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A global overview of the conservation, management and research of the world's waterbird flyways

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Cover photography: Whooper Swans *Cygnus cygnus* arriving at Martin Mere, England. Photo: Paul Marshall. (www.paulmarshallphotography.com)

Migratory waterbirds and avian influenza in the East Asian-Australasian Flyway with particular reference to the 2003-2004 H5N1 outbreak

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ABSTRACT

Wild birds, especially waterfowl, can act as reservoirs for avian influenza A viruses and migrant wild birds may potentially transport viruses over long distances. Concern was expressed regarding the possible role of wild birds in the 2003-2004 outbreak of H5N1 avian influenza in East/Southeast Asia, but it seems unlikely that they directly contributed to the spread of the disease. There is an urgent need for increased virus surveillance work together with studies to increase understanding of bird migration in the region.

INTRODUCTION

The outbreak of H5N1 highly pathogenic avian influenza (HPAI) in East and Southeast Asia in late 2003-early 2004 was unprecedented in both scale and severity. Over 100 million domestic poultry (mostly chickens) died or were slaughtered and there were 34 human cases, of which 23 were fatal (WHO 2004b, FAO 2004a). Media speculation suggested that wild birds had spread the virus (e.g. Kim 2004) and concern has been expressed regarding the potential pandemic threat posed by H5N1 (Guan *et al*. 2004). This paper outlines the ecology of avian influenza, considers the possible role of wild birds in the 2003-2004 outbreak and highlights the urgent need for multidisciplinary studies.

ECOLOGY OF AVIAN INFLUENZA

There are 16 haemagglutinin and 9 neuramidase subtypes of avian influenza A virus (AIV), all of which have been isolated from wild birds (Alexander 2000, Fouchier *et al*. 2005). Poultry are not the normal host for AIV but some strains, particularly H5 and H7, can be highly pathogenic resulting in high mortality. AIV infection in wild birds is usually asymptomatic (Webster *et al*. 1992).

AIV in birds replicates mainly in the intestinal tract, being shed in the faeces (Webster *et al*. 1978). Infected wild ducks may shed virus for two to four weeks (Delogu 2003) and transmission is considered to be principally via the faecal-oral route (Webster *et al*. 1992). However contemporary H9 viruses show an increased ability to replicate in the respiratory tract (Webster *et al*. 2002, Perez *et al*. 2003), and Sturm-Ramirez *et al*. (2004) considered that aerosol transmission and oral-oral contamination via drinking water could be important avenues for transmission of the late 2002 early 2003 H5N1 virus. It has been suggested that this may have happened at a wildlife rescue centre in Cambodia in 2004 (FAO 2004d).

The method(s) of transmission between wild and domestic birds remain largely speculative. Some outbreaks have provided strong circumstantial evidence suggesting that virus was introduced from wild birds (Campitelli *et al*. 2004), for example by contaminating drinking water (Karunakaran *et al*. 1983), whereas in some other studies it was possible that wild birds might have become infected from domestic birds (Nestorowicz *et al*. 1987).

Birds that occur in dense aggregations and which inhabit wetlands and/or aquatic environments are prime candidates for infection and this is reflected in relative infection rates. Waterbirds generally, and waterfowl (Anatidae) in particular, having higher infection rates (~15%) than terrestrial species (~2%) (Alexander 2000, Stallknecht & Shane 1988). Although Hansen (1999) reported 'frequent' occurrence of infection in waders, terns and gulls (Charadriiformes), it appears that waders generally are seldom infected (Melville unpublished).

Avian influenza, based on virus isolates and/or serological evidence, has been recorded from 47 species of wild birds in East Asia (Table 1), and from a further 70 species that occur in East Asia, but in which infection was recorded elsewhere (Table 2).

THE 2003-2004 H5N1 OUTBREAK

The 2003-2004 outbreak of H5N1 occurred in poultry almost simultaneously throughout much of the East/Southeast Asian region with the first cases being reported in Cambodia on 15 December 2003 and in South Korea on 17 December. Outbreaks were confirmed in early January from Vietnam (8th), Japan (12th), Thailand (23rd), China and Laos (27th), and finally Indonesia on 2 February (FAO 2004d, WHO 2004a). Interestingly there was no outbreak in poultry in Hong Kong although H5N1 was isolated from a Peregrine Falcon[1] found dead on 19 January 2004.

These were the first ever outbreaks of HPAI in South Korea, Vietnam, Thailand, and Indonesia, and the first case in Japan since 1925. Subsequently no further countries reported incidents of H5N1. By March the outbreak appeared to have largely subsided, however outbreaks reappeared in Vietnam, Thailand and China in mid 2004 (FAO 2004e).

