Avian Influenza and the Environment: An Ecohealth Perspective

A Report Submitted to UNEP
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Executive Summary

There is growing concern that the near global reach of a highly pathogenic strain of avian influenza, HPAI H5N1, could spark the next influenza pandemic, with a toll potentially running into millions of human lives. Traditional public health measures are rapidly being called into play, with limited success, to prevent the further spread of HPAI H5N1. Vaccines for poultry, culls in areas where outbreaks have occurred, and limitations on trade flows have become common means of controlling outbreaks. Stockpiling of potential antiviral medicines, heightened surveillance, and emergency preparedness are prudent measures to minimise human casualties should a pandemic arise. Left out of the equation for the most part, however, are preparations to redress ecological imbalances that have given rise to the threat in the first place. This gap calls for adopting an ecohealth perspective – one that focuses on the upstream causes of emerging diseases, which are at root questions of ecosystem degradation and ecological imbalance. Restoring health to the world's ecosystems is an essential aspect of the struggle to reduce human vulnerability to emerging and resurging diseases.

Pandemics have a long history. The great 1918-19 pandemic was by all historical accounts the world's most deadly. It involved a virulent influenza virus of subtype H1N1 for which the human population had no prior exposure, and thus no immunity. It is reported to have claimed 30-40 million lives over the course of its first year alone.

Low Pathogenic Avian Influenza, LPAI H5N, has been circulating in poultry in Southeast Asia for well over a decade. However, the related strain of Highly Pathogenic Avian Influenza, HPAI H5N1, did not appear in the region until mid 2003, since when it has been responsible for 105 human fatalities, and for the culling of hundreds of millions of domestic poultry. Since 2004, there has been a dramatic increase in the geographic spread of HPAI H5N1 among domestic poultry and wild birds. It is now found in SE Asia, Russia, the Middle East, the Balkans, Europe, and West Africa.

The likely principal vectors in the spread of H5N1 are trade in domestic poultry and the migration of wild birds harbouring the virus. Scientific opinion continues to waver as to which of these is the primary driver. The spread of H5N1 in a northwesterly direction out of SE Asia would appear to track more closely trade routes than those of wild migratory bird flyways, but even here, wild bird interactions with domestic poultry have probably contributed to the spread.

Examining the status and trends, particularly of poultry production in densely populated areas of SE Asia, makes it clear that this region has served for some decades as an epicentre of avian influenza (AI). Highly concentrated domestic poultry production in densely populated regions, combined with centuries-old cultural practices that place humans and poultry in close mutual proximity, provide the ideal conditions for the emergence of new pathogenic strains of avian influenza.

A number of common practices in animal husbandry, particularly in countries in SE Asia, might exacerbate the problem by facilitating transmission of HPAI H5N1 between

domestic flocks and wild birds. These include: the location of poultry operations in wild migratory bird flyways; open access to watering and feeding areas by wild birds and domestic poultry; waste runoff from domestic poultry operations that ends up in wetlands used by wild birds; and the inadequate use of antiviral drugs in domestic poultry operations.

Traditional medical and public health approaches to limiting the spread of HPAI H5N1 have, at best, been only partially successful. Some practices, such as the improper use of vaccines for domestic poultry, might actually be contributing to the problem if through their use more resistant strains develop. As the virus has continued to spread geographically, human fatalities, while still small in number, continue to rise.

Ecohealth approaches have yet to become a major part of the strategy to limit the spread of H5N1. An ecosystem health approach would call for reducing high concentrations of poultry production, particularly in areas close to high concentrations of humans, for restoring the health of natural wetlands, and for minimising domestic poultry production in major wild bird flyway zones. Restoring the ecological balance entails changes in human behaviour as well as alterations of ecosystems. Key components would include:

1. An overall strategy that seeks to balance the present focus on medical and public health interventions to treat or prevent the spread of disease in poultry and humans, with measures that would reduce underlying causes, rooted in ecological imbalances.

2. A systematic reduction in agricultural practices that increase the probability of emerging pathogenic strains of avian influenza. In particular, this would involve the phasing out of large-scale production of domestic fowl (chickens, geese and ducks) raised in association with high concentrations of humans and other mammals (pigs). As unpalatable as this policy may be to local and regional producers, it is clearly in the interest of heading off the risk of future avian influenza pandemics, with their potentially catastrophic effect at local and regional, as well as global, scales.

3. Prioritising the maintenance and restoration of the health of wetlands in order to prevent the spread of HPAI from domestic flocks to migrating wild birds. If the transfer of Asian lineage H5N1 between domestic flocks and wild birds is to be reduced, it will become essential to take measures to minimise their contact. Restoring wetland health will reduce the need for migrating wild birds to share habitat with domestic poultry.

4. Preventing the degradation of landscapes along wild bird migration routes. In particular, restricting domestic poultry operations in major wild bird flyways will serve to minimise the spread of disease carried by wild birds to domestic poultry, and vice versa.

5. Intensifying efforts to control the illegal trade in poultry and wild birds, which appears likely to have played a major role in the global spread of HPAI H5N1. Although this will, by its very nature, be the most difficult action of all, failure to

address the illegal bird trade will seriously undermine any advances made in the other ecohealth priority areas.

Healthy ecosystems have been recognised by WHO and other bodies as essential for maintaining human health. Yet, around the world, collapsing ecosystems pose increasing risks for human health. This is due in part to the widespread consideration of ecological restoration as a "long-term objective," while continued anthropogenic stress continues to degrade the Earth's natural ecosystems. Further, in the urgency of countering the prospect of an avian influenza pandemic, priorities have been centred on the short term – namely on "fixing the problem," rather than preventing the factors that first led to its emergence.

This report argues for a balanced approach: taking the necessary steps to restore healthy human-dominated ecosystems and wild ecosystems as major strategies for reducing human health vulnerabilities to avian influenza. The Scientific Task Force to the Convention on the Conservation of Migratory Species of Wild Animals recognises the importance of precautionary and preventive approaches, and calls for "improved standards in poultry farms, farming, and marketing practices." The ecohealth approach goes further, arguing that re-establishing and maintaining healthy ecosystems is the essential precondition for sustaining human and animal health.

1. Eco-Cultural Underpinnings of a Potential Avian Influenza Pandemic

The potential for a global influenza pandemic that could claim millions of human lives appears to be increasing, with the spread of a lethal variant of avian influenza in poultry and wild migrating birds. Preparedness for the possibility that Highly Pathogenic Avian Influenza H5N1 (HPAI H5N1) might develop the capability for rapid human-to-human transmission, thus sparking a global pandemic, has risen to the top of the global agenda. However, there remain considerable uncertainties and far more questions than there are answers. Most of these questions are of an epidemiological, medical or veterinary nature. While the answers to such questions are vital to mount effective public health responses, there is also an urgent need to address the more fundamental issue of underlying eco-cultural conditions that appear to increasingly give rise to threats of emerging and resurging diseases (1). Many of the emerging threats to public health, including the threat of an avian influenza pandemic, find their roots in the disruption and degradation of the Earth's ecosystems (2). Thus, a precautionary and preventive strategy must not only consider traditional public health and epidemiological responses, but must also focus on the health of the Earth's ecosystems (3).

Historically, the response to pandemics has been nothing short of pandemonium. Large numbers of fatalities over short periods of time have been known to completely disrupt the social order, compounding local and regional health crises. Today, there are signs of panic reactions on the part of governments and individuals with respect to the possibility that H5N1 will become the next global catastrophe. WHO and many other agencies have felt it necessary to caution that there is no need for immediate alarm. All agree that this is the time for preparedness, and for rethinking how humanity in today's world might cope with a major pandemic that, according to WHO estimates, could result in the loss of 2-7 million lives (1). And even these numbers are relatively modest compared with the great influenza pandemic of 1918-19, which was estimated to have killed 40-50 million people worldwide – with some estimates more than double these figures (4).

Preparedness has traditionally involved getting the epidemiology right. On this score, there is a long way to go towards a full understanding of the routes of transmission, as well as the mechanisms of genetic drift associated with H5N1. One of many unanswered questions regards the likelihood of H5N1 mutating or recombining with a human influenza variant to form a strain that could be transmitted easily between humans. Expert opinion remains divided on the matter. Some virologists claim that such a scenario is not very likely, as H5N1 and its subtypes have been around for nearly a decade without developing the capacity for efficient human-to-human transmission. Others say it may only be a matter of time before H5N1 or a closely related variant becomes capable of such transmission.

Another important question is: what are the vectors responsible for the spread of H5N1 from its origins in SE Asia across Russia and on to Europe and Africa? Here again there is widespread speculation and debate. It is known that the virus is found in a number of wild migratory birds. For example, H5N1 infections have been found in dead bar-headed geese (*Anser indicus*), great black-headed gulls (*Larus ichthyaetus*), brown-headed gulls

(*Larus brunnicephalus*), ruddy shelducks (*Tadorna ferruginea*), and great cormorants (*Phalacrocorax carbo*) (5). From April to June 2005, more than 6000 migratory birds, comprised mainly of the above species, were reported to have died due to H5N1 infection at the Qinghai Lake Nature Reserve in China's Qinghai Province. More recently, migratory ducks have been shown to be asymptomatically carrying the H5N1 virus in Hong Kong and elsewhere in China (6).

There remains uncertainty as to whether the wild birds are victims of the virus, infected by nearby poultry, or vectors – long-distance carriers, from one infected flock to another. Some would argue that the migratory routes (flyways) do, at least loosely, "connect the dots" where H5N1 has occurred (7). Others have concluded the opposite, that there is little correlation between outbreaks and flyways (8). As of this writing, the debate continues, with some scientists appearing to favour the role of wild migratory birds (9) and others the role of poultry trade routes (10). The emerging consensus appears to be that both routes are potentially important; that the spread in some regions and timeframes is primarily driven by migratory birds, while in others it is driven by trade routes, and in still others, by a combination of the two.

There are a host of other questions concerning the effectiveness of first-line antiviral pharmaceuticals to attenuate the effects of HPAI H5N1 in humans; the risks and benefits of wholesale vaccinations of poultry against H5N1; the adequacy of present monitoring capacities for H5N1, particularly in developing countries; and the effectiveness of bird culls to eliminate the threat. Then there is the question of the extent to which public health systems around the world are prepared to deal with the next major influenza pandemic. Would they have adequate monitoring systems, facilities for isolating victims, effective medicines, and sufficient vaccines to protect their populations? Virologists, epidemiologists and public health officials continue to debate these questions.

But preparedness also involves getting the ecology right. Until very recently, ecological degradation was not thought to have much, if anything, to do with understanding patterns of emerging and re-emerging infectious diseases. We now know better. A number of studies have documented the close connections between ecosystem degradation and increased human health vulnerabilities (11-14). It is well established that ecological imbalances are increasingly the cause of resurgent and emergent diseases (15). Many of the diseases afflicting humans are found to be brought about by ecological imbalances triggered by anthropogenic stresses (12, 14-16). Over the past three decades, as humans and microbes have been brought into ever closer contact, a host of newly emerging or resurging infectious diseases has appeared, including Lyme disease, HIV/AIDS, Hepatitis C, Legionnaire's disease, and the human form of Creutzfeldt-Jakob Disease, better known as "mad cow disease" (1). Ecological imbalances have also contributed to increasing the range and incidence of long-established human diseases, including malaria, cholera and dengue fever (13).

To put it the other way around: healthy ecosystems are essential to healthy humans. As the Director of WHO's Department for the Protection of the Human Environment recently stated, "Human health is strongly linked to the health of ecosystems, which meet many of our most critical needs. We in the health sector need to take heed of this in our own planning and, together with other sectors, ensure that we obtain the greatest benefit from ecosystems for good health – now and in the future" (16).

