6
Avian Pox

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INTRODUCTION

Avian pox, a viral disease of birds, is caused by one of the larger viruses of the poxvirus group. This relatively slow-developing disease is characterized in birds by discrete, proliferative lesions on the skin of the toes, legs, or head, and/or mucous membranes of the mouth and upper respiratory tract. Systemic infections may also occur (Tripathy and Reed 2003). It is comparable to the pox infections of wild mammals (see Robinson and Kerr 2001), of domestic mammals (for example, sheep sore-mouth, swine poxes; see Tripathy et al. 1981), and those of man (smallpox). This subgroup of avipoxviruses contains a number of species and strains that vary in their pathogenicity and host specificity.

This widespread avian disease has been found in a large number of bird families, with some (for example, Phasianidae, Emberizidae) seeming more susceptible than others. In most birds avian pox infections are mild and rarely result in death. However, when lesions are on the eyelids or mucous membranes of the oral and/or respiratory cavities, mortality can be high. Those avian populations that have been isolated on islands (for example, Canary Islands, Hawaiian island chain, Galapagos Islands) are more greatly impacted than are birds in continental situations where the hosts, vectors, and viruses have had a longer co-evolutionary history (Vargas 1987; van Riper et al. 2002).

As with many other diseases that are density dependent, avian pox transmission is enhanced with increasing vector and/or host densities. Therefore, this disease is found to have a greater significance in captive situations such as zoos (Fowler 1981), bird rehabilitation centers (Wheeldon et al. 1985), and game farms (Karstad 1965), where birds occur in much higher densities than in the wild. In the wild, the warmer and mesic regions of the world support more potential vectors, thus in these areas the prevalence of avian pox is higher, particularly in flocking wild birds (Annuar et al. 1983; Forrester 1991).

SYNONYMS

Avian pox, pox, bird pox, poxvirus infection, fowl pox, avian diptheria, contagious epithelioma, molluscum contagiosum, Gefluegelpocken (German), viruela aviar (Spanish), variole aviaire (French), bouba (Portuguese).

HISTORY

Avian pox infections were among the earliest described avian diseases (for example, Heusinger 1844) because of the ease in identification of the obvious external lesions. Bollinger (1873) and Borrel (1904) were the first to demonstrate a relationship between histologic lesions and structure of inclusion bodies, setting the stage for histopathologic techniques being employed to confirm visual diagnoses. Evidence that avian poxvirus was associated with the inclusion bodies and was the etiological agent was conclusively demonstrated by Woodruff and Goodpasture (1930).

During the mid-twentieth century, pox virus identification focused on virus culture on the ectodermal chorioallantoic membrane (CAM) of embryonated chicken eggs (Cunningham 1966) and remains today one of the identification tools of choice. Later during the 1950s, electron microscopy gained importance as a diagnostic tool. Today, identification of avian pox strains has moved into the molecular arena, with the use of Gel-electrophoresis and PCR (Polymerase chain reaction) analyses of mitochondrial DNA sequences (Schnitzlein et al. 1988).

The literature on avian pox in wild birds was summarized by Kirmse (1967a), Karstad (1971), and then Bolte et al. (1999). Over the past half-century, the majority of scientific papers on avian pox infections in wild birds have come from case reports of usually singly infected individuals (for example, Simpson et al. 1975; Fitzner et al. 1985). There have been a smaller number of studies (for example, Davidson et al. 1980; Tikasingh et al. 1982; McClure 1989; Forrester 1991, 1992; van Riper et al. 2002; Atkinson et al. 2005, Smits et al. 2005) directed toward questions at the overall host and community population levels. The more recent work on avian pox has focused on areas of molecular structure within wild bird strains when compared to fowlpox virus (for example, Tripathy et al. 2000; Tripathy and Reed 2003), the influence of avian pox on House Finch (*Carpodacus mexicanus*) plumage coloration (for example, Zahn and Rothstein, 1999), and the continued impact on native island birds (Medina et al. 2004; Atkinson et al. 2005).

DISTRIBUTION

The geographic distribution of avian poxviruses is worldwide, with the exception that there are no published records from wild birds with this disease in the Arctic or Antarctic, or some of the more remote regions of the world (Figure 6.1). Published information is greatly skewed geographically to those localities where scientists have been actively working on this disease (for example, North America, Australia, Europe, Asia), thus the few existing published reports from wild birds throughout much of Africa and South America. The current state of our knowledge on avian pox in wild bird populations generally reveals a higher prevalence in temperate and warmer areas of the globe.

Even within continents, avian pox distributions tend to be confined to localized regions. For example, Forrester (1991) examined the distribution of avian pox in Wild Turkeys (*Meleagris gallopavo*) over North America and found the disease concentrated in the moister and warmer southeastern United States, even though Wild Turkeys occur in every state except Alaska. Where avian pox has been introduced to remote islands (for example, Hawaii, Galapagos, Canary Islands), the disease rapidly spreads, resulting in much higher prevalences in the native avifauna than occurs among the introduced avian species (Warner 1968; Vargas 1987; VanderWerf 2001; van Riper et al. 2002; Atkinson et al. 2005, Smits et al. 2005).

HOST RANGE

There are now recognized approximately 183 families and 9,800 species of birds (Clements 2000). Most avian species, if adequately exposed, are susceptible to one or more of the avian poxvirus strains and/or species. Kirmse (1967a) reported naturally occurring avian pox infections in 60 species of wild birds, comprising 20 families. Bolte et al. (1999) has provided a more recent update, of which they found about 20 orders recorded with *Avipoxvirus* infections. We have found records of poxvirus infections in 278 bird species from 70 families and 20 orders (see Table 6.1, at the end of this chapter). It is interesting that avian pox has never been reported from the Tinamous (Tinamiformes), Loons (Gaviiformes), Nightjars (Caprimulgiforme*s*), and Kingfishers (Coraciiformes). It has been only recently that avian pox has been regularly observed in wild waterfowl (Morton and Dietrich 1979; Cox 1980), although it has long been known that domestic ducks and geese are susceptible

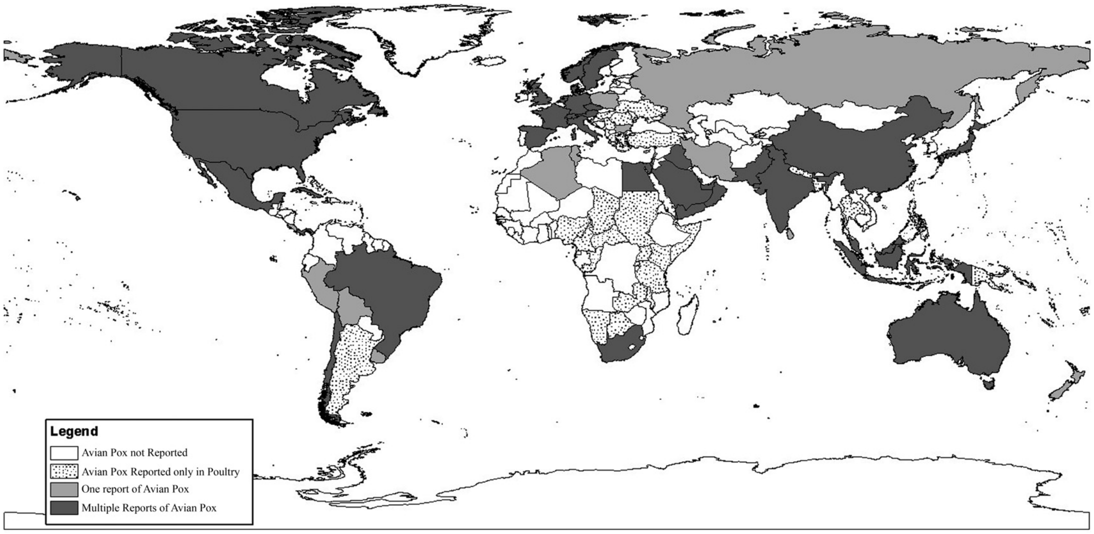


Figure 6.1. Distribution of countries throughout the world in which avian pox has been reported in birds. Those countries with heavy stippling are ones in which avian pox has been reported from multiple bird families; moderate stippling indicates reporting from a single record; and the absence of stippling indicates that avian pox has not positively been identified in those countries.

(Kirmse 1967b). This same pattern holds true for the Falconiformes, Columbiformes, and Psittaciformes (Cooper 1978; Hitchner and Clubb 1980; Petrak 1982), where infections are now being reported from wild birds when, heretofore, earlier cases were reported only infrequently from captive situations.

ETIOLOGY

Avian pox is caused by viruses of the genus *Avipoxvirus* in the family Poxviridae (Murphy et al. 1999). The source and reservoir of avian pox is primarily infected birds but also can be related to viable viruses present on exfoliated scabs and contaminated objects (for example, perches) in the environment or aviary. The virus particle is large, about 150 to 250 nm by 265 to 350 nm in size, and is oval or brick-shaped and covered with irregularly spaced surface knobs (Wilner 1969). Coupar et al. (1990) identified the genome of the avian poxvirus as composed of a single double-stranded, 300 Kb DNA molecule. This DNA-containing, enveloped virus develops in the cytoplasm of infected avian epithelial cells. Infected cells characteristically contain large acidophilic intracytoplasmic inclusions (Bollinger bodies). Electron microscopy of avian pox inclusions reveals viral particles embedded in a rather homogeneous matrix, typical of poxviruses in general (Figure 6.2).

Avian poxviruses can withstand extreme environmental conditions, particularly desiccation, sometimes surviving on perches and in dried scabs for months and years (Tripathy 1993). Much of this can be attributed to the very large size of the virus. The virus is resistant to ether, with the pigeonpox virus being resistant to both chloroform and ether (Tantwai et al. 1979). Andrews et al. (1978) demonstrated that the virus can withstand 1% phenol and 1:1,000 formalin for nine days, but that 1% potassium hydroxide or heating to 50°C for 30 minutes (or 60°C for eight minutes) inactivated the virus.

Avian poxviruses have been classified according to their hosts of origin (Cunningham 1972). Tripathy (1993) listed 13 recognized species. Based on host specificity, poxvirus strains have been identified and classified as mono-, bi-, or tri-pathogenic. A Northern Flicker *(Colaptes auratus)* strain is a good example of a monopathogenic strain because among 19 species of inoculated wild and domestic birds, only the Northern Flicker was found susceptible to infection (Kirmse

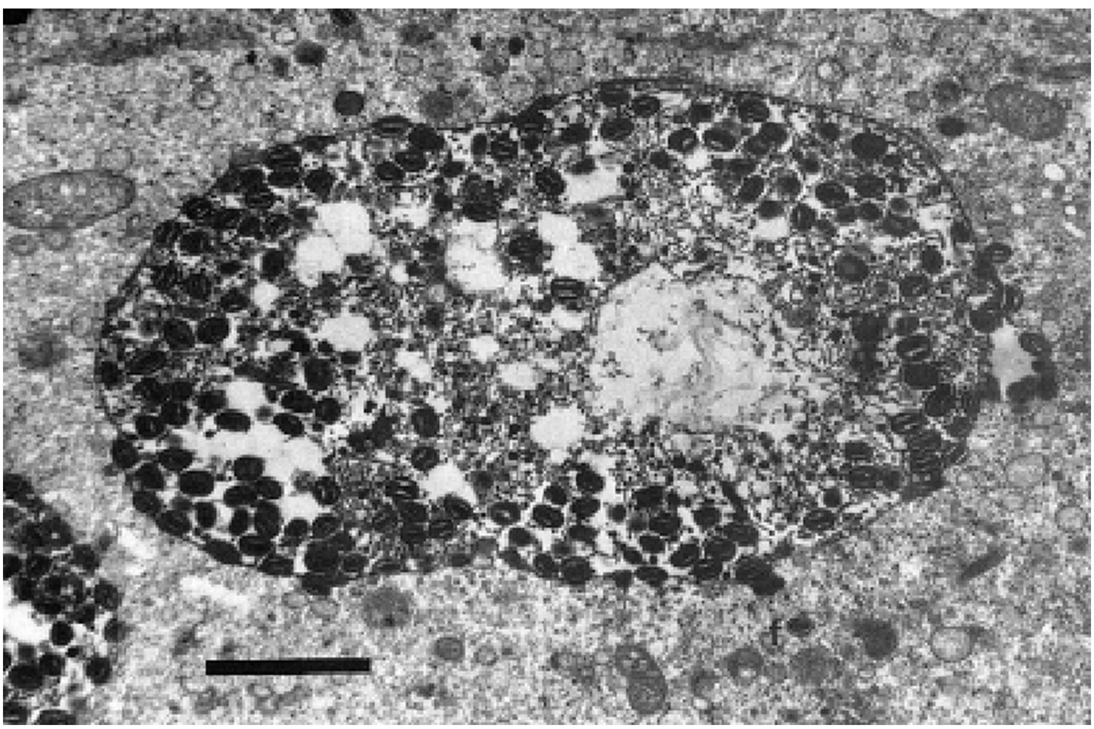


Figure 6.2. An electron micrograph of avian poxvirus inclusion bodies in an Imperial Eagle (*Aquila heliaca*), with some exhibiting the classic "dumbbell"-shaped central core. (Figure published in Hernandez et al. [2001] and reprinted with permission of the author and *Journal of Avian Pathology.*)

1966). More often, avian pox strains are pathogenic for several species (for example, Tripathy et al. 2000).