Populations of migratory waterbirds in East Asia include over 10 million ducks and geese, six million egrets and herons, seven million shorebirds, 20 million seabirds and substantial but un-estimated numbers of rails (Delaney & Scott 2002, Kondratyev *et al*. 2000).

The majority of seabirds remain at sea during the winter and most would be unlikely to come in to contact with domestic poultry, gulls in Asia notably being far less associated with human agricultural activities than in Europe or North America, although a case of H5N1 in a Black-headed Gull in Hong Kong in January 2003 (AFCD 2003) should not be overlooked.

[1] Scientific names are given in Tables 1 & 2

Table 1. Species of wild bird in which avian influenza has been recorded in East/Southeast Asia*

Species		Locality
Little Grebe	*Tachybaptus ruficollis*	Thailand
Great Cormorant	*Phalacrocorax carbo*	China
Little Egret	*Egretta garzetta*	Hong Kong
Grey Heron	*Ardea cinerea*	Hong Kong
Chinese Pond Heron	*Ardeola bacchus*	Hong Kong
Black-crowned Night Heron	*Nycticorax nycticorax*	China
Asian Openbill	*Anastomus oscitans*	Thailand
Mute Swan	*Cygnus olor*	Japan
Tundra Swan	*Cygnus columbianus*	Japan
Whooper Swan	*Cygnus cygnus*	China, Mongolia
Bar-headed Goose	*Anser indicus*	China, Mongolia
Ruddy Shelduck	*Tadorna ferruginea*	China
Eurasian Wigeon	*Anas penelope*	Japan
Falcated Duck	*Anas falcata*	Russian Far East
Baikal Teal	*Anas formosa*	Russian Far East
Common Teal	*Anas crecca*	Japan, Russian Far East
Mallard	*Anas platyrhynchos*	Japan, Russian Far East
Spot-billed Duck	*Anas poecilorhyncha*	Japan
Northern Pintail	*Anas acuta*	Japan, Russian Far East
Tufted Duck	*Aythya fuligula*	Japan
Peregrine Falcon	*Falco peregrinus*	Hong Kong
Brown Crake	*Amaurornis akool*	China
Bar-tailed Godwit	*Limosa lapponica*	China
Whimbrel	*Numenius phaeopus*	China
Common Snipe	*Gallinago gallinago*	Russian Far East
Curlew Sandpiper	*Calidris ferruginea*	Hong Kong
Dunlin	*Calidris alpina*	Japan
Black-tailed Gull	*Larus crassirostris*	Japan, Russian Far East
Black-headed Gull	*Larus ridibundus*	Hong Kong
Relict Gull	*Larus relictus*	China
Brown-headed Gull	*Larus brunnicephalus*	China
Great Black-headed Gull	*Larus ichthaetus*	China
Guillemot	*Uria aalge*	Russian Far East
Black/Spectacled Guillemot	*Cepphus grylle/carbo*	Russian Far East
Red Turtle Dove	*Streptopelia tranquebarica*	Thailand
Little Cuckoo Dove	*Macropygia ruficeps*	Thailand
Yellow-vented Bulbul	*Pycnonotus goiaver*	Malaysia
Oriental Magpie Robin	*Copsychus saularis*	Hong Kong
Japanese White-eye	*Zosterops japonica*	Hong Kong
White-rumped Munia	*Lonchura striata*	Hong Kong
Scaly-breasted Munia	*Lonchura punctulata*	Hong Kong
Eurasian Tree Sparrow	*Passer montanus*	China, Hong Kong
Crested Mynah	*Acridotheres tristis*	Hong Kong
Black Drongo	*Dicrurus macrocercus*	Thailand
Common Magpie	*Pica pica*	South Korea, Hong Kong, China
House Crow	*Corvus splendens*	Hong Kong, Thailand
Large-billed Crow	*Corvus macrorhynchus*	Japan, Cambodia, Hong Kong

* after Stallknecht & Shane (1988) and Olsen *et al*. (2006) with additions.