The question then naturally arises: in a world in which food supplies increasingly derive from highly concentrated and large-scale animal husbandry and farming operations, are surrounding ecosystems becoming more degraded? Clearly the answer here must be affirmative. Highly concentrated animal husbandry yields highly concentrated and often contaminated (both biologically and chemically) wastes, which often are dispersed in the immediate surroundings (17). It is known that both toxic algal blooms and outbreaks of cholera in coastal areas have been triggered by nutrient loading from agricultural fertilizers off the coast of China and other SE Asian countries (18, 19). Further, the combination of high concentrations of poultry (there are an estimated 6 billion chickens in SE Asia alone), in association with dense populations of humans and other mammals (e.g. swine), provides the potentially lethal mixing vessel which facilitates the genetic recombination that is the prerequisite for newly emerging diseases, especially influenza. Such considerations have led researchers to identify SE Asia as an influenza epicentre (20).

In this report we suggest that ecological imbalances are key risk factors for human health (1, 3), and that preparedness for a coming pandemic, as well as a host of other human health vulnerabilities, must include major efforts to restore ecological balance. We look at the trends in the human ecosystem environment, particularly the increased reliance in SE Asia on intensive mixed animal husbandry, where pigs, chickens and ducks are raised in close proximity and freely intermingle with humans. Such conditions are rife for the spread and resurgence of old diseases, as well as the emergence of new ones (1). Although these are ancient eco-cultural systems, there is little question that as the density of human populations increases, while people continue to live in close proximity with their animals under conditions of minimal sanitation, the risk of microbial diseases will continue to rise (12). Today, some ancient practices may prove extremely maladaptive, even serving as launching pads for lethal global pandemics. The open question is: will and can there be rapid adaptation in various cultures, both in the East and the West, to recognise the considerable risks to human health from present farming and animal husbandry practices? It is not just ancient practices coupled with growing populations in the East, but rising consumption in the West, which are fuelling expanding trade. Both clearly need to change.

In the following section, we briefly review the history of pandemics over past centuries, with an emphasis on avian influenza, and outline ecohealth strategies for coping with future pandemics. In Section 3, we examine the relationship of avian influenza to cultural practices and changing environments. In Section 4, we look at the status and trends in key aspects of the social and natural environment that have direct relevance to the risks of future pandemics. In Section 5, we look at adaptive strategies for reducing those risks by adopting an ecohealth approach.

2. The Global Pandemic Threat

2.1 Background: the history of influenza pandemics

Pandemics have a long history. They figured prominently in the Middle Ages as one of the "Four Horsemen of the Apocalypse": War, Famine, Pestilence and Death. Examples of pestilence (referring to a virulent and highly contagious disease) abound both historically and in the present. Cholera, bubonic plague, the 1918-19 influenza pandemic, and the current HIV/AIDS pandemic are just a few of the better known examples. HIV/AIDS, while entirely new to the arsenal of pestilence, has claimed an estimated 25 million lives since the early 1980s. A further 40 million people are believed to be infected with HIV, and that number is reportedly increasing at a rate of 5 million people per year (22).

Bubonic plague was without doubt the great pestilence of the Middle Ages – and it lingered on well into the 20^{th} century, still surfacing occasionally. There were three recorded episodes of bubonic plague in the 6^{th}, 14^{th} and 17^{th} centuries. Between the 14^{th} and 17^{th} centuries, the "black plague" ravaged Europe. It was believed to have originated in China and spread to Europe via trade routes (with black rats, fleas and humans as its vectors). Much of this history from the 14^{th} century outbreak in Europe survives in various eye-witness accounts (23). In October 1347, several Italian merchant ships arrived in Sicily from a voyage to the Black Sea. Many on board were already dying of bubonic plague, and first-hand accounts reveal its devastating impact on individuals and communities:

"Realising what a deadly disaster had come to them, the people quickly drove the Italians from their city. But the disease remained, and soon death was everywhere. Fathers abandoned their sick sons. Lawyers refused to come and make out wills for the dying. Friars and nuns were left to care for the sick, and monasteries and convents were soon deserted, as they were stricken, too. Bodies were left in empty houses, and there was no one to give them a Christian burial." (23)

The speed with which the disease spread was captured, in a somewhat darkly humorous way, by the Italian writer Boccaccio, who observed that its victims often "ate lunch with their friends and dinner with their ancestors in paradise." (23)

***The Doctor Beak of Rome*, an engraving by Paul Fürst. The beak was a primitive gas mask, stuffed with spices, herbs and other substances thought to ward off the plague.**

By the following August, the plague had spread as far north as England, where it was known as “The Black Death”, owing to the telltale black spots on an infected person’s skin. There was a brief let-up over winter – no doubt owing to the fact that the fleas that transferred the pathogen from rats to humans were inactive – before the plague returned in the spring. By the end of five years, perhaps as much as one third of Europe’s entire population had perished. Estimates of the population of Europe in 1347 were 75 million, while for 1352 the corresponding figure was 50 million. Estimates of the global death toll from the pandemic in the 14th century run as high as 200 million (24). Although bubonic plague is no longer a major health problem in Europe, it has not disappeared altogether elsewhere. The last major outbreak killed 855 people in Surat, India, in 1994 (24). About 3,000 cases are reported annually to the World Health Organisation. Black rats, the bacterium’s hosts, have recently reappeared in some parts of the UK (24).

Influenza epidemics also figure prominently in the global history of pestilence. None other than Hippocrates, in 412 BC, was the first to record what appears to have been one of the first known influenza epidemics (25), which wiped out the Athenian army. A further European epidemic was recorded in 1173-74, and it is generally agreed that the first influenza pandemic occurred in 1580. Since then, a number of pandemics have been documented, involving flu-like symptoms such as coughing, shivering, aching pains and sweating. Naturally, for these early episodes it is difficult to be certain about the primary causes of the illness, as flu-like symptoms may well have followed on the heels of other ills, such as plague, smallpox, typhus or measles (26). However, two major flu-like pandemics were widely documented in the 19th century: one in 1847-48 and another in 1889. It is estimated that between 1580 and 1889 the frequency of flu-like pandemics averaged from 20-30 years, while between 1889 and 1977 the range was in the order of 10-40 years. Looking more closely at the 20th century, in which influenza pandemics were meticulously documented, the catastrophic 1918-19 pandemic was followed by lesser but still significant pandemics in 1957 and 1968, as well as a significant outbreak in 1977. While the irregular frequency of influenza pandemics is notable, the fact that the past three decades have been free of such pandemics has led some virologists to conclude that the next pandemic is not likely to be far off.

While recent history suggests that influenza pandemics do not follow regular cycles, their timing appears more likely to be determined by chance factors, including: the emergence of a new viral strain, to which the human population has not previously been exposed; the capacity of that strain to become easily transmitted from human to human; and the capacity of the strain to cause high mortality rates in humans.

The 1889-91 influenza pandemic (which was of the H3N8 subtype) satisfied all three criteria. It apparently began in Central Asia, travelling west to Russia and, after a pause of several months, to Western Europe. There were four distinct waves, and with each successive wave mortality rates increased – with older age groups being the most susceptible (4). The great 1918-19 pandemic was by all historical accounts the world’s most deadly. It involved a virulent influenza virus of the H1N1 subtype for which the human population had no prior exposure, and thus no immunity. It may have claimed 30-40 million lives over the course of its first year alone (27). Estimates of total mortality during the pandemic vary widely, although the generally accepted figure is in the 40-50 million range. This highly potent influenza strain is believed to have originated in China, but resurfaced as an outbreak at Fort Riley in Kansas, USA, in early 1918. The deceptively low initial mortality rate (46 out of 1127 infected) was insufficient to trigger alarm. However, by the time US troops arrived in Europe, the pathogen they brought with them was set ultimately to take more lives than those lost on the battlefield (7, 8). In Spain alone, 8 million people succumbed. As Spain was the first country to declare an epidemic, the outbreak became known as “Spanish Flu”. The outbreak quickly spread to Britain where an estimated quarter of a million perished, with a disproportionately high incidence in adults in the 20-30 year age range (28). A second wave began in Boston in the autumn of 1918 (27), and was even more severe than the first wave – due to a likely mutation of the virus over the summer. The human misery of this pandemic was rapidly compounded by an agricultural disaster. Owing to the war effort and the high death toll from the pandemic, there was a major shortage of field-hands to bring in the harvest. Further adding to the chaos and panic was the fact that there were far too few available doctors to attend to the sick, as most had been sent overseas for the war effort. The outbreak rapidly spread to Russia, China, Japan, South America, South Africa and India – where the death toll was particularly high (estimates range between 12 and 16 million). Possibly only Australia escaped the main onslaught as a result of strict quarantine rules (27). By 1919, the pandemic appeared to have run its course, and disappeared almost as quickly as it had arrived.

2.2 The emerging threat of H5N1

Fig. 1 chronicles the significant dates in influenza history over the past century, leading to the variants of Asian lineage H5N1 which are the cause of current concern – as these subtypes are thought to pose a continuing protean pandemic threat (29). In 1997, the first confirmed cases of H5N1 in humans appeared in Hong Kong, although H5N1 had been found in domestic flocks (e.g. turkeys) at least since the early 1990s. The present strain of H5N1 has genetic characteristics that make it especially pathogenic, not only to poultry but also to other birds, as well as to mammalian hosts. H5N1 refers to the forms of the two surface molecules: hemagglutinin (H) and neuraminidase (N). Hemagglutinin is very important in binding the virus to host cells. Interestingly, while H5, H7 and H9 subtypes have been documented in human infections, these subtypes have not been known to pass efficiently between humans – although this is no guarantee that they might not do so in the future (25).

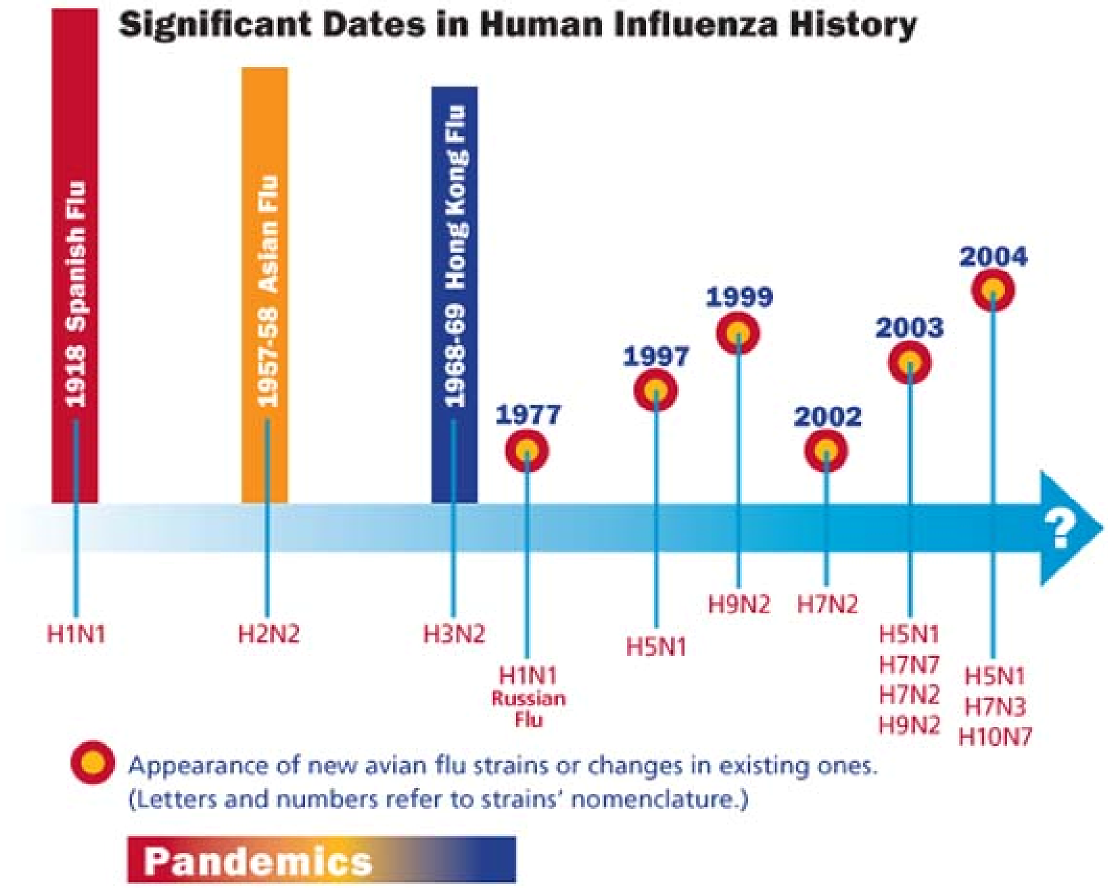


Illustration by Kathryn Seely/Cornell
Fig. 1 Major Influenza Outbreaks Between 1918 and 2004. Source: (8)

