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SPONTANEOUSLY ARISING DISEASE

A 5-Year Retrospective Review of Avian Diseases Diagnosed at the Department of Pathology, University of Georgia

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Summary

Avian samples ($n = 827$) submitted to the University of Georgia from 2006 to 2011 were reviewed to determine common disease entities and taxa-specific patterns. The study included 153 species, with 64.5% Psittaciformes, 11.3% Passeriformes, 7.9% Galliformes, 3.8% Columbiformes and 3.5% Anseriformes. Infectious agents were identified in 226 birds (27.3%); bacterial infections ($n = 119$; 14.4%) were most commonly gram-negative bacilli and *Chlamydia psittaci* and less commonly *Mycoplasma* and *Mycobacterium* spp. Mycotic infections (e.g. *Aspergillus* spp., *Candida* spp.) were identified in 66 birds (7.9%), followed by viruses in 30 birds (3.6%), most commonly polyomavirus and poxviruses. Eighteen birds had macroparasite infections, which were most common in Galliformes and most often involved gastrointestinal *Capillaria* spp. Neoplasia was diagnosed in 76 birds (9.2%) of 25 species, with 79% of the tumours deemed to be malignant. The most common neoplasm was lymphoma ($n = 17$; 22.4%), which was diagnosed in Psittaciformes, Galliformes and Passeriformes. Adenocarcinoma ($n = 9$) was found most frequently in the reproductive and gastrointestinal tracts. Haematopoietic neoplasms included myelocytoma and erythroid leucosis. Atherosclerosis was most common in psittacines (23/32; 71.8%) and in raptors and aquatic birds. Seventeen birds, mostly psittacines and aquatic birds, had amyloidosis, most often in the liver, kidney and spleen. Twenty-two birds had gout, most commonly the visceral form. Overall, bacterial infection was the most frequently diagnosed cause of death in captive birds, most commonly in Psittaciformes, followed by Passeriformes and Galliformes. Neoplasia was most common in Psittaciformes, which generally are longer lived than other taxa studied. Some disease entities (e.g. atherosclerosis and aspergillosis) may be associated with captive conditions, and some may involve a genetic predisposition (e.g. atherosclerosis, amyloidosis and haemosiderosis).

Keywords: avian; disease; infection; neoplasia

Introduction

Birds are taxonomically diverse and have many appealing traits, which in part contributes to their popularity as companion animals and their presence in captive (e.g. breeding) and zoological collections. However, a range of husbandry issues as well as behavioural, physiological or genetic traits among taxa may predispose captive birds to disease, including infections, metabolic and nutritional disorders, and neoplasia (Dorrestein, 2009; Beaufrère *et al.*, 2013). In addition, captive birds often have greater longevity, increasing the likelihood of neoplasia or cumulative conditions (e.g. nutritional, metabolic) associated with husbandry (Reavill and Dorrestein,

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2010). Concurrent inter- and intraspecies interactions may increase the potential for immunosuppression and subsequent pathogen invasion (Doneley, 2009). Despite the accumulation of information on zoo and avian medicine and pathology, comprehensive published reviews of avian diagnostic cases are relatively few (Effron *et al.*, 1977). The purpose of this study is to report a retrospective evaluation of diagnoses across a variety of avian taxa received by the Department of Pathology at the University of Georgia Veterinary Teaching Hospital. Our objectives were to determine common as well as uncommonly diagnosed diseases among various avian taxa and to assess for any associated patterns among taxa and disease categories (i.e. infectious diseases, neoplasia and metabolic/nutritional).

Materials and Methods

The case records for all avian-derived samples submitted to the Department of Pathology, College of Veterinary Medicine, the University of Georgia and the Athens Veterinary Diagnostic Laboratory from January 4, 2006 to January 14, 2011 were examined. Cases consisted of 471 carcasses submitted for postmortem examination, formalin-fixed tissues from 333 birds that underwent field necropsy examinations and 23 biopsy samples. Some biopsy samples were submitted for a specified purpose (e.g. screening for proventricular dilation disease). The majority of cases were companion birds (e.g. parrots, cockatiels, conures and macaws) used for education (e.g. raptors) or were from backyard flocks (e.g. ducks, geese and chickens) or zoological collections (e.g. Passeriformes).

For histopathological examination, tissue samples were fixed in 10% neutral buffered formalin, routinely processed and embedded in paraffin wax. Sections (4 μm) were stained with haematoxylin and eosin (HE). Additional histochemical stains were performed as needed, and most commonly included Lillie Twort Gram stain, periodic acid–Schiff reaction, Giemsa, Grocott's methenamine silver, Ziehl–Neelsen acid fast, modified acid fast and Congo red stains.

Immunohistochemical labelling specific for *Chlamydia* spp. antigen was performed on sections of dewaxed liver, sometimes in conjunction with spleen and kidney, as a confirmatory test in some cases. Antigen retrieval was in citrate buffer (Biogenex, Fremont, California, USA; catalogue number HK-0869K; diluted 1 in 10, pH 6.0) for 10 min at 120°C. Endogenous peroxidase was quenched using H_2O_2 enzyme block (Fisher Scientific, Waltham, Massachusetts, USA; catalogue number 342902) for 5 min and all other blocking was completed with Power Block™ protein block (Biogenex, catalogue number HK085-5K; diluted 1 in 10) for 5 min. The primary antibody, polyclonal rabbit anti-*Chlamydia* antibody (Fitzgerald, Acton, Massachusetts, USA; catalogue number 20-CR19), was diluted 1 in 3,500 using antibody diluent (Dako, Carpinteria, California, USA; catalogue number S0809) with an incubation time of 60 min, and was detected by a 10 min application of biotinylated anti-rabbit secondary antibody (Vector Laboratories, Burlingame, California, USA; catalogue number BA-1000; diluted 1 in 100 in Dako antibody diluent). Labelled streptavidin–biotin (LSAB 2) system horseradish peroxidase (Dako, catalogue number K0675) was used as an amplification system for 10 min, and 3, 3′ diaminobenzidine (DAB) chromogen (Dako, catalogue number K3468; 1 drop of chromogen per 1 ml substrate) was used as the substrate chromogen system for 12 min.

Bacterial and virus culture and polymerase chain reaction (e.g. for *Mycoplasma* spp.) were performed in selected cases for aetiological diagnoses at the Athens Diagnostic Laboratory, an American Association of Veterinary Laboratory Diagnosticians (AAVLD)-accredited laboratory, in accordance with protocols established by the Clinical and Laboratory Standards Institute – Library of Standard.

Gross and histopathological descriptions, ancillary test results and final diagnoses were reviewed to generate data on general disease categories, which included: neoplasia, infectious (i.e. bacterial, viral, fungal, yeast or macroparasitic), metabolic or nutritional (i.e. haemosiderosis, hepatic lipidosis, atherosclerosis or gout) and other (i.e. amyloidosis). In several instances, toxicosis was suspected based on histopathology, but was not confirmed; these cases were considered as suspected toxicoses.

Diagnostic data were analyzed concurrently with taxonomic and demographic data when available. Specific taxonomic data (i.e. genus and species) were unavailable in some cases, which were then analyzed by family or order. Data for biopsy cases were often limited to one or a few tissues, precluding a complete evaluation of the disease processes (e.g. disseminated neoplasia or the extent of infections or metabolic disorders). In some cases, microscopical lesion interpretation was limited by advanced tissue autolysis.

Results

Avian Taxonomy

Samples from 827 birds were submitted during the 5-year study period. Birds originated from private, nonprofit and zoological collections and, rarely, from the wild (e.g. wild birds dying on zoo premises). Eighteen orders were represented, with 153 species, 64.5% of which were Psittaciformes, 11.3% Passeriformes, 7.9% Galliformes, 3.8% Columbiformes and 3.5% Anseriformes. Less common submissions included 2.0% Falconiformes, 1.1% Strigiformes, 1.0% Sphenisciformes, 1.0% Ciconiiformes, 0.7% Piciformes, 0.2% Coraciiformes, 0.2% Pelecaniformes and approximately 0.1% each of Caprimulgiformes, Charadriiformes, Coliiformes, Cuculiformes, Gruiformes and Rheiformes; taxonomic data were unavailable for 3.0% of cases.