Table 2. Species of wild bird which occur in East/Southeast Asia and in which avian influenza has been recorded elsewhere*

Red-throated Diver	*Gavia stellata*	Black-throated Diver	*Gavia arctica*
Great Crested Grebe	*Podiceps cristatus*	Wedge-tailed Shearwater	*Puffinus pacificus*
Little Cormorant	*Phalacrocorax niger*	Glossy Ibis	*Plegadis falcinellus*
Eurasian Spoonbill	*Platalea leucorodia*	Greater White-fronted Goose	*Anser albifrons*
Greylag Goose	*Anser anser*	Brent Goose	*Branta bernicla*
Common Shelduck	*Tadorna tadorna*	American Wigeon	*Anas americana*
Gadwall	*Anas strepera*	Garganey	*Anas querquedula*
Northern Shoveler	*Anas clypeata*	Red-crested Pochard	*Netta rufina*
Common Pochard	*Aythya ferina*	Greater Scaup	*Aythya marila*
Tufted Duck	*Aythya fuligula*	Long-tailed Duck	*Clangula hyemalis*
Velvet Scoter	*Melanitta fusca*	Common Scoter	*Melanitta nigra*
Goosander	*Mergus merganser*	Red-breasted Merganser	*Mergus serrator*
Smew	*Mergus albellus*	Saker Falcon	*Falco cherrug*
Northern Goshawk	*Accipiter gentilis*	Common Buzzard	*Buteo buteo*
Ring-necked Pheasant	*Phasianus colchicus*	Purple Swamphen	*Porphyrio porphyrio*
Common Moorhen	*Gallinula chloropus*	Common Coot	*Fulica atra*
Pied Avocet	*Recurvirostra avosetta*	Black-winged Stilt	*Himantopus himantopus*
Eurasian Oystercatcher	*Haematopus ostralegus*	River Lapwing	*Vanellus dauvcelii*
Eurasian Curlew	*Numenius arquata*	Eurasian Woodcock	*Scolopax rusticola*
Common Redshank	*Tringa totanus*	Spotted Redshank	*Tringa erythropus*
Green Sandpiper	*Tringa ochropus*	Ruddy Turnstone	*Arenaria interpres*
Sharp-tailed Sandpiper	*Calidris acuminata*	Red-necked Stint	*Calidris ruficollis*
Red Knot	*Calidris canutus*	Sanderling	*Calidris alba*
Temminck's Stint	*Calidris temmincki*	Ruff	*Philomachus pugnax*
Pomarine Skua	*Stercorarius pomarinus*	South Polar Skua	*Catharacta maccormicki*
Slender-billed Gull	*Larus genei*	Herring Gull	*Larus argentatus*
Black-legged Kittiwake	*Rissa tridactyla*	Common Tern	*Sterna hirundo*
Arctic Tern	*Sterna paradisaea*	Little Tern	*Sterna albifrons*
Sooty Tern	*Sterna fuscata*	White-winged Tern	*Chlidonias leucopterus*
Black Tern	*Chlidonias niger*	Collared Dove	*Streptopelia decaocto*
Great Spotted Woodpecker	*Dendrocopus major*	Barn Swallow	*Hirundo rustica*
Yellow Wagtail	*Motacilla flava*	White Wagtail	*Motacilla alba*
Common Whitethroat	*Sylvia communis*	Yellow-breasted Bunting	*Emberiza aureola*
Black-faced Bunting	*Emberiza spodocephala*	House Sparrow	*Passer domesticus*
Common Starling	*Sturnus vulgaris*	Carrion Crow	*Corvus corone*

* after Stallknecht & Shane (1988) and Olsen *et al.* (2006) with additions

The large areas of rice paddy throughout much of the region (74 million ha, of which some 38% is in China; IRRI 2004) provide artificial, freshwater wetland habitats which may be used by a wide variety of waterbirds including ducks, geese, waders, storks, ardeids and rallids. All of these birds potentially could come into contact with the large numbers of domestic ducks (Shortridge & Melville 2005) which are widely used for pest control and scavenge in paddis during and immediately after harvest - there being some 19 million in the Mekong delta alone (Bui *et al*. 1998). However most poultry affected by H5N1 were chickens, not ducks, suggesting that direct transfer of virus was unlikely. Furthermore, the outbreak occurred in mid-winter, at a time when most waterfowl populations are thought to be fairly sedentary, although there is evidence of mobility in some ducks populations (Pradel *et al*. 1997), and mid-winter movements of presumed waterfowl have been recorded by radar in Hong Kong (Melville 1980). There were no particularly unusual weather events reported in East Asia which might have resulted in mass movements of waterfowl in the region.

The highest concentrations of migratory Anatidae occur in Japan, South Korea and eastern and central China, south of the 0°C January isotherm (Li & Mundkur 2004). Relatively few migratory ducks occur in Indochina and Thailand, and even less in Indonesia, which suggests that they were unlikely to be carriers of virus in these areas. Ringing data show that at least some ducks migrate from Japan through Taiwan to the Philippines (Yamashina Institute for Ornithology records) yet Taiwan alone was affected by a mildly pathogenic form of H5N2, rather than H5N1, and no avian influenza outbreaks were reported from the Philippines – a situation hard to reconcile with the suggestion that wild birds were the main means of virus transport.

