thraupidae	Tanager	2	1 (50) 1.3–98.7	1 (50) 1.3–98.7	–	–	–	–	–	–	–
Pycnonotidae	Bulbul	2	1 (50) 1.3–98.7	1 (50) 1.3–98.7	–	–	–	–	–	–	–
Chloropseidae	Leafbirds	1	1 (100) 2.5–100	–	–	–	–	–	–	–	–
Paridae	Tit	3	–	–	–	–		–	–		1 (33.3) 0.8–90.6
Passeridae	Sparrow	13	6 (46.2) 19.2–74.9	1 (7.7) 0.2–36	–	–	–	–	–	1 (7.7) 0.2–36	–
Corvidae	Crow, Raven	56	12 (21.4) 11.6–34.4	11 (19.6) 10.2–32.4	15 (26.8) 15.8–40.3	1 (1.8) 0–9.6	21 (37.5) 24.9–51.5	7 (12.5) 5.2–24.1	2 (3.6) 0.4–12.3	1 (1.8) 0–9.6	2 (3.6) ** 0.4–12.3

* based on egg morphology classified als *Choanotaenia*; ** based on egg morphology classified as *Passerilepis*

one St. Vincent parrot (*Amazona guildingii*) (Deem et al., 2008), and in 5/33 parrots (African grey parrots, white cockatoos, macaws, and parakeets) in previous studies (Pees, 2008). *Ascaridia* eggs had been reported in 4/33 psittacines (lori, love bird, white cockatoo, amazon parrot) (Patel et al., 2000). Five *Ascaridia* species are regarded specific to parrots: *Ascaridia hermaphrodita*, *Ascaridia sergiomeiari*, *Ascaridia ornate* (Neotropical area), *Ascaridia nicobarensis* (Oriental area) and *Ascaridia platyceri* (Australia). In addition, a new species *Ascaridia nymphii* was isolated from the gastrointestinal tract of a 48-day-old young cockatiel *Nymphicus hollandicus* in Japan (Abe et al., 2015). Cross-infections with untypical *Ascaridia* spp. may occur as well, if parrots from different geographical areas or different bird orders are kept together (Hartwich and Tschnerner, 1979). In this regard *Ascaridia galli* (primarily chickens) and *A. columbae* (primarily pigeons) had been isolated from parrots following experimental and natural infection (Peirce and Bevan, 1973; Mines and Green, 1983). In the present study, *Ascaridia* eggs were detected in cockatoo, cockatiel and budgerigar (1.4–2.7%) with a higher occurrence than previously

TABLE 4: *Parasite occurrence (in %) within the Anseriformes (n = 337 in total)*

			Number of positive samples (Percent occurence [%]) and 95%-Confidence Interval								
Scientific name	**Common name**	**No. exam.**	***Isospora***	***Eimeria***	***Capillaria***	***Ascaridia***	***Tricho–strongylus***	***Spirurid***	***Synga-mus***	***Cyatho-stoma***	***Amido-stomum***
Anserinae	*Goose*	170	2 (1,2) 0.1–4.2	15 (8.8) 5.0–14.1	22 (12.9) 9.3–18.9	12 (7.1) 3.7–12	6 (3.5) 1.3–7.5	1 (0.6) 0–3.2	3 (1.8) 0.4–5.1	6 (3.5) 1.3–7.5	27 (15.9) 10.7–22.3
Anatinae	*Duck*	148	4 (2.7) 0.7–6.8	7 (4.7) 1.9–9.5	28 (18.9) 13.0–26.2	4 (2.7) 0.7–6.8	–	–	1 (0.7) 0–3.7	–	1 (0.7) 0–3.7
Cygnini	Swan	17	–	2 (11.8) 1.5–36.4	–	–	–	–	–	–	
Mergus merganser	Common Merganser	2	–	1 (50) 1.3–98.7	–	–	–	–	–	–	–

reported in single parakeets, cockatiels, amazon parrots and African grey parrots before (Tsai et al.,1992); however, the occurrence was much lower than the prevalence of *A. galli* in zoo parrots in Pakistan (26.1%) (Khan et al., 2010) and the occurrence of *A. platyceri* (20%) in budgerigars, African grey parrots and Eastern rosella in Poland (Balicka-Ramisz et al., 2007). Specific treatment, hygiene and quarantine are recommended if these parasites are detected (Monks, 2005; Fernando and Barta, 2008).