Karstad (1971) argued that strains adapted to various avian hosts were not different enough to consider them valid poxvirus species because their basic virus characteristics appeared to be identical. Utilizing recent increases in the sophistication of molecular research, Francki et al. (1991) listed fowlpox, turkeypox, canarypox, pigeonpox, quailpox, sparrowpox, starlingpox, juncopox, and psittine poxviruses as valid species. To this species list, Tripathy (1993) added peacockpox, penguinpox, mynahpox, and albatrosspox viruses. Even with this extensive list of avian pox species, the majority of our information on this disease is the result of studies that have come from research on fowlpox in domestic poultry, principally chickens (*Gallus gallus*).

EPIZOOTIOLOGY

There are a number of biotic and abiotic factors that affect the distribution and prevalence of avian pox. Weather (for example, temperature, moisture) conditions (van Riper et al. 2002), vector numbers (Akey et al. 1981), host densities (Forrester and Spalding 2003), and numbers of poxviruses that are present all interact in a synergistic fashion to mold the epizootiological framework of avian pox distribution among bird species and their populations. These four factors also determine in a large part the character and primary causes of an avian pox outbreak. The most important factors influencing avian pox epizootiology are host density, host susceptibility, and numbers of vectors that occur within a certain space and time of the environment (Forrester 1991; van Riper et al. 2002).

Avian pox can occur at any time of the year in wild birds. In temperate regions, where vectors are not active during the winter period, infections occur primarily in the summer (Arnall and Keymer 1975) and early fall (Tripathy 1993). In warmer regions of the world, avian pox is reported throughout the entire year, but most often during fall and winter months. It is at this time that host densities are highest because young-of-the-year are present, complemented by the post breeding flocking behavior of many bird species (van Tyne and Berger 1976; Pettingill 1985). In addition, those vectors that are specific to poxvirus transmission are usually most abundant during the fall and early winter period (Akey et al. 1981; LaPointe 2000). For example, McClure (1989) reported avian pox throughout the year in a population of House Finches from California, but highest prevalence was during the fall and winter. Forrester (1991) found fall peaks of infection in Wild Turkeys from Florida that occurred subsequently to peak mosquito activities (Figure 6.3). In Hawaii, van Riper et al. (2002) found fall and early winter peak infections. In temperate regions of North America, during the fall and early winter the cutaneous form of avian pox is most common, whereas late in the winter the diphtheritic form predominates (Cunningham 1972).

Poxviruses can be transmitted in a number of different ways. Even though they are unable to penetrate unbroken skin, small abrasions are sufficient to permit

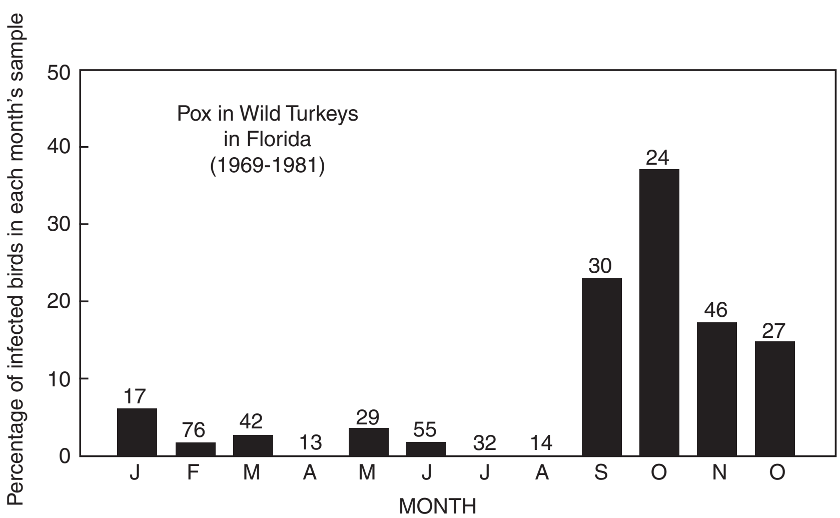


Figure 6.3. Seasonal occurrence of avian pox in Wild Turkeys from 12 counties in Florida, 1969–1981. The numbers on top of each bar indicate sample size. (From Forrester [1991] and reprinted with permission of Bulletin of the Society of vector Ecology.)

infection. The most common method of transmission is by means of biting insects such as mosquitoes, mites, midges, and/or flies. At the time of year when vectors are at the highest numbers, avian pox transmission is greatest (Akey et al. 1981; Forrester 1991). Many biting insects have been shown to be mechanical vectors only, transferring virus from infected to susceptible birds by contamination of their skin-piercing mouthparts (Locke et al. 1965; Shirinov et al. 1972; Akey et al. 1981; Sileo et al. 1990). Transmission can also occur directly by contact between infected and susceptible birds or by contact with contaminated objects, such as bird-feeder perches (Bleitz 1958; Rosen 1959). Aerosol transmission, although rare, can occur from viruses being carried along with dust, particularly in confined situations (that is, aviaries). Burnet (in Kirmse 1967a) found that lesions developed at sites of minor experimental skin injury in birds inoculated intravenously.

Susceptibility of the avian host species is a large factor in the epizootiology of avian pox. In continental regions, where avian pox and its hosts have had a long co-evolutionary history, the most commonly reported (modal) avian pox prevalence of lesions on wild birds is quite low and varies between 0.5 and 1.5%. In more susceptible avian hosts, avian pox prevalence can reach 25% (for example, House Finches in California–[McClure 1989]) and in some populations up to 50% of the birds supporting active lesions (for example, Northern Bobwhites [*Colinus virginianus*] in Georgia and Florida; Davidson et al. 1980). Overall, on remote islands avian pox prevalences tend to be generally higher (for example, Galapagos 28% [Vargas 1987]; Volcano, Hawaii 35% [van Riper et al. 2002]; Kona, Hawaii 10% [Atkinson et al. 2005]; New Zealand >10% [Westerkof 1953]). A recent paper by Medina et al. (2004) identified the first avian pox case in the Canary Islands, and this could well be the beginning of an epizootic for birds of that island (Smits et al. 2005).

CLINICAL SIGNS

Avian pox occurs primarily in two different forms: (1) the more common skin form, in which discrete, wart-like, proliferative lesions develop on the skin (Figures 6.4 and 6.5); and (2) the less common diphtheritic form in which moist, necrotic lesions develop on the mucous membranes of the mouth and upper respiratory tract (Figure 6.6). A third form, systemic infection, is rarely found in wild birds (Tripathy and Reed 2003). Lesions are most common on the unfeathered parts of the body—the legs, feet, eyelids, base of the beak, and the comb and wattles of gallinaceous birds. For example, in Hawaii, van Riper et al. (2002) demonstrated that most lesions in wild birds occur on one toe, with half that number on two toes and the leg. Often the lesions are few in number, appearing as innocuous warty growths on one or two toes, at the base of the bill, or on an eyelid. However, a preponderance of lesions on the eyelids may cause mortality, as has been reported in granivorous birds, such as pheasants, quail, and turkeys that have become unable to see and cannot find food (for example, Forrester and Spalding 2003).

In wild birds that have webbed feet, pox lesions appear along the ramifications of blood vessels in the foot webs, much like the distribution of leaves on branches of a tree. Focal epithelial proliferation and later necrosis and sloughing occur mainly on the plantar surfaces of the webs and toes. When fully developed, these lesions appear as circular pocks, 3 to 5 mm in diameter, with central areas of necrosis, bordered by zones of erythema. In perching wild birds, lesions start as a swelling on the toe, leg, or facial region. The swelling appears

Figure 6.4. Facial avian pox lesions on a young Laysan Albatross (*Diomedea immutabilis*). (From Friend and Franson [1999] with permission of the U.S. Geological Survey.)

Figure 6.5. Avian pox lesions on the feet of a young Laysan Albatross (*Diomedea immutabilis*). (From Friend and Franson [1999] with permission of the U.S. Geological Survey.)

Figure 6.6. Diphtheritic avian pox lesions (arrows) in the oral cavity of a Wild Turkey (*Meleagris gallopavo*). The bird was from Hendry County, Florida and died in 1991. (From Forrester and Spaulding [2003], with photo courtesy of Garry W. Foster and permission from the University Press of Florida.)

smooth, reddish, and dome shaped. Eventually the swelling cracks or bursts and lesions begin to form.

Avian pox lesions heal, following degeneration and sloughing of the abnormally proliferated epithelium. In some instances, toes and whole feet can be lost (van Riper et al. 2002). Following infection with avian poxvirus, many birds recover, but young birds are usually more severely affected than are adults. Individual birds that acquire avian pox infections lose digits and can also become permanently blinded. For example, Forrester (1991) followed the development of cutaneous lesions on a sentinel domestic turkey in Florida (Figure 6.7A–D). On day six post-exposure, small areas of swelling were present; by day eight, small lesions had appeared; by day 15, the lesions had grown considerably by day 29, lesions began to cover the eye; and after 50 days the turkey was blind. When birds are blinded in the wild, emaciation follows and birds quickly succumb because of the inability to procure food or due to predation (for example, Jenkins et al. 1989; Forrester and Spalding 2003).

In some advanced cases, lesions are present on both mucous membranes and skin. Lesions of the mucous membranes, particularly of the mouth and upper air passages, most often result in high mortality (Davidson et al. 1980). In chickens that had the diphtheritic form of pox, mortality rates were higher than in birds with cutaneous pox (Cunningham 1972). In canaries, acute systemic infections are commonly associated with many deaths (Stroud 1933; Arnall and Keymer 1975). In the wild, birds are rarely found alive with advanced avian pox infections because they usually die or are preyed upon prior to reaching this level of intensity.

PATHOGENESIS

Upon successful entry of the poxvirus into avian host epithelium, within one hour the virus penetrates cell

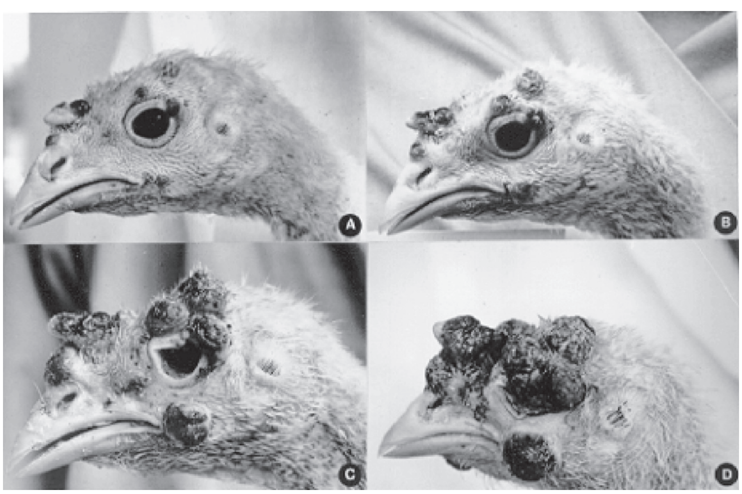


Figure 6.7. Development of cutaneous avian pox lesions on the head of a sentinel domestic turkey that had been infected naturally by vectors at Fisheating Creek (Glades County, FL) during September 1978. After being exposed as a sentinel for two weeks, the turkey was kept in an isolation room at the University of Florida, Gainesville, and observed for the development of lesions. The photographs were taken at eight days (A), 11 days (B), 15 days (C), and 29 days (D) after the bird was removed from the sentinel cage at Fisheating Creek. (From Forrester [1991]; photographs courtesy of Garry W. Foster and by permission of *Bulletin of the Society of Vector Ecology*.)

membranes and then uncoats prior to synthesis of a new virus from precursor material (Arhelger et al. 1962). In the host dermal epithelium, biosynthesis involves two distinct phases, the first being host response during the first 72 hours, followed by synthesis of infectious virus from 72 to 96 hours (Cheever et al. 1968). Beginning at 36 to 48 hours, synthesis of host DNA is accompanied by epithelial hyperplasia, with host DNA declining abruptly at 60 hours. Arhelger and Randall (1964) and Tajima and Ushijima (1966) demonstrated that the replication of viral DNA in the avian host begins between 12 to 24 hours, followed by an exponential rate of synthesis between 60 to 72 hours. Hyperplasia ends at 72 hours with a 2.5-fold increase in cell numbers (Cunningham 1972). The ratio of viral to host DNA increases up to 2:1 at 100 hours, with the maximum titer of virus attained following cell proliferation. There is also, during morphogenesis of the virus, incomplete, intermediate, or developmental forms in transition stages, leading to mature forms or virions.

