State of Michigan

DEPARTMENT OF NATURAL RESOURCES

Michigan Surveillance and Response Plan for Avian influenza in free-ranging wildlife

Issued: January 27, 2006

Revised: August 10, 2021

1. Background

Michigan's original Surveillance and Response Plan for Highly Pathogenic Avian Influenza in Free-ranging Wildlife [hereafter, the Plan] was finalized in January 2006. The impetus for its development, and indeed the entire orientation of the Plan, was to confront the perceived threat of a single, specific variant of avian influenza (AI), namely, highly pathogenic (HP) AI H5N1. As detailed in the original Plan, that virus not only posed an economic threat to domestic poultry operations, but more urgently, was transmissible to humans, and caused high fatality rates in infected humans. Also motivating the response preparations at that time was concern that H5N1 could produce a global human influenza pandemic, potentially with high mortality. With the emergence of the Covid-19 pandemic in 2020, the world is keenly aware of the potential for recombinant viruses of wildlife origin to transmit to humans, with devastating results, for both human economies and human lives.

While the 2006 HPAI pandemic fortunately never materialized, preparations for it were not wasted, as they forced a broad spectrum of government agencies to carefully consider what a coordinated response to AI would look like. Lessons learned about how those agencies would interact with each other, the scientific community, local governments, non-governmental organizations and the general public to mount an effective, yet measured, response were largely productive, and continue to be beneficial today.

At the time the original Plan was written, comparatively little was known about the broad ecology of AI among its many potential hosts. Certainly, detailed information on the pathogenesis, epidemiology and control of AI within domestic poultry had long been available. Basic information was also available on the occurrence of AI viruses in wildlife, particularly waterfowl. And more broadly, a great deal of information had also been accumulated about influenza A viruses (to which the AIs belong) and their biology, as well as their epidemiology and control, in human populations. What was notably missing, however, was a fundamental understanding of how AI viruses cycle between those distinct populations, how they persist, and how they change as they infect different species.

In the decade and a half that has since passed however, a great deal of scientific scrutiny and resources have been brought to bear on those ecological issues. Although many questions remain, that work has considerably clarified the role of wild birds in AI outbreaks. It has better defined which wildlife surveillance and response activities are likely to meaningfully contribute to control of AI outbreaks among domestic poultry and humans, and which are not. Crucially, in contrast to activities undertaken in some previous AI outbreaks, the latter can, and should, now be avoided.

Incorporation of this recent body of knowledge, along with generalization of DNR surveillance and response plans to the occurrence of AIs other than H5N1, is the purpose of the current update. This update is not intended to invalidate the original Plan, but rather to modify it in light of information gained.

1.1. Changing the paradigm: integrating prevention. Unavoidably, the original Plan was reactive, precipitated by the emergence of the H5N1 HPAI in Asia. Preparations for an unforeseen potential outbreak needed to be made rapidly. Yet, in managing diseases in wildlife populations, nearly all success stories have been achieved through prevention. Historically, agencies have an unenviable track record controlling diseases once they become established. Until the necessity of *prevention* becomes an ingrained norm, wildlife management agencies will always be at a huge disadvantage responding to outbreaks.

While there is now evidence suggesting AIs do not become 'established' in wild North American waterfowl *per se* [1], many human-caused, unnatural situations, when minimized, can help disrupt the reactive cycle of crisis responses that usually follows discovery of diseases such as HPAI. Morbidity stress on free-ranging wildlife can be minimized by: long term habitat management to reduce the interactions between wildlife, domestic animals and humans; eliminating supplemental and recreational feeding; mitigating areas of poor surface water quality; controlling invasive species which may outcompete native wildlife or degrade their habitat. Eliminating such incremental stressors maximizes the capacity of wild populations to fight off infectious diseases, ensures that propagation of those diseases that are introduced will be minimized, and speeds resilience, the ability of the population to recover from a disease outbreak. Although managing human activities that foster disease transmission nearly always generates controversy, it is typically the most cost efficient and effective management strategy.

An example relevant to AI regards land management in the vicinity of domestic poultry facilities. During summer 2015 when HPAI H5N2 and H5N8 caused huge economic losses in domestic poultry facilities in the Midwestern US, MDNR received requests that wild waterfowl be culled from wetlands near large poultry facilities, despite no Michigan poultry facilities being infected, nor any isolation of HPAI from wild birds within 100 miles. Notably, the US Department of Agriculture "…and other experts do not recommend the lethal removal of wild birds in order to prevent the spread of HPAI" [2]. Such requests created unnecessary conflicts between stakeholder groups, diverted agency resources in response, and did nothing to decrease infection risks for poultry facilities. In fact, recent evidence suggests that conservation of highly protected migratory waterfowl habitat increases separation of wild waterfowl and domestic poultry and lowers the probability of HPAI infections in domestic poultry facilities where HPAI is circulating [3, 4]. By proactively consulting with facility operators to manage wetlands and landscape features as part of comprehensive biosecurity plans, we can drastically improve disease response and ultimately conserve substantial resources in the face of disease outbreaks.

