



REVIEW

Avian host spectrum of avipoxviruses

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A review is given of the occurrence of poxviruses in different bird species. The first publications appeared in Europe around 1850. At that time, pox as a definite disease entity was diagnosed on the basis of clinical signs, while later the detection of Bollinger's inclusion bodies (1877) allowed an aetiological diagnosis by microscopically visible viral aggregates. Virus isolation in embryonated chicken eggs and direct electron microscopy gained importance as diagnostic tools in the 1950s. Also briefly described are avipoxvirus taxonomy, virus characteristics, clinical signs, modes of prevention and diagnostic procedures.

Of the approximately 9000 bird species, about 232 species in 23 orders have been reported to have acquired a natural poxvirus infection. However, it is likely that many more birds are susceptible to avipoxviruses.

Introduction

Members of the family *Poxviridae* infect and cause disease in many vertebrates and in some arthropods. For centuries, poxviruses stimulated scientific interest for many reasons. Clinicians studied the origin and types of cutaneous lesions. Pathologists followed the distribution of this agent in infected tissues and cells. Ancient physicians in early history treated pox by scarification. Jenner (1798) prevented pox in man by artificial inoculation of volunteers with material from cowpox and initiated the modern era of vaccination.

More recently, poxviruses have been applied to stimulate non-specific resistance. Epidemiologists followed the modes of spread of poxvirus between various vertebrate hosts. Entomologists studied the transmission by various mosquitos. 'Vaccinologists' used and still use modified live poxviruses as vaccines to protect against disease. More recently, molecular virologists employ poxvirus as potent vectors for viral antigens to stimulate immunity (Silva, 1996).

These and other facts provide a reason to review at least one feature of poxviruses, namely the host spectrum of the genus *Avipoxvirus* in birds. This review is focused on natural infections of various bird species with virulent field viruses. At the present time, only anecdotal or circumstantial information exists on the spectrum of avian hosts

which can be infected and/or immunized with modified live (vaccinal) avipoxviruses. Therefore, no reliable information can be provided on those few bird species which can successfully be vaccinated with available live attenuated vaccines. This review also includes some aspects of taxonomy, means of diagnosis, and history of pox in birds.

Definition

All poxviruses are very large, oval or brick-shaped enveloped viruses. Their nucleic acid consists of dsDNA (> 250 kbp) in linear configuration. They have a low G + C content (30 to 40%). The infectivity is usually ether resistant but sensitive to chloroform treatment. They multiply easily in cell cultures and on the chorioallantoic membrane of embryonated eggs and form type A cytoplasmic inclusions in cells of these culture systems (Murphy *et al.*, 1995).

Taxonomy

The family *Poxviridae* consists of two subfamilies, namely *Chordopoxvirinae*, which includes eight genera, and *Entomopoxvirinae*, with three genera. The genus *Avipoxvirus* within the subfamily *Chordopoxvirinae* contains at present 10 species with two additional tentative species (Murphy *et al.*, 1995). There is no exact knowledge on the number

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of species, strains or variants which actually exist within the genus *Avipoxvirus*. Since at least some viruses cause extensive serologic cross-reactions and also cross-protection *in vivo*, and since the genomic sequences of only a few isolates are currently known, a definite assignment of new isolates to well defined poxvirus species waits for future clarification.

Diseases in birds associated with avipoxviruses

Various disease manifestations occur in domestic, pet and free-living birds of many species. The clinical signs in naturally infected birds vary depending on the virulence of the virus, susceptibility of the host, distribution and type of lesions in an infected bird, and other complicating factors (Tripathy & Reed, 1997). The disease may occur in cutaneous or diphtheric/pharyngeal forms, or both. In addition, in some bird species, tumorous changes may develop. A peracute form, associated with sudden death, is rarely seen. Latently infected carriers exist.

Cutaneous pox lesions are characterized by the appearance of nodular lesions on feather-free regions of the body, namely comb, around the beak, wattles, eyelids or even legs and wings. No scar formation is visible after recovery and healing of skin lesions; fibrotic areas only are often a feature on histology (e.g. in eyelids of parrots). Mortality rates are usually low if the cutaneous form prevails. Some poxviruses produce a protein similar to an epidermal growth factor (Moss, 1996).

The diphtheric form affects predominantly the upper respiratory and digestive tract in many bird species. A variable number of affected birds may display simultaneously both the cutaneous and diphtheric forms. The mortality rates of the diphtheric and mixed forms of the disease are higher than in the cutaneous form. However, the mortality also depends on the action of predisposing factors already mentioned. In chickens and turkeys, the mortality is mostly, but not always, low. In canaries and other finches, the losses can reach 80 to 100% of the flocks (Tripathy & Reed, 1997).

Historical aspects of pox

Chinese, arabic, roman and medieval authors described, some in great detail, pox in man and various vertebrates (Meurer, 1991). Even before an exact aetiological diagnosis was established, artificial inoculation of man with pox material from cattle was tried in an attempt to prevent pox. We still use the term 'vaccination', which is derived from the Latin word *vacca* for cattle, the source of pox material to scarify the skin of humans.

The second half of the nineteenth century brought three major discoveries which promoted both diagnostic methods and early steps in virology. The three break-throughs were the significant improvements of the microscope, the technique to produce extremely thin sections and the synthesis of selective stains for these thin sections. Almost at the same time, the concept of infectious transmissible organisms which may cause disease and the idea that all macroorganisms are composed of cells gained credence in the scientific world.

Using these, at that time, new and revolutionary ideas, Bollinger (1873) published his microscopical findings in poxvirus-infected cells in chickens. He detected large, cytoplasmic, eosinophilic inclusions which are now known as Bollinger's inclusion bodies. This pioneering work made it possible to trace poxvirus infections in the early scientific literature long before virus isolations and visualization were possible.

The first attempts to grow some of these small organisms in embryonated chicken eggs were made by Centanni in Italy around the turn of the century (Centanni, 1902). However, at the end of World War II, antibiotics became available for use in virus research. Since then, the use of antibiotics and antimycotics to prevent bacterial and fungal growth has enabled numerous viruses to be isolated.

In the early post-war era, microbiology and pathology had access to the electron microscope and visualization of microorganisms, including viruses, fostered the understanding of the pathogenesis of many infectious diseases including pox.

Treatment and Prevention

As in most viral infections, there is at present no effective treatment of the cause of avian pox. In pet birds, iodine—glycerine application on proliferative skin lesions may be tried but the effects of these palliative measures remain doubtful (van Heelsbergen, 1929).

Live modified virus vaccines have been developed to prevent disease manifestations in chickens, turkeys, homing and meat-type pigeons, canaries and quails. These vaccines are considered to be genetically stable and protect immunocompetent birds for about 1 year. There is a high demand for vaccines in other bird species, such as various expensive or rare falcons, eagles, ostriches and many passeriform birds. Since the host spectrum of many poxvirus isolates remains obscure, available vaccines are often applied on the basis of trial and error experimentation. Cross-protection has been observed in some but not all bird species (Gerlach, 1994). For example, chickens can be protected with pigeon poxvirus. Further investigations are needed to clarify the relationships between these different avipoxvirus species.

Table 1. Host spectrum of the genus Avipoxvirus in birds

Order/Suborder Family/Subfamily	Latin	German	English	Location	Mode of infection	Clinical signs/ lesions/proof	Source
Struthioniformes/Rheae /Rheidae	<i>Rhea americana</i>	Nandu	Greater Rhea	Spain	N	M/—	Vogelsang, 1938
Struthionies/ Struthionidae	<i>Struthio camelus</i>	Strauß	Ostrich	Israel South Africa	N N	M/CAM, TR M/IB, EM	Perelman <i>et al.</i> , 1988 Allwright <i>et al.</i> , 1994
Otidiformes/Otididae	<i>Otis tarda</i>	Großtrappe	Great Bustard	Australia Rumania	N N	L (H,E)/IB, CAM L (B,F)/IB	Raidal <i>et al.</i> , 1996 Cociu <i>et al.</i> , 1972
	<i>Chlamydotis undulata marqueeni</i>	Kragentrappe	Bustard	Germany United Arab Emirates	N N N	M/— M/IB, EM, CAM	Seidel, 1972 Samour <i>et al.</i> , 1996
Gruiformes/Gruidae/Gruinae	<i>Grus grus</i>	Kranich	Crane	Germany	N	—/—	Weiss, 1970
	<i>Grus japonensis</i>	Mandschuren-kranich	Manchurian Crane	China	N	—/A	Zhang <i>et al.</i> , 1996
	<i>Grus canadensis</i>	Canadakranich	Sandhill Crane	China	N	—/A	Zhang <i>et al.</i> , 1996
	<i>Anthropoides virgo</i>	Jungfernkranich	Demoiselle Crane	Florida/USA	N	L (H,F)/IB, EM	Simpson <i>et al.</i> , 1975
Ralliformes/Rallidae/Rallinae	<i>Fulica ana</i>	Blässhuhn	Coot	China India	N N	—/A —/A	Zhang <i>et al.</i> , 1996 Mathur <i>et al.</i> , 1972
Podicipediformes/Podicipedidae	<i>Podiceps cristatus</i>	Haubentaucher	Great Crested Grebe	Switzerland	N	L (E)/—	Bouvier, 1946
Charadriiformes/Scolopaces Scolopacidae/Erolinae	<i>Pelidna alpina</i>	Alpenstrandläufer	Dunlin	Great Britain	N	L (F)/IB	Green, 1969
Scolopacidae/Numeninae	<i>Numenius arquata</i>	Großer Brachvogel	Curlew	Germany	N	L (B)/—	Von Schauberg, 1901
Charadrii/Haematopodidae	<i>Haematopus ostralegus</i>	Austernfischer	Oystercatcher	Great Britain	N	L (B)/—	Green, 1969
Charadrii/Vanellidae	<i>Vanellus vanellus</i>	Kiebitz	Lapwing or Green Plover	Denmark	N	+ /—	Christiansen, 1949
Charadrii/Charadriidae	<i>Pluvialis apricaria</i>	Goldregenpfeifer	Golden Plover	Denmark	N	L (F)/—	Christiansen, 1949
Lariformes/Lari/Laridae	<i>Larus canus</i>	Sturmmöwe	Common Gull	Denmark	N	+ /—	Christiansen, 1949
	<i>Larus argentatus</i>	Silbermöwe	Herring Gull	Great Britain	N	—/—	Miles & Stocker, 1948
Sternidae/Sternae	<i>Thalasseus maximus</i>	Königs-seeschwalbe	Royal Tern	Florida, USA	N	L (F)/IB, EM	Jacobson, 1980
	<i>Sterna fuscata</i>	Russeeschwalbe	Sooty Tern	Australia	N	—/—	Annar <i>et al.</i> , 1983
Sternidae/Anoinae	<i>Anous stolidus</i>	Noddi	Brown Noddy	Australia	N	—/—	Annar <i>et al.</i> , 1983
	<i>Anous tenuirostris</i>	Schlankschnabel-noddi	Lesser Noddy	Australia	N	—/—	Annar <i>et al.</i> , 1983
Alciformes/Alcidae	<i>Uria aalge</i>	Trottelumme	Guillemot	California, USA	N	M/IB	Harris <i>et al.</i> , 1978
	<i>Spheniscus humboldti</i>	Humboldtpinguin	Humboldt Penguin	California, USA	N	M/IB	Hill & Bogue, 1978
Sphenisciformes/Spheniscidae	<i>Spheniscus demersus</i>	Brillenpinguin	Jackass Penguin	Poland	N	L (B,E)/CAM	Lardowska-Plizewska & Plizewski, 1968
Procellariiformes/ Procellariidae	<i>Puffinus puffinus</i>	Schwarzschnabel- sturmtaucher	Manx Shearwater	Cape Town, South Africa Great Britain	N N	—/CAM L (F)/IB	Stannard <i>et al.</i> , 1998 Miles <i>et al.</i> , 1948

Mode of infection: N, natural; E, experimental. Lesions: —, no data available; +, unspecified clinical signs; L, local form (Head, Beak, Feet, Eye, Wings); D, diphtheritic mucosal form; M, mixed form; T, tumour form; P, peracute form. Proof: —, no data available; IB, inclusion bodies; EM, electron microscopy; CAM, chorioallantoic membrane; TR, transmission experiments; A, antibodies.

