The potential role of migratory birds in the transmission of zoonoses

Ioanna Georgopoulou & Vasilios Tsiouris

Summary

The instinct for survival leads migratory birds to exploit seasonal opportunities for breeding habitats and food supplies. Consequently, they travel across national and international borders. These birds are distinguished in local migrants, short-distance, long-distance and vagrant and nomadic migrants. They can transfer micro-organisms across the globe and play a significant role in the ecology and circulation of pathogenic organisms. They are implicated in the transmission of zoonoses as biological and mechanical carriers and as hosts and carriers of infected ectoparasites. They can cause water-borne, tick-borne and insect-borne diseases. Favourable agents, such as seasonality and stress due to migration, influence the transmission of pathogens. The migration of birds is a natural phenomenon that is followed by the unavoidable repercussions of the participation of these birds as carriers or hosts in the transmission of pathogens. It is not possible to interrupt this sequence but risks can be minimised by controlling and preventing perilous situations. Surveillance of wetlands, 'stopovers', places of destination and wintering regions can be done**.** Furthermore, the implementation strict biosecurity measures that reduce contact with migratory birds will limit the transmission of pathogens.

Keywords

Birds, Disease, Influenza, Micro-organisms, Migration, Prevention, Public health, Transmission, Zoonosis.

Il potenziale ruolo degli uccelli migratori nella trasmissione delle zoonosi

Riassunto

L'istinto di sopravvivenza spinge gli uccelli migratori ad esplorare opportunità stagionali per la riproduzione e per rifornirsi di cibo. Per questo intraprendono viaggi attraverso rotte nazionali e internazionali. Gli uccelli migratori si possono definire come: migratori di corta distanza, di lunga distanza, erranti e migratori nomadi. I migratori possono trasportare microrganismi e svolgono un ruolo significativo per l'ecologia e la circolazione degli organismi patogeni. Sono coinvolti nella trasmissione delle zoonosi sia in qualità di portatori biologici e meccanici sia come ospiti e veicolo di ectoparassiti infetti; possono causare patologie trasmesse dall'acqua, da zecche, da insetti. La stagionalità e lo stress causati dalla migrazione sono agenti favorevoli e influenzano la trasmissione dei patogeni. La migrazione degli uccelli è un fenomeno naturale ma non è possibile stabilire il ruolo, se portatori o ospiti, nella trasmissione dei patogeni. Se è vero che non si può interrompere questa catena è però possibile minimizzare i rischi attraverso azioni di controllo e prevenzione delle situazioni di rischio. E' necessario attivare la sorveglianza nelle zone umide, nelle aree di sosta, nelle regioni di destinazione e di svernamento. Inoltre, la realizzazione di misure rigorose di biosicurezza limiterà la trasmissione dei patogeni mediante la riduzione di contatti con gli uccelli migratori.

Avian Diseases Clinic, Faculty of Veterinary Medicine, Aristotle University of Thessaloniki, Staurou Voutyra 11, 54627 Thessaloniki, Greece
ioannag@vet.auth.gr

Parole chiave
Malattia, Microrganismi, Migrazione, Prevenzione, Sanità pubblica, Trasmissione, Uccelli.

Introduction

The instinct for survival encourages migratory birds to exploit seasonal opportunities for breeding habitat and food supplies. The migratory routes of these birds takes them along coasts, mountain ranges, river valleys and other topographical features. Billions of birds travel across national and international borders from eastern Europe to Africa, from North America to Central and South America and from the Arctic to subtropical or tropical zones (6). These birds play a significant role in the ecology and circulation of pathogenic organisms. They carry pathogens that can be transmitted at 'stopovers' and that can be dangerous for domestic animals and humans (5, 9). Although the migration of the birds is a spectacular and natural phenomenon, it also creates unavoidable dangers for public health.

Migratory species of birds are divided into four main categories of migration, namely: the local species, the short-distance migrants, the long-distance migrants and the vagrant and nomadic migrants. Local species move within a few miles, the short-distance migrants travel only a few hundred miles to wintering ranges, the long-distance migrants cover hundreds to thousands of miles to wintering ranges and the vagrant and nomadic species migrate mostly in search of food and due to the scarcity of water (9, 19).

In recent decades, migratory birds and wildlife have been incriminated in and associated with emergent and resurgent diseases (1, 9, 12). They are implicated in the transmission of zoonoses and other microbial pathogens by three main mechanisms, namely: biological carriers, mechanical carriers and carriers of infected ectoparasites (9).

