Chapter 2
Wild birds and avian influenza

AVIAN INFLUENZA IN WETLAND BIRD SPECIES

Although the H5N1 AI virus has been detected across a diverse range of free-ranging wild species (over 75 species of wild birds from 10 different avian orders; Table 2.1), it is wetland or aquatic species that are the most frequently recorded. Birds with affinities for wetland habitats make up nearly 60 percent of the wild species infected with the H5N1 virus and also account for the greater proportion of wildlife mortalities.

The term "wetland" encompasses a variety of inland freshwater and marine coastal habitats that share one common feature; soils or substrates that are at least periodically saturated with or covered by water. This simple description belies the fact that wetland systems are quite complex and exhibit a wide range of differences in substrates, salinity, frequency of flooding and vegetation (Ramsar Convention Manual 1997) - important features that determine the bird species inhabiting a particular wetland.

Waterbirds have evolved foraging and breeding strategies to exploit natural wetlands and can be found in virtually all types of wetland; from perennially submerged bays, lakes, ponds and rivers to seasonally flooded marshlands, swamps and tundra bogs, and tidally flooded estuaries, salt marshes and mudflats (Figures 2.1 and 2.2). Human-created and/

FIGURE 2.1
Roosting shorebirds on a tidal flat, Yalu Jiang, China

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FIGURE 2.2
Typical wetland habitats frequented by waterbirds

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Khorin Tsagaan Nuur, Mongolia

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"Wet" poultry farm in Viet Nam

or altered wetlands have also become important wildlife habitats as natural wetlands are increasingly altered and converted to other types of habitat for human use. Wild birds have been quick to adapt to altered wetlands and are commonly seen at water reservoirs, salt ponds, flooded agricultural fields, irrigation ditches, "wet" poultry farm ponds and aquaculture ponds.

Substantial loss of natural wetlands and the attraction of altered wetlands converted to intensive rice farms are factors that may be resulting in concentrating of waterbirds in smaller habitats, thereby increasing their density and increasing the risk of virus transmission, primarily among and between waterfowl and shorebirds that populate these habitats.

As the most frequently detected wild hosts of the H5N1 virus, wetland birds represent an appropriate target for active disease surveillance. Birds such as ducks, geese, swans, gulls, shorebirds, herons, egrets, storks, rails, coots, gallinules, cormorants and grebes are common wetland species (Table 2.1). A review of their general nesting, migration and foraging strategies is helpful for understanding their potential role in the spread of the H5N1 virus. While the ecological strategies described in this Manual are valid for the majority of species in each group, exceptions can and do occur.

TABLE 2.1
List of the avian taxa in which the H5N1 highly pathogenic avian influenza virus has been detected in wild and/or captive populations* (as of September 2007)**

Order family	Common species	Habitat preferences	Number of species H5N1 detected		
			Total	Wild	Captive
Anseriformes					
Anatidae	Ducks, geese, swans	Wetland, marine	30	11	19
Charadriiformes					
Laridae	Gulls	Marine, wetland	3	3	2
Scolopacidae	Shorebirds	Wetland	1	1	0
Gruiformes					
Rallidae	Rails, coots	Wetland	4	4	0
Pelecaniformes					
Phalacrocoracidae	Cormorants	Marine, wetland	2	2	0
Podicipediformes					
Podicipedidae	Grebes	Wetland, marine	2	2	0
Falconiformes					
Accipitridae	Hawks, eagles	General	7	5	2
Falconidae	Falcons	General	2	1	2
Passeriformes					
Corvidae	Crow, ravens	General	3	3	0
Other	Songbirds	General	12	8	4
Galliformes					
Phasianidae	Pheasants, partridge	General	4	2	2
Columbiformes					
Columbidae	Pigeons, doves	General	2	2	0

* Captive birds include those held in a zoo or sanctuary. Some species may be included both as wild and captive.

** Data source: USGS NHWC website

Waterfowl (Anseriformes)

Ducks, geese and swans (Anatidae family; Figure 2.3), collectively known as waterfowl, are well-studied common hosts for LPAI viruses, and the only bird group in which the viruses have been found all year round in wild populations. A list of the species and numbers of birds counted among the known wild bird fatalities due to the H5N1 virus reveals that waterfowl are, by far, the bird group from which the H5N1 HP and LP AI virus pathotypes have been most commonly recovered. Waterfowl made up the vast majority of wild birds infected during the H5N1 AI mass mortality event in China in 2005/06 and were they also the prevalent group of wild bird species infected during numerous mortality events as the virus spread from east Asia into west Asia and Europe.