Bacterial Infections

Infectious agents were identified in 226 (27.3%) birds, with bacterial infections in about half (119; 52.7%) of these (Table 1). The highest percentage of fatal bacterial infections was diagnosed in Psittaciformes ($n = 55$, 46.2%), followed by Passeriformes ($n = 22$, 18.5%), Galliformes ($n = 18$, 15.1%), Anseriformes ($n = 10$, 8.4%) and Columbiformes ($n = 6$, 5%). Because Psittaciformes was the predominant taxonomic order, bacterial infections and other infectious diagnoses for this group are depicted in Fig. 1. Bacterial infections most commonly involved gram-negative bacilli of unidentified species ($n = 21$; 17.6% of all bacterial infections), followed by *Chlamydia psittaci* ($n = 15$, 12.6%; Figs. 2 and 3) and, less commonly, *Mycobacterium* spp. ($n = 7$, 5.9%), *Mycoplasma* spp. ($n = 6$, 5.0%), *Salmonella* spp. ($n = 5$, 4.2%) and, rarely, *Streptococcus*

Table 1
Infectious causes of disease in 226 of 827 avian cases (27.3%) at the University of Georgia, Pathology Department and Athens Veterinary Diagnostic Laboratory from 2006 to 2011

Order[*]	*Columbiformes* (n = 12)	*Galliformes* (n = 27)	*Passeriformes* (n = 45)	*Psittaciformes* (n = 112)
Fungi/yeast				
Candida spp.	1	2	5	4
Aspergillus spp.	–	3	8	16
Macrorhabdus ornithogaster	–	–	6	8
Encephalitozoon spp.	–	–	–	2
Others	–	2	–	7
TOTAL	1	7	19	37
Bacteria				
Chlamydia spp.	–	–	–	15
Mycobacterium spp.	2	1	1	1
Mycoplasma spp.	–	6	–	–
Others	4	12	21	35
TOTAL	6	19	22	51
Viruses				
Polyomavirus	–	–	1	9
Poxvirus	1	2	–	3
Reovirus	–	–	1	–
Herpesvirus	–	–	–	1
Others	2	1	–	7
TOTAL	3	3	2	20
Parasites				
Helminths	1	–	2	2
Capillaria spp.	–	9	–	–
Coccidia	–	2	4	1
Heterakis spp.	–	2	–	–
Histomonas spp.	–	2	–	–
Cryptosporidium spp.	–	–	2	–
Sarcocystis spp.	–	–	–	5
Other protozoa	1	–	4	–
Ascarids	–	1	–	–
TOTAL	2	16	12	8

[*]Taxonomic orders with ≤10 individuals are not represented in the table and include: Anseriformes ($n = 10$; two with *Mycobacterium* spp., one with *Mycoplasma* spp., and seven with unidentified bacterial infections); Charadriiformes and Cuculiformes ($n = 1$ each; both with *Aspergillus* spp. infections); Ciconiiformes ($n = 1$; mixed infection with *Aspergillus* spp. and bacteria); Falconiformes ($n = 7$, including one with *Candida* spp., *Aspergillus* spp. and *Sarcocystis* spp., two with *Aspergillus* spp., three with various bacteria and one with concurrent *Capillaria* spp. and *Physaloptera* spp.; Piciformes (n = 1; with mixed gram-negative and gram-positive rods); Sphenisciformes ($n = 3$; one with *Aspergillus* spp., one infected by other bacteria and one with poxvirus); undetermined order ($n = 6$; including infections with *Aspergillus* spp., *Macrorhabdus* spp., other fungi, other bacteria, other viruses, *Sarcocystis* spp. and helminths).

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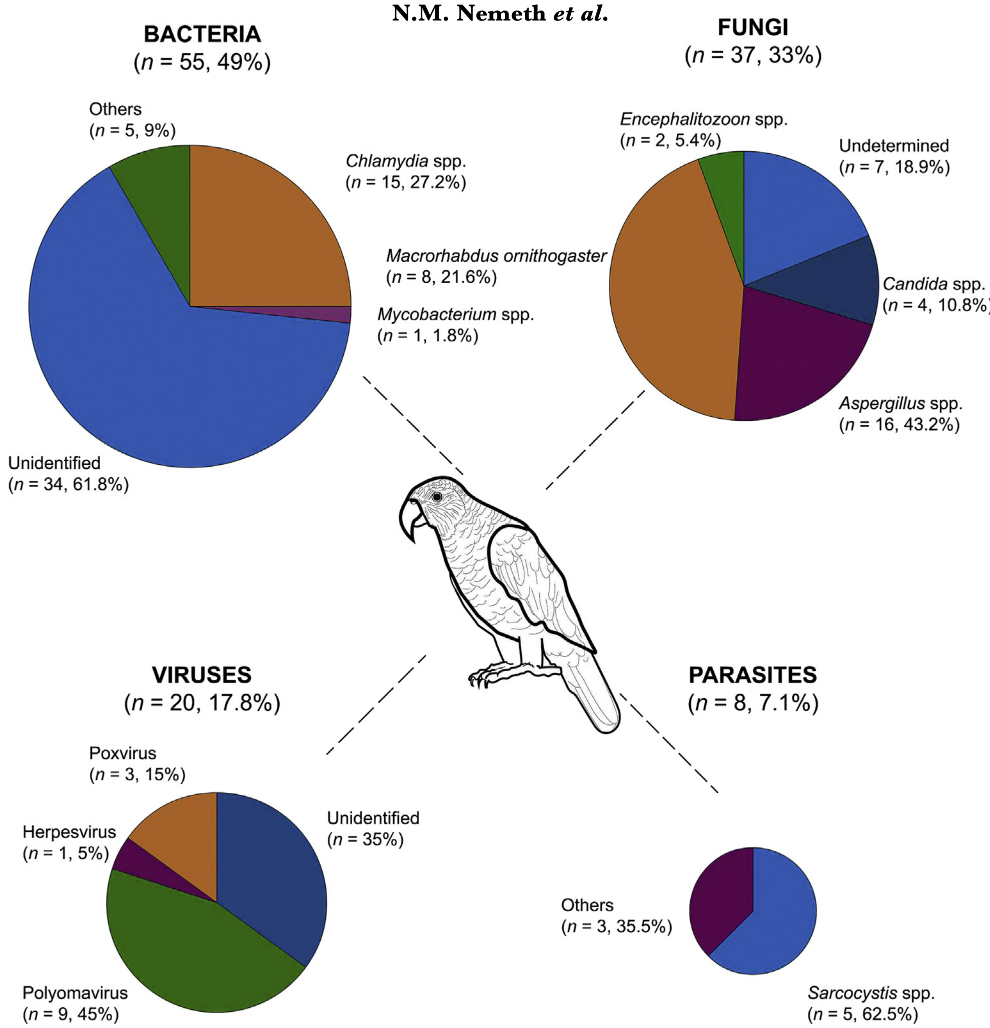

Fig. 1. Frequency of common causes of infectious disease among Psittaciformes ($n = 528$) received at the Department of Pathology and Athens Veterinary Diagnostic Laboratory, University of Georgia from 2006 to 2011. Pie chart sizes are scaled to the proportion of cases for each major category of infectious disease aetiology.

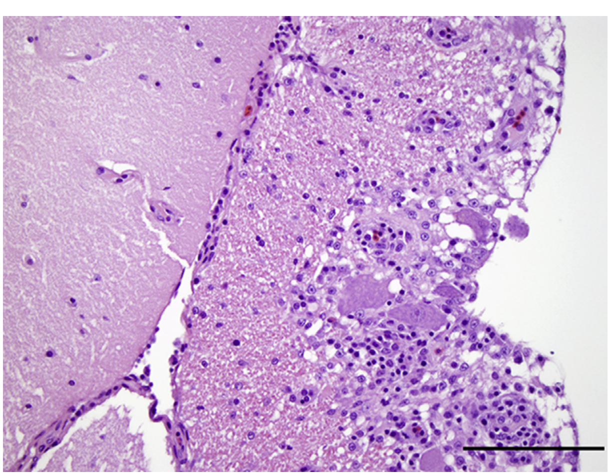

Fig. 2. Microscopical lesions in the cerebellum of a 10-year-old, male blue and gold macaw consisting of dense aggregates of histiocytes, lymphocytes and plasma cells in the meninges associated with *Chlamydia psittaci* infection. HE. Bar, 100 μm.