TABLE 5: *Parasite occurrence (in %) within the Falconiformes and Accipitriformes (n = 204 in total)*

			Number of positive samples (Percent occurence [%]) and 95%-Confidence Interval					
Scientific name	**Common name**	**No. exam.**	***Eimeria***	***Caryo-spora***	***Capilla-ria***	***Ascari-dia***	***Cyathos-toma***	***Porrocae-cum***
Falconiformes (unspecified)	Raptors	14	–	1 (7.1) 0.2–33.9	1 (7.1) 0.2–33.9	–	–	–
Falco	Falcon	54	–	4 (7.4) 2.1–17.9	–	–	–	–
Falco peregrinus	Peregrine Falcon	40	–	13 (32.5) 18.6–49.1	3 (7.5) 1.6–20.4	–	–	–
Falco cherrug	Saker Falcon	21	–	2 (9.5) 1.2–30.4	–	–	–	–
Falco tinnunculus	Eurasian Kestrel	9	–	3 (33.3) 7.5–70.1	1 (11.1) 0.3–48.2	–	1 (11.1) 0.3–48.2	–
Falco subbuteo	Eurasian Hobby	1	–	1 (100) 2.5–100	–	–	–	–
Accipiter	Hawk	24	1 (4.1) 0.1–21.1	–	2 (8.3) 1.0–27	–	1 (4.1) 0.1–21.1	1 (4.1) 0.1–21.1
Accipiter nisus	Eurasian Sparrow Hawk	5	1 (20) 0.5–71.6	–	–	1 (20) 0.5–71.6	–	3 (60) 14.7–94.7
Buteo	Buzzard	11	–	–	1 (9.1) 0.2–41.3	–	–	–
Buteo buteo	Eurasian Buzzard	3	–	–	3 (100) 29.2–100	–	–	–
Buteo rufinus	Long–legged Buzzard	5	–	–	3 (60) 14.7–94.7	–	–	–
Buteo jamaicensis	Red–tailed Hawk	3	–	–	–	1 (33.3) 0.8–90.6	–	–
Geranoaetus melanoleucus	Black–chested Buzzard–Eagle	3	–	–	1 (33.3) 0.8–90.6	–	–	–
Aquila	Eagle	7	–	–	1 (14.3) 0.4–57.9	–	–	–
Haliaeetus albicilla	White–tailed Eagle	2	–	–	1 (50) 1.3–98.7	–	–	–
Haliaeetus vocifer	African Fish–Eagle	1	–	–	1 (100) 2.5–100	–	–	–
Neophron percnopterus	Egyptian Vulture	1	–	–	1 (100) 2.5–100	–	–	–

Galliformes

In Galliformes of this study, the most prevalent parasite genera were *Eimeria, Capillaria* and *Ascaridia*, which is in accordance to previous studies (Orunc and Bicek, 2009; Tomza-Marciniak et al., 2014). Chickens are known to host seven *Eimeria* species in specific sections of their intestines (*Eimeria acervulina, Eimeria tenella, Eimeria maxima, Eimeria necatrix, Eimeria mitis, Eimeria praecox* and *Eimeria brunetti*) (Williams et al., 2009), which may be discriminated using PCR protocols (Vrba et al., 2010). For centuries, *Eimeria* species were assumed to be highly host-specific and adapted to a single host species only; however, recent cross-transmission experiments demonstrated that coccidia are able to adjust to other unspecific hosts, which may play an important role in the evolution and diversification of this genus (Vrba and Pakandl, 2015). As most pathogenic species, *E. tenella* and *E. necatrix* are associated with high mortality in young chickens (Iacob and Duma, 2009), and in hunting pheasants *Eimeria colchici* appears to be harmful. Co-infections with different *Eimeria* species and complications by other pathogens are common (Györke et al., 2013; Alnassan et al., 2014). Other microbiological pathogens were not assessed in the present study.

Regarding the identified nematodes, the occurrence of ascarids and capillarids in Galliformes was higher compared to pigeons which corresponds to recent investigations (n = 629 specimens) in 132 German poultry flocks (Küblböck, 2015). Interestingly, the prevalences of *Ascaridia* in free-ranging birds were three times higher than in indoor facility in the present survey. A possible explanation for this finding is the introduction of nematodes by wild bird species and their accumulation and long term survival within the earth (Clapham, 1934; Campbell, 1935). In contrast, Thapa et al. (2014) found a negative correlation between the outdoor access (i.e. pasture access time) and *Ascaridia (A.) galli* worm burden in organic laying hens, which may be related to the fact that *A. galli* is most probably specific in terms of transmission and epidemiology.