Ducks, geese and swans are a familiar group of waterbirds totalling about 150 species distributed worldwide. In general, they are medium to large birds with heavy bodies, long necks relative to body size, webbed feet and, in most species, a broad, blunt bill – a distinct combination of external features that make them among the most conspicuous and easily recognisable of all the wetland avifauna. Waterfowl have a long history of exploitation by humans both as wild game and domesticated poultry. A few species, most notably the Mallard *(Anas platyrhynchos)* and Greylag Goose *(Anser anser)*, have been raised as domestic birds for thousands of years.

Waterfowl are gregarious and many boreal species form sizable flocks that converge on traditional wetland foraging areas during the northern autumn and winter seasons. In contrast to their gregarious nature outside the breeding season, waterfowl are primarily solitary nesters, although some species such as the Bar-headed Goose nest in colonies of tens to thousands of birds. Most waterfowl nest on the ground in vegetated areas near the water's edge or in the immediate vicinity of water. However, some species breed in shallow submerged habitats by building up vegetation to form a dry nest mound surrounded by water, while other species construct floating nest platforms anchored to emergent vegetation. A number of duck species nest in cavities excavated in tree trunks by other species.

In general, waterfowl are monogamous although the duration of the pair bond differs among groups. In most ducks, pair bonds are temporary and females are responsible for all incubation and brood-rearing duties. By contrast, male swans and true geese share brood raising duties, and long-term, often lifetime, pair bonds are common in these groups.

Waterfowl chicks are highly precocial (i.e. well-developed, active and alert at hatching) and capable of following their parent(s) to water and foraging independently within hours of hatching. Female ducks attend their young until they are able to fly, while geese and swans form family units that may remain intact until the following breeding season.

All waterfowl undergo a brief post-breeding flightless period each year when the flight feathers are shed (moulted) simultaneously. During the moulting period, large numbers of flightless waterfowl often congregate in wetland habitats relatively safe from predators. The complete moult occurs near the breeding grounds during the chick-rearing period for all female waterfowl and males of those species in which both sexes participate in brood-rearing.

Differences in morphology and behaviour allow waterfowl to partition foraging habitats. Waterfowl are commonly characterized as "dabblers", "divers" and "grazers" depending on the particular foraging technique they employ. Many waterfowl species feed on aquatic

FIGURE 2.3
Representative species from the three subfamilies of the Anatidae family

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Wigeon (Anas penelope)

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Bar-headed Goose (Anser indicus)

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Mute Swan (Cygnus olor)

invertebrates and plants that they filter from water or mud as it passes through rows of horny plates (lamellae) lining their bill. Swans, shelducks and "dabbling" ducks forage at or just below the surface (how deep depends on the length of their neck) to feed at the bottom of shallow waters. "Diving" ducks, as the name implies, dive below the surface to forage in deeper substrates that are inaccessible to the "dabblers". Mergansers are an exception among the "diving" ducks, feeding on fish in the water column. "Grazing" waterfowl are characterised by upland foraging geese and ducks adapted for feeding on terrestrial plants and grain. "Grazers" also include several species of African "geese" which are not true geese at all, but grazing ducks.

Shorebirds (Charadriiformes)

Shorebirds or waders (Figures 2.4, 2.5 and 2,6) belong to several families in the Charadriiformes order, a large and diverse avian order that also includes gulls, terns and auks. After waterfowl, shorebirds are perhaps the most common hosts of LPAI viruses, although for the species sampled, the viruses appear seasonally and have only been detected in wild shorebird populations during the northern spring and autumn.

Despite the high overall frequency of LPAI viruses in some shorebirds, the H5N1 HPAI virus has thus far been detected in only one species, the Green Sandpiper *(Tringa ochropus)* in the Scolopacidae family. Furthermore, shorebirds do not appear to transmit or spread H5N1. Even though they share considerable geospatial and temporal overlap with waterfowl on Asian migratory routes, they have not transported the virus to Australia where they spend the southern summer in large numbers (and to where northern hemisphere breeding species of migratory Anatidae do not normally migrate in any numbers).