The next phase consists of a relatively long latent period, with areas of viroplasm within the cytoplasm surrounded by incomplete membranes. The viroplasmic particles condense and acquire an additional outer membrane to become incomplete virions. These virions migrate to vacuoles of the inclusion bodies and thus acquire a membrane coat (Cheville 1966). The virus then emerges from the cells by a budding process, resulting in an additional outer membrane that is obtained from the cell membrane (Arheleger and Randall 1964; Kreuder et al. 1999; Hernandez et al. 2001). This process produces the classical inclusion body (Bollinger body) that is observable via light microscopy. Cunningham (1966) argued that the Bollinger body is not always a structure indispensable for the development and maturation of avian pox in wild birds and that infectious virus may be produced by cells in which matrix inclusion bodies only are present.

Following entry into an avian host, the overall initial incubation period described above varies with the poxvirus strain and host species. Tripathy and Reed (2003) suggested a period from four to 10 days in chickens, turkeys, and pigeons, and Kirmse (1969) found in wild birds incubation periods up to one month. Duration of the disease is equally variable, with avian pox in chickens persisting for about four weeks. Many studies of avian pox in wild birds show a long incubation period duration, with up to several months in Chipping Sparrows *(Spizella passerina)* (Musselman 1928), 82 days in a Mourning Dove *(Zenaida macroura)* (Kossack and Hanson 1954), more than 81 days in a Dark-eyed Junco (*Junco hyemalis*), 13 months in a Northern Flicker (Kirmse 1969), more than 109 days in a Dark-eyed Junco (Hood, pers. com. as cited in Karstad 1971), and 90 to 150 days in the House Finch (McClure 1989).

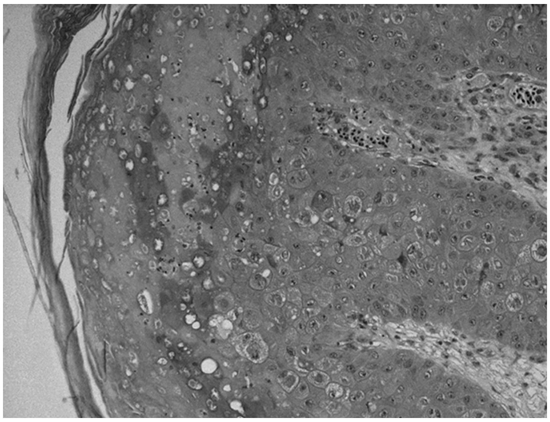
In chickens, cutaneous lesions become inflamed and hemorrhagic just prior to regression (Cunningham 1966). Desiccation and scab formation then follows, with eventual sloughing and replacement by normal skin. This same pattern occurs in wild birds, but cutaneous lesions may be few, sometimes only one or two, and the whole process of development, regression, and healing of lesions may be much prolonged (Karstad 1971). Perhaps the fewer number of lesions in wild birds occurs because of a high natural resistance to infection, combined with minimal host response. Whatever the reasons, it is obvious that a rather good host-parasite relationship exists in such infections and that it is beneficial to survival of the virus for it to be carried for a long period of time by an individual host.

PATHOLOGY

Avian pox infections cause localized proliferations of epithelial cells. Affected cells become hyperplastic and hypertrophic as the increased rate of multiplication occurs in the basal germinal layer of cells within the epithelium. Hypertrophy and large granular acidophilic intracytoplasmic inclusions appear as the cells mature in layers of epithelium above the stratum germinativum (Figure 6.8). The "stacking" of infected epithelial cells to form "pocks" occurs at variable rates, and lesions may persist for different lengths of time in various species (Karstad 1971).

Diphtheritic lesions are infrequently detected in wild bird avian pox infections. Cunningham (1972) described lesions on the mucous membranes of chickens as white, opaque, slightly elevated nodules that rapidly increase in size, often coalescing to form a yellowish, cheesy, necrotic material that has the appearance of a pseudomembrane. He said that the condition is aggravated by invasion of contaminating bacteria and that it may extend to involve the sinuses and pharynx, causing respiratory distress. Wobeser (1997) cites only one known case in waterfowl. In a compilation of physical locations where avian pox has been found on birds throughout the world, we found only five reports of diphtheritic lesions (Table 6.2). This information is based on the references cited by Kirmse (1967a), Bolte et al. (1999), and subsequent published reports.

In the later stages of development, large persistent avian pox lesions may be subject to trauma, resulting in hemorrhage, necrosis, and portals of entry for bacteria and fungi. This was the case with a juvenile Reddish Egret (*Egretta rufescens*) that Conti et al. (1986) and Forrester and Spalding (2003) found in



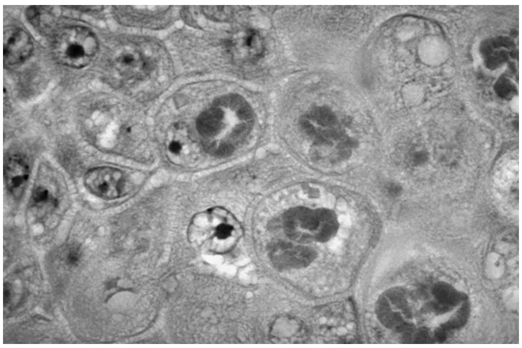


Figure 6.8. (a) Histologic section of avian poxvirus infection of skin from the toe region of a naturally infected domestic chicken (Gallus gallus) collected in Volcano Village, Island of Hawaii. Note the marked epithelial hyperplasia and intracytoplasmic inclusion bodies. H&E stain X 100x. (b) High magnification view of the same lesion showing the ballooning of epithelial cells and the large "Bollinger bodies" in the cytoplasm. 1000x.

Florida. Locke et al. (1965) described mortality in Red-tailed Tropicbirds *(Phaethon rubricauda)* in which avian pox was complicated by secondary mycotic infections. Histologic sections of cutaneous avian pox lesions usually reveal areas of necrosis on or near the surface, in which masses of bacteria or fungi are found. There are usually no obvious systemic effects of these secondary bacterial or mycotic infections.

Secondary infections with bacteria and fungi often occur in wild birds following inflammation of the epithelial cells by the poxvirus. These infections have nothing specific about them, occurring as they would in any skin surface where abrasion and contamination occur (Karstad 1971). Elevated avian pox lesions predispose the skin surfaces to trauma. Bird-banders often find that birds with avian pox lesions become entangled in mist nets in such a way that the warty lesions are injured and bleed (Bleitz 1958). However, in most bird species avian poxvirus infections are mild and self-limiting (Simpson et al. 1975), and the lesions slough off without subsequent secondary bacterial and fungal infections.

The lesions of avian pox in canaries and other more susceptible birds (for example, Hawaiian honeycreepers) are sometimes quite different. Lesions frequently seen are fibrinous inflammation of serous membranes; liver degeneration or necrosis also occurs, with edema and hyperemia of the lungs, and fibrinous pneumonitis often results (van Riper et al. 2002). Such lesions are seen in canaries with the acute systemic form of the disease. In other cases, cutaneous lesions or diphtheritic lesions may predominate. Canaries and honeycreepers may have cutaneous lesions on not only exposed skin areas but also the feathered portions of the body (van Riper and van Riper 1985).

Goodpasture and Anderson (1962) described strains of avian pox isolated from the Dark-eyed Junco and from a Wood Thrush (*Hylocichla mustelina*) that were characterized by the development of intranuclear as well as intracytoplasmic inclusions. Both types of inclusions occurred in the original junco host as well as in chickens infected with the junco strain. In avian pox–infected Dark-eyed Juncos, Karstad (1971) found that one of four had intranuclear as well as typical intracytoplasmic inclusions. He also found typical avian pox intranuclear and intracytoplasmic inclusions in hypertrophied epithelial cells in a cutaneous lesion from a Northern Mockingbird *(Mimus polyglottos).* Furthermore, one of six Northern Flickers with cutaneous avian pox lesions had small, eosinophilic, rod-shaped inclusions in the nuclei of cells that also contained typical Bollinger bodies. Histologic examination of an avian pox lesion from a Savannah Sparrow *(Passerculus sandwichensis)* revealed rod- or brick-shaped inclusions in the cytoplasm of hypertrophic epithelial cells that bore typical Bollinger bodies. In the Imperial Eagle (*Aquila heliaca*), Hernandez et al. (2001) demonstrated more typical inclusion bodies (Figure 6.2).

DIAGNOSIS

The visual observation of lesions on a wild bird does not represent a definitive diagnosis of avian pox infection. In the past, many authors have assumed that because they observed pox-like skin lesions on birds, they were dealing with avian pox (for example, Power and Human 1976). There are a number of avian

Table 6.2. Locations of avian pox lesions found on selected wild bird hosts. This table provides a snapshot of pox intensity by physical location on the bird. By examining the table, one can obtain a general index of where one might expect to find lesions at different physical locations on a sample of infected birds.

	Lesion Location		
ORDER	Feet & Legs	Face & Head	Diphtheritic (Oral cavity)
Struthioniformes	3	1	1
Tinamiformes	–	–	–
Sphenisciformes	1	0	0
Gaviiformes	–	–	–
Podicipediformes	1	0	0
Procellariiformes	2	1	0
Pelecaniformes	2	1	1
Ciconiiformes	2	1	0
Phoenicopteriformes	1	1	0
Anseriformes	28	4	5
Falconiformes	26	6	1
Galliformes	53	11	5
Opisthocomiformes	–	–	–
Gruiformes	2	2	0
Charadriiformes	4	2	0
Pterocliformes	–	–	–
Columbiformes	13	4	2
Psittaciformes	11	1	7
Cuculiformes	1	0	0
Strigiformes	4	3	1
Caprimulgiformes	–	–	–
Apodiformes	2	1	0
Coliiformes	–	–	–
Trogoniformes	–	–	–
Coraciiformes	1	0	0
Piciformes	2	1	0
Passeriformes	217	9	2
TOTAL	377	49	25

diseases that have similar lesions to those of poxvirus infections. Mites and bacteria will sometimes cause lesions on the legs that look very similar to avian pox lesions. Candidiasis, capillariasis, and trichomoniasis all cause lesions in the oral cavity that look similar to the diphtheritic form of avian pox.

Whenever possible, isolation via the propagation of virus on chorioallantoic membranes of chicken embryos should be used as the definitive diagnosis of choice (Hansen 1987). Some strains of avian poxvirus in wild birds do not grow readily in chicken embryos. Krone et al. (2004) were unable to culture poxviruses from a Peregrine Falcon (*Falco peregrinus*) on chicken egg CAM, so they attempted culture in Peregrine Falcon eggs, and van Riper et al. (2002) cultured the Hawaiian avian poxvirus from Hawaii Amakihi (*Hemignathus virens)*, Apapane (*Himatione sanguinea*), Laysan Finch (*Telespiza cantans)*, and Iiwi (*Vestiaria coccinea*) in House Finch eggs.

At a minimum, for a positive demonstration of an avian pox infection there needs to be at least a histological examination of infected tissue that shows *avian poxvirus* intracytoplasmic inclusion (Bollinger) bodies (Kirmse 1966). Demonstration of typical avian poxvirus particles by electron microscopy would also provide a positive confirmation of an avian pox infection (Figure 6.2). Beaver and Chetum (1963) studied the cytopathology of a Dark-eyed Junco poxvirus strain by electron microscopy, and the nuclear inclusion was seen to be devoid of viral particles, being composed of a loose array of irregularly branching filaments. In an avian pox outbreak in the Peregrine Falcon in Germany, Krone et al. (2004) found much the same pattern after negative staining on an electron micrograph.