Table 1.—Continued

Order/Suborder Family/Subfamily	Latin	German	English	Location	Mode of infection	Clinical signs/ lesions/proof	Source
Diomedidae	<i>Diomedea immutabilis</i>	Laysan Albatros	Laysan Albatross	Great Britain Midway Atoll, Pacific Ocean	N	L (F)/CAM, EM	Nuttall <i>et al.</i> , 1985 Sileo <i>et al.</i> , 1990
Pelecaniformes /Phaethontes/ Phaethontidae	<i>Phaeton lepturus</i>	Weisschwanz-Tropikvogel	White-tailed Tropic-bird	Bermuda, USA	N	T, L (H, B, E, F), D/IB, EM	Wingate <i>et al.</i> , 1980
Pelecani/Phalacrocoracidae	<i>Phaeton rubricauda</i>	Rotschwanz-Tropikvogel	Red-tailed Tropic-bird	Hawaii, USA	N	L (B, E, W, F)/IB	Locke <i>et al.</i> , 1965
	<i>Phalacrocorax bougainvillii</i>	Guañaoscharbe	Guanay-Cormorant	Peru	N	—/—	Avila, 1966
Columbiformes /Columbidae	<i>Columba sp.</i>	Taube	Pigeon	Germany	N	+/—	Gurlt, 1849
	<i>Streptopelia decaocto</i>	Türkentaube	Collared Dove	Germany	N	T/IB, EM	Hartig & Frese, 1973
	<i>Patagioenas araucana</i>	Araukanertaube	Chilean Pigeon	Iraq	N	L (E, W, F), D/—	Al-Ani, 1986
	<i>Columba livia</i>	Felsentaube	Rock Pigeon or Feral Pigeon	The Netherlands	N	D/IB, CAM	Cubillos <i>et al.</i> , 1979
	<i>Patumbus palumbus</i>	Ringeltaube	Wood Pigeon	Austria	N	L (B, E, F)/IB, EM	De Jong, 1912
				Great Britain	N	L (B, E, F, H), D/—	Loupal <i>et al.</i> , 1985
				Germany	N	D/—	Dean & Marshall, 1908
				Sweden	N	+/—	Salhoff, 1937
				Great Britain	N	—/—	Hulphers, 1943
				Norway	N	L (B, E)/IB, CAM, EM, TR	Jennings, 1954 Holt & Krogsrud, 1973
	<i>Zenaidura macroura</i>	Carolinataube	Mourning Dove	Australia USA	N	L (H, E, B)/—	Kossack & Hanson, 1954
				New York, USA	N	L (H, E, B, W, F)/—	Locke <i>et al.</i> , 1960
Psittaciformes /Micropsittidae/ Loriculinae	<i>Loriculus vernalis</i>	Frühlings-papageichen	Vernal Hanging Parrot	Germany	N	L (E, B), D/IB —/CAM	Tangredi, 1974 Pilaski <i>et al.</i> , 1990
	<i>Agapornis roseicollis</i>	Rosenköpfchen	Rosy-faced Lovebird	Germany Florida, USA	N	L (H, E)/IB, CAM, TR	Kraft & Teufel, 1971
				Japan	E	D/—	Hitchner & Clubb, 1980
	<i>Agapornis fischeri</i>	Erdbeerköpfchen	Fischer's Lovebird	Florida, USA	N	M/IB, EM	Tsai <i>et al.</i> , 1997
	<i>Agapornis personatus</i>	Schwarzköpfchen	Masked Lovebird	Germany	E	D/—	Hitchner & Clubb, 1980
				California, USA	N	L (H, E)/IB, CAM, TR	Kraft & Teufel, 1971
				Florida, USA	N	L (E)/IB	Emanuelson <i>et al.</i> , 1978
				Japan	E	D/—	Hitchner & Clubb, 1980
	<i>Amazilia finschi</i>	Blaukappen-amazone	Lilac-crowned Amazon	Florida, USA	N	L (E)/IB, EM, CAM	Iwata <i>et al.</i> , 1986
				Indiana, USA	E	D/—	Hitchner & Clubb, 1980
	<i>Amazona autumnalis</i>	Rotstirn-amazone	Red-ored Amazon	Florida, USA	N	L (E), D/IB, CAM, TR	Boosinger <i>et al.</i> , 1982
	<i>Amazona albifrons</i>	Weisstirn-amazone	White-fronted Amazon	Mexico Florida, USA	E	D/—	Hitchner & Clubb, 1980
					N	D/IB, EM	Graham, 1978
					E	D/—	Hitchner & Clubb, 1980

<i>Amazona aestiva</i>	Blaustirnamazone	Blue-fronted Amazon	Florida, USA Bolivia California, USA Mexico Japan South Africa Florida, USA	E E N N N N E	D/— M/CAM, TR D/IB, EM, CAM + /IB, CAM, TR L (E)/IB, EM, CAM M/CAM D/—	Hitchner & Clubb, 1980 Hitchner & Clubb, 1980 McDonald <i>et al.</i> , 1981 Olmos <i>et al.</i> , 1986 Iwata <i>et al.</i> , 1986 Kroesen, 1977 Hitchner & Clubb, 1980
<i>Amazona ochrocephala</i>	Gelbscheitel-amazone	Yellow-crowned Amazon	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Amazona ochrocephala europalliata</i>	Gelbscheitel-amazone	Yellow-naped Amazon	Indiana, USA USA	N, E N	L (E), D/IB, CAM, TR M/IB	Boosinger <i>et al.</i> , 1982 Minsky & Petrak, 1982
<i>Amazona farinaosa</i>	Mülleramazone	Mealy Amazon	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Deropnyx accipitrinus</i>	Fächerpapagei	Hawk-headed Parrot	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Pionus fuscus</i>	Veilchenpapagei	Dusky Parrot	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Pionus sentiloides</i>	Greisenkopf	White-headed Parrot	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Pionus maximiliani</i>	Maximilian-papagei	Scaly-headed Parrot	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Pionus menstruus</i>	Schwarzohr-papagei	Blue-headed Parrot	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Pionites melanocephalus</i>	Grünzüngel-papagei	Black-headed Caique	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Ara rubrogenys</i>	Rotohrara	Red fronted Macaw	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Ara ararauna</i>	Gelbbrustara	Blue and Yellow Macaw	USA	N	M/IB	Minsky & Petrak, 1982
<i>Ara chloroptera</i>	Grünflügelara	Green-winged Macaw	South America	N	M/CAM	Kroesen, 1977
<i>Ara militaris mexicana</i>	Soldatenara	Military Macaw	Texas, USA	N	M/IB, EM	Clark <i>et al.</i> , 1988
<i>Anodorhynchus hyacinthinus</i>	Hyazinthara	Hyacinth-Macaw	South America	N	L (H)/CAM	Kroesen, 1977
<i>Psittacara holochlora</i>	Grünsittich	Green Conure	Indiana, USA	E	L (E,H)/IB	Boosinger <i>et al.</i> , 1982
<i>Psittacara mitrata</i>	Rotmaskensittich	Mitred Conure	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Aratinga solstitialis</i>	Sonnensittich	Sun Conure	Mexico	E	+ /IB, CAM, TR	Olmos <i>et al.</i> , 1986
<i>Eupsittula canicularis</i>	Elfenbeinsittich	Orange-fronted Conure	Mexico	E	+ /IB, CAM, TR	Olmos <i>et al.</i> , 1986
<i>Encognathus leptorhynchus</i>	Langschnabel-sittich	Slender-billed Conure	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Brotopteris pyrrhoptera</i>	Feuerflügelsittich	Grey-cheeked Parrot	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Aprosmictus erythropterus</i>	Rotflügelsittich	Red-winged Parrot	Germany	N	+ /CAM, EM	Winteroll <i>et al.</i> , 1979
<i>Psephotus haematotus</i>	Singsittich	Red-rumped Parrot	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Platyercus eximius</i>	Rosella	Eastern Rosella	Florida, USA	E	D/—	Hitchner & Clubb, 1980
<i>Melopsittacus undulatus</i>	Wellensittich	Budgerigar	Illinois, USA	N	L (E)/TR	Sharma <i>et al.</i> , 1968
<i>Nymphicus hollandicus</i>	Nymphensittich	Cockatiel	Philadelphia, USA	N	—/—	Petrak, 1969
<i>Asio otus</i>	Eule	Owl	Japan	N	L (E)/IB, CAM, EM	Iwata <i>et al.</i> , 1986
<i>Bubo bubo</i>	Waldohreule	Long-eared Owl	Italy	N	D/—	Blair, 1910
<i>Strix varia</i>	Uhu	Eagle Owl	Florida, USA	N	L (F)/EM	Chiocco, 1992
	Streifenkauz	Barred Owl	Italy	E	L (H,F,E)/IB, EM	Deem <i>et al.</i> , 1997
			Florida, USA	N	P/— L (H,F,E)/IB, EM	Maggiara & Valenti, 1903 Deem <i>et al.</i> , 1997