1.2. The value of wild waterfowl. Waterfowl are migratory birds that provide substantial benefits to the people of Michigan and others in the Mississippi Flyway and beyond. Hunting and viewing are the two most quantifiable recreational and economic benefits and several studies have documented these values. Waterfowl hunters in Michigan took about 371,000 hunting trips in 2012 and spent an average of $463 per hunter annually on these trips; collectively, Michigan hunters spent an estimated $22.7 million in 2012 on hunting trips in Michigan [5]. Another study estimated that migratory bird hunters in the U.S. spent an average of $700 per hunter on hunting- related expenses in 2011 [6]. In 2006, the annual economic value of goose hunting in the U.S. portion of the Mississippi Flyway was estimated at $185 million (314,800 hunters x $588/hunter). More recently, the total industry output (direct and indirect) for waterfowl hunting in the U.S. was estimated at about $2.3 billion annually[7]; about 48% of U.S. waterfowl hunters were in the Mississippi Flyway and so this is expected to have resulted in about a $1.1 billion impact for Mississippi Flyway states (including Michigan). Recreational and economic benefits of waterfowl watching are also substantial as 45.1 million U.S. residents participated in bird watching in 2016 and waterfowl were the most-watched bird group enticing people to make trips to watch birds [7].

1.3. Objectives. The objectives of the original Plan were to:

- Determine whether or not HPAI H5N1 virus currently exists in wild birds in Michigan, and its geographic extent, if present;

- Provide a framework for ongoing surveillance to detect introduction of HPAI H5N1 virus into wild birds in the future;
- Act promptly if HPAI H5N1 is present in wild birds, to limit propagation of the virus among wild birds, and transmission of the disease to domestic poultry and humans.

Scientific data published in the last decade and a half have rendered two of these three objectives obsolete. Specifically:

1. Large scale surveillance at both state and continental levels has demonstrated the geographic extent of infection in wild waterfowl cannot be accurately delineated via active surveillance to define areas in which domestic poultry facilities might be at increased risk of infection from wild birds; and
2. There are currently no effective ways to limit propagation of AI viruses in wild birds. Culling of wild birds has not proven to be effective because the viruses do not persist in, nor are they limited to, those hosts, and presence or absence of the AI viruses is not indicative of the risk to domestic poultry operations. The only factor proven to limit risk of infection in domestic poultry facilities to date is heightened biosecurity [10].

Thus, the Objectives of the updated Plan are to:

- Provide a framework to detect the presence of HPAI viruses in Michigan using passive surveillance of wild waterfowl and raptors found dead (or displaying neurological signs or abnormal behavior);
- Work proactively and cooperatively with domestic poultry producers and state/federal agriculture partners to provide recommendations to enhance biosecurity at and around poultry facilities, to prevent opportunities for exchange of AI viruses between domestic poultry and wild birds;
- Work proactively with partners and DNR staff to promote messages concerning
    - current knowledge of AI virus ecology
    - the value of wild waterfowl and the necessity of waterfowl conservation; and
    - steps the public can take to minimize exposure to AI viruses that might be present in wild birds.

2. Surveillance Plan (supersedes Section I in the original Plan)

Since the original Plan was written in 2006, a great deal of surveillance for AIs has been carried out in wild birds around the globe and published in the scientific literature (see Appendix A). Examining that body of work, common themes emerge:

- The presumption that ‘active’ surveillance (i.e. testing carried out on presumably healthy waterfowl captured and tested live, hunter-harvested, or opportunistically tested after culling) is the most sensitive method to detect these viruses is not supported by the accumulated scientific data [11-17]. Rather, it is thus far not a sensitive method to detect the presence of AIs, even in the midst of an outbreak in domestic poultry in the same geographic areas. *Consequently, detection (or lack of detection) of AI viruses in wild waterfowl is not good predictor of geographic risk for domestic poultry.*
- Where HPAI viruses are circulating in wild waterfowl, ‘passive’ surveillance (i.e. testing of sick or dead birds with AI-consistent clinical and pathological findings) is the most sensitive and efficient way to detect them [13, 18]. *Thus, given limited resources, AI surveillance*

based on passive surveillance is most likely to provide evidence of the presence of HP subtypes, although it is also not a good predictor of geographic risk for domestic poultry.