Low Pathogenic Avian Influenza, LPAI H5N1, has been circulating in poultry in SE Asia for well over a decade. However, the related strain of Highly Pathogenic Avian Influenza, HPAI H5N1, began to appear in SE Asia in mid 2003, and has been responsible for the death (and culling) of hundreds of millions of domestic poultry. As of March 24 2006, there were 105 confirmed human fatalities. The initial outbreaks were confined to nine SE Asian countries: the Republic of Korea, Vietnam, Japan, Thailand, Cambodia, the Lao People's Democratic Republic, Indonesia, China and Malaysia. Of these, Japan, the Republic of Korea and Malaysia have apparently controlled their outbreaks and are now considered free of the disease. Since July 2005, HPAI H5N1 has rapidly increased its geographical range, and outbreaks have been reported in a number of countries, particularly in East Asia and the Pacific, as well as in Europe and Eurasia (**Table 1**; see Appendix 1).

The distribution of human fatalities attributable to HPAI H5N, by country, is given in **Table 2** (see Appendix 2). The majority of human fatalities have thus far occurred in Vietnam, Indonesia, Thailand and China. With a few questionable cases, such as that of the mother of an 11-year-old girl who died of H5N1 in the remote village of Pamphaeng Phet, Thailand (30), all the fatalities are believed to have resulted from direct contact of the victim with infected wild or domestic birds. Thus, the WHO pandemic alert currently remains at Phase III, on a scale of VI [from I = low to VI = high]. This relatively low pandemic alert level reflects the fact that the virus has not yet taken that last but critical step of being efficiently spread from person to person (**Table 3**; see Appendix 3).

Fig. 2 shows the relationship between outbreaks of H5N1 and shorebird migration routes. This widely cited figure has serious limitations and may be misleading, as it portrays general migratory bird flyways for shorebirds but not the flyways of specific suspected wild bird carriers of HPAI H5N1 (e.g. ducks, geese, swans and other water birds). Nevertheless, the figure indicates that the spread of H5N1 from SE Asia to Europe has generally tracked in a direction that transits the major flyways, rather than moving along them. This leads to the supposition that trade in poultry is likely to be very important in accounting for the spread of H5N1, although it does not rule out local and regional interactions with wild migrating birds that would further spread the pathogen(31). Clearly both routes are involved in a complex interaction over time and space.

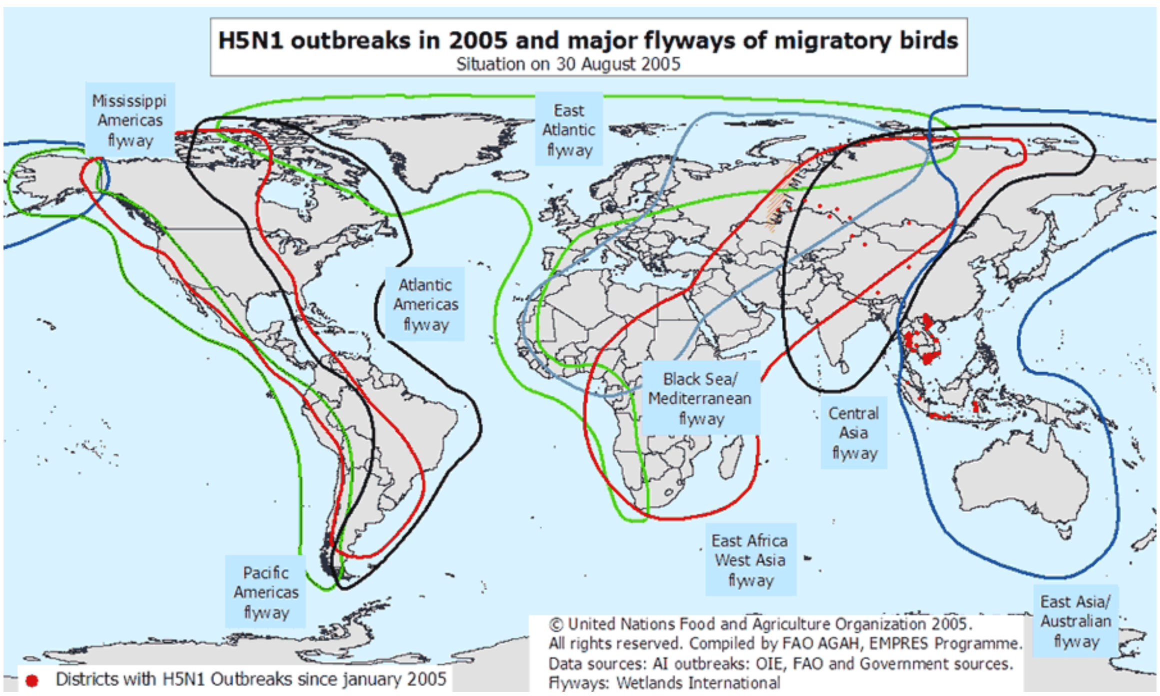


Fig. 2 H5N1 Outbreaks and Shorebird Migration Routes. Source: FAO and Governments

Since late 2003, more than 150 million birds have been culled in attempts to stem the spread of the Asian lineage H5N1 in domestic flocks, but this has not prevented the further spread of the virus – although it has helped reduce the threat in certain regions and countries (25). As shown in **Table 2**, as of March 24 2006, 186 persons have been confirmed infected by Asian lineage H5N1, with 105 deaths attributed to the virus. The highest mortalities have occurred in Vietnam, with 42 deaths, Indonesia, with 22, and Thailand, with 14. In nearly all cases, with a few possible exceptions, confirmed infections appear to have resulted from contact between humans and infected poultry, and in no case has there been sustained human-to-human transmission.

Despite the documented spread of avian influenza from SE Asia to Europe and Africa, and its high lethality in humans, there remains scepticism among virologists as to whether an H5N1 variant will spark the next pandemic. Paul Offit, an immunologist and virologist at the Children's Hospital of Philadelphia, points out that this virus has been circulating widely in domestic poultry for at least eight years (and actually longer if we consider the early outbreaks in turkeys, which date back to 1991) and has yet to jump the species barrier and circulate from human to human. Thus he considers this H5N1 an unlikely candidate for the next pandemic (25). Offit further notes that all the six pandemics that have occurred since the late 1800s have been caused by just three subtypes – H2, H3 and H1 – with none from the present H5 (25). However, other virologists point to the fact that, with the continued geographic spread of H5N1 and the increase in the number of hosts other then poultry (e.g. various species of wild birds, ferrets, domestic cats and mice), there is always the potential for H5N1 to gain the capability of human-to-human transmission. This concern is quite valid, considering the relatively high genetic drift characteristic of H5N1. Nearly all experts are in agreement that another pandemic is highly likely, whether it will be sparked by Asian lineage H5N1 or another variant, and a number of high-level meetings are being held in order to coordinate national and global strategies for confronting a potential influenza pandemic (32). WHO warns that, should an H5N1 variant emerge that is capable of sustained human-to-human transmission, population vulnerability would be universal, as "no virus of the H5 subtype has probably ever circulated among humans."

2.3 Stemming the tide: public health preparedness vs. an ecohealth approach

2.3.1 Conventional approaches: To date, efforts to counter a potential new influenza pandemic have been devoted largely to the traditional approach of "fixing the problem," rather than seeking to reduce the likelihood that the problem will occur in the first place. Highly pathogenic avian influenza of Asian lineage H5N1 appears to be already well entrenched in domestic flocks and is also being found in an increasing number of other hosts, including prominent wild migrating birds (particularly geese, ducks and swans). In a few cases, it has also been found in predators of birds, such as cats. Fixing the problem in conventional veterinary and public health terms focuses on the monitoring of domestic poultry and wild migratory birds, quarantine where there is evidence of infections of poultry with H5N1, culling of infected domestic poultry, the use of vaccines for poultry and eventually for people, and the development and use of antiviral medicines for humans.

Along these lines, there is much work to do. While there are excellent monitoring capabilities in developed countries, these do not yet exist in most developing countries, although great efforts are being made to bring laboratories and personnel on stream in countries where significant outbreaks have occurred. With respect to medical preparedness, there still is uncertainty about the effectiveness of existing antiviral drugs for H5N1. Despite these uncertainties, such drugs are now being stockpiled around the world as the first line of defence to fight a potential pandemic.

Containment also has its uncertainties, insofar as it has not yet been firmly established precisely how H5N1 spreads – whether it is primarily from flock to flock (via trade) or whether it is carried by wild migratory birds that mix with domestic flocks en route. As discussed above, opinion has been divided as to the relative roles of wild migratory birds and trade as primary vehicles for the spread of H5N1 (9, 10). Asian lineage H5N1 has been found in a number of species of dead migratory birds, but it remains unclear as to whether these species have become a natural reservoir of H5N1, or whether they contracted the virus from intermingling with nearby domestic fowl. The recent isolation of HPAI H5N1 in healthy ducks in Hong Kong and other parts of China does suggest that there is the potential for migrating wild birds to serve as a vector in spreading H5N1 (6).

Those who argue against migratory birds as primary conduits for H5N1 point to the fact that the geography of the world's major migratory bird flyways is not well correlated with the geographic progression of H5N1 (8) – although, as mentioned earlier, a more detailed analysis, comparing the flyways of known or suspected HPAI H5N1 carriers with outbreaks in domestic poultry, has yet to be carried out. Those who argue that migrating wild birds serve as a major vector in spreading H5N1 from one region to another claim that the flyways of carriers do roughly "connect the dots" between the locations where H5N1 has been found in poultry (7). These "dots" include: initial outbreaks of avian influenza in domestic fowl in Indonesia, Vietnam, Thailand, Laos, Cambodia and China; outbreaks in Russia and Kazakhstan in July 2005 in both poultry and wild birds (14); more than 6,000 migratory birds dying from infection with H5N1 at China's Qinghai Lake Nature Reserve – a location far from domestic poultry operations – between April and June 2005; an outbreak in August 2005 in Mongolia, where approximately 90 migratory birds died; and 133 breeding hens appearing to have died from infection by H5N1 in Tibet (33).

The FAO suggests that intermixing between migrating wild birds and domestic poultry at lakes and wetlands, particularly in Russia and Kazakhstan, is likely to be the primary source of the outbreaks in poultry (33). While the question of the relative roles of trade routes and migratory bird routes in the spread of HPAI H5N1 continues to be debated (9, 10), it is clear that migratory birds are capable of playing an important role in the spread of H5N1 in some situations, as infected wild birds can travel considerable distances while harbouring the virus (9).