Table 1.—Continued

Order/Suborder Family/Subfamily	Latin	German	English	Location	Mode of infection	Clinical signs/ lesions/proof	Source
Falconiformes/Falcones/ Falconidae/Falconinae							
	<i>Hierofalco peregrinus</i>	Wanderfalke	Peregrine Falcon	Arabian Gulf	N	L (H,E,F)/IB, EM	Cooper, 1969
	<i>Hierofalco rusticolus</i>	Gerfalke	Gyrfalcon	United Arab Emirates	N	L (H,B,F)/IB, EM	Kiel, 1985
	<i>Hierofalco cherrug</i>	Sakerfalke	Saker Falcon	United Arab Emirates	N	L (H,B,F)/IB, EM	Samour & Cooper, 1993
				Arabian Gulf	N	L (F)/IB, EM	Greenwood & Blakemore, 1973
				Germany	N	+ /—	Grimm & Jacobi, 1977
				Afghanistan	N	+ /CAM, EM	Winteroll <i>et al.</i> , 1979
	<i>Hierofalco jugger</i>	Lagarfalke	Lagar Falcon	United Arab Emirates	N	L (H,B,F)/IB, EM	Kiel, 1985
	<i>Tinnunculus tinnunculus</i>	Turmfalke	Common Kestrel	Arabian Gulf	N	L (F)/IB, EM	Greenwood & Blakemore, 1973
Accipitriformes/Accipitres/ Accipitridae/Accipitrinae	<i>Accipiter nisus</i>	Sperber	European Sparrow-Hawk	Germany	E	+ /IB, TR	Kitzing, 1980
	<i>Accipiter gentilis</i>	Habicht	Goshawk	Germany	N	L (B,E,F)/CAM, EM	Tantawi <i>et al.</i> , 1981
				France	N	— /—	Polowinkin, 1901
	<i>Aquila chrysaetos</i>	Steinadler	Golden Eagle	Germany	N	— /—	Heusinger, 1844
				Canada	N	D /—	Gratzl, 1953
				California, USA	N	L (H, E)/IB	Moffatt, 1972
				California, USA	N	L (H,F)/IB	Hill & Bogue, 1977
				Washington, USA	N	L (H,F)/IB	Wheeldon <i>et al.</i> , 1985
	<i>Buteo platyptera</i>	Breitflügelbussard	Broad-winged Hawk	Canada	N	L (F) /—	Garner, 1989
	<i>Buteo jamaicensis</i>	Rotschwanz-bussard	Red-tailed Buzzard	Missouri, USA	N	T, L, (B,F)/IB, TR	Kuntze <i>et al.</i> , 1968
				Dakota, USA	N	L (H, F)/IB	Halliwell, 1972
				Washington, USA	E	L (F)/EM	Pearson & Pass, 1975
				California, USA	N	L (B,E,F)/IB, EM	Fitzner <i>et al.</i> , 1985
	<i>Buteo lagopus</i>	Rauhfußbussard	Rough-legged Buzzard	California, USA	N	L (/Z)/IB	Wheeldon <i>et al.</i> , 1985
				Dakota, USA	N	L (B,E,F)/IB, EM TR	Pearson & Pass, 1975
				Austria	N	L (F)/IB	Wheeldon <i>et al.</i> , 1985
Accipitridae/Circinae	<i>Buteo buteo</i>	Mäusebussard	Common Buzzard	Germany	N	+ /IB, EM	Loupal <i>et al.</i> , 1985
	<i>Circus pygargus</i>	Wiesenweihe	Montagu's Harrier	Germany	N	— /—	Engelmann, 1928
	<i>Circus cyaneus</i>	Kornweihe	Hen-Harrier	Dakota, USA	N	L (F) /—	Wheeldon <i>et al.</i> , 1985
Ciconiiformes/Ciconiidae/Ciconiidae	<i>Ciconia ciconia</i>	Weißstorch	White Stork	Switzerland	N	L (B,F,E)/EM	Zangger & Muller, 1990
	<i>Ciconia nigra</i>	Schwarzstorch	Black Stork	Switzerland	N	L (B,F,E)/EM	Zangger & Muller, 1990
Anatiformes/Anatidae/Anserinae	<i>Anser anser domesticus</i>	Gans	Goose	Germany	N	+ /—	Hertwig & Ducloux, 1849
				Germany	N	+ /—	Spinola, 1858
				Germany	N	+ /—	Röll, 1869
				Canada	E	L (E,F)/IB, CAM	Kirmse, 1966
	<i>Anser anser</i>	Graugans	Greylag Goose	China	N	— /A	Zhang <i>et al.</i> , 1996
	<i>Anser cygnoides</i>	Schwanengans	Swan Goose	Germany	N	D/IB, CAM, TR	Ihlenburg, 1972
	<i>Anser fabalis</i>	Saatgans	Bean Goose	Germany	N	D /—	Ihlenburg, 1972
	<i>Anser sandvicensis</i>	Nene	Nene or Hawaiian Goose	China	N	— /A	Zhang <i>et al.</i> , 1996
				Great Britain	N	— /—	Kear & Brown, 1975
				Great Britain	N	L (F) /—	Kear & Brown, 1975

Table 1.—Continued

Order/Suborder Family/Subfamily	Latin	German	English	Location	Mode of infection	Clinical signs/ lesions/proof	Source
	<i>Crossoptilon auritum</i>	Blauer Ohrfasan	Blue-eared Pheasant	California, USA	N	L (E)/IB, CAM, EM	Ensley <i>et al.</i> , 1978
	<i>Phasianus colchicus</i>	Jagdfasan	Common Pheasant	Oregon, USA	N	—/—	Crawford & Oates, 1979; Crawford 1986
Phasianidae/Gallinae				China	N	M/—	Hu Hongguan, 1982
				Iraq	N	L (E,B,W,F)/EM, TR	Al-Ani, 1986
				China	N	—/A	Zhang <i>et al.</i> , 1996
				Texas, USA	N	L (HF,W)/IB, EM	Wilson & Crawford, 1988
		Prälatfasan	Siamese Fireback	California, USA	N	L(E)/IB, CAM, EM	Ensley <i>et al.</i> , 1978
		Bankivahuhn	Red Junglefowl	California, USA	N	L (E)/IB, CAM, EM	Ensley <i>et al.</i> , 1978
Phasianidae/Tetraoninae	<i>Tympanuchus cupido</i>	Prärehuhn	Prairie Chicken	Virginia, USA	N	L (H)/IB, CAM, TR	Dubose, 1965
	<i>Bonasa umbellus</i>	Kragenhuhn	Ruffed Grouse	USA	N	—/—	Allen & Gross, 1926
				USA	N	—/—	Bump <i>et al.</i> , 1947
		Haselhuhn	Common Hazelhen	Virginia, USA	N	L (H)/IB, CAM, TR	Dubose, 1965
		Felsengebirgs-huhn	Blue Grouse	France	N	—/—	Curasson, 1946
				Oregon, USA	N	—/—	Dickenson, 1967
			Canada	N	L (E,B,F)/IB, TR	Syverson & McTaggart Cowan, 1944	
	<i>Lagopus mutus</i>	Alpenschneehuhn	Rock Ptarmigan	Japan	N	L (H,E)/IB, CAM, TR	Horiuchi <i>et al.</i> , 1965
	<i>Lyrurus tetrix</i>	Birkhuhn	Black Grouse	Denmark	N	+ /—	Christiansen, 1949
	<i>Centrocercus urophasianus</i>	Beifussshuhn	Sage-Grouse	Texas, USA	N	L (HF)/IB, CAM	DuBose, 1965
	<i>Tragopan satyra</i>	Satyr-Tragopan	Satyr Tragopan	France	N	—/—	Mégnin, 1878
	<i>Tragopan temminckii</i>	Temminck-Tragopan	Temminck's Tragopan	China	N	M/—	Hu Hongguan, 1982
	<i>Pardix perdix</i>	Rebhuhn	Common Partridge	Germany	N	L (B)/—	Schäff, 1890
				Germany	N	L (B,E, F)/—	Heinricher, 1890
				Germany	N	M/—	Eberlein, 1894
				Germany	N	L (B,E), D/—	Stadie, 1931
				Denmark	N	L (H,E,B;F)/—	Christiansen, 1935, 1949
	<i>Coturnix coturnix</i>	Wachtel	Common Quail	Great Britain	N	L (B)/—	Pomeroy, 1962
				Austria	N	+ /IB, EM	Loupal <i>et al.</i> , 1985
				Italy	N	M/IB, EM, CAM, A	Mani <i>et al.</i> , 1990
				Mexico	N	L (H,E,W), D/TR	Gallagher, 1917
				Italy	N	D/IB, CAM, EM, TR	Rinaldi <i>et al.</i> , 1972
				China	N	—/A	Zhang <i>et al.</i> , 1996
				Canada	N	L (B,E)/IB, CAM	Karstad, 1965
				California, USA	N	L (H)/IB, EM	Ensley <i>et al.</i> , 1978
				Austria	N	+ /IB, EM	Loupal <i>et al.</i> , 1985
				France	N	—/—	Mégnin, 1878
Phasianidae/Lophophorinae	<i>Lophophorus impejanus</i>	Gelbschwanz-Glanzfasan	Himalayan Monal	Canada	N	L (B,E)/IB, CAM	Karstad, 1965
				California, USA	N	L (H)/IB, EM	Ensley <i>et al.</i> , 1978
Upupiformes/Upupae /Phoeniculidae	<i>Phoeniculus purpureus</i>	Baumhopf	Red-billed Wood-Hoopoe	Austria	N	+ /IB, EM	Loupal <i>et al.</i> , 1985
				France	N	—/—	Mégnin, 1878

Apodiformes/Apodidae	<i>Chaetura pelagica</i>	Schornsteinsgler	Chimney Swift	Pennsylvania, USA	N	L (B,F)/IB, CAM	Worth, 1956
Piciformes/Picidae/Picinae	<i>Colaptes auratus</i>	Goldspecht	Common Flicker	Illinois, USA	N	L (E)/IB	Labisky & Mann, 1961
				Canada	N	+/IB	Kirmse, 1966, 1967
Passeriformes/Tyrannidae/Cotingidae	<i>Cotinga maculata</i>	Prachtkotinga	Banded Cotinga	Germany	N	-/IB	Pilaski <i>et al.</i> , 1990
Pipridae	<i>Pipra erythrocephala</i>	Goldkopfpipra	Goldenheaded Manakin	Trinidad	N	L (E,F)/CAM, TR	Tikasingh <i>et al.</i> , 1982
	<i>Pipra mentalis</i>	Gelbhosenpipra	Red-capped Manakin	Panama	N	-/IB	Kirmse & Lofton, 1969
	<i>Manacus manacus</i>	Säbelpipra	Bearded Manakin	Panama	N	-/IB	Kirmse & Lofton, 1969
Tyrannidae	<i>Empidonax traillii</i>	Weidentyrann	Willow Flycatcher	Trinidad	N	L (E,F)/CAM, TR	Tikasingh <i>et al.</i> , 1982
Grallinidae	<i>Grallina cyanoleuca</i>	Drosselstelze	Magpie-Lark	Panama	N	-/IB	Kirmse & Lofton, 1969
Cracticidae	<i>Gymnorhina tibicen</i>	Flötenvogel	Australian Magpie	Australia	N	-/—	Harrigan <i>et al.</i> , 1975
				Australia	N	L (F)/CAM, EM	Annuar <i>et al.</i> , 1983
				Australia	N	-/—	Fenner, 1959
				Australia	N	-/—	Burnet & Stanley, 1959
				Australia	N	L (B, F)/IB, CAM, EM	Harrigan <i>et al.</i> , 1975
				Australia	N	L (E)/CAM, TR	Chung & Spradbow, 1977
				Australia	N	L (F)/CAM, EM	Annuar <i>et al.</i> , 1983
Corvidae	<i>Colaptes monedula</i>	Dohle	Jackdaw	The Netherlands	N	L (F)/TR	Jansen, 1942
	<i>Corvus frugilegus</i>	Saatkrähe	Rook	Denmark	N	+/-	Christiansen, 1949
	<i>Corvus corax</i>	Kolkrabe	Common Raven	Denmark	N	L (F)/—	Christiansen, 1949
	<i>Corvus corone</i>	Aaskrähe	Carrion Crow	Denmark	N	+/-	Christiansen, 1949
	<i>Corvus cornix</i>	Nebelkrähe	Hooded Crow	Great Britain	N	L (F)/IB	Poulding, 1960
	<i>Corvus hawaiiensis</i>	Krähe	Hawaiian Crow	Germany	N	-/—	Grzimek, 1939
	<i>Cyanocitta cristata</i>	Blauhäher	Blue Jay	Hawaii, USA	N	L/—	Tripathy <i>et al.</i> , 1998
	<i>Pica pica</i>	Elster	Magpie	Pennsylvania, USA	N/E	L (B,F)/TR	Worth, 1956
				Denmark	N	+/-	Christiansen, 1949
				Norway	N	L (H,B,E), D/IB, CAM, EM	Holt & Krogsrud, 1973
Campephagidae	<i>Coarctata novae-hollandiae</i>	Schwarzgesicht-Raupenfänger	Black-faced Cuckoo-shrike	Australia	N	L (W,F)/IB, EM	Sutton & Phillipich, 1983
Cloropseidae	<i>Chloropsis aurifrons</i>	Goldstim-blattvogel	Golden-fronted Leafbird	Germany	N	+/IB	Hertig, 1966
Certhiidae	<i>Certhia familiaris</i>	Waldbaumläufer	Tree-Creeper	Canada	N	L (F)/IB, CAM	Kirmse, 1966
Zosteropidae	<i>Zosterops lateralis</i>	Mantel-brillenvogel	Silvereye	New Zealand	N	L (B,F)/IB, CAM, EM	Austin <i>et al.</i> , 1973
				Australia	N	-/—	Harrigan <i>et al.</i> , 1975
				Australia	N	L (F)/CAM, EM	Annuar <i>et al.</i> , 1983
Estrildidae	<i>Zosterops palpebrosus</i>	Ganges-brillenvogel	Oriental White-eye	Japan	N	+/-	Kawashima, 1962
Passeridae	<i>Padda oryzivora</i>	Reisfink	Java Sparrow	Germany	N	-/—	Kikuth & Gollub, 1932
	<i>Passer domesticus</i>	Hausperling	House Sparrow	Brazil	E	-/IB	Reis & Nobrega, 1937
				USA	E	-/—	Coulston & Maxwell, 1941
				Washington, USA	N	L (E,B)/IB, CAM, TR	Giddens <i>et al.</i> , 1971
				Norway	N	L (H,E,B)/IB, CAM, EM	Holt & Krogsrud, 1973
				California, USA	N	+/IB	Hill & Bogue, 1977
				Germany	N	/EM	Herbst & Krauss, 1989