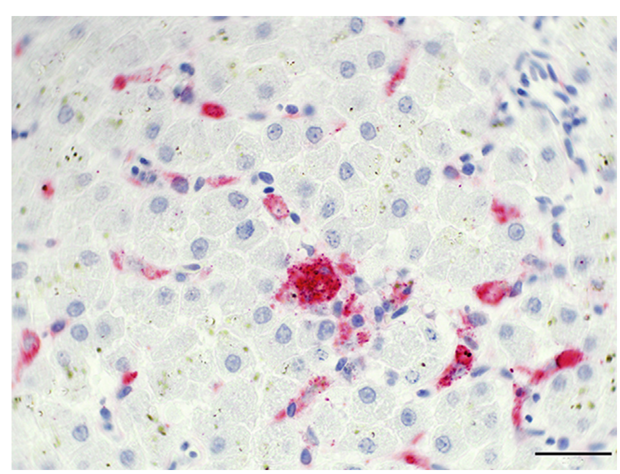

Fig. 3. Immunohistochemical labelling of intrahepatocellular *Chlamydia* spp. in the liver of a 9-year-old umbrella cockatoo. IHC. Bar, 20 μm.

spp. ($n = 2$, 1.7%) and *Nocardia* spp. ($n = 1$, 0.8%). Mycobacteriosis was diagnosed in a variety of species and usually involved multiple tissues; gastrointestinal tract, liver and spleen were most commonly affected, with less common involvement of lung and air sacs. Species diagnosed with mycobacteriosis included an *Amazona* sp. parrot, teal, goose, dove and a peafowl (*Pavo cristatus*) co-infected with *Aspergillus* sp. Nocardiosis was diagnosed in a white-eyed conure (*Psittacara leucophthalmus*) with pneumonia and air sacculitis (Fig. 4) that was co-infected with intestinal *Capillaria* sp.

Viral Infections

Viral infections were diagnosed in 30 birds, most commonly with polyomavirus and avian poxvirus. Polyomavirus manifested as necrotizing hepatitis, splenitis, enteritis and nephritis with intraepithelial intranuclear inclusion bodies, and was diagnosed in psittacines (e.g. budgerigars [*Melopsittacus undulatus*], conures and cockatoos) and one canary (*Serinus canaria*). Cutaneous poxvirus infection was diagnosed in a turkey, pigeon, scarlet macaw and an African penguin. In addition, two co-housed blue-headed parrot (*Pionus menstruus*) nestlings had the diphtheritic form of pox involving the gastrointestinal tract, lungs, air sac, spleen and liver. Less common viral diagnoses included pigeon circovirus in a 6-week-old pigeon, reovirus in an American crow (*Corvus brachyrhynchos*) and herpesvirus in a macaw. The pigeon with circovirus had severe bursal and splenic lymphoid depletion with intrahistiocytic botryoid inclusion bodies. The reovirus-infected crow had lymphoid depletion, enteritis, myocarditis and hepatic haemochromatosis, and the herpesvirus-infected macaw had bone marrow plasmacytosis and erythroid hyperplasia, moderate multifocal hepatic necrosis, severe bursal atrophy with histiocytic and plasmacytic infiltration, moderate multifocal necrotizing steatitis and splenic/hepatic haemosiderosis, with extramedullary haematopoiesis. Marek's disease or lymphoid leucosis was suspected, but not confirmed in four chickens, all but one of which had disseminated lymphoma.

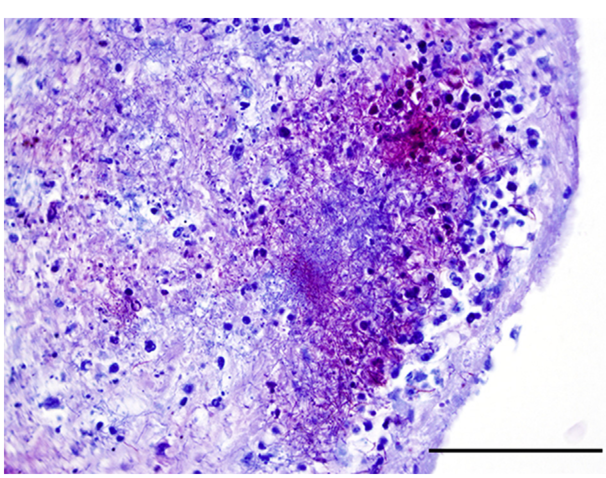

Fig. 4. Microscopical lesions in the anterior thoracic air sac of a 9-year-old, female white-eyed conure consisting of abundant necrotic material and infiltration of histiocytes with positive-staining *Nocardia* spp. Modified acid fast stain. Bar, 20 μm.

Fungal Infections

Fungal infections were identified in 71 birds and were most commonly attributed to *Aspergillus* spp. ($n = 35$), followed by *Macrorhabdus ornithogaster* ($n = 15$) in the proventriculus or the proventricular–ventricular junction, with one bird that was co-infected with *M. ornithogaster* and *Candida* spp. *Candida*-associated lesions were acute catarrhal inflammation and mucosal hyperplasia, sometimes with parakeratosis and mucosal ulceration, and commonly involved the upper gastrointestinal tract, including the oesophagus, crop, ventriculus and, less commonly, the oral cavity and intestine. In addition, two parakeets had enteritis with intraluminal and intra-enterocytic microsporidia most consistent with *Encephalitozoon* spp.; one of these parakeets also had associated proventriculitis and interstitial nephritis.

Protozoan Infections and Macroparasitic Infestations

Protozoan infections, from highest to lowest frequency, included: *Sarcocystis* spp. ($n = 7$), *Atoxoplasma* spp. ($n = 3$) and *Histomonas meleagridis*, *Cryptosporidium* spp. (each $n = 2$; Fig. 5). Macroparasites were relatively rare ($n = 18$) and most often included gastrointestinal *Capillaria* spp. in Galliformes and, less commonly, *Heterakis* spp., *Physaloptera* spp., *Dispharynx* spp. and *Ornithostrongylus* spp.

Co-infections

Co-infections were detected in 31 birds (3.74 %). The most commonly paired pathogens were bacteria with yeast or fungi ($n = 15$, 48.3%). In most cases, bacterial infections were considered as the primary disease process ($n = 15$), while secondary infections ($n = 5$) commonly affected the gastrointestinal tract. Poxviruses were the only viruses involved in co-infections ($n = 3$), which included bacterial and fungal agents in three birds. Two immature turkeys with cutaneous or oesophageal pox had *Aspergillus*-associated pneumonia and bacterial enteritis, respectively, and both

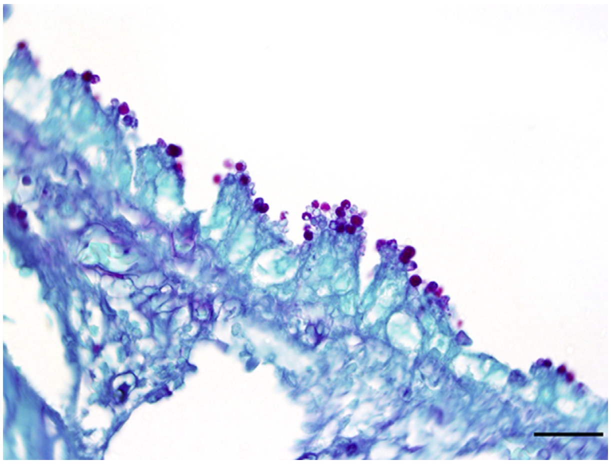

Fig. 5. Microscopical lesions of the trachea of a 7-month-old society finch consisting of epithelial necrosis with intracellular *Cryptosporidium* spp. Periodic acid–Schiff reaction. Bar, 20 μm.

had concurrent intestinal capillariasis. A scarlet macaw with poxviral dermatitis also had bacterial pneumonia and fungal and bacterial stomatitis.