FIGURE 2.4
Eurasian Curlew (*Numenius arquata*), family Scolopacidae (Charadriiformes order)

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FIGURE 2.5
Common Redshank (*Tringa totanus*), family Scolopacidae (Charadriiformes order)

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FIGURE 2.6
Little Ringed Plover (*Charadrius dubius*), family Charadriidae (Charadriiformes order)

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Shorebirds are small to medium-sized birds with relatively long bills and unwebbed feet adapted for wading in mudflats and shallow waters along the margins of wetlands and rocky shores. They are also common in man-made wetlands and agricultural fields. Collectively, the shorebirds include familiar species such as sandpipers, stilts, avocets, oystercatchers, snipe and plovers. Like waterfowl, shorebirds are quite gregarious outside

the breeding season when large migrating and non-breeding flocks gather in traditional wetland foraging and roosting areas.

Structural adaptations have allowed shorebirds to exploit the wide diversity of prey available in productive wetland habitats. The bills and legs of shorebirds are often their most conspicuous features and provide the best clue as to their particular foraging niche. Long-legged species such as stilts wade into deeper waters than the relatively shorter-legged species. The elongated, slender bill is adapted to probing for aquatic invertebrates on or in the damp, soft wetland substrates.

Shorebirds are generally solitary breeders (although few species do nest in large colonies), nesting on the ground in marshy tundra, taiga and grasslands, often well inland. Nests are usually simple scrapes lined with pebbles and bits of vegetation. Shorebird chicks are precocial and usually leave the nest shortly after hatching.

Gulls (Charadriiformes)

Gulls (Figure 2.7) are another familiar and rather homogenous group of medium to large-bodied waterbirds distributed in coastal, pelagic and inland freshwater habitats worldwide. The family including gulls (Laridae) is one of many within the Charadriiformes order. LPAI viruses are seasonally common in many Charadriiform species, including the gulls, and the H5N1 virus has been isolated in three gull species, including two, the Brown-headed Gull and Pallas's Gull affected during the first wild bird outbreak in China in 2005.

FIGURE 2.7
Western Gull (*Larus occidentalis*), family Laridae (Charadriiformes order)

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Gulls in general, and the larger species in particular, are resourceful birds that demonstrate complex behaviour and a highly-developed social structure. They are also very adaptable and many species are quite tolerant of humans. Some gulls congregate in populated areas where several species have increased markedly as they have adapted to exploit human sources of food. In fact, gulls scavenging in refuse piles and areas neighbouring domestic poultry farms provide a potential interface for contact with AI viruses. In the wild, gulls are generalist foragers that feed primarily on fish and aquatic invertebrates. However, the larger, more aggressive species are also opportunistic scavengers and kleptoparasites, and will even prey on unattended chicks of their own species.

Although primarily thought of as coastal and marine species, hence the popular term "sea gull", several gull species breed well inland on interior lakes and marshes. Gulls are primarily ground-nesting colonial species, with colonies ranging in size from tens to thousands of birds. Colonies are usually found in the immediate vicinity of water, often on cliffs, islands or other areas which offer protection from terrestrial predators. Nest sites are usually scrapes on the ground lined with varying amounts of dried vegetation. Gull chicks are quite active and mobile soon after hatching, although they are fed and protected by the parents at least until fledging.

The similar and closely related terns (Sternidae) may also be a target for disease surveillance, as Common Terns were the first species known to suffer a high mortality event as the result of an HPAI infection in 1961. Most terns, however, have a specialised diet that is likely to decrease their risk of exposure to the H5N1 virus because they prey almost exclusively on small fish they capture just below the surface of the water by making shallow dives from the wing. Marsh Terns (*Chlidonias* spp.) feed on small fish and invertebrates in freshwater and coastal wetlands.

Herons, egrets and storks (Ciconiiformes)

Herons (Figure 2.8), egrets and storks are medium-sized to large wading birds that are among the most conspicuous of all the wetland avifauna. They are distributed worldwide in a variety of wetland types, but most species have affinities for freshwater and brackish habitats in tropical to temperate latitudes. Although not generally recognised as common hosts of AI viruses, the H5N1 virus has been found in at least four heron or egret species and two stork species.

These closely related groups share several physical features to match their similar foraging and breeding ecologies. Like shorebirds, their long, slender neck and legs, and unwebbed feet are obvious adaptations for feeding in wetland habitats. Herons, egrets and storks are primarily carnivorous birds that wade through shallow water in search of a variety of prey including fish, amphibians, crustaceans, insects and even some small mammals and birds. They stalk with deliberate almost imperceptible movements, but strike quickly by extending the long neck to spear approaching prey with their long, sharp bills.