Table 1.—Continued

Order/Suborder Family/Subfamily	Latin	German	English	Location	Mode of infection	Clinical signs/ lesions/proof	Source
Fringillidae	<i>Fringilla coelebs</i>	Buchfink	Chaffinch	Canada Germany Great Britain	N E N	L (H)/IB + /IB L (F)/—	Mikaelian & Martineau, 1996 Eberbeck & Kayser, 1932 Keymer & Blackmore, 1964
Carduelidae	<i>Spinus cucullatus</i>	Kapuzenzeisig	Red Siskin	Germany	N	L (E)/CAM, EM	Kaleta & Marschall, 1982
	<i>Spinus pinus</i>	Fichtenzeisig	Pine Siskin	California, USA	N	L (H, E, F)/CAM	Bigland <i>et al.</i> , 1962
	<i>Spinus spinus</i>	Erlenzeisig	Eurasian Siskin	Germany	N	—/—	Hartwig & Lange, 1964
	<i>Pyrrhula pyrrhula</i>	Gimpel	Common Bullfinch	Austria Germany The Netherlands Germany	N E N N	+ /IB, EM P/— L (B, E), D/IB, TR + /—	Loupal <i>et al.</i> , 1985 Polowinkin, 1901 De Jong, 1912 Stadie, 1931
	<i>Pyrrhula erythaca</i> <i>Carduelis carduelis</i>	Maskengimpel Stieglitz	Grey-headed Bullfinch Goldfinch	Austria The Netherlands Germany Great Britain Germany	N N E N N	+ /CAM + /IB, EM L (H, B)/— P/— + /CAM	Kaleta & Ebert, 1969 Loupal <i>et al.</i> , 1985 Dorrestein <i>et al.</i> , 1993 Polowinkin, 1901 Keymer & Blackmore, 1964 Kaleta & Ebert, 1969
	<i>Chloris chloris</i>	Grünling	Greenfinch	Great Britain Germany	N N	—/— + /CAM	Keymer & Blackmore, 1964 Kaleta & Ebert, 1969
	<i>Linaria cannabina</i>	Bluthänfing	Linnet	Germany Germany	E E	P/— —/—	Kaleta & Ebert, 1969 Polowinkin, 1901
	<i>Serinus canaria</i>	Kanariengirlitz	Common Canary	Germany Tunisien Uruguay Germany Japan Germany	N N N N N N	P/— —/— + /— P/— M/IB, CAM, EM, TR, E L (H, B, E, F)/IB, CAM, TR	Hartwig & Lange, 1964 Hertwig, 1849 Loir & Ducloux, 1894 Wolffhügel, 1919 Kikuth & Gollub, 1932 Sato <i>et al.</i> , 1962 Michel & Lindner, 1964
	<i>Erythrura mexicanana</i>	Hausgimpel	House-Finch	Germany New York, USA Austria Oklahoma, USA California, USA California, USA	N N N N N N	T/EM, IB L (H, B, E)/IB, CAM + /IB, EM L (B, E), D/IB, EM L (H, E)/— + /IB	Hartig, 1966 Donnelly & Crane, 1984 Loupal <i>et al.</i> , 1985 Johnson & Castro, 1986 Power & Human, 1974 Hill & Bogue, 1977
	<i>Laxops maculatus</i> <i>Hemignathus obscurus</i> <i>Himatione sanguinea</i>	Alauwahio Akiakoa Apapane	Lana'i Creeper Akiakoa Apapane	Idaho, USA Hawaii, USA Hawaii, USA Hawaii, USA	N N N N	L (B, F)/CAM, EM L (B, F)/— L (B, F)/— L/—	Docherty & Long, 1986 Warner, 1968 Warner, 1968 Tripathy <i>et al.</i> , 1998

Prunellidae	<i>Laiscopus collaris</i> <i>Prunella modularis</i>	Alpenbraunelle Heckenbraunelle	Austria France Great Britain	N N N	+ /IB, EM L (F)/IB L (E,F)/—	Loupal <i>et al.</i> , 1985 Mercier & Poisson, 1923 Edwards, 1955
Alaudidae	<i>Alauda arvensis</i> <i>Galerida cristata</i> <i>Anthus novae-zealandiae</i>	Feldlerche Haubenlerche Spornpieper	Denmark Spain New Zealand	N N N	+ /— L (F)/IB L (H,E,F)/IB	Christiansen, 1949 Groth, 1963 Westerskov, 1953
Icteridae/Quiscalinae	<i>Quiscalus sp.</i> <i>Quiscalus quiscula</i> <i>Quiscalus versicolor</i> <i>Molothrus ater</i>	Grackel Bronzegrackle Braunkopf-Kuhstärkung	New Zealand Texas, USA Maryland, USA USA	N N N N	L (B,E,F)/— L (B,E,F)/IB, CAM, EM L (F)/— L (F)/—	Quinn, 1971 Docherty <i>et al.</i> , 1991 Herman <i>et al.</i> , 1962 Emmel, 1930
Emberizidae/Emberizinae	<i>Plectrophenax nivalis</i> <i>Spizella passerina</i>	Brown-headed Cowbird Schneeammer Schwirrammer	Pennsylvania, USA Maryland, USA Maryland, USA USA	N N E N	+ /— L (F)/— + /IB L (F)/—	Locke, 1961 Herman <i>et al.</i> , 1962 Irons, 1934 Baldwin, 1922
Emberizidae/Zonotrichinae	<i>Spizella arborea</i> <i>Spizella pusilla</i> <i>Junco hyemalis</i>	Baumammer Klapperammer Winterammer	Georgia, USA Canada USA Tennessee & Mississippi, USA New Jersey, USA Tennessee & Mississippi, USA USA	N N N N N N N N	+ /— L (F)/— + /— L (F)/— L (F)/— L (F)/IB, CAM, TR L (F)/IB, CAM	Musselmann, 1928 Kirmse, 1966 Bergstrom, 1952 Goodpasture & Anderson, 1962 Worth, 1956 Goodpasture & Anderson, 1962
	<i>Passerella melodia</i> <i>Passerella iliaca</i> <i>Pipilo ery-throphthalmus</i>	Singammer Fuchsammer Rötelgrundammer	Canada New York, USA New Jersey, USA Tennessee & Mississippi, USA USA	— N E E N	—/IB, CAM, EM + /— — /— — /— + /IB	Beaver & Cheatham, 1963 Kirmse & Lofton, 1969 Coulston & Manwell, 1941 Worth, 1956 Goodpasture & Anderson, 1962
	<i>Zootrichia atricapilla</i> <i>Zootrichia albicollis</i> <i>Zootrichia leucophrys</i> <i>Chlorura chlorura</i> <i>Sporophila sp.</i> <i>Sporophila americana</i> <i>Sicalis flaveola</i> <i>Oryzoborus angolensis</i>	Kronenammer Weißkehlammer Dachsammer Grünschwanz-Grundammer Wechselpfäffchen Safraammer Schwarzkopf-Reisknacker	Washington, USA New Jersey, USA Canada Washington, USA Canada Brazil Canada Brazil Brazil Canada Panama	N N E N N N N E N N	—/IB L (E,B)/IB, CAM, TR L (F)/— + /— —/IB —/IB, TR —/IB —/IB + /IB	Kirmse, 1966 Giddens <i>et al.</i> , 1971 Worth, 1956 Kirmse, 1966 Giddens <i>et al.</i> , 1971 Kirmse & Lofton, 1969 Reis & Nobrega, 1937 Kirmse & Lofton, 1969 Reis & Nobrega, 1937 Reis & Nobrega, 1937 Kirmse & often, 1969 Kirmse & Lofton, 1969
Thraupidae/Thraupinae	<i>Thraupis episcopus</i>	Bischofstangere	Panama	N	+ /IB	Kirmse & Lofton, 1969

Table 1.—Continued

Order/Suborder Family/Subfamily	Latin	German	English	Location	Mode of infection	Clinical signs/ lesions/proof	Source
Traupidae/Hemitrapinae Thraupidae/Cardinalae	<i>Chlorospingus ophthalmicus</i>	Finkentangere	Common Bush-Tanager	Panama	N	+/IB	Kirmse & Loften, 1969
	<i>Cardinalis cardinalis</i>	Rotkardinal	Common Cardinal	Tennessee; Mississippi; USA	N	+/IB	Goodpasture & Anderson, 1962
Thraupidae/Tachyphoniinae	<i>Piranga rubra</i>	Sommertangere	Summer-Tanager	Austria	N	+/IB, EM	Loupal <i>et al.</i> , 1985
	<i>Cyanoloxia cyanea</i>	Ultramarinbischhof	Ultramarine Grosbeak	Panama	N	+/IB	Kirmse & Loften, 1969
	<i>Cyanoloxia cyanoides</i>	Stahlbischhof	Blue-black Grosbeak	Brazil	E	—/IB	Reis & Nobrega, 1937
	<i>Euphonia violacea</i>	Veilchenorganist	Blue-black Grosbeak	Panama	N	+/IB	Kirmse & Loften, 1969
	<i>Tangara chrysophrys</i>	Tropfentangere	Violaceous Euphonia	Trinidad	N	+/-	Tikasingh <i>et al.</i> , 1982
	<i>Oporornis philadelphia</i>	Graukopf-Waldsänger	Speckled Tanager	Germany	N	—/CAM	Pilaski <i>et al.</i> , 1990
	<i>Seiurus aurocapillus</i>	Pfeperwaldsänger	Mourning Warbler	Panama	N	—/IB	Kirmse & Loften, 1969
	<i>Seiurus motacilla</i>	Stelzen-waldsänger	Ovenbird	Panama	N	—/IB	Kirmse & Loften, 1969
	<i>Dendroica tigrina</i>	Tigerwaldsänger	Louisiana Waterthrush	Panama	N	—/IB	Kirmse & Loften, 1969
	<i>Icteria virens</i>	Gelbbrust-Waldsänger	Cape May Warbler	Canada	N	—/IB	Kirmse & Loften, 1969
Sylviidae	<i>Geothlypis trichas</i>	Weidengelb-kehlechen	Yellow-breasted Chat	Canada	N	—/IB	Kirmse & Loften, 1969
	<i>Sylvia curruca</i>	Klapper-grasmücke	Lesser Whitethroat	Canada	N	—/IB	Kirmse & Loften, 1969
Paridae	<i>Baeolophus bicolor</i>	Indianermeise	Tufted Tit	Denmark	N	+/-	Christiansen, 1949
	<i>Parus major</i>	Kohlmeise	Great Tit	USA	N	—/IB	Goodpasture & Anderson, 1962
Muscipidae	<i>Cichloselys philomelos</i>	Singdrossel	Song-Thrush	Germany	E	P/—	Polowinkin, 1901
	<i>Merula migratoria</i>	Wanderdrossel	American Robin	Norway	N	L (HE)/IB, CAM, EM	Holt & Krogsrud, 1973
	<i>Merula merula</i>	Amsel	Common Blackbird	Denmark	N	+/-	Christiansen, 1949
	<i>Hylocichla ustulata</i>	Waldrossel	Wood-Thrush	USA	N	—/IB	Goodpasture & Anderson, 1962
	<i>Catharus ustulatus</i>	Zwergdrossel	Swainson's Thrush	Canada	N	—/—	Kirmse & Loften, 1969
	<i>Catharus minimus</i>	Grauwangen-drossel	Grey-cheeked Thrush	California, USA	N	+/IB	Hill & Bogue, 1977
	<i>Catharus fuscescens</i>	Wilsonsdrossel	Veery	Italy	N	+/-	Maggiore & Valenti, 1903
	<i>Planesticus nudigenis</i>	Nacktaugen-drossel	American Bare-Eyed Thrush	USA	N	—/IB	Goodpasture & Anderson, 1962
	<i>Turdus viscivorus</i>	Misteldrossel	Mistle Thrush	Canada	N	—/—	Kirmse & Loften, 1969
	<i>Arceuthornis pileatus</i>	Wacholderdrossel	Fieldfare	Panama	N	+/IB, CAM	Kirmse & Loften, 1969
<i>Copsychus malabaricus</i>	Schamadrossel	Common Shama	Panama	N	+/IB	Kirmse & Loften, 1969	
<i>Eunyias thalassina</i>	Lazulischmäpper	Verditer Flycatcher	Panama	N	—/IB	Kirmse & Loften, 1969	
<i>Grandala coelicolor</i>	Grandala	Grandala	Trinidad	N	+/-	Tikasingh <i>et al.</i> , 1982	
<i>Turdus viscivorus</i>	Misteldrossel	Mistle Thrush	Italy	N	+/-	Maggiore & Valenti, 1903	
<i>Arceuthornis pileatus</i>	Wacholderdrossel	Fieldfare	Italy	N	+/-	Maggiore & Valenti, 1903	
<i>Copsychus malabaricus</i>	Schamadrossel	Common Shama	Germany	N	+/IB	Hartig, 1966	
<i>Eunyias thalassina</i>	Lazulischmäpper	Verditer Flycatcher	Germany	N	+/IB	Hartig, 1966	
<i>Grandala coelicolor</i>	Grandala	Grandala	USA	N	—/IB	Goodpasture & Anderson, 1962	