Transportation and transmission of pathogens

Biological carriers transport viruses, bacteria, fungi and endoparasites which multiply in the body. The infection of birds can be acute, chronic, latent or asymptomatic. Viruses that can possibly be transported include the arboviruses (Eastern equine encephalitis, West Nile virus), Usutu virus, Newcastle disease virus, duck plague virus, avian pox virus, Sindbis or St Louis encephalitis virus and influenza A virus (1, 9). In this way, the causative agents of ornithosis, mycoplasmosis, avian cholera, erysipelas, avian tuberculosis, coxiellosis, Lyme borreliosis, campylobacteriosis, cholera, colibacillosis, salmonellosis, yersiniosis and listeriosis can also be carried. Likewise, drug-resistant enteropathogens can be transported (1, 3, 9, 10, 17) as can fungi and endoparasites, such as *Aspergillus* spp., *Candida* spp., *Leucocytozoon* spp., *Haemoproteus* spp., *Toxoplasma* spp., *Sarcocystis* spp. and *Cryptosporidium* spp. (1, 8).

Mechanical carriers transmit either external or internal microbial pathogens. External pathogens, like fungal spores, are located on the body of the bird and can survive for at least 12 days on the feathers of migratory swallows. Internal pathogens do not multiply in the avian body but pass through the digestive tract and are viable when excreted. Foot and mouth disease virus is thought to be transmitted by mechanical carriers (1, 9).

Migratory birds can be carriers of infected haematophagous ectoparasites which sometimes serve as vectors for several diseases. Infected immature ixodid and argasid ticks are transported in such a way from one place to another and even from one continent to another (8). Tick-borne pathogens can be viruses, such as tick-borne encephalitis, Tyuleniy, Meaban, Bahig, Hughes group, Sachalin group, Crimean Congo haemorrhagic fever virus, Bhanja, Komerovo, Great Island complex, Thogoto and Dhori viruses, as well as bacteria, such as *Rickettsia* spp., *Anaplasma phagocytophilum*, *Borrelia burgdorferi s.l.* or protozoa-like *Babesia microti*. In addition, fleas can be transmitted on migrating birds over long distances (1, 9).

The mode of transmission of all these micro-organisms can either be direct or indirect. Direct transmission is caused by the migratory bird itself via intimate contact, contact by inhalation of discharged respiratory droplets from coughing or sneezing or by infectious faeces. Indirect transmission occurs via an arthropod, such as a flea, mite, mosquito, sand fly or tick, or an inanimate vehicle like water, food, soil, etc. In addition, the air-borne spread by droplet nuclei, dust etc. is considered to be an indirect mode of transmission (9). The mode of transportation of pathogens by migratory birds depends on the route of transmission (8).

In water-borne infections, the agent, such as avian influenza virus, Newcastle disease virus, *Chlamydia psittaci*, *Escherichia coli*, *Yersinia* spp., *Pasteurella multocida*, *Enterococcus faecalis*, *Clostridium* spp. and *Candida* spp., is shed by infected migratory birds in faeces, in nasal discharge and respiratory exudate into water. In tick-borne infections, the infectious larval or nymphal tick is dropped into a new geographic area during migration. In insect-borne infections, the concentration of the infectious agent in the blood of migrating birds is decisive for infection of competent insect vectors (9).

The effective transmission of pathogens by migratory birds can be influenced by different factors. One of these is seasonality during migration. An example is the increased number of mosquitoes that prevail during the late summer and early autumn when migratory birds return. Another example is the influence of seasonal temperatures on certain pathogens, such as the avian influenza virus which remains infectious in water at a lower ambient temperature from late autumn to early spring when major congregations of migratory waterfowl pass through. Another favourable factor that is effective in causing transmission is the immense stress caused by migration on birds. Fatigue diminishes their resistance to infections, increases the shedding rate of infectious agents and the duration or the level of viraemia/bacteraemia in migrating birds that are already infected (1, 9).

The migration of birds started millions of years ago and has always been followed by a number of unavoidable consequences, such as these birds being carriers or hosts in the transmission of pathogens. Questions have been raised regarding whether or not it is possible to interrupt this natural sequence of pathogen circulation and transmission. It is not possible to break this sequence but the risks of occurrence of transmissible zoonotic pathogens could perhaps be minimised by controlling migratory birds and preventing dangerous situations. The collaboration of all scientific and other groups involved at the national and international levels is needed (4). Additional research into pathogens transmitted by migratory birds, the modes of transmission and the toll these pathogens have on the countries involved would be valuable. Among topics that need to be documented more comprehensively are the following: the exact flyways, stopover places, places of destination and period of departure of the birds. Research efforts must be designed so that they clearly demonstrate the relationships between hosts and pathogens and their environment. The migration ecology in every country should be known and those that are unknown should be scheduled for study (4, 12, 19).