While for any particular outbreak of H5N1, the relative roles of migrating wild birds and trade in domestic poultry may shift, the overall spread of the virus is undoubtedly facilitated by both trade routes and by migratory bird interactions with poultry. Once HPAI reaches a new location, either through trade or migrating birds, it is the interactions between wild birds and poultry, coupled with local trade, that serve to facilitate its spread within a region. The 2005 AEWA, CMS & Ramsar Conferences reached similar conclusions:

> "HPAI is considered to have been spread between countries through a number of different vectors, including through the movement of poultry, other avian livestock and cage birds and associated activities to service the respective industries; through both the legal and illegal trade in birds; movements of people; and eventually through the migration of waterbirds, although aware that the relative significance of these means of spread varies spatially and temporally."

Vigorous efforts are now underway to stem the further spread of Asian lineage H5N1 by vaccinating domestic fowl, and, where outbreaks occur, by imposing strict quarantine and carrying out wholesale culls of infected poultry. Thus far more than 150 million domestic birds have been killed, and this action appears to have successfully eradicated H5N1 in poultry in Japan, Korea and largely in Vietnam. Several years ago, the Netherlands successfully eradicated an outbreak of H7N3 using such control measures. China announced plans in late 2005 to vaccinate its entire poultry population – some 5 billion chickens, geese and ducks (34). The Chinese government has reasoned that the best way to prevent H5N1 from infecting humans is to keep it out of poultry (34). Yet these efforts have not stemmed the spread of H5N1, and the fear is that they cannot, particularly in developing countries, which lack appropriate surveillance and diagnostic equipment and have a seemingly insurmountable shortfall in the necessary financial incentives to compensate farmers for culling flocks (32).

2.3.2 An ecohealth approach: All of the above points to a concerted effort to apply, on massive scales, traditional veterinary medicine, human medicine, and public health approaches to stem a potential pandemic by seeking to "fix the problem," with a focus on isolation, quarantine, culls and medication. Laudable as these efforts are, however, they do not address the "upstream issue," namely the conditions that give rise to emerging diseases, and in particular the root causes of the present HPAI H5N1 epidemic. These causes are eco-cultural in nature, and while any one outbreak may be slowed by heroic efforts directed towards the eradication of a particular pathogen, other outbreaks are still likely to follow. The longer term solution must rest in restoring the health of ecosystems, of which humans, poultry and migrating wild birds are all part.

Once the human ecosystem has become degraded, natural checks and balances which attenuate disease outbreaks are no longer capable of working efficiently. The only long-term solution to avian influenza pandemic threats, as well as a host of other emerging and resurging diseases in both humans and wildlife, is to restore health to the world's ecosystems. Continuing with present policies, in which the "solution" to one problem often gives rise to another, is clearly not sufficient (17). What is needed to complement the present medical/public health approach to influenza pandemics is an ecohealth approach that sets in motion policies to safeguard the health of ecosystems in the interest of a sustainable biosphere – one in which human and animal health can thrive (3).

An ecohealth approach centrally embodies an "upstream" vision. It recognises that healthy ecosystems – i.e. those that retain their natural vigour (productivity), resilience (capacity to bounce back from disturbance), and organisation (e.g. biodiversity and symbiotic relations between species) – are an essential precondition for healthy people (2, 36). It also acknowledges that humans are an intrinsic part of their ecosystems, and that human activity has often been responsible for degrading ecosystems, although it can also be the engine of their maintenance and restoration. An ecohealth approach to avian influenza would seek to re-establish the health of both the natural ecosystems (e.g. wetlands) and human-dominated ecosystems (e.g. agro-ecosystems) as fundamental steps for reducing the potential for emerging diseases.

An ecohealth perspective is based upon a complex-systems approach, integrating natural, social and health sciences (2, 3, 35, 37). As the theme of ecosystem health has evolved over the past quarter century (37-44), it has become abundantly clear that healthy ecosystems are essential for maintaining healthy human populations (2, 3, 14-16, 42). This is a theme recently echoed in policy statements from the World Health Organisation (16) and many other international agencies (44, 45), which recognise that the health of all species, including humans, is critically dependent upon the health of the ecosystems of which they are part (3).

Any strategy for coping with a coming influenza pandemic must therefore incorporate practical interventions for rapidly improving the health of the Earth's ecosystems. This would render humans and other species less vulnerable to disease outbreaks that increasingly derive from ecological imbalances (46). In short, instead of focusing on trying to ***fix the problem*** with the use of vaccines, antiviral drugs and quarantines, an ecohealth strategy would focus on ***preventing the problem*** by concerted efforts to restore health to the Earth's wild and human-dominated ecosystems (2, 3, 14-16). With respect to the current spread of Asian lineage H5N1, an ecohealth approach would seek to understand the influence of the Earth's already compromised ecosystems and continuing imbalances (e.g. owing to climate change and other stresses, such as over-harvesting, pollution, introduction of exotics, and physical restructuring (47)) on changing human health burdens (2).

For example, with respect to the spread of Asian lineage H5N1, an ecohealth approach would ask:

- To what extent have the declines and changes in global distributions of wetlands contributed to the intermingling of migrating wild birds and domestic fowl, particularly in drought-stricken areas where the only remaining aquatic habitat is farm ponds?
- To what extent do multiple-use options in well-known flyways, e.g. along the Jordan Valley, increase the likelihood of the transfer of pathogens via migrating wild birds from domestic flocks in one region to those in another?
- To what extent have increasing intensive poultry operations – which already account for three quarters of the world's poultry supply (17) – compromised water quality in natural wetlands?
- To what extent might compromised water quality open up a potential conduit from disease in poultry operations to disease in wild migratory birds? To what extent does the intensive grain farming adjacent to, and feeding, poultry farms attract migratory birds, allowing a virus transfer between bird species?

- To what extent does the expansion of arable land encroach upon natural bird habitats, forcing their avian residents into more populated areas?
- To what extent do intensive poultry operations per se foster an increased risk of the rapid transmission of bird influenza and other pathogens to other species, including humans?
- To what extent do intensive poultry operations compromise the health of the land and aquatic ecosystems, giving rise to conditions that might foster yet other epidemics, such as cholera?
- To what extent does the limitation of wild areas force more species closer together and promote trans-species viral infection?

All of these questions are of course topics for a suite of major eco-health research projects, each of which would address significant aspects of ecosystem approaches to public health issues (15).

The following section traces the spread of HPA1 H5N1 in relation to cultural practices and changing environments.

3. The Spread of Avian Influenza in Relation to Cultural Practices and the Environment

3.1 Avian influenza endemic in wild birds

On August 31 2005, the Food and Agriculture Organisation (FAO) warned that the HPAI H5N1 virus was likely to be carried long distances along the migratory routes of wild birds, and that regions of the Middle East, Europe, South Asia and Africa should be on high alert (33). On February 7 2006, the Organisation for Animal Health (OIE) reported Africa's first case of H5N1 in the small village of Jaji in northern Kaduna state, Nigeria. The virus was reported to have been responsible for the deaths of thousands of commercial, battery-caged poultry in this region. While initially migratory birds were suspected of introducing H5N1 into Nigeria, where it has thus far been confined to poultry farms, it now appears increasing likely that the introduction resulted from the illegal importation of infected chicks. According to some sources, the illegal trade in animals has escalated to such levels it is now considered to be second only to the drug trade in size (70). In the light of such trends, it is clear that efforts to control the illegal trade in poultry and wild birds must be greatly intensified, if the spread of H5N1 is to be contained.

Wild birds, however, are a potential vector in the spread of HPAI H5N1 from Siberia, where the virus has recently been detected, to the Caspian and Black Seas. H5N1 has already been confirmed in the Black Sea region. As bird migration routes also run across Azerbaijan, Iran, Iraq, Georgia, Ukraine and some Mediterranean countries, these areas are also vulnerable to avian influenza, and outbreaks have been reported in a number of these countries. The FAO suggests that India and Bangladesh, which harbour large numbers of domestic ducks and are situated along one of the major wild bird migration routes, “have the potential to become new large endemic areas of bird flu infection” (33). With respect to Russia and Kazakhstan, the FAO believes that the primary source of infection in poultry was contact between domestic poultry and wild waterfowl at lakes and wetlands (14).

These concerns centre around one of the two major ways in which HPAI H5N1 may be spread – namely by migrating wild birds that are otherwise healthy intermingling with domestic poultry at lakes, wetlands and farm ponds. Here some fundamental ecohealth issues arise, namely: What have been the changes in global and regional environments that might facilitate this intermixing of wild birds and domestic flocks? What are some of the present agricultural practices that foster the spread of Asian lineage H5N1 around the globe? The following sections map out some of these issues.

3.2 Environments and cultural practices facilitating transmission of avian influenza between wild birds and domestic flocks

A number of common practices in animal husbandry might be cited as facilitating the transmission of avian influenza between domestic flocks and wild birds. These are: 1) the location of poultry operations in wild migratory bird flyways; 2) open access to watering and feeding areas by wild migratory birds and domestic poultry; 3) waste runoff from domestic poultry operations that ends up in wetlands used by wild migratory birds; and 4) inadequate antiviral drugs used in domestic poultry operations.

1) With respect to the location of poultry operations, many major flyways coincide with major farming regions, and thus provide an opportunity for the mixing of wild migratory birds and domestic fowl (e.g. the Rift Valley in Jordan). This region provides plentiful opportunities for passing infection between domestic fowl and migrating birds – through direct as well as indirect contact, e.g. passing viruses via contaminated water, faeces, etc. An obvious means for reducing such risk is to reduce the “multiple” use of major flyways – by creating sanctuaries and parks, and minimising the overlap with domestic poultry operations. This is undoubtedly difficult to implement at a regional scale, as most major flyway systems are proximate to major centres of human population and regions of domestic poultry production. Difficult as this may be, a progressive restoration of wetlands along the flyways, and a progressive movement of poultry operations and people outside the flyways, may be the only long-term solution to reducing these risks.

2) With regard to open access to watering and feeding areas by wild migratory birds and domestic poultry, the issue is one of cultural practices and environmental change that have resulted in more commingling of domestic poultry and wild birds at watering and feeding grounds. In SE Asia, the large-scale and ongoing elimination of natural wetlands cannot help but encourage further mixing of migrating wild birds with domestic fowl. This may well be of particular concern in the lowlands of China, where the loss of natural wetlands over centuries has created vast agricultural areas providing food and water for both domestic and wild birds. Such situations provide ideal conduits for HPAI to move from migrating wild birds into domestic flocks. A recent review from Thailand shows a

close association between free-grazing (domestic) ducks in rice paddy systems and the risk of poultry becoming infected with HPAI HN1 (49).

3) Intensive domestic poultry farming results in wastewater contaminated with bird faeces, antibiotics, fertilizers, pesticides, etc. This situation contributes to ecological imbalances downstream (18, 19), and may become an open conduit for H5N1 from domestic flocks to be picked up by wildlife elsewhere. In addition, with the increase in extreme weather events, large rainfalls can make even the most responsible poultry operations become major polluters, when the contents of their sewage lagoons are washed into surrounding and downstream areas. The safety of "best technology" that huge poultry farms claim under these circumstances can turn into a major environmental and health hazard when combined with a hurricane or typhoon.