- Testing of hundreds of thousands of wild birds on a continental scale has shown that HPAI viruses are extremely rare, even where outbreaks in domestic poultry are occurring at the same time [18-20]. A wide variety of LPAI viruses occur only in a minority of tested wild birds, and LP subtypes of greatest concern to domestic poultry production (H5 and H7) are found in ≤1% of wild birds tested in large scale surveys [19]. *Consequently, active surveillance on the scale that can feasibly be undertaken by DNR is extremely unlikely to detect HPAI or LP subtypes of concern to domestic poultry production.* Nonetheless, DNR will continue to participate in surveillance funded by USDA cooperative agreements as staffing allows.
- Where AI viruses have been detected at all, they have predominantly been in dabbling ducks (particularly mallards [21]) and juvenile birds [19, 22, 23]. *Thus, amongst waterfowl, those subgroups are likely to be the most sensitive to sample* to maximize probability of detection when surveillance resources are limited.
- Even when HPAI viruses are detected in North America, significant barriers exist to their movement between migratory flyways by wild birds [24-26]. *Consequently, detection of HPAIs in flyways other than the Mississippi Flyway does not necessarily signal that infection in Michigan is imminent*, or even likely.

For a relevant case study supporting several of the above themes, please see Appendix C: Case Study on HPAI/LPAI Surveillance in Minnesota.

Surveillance results for AI in wild birds in Michigan since the original Plan was written are summarized in Appendix B. Notably, they largely echo results noted elsewhere, i.e. LPAI viruses were detected in a minority (19%) of birds tested, and LP subtypes of greatest concern to domestic poultry (H5 and H7) were rare (present in 3.4% and 0.05% of tested birds, respectively). When HPAI viruses were isolated, they were detected only by passive surveillance (12 Canada geese from Macomb County, mostly juveniles, all with frank neurologic signs or found dead). One hundred thirty-five Canada geese from within a ten mile radius of the HPAI positive birds were culled and opportunistically tested for AIs. All were PCR-negative for HPAI. Serology indicated 88% of birds had been exposed to some influenza A virus, predominantly H5, H6, N2 and N8 subtypes.

Thus, given the extensive resources required to carry it out and its relative insensitivity detecting HPAI, *active surveillance of wild waterfowl is not justifiable nor effective in reaction to concerns about infection of domestic poultry with HPAI*. If cooperative participation in interagency active surveillance for purposes of research is considered useful, funding to support sample collection and handling, as well as staff time spent collecting samples, will need to be provided by the agency requesting sample collection. This approach is consistent with USDA APHIS VS' articulated Plan to "Consider susceptible wildlife populations in the surveillance plan; coordinate with…State wildlife agencies…to perform appropriate surveillance in wildlife populations" [30], p. 1].

Passive surveillance continues to be the most sensitive and cost-effective method to detect AI viruses of concern to agriculture or public health authorities and it will be the basis of DNR-funded surveillance for AI in wild birds. It will be carried out on an ongoing basis within the already established wildlife disease reporting and necropsy protocols of the DNR Wildlife Disease Laboratory (WDL), and the sample submission and AI testing protocols of USDA APHIS Wildlife Services. This approach is consistent with USDA APHIS VS' articulated Plan to

"…rely on robust wild bird and passive surveillance activities for nation notifiable avian influenza surveillance…." [31], p.17].

3. Response Plan (supersedes Section III in the original Plan)

3.1. Education/outreach/communications. A critical part of this response plan update will be to communicate and educate our primary audiences regarding current scientific knowledge regarding AI virus ecology and ways to reduce the exchange of AI viruses between domestic poultry, wild birds, and humans. All communicators should understand and be able to discuss basic AI virus ecology, pathogenesis, how it impacts wildlife, surveillance and testing procedures, and how biosecurity policies can help prevent the introduction and spread of the disease. Our primary audiences will be waterfowl hunters and members of the media.

Communication and education activities will include:

- In the event of new AI detections in wild birds, a press release will be issued to notify the public regarding the details surrounding the detection, the current scientific knowledge regarding AI virus ecology and the importance of waterfowl to Michigan's economy. The release will introduce readers to the updated version of Michigan's Surveillance and Response Plan for Avian Influenza in Free-Ranging Wildlife.
- Talking points, as needed, for media personnel, legislators and other important partners detailing AI detection information, the importance of waterfowl to Michigan's economy, current knowledge regarding AI virus ecology, and how the DNR will be working closely with agricultural producers and state/federal partners to prevent the exchange of AI viruses between domestic poultry, wild birds and humans.
- Create frequently asked questions for DNR and MDARD websites as needed
- Continual provision of up-to-date information on the DNR and MDARD websites
- Information about AI in the annual Waterfowl Hunting Digest, if new detections are found.
- If new detections are found, issue a press release and social media posts before regular duck season detailing the precautions waterfowl hunters should take to keep themselves safe from potential AI infection when handling birds.
- If new detections are found, create and distribute signage for Managed Waterfowl Areas, State Game Areas, Customer Service Centers, and other identified locations, such as Welcome Centers, detailing the safe handling of birds and how to avoid contact with AI viruses.