Priniciples of zoonoses control and prevention

Overall, programmes for zoonoses control and prevention are based on the steps listed below, that have been adopted by international health organisations such as the Food Agriculture Organization (FAO) and World Organisation for Animal Health (*Office International des Épizooties*: OIE). These eleven steps are as follows:

- prevention
- control
- eradication
- neutralisation of reservoirs
- reducing potential contact
- increasing host resistance
- implementing consumer protection strategies
- identifying animals appropriately
- maintaining health
- communication
- education (11).

Prevention, control and eradication

The goal of the first step, prevention, is to inhibit the introduction of disease agents. The second step, control, involves the adoption of measures to reduce disease frequency and severity to a tolerable level. Eradication aims at eliminating the agent from a population or from a geographic area and, in particular, from reservoirs. Prevention and control must be complemented by surveillance, diagnostics and an early warning system (1, 2, 14, 20). Although the surveillance of migratory birds is very difficult, it must include wetlands, stopover places, places of destination and wintering regions (16).

Some countries are setting up integrated monitoring schemes for water bird populations. In the United Kingdom, the Wildfowl and Wetlands Trust has embarked on the long-term health screening of a species of geese as an adjunct to internationally co-operative research and monitoring of this population (20). In France, the National Wildlife Observatory investigates flyway levels to improve the monitoring and management of waterfowl populations (22). In the Ukraine, there are serological and virological surveys of ticks, mosquitoes and birds in the Azov-Black Sea region which have revealed that there is potential for the spread of arboviruses from Africa (21). In all countries associated with the migratory flyways, national programmes must be designed and applied to ensure the surveillance of migratory birds. This should be planned jointly by ornithologists who work in close liaison with veterinary experts. Additional data and information on existing water bird ringing is needed, as are the routes and timing of migration, especially those of the scarcely documented intra-African migrants and the Asia-Pacific and Neotropical flyways which will enable the high-risk periods to be identified (4, 12, 19).

Neutralisation of reservoirs

The fourth basic step for control is reservoir neutralisation which includes the eradication of infected individuals from reservoirs or the manipulation of the environment in which reservoirs reside. Carriers can be eliminated by testing and slaughter or by mass therapy (11), but handling of migratory birds is obviously difficult to perform. Control of the vector is applied in cases of vector-borne agents and reservoirs of wildlife species. The neutralisation of reservoirs and management of the environment are not easy to apply to migratory birds.

Reducing potential contact

Another preventive step is to minimise the potential contact by reducing the opportunity for contact. Known sources of infection can be isolated or susceptible individuals quarantined. In crisis situations, population control programmes also include the strict application of the relevant laws and decisions at a national and international level (11). Transmission by migratory birds can be limited by reducing potential contact through the use of strict biosecurity measures. This is a critical point and should create a barrier between the migratory reservoir and susceptible domestic backyard bird species. Another critical point is the strict isolation of poultry farms. Certainly a total absence of contact between migratory birds and people (including hunters, birdwatchers, ornithologists, people working in the environment) must be applied very carefully. These people must be adequately informed on the risks and measures that need to be taken (11, 20). The risk for interspecies transmission among birds is problematic when wild and domestic species are involved. Ducks, as aquatic birds, most likely come in contact with free-range poultry, especially when congeners induce migrating wild ducks to stop over. Captive-bred mallards, used for hunting purposes and voluntarily placed in the wild to attract other ducks, are very likely to share pathogens with their migratory congeners and facilitate the transmission of diseases to other domestic species (12).

Increasing host resistance

The next step in the control programme against zoonoses is increasing host resistance by genetic selection, stress reduction, chemoprophylaxis and immunisation (11).

Although this is not feasible in migratory birds, it can be used in domestic backyard poultry and on poultry farms.

Implementing consumer protection strategies

Consumer protection strategies concern food diseases, such as infections with *Salmonella* spp., *Clostridium perfringens*, *Campylobacter jejuni*, etc. Hunters and people that cook and eat hunting birds must be aware of the risks involved.