4) Finally, the inadequate use or inferior quality of antiviral drugs and/or vaccines in poultry operations might provide "cover" for the emergence of pathogenic viral strains in domestic fowl. Moreover, these antiviral agents generally depress viral replication by altering DNA or RNA replication. The viral agents themselves may encourage resistant or mutant strains. The issue here is compounded by the fact that in many developing countries, for example in SE Asia, although there are many industrial-level poultry operations, there are also a considerable number of "backyard" activities, where surveillance is minimal and farmers have little knowledge of the complex health-environment interactions and potential linkages of their activities to human infections with avian influenza. Further, in such cases, where farmers depend upon their fowl for a subsistence living, they might naturally be reluctant to destroy their flocks, or to inform the authorities about sick birds – preferring, if they can, to sell them or eat them.

3.3 Environments and cultural practices facilitating transmission from domestic flocks to humans

When it comes to the transmission of HPAI H5N1 from domestic flocks to humans, a number of case studies already suggest that handling sick birds has thus far been the primarily vehicle of transfer of H5N1 from domestic fowl to humans. Lack of awareness in rural communities about the health risks involved in these practices has led to many, if not most, of the deaths thus far attributable to this lethal virus. Culturally sensitive public education is clearly critical in order to minimise future tragedies of this nature.

3.4 Environments and cultural practices facilitating transmission between humans

Fortunately, sustained human-to-human transmission has not yet been documented with respect to H5N1, although limited human-to-human transmission is believed to have taken place in at least one instance (30). Should sustained transmission arise, human behaviour with respect to contact among one another will require immediate and radical change. The large numbers of people who fall ill every year from seasonal influenza epidemics attest to the difficulties in achieving a more precautionary approach to personal behaviour. Simple procedures for reducing risks of transmitting seasonal influenza, such as minimising body contact and washing hands before eating and upon returning from outdoors, are by and large ignored. Similarly, the desirable avoidance of close physical contact with others who have contagious conditions seems to be at loggerheads with common forms of greeting (such as the shaking of hands) and other everyday practices. Further, owing to non-avoidance behaviours, schools, hospitals, doctor's offices and other institutions continue to serve as "hotbeds" for the transfer of pathogens from human to human, as do airports and airplanes.

3.5 Capacity for detection of outbreaks in domestic fowl, mammals and humans, particularly in developing countries

A first-line defence in any protean pandemic involves the rapid detection of outbreaks and their isolation at source. This has been effective to various degrees in recent contagious disease threats, such as SARS and Legionnaire's disease. The concern with Asian lineage H5N1 is that it may emerge in areas where population densities of both birds and humans are high and where effective public health infrastructure is lacking. In such instances, the containment option may go by default. Furthermore, the incubation period of H5N1 is relatively short so its spread within the population may take place rapidly, before it has been confirmed as H5N1 rather than a seasonal influenza or other common disease. The symptoms of H5N1 in the early stages are not unique, and usually it is only when the patient is moribund that H5N1 is suspected.

3.6 Domestic and international trade in wild migratory birds and domestic fowl

In order to have a full understanding of the possible pathways by which Asian lineage H5N1 may circulate within domestic and migratory birds, it is essential to know the volume, destination and route of both the legal and illegal trades in domestic fowl and wild birds. By its very nature, the illegal trade goes largely unreported and must be estimated by indirect means. Given the "jump" in outbreaks between SE Asia and Eastern Europe, and between Europe and Africa, there is clearly a critical need to develop greater information not only on the potential for migratory bird transmission, but on all trade (legal and illegal) that takes place between these regions, including transport and trafficking via third countries.

Having reviewed some of the cultural practices and ecological imbalances that have likely facilitated the spread of Asian lineage H5N1, we now turn to the key elements of status and trends in both the social and natural environment that have relevance to risks of future AI pandemics.

4. Status and Trends: Changing Environments and the Risks of a Catastrophic Avian Influenza Pandemic

4.1 Regions of high density of domestic fowl (with a focus on SE Asia)

One of the keys to stemming the potential of a future pandemic is to identify the "hotspots" where such a potential could most likely originate. In this regard, there has been considerable focus on SE Asia, where there has been a long history of poultry, duck and pig farming in close contact with a high density rural human population. It is these conditions, in association with traditional live animal or "wet" markets, that produce the optimal conditions for increased rates of mutation, re-assortment and recombination of influenza viruses (50, 51). Here we examine the distribution of high density poultry operations in SE Asia.

Southeast Asia is one of the world's most intensive poultry production regions. The FAO's mapping of poultry density (**Fig. 3**) shows that in much of eastern China, particularly along the coast, the density of poultry is in the range of 1000-5000 heads/km^2 and in some areas exceeds that. Other areas in SE Asia also show high local concentrations of poultry. In particular, the entire island of Java, Indonesia, has high densities of poultry production. Significant areas of Vietnam and other SE Asian countries are also at the top end of the scale in terms of poultry density.

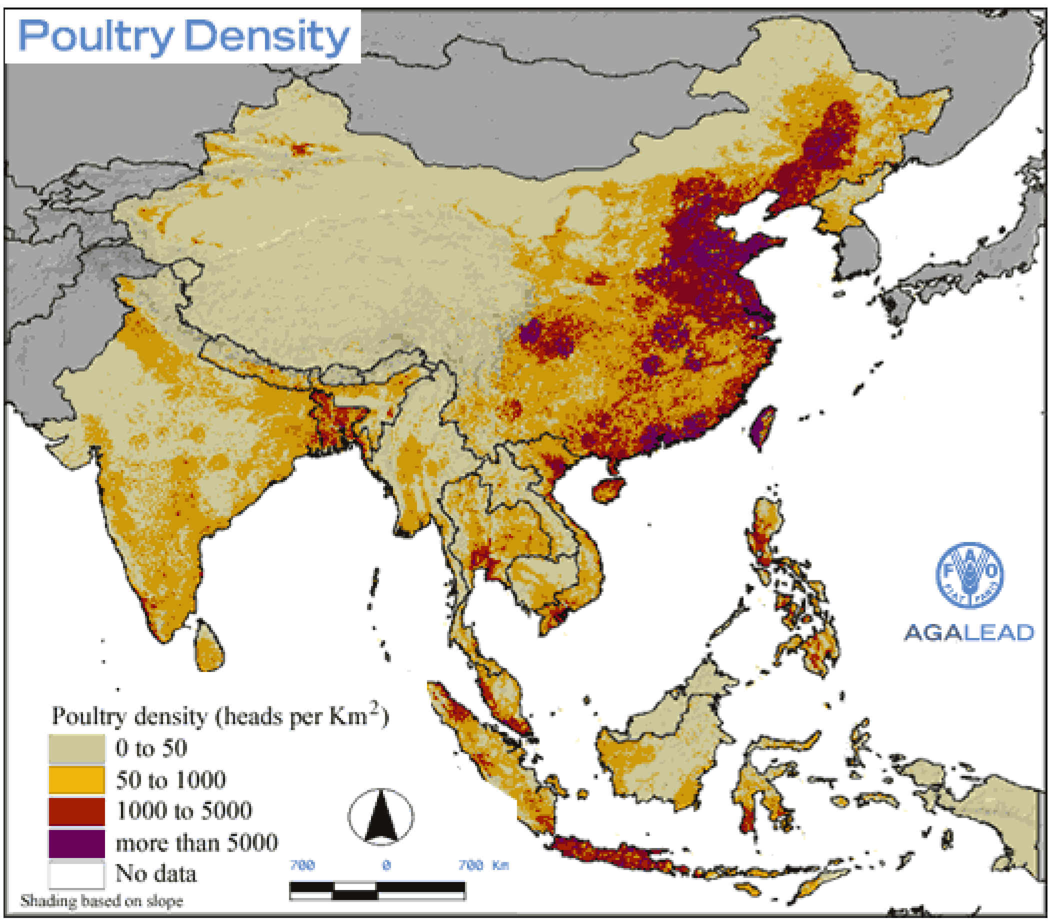


Fig. 3 Poultry Density in Southeast Asia. Source: FAO

The entire Southeast Asian region has experienced enormous growth in poultry production over the past decade (**Fig. 4**), and these high rates of growth are continuing. Poultry production in mainland China increased by 130% between 1993 and 2003, while production in Vietnam increased by more than 170% during the same period. In most countries in SE Asia, poultry production increased by 40% over the same time period – likely mostly driven by international consumption, although trade may also be a factor.

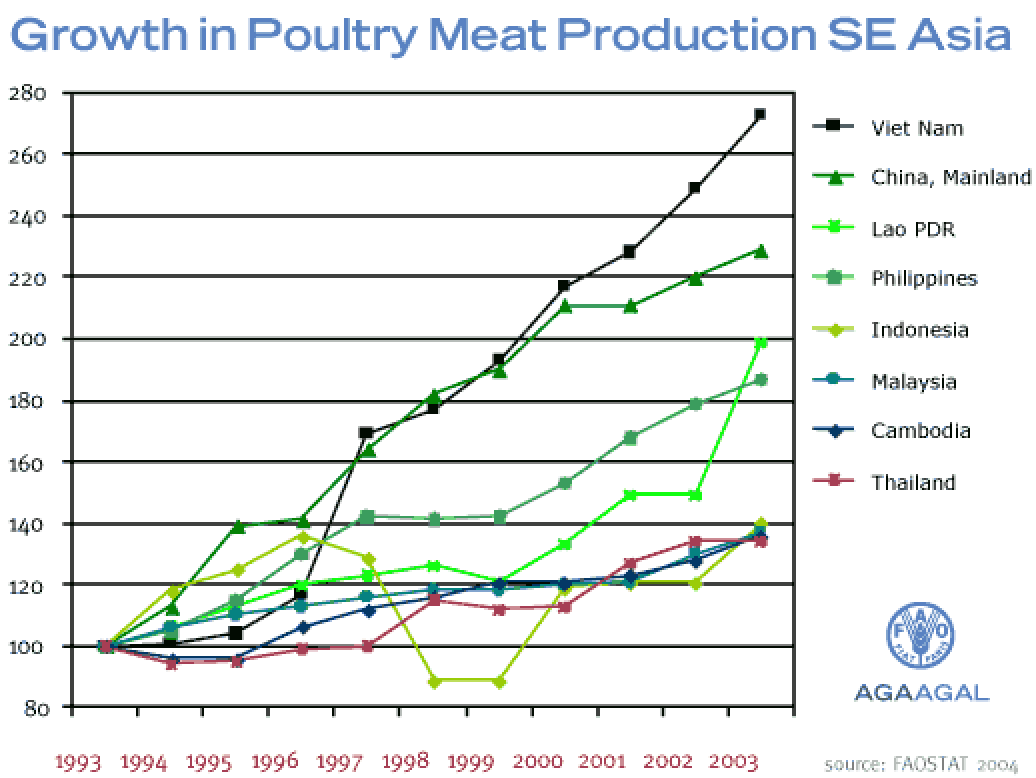


Fig. 4 Growth in Poultry Production in Southeast Asia, 1993-2003. Source: FAO statistics

In brief, high poultry densities in many SE Asian countries, and continued high rates of growth in poultry production, portend increased risks of disease outbreaks, particularly when human population densities in the producing regions are also extremely high. The overlap between high densities of poultry production and human populations, explored in the following section, suggests that SE Asia remains an important influenza epicentre.

4.2 Regions of high density rural human populations in association with domestic fowl and mammals (with a focus on SE Asia)

In this section, we look for the potential overlap of high human population densities and high densities of poultry production (and other meat production, e.g. pigs and ducks) – the mix that produces potential "hotspots" for the re-assortment and mixing of viral genetic material, which could result in highly pathogenic strains for both animals and humans.