Neoplasia

Neoplasia was diagnosed in 76 birds (9% of total submissions) of 25 species, with 61 (79%) of these deemed to be malignant (Table 2). Birds diagnosed with neoplasia ranged in age at the time of diagnosis from 8 months (chicken, Galliformes) to 37 years (a green-winged macaw; *Ara chloropterus*, Psittaciformes). The most common neoplasm was lymphoma ($n = 17$; 22%), which was usually multicentric ($n = 9$; 53%) and often involved the gastrointestinal tract (i.e. proventriculus, ventriculus, small intestine and/or large intestine; 16/17) and, less commonly, the liver and spleen (3/17 and 2/17, respectively; Fig. 6). Some cases involved the pancreas, kidney and lung and, less commonly, the skin, heart, air sacs, nerves and ovary. In addition, focal lymphoma was diagnosed in the choanal slit, liver, conjunctiva, spleen and trachea; two of these were biopsy samples, so anatomical distribution was not assessed. Lymphoma was most prevalent in Psittaciformes (8/17), followed by Galliformes (5/17) and Passeriformes (3/17). Noteworthy cases included splenic, pancreatic and intestinal lymphoma in a screech owl (*Megascops* sp.). A 10-year-old cockatiel (*Nymphicus hollandicus*) had gastrointestinal lymphoma extending from the proventriculus to the large intestine that also infiltrated the kidney, liver and heart.

Carcinoma was diagnosed in 16 birds and involved a variety of tissues (i.e. kidney, liver, lung, air sac, pituitary gland, thyroid gland and subcutis; Table 2, Fig. 7), including four cases of squamous cell carcinoma in the subcutaneous or mucosal tissue. One of these cases included a 26-year-old blue and gold macaw (*Ara ararauna*) with concurrent dermal squamous cell carcinoma in the patagium and spindle cell carcinoma in the dermis and skeletal muscle associated with the carpus. The majority of neoplasms diagnosed as adenocarcinoma arose in New and Old World psittacines (7/10), aged 3–30 years. Adenocarcinoma was most frequently found within the gastrointestinal and reproductive tracts. Two cases involved the isthmus of the proventriculus–ventriculus and included a 20-year-old African grey parrot and a 4-year-old budgerigar with mucinous adenocarcinoma; a papillary adenocarcinoma appeared to originate from the cloaca in a 3-year-old parakeet. Four tumours observed exclusively within the reproductive tract included ovarian–oviductal adenocarcinoma in a 4-year-old lovebird (*Agapornis* sp.), uterine adenocarcinoma in an Australorp chicken, testicular seminoma in a northern cardinal (*Cardinalis cardinalis*) and a Sertoli cell tumour in a chestnut teal (*Anas castanea*). Three psittacines (Moluccan cockatoo [*Cacatua moluccensis*], sun conure [*Aratinga solstitialis*] and rainbow lorikeet [*Trichoglossus moluccanus*]; aged 18–30 years) had adenocarcinoma of pulmonary or air sac origin (one of which was bronchogenic). In addition, an Egyptian goose (*Alopochen aegyptiaca*) had papillary renal adenocarcinoma that compressed the sciatic nerve roots, resulting in lower limb disuse atrophy. A peregrine falcon (*Falco peregrinus*) had an intracoelomic (perirenal) adenocarcinoma that had metastasized to the epicardium. Two additional birds had renal adenoma, including an American kestrel (*Falco sparverius*). Vascular tumours included three cases of haemangiosarcoma in the subcutis of a Lady Gouldian finch (*Erythrura gouldiae*), African grey parrot (*Psittacus erithacus*) and Amazon parrot (*Amazona* sp.). Cutaneous haemangioma on the distal wing was diagnosed in a conure (unknown species) and a cockatiel.

Rarely diagnosed tumours included basal cell carcinoma in a 22-year-old cockatiel, thyroid follicular carcinoma in a 16-year-old conure, feather follicle epithelioma in a 5-year-old cockatiel and a 23-year-old Nanday conure (*Aratinga nenday*), chondrosarcoma in an adult yellow-headed Amazon parrot (*Amazona oratrix*), pancreatic islet cell tumour and malignant cutaneous melanoma in African grey parrots (Fig. 8), myelolipoma in a lovebird, leiomyosarcoma in the subcutis of a macaw (*Ara* sp.) and giant cell tumour of bone in the medial canthus of a 2-year-old cockatiel (Fig. 9). Haematopoietic neoplasms included myelocytoma in a 10-year-old cockatoo (*Cacatua* sp.) and 8-year-old chicken, and

Table 2
Neoplasia diagnosed in birds submitted to the University of Georgia, Pathology Department and Athens Veterinary Diagnostic Laboratory from 2006 to 2011

Taxa	*Neoplasia category*	*System/tissue*	*Number affected*
Strigiformes	Lymphoma	Digestive/liver and pancreas	1
$n = 9$			
Anseriformes	Sertoli cell tumour	Reproductive/testis	1
$n = 30$	Papillary adenocarcinoma	Urinary/kidney	1
Falconiformes	Tubular adenoma	Urinary/kidney*	1
$n = 17$	Carcinoma, undifferentiated	Undetermined/thorax	1
Galliformes	Lymphoma	Respiratory/choanal slit	1
$n = 64$		Disseminated†	4
	Myelocytomatosis	Circulatory/disseminated	1
	Adenocarcinoma	Reproductive/uterus	1
Passeriformes	Lymphoma	Disseminated	2
$n = 91$		Digestive/liver‡	1
	Seminoma	Reproductive/testis	1
	Haemangiosarcoma	Integumentary/skin	1
Psittaciformes	Lymphoma	Lymphatic/spleen	2
$n = 528$		Integumentary/skin and conjunctiva	1
		Digestive/liver, intestine	1
		Disseminated	3
		Respiratory/trachea, glottis	1
	Myelolipoma	Integumentary/subcutis	1
	Myelocytoma	Blood, liver, spleen	1
	Erythroid leucosis	Circulatory/blood	1
	Squamous papilloma	Digestive/buccal	2
	Papilloma (benign)	Integumentary	1
	Polyp	Integumentary/skin over axilla	1
		Integumentary/skin over uropygial gland	1
	Squamous cell carcinoma	Integumentary/skin§	3
		Integumentary/skin over mandible	1
		Integumentary/subcutis extending to bone	1
		Integumentary/cloacal epithelium	1
		Digestive/buccal mucosa	1
	Epithelioma	Integumentary/feather follicle	2
	Adenoma	Digestive/liver	1
	Pancreatic islet cell tumour	Digestive/pancreas‖	1
	Carcinoma	Urinary/kidney	1
		Immune/thyroid (follicular)	1
		Respiratory/air sac	1
		Respiratory/lung¶	1
		Endocrine/pituitary gland	1
		Digestive/cloaca#	1
		Digestive/liver	1
	Adenocarcinoma	Respiratory/lung	1
		Respiratory/lung (bronchogenic)	1
		Respiratory/air sac	1
		Reproductive/ovary	2
		Digestive/proventricular—ventricular junction	2
	Basal cell carcinoma	Integumentary	1
	Fibroma	Integumentary/subcutis	1
	Lipoma	Integumentary/subcutis**	4
	Giant cell tumour	Bone/lateral canthus	1
	Round cell tumour	Digestive/liver	1
	Low-grade sarcoma	Joint/tarsometatarsal	1
	Spindle cell sarcoma	Skin/subcutis	2
	Leiomyosarcoma	Skin/dermis	1
	Chondrosarcoma	Skeletal/cartilage	1
	Haemangioma/haemangiosarcoma	Skin/subcutis	4
	Melanoma	Skin	1

*This bird had concurrent fungal pneumonia (*Aspergillus* spp.).
†This bird had concurrent fungal pneumonia (*Dactylaria* spp.) and Marek's disease.
‡This bird had concurrent terminal septicaemia.
§One of these birds had concurrent squamous cell carcinoma (in the patagium) and spindle cell sarcoma (in the carpus); another had involvement of the uropygial gland.
‖This bird had concurrent bacterial infection in the proventriculus.
¶Pulmonary carcinoma in this bird metastasized to the synsacrum and cranial vertebral column.
#This bird had obstructive renal disease (ureters) associated with the carcinoma.
**One of these birds had epidermal ulceration and dermal xanthomatosis overlying the tumour (secondary to trauma).