Identifying animals appropriately

The next step involves individual animal identification and is of critical importance in zoonoses control programmes for domestic and farm animals. Individual animal identification enables the tracing back of an animal to the farm of origin and, presumably, the source of infection. Animal identification is performed by placing ear tags, chips, tattoos, etc., on each animal (11). This step is not applicable to migratory birds.

Maintaining health

Animal and public health disease control programmes are affected by socioeconomic factors. Cost-benefit analyses are necessary to obtain the approval and application of these programmes. For migratory birds, such heahth maintenance programmes would be very difficult to estimate although the cost-benefit would be seen to be very high.

Communication

Step eleven involves communication and is based on establishing a system among health professionals that must be operational before an emergency occurs. It includes a back-up system (power outage) and mechanism for communication with the public to ensure consumers are accurately informed. It details instructions for dealing with an emergency. This system has been used for some severe zoonoses, such as influenza.

Education

The final step, education, is one of the most effective disease prevention and control strategies. Without an initial awareness campaign, the acceptance of a new control procedure will be delayed. Health professionals in private practice have enormous responsibility and also have the greatest opportunity to inform their patients in regard to health risks and prevention. Collaboration and co-operation are required to ensure that the best solutions are found. Collaborative partnerships involve ornithological, wildlife and wetland management expertise, together with those traditionally responsible for public health and zoonoses (4, 12, 20).

Conclusions

It can be concluded from the prevention strategies for zoonoses transmission by migratory birds that more data are required on the movements of birds, the higher risk periods for introduction and emergence of bird-borne diseases, the knowledge of the relationship between migratory hosts, pathogens, predators, competitors and their environment. Host-pathogen interactions should be described by using data such as antibody prevalence in different species and age classes, frequency of pathogen isolation and characterisation of the strain involved. Complementary laboratory and field experiments within a controlled environment might also provide relevant information. All these investigations should gradually make it possible to evaluate valuable baseline data and to gain new insights into the bird-pathogen relationship in places considered to be at high risk along the routes of migratory birds (4, 12, 20, 24).

Surveillance and monitoring activities should be increased as should response capacity to investigate a zoonosis or unusual disease event in humans or animals worldwide. This will require innovative measures to improve vigilance. International hazard identification, risk communication and risk management strategies will become more important in the future. The role of organisations, such as the OIE the FAO and World Health Organization (WHO), is decisive in the detection and management of the coordination of all activities involving zoonoses on a worldwide scale and especially those that involve migratory birds (1).

Finally, it is necessary to note that some human activities facilitate the spread pathogens carried by birds across the globe through legal or illegal trade of wild and domestic birds or bird products (13, 18). The introduction of West Nile virus to North America in 1999 is considered to be a plausible scenario for the importation of an infected bird (7, 17, 19). Similarly, in 2004, highly pathogenic avian influenza strain H5N1 was isolated in Belgium from crested hawk-eagles (*Spizaetus nipalensis*) smuggled by air travel (23). In Asia, the transmission of the H5N1 influenza virus has mainly been the result of human activity, such as live poultry markets and the international trade of birds, bird products and contaminated equipment (15).

In conclusion, it is clear that migratory birds play an unavoidable role in the transmission of zoonoses. Surveillance systems that promote diagnostic pathogen surveillance of migratory birds, together with outbreak control measures need be reinforced. Furthermore, based on outbreaks of threatening emerging zoonoses, efforts to control zoonoses from a global perspective will be necessary. One must remember that migratory birds have contributed to human evolution in significant ways and have inspired human beings to create aeroplanes and migrate to other countries in search for a better life.