Recent advances in molecular techniques now provide an opportunity for a more detailed and rapid diagnosis of avian pox infections. These techniques have been discussed by Tripathy (2000) and Tripathy and Reed (2003) and include restriction fragment length polymorphism (RFLP) analysis, use of genomic fragments as probes, and polymerase chain reaction (PCR) tests.

IMMUNITY

Birds that have recovered from avian pox infections, or that have been vaccinated, are usually immune to reinfection with that virus strain. This immunity is largely cell mediated, although antibodies can play a role (Fenner 1968). Transovarial transmission of immunity for avian pox has not been demonstrated. Strains isolated from a single host species may vary in the degree of infectivity to other species. For example, a strain of canarypox has been found that can infect chickens, quail (*Coturnix* sp.) and turkeys, but not House Sparrows (*Passer domesticus*) and Rock Doves (*Columba livia*); another canarypox strain infected chickens, Rock Doves, and House Sparrows (Karstad 1971). Irons (1934) found a strain of avian pox from the Rock Dove that produced lesions in the House Sparrow after a series of blind passages. Dobson (1937) described a poxvirus strain isolated from Ring-necked Pheasants (*Phasianus colchicus*) that was transmissible to chickens and Rock Doves. Many of the poxviruses of wild birds are not pathogenic for chickens (for example, Tripathy et al. 2000).

Avian poxvirus strains from one host can provide reciprocal immunity to other host species, and cross-immunity has been proven for several strains of avian pox. For example, chickens may be vaccinated with live pigeonpox strains because they stimulate immunity to typical strains of avian poxviruses without causing serious disease (Cunningham 1972). Dobson (1937) demonstrated that Rock Dove poxvirus immunized birds against a pheasant strain. DuBose (1965) reported reciprocal immunization between strains of poxvirus from the Sage Grouse *(Centrocercus urophasianus)* and a strain isolated from the Blue Grouse *(Dendragapus obscurus).* It seems probable that immunity to avian pox exists in a spectrum of continuous adaptation to various avian host species.

PUBLIC HEALTH CONCERNS

It has not yet been demonstrated that avian poxviruses are transmissible to humans, as are some of the mammalian strains such as cow and sheep poxviruses (Robinson and Kerr 2001).

DOMESTIC ANIMAL HEALTH CONCERNS

Due to the host specificity demonstrated by most avian poxviruses (see the "Etiology" and "Immunity" sections in this chapter), wild birds are presently not considered a significant reservoir of the virus for domestic animals. Kirmse (1966) attempted to infect chickens with strains of poxvirus from the Northern Flicker, Dark-eyed Junco, Song Sparrow *(Melospiza melodia)*, and domestic canary. Only the Song Sparrow strain produced lesions in chickens. Conversely, three poultry strains were pathogenic for chickens but not for several species of wild birds, including the Red-winged Blackbird *(Agelaius phoeniceus)*, European Starling *(Sturnus vulgaris)*, Northern Oriole *(Icterus galbula)*, Gray Catbird *(Dumetella carolinensis)*, Song Sparrow, House Sparrow, White-throated Sparrow *(Zonotrichia albicollis)*, American Robin *(Turdus migratorius)*, Evening Grosbeak (*Coccothraustes vespertinus)*, Indigo Bunting *(Passerina cyanea),* American Goldfinch *(Spinus tristis)*, Brown Thrasher *(Toxostoma rufum)*, Eastern Kingbird *(Tyrannus tyrannus)*, and Common Grackle *(Quiscalus quiscula).* These results may be taken as evidence of host specificity and suggest that pox infections in migratory birds do not presently constitute a threat to the domestic poultry industry.

There is recent evidence that anthropogenic movement of birds can cause avian pox problems for wild as well as captive bird populations. Krone et al. (2004) demonstrated avian pox mortality in Peregrine Falcons that were pen-reared and released in northern Germany. In the Arabian Gulf region, Remple (1988) found that avian pox is common in many of the captive falcons that are used for falconry. In captive parrots, avian pox has become a concern around the world (Petrak 1982; Hitchner and Clubb 1980). In the United States, poxvirus infections are among the more significant health risks associated with releasing pen-reared or game-farm birds such as Wild Turkeys and Northern Bobwhites into the wild for hunting purposes (Davidson et al. 1982; Davidson and Wentworth 1992). Such releases should be discouraged or prohibited, but if they are allowed to occur, only healthy pen-reared birds should be used (Forrester and Spalding 2003).

WILDLIFE POPULATION IMPACTS

Little is known about mortality rates from poxvirus infection in naturally infected, free-flying wild birds. The majority of wild-bird avian pox infections have been reported as mild and self-limiting. In pheasants, quail, and Wild Turkeys, mortality rates are probably similar to chickens with regard to the severity and course of avian pox infections. Davidson et al. (1980) estimated that during an epornitic of avian pox in Northern Bobwhites, morbidity was approximately 2% and mortality varied between 0.6 and 1.2% in a 13,000-km^2 region of Georgia and Florida. During a survey from 1968 through 1984 of 1,052 Wild Turkeys in southern Florida, Forrester and Spalding (2003) reported 15 cases of avian pox. Dobson (1937) reported extensive losses in Ring-necked Pheasants affected by the diphtheritic form of avian pox. Karstad (1965) documented that eyelid lesions prevented feeding and were responsible for extensive losses among captive Impiyan Pheasants (now called Himalyan Monal [*Lophophorus impejanus*]). The outbreak occurred in the fall and subsided after frosts had reduced mosquito populations.

Extremely high mortality rates have been recorded in some epizootics. Gallagher (1916) reported 85% mortality in quail (of unstated species) imported from Mexico, where lesions were present on the unfeathered skin and in the mouth. In the Galapagos Mockingbird (*Nesomimus parvulus*), Vargus (1987) found 13 of 18 healthy fledglings after two months but failed to find any of the 14 young birds that previously had been observed with avian pox lesions. With avian pox now introduced into the Canary Islands (Medina et al. 2004), there exists the potential for transmission to native birds and future epizootics (for example, Smits et al. 2005).

Avian pox infections in Hawaii have been demonstrated to have negative effects on many populations of native birds (van Riper and Scott 2001). Warner (1968) demonstrated extensive poxlike lesions on Laysan Finches that he had brought from Laysan Island to the island of Oahu. Jenkins et al. (1989) reported that avian poxvirus had a negative impact on the few remaining Hawaiian Crows (*Corvus hawaiiensis*) that inhabit the island of Hawaii. In the Elepaio (*Chasiempis sandwichensis*) on Hawaii, VanderWerf (2001) demonstrated a population decline on Mauna Kea Volcano in the year following an epizootic of poxlike lesions. In a larger-scale study, van Riper et al. (2002) recorded high avian pox prevalences (up to 47%) in native birds that inhabit the mid-elevational forests of Mauna Loa, Hawaii. They demonstrated that where vectors and native birds (Hawaiian honeycreepers) had their greatest overlap, avian pox had the greatest negative influence on forest bird populations (Figure 6.9). In controlled laboratory experiments, the authors also demonstrated that avian poxvirus will kill some species of native birds (for example, Hawaii Amakihi), but is mild and self-limiting in the introduced bird species such as the House Finch. Atkinson et al. (2005) found a similar situation in the Hawaii Amakihi in other forests on Mauna Loa, Hawaii.

Avian pox in captive situations (especially canaries) may be associated with extensive losses (Bigland et. al. 1962). Transmission is facilitated by housing large numbers of birds in close quarters. In such situations, transmission may occur by direct and indirect contact, or by inhalation of virus-laden dust. Poxviruses are very resistant to inactivation by drying and, therefore, dust that contains contaminated particles of feathers, skin, or scabs may be highly infective. Under conditions of aerosol exposure, canaries may die with rather acute, apparently generalized systemic infections.

TREATMENT AND CONTROL

For outbreaks in which avian poxvirus is being transmitted by vectors, control should be targeted at reduction of those vector populations. For example, adult mosquitoes can be directly targeted for reduction or, as is most often the case, breeding areas can be manipulated either through direct reduction of larvae or via indirect reduction through biocontrol agents (Service 1976). Control can also be achieved by preventing vector access to birds (for example, by screening) in the case of captive birds. Where birds are being artificially concentrated, such as at home feeders or in aviaries, feeders and perches should be sterilized at least every two weeks (Bleitz 1958). Any strong antiseptic cleaning agent can be used, including bleach. In holding areas or aviaries, diseased birds should be kept in separate, isolated, screened cages.

On occasion, it may be useful to try vaccination where avian pox occurs in captive wild birds. Ideally, one should select for vaccination an avian poxvirus strain that causes a mild infection that would be limited to the skin at the site of vaccine application. Vaccination such as this may prove practical in certain situations, such as with endangered species (see Tripathy et al. 2000). For additional vaccination techniques and information, see Cunningham (1972). If avian pox infections are dust borne, as may occur in some aviaries and outdoor pens, control of dust will be an important factor.

For captive birds that do become infected, Arnall and Keymer (1975) have found success by applying flowers of sulfur directly to the lesion or giving it orally. Removal of the lesions and washing in bicarbonate soda may prove useful, but caution needs to be taken not to further spread the virus. Applying silver

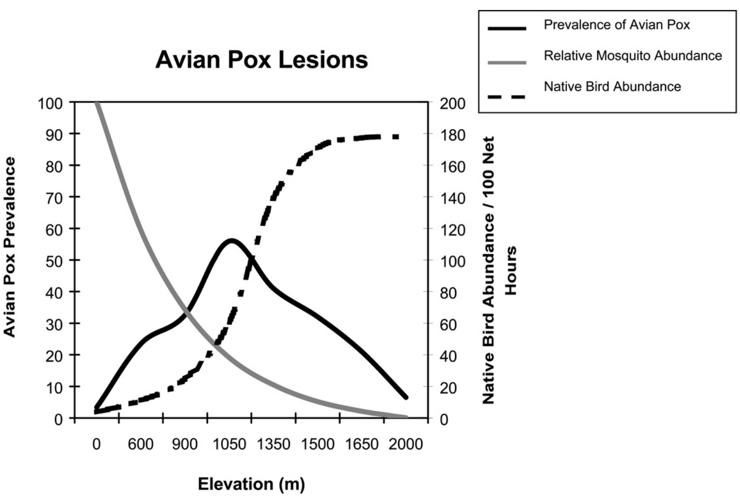


Figure 6.9. Avian pox prevalence compared to relative mosquito and native bird abundances on Mauna Loa Volcano, Hawaii. Values for the solid black line were derived from avian pox prevalence of 3,122 wild forest birds captured from 1977–1980 along a sea-level-to-tree-line elevational gradient on Mauna Loa Volcano, Hawaii. The gray line indicates relative mosquito abundance, whereas the broken line denotes native bird abundances along the elevational gradient.

nitrate, iodine, or 1–2% saline solution directly to the lesion has also shown some success in reducing the level of infection. All techniques are targeted at sterilizing around the lesion, and this is why bathing the infected area seems to help. In fact, broad-spectrum antibiotics are routinely given to birds with avian pox in an attempt to reduce the chance of secondary bacterial infection.

No matter what treatment is used, the disease will run its course. In most situations, prevention is the best treatment against avian pox infection. Keeping areas clean and disinfected is important. Any reduction in potential vector numbers will also help. In highly susceptible avian species, many individuals will probably succumb to infection (for example, Landolt and Kocan 1976). In the more resistant species, immunity quickly develops and the infection is usually gone within a short time period, with minimal damage to the bird.

MANAGEMENT IMPLICATIONS

For the majority of wild bird populations, avian pox appears to be a self-limiting disease. However, in localities where conditions are propitious for transmission (for example, an extremely heavy rainfall year), avian pox prevalences can reach high levels and negatively impact wild bird populations. For example, following an extremely wet year in southern Georgia and northern Florida, Davidson et al. (1980) reported a 12-fold avian pox increase in Northern Bobwhites. The authors estimated that this increase in avian pox infections resulted in an additional 12 to 24 deaths per 1,000 birds. This reduction in total population size had a negative impact on the allowed bag limits for that year. Forrester (1991) postulated that an abnormally early rainy season over a two-year period resulted in a widespread avian pox epizootic, which caused a significant decline in Wild Turkey populations in Florida throughout the 1960s. During these situations it might be wise to reduce the bag limits or shorten the hunting seasons on these game birds.

With the continued increase of bird feeding stations over the world, the concentrated numbers of birds utilizing those feeding stations predisposes them to enhanced transmission of poxviruses. This has been documented by a number of wild bird enthusiasts (for example, Bleitz 1958) and continues to be a problem.