3.2. Biosecurity. *DNR response efforts are designed to proactively maintain separation of wild and domestic bird populations to limit opportunities for infection of wild populations by domestic poultry (and vice versa) as an aid to other farm biosecurity efforts.* Because it is proactive, this approach enhances USDA APHIS VS' articulated Plan to "Develop a wildlife management plan that addresses transmission of HPAI in wild birds as soon as possible after identification of the index case in domestic poultry" [30], p. 5].

The current state of the science does not support the hypothesis that HPAI viruses are maintained in wild waterfowl and transmitted directly to susceptible poultry. Rather, while a variety of LPAI viruses circulate in a minority of wild waterfowl, and they may be a potential source of deposition of LP viruses to the environment, the accumulated body of evidence suggests that wild birds serve only as rare, transient hosts for HPAI viruses. Whether poultry infected with HPAI, the environment, or some bridge vectors are the predominant source of exposure for wild birds is uncertain. Similarly, although both modelling and movement ecology studies suggest an association between waterfowl migrations and AI outbreaks in poultry [32-35], their specific role in subcontinental geographic transport remains unclear [1, 36-38]. Consequently, rigorous disease control and biosecurity measures on poultry farms are the only solution presently available to mitigate the risks of HPAI infection [10, 36]. *Culls of wild birds will not lower the risks of HPAI infection for domestic poultry and will not be carried out by DNR.*

3.3. Suspension of wild bird translocation. The DNR developed a Resident Canada Goose Program to give landowners options to address human-goose conflicts on their sites. Since 1972, the DNR has permitted and coordinated "goose round-ups". Problem geese are trapped and transported out of the area at the request of local residents and/or a local unit of government in mid-late June when the birds are molting (and so flightless). Birds are typically relocated to suitable sites within Michigan. Captured geese may be slaughtered at licensed commercial meat processors for subsequent donation to charitable organizations (i.e. food shelves), or humanely killed for other carcass uses (i.e. animal feed, fertilizer). If no appropriate use can be found, carcasses will be properly disposed of through landfills or incineration.

Although cumulative wild bird surveillance carried out to date (see Appendix A) suggests the risk of transporting HPAI is likely to be small, translocation of wild birds such as nuisance Canada geese will be suspended until surveillance and response activities in domestic poultry document HPAI virus is no longer circulating among domestic poultry facilities, creating a reservoir of infection for free-ranging wild bird populations. Exceptions for Canada goose translocation will be made for approved situations where there are elevated human health and safety concerns. In outreach materials to entities issued permits for translocating Canada geese, DNR emphasizes to permittees that HPAI viruses, though extremely rare, are extremely contagious, pose a serious economic threat to domestic poultry production, and so warrant cooperation with agricultural agencies to minimize risks of AI transmission between wild and domestic birds. Permit holders are informed that the Resident Canada Goose Program can be suspended at any time if HPAI is detected in Michigan, A recent critical review [39] concluded “Previous research tends to overrate the role of geese…as disease vectors; we do not find any evidence that they are significant transmitters to humans or livestock of any of the pathogens considered in this review” (including AIVs).

3.4. Incident Command. Given the current state of science documenting the minimal role of wild waterfowl in the maintenance of HPAI viruses [1] and complete lack of effective methods to manage AI in wild birds, DNR staff may play a limited role in Incident Command Systems (ICS) formed by other agencies to direct AI outbreak response activities. In most cases, direct agency control of wild birds will not be warranted; nonetheless, DNR representation should be included in updates and situation reports for ongoing awareness. This approach is consistent with USDA APHIS VS’ articulated Plan to “integrate wildlife management…authorities and personnel into the ICS as required by the situation” [30], p. 6]. Hazing of wild birds away from poultry facilities may be one possible exception, in situations where known zoonotic HPAI strains are circulating.

Representation may support the potential deployment logistics of DNR-owned excavation equipment or other resources for use in mass burial of depopulated domestic poultry.

4. Occupational Safety for personnel involved in surveillance of free-ranging wild birds

As noted in the original Plan, personnel involved in surveillance of free-ranging wild birds, or in control activities on known or potentially affected premises, are at increased risk for exposure to HPAI virus because of potentially prolonged and direct contact with infected birds and/or contaminated materials. Occupational safety guidance will vary depending whether the subtypes of AI viruses in a particular outbreak are zoonotic or not. DNR staff will follow occupational safety guidance issued by the Centers for Disease Control and Prevention (https://www.cdc.gov/flu/avianflu/h5/index.htm) and the National Institute for Occupational Safety and Health (https://www.cdc.gov/niosh/topics/avianflu/default.html).