The simple comparison of areas of high population density distributions (**Fig. 5**) for Asia with areas of high poultry production (**Fig. 3**) reveals three such "hotspots": 1) most of Eastern Mainland China, as well as a sizeable area of central Western China, where the regions of high population (exceeding on average 700 persons/km^2) appear highly correlated with the higher poultry densities in SE Asia; 2) the island of Java, where both high populations and high poultry densities are found throughout; and 3) Bangladesh, where there is also a striking overlap of high densities of people and poultry – although this region has not, so far, been a centre for outbreaks of avian influenza.

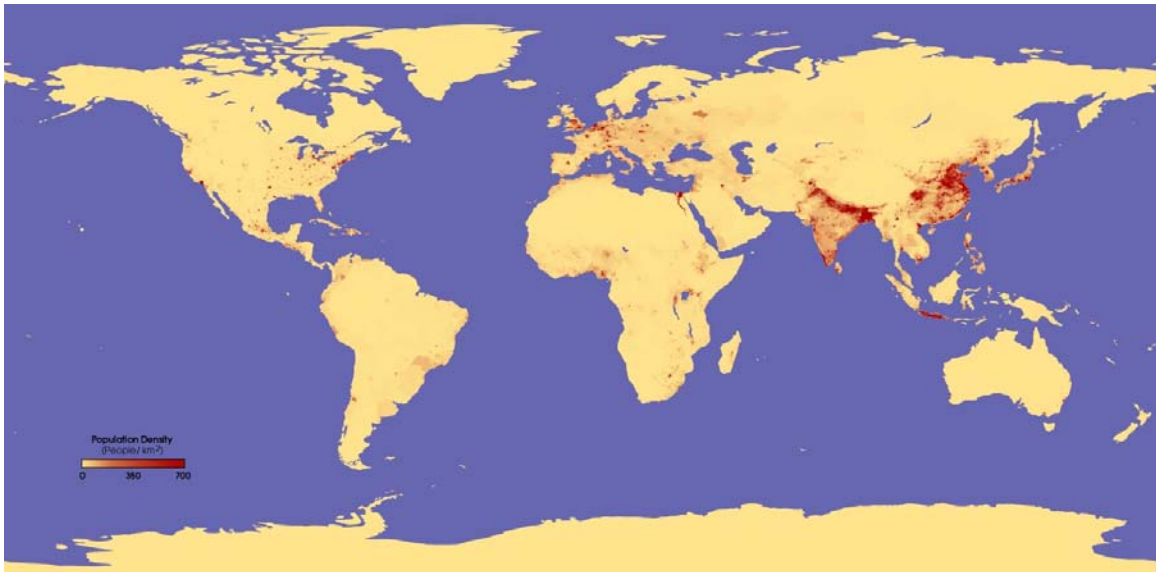


Fig. 5 World Population Density Map

The “hotspots” are key areas where there is a high likelihood of newly emerging strains of highly pathogenic avian influenza. Traditional approaches for controlling influenza outbreaks in domestic poultry, involving monitoring and detection, isolation and culls, and vaccines, are increasingly being employed in China and other risk areas. But the fundamental risk factors remain: namely, that the drivers of avian influenza (and other potential emerging diseases) are the extreme densities of animals and people, and the cultural practices involved in poultry production and marketing. These long established cultural practices may, in view of the risks of human influenza pandemics, be no longer adaptive from the global environmental and human health perspective. Rather, from the “upstream” perspective, a realignment of animal husbandry practices to minimise the risks of emerging diseases is clearly in the interest of global human health. Naturally, restrictive measures that impede livelihoods and cultural traditions will be strongly resisted by those negatively affected, and therefore they may be seen as unrealistic. Yet, where social change is deemed essential, it can be done. For example, in Ho Chi Minh City in Vietnam, owing to the threat of avian influenza, in February 2005 officials banned the long established practice of poultry raising within the city limits (30).

4.3 Bird migratory routes and changing environments: global status and trends

As already discussed, the spread of Asian lineage H5N1 is complex. Three major pathways are likely, singly and interactively: 1) trade routes, i.e. through the movement of infected poultry and wild birds, in both legal and illegal commerce; 2) contact between healthy domestic flocks and infected wild migratory birds which are carriers of H5N1 and other HPAI subtypes; and 3) contact between healthy wild migratory birds and infected domestic flocks.

Whether wild migratory birds are "victims" or "vectors" or both, they are a natural reservoir for various subtypes of avian influenza worldwide (51). Migratory species, particularly juvenile ducks, are known to carry Asian lineage H5N1 without exhibiting clinical signs of disease, and juveniles have both a large infection and shedding rate of HPAI viruses (6). When wild migratory birds mix with domestic flocks, through sharing of habitat, there is an enhanced potential for genetic re-assortment through intermixing of various subtypes of AI, resulting in novel genotypes with altogether different antigenic and other biological characteristics. It is these novel strains that could trigger a human influenza pandemic.

While attention has been focused on identifying the reservoirs of Asian lineage H5N1 and the likely vectors (the various species of wild migratory birds, as well as mammals and other carriers), changes in the environment that increase the likelihood of mixing between domestic and wild birds have been given far less attention.

The rapid decline in the health of many of the world's ecosystems may yet prove to be one of the fundamental determinants of newly emerging infectious diseases (1-3, 15, 53-57). Strategies to reduce future pandemics will need not only to encourage effective means to contain them once they emerge, but also to discourage or remedy environmental changes that facilitate emerging and resurging infectious diseases in the first place. While conventional public health, veterinary and human medicine approaches tend to focus on "downstream" remedies for such diseases, the ecohealth perspective focuses on their "upstream" socio-cultural-ecological determinants. What is called for is a comprehensive integration of the two perspectives (57).

The ecohealth perspective draws attention to changes in the environment, as well as the cultural practices that create ideal mixing opportunities for the emergence of novel and sometimes highly pathogenic AI strains. Here, the degradation and disappearance of wetlands worldwide is of special significance.

4.4 Regional loss of wetlands in areas of SE Asia with concentrated domestic fowl production

Wetland depletion has direct implications for migrating wild birds. Wetland habitat worldwide continues to decline, primarily due to agricultural expansion and urban development, resulting in fewer staging areas for migrating birds. In these situations, remaining wet areas associated with rice paddies and farm ponds would be expected to be increasingly attractive to wild birds that lack sufficient natural habitat during staging, nesting and migration activities.

The Convention on Wetlands, signed in Ramsar, Iran, in 1971, has as its mission "the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world" (58). The 150 countries that are Contracting Parties to the Convention contain significant wetland sites, including 134 million hectares protected under the Ramsar List of Wetlands of International Importance (59). China, Bangladesh and Indonesia are among the signatories to the Convention.

The Ramsar Convention is a global response to the rapid disappearance of wetlands associated with the rampant agricultural and industrial development of the 20th century. Through its registry of "wetlands of significance" and various other means, it has undoubtedly been useful in making the world more aware of the importance of wetlands in the global web of life. However, despite this growing awareness, wetlands around the world have continued to decline in the face of intensive economic development.

In some large and significant regional wetlands, such as the Mesopotamian Marshlands which at one time covered over 20,000 km^2, the transformation has been so extensive that the wetlands have all but disappeared. As late as 2003, with less than 10% of the original Mesopotamian Marshlands remaining, further water diversions were still being undertaken. However, mounting global concern, coupled with direct action by the marsh dwellers in cooperation with Iraq's Ministry of Water Resources, resulted in the re-flooding of part of this massive marshland (60). By early 2004, nearly 40% of the marshland had been re-flooded – leading to the regeneration of reeds and the return of some fish. However, the marshland ecosystem has yet to return to anything close to full functionality (60).

Global wetland losses over the past two centuries have been nothing short of catastrophic. Between the 1780s and 1980s, it is estimated that a 53% decline occurred in the wetlands of the conterminous USA (61). In Canada, since settlement, about 65% of Atlantic tidal and salt marshes, 70% of the lower Great Lakes-St. Lawrence River shoreline marshes and swamps, up to 71% of prairie potholes and sloughs, and 80% of Pacific coast estuarine wetlands are estimated to have been converted to other uses. Primarily, this resulted from agricultural drainage and diking, urban and industrial expansion, the construction of port, road and hydroelectric facilities, and increased demands for recreational properties (62). In Africa, losses in wetlands have varied considerably by area. For example, in Natal, South Africa, the Tugela Basin has seen the loss of over 90% of its wetlands, while in the Mfolozi catchment approximately 58% of the wetlands have been destroyed (63).

The situation in densely populated regions of SE Asia differs from much of the rest of the world, in that extensive wetland loss has occurred over a very long period of time. Since lowland rice cultivation was first established some 6,500 years ago, vast areas of wetland in southern and eastern Asia have been converted into paddy-fields or drained for other forms of agriculture or human settlement (64). As a consequence, for example, no trace remains of the natural floodplain wetlands of the Red River delta in Vietnam, which originally covered 1.75 million hectares. Similarly, virtually nothing remains of the one million hectares of natural floodplain vegetation that once covered most of the Sylhet Basin in Bangladesh or the six million hectares of floodplain wetlands in the lowlands of central Myanmar. It is also assumed that almost all of the 40 million hectares of rice cultivation in the central plains of India were developed at the expense of natural wetlands, as were the 1.9 million hectares of rice cultivation in the central plains of Thailand. In all of these regions, very little natural wetland vegetation survives to the present day (64, 65).

In light of these changes, present reductions in wetlands in SE Asia and elsewhere appear modest. However, considering the already severe contraction of wetlands, continued losses have a critical impact. Current inventories of the world's wetlands indicate that, while significant upland wetlands are still present in much of SE Asia, lowland wetlands have all but disappeared (**Fig. 6**). Under these conditions, it is clear why migrating wild birds in lowland areas make use of rice cultivation areas. This is one of the areas in which interactions between domestic fowl and wild migratory birds are at their greatest.

