An Australian Government Initiative

POULTRY CRC LTD

FINAL REPORT

Sub-Project No: 1.5.7

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Sub-Project Title: Avian Influenza Risk Mitigation for the Free-Range sector of the Australian Poultry Industry

DATE OF COMPLETION: 31 January 2017

ISBN 1 921010 57 6

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Published in 2017

Executive Summary

The poultry industry in Australia faces a somewhat unique situation in relation to avian influenza (AI). Here, unlike the situation in Europe and North America, the threat of an AI outbreak due to AI viruses that are circulating in native wild birds is higher than the threat due to introduction of an exotic AI virus by migratory birds.

The aim of this project was to conduct research and extension to safeguard the Australian commercial chicken industry from avian influenza virus (AIV H5 or H7) outbreaks arising from AI virus in native wild birds infecting a commercial chicken flock. AI viruses H5 and H7 subtypes were specified as the focus because to date all naturally occurring highly pathogenic strains of AI causing acute disease in chickens globally have been of either the H5 or H7 subtype. For this project, the commercial chicken industry was defined as comprising layer chicken farms with more than 1,000 birds, and meat chicken farms with more than 50,000 birds.

This was a 2-phase project in which Phase 1 focused on discovery of new knowledge and Phase 2 on consultation and extension with industry regarding the Phase 1 findings.

Phase 1 commenced in 2015 with conduct of a survey +/- wildlife camera surveillance on 73 farms (cage layer, barn layer, free range layer, barn meat, fee range meat), mostly located in the Sydney Basin.

The on-farm survey found that the level of adoption of biosecurity practices varied across farm types. A high level of biosecurity was found on barn and free range meat chicken farms compared to moderate on barn and free range layer farms, with cage layer farms found to have the largest room for improvement in biosecurity practices. This finding of some deficiency in biosecurity practices on each of the five types of farms led to the research considering AI risk for all five farm types, rather than a focus on free range farms as indicated by the project title.

Using the results of the on-farm survey and camera surveillance and an expert opinion elicitation process, plus information from the literature, three models (exposure scenario tree model, spread scenario tree model, branching process model) were developed in 2016 and used to quantify the risk of AI virus introduction to a commercial chicken farm and spread from one infected farm to other farms.

The exposure scenario tree results suggest that the probability of low pathogenic avian influenza (LPAI) introduction to a commercial chicken farm at any point in time is extremely low for all five farm types, with commercial free range layer farms approximately double the risk of LPAI exposure compared to other farm types. When LPAI virus is introduced, the spread scenario tree model showed a high probability of no establishment of infection for all farm types, that is, on most occasions when one chicken is exposed to LPAI the virus will fail to infect the exposed chicken or the virus will infect the exposed chicken but fail to spread to other chickens.

For the occasions when LPAI infects a chicken flock, the spread model predicted most spread between sheds on the infected farm to occur via equipment and boots. For spread from an infected farm to other farms, most spread was predicted to occur via pickup trucks (for live birds and for dead birds) on all farm types, and also via egg trays and egg pallets for layer farms.

Using the daily mortality data from high pathogenic avian influenza (HPAI) outbreaks in Australia to estimate HPAI virus transmission parameters, the data indicates relatively low levels of transmission; one infected bird infected approximately 1-2 birds in the same shed, and less than 0.1 birds on average in other sheds on the farm. These estimates were similar for outbreaks of HPAI in sheds with caged layer birds and sheds with free range layer birds.

The branching process model, similar to the spread scenario tree model, suggests that when LPAI is introduced to a chicken shed it may not establish infection. For approximately 25% of sheds the

LPAI virus will not successfully infect one chicken and then transmit from bird to bird; a result similar for all five farm types. For the sheds in which LPAI infection does establish, the length of time that LPAI persists within the shed varies between farm types due to the length of the poultry production cycle. For barn meat and free range meat, LPAI does not persist beyond 50 days in one third of sheds and in none beyond 100 days. For layer farms, LPAI does often persist for over 150 days in sheds on barn layer, free range layer and caged layer farms.

The branching process model was also used to consider the effect of an increasing proportion of free range farms on the probability of a HPAI outbreak in a year. For the current total number of commercial chicken sheds in Australia and a plausible range of virus transmission rates, HPAI outbreak probability increases slowly as the proportion of free range sheds increases from the current 30% to 100%, reaching a moderate level in the unlikely scenario that the industry is comprised totally of free range farms.

Investigation of the different ways that LPAI virus can enter a commercial chicken flock using the models showed that use of surface water without treatment had the most risk for all farm types, and that presence of waterfowl on farm, feed spillages and wild bird access to feed storage areas were also important contributions to AI risk.

These model results were based on the best available information at the time of model development, but there is considerable uncertainty about LPAI subtype virus transmission and about virus mutation because available information was extremely limited. The results reflect the situation in the Sydney basin region due to the use of the on-farm survey results, and of weather and LPAI wild bird prevalence data specific to this region. Therefore extension of model results to commercial chicken farms in other regions of Australia must done with some caution. These findings have identified which areas on-farm that should be the focus for biosecurity efforts to minimise the risk of exposure and spread of AI virus on commercial chicken farms.

Phase 2 focused on extension of this new knowledge including, and discussion of the findings and guidelines with industry leaders and government stakeholders at a National Forum and with farmers and farmer advisors at regional workshops hosted by the project, and revision of biosecurity guidelines.

At the events held, participants generally considered the Phase 1 results to agree with prior knowledge, and to be of value because they add rigor and relative quantities to our understanding of the differences in risk of avian influenza between farm types and of the relative contribution of different exposure and spread pathways, thus aiding prioritisation of biosecurity practices to mitigate AI risk. Feedback that queried aspects of model assumptions, structure or input parameters has identified further work that can be conducted to strengthen credibility of results and usefulness to industry (such as consideration of flock size for the exposure scenario tree and use of branching process model to investigate variation in production cycle length). Further, most participants at these events identified practices or viewpoints that could be improved or informed by the study results, and endorsed the proposal of recommended changes to the generic biosecurity manual, and subsequently changes to manuals and QA programs for specific farm types by each industry sector.

This project, having identified biosecurity non-compliance across all farm types and estimated a level of HPAI outbreak risk for all farm types, recommends that this shared risk be viewed as a shared responsibility and responded to through an ongoing process of consultation and collaboration. While this work considered only the chicken industry, the susceptibility of ducks and turkeys requires that collaborative action should also involve these poultry industries.

Collaboration is needed on updates to biosecurity manuals and on education programs to support enhanced on-farm biosecurity for farmers. Animal Health Australia (AHA) has a role to facilitate such collaboration.

It is recommended that the standard industry mindset, in relation to recognition of this shared AI risk, be that:

- Waterfowl are assumed to be LPAI infected and farmers act to minimise water fowl presence on farm
- Chicken flocks are viewed as potentially LPAI infected and farmers adhere to biosecurity practices to prevent virus spread.

This mindset and the subsequent biosecurity implemented will also protect flocks from other endemic infectious diseases.

In relation to on-farm biosecurity, the findings of this project provide a basis to focus AI risk mitigation on the following.

To prevent AI virus entry to flock

- Ensure that all water used for drinking and for environmental control is adequately treated to ensure that viable AI virus is not present.
- Minimise waterfowl presence on farm such as on and around water sources that are used by the farm, and presence on the range on free range farms, and around feed storage areas on all farms.
- Prevent wild bird entry to sheds.
- Clean up feed spills immediately to avoid attracting wild birds.
- Do not return chickens that have escaped from shed or range to the flock.
- No other poultry species aside from chickens kept on farm.

To prevent AI virus spread from an infected shed to other sheds on farm

- Equipment should not be shared between sheds.
- Shared equipment must be cleaned and disinfected prior to use in another shed.

To prevent AI virus spread from an infected farm to other farms

- Thorough decontamination of trucks and chicken crates used for live bird and dead bird collection.
- Trucks used for dead bird disposal should not enter onto the farm.
- For layer farms only, egg trays and egg pallets should be dedicated to the farm and where this is not possible should be made of materials that can be effectively decontaminated and routinely cleaned and disinfected, or made of new disposable materials with only single use.

To culminate the work of this project, a document outlining recommended revisions to the Biosecurity Manual Poultry Production[1] will be provided to AHA. Implementation of the detailed recommended revisions will provide an updated, contemporary manual that reflects the changing poultry industry structure and current understanding of biosecurity relevant to AI risk in the midst of other poultry health and food safety risks. The revised generic manual would be suitable for the industry sectors to use to update their specific manuals. It is understood that the recommended revision will be considered during 2017 by AHA and the peak industry bodies in the consultation process to prepare and publish a new version of this generic biosecurity manual.

[1] DAFF (2009) National Farm Biosecurity Manual Poultry Production. DAFF, Canberra. Available at: http://www.agriculture.gov.au/pests-diseases-weeds/protect-animal-plant/bird-owners/poultry_biosecurity_manual

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Introduction

Avian influenza in Australia

There have been seven HPAI outbreaks reported in Australia since 1976, all involving non-exotic H7 viruses and causing clinical disease on the affected commercial chicken farms. All outbreaks were eradicated, using a ‘stamping out’ strategy, with quarantine and movement restrictions, culling of infected birds and active surveillance of farms at risk (AHA 2011).

For the five outbreaks that occurred between 1976 and 1997, there was evidence of the chickens having direct contact with wild waterfowl or indirect contact via contaminated surface water, or contact with free-range farmed ducks (Forman, Parsonson et al. 1986, Morgan and Kelly 1990, Forsyth, Grix et al. 1993, Selleck, Arzey et al. 2003, Tracey, Woods et al. 2004, Turner 2004, Arzey 2005, Hamilton, East et al. 2009, Hansbro, Warner et al. 2010, DAFF-Queensland 2013). For the two more recent outbreaks in New South Wales, all or some of the layer flock on each farm were under free-range management. Secondary spread of the infection from the index property occurred in three of these outbreaks through fomites, although this spread was limited. Pathways for secondary spread implicated an employee who owned a duck farm for the 1992 outbreak in Bendigo, a dead bird collector contractor for the 1997 outbreak in Tamworth and re-used cardboard egg cartons for the 2013 outbreak in Young (Selleck, Arzey et al. 2003) (DAFF-Queensland 2013).

Low pathogenic AI viruses (LPAI subtypes H4, H5, H6, H7, H9, H10) have been detected in domestic poultry in Australia since 1976, most often in commercial duck farms (DAFF-Queensland 2013). Detection in chickens and turkeys has only occurred in the last decade with one detection in a turkey flock in 2012 and three detections in chicken flocks in 2006, 2010 (virus transmitted to abattoir workers during processing (Arzey, Kirkland et al. 2012)) and 2012. The source of all these LPAI outbreaks, although uncertain, was believed to be direct contact with infected wild birds or via contaminated water sources (DAFF-Queensland 2013).