It is unclear whether the 'first reported' dates really reflect the situation on the ground, especially since Vietnam had potential human cases as early as October 2003 (WHO 2004a). Thus it is possible that virus was present for some time before being reported, in which case wild birds might have assisted its spread. For example, large numbers of rails migrate from mainland Asia to Indonesia where they are trapped for food, being sold in

markets together with domestic poultry (M. Silvius pers. comm.) and this could have allowed for transmission of virus in the autumn of 2003. Little is known of AIV infection rates in rallids: Delogu (2003) reported 1.2% infection in Eurasian Coots in Italy. However, if waterbirds were responsible for introducing the virus to Indonesia it might be expected that at least some of the birds would also have passed through Malaysia and/or The Philippines, yet there were no reports of H5N1 from either country.

Transmission of virus by terrestrial bird species which occur around fish and duck farms, such as, in Southern China, Rufous Turtle Dove *Streptopelia orientalis*, Barn Swallow, Red-billed Starling *Sturnus sericeus* and Eurasian Tree Sparrow is a possibility (virus isolations are known from the swallow and sparrow, and from congeners of the dove and starling), and all four are to a greater or lesser extent migratory, but the timing and extent of the outbreak does not fit known movement patterns.

Most reported cases affected chickens, but domestic ducks and geese were also affected in some areas. Information on mortality in wild birds remains sketchy with a number of unconfirmed reports. The provenance of the Peregrine Falcon found dead in Hong Kong is uncertain (P.J. Leader *in litt*.) and it may have been held in captivity. Large-billed Crows and Common Magpies were reported dead in association with poultry farms in Japan and South Korea, respectively, but presence of H5N1 has not been confirmed. In Thailand several hundred Asian Openbills were reported dead and H5N1 was isolated from at least one individual (The Influenza Sequence Database 2004), while in Cambodia several birds at a wildlife rehabilitation centre were reportedly positive, including free-flying wild Large-billed Crows (FAO 2004d, D.W. Geale *in litt*. 2004). It is noteworthy that no wild waterfowl were recovered anywhere, and extensive surveillance in Hong Kong failed to find any H5N1 virus in wild waterfowl faeces (L. Young *in litt*. 2004).

There are no known wild bird reservoirs of HPAI (Swayne and Suarez 2000). Although there are some instances of HPAI virus isolation from wild birds associated with outbreaks in poultry (as apparently in 2003-2004), the fact that such birds have been found dead suggests that HPAI causes mortality in at least some wild birds, in which case they are unlikely to be effective carriers of infection (Capua *et al*. 2000).

It is noteworthy that despite fears that migratory birds might carry H5N1 northwards in the spring of 2004, there is no evidence that this occurred – although it was suggested that migratory birds and wild waterfowl could have transmitted the disease to a poultry farm near Chau Hu, Anhui, China (OIE 2004), the timing of the outbreak in early July makes this unlikely and the lake apparently supports relatively few waterfowl even in winter (M. Barter, in litt.). A reported die-off of wild birds in Mongolia in mid-March (FAO 2004c) was apparently the result of another cause.

It remains unclear why the 2003-2004 outbreak occurred in such an explosive manner. It seems likely that human activity resulted in at least some of the spread, as in the case of an outbreak in Lhasa, Tibet which appears to have resulted from the introduction of chickens from Lanzhou, Gansu – some 1 500 km away (FAO 2004b). The trade in wild song birds, for example, laughingthrushes *Garrulax* spp. from China to Indonesia (Melville & Lau 1993), also might have provided an avenue for dissemination of virus, while the Buddhist practise of 'merit release' of caged birds might have resulted in local transmission as birds joined local wild populations. It seems more likely however, that the virus had been 'smouldering' for some time, possibly partly masked due to vaccination programmes in some countries (MacKenzie 2004) and that most of the spread was human mediated, aided by poor hygiene standards and biosecurity protocols (Melville and Shortridge 2004).

The 2003-2004 outbreak has highlighted how little we know of both birds and avian influenza in East Asia.