A variety of recent publications address issues relevant to human exposure to potentially zoonotic AI viruses [40-50].

5. Prevention

5.1. Wildlife management practices to improve biosecurity on existing poultry facilities (portions of the following are taken from [2])

Address standing water that may attract wild birds:
- Workers should avoid walking or moving equipment in or near standing water used by wildlife.
- Consider French drains and culverts to carry water away from poultry houses.

Manage risks at ponds and basins including:
- Use deterrent techniques (e.g., wire grids, predator decoys, and scare devices) to keep waterfowl from using water bodies near poultry barns.
- Use fencing to separate natural ponds or vegetation areas from the active area around barns.
- Avoid creating new good wetland habitat near domestic poultry housing and facilities.
- *DNR does not support draining existing wetlands adjacent to domestic poultry facilities.*

Reduce food sources that may attract wildlife:
- Do not feed wildlife.
- Locate feed structures on a clean pad.
- Inspect pipes and connections regularly for leaks.
- Clean up spilled feed in storage areas.
- Mow areas around barns.
- Do not pile used litter near barns.
- Remove fallen fruit from trees near barns.
- Keep carcasses covered at all times.
- Close and latch dumpster and trash can lids.

Remove perches and plug holes that may attract wild birds[1]:
- Repair holes and tears in barn walls.

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[1] While these recommendations reflect good general biosecurity practices, despite considerable speculation [29, 51-53], minimal surveillance data currently exist to substantiate a proximate role for either rodents or passerine birds as bridge vectors [28].

- Remove unnecessary ledges or horizontal surfaces.
- Install exclusionary netting, screen, and perch deterrents.
- Before nesting season begins, wash away or remove old nests in accordance with state and federal regulations (it is unlawful to remove nests with eggs or young in them at any time of the year).
- Inspect foam installation for signs of rodent or bird digging, chewing, or pecking.

Add wildlife deterrents:
- Move decoys and scare devices frequently to improve effectiveness.
- Pyrotechnics can be effective, but require dedicated and trained personnel and may be stressful to domestic poultry.

5.2. Siting and planning new poultry facilities
When siting new poultry facilities, areas where there are wetlands that attract waterfowl and other wildlife should be avoided. Prudent biosecurity planning will minimize any potential exposure risks posed by wild waterfowl, and help avoid conflicts among stakeholders.

5.3. Limiting translocated geese near poultry facilities
Canada geese rounded up under permits from the Resident Canada Goose Program will not be translocated to any sites that are within a 10-mile buffer of a domestic poultry CAFO.

Michigan Department of Natural Resources

Daniel Eichinger, Director Date

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Appendix A: Summary of relevant scientific literature published since the original Plan

Ecology: A large number of studies, mostly incorporating modelling, focused on assessing the possibility and likelihood that HPAI viruses of Eurasian origin could be spread globally by migratory waterfowl [12, 25, 26, 54-66]. That question, highly relevant for HPAI H5N1 in 2006, was rendered moot by the arrival of HPAIs H5N2 and H5N8 in 2015. That modelling work remains informative for planning purposes however, as does other work dealing with potential geographic spread of AI viruses within North America [24-26, 57, 59, 67-75], particularly in the event of emerging zoonotic HPAI viruses.

A recent, multicenter study has demonstrated that following the 2014-2015 outbreak of HPAIs in US domestic poultry, those viruses apparently disappeared from wild bird populations in North America [1]. Further, that disappearance is not explained by actions taken to control that outbreak in domestic poultry. This suggests that the hypothesis of wild waterfowl acting as maintenance reservoirs for AI viruses is flawed. Rather, evidence is mounting that wild waterfowl are only transient hosts for these viruses, effectively acting as transport hosts for HPAIs, and that the origin and reservoirs for these viruses are domestic poultry, particularly domestic ducks, not wild birds [36, 37, 76]. Even LPAI viruses have only rarely proven to be persistent from year to year in wild waterfowl [71]. A recent Mexican study [77] documented waning pathogenicity of a circulating HPAI strain for ducks over time, while virulence for chickens was maintained, suggesting a possible mechanism for decreased probability of spread by wild waterfowl.