AI viruses have been isolated from 25 species of Australian birds, most commonly native duck and coot species (East, Hamilton et al. 2008a). Similar to other areas of the world, these wild bird species are natural reservoirs for the virus and infected birds usually do not show clinical signs (Olsen, Munster et al. 2006, Stallknecht 2008, Hansbro, Warner et al. 2010). To date surveillance activities have not detected high pathogenic avian influenza (HPAI) H5 or H7 viruses in wild birds in Australia, however, different LPAI subtypes, including H5 and H7, have been detected (Peroulis and O'Riley 2004, Haynes, Arzey et al. 2009, Hansbro, Warner et al. 2010). Across surveillance studies conducted in Australia during the last decade, overall prevalence levels measured in migratory shorebirds and native waterfowl have been consistently low (<3%) (Peroulis and O'Riley 2004, Haynes, Arzey et al. 2009, Hansbro, Warner et al. 2010, OCVO 2010).

Phylogenetic analyses of LPAI H10N7 subtype viruses have shown the virus detected in domestic poultry in 2010 and 2012 was also present in wild water birds in Victoria and NSW (Vijaykrishna, Deng et al. 2013). This work supports wild bird contact (direct or indirect and possibly involving domestic ducks) as the virus source for the infections in chickens. Further the phylogenetic analyses suggest that North American H10 virus was introduced in aquatic birds during the last decade and became endemic in Australian wild birds permitting re-assortment of AI viruses with circulating lineages leading to new subtype occurrence, such as LPAI detections in farm flocks since 2010. This paper also suggests the evolution of AI subtypes in Australia may be influenced by major weather events (such as severe droughts) that impact water bird behaviour. Maintaining AI surveillance of wild birds is critical to inform understanding of risk to poultry, as is monitoring of bird sightings for both the shorebirds that make annul trans-hemispheric migrations and the non-migratory native waterfowl that are nomadic in the Australo-Papuan region.

AI risk to the Australian poultry industry

Exotic incursion of HPAI to Australia is a concern due to migratory birds passing through areas in Asia with endemic HPAI H5N1 and other HPAI viruses, and then on arrival in Australia, sharing some habitats with native wild waterfowl (Tracey, Woods et al. 2004, East, Hamilton et al. 2008a, Hansbro, Warner et al. 2010). The potential for AI virus transfer from migratory shorebirds to native waterfowl has been recognised as a pathway for HPAI spread from wild birds to the Australian poultry industry. However formal assessments of the risk of H5N1 introduction to Australian poultry have estimated predominantly low likelihoods. For H5N1 introduction through migratory shorebirds from Asia risk was found to be very low (East, Hamilton et al. 2008a) and for nomadic Australian waterfowl species that access the Australo-Papuan region the risk was low to moderate in North Queensland and negligible for other regions of Australia (East, Hamilton et al. 2008b). These assessments of exotic incursion risk, while demonstrating support for ongoing wild bird surveillance and for biosecurity to prevent wild bird contact with domestic poultry, show that outbreaks in commercial poultry with exotic HPAI viruses will be rare events. This aligns with reality, as to date in Australia, no outbreaks involving exotic HPAI viruses have occurred and no AI viruses of Asian lineage have been found in wild birds (Grillo et al., 2015).

For non-exotic AI viruses circulating in native wild birds in Australia, documented pathways for introduction to domestic poultry include direct contact and indirect contact such as via contaminated water or contaminated feed (Selleck, Arzey et al. 2003, Hamilton, East et al. 2009, Arzey, Kirkland et al. 2012, DAFF-Queensland 2013). Knowledge from wild bird surveillance about LPAI viruses circulating in native species and the fact that all AI outbreaks in Australia have involved non-exotic virus has directed concern about AI risk to the Australian poultry industry away from exotic incursion to endemic LPAI virus exposure via wild birds and mutation to high pathogenic form in domestic poultry flocks.

However few formal assessments of the risk of LPAI virus introduction to domestic poultry in Australia exist.

In 2014 the Animal Health Committee (AHC) avian influenza working group (AIWG) undertook an analysis of historical AI outbreaks in Australia from 1976 to 2013 and a review of the current scientific literature (Amanda Lee, pers comm). This work considered AI risk relating to production systems (including free- range), flock sizes, different poultry species, wild birds, and biosecurity measures (including relating to housing, transport, feed and water supplies).

The overall conclusion was that the following risk factors presented a higher risk: ‘free-range’; larger flock sizes (> 10 000 birds); multi-age, long-lived flocks e.g. layers; poor biosecurity. In addition poultry species was also recognised to influence risk. Ducks and geese represent the highest risk of harbouring LPAI; especially high risk enterprises involving a mixing of ducks or geese with HPAI susceptible species such as chickens or turkeys on the same farm or in close geographical and/or epidemiological contact.

The AIWG noted that there was a pressing need for further active scientific research in Australian poultry farm risk factors that went beyond their qualitative, retrospective literature review.

Of the AI risk assessments undertaken in Australia using a quantitative method to estimate risk, there has been an emphasis on assessing the risk posed by non-commercial poultry to the commercial poultry industries.

For example, the comparative assessment of commercial (over 1,000 birds) and non-commercial (100 to 1,000 birds) poultry operations in Australia that used an expert elicitation process as the main source for estimation of inputs (Hernández-Jover, Roche et al. 2010). Backyard bird producers and fancy bird producers were not included and the assessment was not restricted to a specific area or region in Australia. The two main routes of AI virus introduction from wild birds to both commercial and non-commercial chicken flocks were direct contact and contact with contaminated water supplies, and a similar very low risk of LPAI or HPAI virus introduction was estimated for both operation types. However there was a higher risk for non-commercial operations to acquire infection with LPAI compared to commercial operations (0.032 and 0.020, respectively) and this risk was higher than the risk of HPAI introduction (0.018 in non-commercial and 0.017 in commercial operations). For spread from the index farm, there was a similar risk estimated from non-commercial and commercial poultry operations, and this risk was moderate for LPAI and low for HPAI. Additionally, almost all spread pathways identified people and fomites as being the highest risk for spreading AI viruses off farm, irrespective of the operation type.

Consideration of risk posed by poultry exhibitors in Australia arose from recognition that some practices of these poultry owners (such as allowing wild birds to contact domestic birds, high frequency of bird movements and lack of appropriate isolation for incoming birds) can contribute to AI introduction and spread (Dusan, Toribio et al. 2010, Hernández-Jover, Schemann et al. 2013). Subsequently a risk assessment was conducted to quantitatively assess the probability of introduction of LPAI viruses from wild waterfowl into poultry exhibition flocks and the subsequent spread to other poultry flocks (Hernández-Jover, Schemann et al. 2014). According to reported practices of poultry exhibitors and the LPAI prevalence in wild birds in Australia, the median probability of exposure to a bird kept by a poultry exhibitor was very low, but due to the higher susceptibility of infection of turkeys and waterfowl, this probability was comparatively higher in flocks keeping turkeys and waterfowl than those keeping chickens or pigeons only. Similarly, once exposure has occurred, establishment of infection and subsequent spread was more likely in those flocks keeping waterfowl and turkeys than in those keeping chicken and pigeons only, and spread through movement of birds was the most likely pathway of spread. The median probability of LPAI spread through movement of birds in flocks keeping waterfowl and turkeys was estimated to be moderate compared to very low for chicken flocks and extremely low for pigeon flocks. Sensitivity analysis indicated that the prevalence of LPAI in wild waterfowl and the probability of contact of domestic birds with wild waterfowl were the most influential parameters on the probability of exposure; while the probability of spread was most influenced by the probability of movement of birds and the probability of the exhibitor detecting and reporting LPAI.

Quantitative methodologies

For the recent quantitative risk assessments conducted by Hernandez-Jover et al. (2011, 2014), the quantitative models created implemented **e**xposure and consequence assessments, using scenario trees and Monte Carlo stochastic simulation modelling, following the World Organization for Animal Health (OIE) methodology for risk analysis (OIE 2014). This methodology enables the pathways for pathogen entry and establishment (exposure) in an animal population to be structured as a series of steps, each step with likelihood of occurrence individually parameterised. The pathways for pathogen spread from the index farm (consequence) are likewise structured and the likelihood of spread for each separate pathway estimated. It is the internationally required methodology for the conduct of import risk assessments. The scale of application can be an individual farm or multiple farms within a geographic region or an industry sector. The method allows identification of the most influential parameters in a pathway and as such, the points at which mitigation practices can be targeted to reduce the potential risk of a pathogen incursion. The effect of interventions to mitigate risk can be reflected by changes to the likelihood inputs for these identified influential steps in a pathway. The scenario tree approach provides flexibility so that each assessment can be tailored to represent the context of the animal industry/farm type under consideration.

In addition, aspects of disease spread and evaluation of alternate control actions can be investigated using mathematical models and epidemiological models. These models may be applied to investigate spread within-farm or between-farm and Hamilton (2011) provides a concise review of the multiple examples of both within-farm and between-farm models specific to AI in the literature. For AI in the Australian context, AISPREAD is a large-scale stochastic simulation model designed to investigate the potential spread and control of HPAI in Australia with a view to inform the development of contingency plans. This model considers potential spatial and temporal spread of HPAI between individual commercial chicken meat, chicken egg layer, duck and turkey farms in

Australia and is able to assess the efficacy of potential mitigation strategies such as surveillance, quarantine, diagnosis, culling, movement restrictions and emergency vaccination (Hamilton, 2011). Although this model considers farm type in terms of length of production cycle and bird age category (multi-age or single), it does not incorporate consideration of free-range and non-free-range management.

An alternative approach to this type of large-scale simulation model is the stochastic branching process model (Grimmett and Stirzaker 1992) of disease spread within and between regions, and use of probability generating functions (Becker 1974, Trapman, Meester et al. 2004, Miller 2007) to calculate the probability that disease is eliminated under control strategies. A specific strength of this approach is disease importation and assessment of control, and it has been used to model disease emergence for both human diseases (Lloyd-Smith, Schreiber et al. 2005), and those of livestock (Trapman, Meester et al. 2004, Reluga, Meza et al. 2007, Glass and Barnes 2013)

Biosecurity relevant to AI in the Australian poultry industry

Current industry biosecurity guidelines developed by industry and/or Animal Health Australia are available for poultry in general, and for specific industries and sectors, such as Chicken Layer, Chicken Broiler, Duck and Turkey. Biosecurity practices relevant to AI include keeping wild birds away from poultry, ensuring clean water supply, keeping feed secure and cleaning up any feed spills promptly to prevent congregation of wild birds (DAFF 2009).

In terms of particular recommendations for free-range farms about on-farm actions to reduce AIV introduction, the current National Farm Biosecurity Manual for Poultry Production (2009) provides only general statements based on common features of AI outbreaks in Australia such as to "minimise the congregation of waterfowl and the impacts of wild birds".

Arzey and Littleton (2007) produced guidelines on biosecurity which were specifically directed towards free range layers at a practical farming level in New South Wales. The guidelines identify some of the significant and obvious risk areas, including such aspects as farm locality, proximity to other farms and effective vaccination programs, and also describe basic day-to-day biosecurity and high risk biosecurity for circumstances of high disease pressure, such as Newcastle disease or avian influenza outbreaks. However, the information presented is very generic, specific to one state and cannot be incorporated into industry practices per se.