The prevalence of *Syngamus* in pheasants in this study was low (3.4 %) and even if the intensity of infection is

TABLE 6: *Parasite occurrence (in %) within the Strigiformes (n = 51 in total)*

			Number of positive samples (Percent occurence [%]) and 95%-Confidence Interval			
Scientific name	**Common name**	**No. exam.**	***Eimeria***	***Caryospora***	***Capillaria***	***Syngamus***
Bubo bubo	Eurasian Eagle Owl	19	–	–	2 (10.5) 1.3–33.1	1 (5.3) 0.1–26
Bubo scandiacus	Snowy Owl	12	2 (16.7) 2.1–48.4	1 (8.3) 0.2–38.5	–	–
Strigiformes	Owl	8	2 (25) 3.2–65.1	–	–	–
Strix nebulosa	Great Grey Owl	6	4 (66.7) 22.3–95.7	–	1 (16.7) 0.4–64.1	–
Strix aluco	Tawny Owl	4	–	1 (25) 0.6–80.6	2 (50) 6.8–93.2	–
Athene noctua	Little Owl	1	–	1 (100) 2.5–100	–	–
Otus scops	Scops Owl	1	–	–	1 (100) 2.5–100	–

reported to decrease with higher age, there seems to be no difference in the prevalence between juvenile and adult pheasants (Campbell, 1935).

Passeriformes

Coccidian species, especially from the genus *Isospora*, are regarded as the most common endoparasites in captive and free-ranging Passeriformes (Dolnik and Hoi, 2010). This corresponds to the results of the present study. In 58 species and 21 families of the order Passeriformes, two species of *Eimeria* and 81 species of *Isospora* have been reported (Berto et al., 2011) and respective species are regarded host specific (Lopez et al., 2007; Greiner, 2008). In Buntings (Emberazidae) and Tanagers (Thraupidae) 30 different *Isospora* spp. were reported (Pereira et al., 2011). In the present study, the occurrence of *Isospora* oocysts was 11.5% in canaries and therefore below the occurrence in canaries examined in Brazil (50.5%) (De Freitas et al., 2003), and in Elazığ Province in Turkey (28.1%) (Saki and Özer, 2012). Likewise, the prevalence of *Isospora bocamontensis* has been reported to be high (44.5%) in captive yellow cardinals (*Gubernatrix cristata*) (Pereira et al., 2011) and may be even higher in free-ranging passerines (Schwalbach, 1960). *Isospora canaria* and *Isospora serini* have been described in canary birds (Box, 1977) with *I. serini* representing an exception to the coccidian life-cycle (Joseph, 2003). By developing extra-intestinally in monocytes, *I. serini* is able to survive for several months within the avian host and causing so called "atoxoplasmosis" (Box, 1977). This disease may be associated with reduced weight and reproduction, neurological and respiratory signs, hepatomegaly and sudden death (De Freitas et al., 2003). Some avian families, such as Fringillidae and Sturnidae seem to be at highest risk of contracting fatal atoxoplasmosis. Molecular methods are necessary for the differentiation of oocysts from enteric and extra-enteric coccidian species (Dolnik et al., 2009). As the shedding of oocysts has been reported to vary during the day, samples should be collected in the late afternoon, when oocyst shedding is supposed to increase (Lopez et al., 2007).

In corvids of the present study, a high rate of parasitism was found (37.5% for *Porrocaecum* eggs and 26.8% for *Capillaria* eggs). Little is known about the pathogenic effects of *Capillaria* spp. in these avian hosts besides the formation of diphtheritic membranes in the gastrointestinal tract and emaciation caused by *Capillaria contorta (Eucoleus contortus*) (Helmboldt et al., 1971). Eggs of the gapeworm *Syngamus trachea* were found in 15.2% of the crow samples in the present study, which has been described in the respiratory tract of free-ranging crows, robins, jays and starlings in a previous report (Campbell, 1935).

Anseriformes

Gizzard worm (*Amidostomum*) eggs (15.9%) and *Capillaria* eggs (12.9%) were frequently detected in geese and ducks (18.9% for *Capillaria* eggs) in the present study. This is in accordance with studies from Iraq, as *Capillaria* were the most frequent nematodes found in geese (42.5%) and ducks (38.8%) (Al-Taee et al., 2011). *Amidostomum* represents a common parasite of waterfowl, especially of the family Anatidae (geese, ducks and swans) (Fedynich and Thomas, 2008) and has been detected in common eiders (*Somateria mollissima*) found dead along the Dutch coast. The parasite is associated with high mortality (Borgsteede, 2005). *Amidostomum anseris* was the most prevalent nematode (40–50%) found in 5–9 week old geese in Poland (Kornas et al., 2015). Adult birds seem to harbour more parasites than juveniles. Males are also more affected than females, which may be associated with different behavioural and feeding patterns. Clinical signs associated with parasitism are more severe in juvenile individuals (Borgsteede, 2005). In our survey 3.5% of geese shed eggs of *Cyathostoma*, which have been found in the nose, the infraorbital sinus and the trachea of waterfowl previously (Krone et al., 2007). *Cyathostoma bronchialis* has been considered as a virulent nematode in young individuals (Fernando et al., 1973). Therefore, antiparasitic treatment may be advisable.