The artificially increased host densities of wild birds at feeding stations is paralleled with what captive breeders are finding in regard to the transmission of avian pox. Donnelly and Crane (1984) described an epornitic of avian pox in a research aviary (Graham 1978; Petrak 1982). The situation becomes even more of a management concern when one is dealing with the captive breeding of endangered species such as Whooping Cranes (*Grus Americana*), Hawaiian honeycreepers, or Bali Mynas (*Leucospar rothschildi*).

Another situation in which land and wildlife managers must be concerned with the implications of avian pox infection is on the more remote islands of the world. For example, in Hawaii, where the native birds have had only a short history of co-evolution with the introduced avian poxvirus, the distribution and numbers of many native species are presently being negatively impacted by this disease (Warner 1968; van Riper et al. 2002; Atkinson et al. 2005). In the Galapagos Islands, Vargas (1987) demonstrated that in some years avian poxvirus greatly impacts the numbers of Galapagos Mockingbird young that survive to adulthood. The first detection of avian pox in the Canary Islands (Medina et al. 2004) should be followed closely by wildlife managers because the native birds on that island are probably very susceptible to *Avipoxvirus avium.* Although islands are indeed unique situations, on islands such as Trinidad that are closer to continents, Tikasingh et al. (1982) suggested that avian pox might not always greatly impact native birds.

In summary, wherever avian pox is a potential concern, monitoring of bird populations would assure early detection of infected birds. Programs such as MAPS (Monitoring Avian Productivity and Survivorship) developed by DeSante (1996) would provide wildlife managers with an early detection of any increase of avian pox lesions in wild bird populations. When infected birds are collected, some sort of standardized necropsy and reporting protocol should be developed, one like that developed by van Riper and van Riper (1980). Another example of a survey and reporting system that could be emulated is the "House Finch Disease Survey" (http://www.birds.cornell.edu/hofi/index.html) initiated by the Cornell Laboratory of Ornithology and described in Dhondt et al. (1998). This Web-based system documents the spread of conjunctivitis in the House Finch and could be easily modified to be used for a survey of avian pox. Following receipt of presence/absence information on lesions, more detailed laboratory analyses (see the "Diagnosis" section of this chapter) can be undertaken. It has been clearly shown that detecting disease in its early stages of spread is the preferred method of wildlife disease management (Friend 1987). After avianpox prevalence becomes high, this disease will "run its course" and has the potential to greatly impact certain wild bird populations.

Table 6.1. Orders, families, and representative species of birds throughout the world recorded with avian pox. Taxonomy of avian orders, families and species follows Clements (2000), as does common family and common species names. Representative literature citations are included for each country in which avian pox has been reported. For those avian orders and families where avian pox has not been reported, lines in the table are blank.

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
Struthioniformes	Struthionidae	Ostrich	*Struthio camelus*	Ostrich	Israel	Perelman et al. 1988
			Struthio camelus	Ostrich	South Africa	Allwright et al. 1994
			Struthio camelus	Ostrich	Australia	Raidal et al. 1996
			Struthio camelus	Ostrich	Italy	Cerrone et al. 1999
	Rheidae	Rheas	*Rhea americana*	Greater Rhea	Spain	Vogelsang 1938
	Casuariidae	Cassowaries				
	Dromaiidae	Emu				
	Apterygidae	Kiwis				
Tinamiformes	Tinamidae	Tinamous				
Sphenisciformes	Spheniscidae	Penguins	*Spheniscus humboldti*	Humboldt Penguin	Poland	Landowska-Plazewska and Plazewski 1968
			Spheniscus demersus	Jackass Penguin	Cape Town, South Africa	Stannard et al. 1998
Gaviiformes	Gaviidae	Loons				
Podicipediformes	Podicipedidae	Grebes	*Podiceps cristatus*	Great Crested Grebe	Switzerland	Bouvier 1946
Procellariiformes	Diomedeidae	Albatrosses	*Phoebastria immutabilis*	Laysan Albatross	Midway Atoll, Pacific Ocean	Sileo et al. 1990
	Procellariidae	Shearwaters & Petrels	*Puffinus puffinus*	Manx Shearwater	Great Britain	Miles and Stocker, 1948; Nuttall et al. 1985
	Hydrobatidae	Storm-Petrels				
	Pelecanoididae	Diving-Petrels				
Pelecaniformes	Phaethontidae	Tropicbirds	*Phaethon lepturus*	White-tailed Tropicbird	Bermuda	Wingate et al. 1980
			Phaethon rubricauda	Red-tailed Tropicbird	Hawaii, U.S.A.	Locke et al. 1965
	Pelecanidae	Pelicans				

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
	Sulidae	Boobies & Gannets				
	Phalacrocoracidae	Cormorants	*Phalacrocorax bougainvillii*	Guanay Cormorant	Peru	Avila 1966
	Anhingidae	Anhinga & Darters				
	Fregatidae	Frigatebirds				
Ciconiiformes	Ardeidae	Herons, Egrets & Bitterns	*Ardea herodias*	Great Blue Heron	Florida, U.S.A.	Forrester and Spalding 2003
			Ardea alba	Great Egret	Florida, U.S.A.	Forrester and Spalding 2003
			Egretta rufescens	Reddish Egret	Florida, U.S.A.	Forrester and Spalding 2003
			Egretta thula	Snowy Egret	Florida, U.S.A.	Forrester and Spalding 2003
	Scopidae	Hamerkop				
	Ciconiidae	Storks	*Ciconia ciconia*	White Stork	Switzerland	Zangger and Muller 1990
			Ciconia nigra	Black Stork	Switzerland	Zangger and Muller 1990
	Balaenicipididae	Shoebill				
	Threskiornithidae	Ibis & Spoonbills	*Ajaia ajaja*	Roseate Spoonbill	Florida, U.S.A.	Spalding and Forrester 1991
Phoenicopteriformes	Phoenicopteridae	Flamingos	*Phoenicopterus chilensis*	Chilean Flamingo	—	Arai et al. 1991
Anseriformes	Anhimidae	Screamers				
	Anatidae	Ducks,	*Anser anser*	Greylag Goose	Germany	Ihlenburg 1972
		Geese & Swans	*Anser anser*	Greylag Goose	China	Zhang et al. 1996
			Anser cygnoides	Swan Goose	Germany	Ihlenburg 1972
			Anser cygnoides	Swan Goose	China	Zhang et al. 1996
			Anser fabalis	Bean Goose	Great Britain	Kear and Brown 1975
			Branta sandvincensis	Hawaiian Goose	Great Britain	Kear and Brown 1975
			Branta canadensis	Canada Goose	Canada	Cox 1980

			Cereopsis novaehollandiae	Cape Barren Goose	Australia	Wobeser 1981
			Anser indicus	Bar-headed Goose	China	Zhang et al. 1996
			Cygnus columbianus	Tundra Swan	Maryland, U.S.A.	Montgomery et al. 1980
			Cygnus olor	Mute Swan	New York, U.S.A.	Leibovitz 1969
			Chenopis atrata	Black Swan	Australia	Harrigan et al. 1975
			Anas sp.	Duck	India	Rao 1965
			Anas sp.	Duck	Canada	Kirmse 1967b
			Anas platyrhynchos	Mallard	China	Zhang et al. 1996
			Anas crecca	Green-winged Teal	Alaska, U.S.A.	Morton and Dietrich 1979
			Anas clypeata	Northen Shoveler	India	Mathur et al. 1972
			Anas penolope	European Wigeon	India	Mathur et al. 1972
			Cairina moschata	Muscovy Duck	Germany	Ihlenburg 1972
			Aix galericulata	Mandarin Duck	France	Megnin 1878
			Aix sponosa	Wood Duck	Florida, U.S.A.	Spalding and Forrester 2003
			Nettion crecca	Common Teal	India	Mathur et al. 1972
			Tadorna ferruginea	Ruddy Shelduck	China	Zhang et al. 1996
			Melanitta nigra	Black Scoter	Pennslyvania, U.S.A.	Ratcliff 1967
			Bucephala clangula	Common Goldeneye	Saskatchewan, Canada	Wobeser 1981
			Aythya affinia	Lesser Scaup	Alberta, Canada	Wobeser 1981
Falconiformes	Cathartidae	New World Vultures	*Cathartes aura*	Turkey Vulture	Florida, U.S.A.	Forrester and Spalding 2003
			Vultur gryphus	Andean Condor		Kim et al. 2003
	Pandionidae	Osprey				
	Accipitridae	Hawks, Eagles & Kites	*Accipiter nisus*	Eurasian Sparrowhawk	Iraq	Tantawi et al. 1981
			Accipiter gentilis	Northern Goshawk	Germany	Polowinkin 1901
			Accipiter gentilis	Northern Goshawk	France	Heusinger 1844

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
			Aquila chrysaetos	Golden Eagle	Germany	Gratzl 1953
			Aquila chrysaetos	Golden Eagle	Canada	Moffatt 1972
			Aquila chrysaetos	Golden Eagle	California, . U.S.A	Hill and Bogue 1977
			Aquila chrysaetos	Golden Eagle	Washington, U.S.A.	Garner 1989
			Aquila heliaca	Imperial Eagle	Spain	Hernadez et al. 2001
			Buteo platyptera	Broad-winged Hawk	Canada	Kuntze et al. 1968
			Buteo jamaicensis	Red-tailed Hawk	Missouri, U.S.A.	Halliwell 1972
			Buteo jamaicensis	Red-tailed Hawk	Dakota, U.S.A.	Pearson and Pass 1975
			Buteo jamaicensis	Red-tailed Hawk	Washington, U.S.A.	Fitzner et al. 1985
			Buteo jamaicensis	Red-tailed Hawk	California, U.S.A.	Wheeldon et al. 1985
			Buteo lagopus	Rough-legged Hawk	Dakota, U.S.A.	Pearson and Pass 1975
			Buteo lagopus	Rough-legged Hawk	California, U.S.A.	Wheeldon et al. 1985
			Buteo buteo	Eurasian Buzzard	Austria	Loupal et al. 1985
			Circus pygargus	Montagu's Harrier	Germany	Englemann 1928
			Circus cyaneus	Northern Harrier	Dakota, U.S.A.	Wheeldon et al. 1985
	Sagittariidae	Secretary-bird				
	Falconidae	Falcons & Caracaras	*Falco peregrinus*	Peregrine Falcon	Arabian Gulf	Cooper 1969
			Falco peregrinus	Peregrine Falcon	United Arab Emirates	Kiel 1985
			Falco peregrinus	Peregrine Falcon	Germany	Krone et al. 2004
			Falco rusticolus	Gyrfalcon	United Arab Emirates	Samour and Cooper 1993
			Falco cherrug	Saker Falcon	Arabian Gulf	Greenwood and Blakemore 1973
			Falco cherrug	Saker Falcon	Germany	Grimm and Jacobi 1977

			Falco cherrug	Saker Falcon	Afganistan	Winteroll et al., 1979
			Falco cherrug	Saker Falcon	United Arab Emirates	Kiel 1985
			Falco jugger	Laggar Falcon	Arabian Gulf	Greenwood and Blakemore 1973
			Falco tinnunculus	Eurasian Kestrel	Germany	Kitzing 1980
Galliformes	Megapodiidae	Megapodes				
	Cracidae	Guans, Chachalacas & Allies				
	Meleagridae	Turkeys	*Meleagris gallopavo*	Wild Turkey	France	Heusinger 1844
			Meleagris gallopavo	Wild Turkey	Germany	Bollinger 1877
			Meleagris gallopavo	Wild Turkey	India	Pandey and Mallick 1974
			Meleagris gallopavo	Wild Turkey	Florida, U.S.A.	Akey et al. 1981
			Meleagris gallopavo	Wild Turkey	Georgia, U.S.A.	Wheeldon et al. 1985
			Meleagris gallopavo	Wild Turkey	Malaysia	Ideris and Ibrahim 1986
			Meleagris gallopavo	Wild Turkey	Oregon, U.S.A.	Lutz and Crawford 1987
	Tetraonidae	Grouse	*Tetrastes bonasia*	Common Hazelhen	France	Cruasson 1946
			Dendragapus obscurus	Blue Grouse	Oregon, U.S.A.	Dickenson 1967
			Dendragapus obscurus	Blue Grouse	Canada	Syverton and McTaggert Cowan 1944
			Lagopus mutus	Rock Ptarmigan	Japan	Horiuchi et al. 1965
			Tetrao tetrix	Black Grouse	Denmark	Christiansen 1949
			Bonasa umbellus	Ruffed Grouse	U.S.A.	Bump et al. 1947
			Centrocercus urophasianus	Sage Grouse	Texas, U.S.A.	Dubose 1965
			Tympanuchus cupido	Greater Prairie-Chicken	Virginia, U.S.A.	Dubose 1965
	Odontophoridae	New World Quail	*Callipepla squamata*	Scaled Quail	Texas, U.S.A.	Wilson and Crawford 1988