Response to state of knowledge

This project was undertaken to address gaps in current knowledge about likelihood of AI virus introduction to commercial poultry kept under free-range and non-free-range management in Australia and actions to mitigate AI introduction and spread, and to consider how new knowledge may be incorporated into industry biosecurity guidelines.

Aim, Structure & Objectives

Aim
To conduct research and extension with the aim to safeguard the Australian commercial chicken industry from avian influenza virus (AIV H5 or H7) outbreaks. AI viruses H5 and H7 subtypes are specified because to date all naturally occurring highly pathogenic strains of AI causing acute disease in chickens globally have been of either the H5 or H7 subtype. For this project, the commercial chicken industry was defined as comprising layer chicken farms with more than 1,000 birds, and meat chicken farms with more than 50,000 birds.

Structure
This was a 2-phase project.
Phase 1 focused on discovery of new knowledge and most of the research activities comprise the work to be reported in the PhD of Angela Scott. This research phase of the project involved conduct of an on-farm survey, wildlife camera surveillance on farm, expert opinion elicitation, and development of three models used to quantify the risk of AI virus introduction to a commercial chicken farm and spread from one infected farm to other farms.
Phase 2 focused on extension of this new knowledge including, and discussion of the findings and guidelines with range of industry players at a National Forum and regional workshops hosted by the project, and revision of biosecurity guidelines.

Objectives
The objectives for Phase 1 and for Phase 2 as stated in the project contract are listed in the following table with detail on the project activity/s that contributed to their achievement.

Phase 1 (Research)

Objectives	Achieved via					
	On-farm survey	Wildlife camera surveillance	Expert opinion elicitation	Exposure scenario tree model	Spread scenario tree model	Branching process model
Industry level						
1. To quantify AI risk between caged, cage-free and free-range farms in the chicken layer sector			☑	☑	☑	☑
2. To quantify AI risk between barn and free-range farms in the chicken broiler sector			☑	☑	☑	☑
3. To quantify the AI risk posed by free-range farms pose in the chicken layer sector compared to the chicken broiler sector			☑	☑	☑	☑
4. To quantify and compare the AI risk posed by free-range layer farms located in different geographic regions of New South Wales	In consultation with the Project Steering Committee it was determined that the National AI Wild Bird surveillance data from one site in NSW was insufficient to support work related to Objectives 4&5 during the period of this project.					
5. To quantify and compare the AI risk posed by free-range broiler farms located in different geographic regions of New South Wales						
Farm level						
6. To describe the types and frequency of interactions between commercial flocks and wild birds on free-range and non-free range farms		☑				
7. To describe free-range farm structure and management practices that are known risk factors and to identify any as yet unknown risk factors for AI virus entry and spread	☑					
8. To quantify the AI risk on free-range farms of known risk factors and of any new risk factors identified by this project and determine the risk factors that pose highest AI risk that are amenable to change			☑	☑	☑	
9. To quantify risk reduction achieved by actions that can be implemented on free-range farms to lower farm risk of AI virus entry and establishment				☑		
10. To quantify risk reduction achieved by actions that can be implemented on free-range farms to lower farm risk of AI virus spread from an infected farm to other farms					☑	

Phase 2 (Consultation & Extension)

Objectives	Achieved via
11. To consult at a national forum with key industry and government stakeholders about the findings and recommendations from Phase 1. The forum will discuss the adoption mechanisms and potential implications of the research findings, including revisions to biosecurity guidelines for free-range farms, and to consider implications for industry quality assurance (QA) programs.	National Forum held in Sydney on 23 August 2016. Attended by 62 participants representing key industry and government stakeholders across most sectors of the Australian poultry industry.
12. To revise enterprise-level biosecurity guidelines for free-range layer and broiler farms with intent to incorporate practical risk mitigation steps identified in Phase 1 and agreed from the national forum. Peak industry body representatives will be involved in	Consultation at the National Forum and the Regional Workshops, and with the Project Steering Committee directed the Project Team to focus recommendations for revision on the DAFF (2009) National Farm

the review process to ensure the recommendations are thorough, practical, and relevant to each industry.	Biosecurity Manual Poultry Production. Recommended revisions to this 2009 generic manual aim to provide an updated version that is contemporary reflecting the changing poultry industry structure and which the different segments of the industry could use to revise their species specific manuals.
13. To promote the findings and revised guidelines at regional workshops. Fact sheets and technical brochures will be published and circulated to industry members to promote awareness of the changes and principles.	Six regional workshops (2 in NSW, 2 in Vic, 1 in Qld, 1 in SA) were held from 17 November - 08 December 2016 including an additional 6th workshop on request in South Australia. Across these workshops a total of 136 producers and poultry industry representatives attended with representation from chicken meat, commercial eggs, free-range eggs and meat, duck meat, turkey meat and mixed type farms. For communication tools, a brochure presenting the main outcomes from the National Forum and Regional Workshops was developed, and text/diagram stating the key on-farm biosecurity messages based on project research provided to Animal Health Australia. The absence of a CRC Communications Officer in 2016 required reduction in this aspect of the project.

Phase 1 Overview – Methodology & Results

1. On-Farm Survey

Objective: To describe farm structure, management practices, biosecurity practices and wild animal exposure and inform understanding of variation in structure and management between farm types. *Relates to Project Objective 7.*

Methods: On-farm interviews with poultry farmers were conducted using a comprehensive questionnaire which consisted of approximately 130 questions divided into seven sections: farm information, water management, poultry health, range information, wild birds, other wild animals and biosecurity. The biosecurity section also consisted of questions related to information sources and biosecurity ratings and perceptions of farmers.

The Sydney basin bioregion, which extends from Seaham to Bateman's Bay, was selected as the region in which to survey farms. It was selected because it met selection criteria regarding 1) a bioregion with defined geophysical and climatic conditions; 2) all farm types of interest (cage, barn and free range of both egg and meat chicken farms) present; and 3) history of a HPAI outbreak (Maitland in 2012). A comprehensive farm list sourced from various corporations, integrators and private consultants was created and farms were randomly selected from it and farmers then contacted by telephone to invite them to participate in the survey. Additional free range broiler farms were also surveyed in South East Queensland to provide a more representative sample of this sector. In total 73 chicken farms were visited; nine cage layer, nine barn layer, 25 free range layer, 15 non-free range broiler and 15 free range broiler farms (6 NSW, 9 Qld).

Results:

Water management

An average of 1, 1.2, 1.3 dams are present on cage, barn and free range layer farms respectively and an average of 1.2 and 1.9 dams present on non-free range and free range broiler farms respectively. Overall farms had an average of 1.4 dams. The source of drinking water for chickens was town water for 64% of farms, followed by bore water (21%), a natural nearby water body (8%) and a farm dam (7%). Drinking water is treated on 96% of farms and this includes farms using town water, which is assumed to be treated. Water used for environmental control methods such as foggers, cooling pads and irrigation of the range area was from the same source as the drinking water on 65 farms. However 8 farms use a different water source and on 7 of these farms, the water from this source is not treated.

Animals and wild birds on farm

Dogs and cats were kept on 71% of farms, followed by ruminants (45%), horses (14%), other animals (5%) and pigs (1%). Dogs and cats had access to the sheds on 67% of cage layer farms, and access to the range on 44% of free range layer farms.

Across all farm types, 56% of farmers reported seeing wild birds inside chicken sheds (eg sparrow, finch) and 78% reported wild birds in feed storage areas (eg pigeon, mynah). Waterfowl were commonly reported on waterbodies by all farm types and were among the wild birds seen on the range for 87% of free range meat farms and 88% of free range layer farms.

Chickens were reported to escape from shed or range and be returned to sheds on 11% of cage layer farms and 84% of free range layer farms.

Biosecurity

More than half of farms disinfect vehicles (57%) between farms and share equipment (78%) between sheds. Of those that share equipment between sheds, only 14% of farms disinfect the equipment between sheds. Most farms also use foot baths (76%) and have visitor recording systems in place

(77%). All of these biosecurity practices gained an average farmer perceived rating of 'very important'.

2. Wildlife camera surveillance

Objective: To describe the type of wildlife visiting commercial chicken farms and compare number of wildlife visits across farm types. *Relates to Project Objective 6.*

Methods: Recoynx Hyperfire HC500® cameras were placed on 30 of the surveyed farms. These cameras are motion sensitive and have infrared ability to capture photos at night. Cameras were set up on five cage/barn layer farms, 14 free range layer farms, five non-free range broiler farms and six free range broiler farms. One camera was placed to capture a silo on the farm, one camera was placed to observe a shed wall and a third camera was placed on free-range farms to capture activity on the range. Cameras were set up for a 7 day period during spring in the Sydney basin region and summer in south-east Queensland. All images were examined individually by visual observation and unknown species identification confirmed by an avian specialist (Dr David Phalen). In order to estimate the number of individual wild animals captured in images, images were converted to wild animal visits where each visit involved a different wild animal. This was performed by removing images with the same date and time so that only one image of a series of images featuring the same wild animal was left.

Results:
A total of 594 wildlife visits were captured with 87% of these involving wild birds and 13% involving wild mammals and marsupials (mainly rats, foxes and kangaroos). Of the 516 wild bird visits, 81% involved perching birds (e.g. sparrows, crows, magpies), 9% pigeons and 7% egrets and herons. Comparison of visit number per farm type adjusted by number of farms per farm type, 70% of wildlife visits were on cage layer farms, followed by 15% on free range layer, 6% barn layer farms, 6% on free range meat farms and 1% on barn meat farms.

3. Expert opinion elicitation

Objective: To obtain the input of experts to estimate the probability of specific pathways related to the introduction and spread on AI virus in the Australian broiler and layer industry. These estimates were used to inform input parameters for the AI introduction and spread modelling when no information was available in the literature. *Relates to Project Objectives 1/2/3/8.*

Methods: Twelve poultry veterinarians and scientists were identified as experts, based on their experience in the Australian poultry industry, knowledge of the AI virus, knowledge of wild bird prevalence or involvement in the management of HPAI outbreaks in Australia or overseas, and invited to participate. Using a modified Delphi method, the 10 experts who participated first completed a questionnaire that asked for initial probability estimates for specific pathways in stated scenarios for each farm type. Second, a workshop was conducted in which the experts were shown group averages of their estimates, discussion was facilitated between participants and final estimates obtained for all pathways. Combined probability estimates were then calculated using the final individual estimates of each expert weighted according to level of relevant expertise.

Results: Indirect contact with wild birds either via a contaminated water source or fomites was considered as the most probable pathway of introduction of LPAI on poultry farms of all operation types. Distance of shed from the water body was considered a potential pathway for introduction only when the operation type was free range and the water body was within 500m distance from the shed. Detection of mild clinical signs of LPAI in a shed was considered to be more probable on broiler as compared to layer farms while the probability that LPAI will mutate to HPAI was considered to be higher on layer farms. Shared personnel, equipment and aerosol dispersion were the most probable pathways of spread of virus from shed to shed. For spread of LPAI and HPAI from farm to farm, shared pick-up trucks for broiler and shared egg trays and pellets for layer farms were considered most probable.