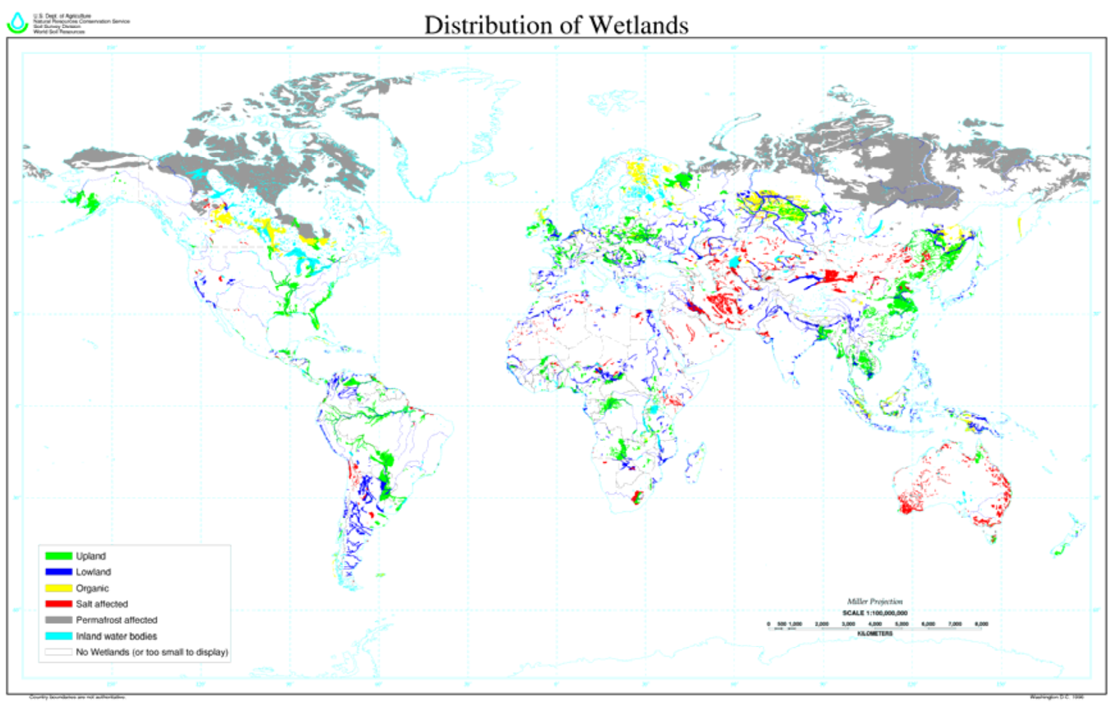
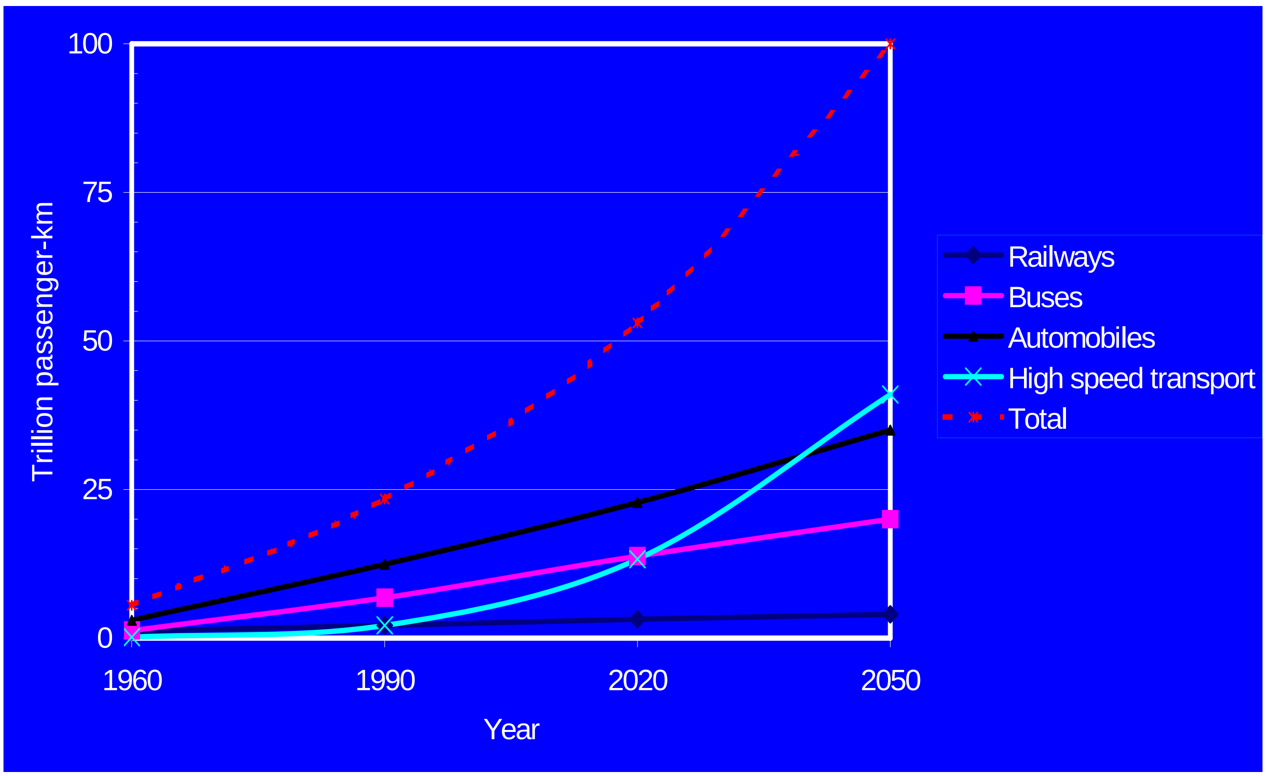


Fig. 6 The World's Wetlands (http://soils.usda.gov/use/worldsoils/mapindex/wetlands.html)

4.5 Increased human mobility: global status and trends

Human mobility comes into the equation as one of the socio-cultural factors that are increasingly tipping the balance in favour of the rapid spread of newly emerging and re-emerging infectious diseases. Highly correlated with income, human mobility has increased rapidly in all major regions of the world over the past century (66). In North America, between 1960 and 1990, average per capita incomes and human traffic volumes both doubled. In China, where the average income tripled, motorised transportation (vehicles, trains and aircraft) increased tenfold. Around the world, air travel has risen sharply, while slower forms of transport, particularly railways, have gone into decline.

In 1960, there were an estimated 5.5 trillion person/kilometres (PKM) travelled, 54% of which was accounted for by automobile and only 3% by air (66). By 1990, global traffic had increased to 23.4 trillion PKM, 9% of which was by air. The estimates for 2020 are for 53 trillion PKM with 25% by air. Combine these with figures for the growth in transport of goods, including live animals (e.g. the gigantic "sheep ships" regularly leaving from Western Australia for the Middle East), and a clear picture emerges of the socio-economic means by which highly pathogenic viruses could quickly engulf the globe. A recent update of these estimates predicts that global mobility will continue to rise, with a threefold increase projected by 2050, as shown in **Fig. 7**.



4.6 Trade in domestic fowl and in exotic birds from SE Asia and Europe and North America

The trade routes are undoubtedly one of the means by which the transfer of Asian lineage H5N1 from SE Asia to the Middle East and Eastern Europe has occurred. Available information pertains only to legal trade, yet it is also recognized that illegal trade in both

Fig. 7 Recent and Projected Trends in Global Human Mobility (www.webs1.uidaho.edu/niatt/outreach/ITD_Futures_files/frame.htm#slide0012.htm)

4.6 Trade in domestic fowl and exotic birds between SE Asia and Europe and the USA

Trade routes are undoubtedly one of the major channels through which Asian lineage H5N1 could have been transferred from SE Asia to the Middle East and Eastern Europe. Although available information pertains only to legal trade, it is also recognised that illegal trade in both poultry and exotic birds may be an important factor in the spread of avian influenza.

Yet despite mounting concerns that HPAI is being spread through the poultry trade (52), 2006 is likely to be a record year in global international trade in red and poultry meat (48). While trade restrictions have been imposed as precautionary measures associated with a range of disease outbreaks – including AI in Asia, the Middle East and Eastern Europe, foot and mouth disease (FMD) in Brazil, and bovine spongiform encephalopathy (BSE) in Canada and USA – such restrictions have been overshadowed in many instances by the strength of demand in the importing countries.

It is true that there has been a slight decline in poultry exports from some SE Asian countries since the recent H5N1 outbreaks, owing both to culls and trade restrictions. Impacts on poultry exports from Indonesia and Thailand have been particularly severe, with Thailand losing an estimated 20-25% of its poultry inventory and a reported 23% of small- and medium-sized Thai chicken producers exiting the industry after the recent outbreaks. In 2006, while Thai broiler meat production is projected to increase to over 1.1 million tons, this remains 16% below the pre-HPAI levels of 2003. Indonesian broiler meat production, which is projected to reach 672,000 tons in 2006, also remains below 2003 levels (67).

China's broiler meat production in 2006 is forecast to be in the order of 10.2 million metric tons or 7.7 billion birds (68). This represents an increase of approximately 3% from 2005 and is attributed both to strong internal demand and increased exports (62). This rate of growth has only slightly decreased over previous years, due to the H5N1 outbreaks in 2004 and lingering concerns about avian influenza. Occasional outbreaks of HPAI in the western region of China and in neighbouring countries in 2005 added to the risks, and some farmers have since turned to geese and ducks for more secure profits (67).

In summary, trade in poultry – and likely in wild birds – continues to boom across SE Asia, although in some regions they remain significantly below the peak levels witnessed in 2003. Overall, the large volume of trade in poultry coming from SE Asia adds to the risk factors that could spark a future human avian influenza pandemic.

4.7 Synthesis of risk factors and an avian influenza pandemic

The outbreak of a future human influenza pandemic will depend critically upon many chance factors. First and foremost is the capacity of a virus to transform into a new genotype with the capability of ready human-to-human transmission. The current Asian lineage H5N1 genotype(s) has been circulating for 7-8 years, but this genetic change has not yet occurred, although the probability of this happening may likely increase with the recent evolution of two distinct sub-populations of H5N1 (6). However, other variants may arise in this situation that will more readily make the leap. This is one of the most difficult areas to assess in terms of likelihood, albeit one of the most crucial.

Other factors, dealt with in the above sections, are more readily assessed. They all point to increasing risks to global health. High and increasing densities of domestic poultry (Sec. 4.1) combined with extremely high densities of humans (Sec. 4.2) provide a potent recipe for potentially catastrophic consequences when it comes to newly emerging infectious diseases. Further, the cultural practice of “wet markets,” with close associations between people and their livestock, add considerably to the risk of disease outbreaks. It is for all these reasons that the world community is increasingly concerned about the risks posed by avian influenza.

Other risk factors add to this pessimistic outlook. Some wild birds are a known reservoir of Asian lineage H5N1, and may in the future become one means for its global spread, particularly to developing countries along traditional migration routes (Sec 4.3). If this takes place, H5N1 could become endemic in South America and Africa, impacting on poor countries with little or no means for monitoring and containing the virus. The continuing decline in natural wetlands in already depleted regions, and in areas in which there is highly concentrated domestic poultry production, also poses considerable risks (Sec. 4.4). Wetland depletion inevitably forces increased “mixing” between wild migratory species and domestic flocks, and thus more opportunities for the emergence of novel strains of HPAI. The rapid rise in human mobility (Sec. 4.5) and the increased international trade in poultry (Sec 4.6) further add to the risks of a coming pandemic, by providing the means for the rapid dissemination of highly pathogenic and novel strains of AI worldwide. These risks are increased manifold by the suspected magnitude of the illegal international trade in poultry and wild birds, which by its very nature defies official control.

5. An Ecohealth Perspective on Reducing the Risks of Future Avian Influenza Pandemics

In this section, we develop the implications of an ecohealth perspective for policy guidance on global preparedness for a possible coming avian influenza pandemic. The linkages between environmental conditions and human disease are pervasive. In light of the severity of the potential consequences of a coming pandemic, far more effort is needed in the “upstream” direction – that is reducing the probability and severity of future pandemics by employing an ecohealth approach to prevention. The ecohealth approach would suggest the following priorities:

1. An overall strategy that seeks to balance the present focus on the “quick fix” (i.e. medical and public health interventions to treat and prevent the spread of disease in poultry and humans) with means for addressing the underlying causes, rooted in ecological imbalance (i.e. the ecohealth approach). This approach prioritises restoring health to the world's human-dominated ecosystems, as a fundamental prerequisite for reducing the risks of pandemics. The medical/public health approach, with its focus on immediate problems through culls, quarantine, vaccines and anti-viral drugs, should help to minimise losses of human and animal lives owing to a particular pestilence outbreak. However, it does not approach the problem at its source. Simply put, more concentrated poultry and farm animal production systems in SE Asia, in close proximity to human populations, are likely to continue to serve as an epicentre for emerging diseases, including HPAI H5N1. The increased intensity of production generally takes place in environments with already compromised ecosystem health. Further, by its own processes, poultry production presents the risk of further environmental degradation. Obviously, meeting global demand for food is of the highest priority – but meeting it in ecologically unsustainable ways that continue to degrade ecosystems and increase the risk of future pandemics is hardly the solution.