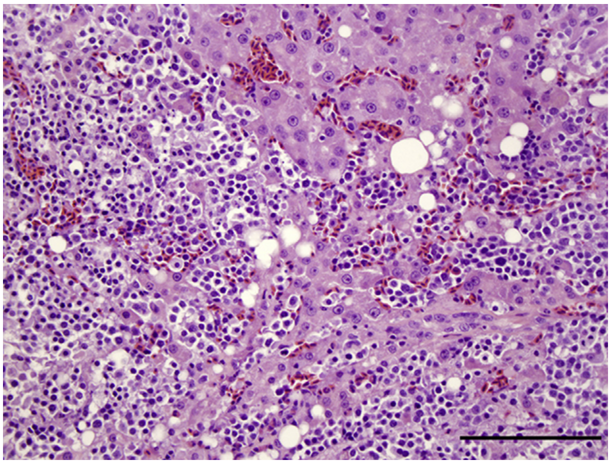

Fig. 6. Microscopical lesions in the liver of 2.5-year-old, male parakeet consisting of dense aggregates of neoplastic lymphocytes replacing hepatic parenchyma. HE. Bar, 100 μm.

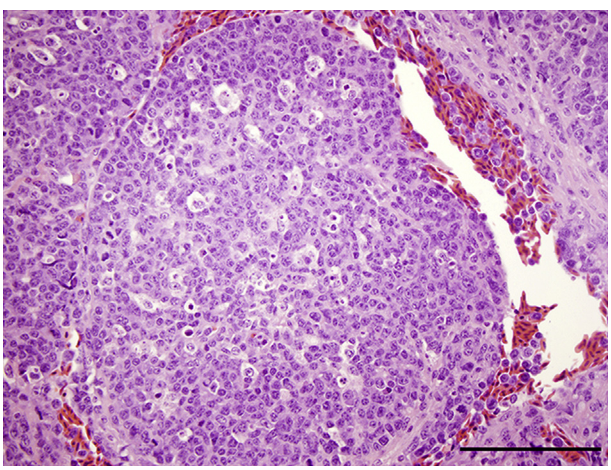

Fig. 7. Microscopical lesions in the air sac of a 17-year-old, female Goffin's cockatoo with disseminated carcinoma most likely originating in the air sacs. HE. Bar, 100 μm.

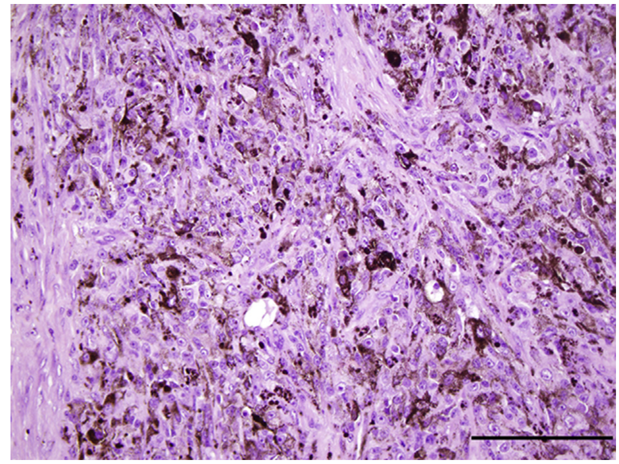

Fig. 8. Microscopical lesions in the subcutaneous tissue of the neck of a 14-year-old, female African grey parrot with melanoma. HE. Bar, 100 μm.

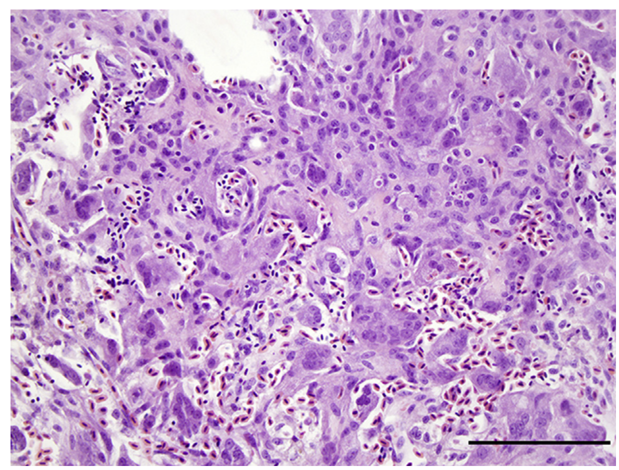

Fig. 9. Microscopical lesions of a mass at the lateral canthus of the eye of a 2-year-old, female cockatiel with giant cell tumour of bone and associated multinucleated giant cells, fibrosis and reactive bone. HE. Bar, 100 μm.

erythroid leucosis in an 8-year-old eclectus parrot (*Eclectus roratus*). Squamous papilloma was diagnosed in the skin and oral cavity of an Amazon parrot and macaw, respectively.

Nutritional and Metabolic Diseases

Nutritional and metabolic diseases included haemosiderosis, hepatic lipidosis, atherosclerosis and gout (Table 3). Haemosiderosis was observed in 38 birds of various species; however, it was most prevalent among Psittaciformes ($n = 23$), followed by Piciformes ($n = 4$) and Anseriformes, Columbiformes, Passeriformes ($n = 2$ each) and Ciconiiformes, Falconiformes, Gruiformes, Pelecaniformes and Sphenisciformes ($n = 1$ each). Haemosiderosis was more commonly diagnosed in adult ($n = 25$) than in juvenile birds ($n = 2$; unknown $n = 11$) with no obvious sex bias (females $n = 13$ versus males $n = 11$, unknown $n = 14$).

Hepatic lipidosis was observed in various species ($n = 64$, 7.7% of all cases), primarily those in the order Psittaciformes ($n = 36$, 6.8% of all cases; including Amazons and other parrots [$n = 13$], cockatiels [$n = 8$], parakeets [$n = 7$] and budgerigars [$n = 3$]), followed by Passeriformes ($n = 7$), Columbiformes ($n = 6$), Ciconiiformes, Falconiformes and Strigiformes ($n = 2$ each) and Anseriformes, Galliformes, Pelecaniformes, Sphenisciformes ($n = 1$ each); taxa were not recorded for four birds with hepatic lipidosis. Hepatic lipidosis was considered the primary or sole disease process in 10 birds, but was more commonly observed concurrently with other conditions, such as

Table 3
Metabolic and/or nutritional disorders and amyloidosis among birds submitted to the University of Georgia, Pathology Department and Athens Veterinary Diagnostic Laboratory from 2006 to 2011

Taxa (total number per order)[*]	*Haemosiderosis*	*Hepatic lipidosis*	*Gout*	*Atherosclerosis*	*Amyloidosis*
	Number (%)[†]	*Number (%)*	*Number (%)*	*Number (%)*	*Number (%)*
Anseriformes ($n = 30$)	2 (6.6)	1 (3.3)	2 (6.7)	3 (10)	3 (10)
Ciconiiformes ($n = 8$)	1 (12.5)	2 (25)	–	1 (12.5)	4 (50)
Coliiformes ($n = 1$)	–	1 (100)	–	–	–
Columbiformes ($n = 31$)	2 (6.5)	6 (19.3)	–	–	–
Falconiformes ($n = 17$)	1 (5.9)	2 (11.8)	1 (5.9)	2 (11.8)	–
Galliformes ($n = 64$)	–	1 (1.6)	1 (1.6)	1 (1.6)	2 (3.1)
Gruiformes ($n = 1$)	1 (100)	–	–	1 (100)	–
Passeriformes ($n = 91$)	2 (2.2)	7 (7.7)	2 (2.2)	–	3 (3.3)
Pelecaniformes ($n = 2$)	1 (50)	1 (50)	–	1 (50)	–
Piciformes ($n = 6$)	4 (66.6)	–	1 (16.6)	–	–
Psittaciformes ($n = 528$)	23 (4.3)	36 (6.8)	13 (2.5)	23 (4.3)	5 (0.9)
Sphenisciformes ($n = 8$)	1 (12.5)	1 (12.5)	–	–	–
Strigiformes ($n = 9$)	–	2 (22.2)	1 (11.1)	–	–
Other ($n = 13$)	–	4 (30.7)	1 (7.7)	–	–
Total	38 (4.6)	64 (7.7)	22 (2.6)	32 (3.9)	17 (2.1)

[*]No nutritional or metabolic disease was documented in *Coraciiformes* ($n = 2$), *Caprimulgiformes* ($n = 1$), *Charadriiformes* ($n = 1$), Cuculiformes ($n = 1$), Rheiformes ($n = 1$) and birds of unidentified taxa ($n = 12$).
[†]Percentages indicate the number of birds affected with the corresponding disorder over the total number of birds examined for the respective taxonomic orders.

atherosclerosis ($n = 7$), neoplasia (e.g. lymphoma and adenocarcinoma; $n = 2$), as well as viral (e.g. reovirus, circovirus and polyomavirus; $n = 5$), bacterial (e.g. bacterial cloacitis, enterotyphlocolitis, pneumonia, septicaemia and mycobacteriosis; $n = 7$) and fungal (e.g. *M. ornithogaster*, *Aspergillus* spp., *Candida* spp. and *Encephalitozoon* spp.; $n = 6$).