Most species breed in conspicuous colonies, constructing large stick nests in the upper branches of trees in and around wetlands, although the White Stork *(Ciconia ciconia)* of Eurasia will build nests on rooftops and other artificial structures. Chicks are altricial (i.e. hatch blind and helpless) and require continuous parental care for several weeks after hatching.

FIGURE 2.8
Grey Heron (*Ardea cinerea*), Ardeidae family (Ciconiiformes order)

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Grebes (Podicipediformes)

Grebes (Podicipedidae family; Figure 2.9) are small to medium-sized diving birds that are probably the most aquatic of all the species described here. In fact, grebes are quite awkward on land and are rarely, if ever, encountered out of water, except during migratory flights. This is another group not usually recognised as a common host of AI viruses, although the H5N1 virus has been found in at least two species, the Little Grebe *(Tachybaptus ruficollis)* and the Great Crested Grebe *(Podiceps cristatus)*.

Although some species migrate to coastal waters after the breeding season, grebes breed exclusively in freshwater wetlands. Their loose colonies of floating nest platforms anchored to emergent vegetation range in number from a few to hundreds of nests. Both parents participate in raising the precocial chicks which are often carried on the backs of the parents as they swim.

Grebes are often observed swimming with just the head and neck exposed, a feat they accomplish by pressing or releasing their feathers against the body to adjust buoyancy. Aided by lobed membranes on each toe that are characteristic of the family, all grebes are accomplished divers. The grebe diet consists of fish and aquatic invertebrates they obtain while diving. They also habitually consume their own feathers.

FIGURE 2.9
Great Crested Grebe (*Podiceps cristatus*), (Podicipediformes order)

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Coots, gallinules, rails and crakes (Gruiformes)

The members of the Rallidae family, including the coots and rails (Figures 2.10 and 2.11), gallinules, moorhens and crakes are perhaps the least familiar of the wetland birds described here. With the exception of the gregarious coots, most species are solitary, retiring birds which skulk in or along the margins of heavily vegetated wetlands, quickly disappearing into cover at the first sign of danger. Most species are highly vocal and much more likely to be heard than seen.

The family can be divided into two "natural" groups, the aquatic coots and gallinules and the more terrestrial marsh-dwelling rails and crakes. Species such as the widespread Coot *(Fulica atra)* and Common Moorhen *(Gallinula chloropus)* appear to be more vulnerable to the H5N1 virus, although at least one crake species has also been infected.

In keeping with their more aquatic habits, coots and gallinules construct floating nest platforms anchored to emergent vegetation. By contrast, rail nests are concealed in the thick vegetation along the wetland margins, sometimes over water. All Rallidae species are generalist feeders, consuming whatever food happens to be available at any given time, including aquatic plants and invertebrates. Rails and crakes tend to forage along the damp wetland margins, using their long toes for walking across marshy vegetation. Coots and gallinules feed in the shallow water by diving (coots) or tipping-up (gallinules) to feed on aquatic invertebrates and plants.

FIGURE 2.10
Coot (*Fulica atra*), Gruiformes order

CREDIT: ROB ROBINSON

FIGURE 2.11
Water Rail (*Rallus aquaticus*), Gruiformes order

CREDIT: PIETER VAN EIJK

Cormorants (Pelecaniformes)

Cormorants (Figure 2.12) are a homogenous family (Phalacrocoracidae) of medium-sized to large diving birds related to the pelicans. Cormorants are considered occasional hosts of AI viruses, and the H5N1 virus sub-type has been isolated in at least two species, including

FIGURE 2.12
Great Cormorant (*Phalacrocorax carbo*), Pelicaniformes order

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the widespread Great Cormorant *(Phalacrocorax carbo)* which can be found in coastal and inland wetlands throughout much of Eurasia, Africa and Australia. Interestingly, cormorants are often infected with Newcastle Disease virus (paramyxoviridae)[3], which causes a common widespread poultry disease, despite limited or no known interaction among these groups.

Although primarily marine and coastal birds, several cormorant species breed well inland in freshwater wetlands. Cormorants are colonial breeders, nesting in often large colonies on cliffs and offshore rocks in coastal areas or in the branches of trees at inland or coastal wetlands. Chicks are altricial and require continuous parental care for several weeks after hatching.