Similarly, in Wisconsin, testing of wild passerine birds, small mammals and wild waterfowl on and within 5 miles of a domestic poultry facility infected with HPAI H5N2 in April 2015 showed no evidence of viral shedding or specific antibody to HPAI 5 months after the farm was depopulated [38]. In addition, wild waterfowl in an adjacent natural area showed no evidence of exposure to or viral shedding of the HPAI H5N2 that infected the poultry facility. Even when those waterfowl were shedding LPAI viruses, passerines and small mammals living in wetland habitats with them showed no evidence of exposure or active infection. Those authors concluded there was no evidence that wildlife species living on poultry farms “maintained transmission or experienced widespread exposure to…any AI virus”, and “were not likely to be important in epizootic transmission of viruses during the poultry outbreak at this facility”. Some authors have even hypothesized a role for molluscs [78]. Thus, despite continued speculation [29, 52, 53],while wild [52, 79-84] and feral [44] species commonly living on farms can be infected with AI viruses in an experimental setting, current evidence suggests they do not maintain AI viruses nor act as a source of infection for domestic poultry. In contrast, recent Eurasian surveillance suggests undetected maintenance of HPAI viruses in galliform poultry over multiple years [85]. Some evidence suggests a role for domestic ducks as a proximate source of infection for domestic chickens and turkeys [15, 86-89].

Rapid lethality of HPAI viruses likely limits the effectiveness of wild migratory birds as transport hosts [26, 39]. Highly-pathogenic AI viruses are likely to result in shorter, less prevalent infections than LPAIs, but with higher mortality, leading to comparatively greater environmental contamination by LPAI viruses, and greater exposure [90]. This may help explain why HPAI are more difficult to detect [91]. Lineages of specific gene segments, if not the entire viruses, have been shown to persist locally in waterfowl across multiple seasons [92]. Persistence of LPAI viruses in the environment, giving rise to indirect transmission, has sometimes been overlooked [36, 93]. Recent discussions of environmental sampling have been published [94, 95]. Avian influenza viruses remain infectious in water for weeks to months with pH, salinity, temperature and viral strain affecting stability [93, 96-99]. The instability of AI viruses in seawater at prevailing temperatures may help explain their relatively lower prevalence in diving ducks that use oceanic habitats [99-103]. In general, colder temperatures and neutral to alkaline fresh water favor persistence. It is plausible that surface waters contaminated with AI viruses by the feces of infected waterfowl act as persistent reservoirs of infection for wild waterfowl migrating through an area. While individual birds may not harbor the viruses for very long, nor transport them very far (but see [75]), in aggregate a minority of wild waterfowl may disseminate them over substantial distances by a succession of short jumps.

While dabbling ducks now appear to be the primary wild birds infected with AI viruses (see Surveillance, below), other recent studies have investigated AI viruses in waders [104] and gulls [105, 106] and divers [99-103]. In a study of Canada geese, no AI viruses were isolated from 1,668 cloacal swabs and prevalence of AI specific antibody was low (1.2%) [107]. Persistence of AI virus in goose feces and water contaminated by them was limited compared to published estimates for ducks. Authors of that study concluded that Canada Geese play a minor, if any, role as a reservoir for LPAI viruses. HPAI H5N1 was highly lethal in this species unless partial immunity from previous infection with other AI viruses conferred some protection [108, 109]. A recent critical review of the potential role of geese and swans as vectors of diseases relevant to humans and livestock [39] concluded that while these species may play some role in the transmission ecology of AI viruses, "we do not find any evidence that they are significant transmitters to humans or livestock of any of the pathogens considered", including AI viruses.

An additional consideration in AI ecology is the role played by commerce in poultry products during outbreaks [110]. While the potential role of wild waterfowl as a source of introduction of AI viruses into new areas has been more extensively scrutinized, interstate and international trade in poultry products also carry risks that are not negligible [110, 111]. Moreover, infected domestic poultry products may spread AI viruses locally after introduction via either wild or domestic birds. Outdoor ranging of domestic poultry has been identified as major risk factor for AI infections [88, 112-116], and consequently small backyard flocks are considered to be at substantial risk [117-120]. In Colorado [119], >96% of backyard domestic poultry flocks studied had free access to the outdoors, and almost half were moved from the home premises in a year's time. In Maryland backyard flocks with multiple species of domestic poultry, 70% did not separate them from each other (e.g. chickens not separated from ducks) [117]. Those authors found biosecurity practices on these farms "highly variable". Such management practices create bridging exposures between waterfowl habitat potentially contaminated with AI viruses to domestic chickens and turkeys that may then be moved to other poultry facilities, or that may contaminate shared vendors or equipment that contact multiple domestic poultry facilities. This may partially explain the epidemiological association between poultry farm densities and risk of AI infection in some areas [88, 113, 121]. To date, evidence suggests such sources are the most likely to spread AI viruses between domestic poultry facilities, not wild bird movement.