Mimidae	<i>Mimus polyglottus</i>	Spottdrossel	Mockingbird	Spain	N	L (H,B,F,E)/IB, EM	Oros <i>et al.</i> , 1997
				Canada	N	—/IB	Kirmse, 1966
Troglodytidae	<i>Dumetella carolinensis</i>	Katzendrossel	Catbird	Canada	N	—/IB	Kirmse, 1966
	<i>Troglodytes troglodytes</i>	Zaunkönig	Wren	Denmark	N	+ /—	Christiansen, 1949
Sturnidae	<i>Gracula religiosa</i>	Beo	Hill Myna	Malaysia	N	M/IB, CAM	Karpinski & Clubb, 1986
	<i>Leucopsar rothschildi</i>	Balistar	Bali Myna	Malaysia	N	M/CAM, TR	Reed & Schrader, 1989
	<i>Sturnus vulgaris</i>	Star	Common Starling	Washington, USA	N	L (E,P)/IB, CAM, TR	Landolt & Kocan, 1976
				USA	N	+ /IB	Goodpasture & Anderson, 1962
				Germany	N	+ /IB	Hartig, 1966
				Germany	N/E	D/IB, CAM, EM, TR, A	Lüthgen, 1983
				Austria	N	M/IB, EM	Loupal <i>et al.</i> , 1985
	<i>Cosmopsarus regius</i>	Königsglanzstar	Regal Starling	Germany	N	L (H)/IB, CAM, EM	Pilaski <i>et al.</i> , 1990
	<i>Lamprolornis sp.</i>	Glanzstar	Glossy Starling	Germany	E	M/—	Lüthgen, 1983

Diagnostic Tools

The clinical signs seen in the cutaneous form of pox are very characteristic and allowed even early investigators to provide a reasonably realistic diagnosis. The clinical recognition of pox in the diphtheric and mixed forms is much less easy. In addition to signs, histology provides good evidence for the presence of poxviruses. Histology became possible from the work of Bollinger (1877). He detected and described inclusion bodies in the cytoplasm of infected cells which can be detected in smears or tissue sections stained with Wright's, Giemsa or other stains.

Today, the diagnostic work generally provides a diagnosis of the genus *Avipox* but not a species diagnosis within this genus. Such a diagnosis is based on virus isolation on the chorioallantoic membrane of embryonated chicken eggs (Woodruff & Goodpasture, 1931) or in cell cultures of avian origin (Findlay, 1928). Attempts to assign new avipoxvirus isolates to one of the known avipox species on the basis of their lesions on the chorioallantoic membrane of inoculated eggs, in chicken embryo fibroblast cultures, or by subcutaneous versus intravenous inoculation of several susceptible bird species has met to date with limited success. The number of isolates is now too large and the types of reactions in these systems is too similar to allow clear-cut differentiations between avipoxvirus species. Molecular methods such as restriction enzyme analysis and/or detailed genomic studies may provide more accurate data in the future (Fenner, 1996).

Since the early 1950s, the large poxvirus particles have been visualized by electron microscopy of pre-purified skin scabs or pharyngeal swabs. Direct electron microscopy of negatively stained preparations provides a reliable and rapid genus diagnosis but again no species diagnosis of pox.

Taxonomy of Birds

The authors have made use of the '*List of Birds of the World*' published by Wolters (1975–1982) for taxonomy and nomenclature of bird species. Wolters provides vernacular bird names in the English and German languages in addition to the generally accepted scientific terminology. On occasions, additional reference was made to '*Distribution and Taxonomy of Birds of the World*' published by Sibley & Monroe (1990).

Host Spectrum of the Genus *Avipoxvirus*

The earliest but also most comprehensive publications on the host range of pox in birds are cited in Table 1. In this table, the scientific names and the vernacular names in the English and German languages are given. The ancient literature in particular made frequent use of names which are now obsolete but still sufficiently clear to allow

identification of both the disease and the birds affected. However, names like *avian diphtheria*, *epithelioma contagiosum*, *variola gallinarum* and many others are not cited. Some reports on pox contain only vague terms for birds like *dove*, *owl*, and *goose*. Those publications are omitted here. Of the approximately 9000 bird species, about 232 species in 23 orders have been reported to have acquired a natural poxvirus infection and to have developed various forms of pox (Table 1).

References

- Akey, B.L., Nayar, J.K. & Forrester, D. J. (1981). Avian pox in Florida wild turkeys: *Culex nigripalpus* and *Wyeomyia vanduzeei* as experimental vectors. *Journal of Wildlife Diseases*, 17, 597–599.
- Al-Ani, M.O.A. (1986). An outbreak of pox among pheasants in Iraq. *Avian Pathology*, 15, 795–796.
- Allen, A.A. & Gross, A.D. (1926). Cited in: DuBose (1965).
- Allwright, D.M., Burger, W.P., Geyer, A. & Wessels, J. (1994). Avian pox in ostriches. *Journal of the South African Veterinary Association*, 65, 23–25.
- Alfalluji, M.M., Tantawi, H.H., Al-Bana, A. & Al Sheikhly, S. (1979). Pox infection among captive peacocks. *Journal of Wildlife Diseases*, 15, 597–599.
- Amour, H.J., Kaaden, O.-R., Wernerg, U. & Bailey, T.A. (1996). An epornitic of avian pox in Houbara bustards (*Chlamydotis Undulata macqueenii*). *Journal of Veterinary Medicine*, B, 43, 287–292.
- Annar, B.O., Mackenzie, J.S. & Lalor, P.A. (1983). Isolation and characterization of avipoxvirus from wild birds in Western Australia. *Archives of Virology*, 76, 217–229.
- Austin, F.J., Bull, P.C. & Chaudry, M.A. (1973). A poxvirus isolated from Silvereyes (*Zosterops lat.*) from Lower Hutt, New Zealand. *Journal of Wildlife Diseases*, 9, 111–114.
- Avila, E. (1966). El epitelioma contagioso en el guanay. Cited in: Kirmse (1966).
- Baldwin, S.P. (1922). Adventures in bird-banding in 1921. *The Auk*, 39, 210–224.
- Beaver, D.L. & Cheatham, W.J. (1963). Electron microscopy of junco pox. *American Journal of Pathology*, 42, 23–39.
- Bergstrom, E.A. (1952). Foot pox in passerines. *Bird Banding*, 23, 169–170.
- Bigland, C.H., Whenham, G.R. & Graesser, F.E. (1962). A pox like infection of canaries: report of an outbreak. *Canadian Veterinary Journal*, 3, 347–351.
- Blair, W.R. (1910). Cited in: Stehle, S. (1965). Krankheiten bei Greifvögeln (Accipitres) und bei Eulen (Striges) mit Ausnahme parasitärer Erkrankungen. Dissertation thesis, Hannover, Germany.
- Blankenship, L.H., Reed, R.E. & Irby, H.D. (1966). Pox in mourning doves and Gambel's quail in Southern Arizona. *Journal of Wildlife Management*, 30, 253–257.
- Bollinger, O. (1873). Ueber Epithelioma contagiosum beim Haushuhn und die sogenannten Pocken des Geflügels. *Archiv für pathologische Anatomie und Physiologie und für klinische Medizin*, 58, 349–361.
- Bollinger, O. (1877). Ueber Menschen- und Thierpocken, über den Ursprung der Kuhpocken und über intrauterine Vaccination. *Volkmann's Sammlung klinischer Vorträge Nr. 116, Abteil. II*, 2, 1021–1060.
- Boosinger, T.R., Winterfield, R.W., Feldman, D.S. & Dhillon, A.S. (1982). Psittacine pox virus: virus isolation and identification, transmission and cross-challenge studies in parrots and chickens. *Avian Diseases*, 26, 437–444.
- Bouvier, G. (1946). Observations sur les maladies du gibier, de quelques animaux sauvages et des poissons (1942–1945). *Schweizer Archiv für Tierheilkunde*, 88, 268–274.
- Brandly, C.A. & Dunlap, G.L. (1938). An outbreak of pox in turkeys with notes on diagnosis and immunization. *Poultry Science*, 17, 511–515.
- Bump, G. *et al.* (1947). Cited in: Westerskov, K. (1953). Bird pox in a New Zealand pipit. *Notornis*, 5, 168–170.