All cormorants share predominately dark plumages, relatively long necks and hooked bills. They use their webbed feet for propulsion while diving to capture fish which make up the bulk of their diet. Although waterbirds, cormorants lack waterproof plumage and scores of roosting birds are often seen with wings extended to dry in the sun.

[3] In its most virulent form, velogenic viscerotropic Newcastle disease in poultry, the disease can resemble HPAI clinically and require laboratory analysis to discriminate between causative agents.

FIGURE 2.13
Common Buzzard (*Buteo buteo*), Accipitridae family (Falconiformes order)

CREDIT: CLEMENT FRANCIS

FIGURE 2.14
American Kestrel (*Falco sparverius*), Falconidae family (Falconiformes order)

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FIGURE 2.15
Tawny Eagle (*Aquila rapax*), Accipitridae family (Falconiformes order)

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Raptors (Falconiformes)

Many species of raptors, the collective term for diurnal birds of prey such as hawks, eagles, falcons and condors (Accipitridae family) (Figures 2.13, 2.14 and 2.15), have been fatally affected by H5N1 virus. Although not generally considered "wetland" birds, their role as predators and scavengers of other bird species may leave raptors vulnerable to AI viruses through consumption and exposure. It is believed that raptors contract the disease through direct contact with infected tissues as they scavenge the carcasses of poultry and wild birds that have died from H5N1, or prey upon infected birds weakened by the virus.

Raptors are a widespread and conspicuous group of birds distributed in a variety of habitats worldwide. Characterised by their strong talons, sharp hooked bill and keen eye-sight, obvious adaptations for a predatory lifestyle, raptors consume a wide variety of prey, including insects, fish, amphibians, reptiles, birds and mammals. Raptors range greatly in size from small falcons with wingspans of less than 30 cm to vultures and condors with wingspans of over 3 m. Unlike most other bird groups, raptors exhibit an often marked sexual size dimorphism, with females up to twice as large as males.

Raptors are generally solitary nesters that construct nests in a variety of habitats including trees, cliffs, natural cavities and sometimes on the ground. Raptors are generally monogamous, with both sexes providing prolonged care for their altricial chicks which do not achieve sexual maturity for 1-3 years.

"BRIDGE" SPECIES

Several bird groups without particularly strong ties to wetland habitats, but with a high tolerance for human-altered habitats, have also been known to become infected fatally from H5N1 (Table 2.1). Prevalent among these are several species of songbirds or perching

birds (Passeriformes) such as crows (Corvidae family; Figure 2.16), sparrows (Passeridae family; Figure 2.17), mynas (Sturnidae family; Figure 2.18) and the ubiquitous feral pigeon *(Columba livia)* of the Columbiformes order. Corvids, sparrows and pigeons have broad and diverse habitat preferences, but all are familiar birds that have adapted to exploit anthro-

FIGURE 2.16
Large-billed Crow (*Corvus macrorhynchos*), Corvidae family, Passeriformes order

CREDIT: CLEMENT FRANCIS

FIGURE 2.17
House Sparrow (*Passer domesticus*), Passeridae family (Passeriformes order)

CREDIT: CLEMENT FRANCIS

FIGURE 2.18
Indian Myna (*Acridotheres tristis*), Sturnidae family (Passeriformes order)

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pogenic food sources. Their close association with humans often results in close contact with domestic poultry, especially at open poultry farms where food is readily available. Thus, these species may serve as links between wild birds in natural habitats and domestic poultry, acting as a "bridge" in the transmission of AI viruses from poultry to wildlife or vice versa.

Potential "bridge" species warrant specific surveillance and monitoring efforts at HPAI poultry outbreaks and wildlife mortality events to determine their potential for contracting the disease and possible role in transmitting the virus to or from wild habitats.

MIGRATORY BIRDS AND SPREAD OF THE H5N1 VIRUS

Many bird species travel long distances between their breeding grounds and non-breeding areas. Waterfowl are perhaps the most familiar of these seasonal migrants, but for many northern hemisphere breeding bird species, including shorebirds, songbirds, raptors and many others, at least a portion of, if not the entire population makes seasonal migrations. As natural reservoirs or known hosts for AI viruses, the movements of these species can play an important role in the maintenance and spread of LPAI viruses and may also have a role in the spread of the H5N1 virus.