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
			Callipepla gambelii	Gambel's Quail	Arizona, U.S.A.	Blankenship et al. 1966
			Callipepla californica	California Quail	Oregon, U.S.A.	Crawford et al. 1979
			Callipepla californica	California Quail	Hawaii, U.S.A.	Perkins 1903
			Colinus virginianus	Northern Bobwhite	Georgia & S. Carolina, U.S.A.	Stoddard 1931
			Colinus virginianus	Northern Bobwhite	Georgia & Florida, U.S.A.	Davidson et al. 1980
			Colinus virginianus	Northern Bobwhite	Malaysia	Reed and Schrader 1989
	Phasianidae	Pheasants & Partridge				
			Alectoris rufa	Red-legged Partridge	Spain	Buenestado et al. 2004
			Chrysolophus pictus	Golden Pheasant	Germany	Bollinger 1873
			Crossoptilon crossoptilon	White Eared-Pheasant	California, U.S.A.	Ensley et al. 1978
			Crossoptilon crossoptilon	White Eared-Pheasant	China	Hu Hongguan 1982
			Crossoptilon auritum	Blue Eared-Pheasant	California, U.S.A.	Ensley et al. 1978
			Phasianus colchicus	Ring-necked Pheasant	Oregon, U.S.A.	Crawford et al. 1979
			Phasianus colchicus	Ring-necked Pheasant	Hawaii, U.S.A.	Perkins 1903
			Phasianus colchicus	Ring-necked Pheasant	China	Hu Hongguan, 1982; Zhang et al. 1996
			Phasianus colchicus	Ring-necked Pheasant	Iraq	Al-Ani, 1986
			Phasianus colchicus	Ring-necked Pheasant	Texas, U.S.A.	Wilson and Crawford 1988
			Lophura diardi	Siamese Fireback	California, U.S.A.	Ensley et al. 1978

			Gallus gallus	Red Junglefowl	California, U.S.A.	Ensley et al. 1978
			Tragopan satyra	Satry Tragopan	France	Megnin 1878
			Tragopan temminckii	Temminck's Tragopan	China	Hu Hongguan 1982
			Perdix perdix	Gray Partridge	Germany	Stadie 1931
			Perdix perdix	Gray Partridge	Denmark	Christiansen 1949
			Perdix perdix	Gray Partridge	Great Britain	Pomeroy 1962
			Perdix perdix	Gray Partridge	Austria	Loupal et al. 1985
			Perdix perdix	Gray Partridge	Italy	Mani et al. 1990
			Coturnix coturnix	Common Quail	Mexico	Gallagher 1916
			Coturnix coturnix	Common Quail	Italy	Rinaldi et al. 1972
			Coturnix coturnix	Common Quail	China	Zhang et al. 1996
			Lophophorus impejanus	Himalayan Monal	Canada	Karstad 1965
			Lophophorus impejanus	Himalayan Monal	California, U.S.A.	Ensley et al. 1978
			Lophophorus impejanus	Himalayan Monal	Austria	Loupal et al. 1985
			Pavo cristatus	Indian Peafowl	Iraq	Alfalluji et al. 1979
			Pavo cristatus	Indian Peafowl	China	Hu Hongguan 1982
	Numididae	Guineafowl	*Numida meleagris*	Helmeted Guineafowl	Germany	Tietz 1932
Opisthocomiformes	Opisthocomidae	Hoatzin				
Gruiformes	Mesithornithidae	Mesites				
	Turnicidae	Buttonquail				
	Gruidae	Cranes	*Grus grus*	Common Crane	Germany	Zhang et al. 1996
			Grus japonensis	Red-crowned Crane	China	Zhang et al. 1996
			Grus canadensis	Sandhill Crane	Florida, U.S.A.	Simpson et al. 1975; Forrester and Spalding 2003
			Anthropoides virgo	Demoiselle Crane	China	Zhang et al. 1996
	Aramidae	Limpkin				
	Psophiidae	Trumpters				
	Rallidae	Rails, Gallinules & Coots	*Fulica atra*	Eurasian Coot	India	Mathur et al. 1972
	Helionorithidae	Finfoots				
	Rhynochetidae	Kagu				
	Eurypygidae	Sunbittern				
	Cariamidae	Seriemas				
	Otididae	Bustards	*Otis tarda*	Great Bustard	Rumania	Cociu et al. 1972
			Otis tarda	Great Bustard	Germany	Seidel 1972
			Chlamydoitis undulata	Houbara Bustard	United Arab Emirates; Middle East	Samour et al. 1996; Bailey et al. 2002

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
Charadriiformes	Jacanidae	Jacanas				
	Rostratulidae	Painted-Snipes				
	Dromadidae	Crab Plover				
	Haematopodidae	Oystercatchers	*Haematopus ostralegus*	Eurasian Oystercatcher	Great Britain	Green 1969
	Ibidorhynchidae	Ibisbill				
	Recurvirostridae	Avocets & Stilts				
	Burhinidae	Thick-knees				
	Glareolidae	Pratincoles & Coursers				
	Charadriidae	Plovers & Lapwing	*Vanellus vanellus*	Northern Lapwing	Denmark	Christiansen 1949
			Pluvialis apricaria	Eurasian Golden-Plover	Denmark	Christiansen 1949
	Pluvianellidae	Magellanic Plover				
	Scolopacidae	Sandpipers	*Pelidna alpina*	Dunlin	Great Britain	Green 1969
			Numenius arquata	Eurasian Curlew	Germany	Von Schauberg 1901
			Calidris alba	Sanderling	Florida, U.S.A.	Krueder et al. 1999
	Pedionomidae	Plains-wanderer				
	Thinocoridae	Seedsnipes				
	Chionididae	Sheathbills				
	Stercorariidae	Skuas & Jaegers				
	Laridae	Gulls	*Larus canus*	Mew Gull	Denmark	Christiansen 1949
			Larus argentatus	Herring Gull	Great Britain	Miles and Stocker 1948
	Sternidae	Terns	*Sterna masima*	Royal Tern	Florida, U.S.A.	Jacobson 1980
			Sterna fuscata	Sooty Tern	Australia	Annuar et al. 1983
			Anous stolidus	Brown Noddy	Australia	Annuar et al. 1983
			Anous tenuirostris	Lesser Noddy	Australia	Annuar et al. 1983
	Rynchopidae	Skimmers				
	Alcidae	Auks, Murres & Puffins	*Uria aalge*	Common Murre	California, U.S.A.	Harris et al. 1978; Hill and Bogue 1978
Pterocliformes	Pteroclidae	Sandgrouse				

Columbiformes	Columbidae	Pigeons & Doves	*Columba sp.*	Pigeon	Germany	Hartig and Frese 1973
			Columba livia	Rock Dove or Feral Pigeon	The Netherlands	de Jong 1912
			Columba livia	Rock Dove or Feral Pigeon	Austria	Loupal et al. 1985
			Columba livia	Rock Dove or Feral Pigeon	Florida, U.S.A.	Forrester and Spalding 2003
			Columba junoniae	Laurel Pigeon	Canary Islands, Spain	Medina et al., 2004
			Columba palumbus	Common Wood-Pigeon	Great Britain	Jennings 1954
			Columba palumbus	Common Wood-Pigeon	Germany	Salhoff 1937
			Columba palumbus	Common Wood-Pigeon	Sweden	Hulphers 1943
			Columba palumbus	Common Wood-Pigeon	Norway	Holt and Krogsrud 1973; Weli et al. 2004
			Columba palumbus	Common Wood-Pigeon	New York, U.S.A.	Tangredi 1974
			Columba araucana	Chilean Pigeon	Chile	Cubillos et al. 1979
			Zenaida macroura	Mourning Dove		Kossack and Hanson 1954
			Zenaida macroura	Mourning Dove	Florida, U.S.A.	Forrester and Spalding 2003
			Streptopelia decaocto	Eurasian Collard-Dove	Iraq	Al-Ani 1986
Psittaciformes	Cacatuidae	Cockatoos & Allies	*Nyphicus hollandicus*	Cockatiel	Japan	Iwata et al. 1986
	Psittacidae	Parrots, Macaws & Allies	*Loriculus vernalis*	Vernal-Hanging Parrot	Germany	Pilaski et al. 1990
			Agapornis roseicollis	Rosy-faced Lovebird	Germany	Kraft and Teufel 1971
			Agapornis roseicollis	Rosy-faced Lovebird	Florida, U.S.A.	Hitchner and Clubb 1980
			Agapornis roseicollis	Rosy-faced Lovebird	Japan	Tsai et al. 1997

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Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
			Agapornis fischeri	Fischer's Love bird	Florida, U.S.A.	Hitchner and Clubb 1980
			Agapornis personatus	Yellow-collared Lovebird	Germany	Kraft and Teufel 1971
			Agapornis personatus	Yellow-collared Lovebird	California, U.S.A.	Emanuelson et al. 1978
			Agapornis personatus	Yellow-collared Lovebird	Florida, U.S.A.	Hitchner and Clubb 1980
			Agapornis personatus	Yellow-collared Lovebird	Japan	Iwata et al. 1986
			Amazona finschi	Lilac-crowned Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
			Amazona finschi	Lilac-crowned Parrot	Indiana, U.S.A.	Boosinger et al. 1982
			Amazona autumnalis	Red-lored Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
			Amazona albifrons	White-fronted Parrot	Mexico	Graham 1978
			Amazona albifrons	White-fronted Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
			Amazona aestiva	Blue-fronted Parrot	Bolivia	Hitchner and Clubb 1980
			Amazona aestiva	Blue-fronted Parrot	California, U.S.A.	McDonald et al. 1981
			Amazona aestiva	Blue-fronted Parrot	Mexico	Olmos et al. 1986
			Amazona aestiva	Blue-fronted Parrot	Japan	Iwata et al. 1986
			Amazona aestiva	Blue-fronted Parrot	South Africa	Petrak 1982
			Amazona ochrocephala	Yellow-crowned Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
			Amazona ochrocephala	Yellow-crowned Parrot	Indiana, U.S.A.	Boosinger et al. 1982
			Amazona orchrocephala	Yellow-crowned Parrot	U.S.A.	Minsky and Petrak 1982

Amazona farinosa	Mealy Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
Deroptyus accipitrinus	Red-fan Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
Pionus fuscus	Dusky Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
Pionus senilis	White-crowned Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
Pionus maximiliani	Scaly-headed Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
Pionus menstruus	Blue-headed Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
Pionus melano-cephalus	Black-headed Caique	Florida, U.S.A.	Hitchner and Clubb 1980
Ara rubrogenys	Red-fronted Macaw	Florida, U.S.A.	Hitchner and Clubb 1980
Ara ararauna	Blue-and-Yellow Macaw	U.S.A.	Minsky and Petrak 1982
Ara chloroptera	Red-and-green Macaw	South America	Kroesen 1977
Ara militaris	Military Macaw	Texas, U.S.A.	Clark et al, 1988
Anodorhynchus hyancinthinus	Hyacinth Macaw	South America	Kroesen 1977
Psittacara holochlora	Green Parakeet	Indiana, U.S.A.	Boosinger et al. 1982
Aratinga mitrata	Mitred Parakeet	Florida, U.S.A.	Hitchner and Clubb 1980
Aratinga solstitialis	Sun Parakeet	Mexico	Olmos et al. 1982
Aratinga canicularis	Orange-fronted Parakeet	Mexico	Olmos et al. 1982
Enicognathus leptorhynchus	Slender-billed Parakeet	Florida, U.S.A.	Hitchner and Clubb 1980
Aprosmictus erythropterus	Red-winged Parrot	Germany	Winteroll et al. 1979
Brotogeris pyrrhoptera	Grey-cheeked Parrot	Florida, U.S.A.	Hitchner and Clubb 1980