4. Exposure scenario tree model – Entry of AI virus to commercial chicken farms - *How does the virus get in?*

Objective: To define pathways for the entry of LPAI virus entry and for each pathway to quantify and compare the probability of introduction to Australian commercial chicken farms (cage layer, barn layer, free range layer, barn meat, free range meat). For the pathways/s with highest probability, to estimate the effect on probability of introduction caused by changes to on-farm practice/s. *Relates to Project Objectives 1/2/3/8/9.*

Methods: Pathways for entry of LPAI virus to a commercial chicken farm, the steps for each pathway defined and the data to inform the probability of each step occurring were based on an extensive literature review and the results of the on-farm survey, wildlife camera surveillance and expert opinion elicitation.

Each pathway was portrayed using a scenario tree (Martin, Cameron et al. 2007) and developed using Microsoft Excel (PC/Windows 7, 2010) with the input data for each step being a distribution (stochastic estimate) not a single number (deterministic estimate). Separately for each farm type, the probability of each pathway occurring was estimated using Monte Carlo stochastic simulation modelling using the program @RISK 7.0 (Palisade Corporation, USA). Each simulation consisted of 50,000 iterations sampled using the Latin hypercube method with a fixed random seed of one.

Results: At any point in time, the overall probability LPAI virus entry or exposure is extremely low for all farm types. Comparison between farm types shows the overall probability is higher for free range layer farms than cage layer, barn layer, barn meat and free range meat. For all farm types, the overall probability is lowest in summer and notably higher during autumn, winter and spring. Increasing the total number of wild birds present on a farm and the proportion of waterfowl among the wild birds present, increases the overall probability of LPAI being introduced. The overall probability is reduced most by reducing the proportion of waterfowl among wild birds present on the farm and reducing the presence of waterfowl in feed storage areas and on range areas.

5. Spread scenario tree model – Spread of AI virus from an infected commercial chicken farm to other farms - *How can the virus spread to other farms?*

Objective: To define pathways for the spread of AI virus from shed-to-shed on an infected farm, and from an infected farm to other farms. For each pathway to quantify and compare the probability of spread each type of Australian commercial chicken farm (cage layer, barn layer, free range layer, barn meat, free range meat). *Relates to Project Objectives 1/2/3/8/10.*

Methods: The extensive literature review and the results of the on-farm survey, wildlife camera surveillance and expert opinion elicitation were used to define pathways for shed-to-shed spread and farm-to-farm spread, and to determine the steps for each pathway. In order for spread to occur, the AI virus must infect an exposed chicken and then be transmitted bird-to-bird to establish AI infection in a shed (termed establishment in this work). The probability of establishment in a shed was based on the branching process model results. The probability of mutation from LPAI to HPAI was based on expert opinion. For both LPAI and HPAI, shed to shed spread was estimated using a combination of scientific literature and on-farm surveys and farm to farm spread was estimated using expert opinion.

Similar to the exposure scenario tree, each pathway was portrayed by a scenario tree (Martin, Cameron et al. 2007) developed using Microsoft Excel (PC/Windows 7, 2010) with input data for each step being a distribution not a single number. Separately for each farm type, the probability of each pathway occurring was estimated using Monte Carlo stochastic simulation modelling using the program @RISK 7.0 (Palisade Corporation, USA). Each simulation consisted of 50,000 iterations sampled using the Latin hypercube method with a fixed random seed of one.

Results: Ability of the LPAI virus to establish in a shed strongly influences whether or not infection of one chicken in a shed will lead to spread shed-to-shed on that farm and spread farm-to-farm. For all farm types, the most likely end-point after one chicken is exposed with LPAI is no establishment, that is, the virus fails to infect the exposed chicken or the virus infects the exposed chicken but fails to spread to other chickens such that the virus dies out. For free range meat and free range layer farms there is a slightly higher probability that establishment will occur than other farm types because free range birds have a higher probability of direct exposure to AI virus than indirect exposure which increases the probability of infection.

For shed-to-shed, the main pathways considered were boots/clothing, equipment, vermin (insects and rodents), aerosol and domestic animals (dogs and cats). Of these, sharing equipment between sheds is the most likely pathway of shed-to-shed spread of AI virus.

The overall probability of LPAI spread farm-to-farm given one bird is exposed to LPAI virus is very low to low for all farm types, and for HPAI is extremely low for all farm types. Of the pathways considered, pick-up trucks (for both dead and alive birds) was the most likely pathway of farm-to-farm spread of AI virus for all farm types. For all layer farm types (cage, barn, free range), egg trays and egg pallets were also found to be important pathways of farm-to-farm spread.

6. Branching process model – AI virus in a chicken flock – Establishment, Mutation and Spread - *How does the virus behave in a flock?*

Objective: To model how changes in industry structure are likely to affect the probability of HPAI outbreaks. *Relates to Project Objectives 1/2/3.*

Methods: A stochastic branching process was developed that incorporates distinct population structures, a continuous low-level risk of LPAI virus introduction, several mechanisms of spread (within and between sheds, and between farms), and a stochastic process for mutation from LPAI to HPAI virus. Data relevant to Australian conditions to inform model parameters were extremely limited including only wild bird and sentinel bird surveillance, and reports on Australian HPAI outbreaks. There are no Australian data on the frequency of LPAI introduction into commercial flocks, nor on LPAI virus transmission rates within sheds, between sheds or between properties, and the mutation process from LPAI to HPAI is poorly understood. Given this situation, plausible ranges for influential parameters were investigated. The model was used to explore aspects such as the establishment and persistence of LPAI in a shed; the change in probability of a HPAI outbreak with changes to the proportion of free range farms; the probability of spread to a second shed on a farm by the time that mortality threshold triggers investigation of first shed; and the impact on overall HPAI outbreak probability of specific pathways to aid understanding of mitigation impact.

Results: Estimation of transmission parameters from daily mortality data of Australian HPAI outbreaks indicate that one infected bird infects approximately 1-2 birds in the same shed, and 0.02-0.09 birds (on average) in other sheds on the premises. These estimates were similar for outbreaks of HPAI in caged layer and free range layer sheds.

The model suggests that when LPAI is introduced to a chicken shed, in about 25% of sheds the LPAI will not establish, that is, the LPAI virus will not successfully infect one chicken and then transmit from bird to bird. This result was similar for all 5 farm types, and is a consequence of the fairly low estimated transmission for AIV in poultry. In the sheds in which LPAI does establish, the length of time that LPAI persists within the shed varies between farm types due to the length of the production cycle. For barn meat and free range meat, LPAI does not persist beyond 50 days in one third of sheds and in none beyond 100 days. For layer farms, LPAI does often persist for over 150 days in sheds on barn layer, free range layer and caged layer farms.

Using the current total number of all commercial chicken sheds in the Australian industry, the model suggests for a plausible range of transmission rates that the probability of a HPAI outbreak in a year increases slowly as the proportion of free range sheds increases from the current 30% to 100%. Even for the unlikely scenario that the industry is composed entirely of free range farms the relative increase in probability of HPAI outbreak remains below 50%. The relative contribution of the layer sector and the meat sector to this increase in HPAI outbreak probability was investigated for scenario with 60% free range farms (double the current). This showed that the layer sector was the predominant contributor at lower transmission rates even though there are many more meat farms than layer farms, but at higher transmission rates the contribution of the meat sector increased and approached similar level to the layer sector.

Using the model to investigate probability of spread to a second shed on a HPAI infected farm at the time of detection in one shed on a meat farm, we found that by the time that a daily mortality of 1% triggers an investigation in one shed infected with HPAI virus, it is virtually certain that the virus will have spread to at least one other shed on the infected farm. This result was the same for barn meat and free range meat farms. Similarly, for cage, barn and free range layer farms, by the time that a weekly mortality of 1% triggers an investigation, it is almost certain that the HPAI virus will have spread to at least one other shed on the infected farm.

Role of specific pathways (such as feed storage spillage, use of surface water and water treatment) was evaluated by estimation of the proportional reduction in probability of HPAI outbreak compared to current situation using this model. Use of surface water without treatment was found to be the most risky pathway for all farm types. Reducing feed spillage and restricting bird access to feed storage was estimated to reduce the probability of HPAI outbreaks by approximately 30%.

Phase 2 Overview – Methodology & Outcomes

1. National forum

Objective: To consult with key industry and government stakeholders about Phase 1 findings and recommendations, to discuss adoption mechanisms and potential implications for biosecurity programs including considerations for recommending changes to current biosecurity guidelines and implications for industry quality assurance programs. *Relates to Project Objective 11.*

Method: A National Forum hosted by the University of Sydney was held at the Stamford Plaza Sydney Airport on 23 August 2016. It was attended by 62 participants representing key industry and government stakeholders across most sectors of the Australian poultry industry. Participants included egg and chicken meat and duck meat producers and their value chain, researchers, veterinary advisers, and representatives of the Australian Egg Corporation Ltd (AECL), Australian Chicken Meat Federation (ACMF), Animal Health Australia (AHA), Victorian Farmers Federation (VFF), Queensland United Egg Producers (QUEP) and State and Australian Governments.

The aims of the Forum were to:

- Consult with key industry and government stakeholders about the findings and recommendations from work done within the AI Risk project.
- Discuss the adoption mechanisms and potential implications of the research findings for biosecurity programs.
- Develop and recommend changes in current biosecurity manuals for egg production/chicken meat/free-range layer and chicken meat farms, and to consider implications for industry quality assurance (QA) programs.

Pre-reading was provided to invited participants consisting of the Forum Agenda, general guidelines regarding accommodation and transportation, and a report on Poultry CRC Project 1.5.7 that provided background on the aim and structure of the project, and on the methods and some findings of Phase 1 of the project.

Participants in Small Group Workshops were seated at eight tables with 8 to 9 participants at each table grouped to represent the science, poultry farming, industry and government policy and veterinary segments of the poultry industry. Each table had a nominated facilitator with the intention of providing inputs from each participant towards a collective response to the questions raised at the workshops.

The key questions that were asked at the Forum were as follows:

<u>First Small group workshop</u>

Based on the science presented

- What are the priority actions that should be taken to stop AI virus getting onto a farm?
- What criteria did you use to prioritise alternate actions?
- What else can we do to learn how often chicken flocks are infected with LPAI virus?

<u>Second Small group workshop</u>

Based on the science presented

- What are the priority actions that should be taken to stop low pathogenic AI virus moving between farms?
- What criteria did you use to prioritise alternate actions?

<u>Plenary discussion</u>

- From our list of priority actions based on small group work, which actions need to be emphasised in the revisions to biosecurity manuals?
- What are the key messages relevant to QA programs to communicate to poultry

farmers in upcoming regional workshops?

The workshop was independently facilitated by Michael Williams of Michael Williams & Associates Pty Ltd.

Outcomes:
Research findings were generally considered to agree with prior knowledge, and to be valued because they added rigor and relative quantities to our understanding of the differences in risk of avian influenza between farm types.