Migration between breeding and non-breeding (wintering) grounds is a well-documented phenomenon that enables migratory species to exploit seasonally abundant food supplies in habitats that are highly productive during the breeding season, but less productive, frozen or barren during other times of the year. The extent of migratory movements can vary greatly both among and within species. In fact, certain segments of a population may stay in a hospitable area all year as permanent "residents" if conditions permit.

Some species like shorebirds, have very long trans-equatorial annual migrations; they breed in high latitudes of the arctic during the northern summer, then travel to more hospitable middle or southern latitudes as far south as South America, South Africa and Australasia in the northern autumn and winter. Migratory routes of birds are grouped together as "flyways" (Figure 2.19) to assist international management and conservation efforts. A flyway can be defined as "the entire range of a migratory bird species (or groups or related species or distinct populations of a single species) through which it moves on an annual basis from the breeding grounds to the non-breeding areas, including intermediate resting and feeding places as well as the area within which the birds migrate" (*see* Boere and Stroud 2006 for further explanation).

Other groups, such as the northern hemisphere ducks that breed at the higher latitudes, may migrate only as far south as the equator; for example, the Northern Pintail (*Anas acuta*), a common and widespread duck which breeds in the northern areas of Europe and Asia and across most of Canada, Alaska and the mid-western United States (Figure 2.20), migrates south to East, South and Southeast Asia, West and East Africa and in North America southward to northern South America.

Some species may use different flyway routes for their mainly southward (northern autumn) and northward (northern spring) migrations, and different populations of the same species may use distinct flyways to arrive at separate non-breeding areas.

Northern hemisphere stereotypes regarding migration in waterfowl and many other waterbird species do not apply to southern hemisphere species. South African and Australian waterfowl tend to be nomadic, their movements dictated by available food supplies and rainfall, rather than truly migratory. However, a few southern hemisphere species regularly migrate north from Australian breeding grounds to Southeast Asia.

While the role of some migratory species in the propagation and spread of strains of LPAI has been long established, their role in the spread of the H5N1 HPAI virus is less clear. During the early H5N1 HPAI outbreaks in domestic poultry in Southeast Asia in 2003/04, there was no strong evidence that wild birds could become infected, then move long distances and shed the virus as they moved. During this period, the spread of the virus through domestic poultry, including the domesticated Mallard Duck *(A. platyrhynchos)*, was mostly attributed to movement of animals through trade, and most cases of H5N1 in wild birds coincided with nearby poultry outbreaks. Wet markets and trade involving caged wild birds are mechanisms for disease spread over short, medium or long distances. Raptors and passerines are popular species commonly trafficked in the international bird market (both legal and illicit). In fact, in 2004, raptors smuggled into Belgium were the first H5N1 HPAI infected birds detected in Europe.

However, the situation changed when the H5N1 AI virus spread into western Asia and Europe in 2005/06. Small localised wildlife cases and outbreaks were recorded in several countries where stringent poultry biosecurity measures were in place. Likely because of the biosecurity and hygienic measures, nominal spill over of the virus into commercial poultry operations occurred. The discoveries of sick, moribund and dead migratory birds infected with the H5N1 AI virus in scattered locations across western Europe suggested incursion of the disease via wildlife movements, hypothesised as abnormal local movements in response to severe cold weather. Studies reporting the virus in apparently healthy migratory birds

FIGURE 2.19
General "flyways" used by migratory shorebird species that move between northern summer breeding grounds and wintering areas and connect the northern and southern hemispheres