Surveillance: A study of nearly 5000 wild birds in the Pacific Flyway in 2015 detected HPAIs in only 1.3% of tested hunter-harvested birds, but in 6.7% of birds tested as part of morbidity and mortality investigations [18]. Continent-wide surveillance for AIs in 2007-2011 tested nearly 198,000 wild birds from >200 species in the US, and detected 0 HPAI viruses. Concurrently a number of AI outbreaks occurred in US domestic poultry. Overall, 11.4% of tested birds were positive for any AI virus. Low pathogenicity H5 and H7 viruses were isolated from only 1.1% and 0.2% of birds tested, respectively. Where AI viruses were found, they disproportionately came from dabbling ducks [19]. Notably, birds involved in die-offs comprised <0.1% of the 198,000 samples. Testing of more than 101,000 fecal samples collected as part of the same surveillance program detected zero HPAI viruses, and LPAI viruses in 5.1% of samples [20]. That study determined that "wild birds in the USA were free of highly-pathogenic avian influenza virus…at the 99.9% confidence level during the surveillance period." Analysis of a subset (2007-2009) of data from the same surveillance program found year to year variations in prevalence by migratory flyway, and highest prevalence in hatch-year waterfowl [22, 122]. Juveniles are likely infected with LPAI early in fall migrations [24]. An analysis of LPAI virus isolates from the nationwide surveillance program described 33 virus subtypes, of which H5N2 was most common, accounting for 40% of all isolations [123]. A study in western Lake Erie demonstrated the presence of a variety of influenza A viruses in overwintering Anseriformes at a low (4.5%) prevalence [124]. A summary of AI surveillance in Canada 2005-2009 detected LPAI viruses in 30% of live wild ducks sampled, all of North American lineage, but no HP viruses [125]. Sampling of nearly 5000 wild ducks over a two year period in northwest Minnesota detected AI viruses in 13% of them. Results in juvenile mallards were found to adequately represent temporal and spatial prevalence and virus subtype diversity of the entire sample [23].

Surveillance of apparently healthy wild birds ("active surveillance") has not provided early warning of likely infection for the poultry industry.[12] Testing of birds involved in die-offs ("passive" surveillance) has detected the virus in the environment, but not isolated its source. Subsequent to the introduction of HPAI H5N2 into the Pacific Northwest in 2014, passive surveillance was more sensitive at detecting HPAI viruses in wild birds than active surveillance [13]. Evidence suggests cloacal swabbing and blood draws for AI testing do not adversely affect survival of sampled wild waterfowl.[126] Modelling suggests HPAI is more difficult to detect than LPAI via cloacal swabs [24].

In spite of genetic evidence of AI virus contributions from strains adapted to domestic swine [127] and horses [128], thus far, surveillance for AI viruses in wild mammals has been unremarkable [28, 129].

Appendix B: Summary of Avian Influenza testing of wild birds in Michigan, 2006-2017* (DNR and USDA-APHIS-Wildlife Services)

Year	Number of Samples	PCR + for any AI Virus	PCR + for H5	PCR + for H7	PCR+ for N1	Virus Isolates
2006	2093	573	82	0	8	6
2007	1706	261	34	0	4	10
2008	1648	248	32	3	1	5
2009	1566	222	76	0	0	7
2010	1246	229	42	2	2	11
2011-12†	198	0	0	0	0	0
2013	127	0	0	0	0	0
2014	178	1	0	0	0	0
2015	1097	277	73	0	0	23
2016	609	134	23	0	0	5
2017	420	106	6	0	0	1
Grand Total	**10888**	**2051**	**368**	**5**	**15**	**68**

* Since 2017, 26 wild birds (10 in 2018 and 16 in 2019) presented for necropsy at DNR WDL were tested. No AI viruses were detected.

† Serological samples were also taken on 378 birds. Of those 254 were antibody positive but none were actively shedding virus.

Matrix of subtypes isolated

I.D.	N1	N2	N3	N4	N5	N6	N7	N8	N9	?
H1	3	NA	NA	NA	NA	NA	NA	NA	NA	NA
H2	NA	1	1	NA	NA	NA	NA	NA	NA	1
H3	1	1	NA	NA	NA	NA	NA	NA	NA	NA
H4	NA	1	NA	NA	NA	6	NA	NA	NA	NA
H5	4	21 (6)*	2	NA	NA	NA	NA	NA	NA	6*
H6	NA	1	NA	NA	1	NA	NA	NA	NA	NA
H7	NA	NA	1	NA	NA	NA	NA	NA	NA	NA
H8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
H9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
H10	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
H11	NA	1	NA	NA	NA	NA	NA	NA	2	NA
H12	NA	NA	NA	NA	1	NA	NA	NA	NA	NA
H13	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
H14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
H15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
H16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
?	2	NA	NA	NA	NA	NA	NA	NA	NA	NA