- Burnet, F.M. & Stanley, W.M. (1959). Animal viruses. In *The Viruses. Biochemical, Biological and Biophysical Properties* Vol. III (p. 428). New York: Academic Press.
- Centanni, E. (1902). Die Vogelpest. *Zentralblatt für Bakteriologie, Abteil. I, Orig.* 31, 145–152, 182–201.
- Chiocco, D. (1992). Owlpoxvirus isolation and cross-challenge studies in chickens. *Acta Medica Veterinaria*, 38, 261–266.
- Christiansen, M. (1935). De vigtigste smitsomme sygdomme hos vildtet. *Maanedsskrift for Dyrlaeger*, 47, 548–551.
- Christiansen, M. (1949). Diseases in wild birds. *Dansk Ornithologisk Forening Tidsskrift*, 43, 189–215.
- Chung, Y.S. & Spradbow, P.B. (1977). Studies on poxvirus isolated from a magpie in Queensland. *Australian Veterinary Journal*, 53, 334–336.
- Clark, F.D., Hume, G.M. & Hayes, E.S. (1988). An isolated case of avian pox in a military macaw (*Ara militaris mexicana*). *Companion Animal Practice*, 2, 34–35.
- Cociu, M., Wagner, G., Micu, N., Tuschak, E. & Mihaescu, G. (1972). Geflügelpocken bei einer Trappe (*Otis tarda*). *Diseases of Zoo Animals, 14th International Symposium, Wroclaw* (pp. 81–83).
- Cooper, J.E. (1969). Two cases of pox in recently imported peregrine falcons (*Falco peregrinus*). *Veterinary Record*, 85, 683–684.
- Coulston, F. & Manwell, R.D. (1941). Successful chemotherapy of a virus disease of the Canary. *American Journal of Veterinary Research*, 2, 101–107.
- Cox, W.R. (1980). Avian pox infection in a Canada goose (*Branta canadensis*). *Journal of Wildlife Diseases*, 16, 623–628.
- Crawford, J.A. (1986). Differential prevalence of avian pox in adult and immature California quail. *Journal of Wildlife Diseases*, 22, 564–566.
- Crawford, J.A., & Oates, R.M. (1979). Avian pox in California quail from Oregon. *Journal of Wildlife Diseases*, 15, 447–449.
- Cubillos, A., Schlatter, R. & Cubillos, V. (1979). Diftero-viruela aviar en Torcaza (*Columba araucana*, Lesson) del sur del Chile. *Journal of Veterinary Medicine B*, 26, 430–432.
- Curasson, G. (1946). Variole aviaire. *Maladies Infectieuses des Animaux Domestiques* Vol. I (pp. 152–160). Paris.
- Davidson, W.R., Kellogg, F.E. & Doster, G.I. (1980). An epornitic of avian pox in wild bobwhite quail. *Journal of Wildlife Diseases*, 16, 293–298.
- Dean, G. & Marshall, W.E. (1908). Observations indicating that the recent outbreak of diphtheria in the wood pigeon (*Columba palumbus*) is caused by a 'filter-passer'. *Journal of Pathology and Bacteriology*, 13, 29–33.
- Deem, S.L., Heard, D.J. & Fox, J.H. (1997). Avian pox in eastern screech owl and barred owls from Florida. *Journal of Wildlife Diseases*, 33, 323–327.
- Dickenson, E.M. (1967). Fowlpox in domestic poultry. *Station Bulletin. Oregon Agricultural Experiment Station, Corvallis*, 411, 5–27.
- Docherty, D.E. & Long, R.I.R. (1986). Isolation of a poxvirus from a house finch *Carpodacus mexicanus* (Müller). *Journal of Wildlife Diseases*, 22, 420–422.
- Docherty, D.E., Long, R.I.R., Flickinger, E.L. & Locke, L.N. (1991). Isolation of poxvirus from debilitating cutaneous lesions on four immature grackles (*Quiscalus* sp.). *Avian Diseases*, 35, 244–247.
- Donnelly, T.M. & Crane, L.A. (1984). An epornitic of avian pox in a research aviary. *Avian Diseases*, 28, 517–525.
- Dorrestein, G.M., van der Hage, M.H. & Grinwis, G. (1993). A tumour-like pox-lesion in masked bullfinches (*Pyrrhula erythaca*). *Proceedings of the 2nd meeting of the European Association of Avian Veterinarians, Utrecht* (pp. 232–240).
- DuBose, R.T. (1965). Pox in the sage grouse. *Bulletin of the Wildlife Disease Association*, 1, 6.
- Eberbeck, E. & Kayser, W. (1932). Über das Vorkommen von Pockenerkrankungen von Kanarienvögeln, Buchfinken und Sperlingen. *Archiv für wissenschaftliche und praktische Tierheilkunde*, 65, 307–310.
- Eberlein, R. (1894). Geflügel-diphtherie bei Rebhühnern. *Monatshefte für die praktische Tierheilkunde*, 5, 433–443.
- Edwards, G.R. (1955). Excrescences about the eyes and on the legs and feet of dunlocks. *British Birds*, 48, 186–187.
- Emanuelson, S., Carney, J. & Saito, J. (1978). Avian pox in two black-masked coureurs. *Journal of the American Veterinary Medical Association*, 173, 1249–1250.
- Emmel, M.W. (1930). Epidermoid cancers on the feet of wild birds. *Journal of the American Veterinary Medical Association*, 77, 641–644.
- Engelmann, F. (1928). *Die Raubvögel Europas*. Radebeul: Neumann-Neudamm, p. 691.
- Ensley, P.K., Anderson, M.P., Costello, M.L., Powell, H.C. & Cooper, R. (1978). Epornitic of avian pox in a zoo. *Journal of the American Veterinary Medical Association*, 173, 1111–1114.
- Fenner, F. (1959). Cited in: Harrigan *et al.* (1975).
- Fenner, F. (1996). Poxviruses. In B.N. Fields, D.M. Knipe, P.M. Howley, *et al.* (Eds.), *Virology* (pp. 2673–2702). Philadelphia: Lippincott-Raven Publishers.
- Findlay, G.M. (1928). A note on the cultivation of fowlpox. *British Journal of Experimental Pathology*, 9, 28–32.
- Fitzner, R.E., Miller, R.A., Pierce, C.A. & Rowe, S.E. (1985). Avian pox in a red-tailed hawk (*Buteo jamaicensis*). *Journal of Wildlife Diseases*, 21, 298–301.
- Gallagher, B. (1917). Epithelium contagiosum of quail. *Journal of the American Veterinary Medical Association*, 50, 366–369.
- Garner, M.M. (1989). Bumblefoot associated with poxvirus in a wild golden eagle (*Aquila chrysaetos*). *Companion Animal Practice*, 19, 17–20.
- Gerlach, H. (1986). Gesundheitsprobleme bei farmmäßig gehaltenen Virginischen Baumwachteln (*Colinus virginianus*). *Der praktische Tierarzt*, 67, 212, 215.
- Gerlach, H. (1994). Avipoxvirus. In B.W. Ritchie, G.J. Harrison, L.R. Harrison (Eds.), *Avian Medicine: Principles and Application* (pp. 865–874). Florida: Wingers Publishing.
- Giddens, W.E., Swango, L.J., Henderson, J.D., Lewis, R.A., Farner, D.S., Carlos, A. & Dolowy, W.C. (1971). Canary pox in sparrows and canaries (*Fringillidae*) and in weavers (*Ploceidae*). *Veterinary Pathology*, 8, 260–280.
- Goodpasture, E.W. & Anderson, K. (1962). Isolation of wild avian pox virus including both cytoplasmic and nuclear inclusions. *American Journal of Pathology*, 40, 437–453.
- Graham, C.L.G. (1978). Poxvirus infection in a spectacled Amazon parrot (*Amazona albifrons*). *Avian Diseases*, 22, 340–343.
- Gratzl, E. (1953). Diphtherie bei einem Steinadler. *Der Falkner*, 3, 2.
- Green, G.H. (1969). Suspected pox virus infection of a dunlin. *British Birds*, 62, 26–27.
- Greenwood, A.G. & Blakemore, W.F. (1973). Pox infection in falcons. *Veterinary Record*, 93, 468–469.
- Grimm, F. & Jacobi, J. (1977). Krankheiten bei Patienten der Klinik des Lehrstuhls für Krankheiten des Hausgefüglers, der Zier- und Wildvögel München, 1976. *Berliner und Münchener Tierärztliche Wochenschrift*, 90, 123–125.
- Groth, W. (1963). Ein Beitrag zur Geschwulstbildung bei wildlebenden Vögeln. *Berliner und Münchener Tierärztliche Wochenschrift*, 76, 192–194.
- Grzimek, B. (1939). Die Pockendiphtherie. *Krankes Geflügel* Vol 2 (pp. 56–63). Berlin: Pfennigstorf.
- Gurlt, (1849). Beiträge zur pathologischen Anatomie der Hausvögel. *Magazin für die gesamte Tierheilkunde*, 15, 72–84.
- Halliwell, W.H. (1972). Avian pox in an immature red-tailed hawk. *Journal of Wildlife Diseases*, 8, 104–105.
- Harrigan, K.E., Barker, I.K. & Studdert, M.J. (1975). Poxvirus infection in the white backed magpie and pox-like conditions in other birds in Australia. *Journal of Wildlife Diseases*, 11, 343–346.
- Harris, J.M., Williams, A.S. & Dutra, F.R. (1978). Avian pox in a group of common (California) murrelets (*Uria aalge*). *Veterinary Medicine/Small Animal Clinician*, 73, 918–919.
- Hartig, F. (1966). Verhütung und Bekämpfung der Kanarienspocken. *Kanarienfremd*, 19, 215–217.
- Hartig, F. & Frese, K. (1973). Tumorförmige Kanariens- und Taubenpocken. *Journal of Veterinary Medicine B*, 20, 153–160.
- Hartwig, H. & Lange, W. (1964). Vakzinierungsversuche bei Kanarienvögeln gegen Pocken. *Deutsche Tierärztliche Wochenschrift*, 71, 180–183.
- Heelsbergen, T. van (1929). *Handbuch der Geflügelkrankheiten und der Geflügelzucht* (pp. 230–262). Stuttgart: Ferdinand Enke Verlag.