TABLE 7: *Parasite occurrence (in %) within the Struthioniformes (n = 48 in total)*

			Number of positive samples (Percent occurence [%]) and 95%-Confidence Interval				
Scientific name	**Common name**	**No. exam.**	***Isospora***	***Eimeria***	***Capillaria***	***Libyostrongylus/Codiostomum***	***Deletrocephalus***
Struthio camelus	Ostrich	17	–	–	–	1 (5.9) 0.1–28.7	–
Rheidae	Rhea	15	–	2 (13.3) 1.7–40.5	4 (26.7) 7.8–55.1	1 (6.6) 0.2–31.9	3 (20) 4.3–48.1
Dromaius	Emu	15	1 (6.6) 0.2–31.9	1 (6.6) 0.2–31.9	1 (6.6) 0.2–31.9	4 (26.7) 7.8–55.1	–
Apteryx	Kiwi	1	–	–	–	–	–

Falconiformes/Accipitriformes

The most prevalent parasite found in falcons was *Caryospora* (9.6%), which is in accordance to reports from Europe, the Middle East and North America, where prevalences of 60–65% have been estimated for captive, young falcons (Forbes, 2008). In contrast to *Eimeria*, *Frankelia* and *Sar-*

cocystis, the detection of *Caryospora* is of clinical significance, especially for young individuals between 30–80 days of age, when combined with stress or immune suppression (Forbes, 2008). *Caryospora cherrughi* and *Caryospora biarmicusis* were described in saker falcons (*Falco cherrug*) and in lanner falcons (*Falco biarmicus*), respectively (Alyousif et al., 2011; Alfaleh et al., 2013). *Sarcocystis* oocysts were found in one accipiter hawk in the present survey. Birds may serve as intermediate or definitive host for *Sarcocystis* (Olias et al., 2010; Olias et al., 2014). *Sarcocystis calchasi* uses pigeons and possibly other avian species as intermediate hosts and hawks (*Accipiter gentilis* and *Accipiter nisus*) as definitive hosts (Olias, 2010; Olias et al., 2011; Mayr, 2016). In the definitive hosts clinical signs are absent, although in intermediate hosts, such as the pigeons and psittacines, clinical signs may be observed and include paralysis, torticollis and opisthotonus (Olias, 2010; Olias et al., 2010; Olias et al., 2014). Hawks shed *Sarcocystis* oocysts 6 days after ingesting muscle cysts (Olias et al., 2009), which must be considered for faecal examination.

The overall occurrence of nematodes in the present study was below a previous study in South Italy, where in 74% of the 116 necropsied birds of prey pathological findings in the respiratory and digestive tracts were associated with nematodes (Santoro et al., 2010). Likewise in studies performed purely in free-living birds, infection in 54–80% of the adult individuals (Ferrer et al., 2004). In our study, *Porrocaecum* eggs were found in 13.8% of the hawks examined. *Porrocaecum angusticolle* and *Porrocaecum depressum* are parasites with worldwide distribution in birds of prey (Morgan and Schiller, 1950). Clinical signs associated with parasitism are anorexia with subsequent death (Keymer et al., 1981). Infection with ascarids is more pathogenic in nestling, young, immune suppressed and stressed birds (Forbes, 2008). Peritonitis or secondary bacterial infections may contribute to higher morbidity in individuals independent of age (Greve et al., 1986).

Capillaria spp. eggs were demonstrated in 7.6% of the samples from birds of prey in the present study. *Capillaria* are common parasites in raptors (Forbes, 2008), which harbour four different *Capillaria* species: *C. contorta* (syn. *E. contortus*), *Eucoleus dispar, Baruscapillaria falconis* and *Capillaria tenuissima* (Yabsley, 2008). Severe infections with *C. contorta* and *E. dispar* may cause thick yellow exudates in the upper gastrointestinal tract (Clausen and Gudmundsson, 1981).

Cyathostoma eggs were detected in one Eurasian Kestrel and one hawk. Previous studies frequently found *Cyathostoma* sp. in raptors (Simpson and Harris, 1992; Borgsteede and Okulewicz, 2001; Krone et al., 2007), although clinical signs associated with infection were uncommon (Lavoie et al., 1999; Krone et al., 2007). 3% of raptors and 9% of goshawks had air sac lesions associated with *Cyathostoma variegatum* infection (Krone et al., 2007). *Cyathostoma lari* has been isolated from the orbital cavity and the lower eyelid of birds of prey (Simpson and Harris, 1992).