It was considered that the research would inform changes to the biosecurity manuals and that recommended changes should focus on the generic biosecurity manual, and subsequently changes to manuals and QA programs for specific farm types can be progressed by industry sectors.

Principal recommendations from the National Forum:

- The research undertaken has identified risks associated with specific areas of biosecurity, especially water, wild bird management and feed storage areas, and these should be identified in manuals and rewritten to reflect the level of risk.

- Adoption of the research findings from the project requires additional thought to be given to manual content that reflects industry changes and new knowledge, and additionally are appropriate for the non-aligned sector, are able to be adopted, and are cost/benefit considered and explained.

- The manuals should have mandatory "must" instruction and should be more targeted. The manuals should be extended to include food pathogens and be auditable by industry and independently. They should refer to only one level of biosecurity (eg Level 2 – high risk) and should be based on the assumption that LPAI is already present on farm.

- Although the modelling studies were constrained by lack of data on LPAI subtypes in Australia, they did provide improved definition of the risks of introduction of LPAI virus into different farm types and should be further developed.

- Improved risk analysis could be achieved through the provision of data from additional passive surveillance both national and on-farm and the use of sentinel flocks. The methods and benefits of surveillance should be explained and included in the manual.

2. Biosecurity manual

Objective: Based on Phase 1 findings and consultation during Phase 2, to provide recommendations for update to National Farm Biosecurity Manual Poultry Production[2]. *Relates to Project Objective 12.*

Method: Consultation at the National Forum and the Regional Workshops and with the Project Steering Committee directed the Project Team to focus recommendations for revision on the DAFF (2009) National Farm Biosecurity Manual Poultry Production.

Duncan Rowland (AHA Executive Manager, Biosecurity and Product Integrity Services) who collaborated on National Forum and this manual revision component of the project provided pdf files of the various poultry related biosecurity manuals that AHA have facilitated preparation of.

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[2] DAFF (2009) National Farm Biosecurity Manual Poultry Production. DAFF, Canberra. Available at: http://www.agriculture.gov.au/pests-diseases-weeds/protect-animal-plant/bird-owners/poultry_biosecurity_manual

In preparing the recommended revisions to the generic manual, the outcomes and recommendations from the National Forum and the Regional Workshops were considered. In addition, the current National Farm Biosecurity Technical Manual for Egg Production (AHA 2015) was considered to provide contemporary requirements and wording that matched many of the recommendations from the National Forum. Rather than reword the 2009 generic Manual, it was decided to recommend substitution of those applicable paragraphs from the National Farm Biosecurity Technical Manual for Egg Production (AHA 2015) into the 2009 generic Manual. Hence, when reviewing the comments on the generic manual, a copy of the Technical Manual for Egg production should be consulted.

Recommended revisions to the this generic manual were drafted by Phase 2 consultant Clive Jackson and then reviewed by selected Project Team and Project Steering Committee members before finalisation.

Outcome: Recommended revisions to this 2009 generic manual provide an updated version that is contemporary reflecting the changing poultry industry structure and Phase 1 research findings within this context, and which the different segments of the industry could use to revise their specific manuals.

The proposed revisions relate largely to risks associated with AIV and we did not broaden consideration to other infectious agents or food pathogens related to farm biosecurity at large as suggested by participants at the National Forum. However the points recommended for revision will also assist risk mitigation for other infectious agents.

In order for the recommendations to be incorporated into biosecurity manuals and adopted on farm, further consultation and extension activities are needed beyond the term of this project. Suggestions for this process were discussed at the National Forum and Regional workshops, and points raised are noted in reports of these activities (Appendix C & D).

This further consultation with industry regarding recommended revisions to the generic biosecurity manual is not the responsibility of the Project Team. We understand that during 2017 AHA and the peak industry bodies will implement their usual consultation processes to consider the recommended revisions, to incorporate changes deemed to be appropriate, and subsequently, to publish an updated generic biosecurity manual. To support this process, Project Team members are willing to be contacted whenever further explanation and justification is needed to inform consideration of a recommendation.

3. Regional workshops

Objective: To promote awareness and understanding of the Phase 1 findings, and better understanding of on-farm biosecurity among producers. To consult with producers and their advisors about adoption mechanisms and potential implications of Phase 1 findings for biosecurity programs including considerations for recommending changes to current biosecurity guidelines and implications for industry quality assurance programs. *Relates to Project Objective 13.*

Method: The required number of five regional workshops in the project contract was exceeded with a sixth workshop presented in South Australia at the request of Margaret Sexton.

Six workshops were held across four States during the period 17th November to 8th December 2016. The locations were at Camden and Maitland in NSW, Frankston and Bendigo in Victoria, Ipswich in Queensland and Adelaide in South Australia.

An initial flyer was sent through a range of poultry organisations, state government and associated service companies and was published on three websites seeking interest in attendance at one of the workshops. A second flyer was sent to the producers and poultry industry representatives who indicated their workshop preference. The second flyer provided details of the Venue and of the Agenda for the workshop.

The workshop agenda followed a set format of technical presentation and facilitation that included three PowerPoint presentations prior to lunch followed by a round-table discussion after lunch directed at three or four specific questions that arose from the morning's presentations. A general discussion followed with a summation of the main outcomes from the workshop presented to the attendees.

Phase 2 consultant Dr Clive Jackson and PhD candidate Angela Scott conducted the regional workshops, with logistic support from Joanne Geist (USyd PRF Administration).

Outcome: Some 153 producers and poultry industry representatives indicated their interest in attending one of the six workshops. Following a number of apologies, participation in the workshops was Camden (24), Maitland (24), Frankston (22), Bendigo (11), Ipswich (15) and Adelaide (40). Participants were grouped in roundtables largely representing the type of poultry industry in which they worked. Consequently, there were chicken meat groups (9), commercial eggs (3), free-range eggs and meat (3), duck meat (2) and turkey meat and mixed type (1 each). Following the technical presentations, a number of questions were asked seeking clarification especially around waterfowl habitat, risk modelling and biosecurity manual wording. The workshops focused on the set questions in the Agenda about biosecurity/QA programs in use and the important measures in those programs, additional biosecurity measures learnt from the presentations and whether they could be adopted cost effectively. Answers to further questions were sort in Adelaide where SARDI had an additional objective of identifying and mitigating risks in South Australia and seeking comment on PIRSA's role in assisting in those areas.

The principal outcomes from the workshops were the creation of a significant degree of enthusiasm amongst the participants to progress a high level of biosecurity on their farms with this extending to thoughts of how to develop a regional or state-wide network of co-operation on biosecurity especially when emergency animal diseases are notified. Whilst many participants were actively involved in the implementation of biosecurity programs and procedures based upon the prescribed generic or species manuals and company/industry QA programs they did identify areas where those programs could be improved though inclusion of some of the significant risks identified in the Phase I project studies provided at the workshops. In particular, they listed the high risk of an AI outbreak emanating from contact with waterfowl and the need for adequate bird proofing, correct water treatment, surface water reduction and wild bird surveillance. They also focused on the need for further education/training in biosecurity, the need for rational auditing and continued improvement in biosecurity of farm access, equipment hygiene and bird pick-up and disposal.

4. Communication tools

Objective: To promote the findings and outcomes of this project. *Relates to Project Objective 13.*

Method: In the project contract, Activity 6.2 Development of communication tools was to produce fact sheets and technical brochures to be published and circulated to industry members to promote awareness of changes and principles re on-farm biosecurity arising from this project. However this did not progress as originally envisaged due to the absence of a Communications Officer employed by the CRC during 2016. This lack of specialised support from the CRC was recognised early in 2016 and alternate support from AHA sought via Duncan Rowland. AHA gave a positive response to this initial request, and Clive Jackson was put in contact with Harley McNamara (AHA Communications Coordinator).

The revised and reduced approach to communication tools consists of a brochure presenting the main outcomes from the National Forum and Regional Workshops, and the provision of text/diagram stating the key on-farm biosecurity messages based on project research suitable for flyer or poster provided to Animal Health Australia.

Outcomes:

1. **Brochure**
   Presenting the main outcomes from the National Forum and Regional Workshops. To be prepared by Clive Jackson. Its purpose will be to notify stakeholders of Phase 2 activities. This will be distributed at APSS and APVA conferences in February 2017, and via contact networks of Project Team and Project Steering Committee.

2. **Text/Figure content for a communication tool suitable for producers**
   Clive Jackson and Angela Scott with support from Peter Groves and Jenny-Ann Toribio to prepare text and figure/s stating the key on-farm biosecurity messages based on project research. This will be provided to Harley McNamara (AHA Communications Coordinator) for use in development of poster and/or flyer by AHA.

3. **Conference presentation at 2017 APVA**
   Clive Jackson will present a conference paper on Phase 2 activities and outcomes including recommended revisions to the generic biosecurity manual.

Discussion of Results from Phase 1

This project has focused on the potential for avian influenza outbreaks on commercial chicken farms involving non-exotic H5 and H7 AI viruses circulating in wild birds in Australia. It has not considered outbreaks involving exotic avian influenza viruses with exposure of chicken flocks to HPAI from migratory birds, from native wild birds infected by migratory species or from nomadic Australian waterfowl infected during visits to the Australo-Papuan region. Work by East at al (2008) and others predicted that exotic HPAI outbreak in Australian commercial poultry is a rare event, and this is supported by the actual occurrence of HPAI outbreaks in this country, none of which involved exotic virus. In this regard, the Australian situation is relatively unique in terms of global HPAI occurrence. Whilst the devastation caused by exotic HPAI entering poultry flocks is evident from recent events in Europe and North America, it is appropriate that consideration of AI risk to the Australian poultry industry focus first on non-exotic AI as done by this project.

On-farm survey

The survey demonstrated that the level of adoption of biosecurity practices varies across the different meat chicken and egg farms in the Sydney Basin. A high level of biosecurity was found in barn and free range meat chicken farm types and compared to barn and free range layer farms, with cage layer farms found to have the largest room for improvement. Overall there is some degree of room for improvement across all farm types.

This finding of some deficiencies in biosecurity practices on all farm types led to consideration over Phase 1 and Phase 2 of this project of all farm types, with more emphasis on investigation of the risk for each farm type given the production system and biosecurity practice level identified in the on-farm survey than reflected in the Project Objectives which emphasised evaluation for free-range farms.

The results indicate a generally high level of biosecurity among the meat chicken farms, and this is likely due to the vertical integration of this sector. More private ownership amongst the layer farms results in a greater variation in the level of biosecurity as there is no governing body to enforce adoption of biosecurity practices. In particular, cage layer farms tend to rate poorest in the level of biosecurity amongst the farm types. The results from the personal biosecurity ratings also reflect this; where cage layer farms had the lowest average rating compared to the other farm types. This demonstrates some degree of awareness of farm biosecurity amongst the farmers. Most cage layer farms visited were old, family-run farms that had been passed onto the next generation. This contrasts with barn and free range layer farms which are relatively newer due to the recent expansion of cage-free eggs. It is likely newer farms seek technical services and support more frequently than old farms but the age of the farms was not captured in the survey.