References

1. Bengis R.G., Leighton F.A., Fisher J.R., Artois M., Mörner T. & Tate C.M. 2004. The role of wildlife in emerging and re-emerging zoonoses. *Rev Sci Tech*, **23** (2), 497-511.
2. Brown C. 2004. Emerging zoonoses and pathogens of public health significance – an overview. *Rev Sci Tech*, **23** (2), 435-442.
3. Chuma T., Hashimoto S. & Okamoto K. 2000. Detection of thermophilic *Cambylobacter* from sparrows by multiplex PCR: the role of sparrows as a source of contamination of broilers with *Cambylobacter*. *J Vet Med Sci*, **62**, 1291-1295.
4. Clark J. 2006. Migration and flyway atlases. Workshop Introduction. *In* Waterbirds around the world, 1st Ed. (G. Boere, C. Galbraith & D. Stroud, eds). The Stationery Office, Edinburgh, 568.
5. Ehrlich P.R., Dobkin D.S. & Wheye D. 1988. *In* The birder's handbook: a field guide to the natural history of North American birds, 1st Ed. Simon and Schuster Inc., New York, 720 pp.
6. Gill F.B. 1995. Migration. *In* Ornithology, 2nd Ed. W.H. Freeman and Co., New York, 287-309.
7. Gould E.A. 2003. Implication for northern Europe of the emergence of West Nile virus in the USA. *Epidemiol Infect*, **131**, 583-589.
8. Hasle G., Mehl R., Bjune G. & Leinaas H.R. 2004. Transport of ticks by migratory birds in Norway. *In* Proc. Third African acarology symposium, 11-15 January, Giza (www.reiseklinikken.no/bstract_Cairo.htm accessed on 29 November 2008).
9. Hubalek Z.2004.An annotated checklist of microorganisms associated with migratory birds. *J Wildlife Dis*, **40** (4), 639-659.
10. Hudson C.R., Quist C., Lee M.D., Keyes K., Dodson S.V., Morales C., Sanchez S., White D.G. & Maurer J.J. 2000. Genetic relatedness of *Salmonella* isolates from nondomestic bird in southeastern Unites States. *J Clin Microbiol*, **38**, 1860-1865.
11. Hugh-Jones M., Hubbert W.T. & Hagstad H.V. 1995. Principles of zoonoses control and prevention. *In* Zoonoses, recognition, control, and prevention, 1st Ed. Iowa State University Press, Ames, 79-120.
12. Jourdain E., Goutier-Clerc M., Bicout D.J. & Sabatier P. 2007. Birds migration routes and risk for pathogen dispersion into western Mediterranean wetlands. *Emerg Infect Dis*, **13** (3), 363-372.
13. Karesh W.B., Cook R.A., Bennett E.L. & Newcomb J. 2005. Wildlife trade and global disease emergence. *Emerg Infect Dis*, **11**, 1000-1002.
14. Kellar J.A. 2005. Portrait of the national veterinary service as a surveillance continuum. *Prev Vet Med*, **67** (2-3), 109-115.
15. Melville D.S. & Shortridge K.F. 2004. Influenza: time to come to grips with the avian dimension. *Lancet Infect Dis*, **4**, 261-262.
16. Piersma T. & Warnock N. 2006. Migration ecology. Workshop Introduction. *In* Waterbirds around the world, 1st Ed. (G. Boere, C. Galbraith & D. Stroud, eds). The Stationery Office, Edinburgh, 505.

17. Rappole J.H. & Hubalek Z. 2003. Migratory birds and West Nile virus. *J Appl Microbiol,* **94** (Suppl), 47S-58S.
18. Rappole J.H., Derrickson S.R. & Hubalek Z. 2006. Migratory birds and spread of West Nile virus in the western hemisphere. *Emerg Infect Dis*, ***6***, 319-328.
19. Reed K.D., Meece J.K, Henkel J.S. & Shukla S.K. 2003. Birds, migration and emerging zoonoses: West Nile virus, Lyme disease, influenza A and enteropathogens. *Clin Med Res*, **1** (1), 5-12.
20. Rocke T. 2007. Disease emergence and impacts in migratory waterbirds. Workshop Introduction. *In* Waterbirds around the world, 1st Ed. (G. Boere, C. Galbraith & D. Stroud, eds). The Stationery Office, Edinburgh, 410-411
21. Rusev I. & Korzuykov A. 2006. Ukraine as an ecological corridor for the transcontinental migration of birds in the Afro-Eurasian region and questions of epidemiological safety. *In* Waterbirds around the world, 1st Ed. (G. Boere, C. Galbraith & D. Stroud, eds). The Stationery Office, Edinburgh, 446.
22. Vallance M. & Ferrand Y. 2006. Priority needs for co-ordinated research at flyway level to improve monitoring and management of waterbird populations, as identified by the French national observatory of wildlife. *In* Waterbirds around the world, 1st Ed. (G. Boere, C. Galbraith & D. Stroud, eds). The Stationery Office, Edinburgh, 459-462.
23. Van Borm S., Thomas I., Hanquet G., Lambrecht B., Boschmans M., Dupont G., Decaestecker M., Snacken R. & van den Berg T. 2005. Highly pathogenic H5N1 influenza virus in smuggled Thai eagles, Belgium. *Emerg Infect Dis*, **11**, 702-705.
24. Vorou R.M., Papavassiliou V.G. & Tsiodras S. 2007. Emerging zoonoses and vector-borne infections affecting humans in Europe. *Epidemiol Infect*, **135**, 1231-1247.