- Heinricher, E. (1890). Mißbildungen am Schnabel und an den Ständern des Rebhuhnes. *Weidmanns Heil*, 10, 193–196.
- Herbst, W. & Krauss, H. (1989). Isolation of a poxvirus from a sparrow (*Passer domesticus*). *Journal of Veterinary Medicine B*, 36, 477–479.
- Herman, C.M., Locke, L.N. & Clark, G.M. (1962). Foot abnormalities in wild birds. *Bird-Banding*, 33, 191–198.
- Hertwigk (1849). Beiträge zu den Krankheiten der Vögel. *Magazin für die gesammte Thierheilkunde*, 15, 85–116.
- Heusinger, C.F. (1844). *Recherches de Pathologie Comparée* Vol. 1. Cassel: Henri Hotop.
- Hill, J.R. & Bogue, G. (1977). Epornitic of pox in a wild bird population. *Journal of the American Veterinary Medical Association*, 171, 993–994.
- Hill, J.R. & Bogue, G. (1978). Natural pox infection in a common murre (*Uria aalge*). *Journal of Wildlife Diseases*, 14, 337–338.
- Hitchner, S.B. & Clubb, S.L. (1980). Relationship between poxvirus of parrots and of other birds. *Proceedings 29th Western Poultry Disease Conference, Acapulco, Mexico* (pp. 149–151).
- Holt, G. & Krogsrud, J. (1973). Pox in wild birds. *Acta Veterinaria Scandinavica*, 14, 201–203.
- Horiuchi T., Kawamura, H., Shoya, S. & Umikawa, S. (1965). Avian pox of a japanese ptarmigan (*Lagopus mutus japonicus*). *National Institute of Animal Health Quarterly*, 5, 125–129.
- Hu Hongguan (1982). Pox in Phasianids. *Animal Science Veterinary Medicine, Nanjing*, 14, 236.
- Hulphers, G. (1943). Meddelande, fraan Svenska jagareförbundet s viltundersökning. *Svensk Jakt*, 81, 375–380.
- Ideris, A. & Ibrahim, A.L. (1986). Poxvirus infection in turkeys. *Kajian Veterinar*, 18, 85–87.
- Ihlenburg, H. (1972). Zur Pockeninfektion beim Wassergeflügel. *Diseases of Zoo Animals, 14th International Symposium, Wroclaw* (pp. 77–80).
- Irons, V. (1934). Cross-species transmission studies with different strains of bird-pox. *American Journal of Hygiene*, 20, 329–351.
- Iwata, Y., Fukushi, H., Suzuki, Y & Hirai, K. (1986). Poxvirus infection in Psittacine birds. *Research Bulletin of the Faculty of Agriculture, Gifu University*, 51, 201–205.
- Jacobsen, E.B., Raphael, B.L., Nguyen, H.T., Greiner, E.C. & Gross, T. (1980). Avian pox infection, aspergillosis and renal trematosis in a royal tern. *Journal of Wildlife Diseases*, 16, 627–631.
- Jansen, J. (1942). Pokken bij de kaww. *Tijdschrift vor Diergeneskunde*, 69, 128–131.
- Jenner, E. (1798). *An Inquiry into the Causes and Effects of the Variolae Vaccinae*. London.
- Jennings, A.R. (1954). Diseases in wild birds. *Journal of Comparative Pathology*, 64, 356–359.
- Johnson, B.J. & Castro, A.E. (1986). Canary pox causing a high mortality in an aviary. *Journal of the American Veterinary Medical Association*, 189, 1345–1347.
- Jong, de D.A. (1912). Epithelioma contagiosum bij Pyrrhula vulgaris. *Tijdschrift Veertsenigk*, 39, 734–736.
- Kaleta, E.F. & Ebert, U. (1969). Zur Prophylaxe und Therapie der Kanarienvogel. *Deutsche tierärztliche Wochenschrift*, 76, 690–691.
- Kaleta, E.F., & Marschall, H.-J. (1982). Pocken beim Kapuzenzeisig (*Carduelis cucullata*). *Journal of Veterinary Medicine B*, 29, 776–781.
- Karpinski, L.G. & Clubb, S.L. (1986). An outbreak of pox in imported mynahs. *Annual Meeting of the Association of Avian Veterinarians, Miami*, 35–37.
- Karstad, L. (1965). An outbreak of pox in impeyan pheasants. *Bulletin of the Wildlife Disease Association*, 1, 3.
- Kawashima, H. (1962). Die Forschung über die Geflügelpocken. *Japanese Journal of Veterinary Sciences*, 24, 19–28, 53–64, 122–132, 225–235.
- Kear, J. & Brown, M. (1975). A pox-like condition in the Hawaiian goose. *International Zoo Yearbook of the Zoological Society of London*, 16, 133–134.
- Keymer, I.F. & Blackmoore, D.K. (1964). Diseases of the skin and soft parts of wild birds. *British Birds*, 57, 175–179.
- Kiel, H. (1985). Pockeninfektion bei Jagdfalke. *Proc. of the II DVG-Tagung über Vogelkrankheiten, München*, 202–206.
- Kikuth, W. & Gollub, H. (1932). Versuche mit einem filtrierbarem Virus bei einer übertragbaren Kanarienvogelkrankheit. *Zentralblatt für Bakteriologie*, 125, 313–320.
- Kirmse, P. (1966). Experimental pox infection in waterfowl. *Bulletin of the Wildlife Disease Association*, 2, 209–216.
- Kirmse, P. (1967). Host specificity and pathogenicity of pox viruses from wild birds. *Bulletin of the Wildlife Disease Association*, 5, 376–385.
- Kirmse, P. & Loften, H. (1969). Avian pox in migrant and native birds in Panama. *Bulletin of the Wildlife Disease Association*, 5, 376–385.
- Kitzing, D. (1980). Neuere Erkenntnisse über das Falkenpockenvirus. *Der praktische Tierarzt*, 61, 952–956.
- Kossack, C.W. & Hanson, H.C. (1954). Fowlpox in the mourning dove. *Journal of the American Veterinary Medical Association*, 124, 199–201.
- Kraft, V. & Teufel, P. (1971). Nachweis eines Pockenvirus bei Zwergpapageien (*Agapornis personata* und *Agapornis roseicollis*). *Berliner und Münchener Tierärztliche Wochenschrift*, 84, 83–87.
- Kroesen, G. (1977). Cited in Minsky & Petrak (1982).
- Kuntze, A., Schröder, H.-D. & Ippen, R. (1968). Geflügelpocken bei Breitschwingenbussarde n (*Buteo platypterus*). *Diseases of Zoo Animals, 10th International Symposium, Salzburg* (pp. 161–163).
- Labisky, R.F. & Mann, S.H. (1961). Observation of avian pox in a yellow-shafted flicker. *The Auk*, 78, 642.
- Landolt, M. & Kocan, R.M. (1976). Transmission of avian pox from starlings to Rothchild's Mynahs. *Journal of Wildlife Diseases*, 12, 353–356.
- Landowska-Plazewska, E. & Plazewski, L. (1968). Ausbruch von Vogelpocken bei Humboldtpinguinen im Warschauer Zoo. *Diseases of Zoo Animals, 10th International Symposium, Salzburg* (pp. 157–159).
- Leibovitz, L. (1969). Natural occurrence and experimental study of pox and Haemoproteus infections in a mute swan. *Bulletin of the Wildlife Disease Association*, 5, 130–136.
- Locke, L.N. (1961). Pox in mourning doves in the United States. *Journal of Wildlife Management*, 25, 211–212.
- Locke, L.N., Herman, C.M. & King, E.S. Jr. (1960). Case report: pox in the mourning dove in Maryland. *Avian Diseases*, 4, 198–202.
- Locke, L.N., Wirtz, W.O. & Brown, E.E. (1965). Pox infection and secondary cutaneous mycosis in a red-tailed tropicbird. *Bulletin of the Wildlife Disease Association*, 1, 60–61.
- Loir, A. & Ducloux, E. (1894). Contribution a l'étude de la diphtérie aviaire en Tunisie. *Annales de l'Institute Pasteur*, 8, 599–607.
- Loupal, G., Schönbauer, M. & Jahn, J. (1985). Pocken bei Zoo- und Wildvögeln. *Journal of Veterinary Medicine B*, 32, 326–336.
- Lüthen, W. (1983). Untersuchungen über die Bildung präzipitierender Antikörper bei der Pockenerkrankung der Tauben. *Journal of Veterinary Medicine B*, 15, 772–781.
- Maggiara, A. & Valenti, G.L. (1903). Über eine infektiöse Krankheit beim Genus *Turdus*. *Zentralblatt für Bakteriologie*, 34, 326–335.
- Mani, P., Fabiani, O., Bellini, S. & Fontanelli, M. (1990). Caratteristiche di crescita, morfologico-strutturali ed antigeniche di uno stipite di avipoxvirus isolato dalla starna (*Perdix perdix*). *Zootecnica International* 28. *Convegno Forli*, 147–152.
- Mathur, B.B.L., Verma, K.C., Agarwal, K. & Kumar, S. (1972). Serological survey for the detection of certain common respiratory infections in migratory birds: a note. *Indian Journal of Animal Science*, 42, 144–145.
- McDonald, S.E., Lowenstine, L.J. & Ardans, A.A. (1981). Avian pox in blue-fronted Amazon parrots. *Journal of the American Veterinary Medical Association*, 179, 1218–1222.
- Mégnin, M.P. (1878). Observations de pathologie ornithologique. *Recueil de Médecine Vétérinaire*, 6, 1052–1063.
- Mercier, L. & Poisson, R. (1923). Un cas d'épithélioma contagieux chez un oiseau sauvage. *Compte rendu de seanas de la Societe de biologie*, 89, 1196–1198.
- Meurer, J. (1991). Die Pocken der Vögel: Ätiologie, Wirtsspektrum und Epizootologie – eine veterinärhistorische Studie. Dissertation thesis, Gießen, Germany.
- Michel, H. & Lindner, K.E. (1964). Über das Auftreten von Pocken-erkrankungen bei Kanariern im Raum Leipzig. *Monatshfte für die Veterinärmedizin*, 19, 902–904.