Atherosclerosis was most common in psittacines (23/32; 71.8%), with characteristic lesions of expansion of vessel walls by intimal nodular to villous proliferations (sometimes extending into the vessel lumen), as well as medial vacuoles, lipid-laden macrophages, cholesterol clefts and mineral deposits, with occasional adjacent granulation tissue. This was also observed in raptors (i.e. an American kestrel, a peregrine falcon and a Eurasian eagle-owl, *Bubo bubo*) and aquatic birds (i.e. ducks, flamingos, swans and pelicans). The age range of affected birds was wide (1–42 years), with the majority >10 years old (60%; 15/25). Specific blood vessels affected were not consistently described for all cases of atherosclerosis; however, half of the cases involved the aorta and other great vessels of the heart and were in Psittaciformes ($n = 16/32$; 50%). Lesions were most often considered severe ($n = 13$; 48.1%), followed by mild ($n = 9$; 33.3%) and moderate ($n = 5$; 18.5%).

Twenty-two birds had urate deposition (gout), which was characterized as visceral in all but three cases, and most commonly manifested as tubulointerstitial nephritis with intratubular urate tophi. Visceral gout was documented in birds aged 28 days (African grey parrot) to 21 years (yellow-collared macaw, *Ara auricollis*). Most affected birds were Psittaciformes (13/22). Others included a Canada goose (*Branta canadensis*), Cooper's hawk (*Accipiter cooperii*), peafowl (*P. cristatus*), American singer's canary (*Serinus* sp.), finch (unknown species) and toucanet (*Aulacorhynchus* sp.). Intraosseous gout was diagnosed in a 1-month-old Canada goose with premature growth plate closure in the tibiotarsal and metatarsal joints. Conditions concurrent with gout included hepatic haemosiderosis in two psittacines and one toucanet, atherosclerosis in an African grey parrot and bacterial septicaemia in two psittacines.

Amyloidosis

Seventeen birds, including primarily psittacines ($n = 5$) and aquatic birds ($n = 7$), had systemic amyloidosis (Table 3), most often in the liver, kidney and spleen and, less commonly, in the intestine, pancreas (Fig. 10) and heart. In some cases, amyloid was primarily in blood vessel walls and occasionally involved a severe inflammatory response consisting of lymphocytes and plasma cells. Ages of affected birds ranged from 1 year (Aseel chicken, *Gallus* sp. and African pygmy goose, *Nettapus auritus*) to 15 years of age (*Pionus* sp. parrot). An eagle-owl (*Bubo* sp.) had chronic pododermatitis with amyloidosis and fibrosis. Eleven birds with amyloidosis had concurrent

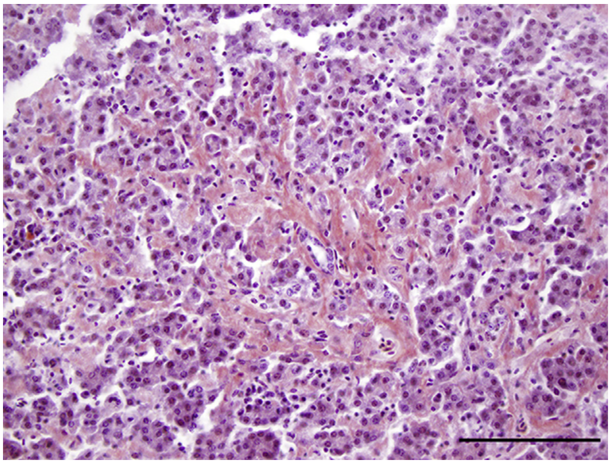

Fig. 10. Amyloid deposits surrounding and replacing acini within the pancreas of a finch. Congo red. Bar, 100 μm.

conditions ranging from infections (e.g. mycobacteriosis, histomoniasis and aspergillosis) to hepatic haemochromatosis or lipidosis and neoplasia (Sertoli cell tumour).

Toxicoses

A total of 34 birds were suspected of having lesions associated with toxicosis in several organs. These included Psittaciformes ($n = 26$), Pelecaniformes, Galliformes and Strigiformes ($n = 2$ each), Anseriformes ($n = 1$) and unknown species ($n = 1$). Lesions included degeneration and necrosis of the liver in nearly half of cases and, less commonly, similar lesions in the kidneys, lungs and air sacs. These cases were not confirmed; however, the extent and nature of the lesions suggested a toxic aetiology, which included, but were not limited to, pulmonary toxins (e.g. overheated polytetrafluoroethylene [Teflon] coated cooking pans or heat lamps, fumes from burnt foods or cooking oils), airborne toxins (e.g. aerosolized household chemicals), carbon monoxide, zinc and mycotoxins (e.g. aflatoxins). A few of these birds had concurrent lesions in the pancreas, central nervous system and crop.

Discussion

Bacterial infection (often septicaemia) was the most commonly diagnosed condition, contributing to or considered as the ultimate cause of death among captive birds of 153 species examined over a 5-year period. The highest percentage of bacterial infections was reported in Psittaciformes, followed by Passeriformes, Galliformes, Columbiformes and Anseriformes; bacterial infections were responsible for the majority of deaths for birds in each of these orders. Bacteria observed in lesions were primarily gram-negative bacilli of unidentified species; however, *C. psittaci*, *Mycobacterium* spp. and others were detected. In some cases, husbandry and other captive bird management approaches may have facilitated bacterial infections and their spread. For example, because passerines have minimal ceca, they have less enteric microflora to aid in microbial digestion (Dorrestein, 2003). Hence, granivorous passerines (e.g. finches and canaries) limited to a seed diet (i.e. without protein and vitamin supplementation) may develop imbalances in intestinal microflora that permit proliferation of Enterobacteriaceae (e.g. *Escherichia coli*, *Klebsiella* spp. and *Enterobacter* spp.) as well as yeast (*Candida albicans*). This imbalance may be exacerbated by stress from changes in husbandry, poor hygiene or failure to meet energy requirements (Dorrestein, 2003). In addition, gram-negative enteric bacteria (e.g. *Escherichia coli*, *Klebsiella* spp., *Enterobacter* spp. and *Pseudomonas* spp.), *Chlamydia psittaci* and *Mycobacterium* spp. infections have led to respiratory infections culminating in septicaemia in *Amazona* spp. and African grey parrots (Levine, 2003).

Mycobacterial infections were rarely diagnosed in the present study and affected single birds in a variety of taxa, several of which had concurrent gout or amyloidosis. The present findings agree with a previous study in that the primary lesions of mycobacteriosis in birds are often in the liver and lungs, followed by disseminated infections (Witte *et al.*, 2008). The eye, retrobulbar tissue, nasal sinuses and the oral cavity can also be affected, as is seen in Amazon parrots (Montali *et al.*, 2001).

Mycoplasma and *Nocardia* spp. infections were also recognized in the present study. *Mycoplasma* infections were limited to Galliformes (e.g. chickens and a pheasant) and an Anseriform (duck) with synovitis, sinusitis, tracheitis and pneumonia, which are also common in poultry infected with particular *Mycoplasma* species (Yilmaz and Timurkaan, 2011). Consistent with nocardiosis diagnosed in a white-eyed conure in the present study, the lung is usually the primary site of *Nocardia* spp. infection in birds (Schmidt *et al.*, 2015).