The majority of cage layer farms had multi-age sheds (78%) and most farms (67%) did not perform thorough cleaning of sheds between batches. This allows persistence and circulation of pathogens. Of note is AI, where it is generally acknowledged that the longer the circulation of LPAI in poultry, the greater the risk that mutation to HPAI will occur (Alexander 2007).

The presence of rodents and wild birds inside sheds in all farm types is of concern. Biosecurity guidelines recommend rodent control and prevention of bird entry to poultry sheds due to the potential for pathogen exposure and spread. Wild birds reported inside sheds by farmers were all small bird species such as sparrows or finches belonging to the order of Passeriformes. In regard to AI and egg drop syndrome (EDS) introduction, the high level of reporting of waterfowl (order Anseriformes) on nearby water bodies is a more direct concern. It is essential if water from these waterbodies is used by the farms that effective water treatment be performed irrespective of use as a drinking water source for chickens or for environment control (cooling pads, foggers, range irrigation). The survey results show that although there was a high level of water treatment across all farm types, this was not complete and there are farms that need to implement or improve water treatment protocols.

Level of farmers who reported chickens escaping from sheds or from the range and being returned was certainly higher than expected. The fact this practice was reported on 11% of cage layer farms and 84% of free range layer farms led to consideration of the opportunity for chickens to have wild bird exposure outside the shed or range and inclusion of this as a pathway for AI exposure in the scenario tree exposure model.

Wildlife camera surveillance

The wild bird results obtained from this study were compared with published data on the relative abundance of wild bird species in NSW from 1971 to 2000. Such published data lists the Australian Raven, Pacific Black Duck, magpie, peewee, willie wagtail, white-faced heron and crested pigeon in the top 20 most abundant species recorded in NSW and the Australian Capital Territory (ACT) (Cooper, McAllan et al. 2014). These species were commonly identified in this study. However, the mynah and the house sparrow, found to be the most frequently and the fifth most frequently sited species identified in this study respectively are not listed in the top 20 most abundant species in NSW and the ACT. The common mynah which comprised the majority of the mynah category is an introduced species to Australia, as is the house sparrow. This finding suggests that species abundance alone does not determine presence on farm, and that introduced wild bird species may more commonly visit poultry farms or farms in general compared to native wild birds in Australia. Manual wild bird counts on Canadian poultry farms revealed the European Starling, an introduced species to Canada, was the most common wild bird identified (Burns, Ribble et al. 2012). In addition, survey results on North American dairy farms also revealed the European Starling, house sparrow and Rock pigeon were the most common wild birds seen, all of which are introduced species to North America (Shwiff, Carlson et al. 2012). There is potentially a high supply of food and shelter on farms for wild animals. It is known introduced species commonly out-compete native species and may have already done so on the farms studied (Phillips and Shine 2006, Shwiff, Carlson et al. 2012).

There is little evidence of direct contact between wild animal and chicken found by this study. Few wild animal visits included an image with a wild animal and chicken captured on the same photograph; all of which were on the range at free range layer farms. Direct physical contact between live chickens and wild birds was not seen. Further the time periods of day with most wild animal visits to the range on free-range farms were times that chickens are not allowed on the range. For wild animal visits captured by cameras in silo areas, the frequency of wild animal visits in certain time periods suggested relationship with feed delivery, but as time of feed delivery was not asked in the on-farm survey this could not be verified. From this work it seems direct physical contact between chickens and wild birds is rare, and potentially some wild bird species may avoid range areas when chickens are present due to intimidation by the chickens.

While most wild animal visits occurred on layer farms, it is acknowledged that ability to observe interactions between wild animals and chickens on free range meat chicken farms was limited by the following. Two meat chicken farms included did not have chickens present on the farm during the study period, as sheds were already depopulated. In addition, for two farms chickens were not yet old enough to be allowed range access during the study period. Further, the on-farm survey found that a lower median proportion of birds use the range on meat chicken free range farms compared to layer free range farms. This may be due to the rapid growth rate of meat chickens which can lead to diseases, such as cardiovascular and musculoskeletal abnormalities, that cause chickens to spend more time sitting than walking (Robins and Phillips 2011).

This camera surveillance, conducted for only one week per farm, did not permit consideration of seasonal variations in the types and frequencies of wild animal visits. Given influence of season and climatic conditions on the presence of some wild animal species, setting up cameras on farm for a longer period of time (such as one year) would aid understanding of interactions between chickens and wildlife. For meat chicken farms, it would also provide surveillance for periods when sheds are populated, and on free range meat chicken farms, for periods when chickens are of an appropriate age for range access.

Expert opinion elicitation

The 10 experts who participated in the expert opinion elicitation process had a wide range of experience. They included six poultry veterinarians employed in private consultancy (three experts), poultry companies (two experts) and university sector (one expert) with an average of about 35 years of experience mostly in the Australian poultry industry. The other four included a virologist (7 years of experience in AI virology), an epidemiologist (50 years' experience), a wild bird expert (10 years of wild bird surveillance experience) and an avian diagnostic pathologist (33 years of experience). Thus this group of experts constituted extensive knowledge of commercial poultry production and of avian diseases in Australia.

The modified Delphi method was a valuable tool to elicit experts' opinion on the possible pathways of introduction and spread of AI virus in all production types of the broiler and layer industry of Australia. The estimates obtained were able to distinguish the level of risk as perceived by the experts in cage versus barn versus free range production systems for both broiler and layer farms. The various estimates generated from this component of the research were used later to inform the modelling work particularly as input values in the spread scenario tree model.

Scenario tree models

The output probabilities obtained from the exposure scenario tree and the spread scenario tree models can applied with reasonable confidence to the Sydney basin region due to the use of weather and LPAI wild bird prevalence data specific to this region. In addition, the majority of on-farm surveys were conducted in this region. Applying these output probabilities to commercial chicken farms in other regions of Australia must be cautioned as differences in farm management practices may exist as well as differences in weather conditions and LPAI wild bird prevalence (BOM Grillo, Arzey et al. 2015, 2016).

Exposure scenario tree

The exposure scenario tree results suggest that the probability of LPAI exposure for a commercial chicken farm at any point in time is extremely low for all farm types, with commercial free range layer farms approximately double the risk of LPAI exposure compared to other farm types. The farm type with the greatest median probability of exposure was free range layer farms (0.00075), followed by barn meat chicken farms (0.00037), free range meat chicken and cage layer farms (both 0.00032) and lastly barn layer farms (0.00030). The higher probability of introduction in free range layer farms is in agreement with Gonzales, Stegeman et al. (2012) which found that outdoor layer farms had a 13 times higher rate of introduction of LPAI virus than indoor layer farms in the Netherlands. It has been indicated that the most efficient means of introduction is through direct contact with infected birds (Swayne 2008). Free range farms have access to the outdoors where direct exposure to wild birds is more likely to occur compared to indoor farms; free range layer farms have the highest median probability of direct exposure (0.00056), followed by free range meat chicken farms (0.00016) and cage layer farms (0.00011). However, during the on-farm survey it was found that free range meat chickens are relatively restricted in their access to the outdoors; determined by their age and suitable weather conditions outside. This explains the lower probability of LPAI exposure in free range meat chicken farms compared to free range layer farms.

These output probabilities from the exposure scenario tree model are the probability of LPAI exposure to one commercial chicken farm at any point in time. In this project a commercial chicken farm was defined as a layer farm or meat chicken farm which houses more than 1000 chickens or 50,000 chickens, respectively. The farm survey results used in the scenario tree models reflects a range of flock size (ranging from 1,450 birds on a free range layer farm to 467,000 birds on a cage layer farm). There is epidemiological evidence that large flock sizes are at greater risk of HPAI introduction compared to small flock sizes (Thomas, Bouma et al. 2005). Whilst there is limited information to suggest that this is true for LPAI introduction, it is logical to acknowledge that larger flocks may have more wild bird contacts which may increase the risk of LPAI exposure. This will be explored further by Angela Scott (PhD candidate) subsequent to project completion to evaluate the influence of flock size on the overall probability of exposure by considering the number of sheds on a farm.

For exposure, the most influential input parameters related to waterfowl presence on the farm; particularly when the proportion of wild birds on the property are mostly waterfowl and these birds are around feed storage areas and waterfowl are on the range. Waterfowl on waterbodies was not a highly influential parameter due to the high proportion of farms that treat surface water and the low probability of aerosol transmission of LPAI from wild waterfowl on waterbodies to commercial chickens (Jonges, Leuken et al. 2015). However, waterbodies are an attractant for waterfowl and artificial waters such as dams are used extensively by waterfowl (Read 1999). It is possible for waterfowl on waterbodies to move to feed storage areas or the range of the farm. In order to effectively reduce the probability of LPAI exposure to Australian commercial chickens, efforts must be considered to ethically and effectively deter waterfowl from Australian chicken farms. Farm dams play an important role in water supply and irrigation in Australian agriculture and so the removal of open water sources can be of a great detriment to the farmer (Tingey-Holyoak 2014). In addition, covering open water sources as well as netting ranges is also cost prohibitive (Atzeni, Fielder et al. 2016). Recommendations from a critical review on the deterrence of wild waterfowl from Australian poultry production areas include maintaining optimal grass height, preventing grass going to seed, improving drainage on range areas and around sheds and prompt cleaning of feed spills around feed storage areas. Other more sophisticated options include the development of a 24/7 waterfowl monitoring system on farm and then trialling a range of cost-effective radar-activated on-demand auditory, visual or physical deterrent systems (Atzeni, Fielder et al. 2016).

The probability of direct exposure is more likely in free range farms as in general both chickens and wild birds including waterfowl can access the range area. For this project, direct exposure was defined as physical contact between a wild bird and a commercial chicken or direct contact between a commercial chicken and wild bird faeces.. When direct exposure occurs there is a greater probability that a chicken will be infected compared to indirect exposure (defined as a commercial chicken coming into contact with the virus through a medium i.e. through water, fomites or vectors), and this leads to a higher likelihood of LPAI infection occurring on free range farms.

In relation to season, the probability of LPAI exposure was estimated to be lowest in summer for all farm types, and was similar in winter and autumn/spring for free range meat chicken farms, highest in winter for free range layer farms and highest in autumn and spring for all other farm types. In comparison with actual months of HPAI outbreak occurrence in Australia, one Australian HPAI outbreak occurred in winter (July), four occurred in autumn and spring (May, October, November) and two occurred in summer (December and January). The three latest outbreaks that occurred in Tamworth 1997, Maitland 2012 and Young 2013 occurred in October or November (Swayne 2008, NSW Government 2012, Australian Government 2013). The mechanisms of mutation from LPAI to HPAI are poorly understood and are difficult to predict. In some overseas outbreaks, LPAI viruses have been detected in domestic poultry weeks or months prior to the subsequent HPAI virus outbreaks (Stech and Mettenleiter 2013). This may explain the Australian HPAI outbreaks that occurred in summer where the probability of LPAI exposure is estimated to be lowest compared to the other seasons. In this scenario, exposure may have occurred in spring instead, where the virus then circulated within the flock for months and mutation subsequently occurred in summer. On the other hand, Fusaro, Tassoni et al. (2015) demonstrated that some H7 LPAI subtypes can mutate quickly in order to adapt to the new host species.