2. An effort aimed at the transformation of farm practices, particularly in SE Asia, by phasing out large-scale concentrations of domestic fowl (chickens, geese and ducks) raised in association with high concentrations of humans and other mammals (e.g. pigs). This is in line with the FAO recommendation that "close contacts between humans, domestic poultry and wildlife should be reduced and closely monitored. On farms and in markets, domestic birds should be strictly separated from wild animals to the greatest extent possible. Vaccinating poultry could also be considered in at-risk situations" (10). Of course, some of these practices are many generations old, and farmers are likely to be reluctant to change – particularly in situations of subsistence agriculture, where change may mean increased risk of starvation. Yet cultures do adapt, when it becomes clear that existing practices can no longer be sustained without risks to individuals and community. As unpalatable as this may be, where it is clearly in the interest of preventing future pandemics with potentially catastrophic consequences, such steps can and should be undertaken. Some governments have already instituted unpopular measures to reduce risk, such as the banning of poultry-raising in Ho Chi Minh City.

3. Maintaining or restoring the health of wetlands as a key priority for preventing the future spread of HPAI. If the transfer of Asian lineage H5N1 is from domestic flocks to wild migratory birds, or vice versa, it becomes essential to ensure that wetland habitat is adequate so that wild birds are not driven, by default, to seek farm ponds and other artificial water sources used by domestic poultry. Mitigating the loss of, and restoring health to, wetlands will reduce the likelihood of migrating wild birds intermingling with domestic fowl. While many migratory water birds may now depend upon agricultural systems along their migration routes, this dependence derives in part from the absence or reduction of their natural feeding habitat.

4. Preventing the degradation of landscapes along wild bird migration routes to help maintain separation between wild bird habitat and habitat used by domestic fowl. Migratory bird flyways are under threat around the world, owing to habitat change. Proposals to prevent the further degradation and restore health to the landscapes along migration routes should be carried out not only in the interest of protecting biodiversity, but in the interest of promoting the health of humans and minimising risks of an avian influenza pandemic. For example, in Jordan's Rift Valley, there is a proposal to secure the area to protect millions of migrating wild birds that annually cross the valley. These proposals should now be given the added weight that such protection will also provide an "upstream" defence against future AI pandemics. Intensive poultry operations along wild bird migration routes are incompatible with protecting the health of ecosystems that these birds depend upon – as well as increasing the risk of the transfer of pathogens between migrating birds and domestic fowl.

Healthy ecosystems have been recognised by WHO and other international bodies as essential for maintaining human health. Yet all too often, the goal of obtaining ecosystem health is relegated to lofty "long-term objectives," while in the short term actions are undertaken that further compromise the health of the Earth's ecosystems. In the urgency of countering the prospect of an avian influenza pandemic, priorities are centred on the short term, namely "fixing the problem" rather than preventing its emergence in the first place. This report argues for a balanced approach: taking the necessary steps to restore healthy human-dominated ecosystems and healthy wild ecosystems as a critical requirement for reducing human health vulnerabilities to emerging diseases. The Scientific Task Force to the Convention on the Conservation of Migratory Species of Wild Animals recognises the importance of precautionary and preventive approaches and calls for: "regulation of animal markets; precautionary suspension or restriction of the global wild bird trade; and improved standards in poultry farms, farming, and marketing practices" (69). The ecohealth approach goes even further, arguing for establishing health at the ecosystem level as an essential condition for sustaining human and animal health (3).

5. Intensifying efforts to control the illegal trade in poultry and wild birds. Illegal activities have long been among the banes of efforts to restore health to the world's ecosystems. In the case at hand, it has become clear that illegal trade can and likely has played a major role in the continuing global spread of HPAI H5N1. By its very nature, this is a most difficult phenomenon to bring under control. However, success in achieving the other priorities might be considerably offset if this trade is able to continue. Every possible measure should be taken to stop the illegal trade in poultry and wild birds, owing to its severe implications for long-term global health.

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Appendix 1

Table 1: Cumulative list of countries that have reported HPAI H5N1 in poultry and wild birds since December 2005 (Source: CDC Website)

Since December 2003, avian influenza A (HPAI H5N1) infections in poultry or wild birds have been reported in the following countries:

Africa:
- Cameroon
- Niger
- Nigeria

East Asia & the Pacific:
- Cambodia
- China
- Hong Kong (SARPRC)
- Indonesia
- Japan
- Laos
- Malaysia
- Mongolia
- Myanmar (Burma)
- Thailand
- Vietnam

South Asia:
- Afghanistan
- India
- Kazakhstan
- Pakistan (H5)

Near East:
- Egypt
- Iraq (H5)
- Iran
- Israel
- Jordan

Europe & Eurasia:
- Albania
- Austria
- Azerbaijan
- Bosnia & Herzegovina
- Bulgaria
- Croatia
- Denmark
- France

Georgia
Germany
Greece
Hungary
Italy
Poland
Romania
Russia
Serbia & Montenegro
Slovak Republic
Slovenia
Sweden
Switzerland
Turkey
Ukraine

For additional information about these reports, visit the World Organisation for Animal Health website.

Updated March 29, 2006

Appendix 2

Table 2: Cumulative Number of Confirmed Human Cases of Avian Influenza A (H5N1) Reported to WHO

Country	2003		2004		2005		2006		Total	
	cases	deaths	cases	deaths	cases	deaths	cases	deaths	cases	deaths
Azerbaijan	0	0	0	0	0	0	7	5	7	5
Cambodia	0	0	0	0	4	4	1	1	5	5
China	0	0	0	0	8	5	8	6	16	11
Indonesia	0	0	0	0	17	11	12	11	29	22
Iraq	0	0	0	0	0	0	2	2	2	2
Thailand	0	0	17	12	5	2	0	0	22	14
Turkey	0	0	0	0	0	0	12	4	12	4
Vietnam	3	3	29	20	61	19	0	0	93	42
Total	3	3	46	32	95	41	42	29	186	105

Total number of cases includes number of deaths. WHO reports only laboratory-confirmed cases.

Source: WHO, March 24 2006.

Appendix 3

Table 3: WHO Pandemic Alerts and Response

Inter-Pandemic Period

Phase 1

No new influenza virus subtypes have been detected. An influenza virus subtype that has caused human infection may be present in animals. If present in animals, the risk of human infection or disease is considered to be low.

Response

Strengthen influenza pandemic preparedness at the global, regional, national and sub-national levels.

Phase 2

No new influenza virus subtypes have been detected in humans. However, a circulating animal influenza virus subtype poses a substantial risk of human disease.

Response

Minimise the risk of transmission to humans; detect and report such transmission rapidly if it occurs.

Pandemic Alert Period

Phase 3 (current)

Human infection(s) with a new subtype, but no human-to-human spread, or at most rare instances of spread to a close contact.

Response

Ensure rapid characterisation of the new virus subtype and early detection, notification and response to additional cases.

Phase 4

Small cluster(s) with limited human-to-human transmission but spread is highly localised, suggesting that virus is not well adapted to humans.

Response

Contain the new virus within limited foci or delay spread to gain time to implement preparedness measures, including vaccine development.

Phase 5

Large cluster(s) but human-to-human spread still localised, suggesting that the virus is becoming increasingly better adapted to humans, but may not yet be fully transmissible (substantial pandemic risk).

Response

Maximise efforts to contain or delay spread, to possibly avert a pandemic, and to gain time to implement pandemic response measures.

Pandemic Period

Phase 6

Pandemic: increased and sustained transmission in general population.

Response

Minimise the impact of the pandemic.

Notes: The distinction between ***phase 1*** and ***phase 2*** is based on the risk of human infection or disease resulting from circulating strains in animals. The distinction is based on various factors and their relative importance according to current scientific knowledge. Factors may include pathogenicity in animals and humans, occurrence in domesticated animals and livestock or only in wildlife, whether the virus is enzootic or epizootic, geographically localised or widespread, and/or other scientific parameters.

The distinction between ***phase 3***, ***phase 4*** and ***phase 5*** is based on an assessment of the risk of a pandemic. Various factors and their relative importance according to current scientific knowledge may be considered. Factors may include rate of transmission, geographical location and spread, severity of illness, presence of genes from human strains (if derived from an animal strain), and/or other scientific parameters.

Source: WHO/CDS/CSR/GIP/2005.5.

Appendix 4

Biographical Notes on Contributors to this Report

The following members of EcoHealth Consulting contributed to this paper. Further information about the activities of the EHC group can be found at: www.ecohealthconsulting.com.

David Rapport, PhD, F.L.S. (London) is one of the originators of the concept of ecosystem health. He has served as President of the International Society for Ecosystem Health (1993-2000) and as editor-in-chief of the international peer-reviewed journal Ecosystem Health (Blackwell, 1995-2002). Dr. Rapport co-founded the program in environmental statistics at Statistics Canada, where he led the development of the Stress-Response-Environmental Statistical System. He is co-author of Canada's first national State of Environment Report (1986). He held the Tri-Council Eco-Research Chair in ecosystem health at the University of Guelph and co-founded the ecosystem health program in the faculty of medicine at the University of Western Ontario, where he holds an honorary professorship. He also holds an honorary professorship in the Institute of Applied Ecology, Chinese Academy of Science, Shenyang. Dr. Rapport serves on the editorial boards of Ecological Economics (Elsevier), EcoHealth (Springer) and Ecological Indicators (Elsevier). He has carried out eco-health assessments on three continents (Europe, North America and Australia). His most recent book is Managing for Healthy Ecosystems (Lewis Press, 2003).

John Howard, MD, is a professor of Paediatrics and Medicine in the Faculty of Medicine and Dentistry at the University of Western Ontario. His previous roles include Assistant Dean of Undergraduate Education and Assistant Dean of Alumnae Affairs. He is a highly renowned teacher, having received many teaching awards – including a 2002 UWO Pleva Award recognising outstanding UWO teachers, and a 2002 OCUFA Award recognising outstanding Ontario professors. Dr. Howard's academic interests have been medical leadership and medical education. Dr. Howard has had extensive leadership experience in education and in hospital restructuring. His present academic role is leading the Ecosystem Health initiative in the Faculty which considers each patient as a marker of the health of the ecosystem. Dr. Howard provides both adult and paediatric care in diseases of the gastrointestinal tract. In 2001, he was recognized as the "Consultant of the Year" – recognising excellence in compassion, communication and clinical abilities.

Luisa Maffi, PhD, is President and CEO of Terralingua, an international NGO devoted to promoting the integrated conservation of biological and cultural diversity. She is one of the originators of the concept of biocultural diversity. Her edited volume On Biocultural Diversity, published by Smithsonian Institution Press (2001), is widely considered a foundational work in this field. Dr. Maffi's work has been supported by major grants from the US National Science Foundation, US National Institutes for Health, Ford Foundation, and The Christensen Fund. This work includes both global and regional assessments of biocultural diversity, as well as participatory community projects. Terralingua's collaboration has been actively sought by major international organisations such as WWF, Conservation International, IUCN, UNEP and UNESCO, as well as academic institutions such as the Smithsonian Institution, the Field Museum of Natural History, Northern Arizona University, and the University of Florida.

Bruce Mitchell, PhD, is Professor of Geography, cross-appointed in the School of Planning, and Associate Provost, Academic and Student Affairs, at the University of Waterloo, Ontario. His research specialisation is the institutional and policy aspects of water management, and integrated resource and environmental management. He has extensive experience in Canada, Australia and Indonesia. He has written/edited 24 books and over 130 articles, and his work has been translated into Chinese, Indonesian and Spanish. He has received numerous awards, including the Award for Scholarly Distinction in Geography from the Canadian Association of Geographers, and the Distinguished Service Award from the Canadian Water Resources Association. He has served as a consultant to or advisor for provincial and federal governments in Canada, as well as the Organisation for Economic Cooperation and Development and UNESCO, the International Joint Commission, the Government of Western Australia, and numerous private consulting firms. Dr. Mitchell is a fellow of the Royal Society of Canada.