Co-housed captive birds, including those in artificially created wild bird habitats and breeding aviaries, have increased opportunities for pathogen transmission. Suboptimal housing or habitat can predispose birds to infections due to stress-induced immunosuppression, which can also result from other husbandry (e.g. improper temperatures and lighting, inadequate diet and overcrowding) and anthropogenic causes (e.g. antibiotics, steroids, vaccines and toxins), as well as reproduction and underlying disease (Dorrestein, 2009; Beernaert *et al.*, 2010). For example, environments with high concentrations of *Aspergillus* spp. spores, which are more likely to thrive in warm, humid areas with poor ventilation and sanitation, can facilitate pulmonary and systemic infections with this fungus (Beernaert *et al.*, 2010). Megabacteriosis (*Macrorhabdus ornithogaster*) has often been associated with maldigestion or malabsorption leading to chronic wasting; however, it has also been detected in the absence of clinical signs or pathological changes (Schmidt *et al.*, 2015). In the present study, heavy loads of *M. ornithogaster* were observed in the proventriculus and/or ventriculus in numerous budgerigars and a few finches; however, these birds were often not noted to have poor nutritional condition. One finch with megabacteriosis was co-infected with *Candida* spp. and another had concurrent bacterial septicaemia. *Candida* spp. was most commonly diagnosed in Passeriformes and Psittaciformes, and over half of the birds with *Candida* spp. infection had co-infections, primarily with other fungi and bacteria.

The majority of viral infections detected in the present study were attributed to polyomavirus and poxvirus. Polyomavirus was documented mostly in psittacines (e.g. budgerigars, conures and cockatoos), while poxvirus (usually cutaneous) was found in a greater variety of species (e.g. turkey, pigeon, macaw and penguin). Two co-housed blue-headed parrot nestlings had diphtheritic pox with dissemination to respiratory and visceral tissues. Poxvirus has been previously documented in blue-headed parrots and other psittacine and non-psittacine species. Species within the families Phasianidae and Emberizidae are considered especially susceptible; infection is often mild, with higher mortality rates associated with the diphtheritic form (van Riper and Forrester, 2007). Rarely diagnosed viruses in the present study included circovirus in a pigeon, a reovirus in a crow and a herpesvirus in a macaw. As with the present study, circoviral infections in pigeons usually affect individuals of <1 year of age and can be associated with severe muscle wasting, bursal and splenic lymphoid depletion, and secondary bacterial and *Trichomonas* spp. infections, which are often the cause of mortality (Raue *et al.*, 2005; Marlier and Vindevogel, 2006). The present study is consistent with past studies of corvid reoviral infections in that the liver, spleen, intestine and heart are commonly affected (Affolter *et al.*, 2007; Lawson *et al.*, 2015), which primarily manifest as hepatic and splenic necrosis, haemorrhagic or necrotizing enteritis, and extensive cardiac necrosis with mild inflammation (Affolter *et al.*, 2007).

Co-infections were detected in 28 birds, primarily Galliformes (mostly turkeys), Passeriformes (mostly finches) and Psittaciformes (e.g. Amazons and other parrots). The distribution of commonly involved infectious agents was inconsistent, and included *Candida* spp., *Aspergillus* spp., *Capillaria* spp. and avian poxvirus. Macroparasite infections were rarely documented in the present study; however, in some cases, they were associated with lesions resulting from parasite migration (e.g. granulomas) or concurrent septicaemia or other infections. As with the present study, helminth infections are considered rare in captive small passerine species, while coccidial infections are common (Dorrestein, 2003).

Neoplasms in the present study were diagnosed in a variety of species, the majority of which were Psittaciformes, followed by Galliformes (mostly chickens) and, less commonly, Strigiformes, Falconiformes, Passeriformes and Anseriformes. This distribution of taxa likely reflects longevity as a factor in the incidence of neoplasia in captive birds. Lymphoma was the most commonly diagnosed neoplasm, similar to a retrospective study of non-poultry birds in Victoria, Australia (Reece, 1992). Lymphoid neoplasia (specifically lymphoma) is considered the most common haemolymphatic neoplasm in birds, and has been reported in many species, including Galliformes (e.g. chickens, turkeys, quail and pheasants), Anseriformes (e.g. ducks and geese), Columbiformes (pigeons), Psittaciformes and Passeriformes. Among companion birds, lymphoid neoplasms are especially common in canaries and have also been documented in budgerigars and other Old and New World psittacines (Coleman, 1995). The most common anatomical distribution of lymphoma in birds is the liver, followed by spleen and kidney, although neoplastic lymphoid cells can infiltrate distant sites, including skin, bone, brain, reproductive and gastrointestinal tracts, skeletal muscle and lungs (Leach, 1992; Coleman, 1995). Multicentric, cutaneous and alimentary lymphoma has been reported in psittacines and raptors, including a screech owl (*Megascops* sp.), great-horned owl (*Bubo virginianus*) and snowy owl (*Nyctea scandica*) (Halliwell, 1971; Hruban *et al.*, 1992; Bienzle, 2011). In the present study, lymphoma almost always involved the gastrointestinal tract and was usually multicentric. The liver and spleen were also commonly affected, and in some cases, neoplastic lymphocytes extended to the pancreas, kidney and lung and, less commonly, to skin, heart, air sacs, nerves and ovary. Focal lymphoma was diagnosed in the choanal slit, liver, conjunctiva, spleen and trachea. Additional haematopoietic neoplasms diagnosed in the present study included myelocytoma in a cockatoo and chicken and erythroid leucosis in an eclectus parrot.

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Malignant alimentary tract neoplasia, such as adenocarcinoma, is generally considered uncommon in psittacines and other companion birds. However, in some species, adenocarcinoma may have a predilection for the gastrointestinal tract. For example, grey-cheeked parakeets (*Brotogeris pyrrhopterus*) may be predisposed to adenocarcinoma at the isthmus of the proventriculus and ventriculus (Rae *et al*., 1992), which has also been reported in a great-horned owl and Humboldt penguin (*Spheniscus humboldti*) (Yonemaru *et al*., 2004). Approximately 11% of the neoplasms in the present study were diagnosed as adenocarcinoma and occurred most often in psittacines. Anatomical locations varied, and most involved the respiratory and reproductive tracts with occasional involvement of other organs, such as kidney. The present study included mucinous adenocarcinoma at the proventricular–ventricular junction in a parakeet; previous reports of this neoplasm involved the pancreas of a mandarin duck, lung and thoracic air sacs of domestic ducks (Yamamoto *et al*., 2004) and proventriculus of a barred owl (*Strix varia*) with metastases to the colon and visceral serosae (Kummrow *et al*., 2007).

Similar to gastrointestinal tumours, renal and hepatic tumours are rarely reported in psittacines and other birds (Vantoor *et al*., 1984; Abdul-Aziz *et al*., 2008). Renal tumours of varying morphologies have been described in budgerigars, from papilliferous adenoma to malignant carcinoma, together with nephroblastoma, mostly in young males (Vantoor *et al*., 1984). Renal tumours in the present study were diagnosed in wildlife species and included papillary renal adenocarcinoma in a Canada goose and renal tubular adenoma in an American kestrel. In addition, an undifferentiated perirenal adenocarcinoma with cardiac metastasis was diagnosed in a peregrine falcon. Renal adenocarcinoma has been diagnosed previously in two budgerigars and a cockatiel, one of which had metastasis to the liver and another had invasion of the ischiatic nerve, leading to hindlimb lameness (Bullmore, 1981; Freeman *et al*., 1999). Primary liver tumours were diagnosed rarely in the present study, although other neoplasms (i.e. lymphoma, myelocytoma and erythroid leucosis) involved the liver as part of a multisystemic presentation in numerous birds. Pituitary tumours are most often recognized in budgerigars (Langohr *et al*., 2012), consistent with a pituitary carcinoma in a budgerigar in the present study. Testicular tumours are generally uncommon in birds (Leach, 1992; Abdul-Aziz and Fletcher, 2008; Schmidt *et al*., 2015), but are more frequently diagnosed in budgerigars and cockatiels (Reavill, 2004). Seminoma was diagnosed in a northern cardinal and Sertoli cell tumour in a chestnut teal in the present study.

The integumentary system is considered one of the most common sites of neoplasia among companion psittacines (Filippich, 2004). Cutaneous forms of haemangiosarcoma are well documented in budgerigars, with an average age of 11 years (range, 3–20 years), and have also been reported in chickens, swans, Amazon parrots and other psittacines, canaries and finches (Reavill, 2004; Reavill and Dorrestein, 2010). These observations are in line with the present study, in which haemangiosarcoma was found in the skin (i.e. epidermis and dermis) of an African grey and Amazon parrot (over the wing) and a Lady Gouldian finch (unidentified anatomical location). These tumours can arise in the beak, neck, wings, inguinal region, feet, legs, cloaca and spleen (Reavill, 2004; Reavill and Dorrestein, 2010). Squamous cell carcinoma has been reported in the integument, uropygial gland, patagium, choana and crop, beak, oropharynx and oesophagus in variety of avian taxa, from flamingos and penguins to parakeets and poultry (Ferrell *et al*., 2006; Klaphake *et al*., 2006; Youl and Gartrell, 2006; Beaufrère *et al*., 2007; Suedmeyer *et al*., 2007; Abu *et al*., 2009; Pesaro *et al*., 2009; Nakamura *et al*., 2010). Squamous cell carcinoma was most common in the skin and subcutis, and less often found in the oral mucosa of psittacines in the present study; anatomical locations included the patagium, mandible and carpus. Consistent with the present cases, squamous cell carcinoma rarely metastasizes, but can be locally invasive (Latimer, 1994; Ramis *et al*., 1999).