The seasonal variations on the probability of exposure are influenced by the wild bird LPAI prevalence data and rules on outside weather conditions determining whether or not chickens can access range. Seasonal effects on the prevalence of LPAI within Australia do not appear to fluctuate as greatly as in the Northern hemisphere (Hansbro, Warner et al. 2010, Grillo, Arzey et al. 2015). In the northern hemisphere, there is generally a low prevalence of LPAI in winter, an increase in viral prevalence in summer followed by a peak in prevalence in autumn (Causey and Edwards 2008, Vandegrift, Sokolow et al. 2010). This contrasts with Australian data which reveals a high and low prevalence of LPAI in winter and summer respectively (Hansbro, Warner et al. 2010, Grillo, Arzey et al. 2015). In the northern hemisphere, the increased prevalence in summer is thought to be due to the progressive influx of immunonaïve juvenile waterfowl to the population following breeding in spring (van-Dijk, Hoye et al. 2014). In Australia, the breeding seasons and movements of native waterfowl species are less predictable; many populations are nomadic but do not migrate which contrasts with the waterfowl populations in the Northern hemisphere which are well known for their annual migrations over long distances. Movements and breeding of Australian waterfowl are instead largely determined by the distribution of surface water and rainfall (Tracey, Woods et al. 2004, Cooper, McAllan et al. 2014).

Spread scenario tree

The spread scenario tree model indicates a high probability of no establishment for all farm types (median probability range 0.89-0.96). This finding that it is most likely when one chicken is exposed to AI virus that the virus will fail to infect the exposed chicken or the virus will infect the exposed chicken but fail to spread to other chickens is supported by East, Ainsworth et al. (2010) where sentinel free range flocks in the Riverland areas of Victoria with 17 samples that tested positive for AI antibodies showed no evidence of chicken to chicken transmission. However, these results contrast with work performed at the Australian Animal Health Laboratory (AAHL) where chickens inoculated and subsequently infected with various LPAI subtypes were placed in direct contact with other chickens. All chickens in direct contact with these infected chickens subsequently became infected (Selleck 2015). In addition, the spread model assumes only one chicken on a farm is exposed to the virus; it is unknown how many chickens are exposed to LPAI virus over a production cycle on Australian commercial chicken farms.

For the small proportion of instances when AI establishment and spread was predicted by the model, it was shown that the different pathways of LPAI and HPAI spread between sheds have differing probabilities. For LPAI spread between sheds, equipment and vermin were the most likely pathways and aerosol was the least likely pathway. For HPAI spread between sheds, equipment and boots were the most likely pathways and vermin was the least likely pathway. This is largely due to differences in the survival or detection of the virus in these different pathways. For example, LPAI spread via aerosol is regarded as unlikely in the literature but detections of HPAI in air samples have been relatively frequently reported particularly during the 2015 HPAI outbreaks in the United States of America (USA) (Jonges, Leuken et al. 2015, McCluskey 2015). This is likely due to the higher levels of viral replication that occurs in the respiratory tract of birds with HPAI infection compared to LPAI infection (Swayne 2008). The relatively low probability of HPAI spread between sheds via vermin compared to higher probability for LPAI is likely due to the more information available in the literature on rodent inoculation with HPAI compared to LPAI. Feeding of flies with LPAI and HPAI resulted in similar not different proportions of positive virus isolations for LPAI and HPAI (Sawabe, Tanabayashi et al. 2009, Nielsen, Sovgard et al. 2011). Thus the pathway of shed to shed spread via vermin is possibly of the same importance for both LPAI and HPAI.

The input value probabilities for the farm to farm spread pathways were derived from expert opinion. The output probabilities from the farm to farm spread model on the differing pathways of spread largely reflect the expert opinion answers where relatively higher probabilities of farm to farm spread were given to pickup trucks, egg trays and egg pallets (Singh et al. 2016). These answers were largely influenced by the previous Australian HPAI outbreaks; an epidemiological investigation of the 2013 HPAI outbreak in Young, NSW suggested that the most likely route of spread of this virus to another farm was the contamination of cardboard egg trays (Roth 2014). Similarly, a dead bird pick-up vehicle which visited multiple farms was the only identifiable link between farms that were affected by the 1997 HPAI outbreak in Tamworth, NSW (Selleck, Arzey et al. 2002). This compares with an expert opinion elicitation workshop published in 2011 which asked the probability of HPAI spread between poultry farms to inform models simulating the transmission and control of HPAI epidemics in the Australian poultry industries. The results of this workshop showed that meat chicken pick up crews followed by slaughter crews, manure collection and cardboard egg trays were rated as the most likely probabilities of transmission between farms (Hamilton 2011). Differences in answers between these results and the more recently conducted expert opinion workshop are likely due to the fact that the 2012 and 2013 HPAI outbreaks had not occurred yet during the first expert opinion workshop.

It was difficult to estimate the probability of the different spread pathways of AI between farms due to the difficulty in obtaining the required information i.e. the survival of the virus on these pathways and the volume and frequency in which these pathways occur. For example, feed delivery vehicles, bird pick up vehicles and egg collection vehicles may all visit different farms and visit some farms more frequently than others. The extent of the complexity in obtaining information about the volume, frequency and types of contacts between farms was realised during this project. It was due to this difficulty that expert opinion answers were used to estimate these input parameters. The volume and frequency of each pathway occurring over a stated time period is not incorporated in the spread scenario tree model but is an important consideration as highly probable pathways may actually occur infrequently and vice versa.

For the instances when AI establishment and spread was predicted to occur, spread farm-to-farm is more likely for LPAI than HPAI for all farm types. This difference between LPAI and HPAI spread arises from differences in farmer detection and reporting of suspect disease due to the lower level of clinical disease in a LPAI infected flock compared to HPAI, and the time required for the virus circulating in a LPAI infected flock to mutate to HPAI. Clearly, given assumption of virus introduction as LPAI from wild birds made in this work, HPAI spread can only occur if AI virus mutates in the LPAI infected chicken flock to HPAI. Given the time period required for mutation to occur, the spread model found that HPAI spread is also more likely to occur on layer farms compared to meat chicken farms due to the longer production cycle length of layer flocks.

Considerations with scenario tree models

The scenario tree model methodology has provided quantification of probability of LPAI exposure to a commercial chicken flock, and of LPAI spread / HPAI spread given LPAI exposure to one chicken. It has identified which areas on-farm that should be the focus for biosecurity efforts to minimise the risk of exposure and spread of AI virus on commercial chicken farms.

The results are based on model inputs that were the best available information at the time of model development. We consider that the data from the on-farm survey was a sound basis for inputs related to farm management for commercial chicken farms in the Sydney basin, as was the wild bird AI surveillance data for AI prevalence in specific bird orders for the Sydney basin. However, there are a large number of uncertainties related to the mechanisms of the virus, particularly its behaviour in Australian commercial poultry settings. For example, susceptibility of chickens to LPAI H5 and H7 subtypes present in Australia via direct and indirect exposure pathways, and the ability of the subtypes to establish and spread in chicken flocks. In addition, the spread model assumes only one chicken on a farm is exposed to the virus; it is unknown how many chickens are exposed to LPAI virus over a production cycle on Australian commercial chicken farms. In order for model validation to occur, sampling of commercial chickens to determine their level of exposure to LPAI is needed.

The scenario models developed are limited in their ability to reflect risk over time. The exposure scenario tree provides probability of exposure estimate for one farm at a point in time. The spread scenario tree considers in effect, the probability of one occurrence for each pathway, and does not account for actual differences in frequency of occurrence for the different pathways.

Comparison of model results with poultry AI occurrence in Australia is a means to validate the model.

For the exposure scenario tree, the extremely low probability of exposure concurs with LPAI detections in Australia, of which there are only 15 in poultry since 1976 and only 2 on chicken only farms. These detections have been a result of passive surveillance (diagnostic submissions), active surveillance (during HPAI outbreaks) and incidental findings not associated with disease. The majority of these involved domestic duck flocks with five on combined duck and chicken farms; two on breeder duck farms; two on mixed breeder and meat duck farms; and two on duck meat farms. Of the remaining, two involved turkey meat farms and two breeder chicken farms. LPAI has never been detected on a meat chicken farm or on a chicken only layer farm in Australia (Arzey 2013). The exposure model considers commercial chicken farms only, thus comparison can only be made with the two LPAI detections in the breeder chicken farms as breeder chickens are effectively similar to layer chickens housed in barn systems that usually with good biosecurity (Scott, Turner et al. 2009). While it is likely that LPAI detections are underreported given they may be sub-clinical, it appears that LPAI infection of chickens is a rare event. Further research is warranted to provide data on AI virus characteristics and behaviour in an Australian context.

Further validation of these models requires some routine sampling of Australian commercial chicken farms for LPAI. However, farms with positive detections of the H5 or H7 virus via cloacal or oropharyngeal swabs must be depopulated and quarantine measures put into place as stated in the Australian Veterinary Emergency Plan (AHA 2015). In addition, all H5 and H7 virus detections must be notified to the World Organisation for Animal Health (OIE) (OIE 2014). Therefore serological surveys for antibody against LPAI could be used as an alternative testing mechanism. This has occurred in the Netherlands where all poultry farms are tested for evidence of seroconversion at least once a year and outdoor layer farms tested three to four times per year. This enabled information on the introduction rates between different farm types to be obtained (Gonzales, Stegeman et al. 2012). To date in Australia serology testing for this type of purpose has been limited to retrospective testing of small, sentinel free-range flocks located near waterfowl habitat and far from commercial chicken enterprises. Results from this work showed an extremely low introduction rate; from 2000 samples collected over eight years, 0.85% (17) samples tested positive for AI antibodies and 4.35% (87) were uncertain. It is likely that H5 and H7 subtypes only constitute a small percentage of these detections (East, Ainsworth et al. 2010). Although useful, this information cannot be confidently applied to commercial chicken enterprises due to stark differences in the number of birds in a flock, management practices and farm locations.

In relation to validation of the spread scenario tree results when establishment and spread is predicted, there is limited information to determine if shed to shed spread occurred on Australian LPAI infected farms. There is evidence that shed to shed spread may have occurred on two farms; specifically chickens in several sheds of one farm were seropositive to LPAI H6N2 in 2006 and LPAI H9N2 was detected in three sheds on a turkey farm in 2012 (DAF 2013). However, it is also possible independent introductions and infections occurred on the sheds of these farms instead of spread. There was only one case with evidence of farm to farm LPAI spread; a second turkey farm was identified with H9N2 during trace back surveillance initiated following the incident on the first turkey farm in 2012. This second turkey farm showed no clinical signs or increased mortality (Arzey 2013). For HPAI outbreaks in Australia, most had the virus spread to other sheds within the farm. However, all outbreaks were effectively controlled via the stamping out procedure and thus limited farm to farm spread occurred (Swayne 2008, NSW Government 2012, Australian Government 2013).