*# of HP isolates in red; all were Canada geese

Isolated subtypes by year

2006 3- H5N1; 2- H5N2; 1- H6N5
2007 1- H5N1; 5- H5N2; 1- H6N2; 1- H3N1; 2- H?N1
2008 3- H5N2; 2- H5N3
2009 5- H5N2; 1- H2N3; 1- H10N?
2010 3- H5N2; 3- H4N6; 1- H3N2; 1- H7N3; 1- H4N2; 1- H11N9; 1- H2N2
2015 6- H5N2 (HP); 6- H5N? (HP); 3- H5N2; 3- H1N1; 2- H4N6; 1- H11N2; 1-H12N5; 1-H2N?
2016 1- H4N6; 1- H11N9

Distribution of virus isolates by host species, 2006-2010

Year	Subtype	Species
2006	H5N1	Mute Swan (2)
2006	H5N1	Green wing Teal (GWT)
2006	H5N2	Mallard (2)
2006	H6N5	Mallard
2007	H5N1	Black Duck
2007	H5N2	Mute Swan
2007	H5N2	Mallard (3)
2007	H5N2	GWT
2007	H6N2	Mallard
2007	H3N1	Northern Pintail
2007	H?N1	Mallard
2007	H?N1	Black Duck
2008	H5N2	GWT
2008	H5N2	Mallard
2008	H5N2	Wigeon
2008	H5N3	Black Duck(2)
2009	H5N2	Mallard (2)
2009	H5N2	Pintail (2)
2009	H5N2	Black Duck
2009	H2N3	Mallard
2009	H10N?	Pintail
2010	H5N2	Mallard (2)
2010	H5N2	Wigeon
2010	H4N6	Mallard (2)
2010	H4N6	Black Duck
2010	H3N2	Black Duck
2010	H7N3	Mallard
2010	H4N2	Pintail
2010	H11N9	GWT
2010	H2N2	Mallard

Appendix C: Case Study on HPAI/LPAI Surveillance in Minnesota

Minnesota provides a particularly relevant surveillance case study for Michigan. During an outbreak of HPAI H5N2 throughout Minnesota in 2015, affecting 104 infected farms in 23 counties from which 9 million domestic poultry were depopulated, comprehensive surveillance for AI viruses in wild birds took place concurrently [11]:

- Zero HPAI and 85 LPAI viruses were detected among over 3,000 waterfowl fecal samples [27].
- Testing of 158 sick or dead wild birds (raptors, Galliformes, waterfowl and Passeriformes) detected a single isolate of HPAI H5N2 in a Cooper's hawk (a species which does not typically prey on waterfowl) 10 miles from the nearest infected poultry facility (a chickadee initially suspect on PCR was not confirmed positive on subsequent tests). These findings are consistent with other recent studies which have failed to detect AI viruses in songbirds [28], despite their speculated potential role as bridge vectors from waterfowl to poultry [29].
- Testing of 84 hunter-harvested wild turkeys in counties with infected domestic poultry farms yielded zero AI virus detections.
- Oropharyngeal and cloacal swabs of 619 live wild Canada geese detected zero HP and 2 (0.3%) LPAI viruses. Serology of those same birds showed exposure to influenza A viruses of any type in 34% of birds sampled, but only a single potential exposure to HPAI.
- A similarly designed project in dabbling ducks at two sites in northwest and southern counties detected zero HP and 77 (21%) LPAI viruses from swab samples. Serology showed 23% exposure to any influenza A in the south and 56% in the northwest. Only a single potential exposure to a HPAI was found among the 727 (0.1%) ducks bled.
- Testing of hunter-harvested dabbing ducks in counties with high domestic poultry production, both those that had HPAI infected facilities the previous spring and those that did not. Of 907 birds tested, zero HP and 181 (20%) LPAI viruses were detected. Prevalence of LPAI viruses was only slightly higher in counties that had HPAI previously (25%) than those that had not (15%).
- In addition, testing for HPAI viruses was also carried out as part of USDA/USGS/USFWS cooperative nationwide surveillance program. Among oropharyngeal, tracheal and/or cloacal swabs taken from 545 live and hunter-harvested dabbling ducks, zero HP and 95 (17%) LPAI viruses were detected.

In summary, despite sampling within the same time period and geographic area as an ongoing HPAI outbreak in domestic poultry, testing of wild birds in MN detected only a single HPAI-infected bird from among 6,179 tested (0.02% prevalence). The only positive bird was a raptor detected via passive surveillance. LPAI viruses were detected, but in a minority of birds and at rates consistent with published findings from across the US. There was not a strong relationship between LPAI infections in wild birds and HPAI infections in domestic poultry, nor was the finding of LPAI viruses informative for spatial prediction of risks to poultry facilities. Active surveillance was not a sensitive method to detect HPAI viruses, compared to passive surveillance of sick and dying birds. The one HPAI infected raptor was of a species that does not typically prey on waterfowl. An accipiter, it could just as easily have been exposed to HPAI from passerines living in proximity to infected domestic poultry operations as via wild waterfowl.