- Mikaelian, I. & Martineau, D. (1996). Cutaneous avian pox in a house sparrow. *Canadian Veterinary Journal*, 37, 434.
- Miles, J.A.R., & Stocker, M.G.P. (1948). Puffinosis, a virus epizootic of the Manx Shearwater (*Puffinus puffinus*). *Nature*, 161, 1016–1017.
- Minsky, L. & Petrak, M.L. (1982). Diseases of the digestive system. In M.L. Petrak (Ed.), *Diseases of Cage and Aviary Birds* (pp. 432–448). Philadelphia: Lea & Febiger.
- Moffat, R.E. (1972). Natural pox infection in a golden eagle. *Journal of Wildlife Diseases*, 8, 161–162.
- Montgomery, R.D., Chowdury, K.A. & Reese, J.G. (1980). Avian pox in a whistling swan. *Journal of the American Veterinary Medical Association*, 177, 930–931.
- Moss, B. (1996). Poxviridae: the viruses and their replication. In B.N. Fields, D.M. Knipe, P.M. Howley, et al. (Eds), *Virology* (pp. 2637–2701). Philadelphia: Lippincott-Raven Publishers.
- Morton, J.K. & Dietrich, R.A. (1979). Avian pox infection in an American green-winged teal (*Anas crecca carolinensis*). *Journal of Wildlife Diseases*, 15, 451–453.
- Murphy, F.A., Fauquet, C.M., Bishop, D.H.L., Ghabrial, S.A., Jarvis, A.W., Martelli, G.P., Mayo, M.A., Summers, M.D., et al. (1995). Avipoxvirus. *Virus taxonomy, classification and nomenclature of viruses* (p. 85). Vienna, New York: Springer.
- Musselmann, T.E. (1928). Foot disease of shipping sparrow (*Spizella passerina*). *The Auk*, 45, 137–147.
- Nuttall, P.A., Brooke, M.D. & Rerrins, C.M. (1985). Pox virus infection in the Manx Shearwater (*Puffinus puffinus*). *Journal of Wildlife Diseases*, 21, 120–124.
- Olmos, P.R., Martinez, B.L., Lopez, J.E. & Martinez, L.P. (1986). Patogenicidad y antigenidad de un aislamiento sospechoso de viruela de los loros (*Amazona stiva*), en gallinas. *Veterinario, Mexico*, 17, 104–109.
- Oros, J., Rodriguez, F., Bravo, C. & Fernandez, A. (1997). Debilitating cutaneous poxvirus infection in a Hodgson's grandala (*Grandala coelicolor*). *Avian Diseases*, 41, 481–483.
- Pandey, K.D. & Mallick, B.B. (1974). Studies on pox infection in turkeys. *Indian Veterinary Journal*, 51, 33–35.
- Pearson, G.L. & Pass, D.A. (1975). Fatal pox infection in a rough-legged hawk. *Journal of Wildlife Diseases*, 11, 224–228.
- Perelman, B., Gur-Lavie, A. & Samberg, Y. (1988). Pox in ostriches. *Avian Pathology*, 17, 735–739.
- Petrak, M.L. (1969). Canary pox. *Diseases of Cage and Aviary Birds* (pp. 373–376). Philadelphia, Lea & Febiger.
- Pilaski, J., Rotschuh, L. & Encke, W. (1990). Ein Pockenausbruch in einem Ziervogelbestand des Krefelder Zoologischen Gartens. *Verhandlungsberichte des 32. Internationalen Symposiums über die Erkrankungen der Zoo- und Wildtiere, Eskilstuna* (pp. 157–164).
- Polowinkin, P. (1901). Beitrag zur pathologischen Anatomie der Taubenpocke. *Archiv für Tierheilkunde*, 27, 86–109.
- Pomeroy, D.E. (1962). Birds with abnormal bills. *British Birds*, 55, 49–72.
- Poonacha, K.B. & Wilson, M. (1981). Avian pox in pen-raised bobwhite quail. *Journal of the American Veterinary Medical Association*, 176, 1264–1265.
- Poulding, R.H. (1960). Fowlpox in a carrion crow. *British Birds*, 53, 174–175.
- Power, D.M. & Human, G. (1974). A local occurrence of avian pox in the house finch. *Journal of Wildlife Diseases*, 10, 262–263.
- Quaglio, G. (1959). Cloacite difterioide contagiosa nell'antria. *Atti Società Italiana della Scienze Veterinarie*, 13, 599.
- Quinn, P.J. (1971). Suspected case of bird pox in a small population of New Zealand pipits. *Notornis*, 18, 217.
- Raidal, S.R., Gill, J.H. & Cross, G.M. (1996). Pox in ostrich chicks. *Australian Veterinary Journal*, 73, 32–33.
- Rao, C.G. (1965). Studies on pox in ducks in Andhra Pradesh. *Indian Veterinary Journal*, 42, 151–155.
- Ratcliff, H.L. (1967). *Report of the Penrose Research Laboratory of the Zoological Society* (pp. 11–12). Philadelphia.
- Reed, W.M. & Schrader, D.L. (1989). Pathogenicity and immunogenicity of mynah pox virus in chicken and bobwhite quail. *Poultry Science*, 68, 631–638.
- Reis, J. & Nobrega, P. (1937). Sobre um virus tripathogenico de bouba de canario. *Archivos do Instituto Biologico, Sao Paulo, Brasilia*, 8, 211–214.
- Renesse, J. (1897). Diphteritis bei Hühnern und Fasanen. *Oesterreichische Monatsschrift für Tierheilkunde*, 371–372.
- Rinaldi, A., Mahnel, H., Nardelli, L., Andelli, G.C., Cervio, G. & Valeri, A. (1972). Charakterisierung eines Wachtelpockenvirus. *Journal of Veterinary Medicine B*, 19, 199–212.
- Röll, M.F. (1869). Die Pocken des Geflügels. *Lehrbuch der Pathologie und Therapie der Haustiere* Vol 2 (pp. 406–407). Wien, Wilhelm Braumüller-Verlag.
- Salhoff, S. (1937). Pockendiphterite bei Wildtauben. *Tierärztliche Wochenschrift*, 53, 349.
- Samour, J.H. & Cooper, J.E. (1993). Avian pox in birds of prey (Order Falconiformes) in Bahrain. *Veterinary Record*, 132, 343–345.
- Sato, T., Sugimori, T. & Ishii, S. (1962). Etiologic study on an outbreak of canary pox in Japan 1958. *Japanese Journal of Experimental Medicine*, 32, 247–261.
- Schäff, E. (1890). Über eine eigentümliche Krankheit der Rebhühner. *Deutsche Jägerzeitung*, 13, 558–559.
- Schauberg, von, R. (1901). Eine monstrose Schnabelbildung. *Ornithologische Monatsberichte*, 9, 18–19.
- Seidel, B. (1972). Zu einigen Erkrankungen der Haut und ihrer Anhangsorgane bei Zootieren. *Diseases of Zoo Animals, 14th International Symposium, Wrocław* (pp. 171–181).
- Sharma, V.K., Simon, J. & Hanson, L.E. (1968). Histologic study of tissue reaction in canaries, chicken embryos infected with a pox agent. *Avian Diseases*, 12, 594–606.
- Sibley, C.G. & Monroe, B.L.Jr. (1990). *Distribution and Taxonomy of Birds of the World*. New Haven and London: Yale University Press.
- Sileo, L., Sievert, P.R. & Samuel, M.D. (1990). Causes of mortality of albatross chicks at midway atoll. *Journal of Wildlife Diseases*, 26, 329–338.
- Silva, R.F. (1996). Recombinant poultry vaccines: cornucopia or hollow promises? *AgBiotech News and Information*, 8, 145N–150N.
- Simpson, C.F., Forrester, D.J. & Nebitt, S.A. (1975). Avian pox in Florida sandhill cranes. *Journal of Wildlife Diseases*, 11, 112–115.
- Spinola, W.T.J. (1858). *Handbuch der speciellen Pathologie und Therapie für Thierärzte* Vol. II. Berlin: Hirschwald.
- Stadie, R. (1931). Geflügelpockenkrankheit bei Rebhühnern. *Deutsches Weidwerk*, 36, 572.
- Stannard, L.M., Marais, D., Kow, D & Dumbell, K.R. (1998). Evidence for incomplete replication of a penguin poxvirus in cells of mammalian origin. *Journal of General Virology*, 79, 1637–1646.
- Stoddard, H.L., (1931) Cited in: Davidson et al. (1980).
- Sutton, R.H. & Fillipich, L.J. (1983). Poxvirus infection in a black-faced cockoo-shrike (*Coracina novaehollandiae*). *Australian Veterinary Journal*, 60, 673–675.
- Syvertson, J.T. & McTaggart Cowan, I. (1944). Bird pox in the sooty grouse (*Dendragapus fuliginosus fuliginosus*) with recovery of the virus. *American Journal of Veterinary Research*, 5, 215–222.
- Tangredi, B.P. (1974). Avian pox in a mourning dove. *Veterinary Medicine/Small Animal Clinician*, 69, 700–701.
- Tantawi, H.H., Al Sheikhly, S. & Hassan, F.K. (1981). Avian pox in Buzzard (*Accipiter nisus*) in Iraq. *Journal of Wildlife Diseases*, 17, 145–146.
- Tietz, G. (1932). Über die Empfänglichkeit verschiedener Vogelarten für eine Infektion mit originärem Hühner- und Taubenpockenvirus. *Archiv für wissenschaftliche und praktische Tierheilkunde*, 65, 244–255.
- Tikasingsh, E.S., Worth, C.B., Spence, L. & Aitken, T.H.G. (1982). Avian pox in birds from Trinidad. *Journal of Wildlife Diseases*, 18, 133–139.
- Tripathy, D.N. & Reed, W.M. (1997). Pox. In B.W. Calnek, et al. (Eds), *Diseases of Poultry* (pp. 643–659). Ames, IA: Iowa State Press.
- Tripathy, D.N., Schnitzlein, W.M., Morris, P.J., Janssen, D.L., Zuba, J.Z., Massey, G & Atkinson, C.T. (1998). Characterization of poxviruses from Hawaiian forest birds. *XIIIth International Poxvirus Symposium, 6–10 June 1998 St. Thomas, Virgin Islands* (p. 29).
- Tsai, S.S., Chang, T.C., Yang, S.F., Chi, Y.C., Cher, R.S., Chien, M.S. & Itakura, C. (1997). Unusual lesions associated with avian poxvirus infection in rosy-faced lovebirds (*Agapornis roseicollis*). *Avian Pathology* 26, 75–82.

- Vogelsang, E.G. (1938). Viruela aviaria en el Nandú (Rhea americana). *La Semana Médica*, 45, 556–557.
- Warner, R.E. (1968). The role of introduced diseases in the extinction of the endemic Hawaiian avifauna. *Condor*, 70, 101–120.
- Weiss (1970). Cited in: A. Mayr & H. Mahnel (1970). Charakterisierung eines vom Rhinoceros isolierten Hühnerpockenvirus. *Archiv der gesamten Virusforschung*, 31, 51–60.
- Westerskov, K. (1953). Bird pox in a New Zealand pipit. *Notornis*, 5, 168–170.
- Wheeldon, E.B., Sedgwick, C.J. & Schulz, T.A. (1985). Epornitic of avian pox in a raptor rehabilitation center. *Journal of the American Veterinary Medical Association*, 187, 1202–1204.
- Wilson, M.H. & Crawford, J.A. (1988). Poxvirus in scaled quail and prevalences of poxvirus-like lesions in northern bobwhites and scaled quail from Texas. *Journal of Wildlife Diseases*, 24, 360–363.
- Wingate D.B., Barker, J.K. & King, N.W. (1980). Poxvirus infection of the white-tailed tropicbird (*Phaeton lepturus*) in Bermuda. *Journal of Wildlife Diseases*, 16, 619–622.
- Winteroll, G., Mousa, S. & Akrae, M. (1979). Pockenisolat aus Psittaciden und Falken - Nähere Charakterisierung. *DVG-Fachgruppe Geflügel - Tagung Krankheiten der Vögel, München*, 117–125.
- Wolffhügel (1919). Cited in: Kohn, F.G. (1927). Epitheliosa cutis beim Rebhuhn in freier Wildbahn. *Prager Archiv für Tiermedizin*, 7, 181–190.
- Wolters, H.E. (1975–1982) *List of Birds of the World*. Hamburg and Berlin: Paul Parey.
- Woodruff, G. M. & Goodpasture, E. W. (1931). The susceptibility of the CAM of chick embryos to infection with the fowlpox virus. *American Journal of Pathology*, 7, 209–222.
- Worth, C.B. (1956). A pox virus of the slate-colored Junco. *The Auk*, 73, 230–234.
- Zangger, N. & Muller, M. (1990). Endemic poxvirus infection in white storks (*Ciconia ciconia*) and black storks (*Ciconia nigra*) in Switzerland. *Schweizerisches Archiv für Tierheilkunde*, 132, 135–138.
- Zhang-DeLing, Jia-Jun Yuan, Chen FuWang, Wie-WanRen, Zhang-Cheng Hu, Wu-LianHua (1996). Serological investigation of 16 infectious diseases in rare birds in the Lhazou area. *Chinese Journal of Veterinary Medicine*, 22, 22.

RÉSUMÉ

Espèces aviaires infectées par les poxvirus aviaires

Une synthèse bibliographique relative à la description des poxvirus chez les différentes espèces d'oiseaux est présentée. Les premières publications en Europe datent des années 1850. A cette époque la variole était définie comme une entité pathologique diagnostiquée sur la base des symptômes cliniques. Ce n'est que plus tard en 1877 qu'un diagnostic étiologique a pu être établi par la visualisation d'agrégats visibles au microscope, correspondant aux corps d'inclusion de

Bollinger. Beaucoup plus tard dans les années 1950, les méthodes d'isolement du virus et d'observation directe du virus en microscopie électronique ont représenté une avancée importante pour le diagnostic.

Ainsi la taxonomie des poxvirus aviaires, les caractéristiques du virus, les symptômes, les méthodes de prévention et les techniques de diagnostic sont brièvement décrits.

Parmi les 9000 espèces d'oiseaux, il a été rapporté que 232 espèces appartenant à 23 ordres ont été l'objet d'une infection naturelle par un poxvirus. Il est cependant probable que beaucoup plus d'oiseaux sont sensibles aux poxvirus aviaires.

ZUSAMMENFASSUNG

Vogelwirtsspektrum der Avipoxviren

Es wird ein Überblick über das Vorkommen von Pockenviren bei verschiedenen Vogelarten gegeben. Die ersten Publikationen erschienen in Europa um 1850. Zu der Zeit wurden Pocken auf der Grundlage der klinischen Symptome als eine bestimmte Krankheits-Entität diagnostiziert, wohingegen später der Nachweis von Bollinger'schen Einschlusskörperchen (1877) eine ätiologische Diagnose durch mikroskopisch sichtbare Virusaggregate ermöglichte. Die Virusisolierung in embryonierten Hühnereiern und die direkte Elektronenmikroskopie gewannen in den 1950er Jahren Bedeutung als diagnostische Hilfsmittel. Kurz beschrieben werden auch die Vogelpockenvirus-Taxonomie, die Virus-Charakteristika, die klinischen Symptome, Präventionsmethoden und diagnostische Verfahren.

Von den ungefähr 9000 Vogelarten ist über etwa 232 Arten in 23 Ordnungen berichtet worden, dass sie eine natürliche Pockenvirusinfektion bekommen haben. Es ist jedoch wahrscheinlich, dass viel mehr Vögel für Vogelpockenviren empfänglich sind.

RESUMEN

Hospedadores aviares de avipoxvirus

Se realiza una revisión de la incidencia de la infección por poxvirus en diferentes especies aviares. Las primeras publicaciones aparecieron en Europa alrededor de 1850; en aquella época la viruela, como entidad patológica definida, se diagnosticaba mediante el cuadro clínico mientras que más tarde, en 1877, la detección de los cuerpos de inclusión de Böllinger permitía un diagnóstico etiológico mediante la visualización microscópica de éstos. El aislamiento vírico en huevos embrionados de pollo y la observación directa mediante técnicas de microscopía electrónica adquirieron importancia en la década de los 50. También se describe brevemente la taxonomía y características de los avipoxvirus así como los signos clínicos, métodos de prevención y de diagnóstico.

De las aproximadamente 9000 especies aviares existentes, en cerca de 232 especies pertenecientes a 23 ordenes diferentes, se han descrito infecciones naturales por pox virus. Sin embargo es probable que muchas más sean susceptibles a los avi poxvirus.