Additional cutaneous tumours were relatively uncommon in the present study and included basal cell carcinoma and feather follicle epithelioma. Basal cell tumours are reported rarely in birds, but have been documented in canaries bred for specific feather patterns, as well as in the skin of the third eyelid and in the cervical region of a conure and Amazon parrot (Reavill, 2004). Feather follicle epithelioma is reported most commonly in canaries and budgerigars, and in the former are also believed to be associated with breeding for specific plumage characteristics (Reece, 1992; Frasca *et al*., 1999). In the present study, feather follicle epithelioma was diagnosed in a cockatiel and Nanday conure. Squamous papilloma of the skin or oral mucosa was diagnosed in two psittacines in the present study. These benign tumours are most commonly seen in the cloacal mucosa of New World parrots, but can also arise from the mucosa of the oral cavity, conjunctiva, nasolacrimal duct, oesophagus, crop, proventriculus and ventriculus (Rosskopf, 2003; Schmidt *et al*.,

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2015). Cutaneous myelolipoma is considered an uncommon choristoma, and as in the present as well as in past studies, is often seen on the wings of adult female cockatiels and as multiple subcutaneous masses in lovebirds (Reavill and Dorrestein, 2010).

Hepatic accumulations including haemosiderin and lipid were frequently observed among captive birds in the present study, and may be associated with husbandry (e.g. sedentary lifestyle and diet) and genetic factors. For example, some avian taxa may be genetically predisposed to iron storage disease when living in captivity, such as the families Paradiseadae (birds of paradise), Ramphastidae (toucans) and Sturnidae (starlings) (Klasing *et al.*, 2012). Intestinal iron absorption rates may be evolutionarily adapted to low dietary iron levels in these species. Excess dietary iron may be deposited in tissues (e.g. liver, heart and spleen) as haemosiderin, leading to lysosomal damage and oxidative cell membrane injury (Sheppard and Dierenfeld, 2002). This damage is often subclinical, but can result in overt disease; for example, increased dietary iron in chickens led to depression, lethargy, liver degeneration and ventricular ulceration (Pescatore and Harter-Dennis, 1989). Hepatic lipidosis was relatively rare and not considered a significant contributor to death in the present study; however, it can be fatal in domestic turkeys (Gazdzinski *et al.*, 1994). Although difficult to discern as a primary or secondary change, hepatic lipidosis in most birds in the present study was likely associated with diet (e.g. high fat or biotin, choline or methionine deficiencies), which is a common cause in captive psittacines and chickens. Additional potential causes of hepatic lipidosis include metabolic disease (e.g. diabetes mellitus) and toxicosis (e.g. aflatoxicosis) (Gazdzinski *et al.*, 1994; Schmidt *et al.*, 2015).

Atherosclerosis is observed commonly in the great vessels of the aged psittacine heart, and is most often diagnosed in cockatiels, Amazon parrots, African grey parrots and macaws, and sporadically in other species (Reavill and Dorrestein, 2010). Risk factors for atherosclerosis include age (≥8 years), sex (females), inactivity, high-fat diet and concurrent conditions such as reproductive disease, hepatic disease or myocardial fibrosis (Reavill and Dorrestein, 2010; Beaufrère *et al.*, 2013). Similarly, the development of gout, which can be suggestive of renal failure, may also be associated with management factors such as exposure to cold, moisture, excessive dietary protein, dehydration and vitamin A or B_{12} deficiency, as well as viral infections (e.g. influenza A viruses, infectious bronchitis virus and avian nephritis virus) (Lierz, 2003; Ivanics *et al.*, 2007; Bulbule *et al.*, 2013). In the present study, gout was diagnosed uncommonly, and most often affected the kidneys of psittacines.

Reactive, systemic amyloid A (AA) amyloidosis in birds is often related to chronic infections and inflammation (e.g. antigenic stimulation), including mycobacteriosis, toxoplasmosis, aspergillosis, abscesses, pulmonary granulomas, osteomyelitis and bacterial or coccidial enteritis (Cowan, 1968; Landman *et al.*, 1998; Murakami *et al.*, 2014). Some of these infections may be more common among captive birds due to husbandry-related factors (Beernaert *et al.*, 2010). Amyloidosis has a predilection for some avian taxa in which it can be fatal, most notably waterfowl in the order Anseriformes (e.g. ducks, geese and swans), as well as in Gruiformes (e.g. cranes, rails and coots) and Phoenicopteriformes (i.e. flamingos). Further, disease is often observed in species that undergo elevated stress levels due to poor adaptation to captivity or specialized husbandry needs (e.g. zoos, farms) (Landman *et al.*, 1998). Birds that are less restricted to aquatic environments, such as Columbiformes, Psittaciformes and Passeriformes may be affected less commonly (Cowan, 1968; Schmidt *et al.*, 2015). However, half of the birds diagnosed with amyloidosis in the present study were non-aquatic species, including passerines (i.e. finches and a starling), psittacines (i.e. cockatiel, conure, macaw and lory) and an owl. However, this may, in part, reflect the relatively higher numbers of these avian taxa included in the present study (versus waterfowl). Additional predisposing factors may include genetics, age, surgery, neoplasia, toxicosis, stress due to crowding, aggressive inter- or intraspecific interactions and changes in diet or environment (Nouri *et al.*, 2011). Diseases concurrent with amyloidosis in the present study included Sertoli cell tumour in a chestnut teal, hepatic lipidosis or haemochromatosis in several psittacines and flamingos, and lymphoid neoplasia in an owl. In a previous report, a zebra finch (*Taeniopygia guttata*) had concurrent systemic amyloidosis, testicular interstitial cell tumour and enteric salmonellosis, and it was suggested that secondary *Salmonella* spp. infection accelerated the severity of amyloidosis (Nouri *et al.*, 2011). The liver was the most common site of amyloid deposition in the present study, with variable involvement of kidney, spleen and pancreas. These findings are consistent with past observations of amyloidosis in waterfowl and psittacines; the intestine was also affected commonly in the former, and spleen and kidney in the latter (Tanaka *et al.*, 2008; Schmidt *et al.*, 2015).

Analyses of retrospective diagnostic data may provide insights into general disease patterns across a wide variety of taxa and over time, as well as reveal risk factors or associations that could aid in ante- and post-mortem diagnoses, treatment and disease prevention. Furthermore, rare disease processes and anomalies may be revealed. However, these studies have inherent limitations, which may include, as in the present study, lack of complete and consistent systemic data collection due to limited tissue (e.g. biopsy sampling), incomplete submission information (e.g. taxonomic classification) and inconsistent diagnostic testing, potentially leading to underdiagnosis of some diseases (e.g. toxicosis or neoplasia). Therefore, final or concurrent diagnoses and full extent of disease (e.g. metastasis or systemic infections) may not be accurate in all cases. In the present study, biases among taxonomic groups or submitted case material may be associated with the data source (i.e. a veterinary diagnostic laboratory associated with a veterinary teaching institution).

The present study and past studies demonstrate that aspects of a captive lifestyle among birds, especially those with complex husbandry needs due to evolutionary adaptations to life in the wild, serve as important risk factors for a variety of diseases or conditions (Landman *et al*., 1998; Beernaert *et al*., 2010). Further, a predilection for certain diseases may be related to genetic inheritance or environmental conditions. As such, among captive birds, bacterial infections, amyloidosis and haemosiderosis may represent diseases or conditions that can be prevented or managed by an improved understanding of species-specific needs, including appropriate alterations in husbandry and overall aviary management with an enduring goal of minimizing stress levels (Nouri *et al*., 2011).

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Conflict of Interest Statement

None of the authors have any financial or personal relationships that could bias the content of this paper.

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