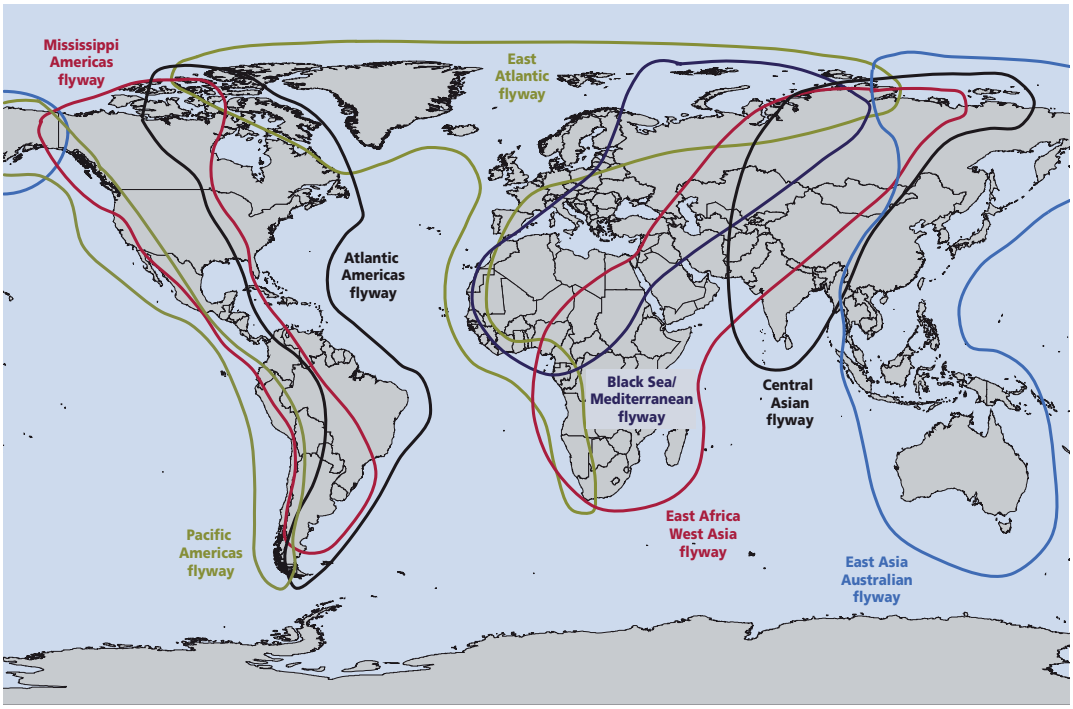
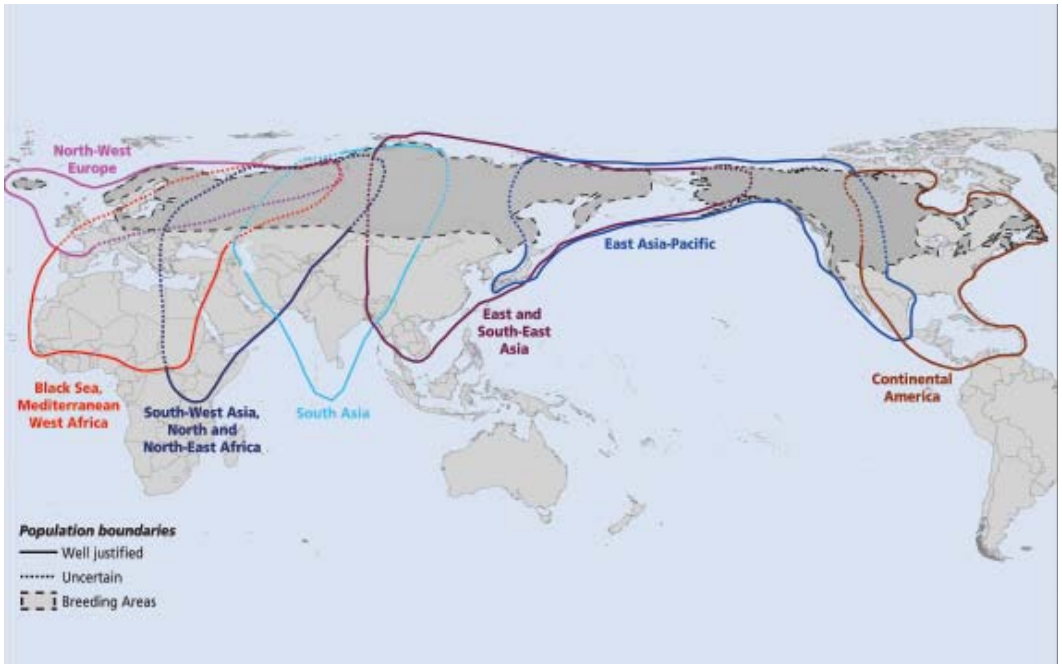


FIGURE 2.20
Major flyways of the Northern Pintail (*Anas acuta*) duck



are limited, but do suggest the possibility that wildlife movements may serve as a mechanism in the introduction of the virus, with husbandry and poultry commercialisation more responsible for disease spread. However, it has yet to be demonstrated that infected wild birds made long distance movements concurrently shedding the H5N1 virus during long distance movements. More information is needed to understand the role of migratory birds in this context.

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