Strigiformes

Eimeria oocysts (15.4%) and *Capillaria* eggs (11.5%) were the most prevalent parasites in owls found in the present study. Likewise, protozoan (*Cryptosporidium, Eimeria* and *Isospora*) and nematode (*Capillaria* and Strongylida) detection in faecal samples were reported in captive owls in Brazil displaying clinical signs of disease (Da Silva et al., 2009). Fatal parasitic pneumonia with severe lesions in air sacs and lung tissues caused by *Cyathostoma* was described in different captive owl species. Interestingly, the host reaction was more pronounced against parasite eggs than against adult or larval worms (Krone et al., 2007). In raptors, species-specific parasites and parasites from prey (spurious parasites; e.g. from rodents) should be differentiated (Papini et al., 2012).

Struthioniformes

In 10.4% of the samples of Struthioniformes tested in the present study *Capillaria* eggs were found. These parasites are clinically more important in young than in adult Struthioniformes, as reviewed in Craig and Diamond (1996). In the greater rhea (*Rhea Americana*) *Capillaria parvumspinosa* has been described (Yamaguti, 1961), but detailed prevalence data are not available.

The occurrence of *Libyostrongylus/Codiostomum* eggs in ostriches, rheas and emus was 12.5% in the present study. The eggs of both genera are morphologically indistinguishable (Ederli and Oliviera, 2014) and mixed infections of both species may occur (De Andrade et al., 2011). They are considered highly virulent nematodes. *Codiostomum struthionis* causes nodular hemorrhagic lesions with ulcers and edema in ostrich caeca (De Oliveira et al., 2009). *Libyostrongylus* belongs to the most virulent nematodes, causing high mortality of young and occasionally adult ratites (Schulze et al., 2006). *Libyostrongylus dentatus* and *Libyostrongylus douglasi* were described in the proventriculus and gizzard of ostriches (De Andrade et al., 2011) the latter was also isolated from the brain of routinely necropsied farm-kept ostriches in Croatia (Tisljar et al., 2007). A third species, *Libyostrongylus magnus* was described by Ederli and Oliveira (2009). Moreover, *Deletrocephalus cesarpintoi* has been detected in the large intestines of two captive *Rhea americana americana* suffering from lethargy and bad general physical condition with a fatal outcome (Avelar Ide et al., 2014). The hematophagus *Deletrocephalus dimidiatus* has been reported to cause mucosal hemorrhages in the small and large intestines and rectum with dark liquid faeces (Zettermann et al., 2005).

Limitations of the present study

There are some limitations to this cross-sectional study. Only a faecal flotation technique was performed, which is not applicable for the detection of certain parasites (e.g. amoebae, trematodes or different flagellates such as trichomonads/diplomonads). All samples were submitted to the diagnostic laboratory with the request for routine parasitological examination. This sample set represents pre-selected/non-random group of animals. Samples were submitted either as part of a routine assessment of animal health or because the animals were displaying clinical signs of disease. As sample numbers were limited within some bird groups, the occurrence data does not necessarily mirror the real parasite prevalence in the respective avian group. Because of the retrospective nature of the study no data were available regarding age, sex, type of husbandry or previous antiparasitic treatment, which might have influenced findings and might have offered interesting information.

Conclusion

The aim of this study was to evaluate a large number of avian faecal samples (10 356 birds belonging to 20 orders) sent to a diagnostic laboratory using a flotation technique. Findings indicate that endoparasite infections in captive birds are common in occurrence and are common in different bird species. However, various bird species differ considerably in the spectrum and the occurrence of parasitic pathogens. Therefore, knowledge concerning the species-specific parasite spectrum and occurrence is of importance in order to provide targeted treatment and control strategies. Parasitism may be subclinical or lead to non-specific clinical signs. Therefore, faecal analysis using a flotation technique can be a useful adjunct to routine clinical examination in assessment of avian health in single patients and as a management tool for avian collections.

Conflict of interest

M. Globokar and N. Pantchev are employed by IDEXX Laboratories. There is no commercial conflict of interest as the information generated here is solely for scientific dissemination. The authors declare that they have no competing interests.

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Address for correspondence:
Dr. med. vet. Majda Globokar
IDEXX Laboratories
Moerikestraße 28/3
71636 Ludwigsburg
Germany
majda-globokar@idexx.com