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
			Psephotus haemotonotus	Red-rumped Parrot	Florida, U.S.A.	Hitchner and Clubb 1980
			Platycercus eximius	Eastern Rosella	Florida, U.S.A.	Hitchner and Clubb 1980
			Melopsittacus undulatus	Budgerigar	Illinois, U.S.A.	Sharma et al. 1968
			Melopsittacus undulatus	Budgerigar	Philadelphia, U.S.A.	Petrak 1982
Cuculiformes	Musophagidae	Turacos				
	Cuculidae	Cuckoos	*Chrysococcyx caprius*	Dideric Cuckoo	South Africa	Markus 1974
Strigiformes	Tyonidae	Barn-Owls				
	Strigidae	Typical Owls				
			Otus asio	Eastern Screech-Owl	Florida, U.S.A.	Deem et al. 1997; Forrester and Spalding 2003
			Asio otus	Northern Long-eared Owl	Italy	Chiocco 1992
			Asio otus	Northern Long-eared Owl	Florida, U.S.A.	Forrester and Spalding 2003
			Bubo bubo	Eurasian Eagle-Owl	Italy	Maggiora and Valenti 1903
			Bubo virginianus	Great Horned Owl	Florida, U.S.A.	Forrester and Spalding 2003
			Strix varia	Barred Owl	Florida, U.S.A.	Deem et al. 1997; Forrester and Spalding 2003
Caprimulgiformes	Steatornithidae	Oilbird				
	Aegothelidae	Owlet-Nightjars				
	Podargidae	Frogmouths				
	Nyctibiidae	Potoo				
	Caprimuligidae	Nightjar & Allies				
Apodiformes	Apodidea	Swifts	*Chaetura pelagica*	Chimney Swift	Pennsylvania, U.S.A.	Worth 1956
	Hemiprocnidae	Treeswifts				
	Trochilidae	Humminbirds				

Coliiformes	Coliidae	Mousebirds				
Trogoniformes	Trogonidae	Trogon				
Coraciiformes	Alcedinidae	Kingfisher				
	Todidae	Todies				
	Momotidae	Motmot				
	Meropidae	Bee-eaters				
	Coraciidae	Typical Rollers				
	Brachypteraciidae	Ground-Roller				
	Leptosomidae	Cuckoo-Roller				
	Upupidae	Hoopoes	*Phoeniculus purpureus*	Red-billed Wood-Hoopoe	France	Megnin 1878
	Phoeniculidae	Woodhoopoes				
	Bucerotidae	Hornbills				
Piciformes	Galbulidae	Jacamars				
	Bucconidae	Puffbirds				
	Capitonidae	Barbets				
	Ramphastidae	Toucans				
	Indicatoridae	Honeyguides				
	Picidae	Woodpeckers & Allies	*Colaptes auratus*	Northern Flicker	Illinois, U.S.A.	Labisky and Mann 1961
			Colaptes auratus	Northern Flicker	Ontario, Canada	Kirmse, 1967c, 1969; Karstad 1971
			Colaptes auratus	Northern Flicker	Florida, U.S.A.	Forrester and Spalding 2003
Passeriformes	Eurylaimidae	Broadbills				
	Philepittidae	False-sunbirds (Asities)				
	Funariidae	Ovenbirds				
	Dendrocolapitidae	Woodcreepers				
	Thanmophilidae	Typical Antbirds				
	Formicariidae	Antthrushes & Antpittas				
	Conopophagidae	Anteaters				
	Rhinocryptidae	Tapaculos				
	Phytotomidae	Plantcutters				
	Cotingidae	Cotingas	*Cotinga maculata*	Banded Cotinga	Germany	Pilaski et al. 1990
	Pipridae	Manakins	*Manacus vitellinus*	Golden-collared Manakin	Panama	Kirmse and Loftin 1969

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
			Manacus manacus	White-bearded Manakin	Trinidad	Tikasingh et al. 1982
			Pipra erythrocephala	Golden-headed Manakin	Trinidad	Tikasingh et al. 1982
			Pipra mentalis	Red-capped Manakin	Panama	Kirmse and Loftin 1969
	Tyrannidae	Tyrant Flycathers	*Empidonax traillii*	Willow Flycatcher	Panama	Kirmse and Loftin 1969
			Empidonax traillii	Willow Flycatcher	Costa Rica, Arizona, U.S.A.	van Riper, pers. observation
	Oxyruncidae	Sharpbill				
	Pittidae	Pittas				
	Atrichornithidae	Scrub-birds				
	Menuridae	Lyrebirds				
	Acanthisittidae	New Zealand Wrens				
	Alaudidae	Larks	*Alauda arvensis*	Sky Lark	Denmark	Christiansen 1949
			Galerida cristata	Crested Lark	Spain	Groth 1963
			Calandrella rufescens	Lesser Short-toed Lark	Canary Islands, Spain	Smits et al. 2005
	Hirundinidae	Swallows				
	Motacillidae	Wagtails & Pipits	*Anthus novae-seelandiae*	Australasian Pipit	New Zealand	Westerkov 1953
			Anthus novae-seelandiae	Australasian Pipit	New Zealand	Quinn 1971
			Anthus berthelotti	Berthelot's Pipit	Canary Islands, Spain	Smits et al. 2005
	Campephagidae	Cuckoo-shrikes	*Coaracina novaehollandiae*	Black-faced Cuckoo-shrike	Australia	Sutton and Fillipich 1983
	Pycnonotidae	Bulbuls	*Pycnonotus jocosus*	Red-whiskered Bulbul		van Riper et al., 1979
	Regulidae	Kinglets				
	Chloropseidae	Leafbirds	*Chloropsis aurifrons*	Golden-fronted Leafbird	Germany	Hertig 1966

Aegithinidae	Ioras				
Ptilogonatidae	Silky-flycatchers				
Bombycillidae	Waxwings				
Hypocoliidae	Hypocolius				
Dulidae	Palmchat				
Cinclidae	Dipper				
Troglodytidae	Wrens	*Troglodytes troglodytes*	Wren	Denmark	Christiansen 1949
Mimidae	Mockingbirds & Thrashers	*Mimus polyglottus*	Northern Mockingbird	Spain	Oros et al., 1997
		Mimus polyglottus	Northern Mockingbird	Canada	Kirmse, 1966; Karstad 1971
		Mimus polyglottus	Northern Mockingbird	Florida, U.S.A.	Forrester and Spalding 2003
		Nesomimus parvulus	Galapagos Mockingbird	Galapagos Islands	Vargus 1987; Thiel et al. 2005
		Dumetella caroloinsis	Gray Catbird	New Jersey, U.S.A.	Kirmse et al. 1966
Prunellidae	Accentors	*Prunella collaris*	Apline Accentor	Austria	Loupal et al. 1985
		Prunella modularis	Dunnock	France	Mercier and Poisson 1923
		Prunella modularis	Dunnock	Great Britain	Edwards 1955
Turdidae	Thrushes & Allies	*Turdus migratorius*	American Robin	New Jersey, U.S.A.	Kirmse et al. 1966
		Turdus migratorius	American Robin	U.S.A.	Goodpasture and Anderson 1962
		Turdus migratorius	American Robin	Ontario Canada	Kirmse 1966
		Turdus migratorius	American Robin	California, U.S.A.	Hill and Bogue, 1977
		Turdus merula	Eurasian Blackbird	Italy	Maggiora and Valenti 1903
		Turdus philomelos	Song Thrush	Denmark	Christiansen 1949
		Turdus nudigenis	Bare-eyed Thrush	Trinidad	Tikasingh et al. 1982
		Turdus pilaris	Fieldfare	Italy	Maggiora and Valenti 1903
		Catharus minimus	Gray-cheeked Thrush	Ontario Canada	Kirmse 1966

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
			Catharus minimus	Grey-cheeked Thrush	Panama	Kirmse and Loftin 1969
			Catharus fuscescens	Veery	Panama	Kirmse and Loftin 1969
			Catharus ustulatus	Swainson's Thrush	Canada	Kirmse, 1966
			Hylocichla mustelina	Wood Thrush	U.S.A.	Goodpasture and Anderson 1962
			Hylocichla mustelina	Wood Thrush	Canada, Panama	Kirmse 1966; Kirmse and Loftin 1969
			Myadestes obscurus	Omao	Hawaii, U.S.A.	van Riper and van Riper 1985; van Riper et al. 2002
	Cistiocolidae	Cisticolas & Allies				
	Sylviidae	Old World Warblers	*Sylvia curruca*	Lesser Whitethroat	Denmark	Christiansen 1949
			Sylvia atricapilla	Blackcap	Czech Republic, Austria	Rajchard 2001
	Polioptilidae	Gnatcatchers				
	Muscicapidae	Old World Flycatchers	*Copsychus malabaricus*	White-rumped Shama	Germany	Hartig 1966
			Eumyias thalassina	Verditer Flycatcher	Germany	Hartig 1966
			Grandala coelicolor	Grandala	U.S.A.	Goodpasture and Anderson 1962
			Chasiempis sandwichensis	Elepaio	Hawaii, U.S.A.	Perkins 1903; van Riper and van Riper 1985; VanderWerf 2001; van Riper et al., 2002; Atkinson et al. 2005
	Platysteiridae	Wattle-eyes				
	Rhipiduridae	Fantails				
	Monarchidae	Monarch Flycatchers				
	Pteroicidae	Australasian Robins				

Pachycephalidae	Whistlers & Allies				
Picathartidae	Rockfowl				
Timaliidae	Babblers				
Pomatostomidae	Pseudo-babblers				
Paradoxornithidae	Parrotbills				
Orthonychidae	Logrunner & Chowchilla				
Cinclosomatidae	Whipbirds & Quail-thrushes				
Aegithalidae	Long-tailed Tits				
Maluridae	Fairywrens				
Acanthizidae	Thornbills & Allies				
Epthianuridae	Australian Chats				
Neosittidae	Sitellas				
Climacteridae	Australasian Treecreepers				
Paridae	Chickadees & Tits	*Baeolophus bicolor*	Tufted Titmouse	U.S.A.	Goodpasture and Anderson 1962
		Parus major	Great Tit	Germany	Polowinkin 1901
		Parus major	Great Tit	Norway	Holt and Krogsrud 1973
Sittidae	Nuthatches				
Tichidromidae	Wallcreeper				
Certhiidae	Creepers	*Certhia familiaris*	Tree-Creeper Canada	Canada	Kirmse 1966
Rhabdornithidae	Phillippine Creepers				
Remizidae	Penduline Tits				
Nectarinidae	Sunbirds & Spiderhunters				
Melanocharitidae	Berrypeckers & Longbills				
Paramythiidae	Tit Berrypecker & Crested Berrypecker				
Dicaeidae	Flowerpeckers				
Pardalotidae	Pardalotes				
Zosteropidae	White-eyes	*Zosterops lateralis*	Silver-eye	New Zealand	Austin et al. 1973
		Zosterops lateralis	Silver-eye	Australia	Harrigan et al. 1975
		Zosterops lateralis	Silver-eye	Australia	Annuar et al. 1983

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
			Zosterops palpebrosus	Oriental White-eye	Japan	Kawashima 1962
			Zosterops japonicus	Japanese White-eye	Hawaii, U.S.A.	van Riper and van Riper 1985; van Riper et al. 2002
	Promeropidae	Sugarbirds				
	Meliphagidae	Honeyeaters				
	Oriolidae	Old World Orioles				
	Irenidae	Fairy-bluebirds				
	Laniidae	Shrikes	*Lanius sp.*	Shrike	Southern Africa	Abrey 1993
	Malaconotidae	Bushshrikes & Allies				
	Prionopidea	Helmetshrikes				
	Vangidae	Vangas				
	Dicruridae	Drongos				
	Callaeidae	Wattlebirds				
	Grallinidae	Mudnest-builders	*Grallina cyanoleuca*	Magpie-Lark	Australia	Harrigan et al. 1975; Annuar et al. 1983
	Corcoracidae	White-winged Chough & Apostlebird				
	Artimidae	Woodswallow				
	Pityriaseidae	Bristlehead				
	Cracticidae	Bellmagpies & Allies	*Gymnorhina tibicen*	Australian Magpie	Australia	Burnet and Stanley 1959; Harrigan et al. 1975; Chung and Spradbow 1977; Annuar et al. 1983
	Paradisaeidae	Birds-of-Paradise				
	Ptilonorhynchidae	Bowerbirds				
	Corvidae	Crows, Jays & Magpies	*Coleus monedula*	Jackdaw	The Netherlands	Jansen 1942
			Corvus frugilegus	Rook	Denmark	Christiansen 1949
			Corvus corax	Common Raven	Denmark	Christiansen 1949
			Corvus corone	Carrion Crow	Denmark	Christiansen 1949