INTER-FLYWAY CONNECTIONS

Whilst migrant waterfowl may not have played a significant role in the spread of H5N1 in 2003-2004, their potential role in the spread of viruses should not be overlooked. Not only is there potential for North-South spread along the East Asian-Australasian Flyway but also for East-West spread. Although the differing Eurasian and North American influenza A virus lineages are thought to have arisen as a result of the general lack of interchange between birds in these land masses there is mixing of some populations. Wrangel Island, for example, is used as a post-breeding moulting ground by Brent Geese from both Siberian and Alaskan breeding areas (Ward *et al*. 1993), and ~2% of recoveries of Pintail ringed wintering in Japan have been in North America (Yamashina Institute for Ornithology records). Dunlin winter in large numbers along the coast of eastern China and inland, and DNA analysis indicates that at least some of these birds are from the Alaskan breeding population (Wenink & Baker 1996), and thus may mix with those that winter along the west coast of the USA south to California (Warnock & Gill 1996).

Webby *et al*. (2002) postulated that an outbreak of H6N2 influenza in California which had genetic similarities to viruses from chickens in Eurasia might indicate convergent evolution in which common mutations arose as viruses adapted to the chicken host, but there remains the possibility of importation of Eurasian genes via migratory waterfowl.

Our knowledge of the East and Central Asian Flyways is limited, but they appear to overlap extensively in western China, Mongolia and central Siberia allowing for interchange between them. Thus Bar-headed Geese *Anser indicus* migrate from the Tibetan plateau to winter in India or southwest China (Zhang & Yang 1997) and Great Cormorants from the same area also winter in India (Kumar 2003). In view of the fact that the Thai breeding population of Asian Openbills migrates to Bangladesh (McClure 1974), isolation of H5N1 from at least one of these birds highlights the potential for spread of this virus to the Indian subcontinent. Such movements potentially could provide a route for the westward spread of novel virus forms from South China, the hypothetical epicentre for the emergence of pandemic influenza viruses (Shortridge & Stuart-Harris 1982).

THE FUTURE

Avian influenza is asymptomatic in wild birds, and the only record of significant mortality was of 1 300 Common Terns in South Africa (Becker 1966). This pales to insignificance in comparison with some other pathogens such as fowl cholera which killed over ten thousand Baikal Teal in Korea in 2000 (Kwon & Kang 2002), and botulism which resulted in the death of four to five million wild waterfowl in the western USA in 1952 (Locke & Friend 1987). This may help explain the scant attention that avian influenza has received from most ornithologists to date – it did not even feature in a review of avian related zoonoses (Cooper 1990). With the potential for a new pandemic

there is an urgent need for ornithologists to work with influenza virologists to implement widespread surveillance in wild birds, as well as promoting migration studies, to help elucidate the role of wild birds in the ecology of avian influenza.

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Avian influenza is now endemic in poultry in Southeast Asia and, as of 20 June 2006, there have been 228 human cases with 130 deaths (WHO 2006). Whilst there is currently little evidence of human-to-human transfer of virus (Williamson 2006), there remains concern that a readily transmissible form may emerge and start a pandemic (WHO 2005).

In April/May 2005 some 6,000 waterfowl were reported dead at Qinghai Hu, China, including Great Cormorant, Bar-headed Goose, Ruddy Shelduck, Great Black-headed Gull and Brown-headed Gull. H5N1 virus taken from these birds was closely related to viruses circulating in poultry and wild birds in southern China (Chen *et al*. 2005, Liu *et al*. 2005). In early August H5N1 was recovered from a Bar-headed Goose and three Whooper Swans found dead in Mongolia (OIE 2005), and H5N1 was reported from poultry and wildfowl in Russia and Kazakhstan in August.

Throughout late 2005 and early 2006, H5N1 apparently spread westwards across parts of Central Asia and Europe, reaching

Africa in February 2006, infecting both domestic poultry and a variety of wild birds - Mute Swans in particular appeared to suffer high mortality in Europe. A virus from birds in Western Siberia and Europe is very similar to that from Qinghai (Brown *et al*. 2006.), however, the role of wild birds in spreading the virus remains uncertain and trade in live poultry and products has been implicated in some cases (Melville & Shortridge 2006). Highly pathogenic H5N1 virus has been isolated from apparently healthy ducks and Eurasian Tree Sparrows in China (Chen *et al*. 2006, Kou *et al*. 2005) and H5N1 virus seems to be moving between domestic and wild birds and back again (Chen *et al*. 2006). In April/May 2006 there were further outbreaks in wild waterfowl in both China and Mongolia (FAO 2006), but the situation in Bar-headed Geese has become further complicated with the discovery that these are being artificially reared in Qinghai (Butler 2006).

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Bar-headed Geese *Anser indicus,* Brown-headed Gulls *Larus brunnicephalus* and a Great Black-headed Gull *Larus ichthyaetus* at Qinghai Hu, China, about a week before the outbreak of HPAI H5N1 there in May 2005. The close mixing of these species indicates the potential for viral transmission between species. Photo: Jemi & John Holmes.