		Corvus corone	Carrion Crow	Great Britain	Poulding 1960
		Corvus corone	Carrion Crow	Germany	Grzimek 1939
		Corvus hawaiiensis	Hawaiian Crow	Hawaii, U.S.A.	Jenkins et al. 1989; Tripathy et al. 2000
		Cyanocitta cristata	Blue Jay	Pennsylvania, U.S.A.	Worth 1956
		Pica pica	Black-billed Magpie	Denmark	Christiansen 1949
		Pica pica	Black-billed Magpie	Norway	Holt and Krogsrud 1973
		Cyanocitta cristata	Blue Jay	Florida, U.S.A.	Forrester and Spalding 2003
Sturnidae	Starlings	*Gracula religiosa*	Common Hill Myna	Malaysia	Karpinski and Clubb 1986
		Gracula religiosa	Common Hill Myna	Malaysia	Reed and Schrader 1989
		Leucopsar rothschildi	Bali Myna	Washington, U.S.A.	Landolt and Kochan 1976
		Sturnus vulgaris	European Starling	U.S.A.	Goodpasture and Anderson 1962
		Sturnus vulgaris	European Starling	Germany	Hartig 1966
		Sturnus vulgaris	European Starling	Germany	Luthgen 1983
		Sturnus vulgaris	European Starling	Austria	Loupal et al. 1985
		Cosmopsarus regius	Regal Starling	Germany	Pilaski et al. 1990
		Lamprotornis sp.	Glossy Starling	Germany	Luthgen 1983
Passeridae	Old World Sparrows	*Passer domesticus*	House Sparrow	Brazil	Reis and Nobrega 1937
		Passer domesticus	House Sparrow	U.S.A.	Coulston and Manwell 1941
		Passer domesticus	House Sparrow	Washington, U.S.A.	Giddens et al. 1971
		Passer domesticus	House Sparrow	Norway	Holt & Krogsrud 1973; Weli et al. 2004
		Passer domesticus	House Sparrow	California, U.S.A.	Hill and Bogue 1977
		Passer domesticus	House Sparrow	Germany	Herbst and Krauss 1989

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
			Passer domesticus	House Sparrow	Canada	Mikaelian Martineau 1996
			Passer domesticus	House Sparrow	Hawaii, U.S.A.	van Riper and van Riper 1985
			Passer melanurus	Cape Sparrow	South Africa	Markus 1974
			Passer montanus	Tree Sparrow	Japan	Honma and Chiva 1976
	Ploceidae	Weavers & Allies	*Ploceus velatus*	African Masked-Weaver	South Africa	Markus 1974
			Quelea quelea	Red-headed Quelea	Africa	Barre 1975
	Estrildidae	Waxbills & Allies	*Padda oryzivora*	Java Sparrow	Germany	Kikuth and Gollub 1932
	Viduidae	Indigobirds				
	Vireonidae	Vireos & Allies				
	Fringillidae	Siskins, Crossbills & Allies	*Fringilla coelebs*	Chaffinch	Germany	Eberbeck and Kayser 1932
			Fringilla coelebs	Chaffinch	Great Britain	Keymer and Blackmore 1964
			Carduelis cucullata	Red Siskin	Germany	Kaleta and Marschall 1982
			Carduelis pinus	Pine Siskin	California, U.S.A.	Bigland et al. 1962
			Carduelis spinus	Eurasian Siskin	Germany	Hartwigk and Lange 1964
			Carduelis spinus	Eurasian Siskin	Austria	Loupal et al. 1985
			Carduelis carduelis	European Goldfinch	Germany	Polowinkin 1901
			Carduelis carduelis	European Goldfinch	Great Britain	Keymer and Blackmore 1964
			Carduelis carduelis	European Goldfinch	Germany	Kaleta and Ebert 1969
			Carduelis cucullata	Red Siskin	Germany	Kaleta and Marschall 1982

		Carduelis chloris	European Greenfinch	Great Britain	Keymore and Blackmore 1964
		Carduelis chloris	European Greenfinch	Germany	Kaleta and Ebert 1969
		Pyrrhula phrrhula	Common Bullfinch	Germany	Polwinkin 1901
		Pyrrhula phrrhula	Common Bullfinch	The Netherlands	De Jong 1912
				Germany	Stadie 1931
		Pyrrhula phrrhula	Common Bullfinch	Germany	Kaleta and Ebert 1969
		Pyrrhula phrrhula	Common Bullfinch	Austria	Loupal et al. 1985
		Linaria cannabina	Eurasian Linnet	Germany	Polowinkin 1901
		Linaria cannabina	Eurasian Linnet	Germany	Hartwigk and Lang 1964
		Serinus canaria	Island Canary	Germany	Hartig 1966; Kikuth and Gollub 1932; Michel and Lindner 1964
		Serinus canaria	Island Canary	Tunisia	Loir and Ducloux 1894
		Serinus canaria	Island Canary	Uruguay	Wolffhugel 1919
		Serinus canaria	Island Canary	Japan	Sato et al. 1962
		Serinus canaria	Island Canary	New York, U.S.A.	Donnely and Crane 1984
		Serinus canaria	Island Canary	Austria	Loupal et al. 1985
		Serinus canaria	Island Canary	Oklahoma, U.S.A.	Johnson and Castro 1986
		Carpodacus mexicanus	House Finch	California, U.S.A.	Power and Human 1976; Hill and Bogue 1977
		Carpodacus mexicanus	House Finch	Idaho, U.S.A.	Docherty and Long 1986
		Leucosticte tephrocotis	Gray-crowned Rosy-Finch	Alaska, U.S.A.	Bergstrom 1952
Drepanididae	Hawaiian Honeycreepers	*Paroreomyaz maculata*	Lanai Creeper	Hawaii, U.S.A.	Munro 1944
		Hemignathus obscurus	Akialoa	Hawaii, U.S.A.	Perkins 1893

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
			Himatione sanguinea	Apapane	Hawaii, U.S.A.	Perkins 1893; Amadon 1950; van Riper and van Riper 1985; Tripathy et al. 2000; van Riper et al., 2002; Atkinson et al. 2005
			Psittirostra psittacea	Ou	Hawaii, U.S.A.	Perkins 1893
			Rhodacanthus spp. (n=3)	Koa Finches	Hawaii, U.S.A.	Perkins 1893
			Telespiza cantans	Laysan Finch	Hawaii, U.S.A.	Warner 1968; van Riper and van Riper 1985; van Riper et al. 2002
			Loxops coccineus	Akepa	Hawaii, U.S.A.	Henshaw 1902
			Hemignathus virens	Hawaii Amakihi	Hawaii, U.S.A.	van Riper and van Riper 1985; van Riper et al. 2002; Atkinson et al. 2005
			Vestiaria coccinea	Iiwi	Hawaii, U.S.A.	Warner 1968; van Riper and van Riper 1985; van Riper et al. 2002
	Peucedramidae	Olive Warbler				
	Parulidae	New World Warblers	*Oporornis philadelphia*	Mourning Warbler	Panama	Kirmse and Loftin 1969
			Seiurus aurocapillus	Ovenbird	Panama	Kirmse and Loftin 1969
			Seiurus motacilla	Louisiana Waterthrush	Panama	Kirmse and Loftin 1969
			Dendroica tigrina	Cape May Warbler	New Jersey, U.S.A.	Kirmse et al. 1966
			Dendroica petechia	Yellow Warbler	Galapagos Islands	Thiel et al. 2005

		Icteria virens	Yellow-breasted Chat	New Jersey, U.S.A.	Kirmse et al. 1966
		Geothlypis trichas	Common Yellowthroat	New Jersey, U.S.A.	Kirmse et al. 1966
Coerebidae	Banaquit				
Thraupidae	Tanagers & Allies	*Thraupis episcopus*	Blue-grey Tanager	Panama	Kirmse and Loftin 1969
		Chlorospingus ophthalmicus	Common Bush-Tanager	Panama	Kirmse and Loftin 1969
		Piranga rubra	Summer-Tanager	Panama	Kirmse and Loftin 1969
		Euphonia violacea	Violaceous Euphonia	Trinidad	Tikasingh et al. 1982
		Tangra guttata	Speckled Tanager	Germany	Pilaski et al. 1990
Emberizidae	Buntings, Sparrows, Seedeaters & Allies	*Plectrophenax nivalis*	Snow Bunting	Maryland, U.S.A.	Irons 1934
		Spizella passerina	Chipping Sparrow	U.S.A.	Baldwin 1922
		Spizella passerina	Chipping Sparrow	Georgia, U.S.A.	Musselmann 1928
		Spizella passerina	Chipping Sparrow	Ontario Canada	Kirmse 1966
		Spizella passerina	Chipping Sparrow	Florida, U.S.A.	Stevenson and Anderson 1994
		Spizella arborea	American Tree Sparrow	U.S.A.	Bergstrom 1952
		Spizella pussilla	Field Sparrow	Tennessee & Mississippi, U.S.A.	Goodpasture and Anderson 1962
		Spizella pussilla	Field Sparrow	Ontario Canada	Kirmse 1966
		Passerculus sandwichensis	Savannah Sparrow	Canada	Karstad 1971
		Junco hyemalis	Dark-eyed Junco	New Jersey, U.S.A.	Worth 1956
		Junco hyemalis	Dark-eyed Junco	Tennessee & Mississippi, U.S.A.	Goodpasture and Anderson 1962
		Junco hyemalis	Dark-eyed Junco	U.S.A.	Beaver and Cheatham 1963
		Junco hyemalis	Dark-eyed Junco	Ontario Canada	Kirmse 1966
		Melospiza melodia	Song Sparrow	New York, U.S.A.	Coulston and Manwell 1941

(*Continued*)

Table 6.1. (Continued)

Order	Family	Common Family Name	Species	Common Species Name	Country Reported	References
			Melospiza melodia	Song Sparrow	Ontario Canada	Kirmse 1966
			Passurella iliaca	Fox Sparrow	New Jersey, U.S.A.	Worth 1956
			Pipilo erythrophtalmus	Eastern Towhee	Tennesseee & Mississippi, U.S.A.	Goodpasture and Anderson 1962
			Pipilo erythrophtalmus	Eastern Towhee	Canada	Kirmse 1966
			Pipilo chlorurus	Green-tailed Towhee	Canada	Kirmse 1966
			Zonotrichia atricapilla	Golden-crowned Sparrow	Washington, U.S.A.	Giddens et al. 1971
			Zonotrichia albicollis	White-throated Sparrow	New Jersey, U.S.A.	Worth 1956
			Zonotrichia albicollis	White-throated Sparrow	Canada	Kirmse 1966
			Zonotrichia leucophrys	White-crowned Sparrow	Washington, U.S.A.	Giddens et al. 1971
			Sporophila corvina	Variable Seedeater	Panama	Kirmse and Loftin 1969
			Sporophila sp.	Seedeater	Brazil	Reis and Nobrega 1937
			Sicalis flaveola	Saffron Finch	Brazil	Reis and Nobrega 1937
			Oryzoborus angolensis	Chestnut-bellied Seed-Finch	Brazil	Reis and Nobrega 1937; Kirmes and Loftin 1969
			Oryzoborus funereus	Thick-billed Seed Finch	Panama	Kirmse and Loftin 1969
			Aimophila cassinii	Cassin's Sparros	Kansas, U.S.A.	Savage and Dick 1969
			Geospiza spp.	Ground Finches	Galapagos Islands	Thiel et al. 2005
	Cardinalidae	Caltators, Cardinals & Allies	*Cardinalis cardinalis*	Northern Cardinal	Tennessee & Mississippi, U.S.A.	Goodpasture and Anderson 1962
			Cardinalis cardinalis	Northern Cardinal	Austria	Loupal et al. 1985

		Cardinalis cardinalis	Northern Cardinal	Hawaii, U.S.A.	van Riper and van Riper 1985
		Cyanoloxia cyanea	Ultramarine Grosbeak	Brazil	Reis & Nobrega 1937
		Cyanocompsa cyanoides	Blue-black Grosbeak	Panama	Kirmse and Loftin 1969
Icteridae	Troupials & Allies	*Quiscalus sp.*	Grackle	Texas, U.S.A.	Docherty et al. 1991
		Quiscalus quiscula	Common Grackle	Florida, U.S.A.	Forrester and Spalding 2003
		Quiscalus quiscula	Common Grackle	Maryland, U.S.A.	Herman et al. 1962
		Quiscalus quiscula	Common Grackle	U.S.A.	Emmel 1930
		Molothrus ater	Brown-headed Cowbird	Pennsylvania, U.S.A.	Locke 1961
		Molothrus ater	Brown-headed Cowbird	Maryland, U.S.A.	Herman et al. 1962
		Molothrus ater	Brown-headed Cowbird	Alabama, U.S.A.	Stewart 1963
		Agelaius phoeniceus	Red-winged Blackbird	Florida, U.S.A.	Fisk 1972

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