Branching process model

A stochastic branching process model was applied to consider the research questions at shed-level and at industry-level, including to consider how changes in industry structure are likely to influence the probability of HPAI outbreaks. This type of model is particularly robust when comparing the probability of disease outbreaks under different scenarios, and for assessing mitigation and response strategies aimed at reducing risk. Such models allow for distinct local conditions (such as different housing conditions between industry sectors), can take account of transmission at both local (shed) and global (farm and industry) scales, and can incorporate a continuous low-level risk of disease introduction.

In this work, due to the absence of Australian data on the frequency of LPAI introduction into commercial flocks and on AI transmission rates within sheds, between sheds or between properties; plus limited understanding of the mutation process from LPAI to HPAI, the model was used to provide a relative assessment such as to compare the relative probabilities between enterprise types (free-range or barn/caged, meat or layer). Uncertainty regarding input parameters was directly addressed through consideration of the full plausible range of values for the driving parameters. So while it is not possible to estimate the probabilities of LPAI or HPAI outbreaks in Australia with confidence because of these knowledge gaps, the model results inform understanding of credible differences, but the magnitude of difference must be interpreted with caution given the lack of knowledge about AI virus behaviour in chickens in the Australian commercial industry context. By design, the model provides a general understanding of how free-range access, production cycle length, the size of enterprise-type sectors and specific farming practices, likely impact on the probability of HPAI outbreaks in the Australian chicken industry.

For the Australian industry, the model has demonstrated that the probability of LPAI establishment is not very different between meat and layer sectors (when the number of farms in each sector is considered), and is higher in free-range enterprises compared with barn or caged systems. However the probability of HPAI outbreaks is influenced most by the production-cycle length with a longer production period driving the persistence of LPAI, and increasing the probability of mutation to HPAI. This shows the importance of restocking practices on the probability of persistence of LPAI in a shed. Under both chicken meat farm types, restocking results in interruption of LPAI spread, whereas there is an approximately 48% chance that LPAI persists for over 150 days for layers, regardless of farm type or the number of age cohorts in the shed. For low virus transmission rates, there is a far greater probability of an HPAI outbreak in the layer sector than the meat sector, although there is little difference between these probabilities for the different sectors when transmission rates are high.

A key question of this project investigated using the branching process model was the influence of the proportion of free range farms on the probability of a HPAI outbreak. The finding that the increase in HPAI outbreak probability relative to current probability only reaches moderate (below 50%) when free range farms constitute most/all of the industry may be counter to expectation. The respective contributions of the layer and meat sectors to the low to moderate increase in HPAI outbreak probability were influenced by virus transmission rate being virtually all the layer sector at low transmission rates, and with an increasing contribution from meat sector approaching parity at higher transmission rates. This finding reinforces the complex interplay of factors (virus characteristics and behaviour in chickens, production cycle, management system, number and type of farms) that influence the probability of a HPAI outbreak for the chicken industry in Australia.

For the evaluation of mitigation impact by consideration of specific pathways, this model was able to facilitate comparison that incorporated consideration of layer and meat sector sizes and differences between farm types, and was not dependent on virus introduction rates, and marginally dependent on within-shed transmission rates. The inputs for relative contribution of different pathways were drawn from the scenario tree analyses, and thus the results are highly dependent on these pathway proportions which have associated uncertainty. Overall use of the model for this purpose provided a robust means of understanding how proportional reductions in pathway risk by enterprise type can affect the probability of HPAI outbreaks across the Australian industry. The results definitely showed that the use of untreated surface water remains the most risky pathway for LPAI introduction and thus for a critical mitigation to reduce the likelihood of a HPAI outbreak for the chicken industry. The current high level of adoption of water treatment for drinking water and for environmental control across farms in the on-farm survey is thus absolutely essential to safeguard the industry and must be extended to ensure adoption by all farms. Feed spillage, a pathway identified by this project, was found to be the pathway of highest risk in the current industry context in which the majority of farms are implementing water treatment.

At the National Forum industry stakeholders asked that this model be used to investigate the impact on HPAI outbreak probability of variation in production-cycle length (such as a a shorter and longer grow out period for meat chickens). The results of this application are not yet complete and will be presented in a forthcoming research paper.

These results illustrate relative interaction characteristics between the system drivers that are consistent across the plausible introduction and transmission rate intervals considered. But to provide precise risk estimates for Australia by industry sector, the nature of LPAI introduction and transmission rates in domestic flocks need to be quantified. This requires the current knowledge gaps about the exposure of commercial chickens to Australian LPAI subtypes and the ability of these viruses to infect and spread among chickens to be filled. We understand that data are currently available from sentinel flocks in the Riverland area of Victoria that could provide an understanding of LPAI introduction, virus subtype (H5 and H7) transfer probabilities, and within flock transmission rates. Research using this data would extend on the work done by East et al (2010), lead to a more rigorous assessment of risk for the Australian poultry industry and could make a significant contribution to national and international poultry biosecurity research. Data on similar sentinel chicken flocks in NSW may also considered for use in this investigation.

Implications

The work conducted by this project has implications for approach and action at farm and at industry level, and for future activities in relation to industry guidelines and to research.

In order for these implications to be realised and acted on requires stakeholders to view Phase 1 project findings as credible and Phase 2 activities and outcomes as worthwhile and a mandate for action.

The Phase 1 research findings have been discussed with a number of industry and scientific audiences (Table 1). Mostly the results were considered to agree with prior knowledge, and to be of value because they add rigor and relative quantities to our understanding of the differences in risk of avian influenza between farm types and of the relative contribution of different exposure and spread pathways, thus aiding prioritisation of biosecurity practices to mitigate AI risk. Feedback that has queried aspects of model assumptions, structure or input parameters has identified further work that can be conducted to strengthen credibility of results and usefulness to industry (such as consideration of flock size for the exposure scenario tree and use of branching process model to investigate variation in production cycle length).

During Phase 2, the implications of Phase 1 findings for biosecurity practice on-farm and for collective perception and action by sector and as a livestock industry, were discussed at gatherings with industry that involved industry leaders, farmers and farm advisors. The majority of participants at the gatherings identified practices or viewpoints that could be improved or informed by the study results, and endorsed the proposal of recommended changes to the generic biosecurity manual, and subsequently changes to manuals and QA programs for specific farm types by each industry sector.

Table 1 List of industry and scientific conferences and meetings at which Phase 1 methods and results were presented during 2015-2016

National Avian Influenza Wild Bird Steering Group Meeting	September 2015	J-A Toribio, A Scott
Australian Poultry Science Symposium	February 2016	A Scott
Spatially Enabled Livestock Management Symposium	March 2016	A Scott
Poultry Information Exchange	May 2016	M Singh, A Scott
Australian Poultry Veterinarian Association	May 2016	A Scott
National Science Exchange	June 2016	B Barnes
Australia / New Zealand College of Veterinary Scientists Conference	July 2016	A Scott
AI Risk Mitigation National Forum	August 2016	A Scott, M Hernandez-Jover, B Barnes
National Avian Influenza Wild Bird Steering Group Meeting	September 2016	J-A Toribio, A Scott, K Glass
Elizabeth Macarthur Agricultural Institute Seminar	October 2016	J-A Toribio, A Scott
Australia-New Zealand Society of Risk Analysis Conference	November 2016	A Scott
South Australia World Poultry Industry Day	November 2016	A Scott, C Jakson
AI Risk Mitigation Workshops on Farm Biosecurity – total of six workshops	November-December 2016	A Scott, C Jackson

Commercial poultry farms

Biosecurity practices vary across the meat chicken and egg farms in the Sydney Basin, and are likely to also vary in other areas of the country. The high level of biosecurity found in barn and free range meat chicken farms is notable and continuing high levels of compliance must be supported by this industry sector. Meat chicken industry investment in an integrated and audited system acts as insurance for food safety and disease prevention purposes. For the layer sector, the lower level of biosecurity compliance suggests that this sector needs more collective initiatives to support understanding and adoption. The existence of older layer farms with less biosecure sheds in the Sydney Basin, several of which participated in the on-farm survey, highlights the need for minimum standards in layer shed design to be defined and applied across this industry sector.

One farm that is not adhering to highly influential biosecurity practices (such as adequate treatment of surface water) places their farm at risk of a HPAI outbreak, and poses a risk to industry at large due to the potential for spread. Although at a point in time outbreak probability may be low/extremely low, persistent non-compliance will accumulate risk and thus elevate the risk over time. This type of behaviour should not be condoned by industry and should be monitored in some manner on corporate farms and on independent farms. It may become necessary to evaluate compliance with the biosecurity requirements under the Emergency Animal Disease Response Agreement (EADRA) and/or non-compliance with state biosecurity legislature as to whether penalties need to be applied.

The fact that there were farms across all farm types not complying with highly influential biosecurity practices shows a need to focus on producer education across all farm types with continued or increased industry investment on enhancement of adoption. It was recognized repeatedly during Phase 2 that essential biosecurity practices must be able to be adopted and need to have a cost/benefit analysis undertaken and explained to producers. Although not stated explicitly at the forum, it appears that economic evaluation of alternate approaches to achieve essential biosecurity such as deterring wild birds from the range is an area for further research. In addition for the layer industry that had the higher levels of noncompliance, research is warranted to further investigate current practices and the factors motivating and hindering biosecurity adoption.

Minimising waterfowl presence on farm was identified as a highly influential biosecurity practice to mitigate LPAI exposure. Deterring wild waterfowl requires avoidance of water and of food sources that will attract these wild birds to the farm. This particularly relates to waterfowl presence on and around water sources that are used by the farm, and to their presence in areas accessed by chickens such as the range on free range farms, and including feed storage areas and feed spills that escaped chickens will be attracted to similar to wild birds. The literature cites for deterrence of waterfowl actions such as maximal grass height around shed and range areas, preventing grass going to seed, improving drainage on range areas and around sheds and prompt cleaning of feed spills around feed storage areas. Systems for 24/7 waterfowl surveillance at high risk areas on farm (eg dam surface and surrounds) are under investigation including the evaluation by Atzeni et al (2016) that is trialling a range of cost-effective radar-activated on-demand auditory, visual or physical deterrent systems.

Commercial chicken industry

This work shows that all sectors of the Australian commercial chicken industry contribute to current industry risk of a HPAI outbreak. When sector size in terms of farm number is considered, the risk of LPAI introduction and establishment on free range farms is only approximately twice that of other farms. Furthermore, an increasing proportion of free range farms will lead to some but not substantial increase in probability of a HPAI outbreak with respective contribution to this increase from free range layer sector and free range meat sector linked to virus transmission rate, which at present is not understood for Australian AI subtypes H5 and H7.

Recognition that HPAI outbreak risk is a shared risk, not a risk arising solely from one sector of the industry, means that AI prevention to protect the industry is a shared responsibility. Collaboration between industry sectors on efforts to educate farmers and support enhanced biosecurity on farm is needed. Animal Health Australia has a role to facilitate such collaboration.

Estimated higher relative risk of a HPAI outbreak following LPAI establishment on a layer farm compared to a meat farm, even after adjustment for differences in farm number, arises from the difference in production cycle length rather than differences in farm management. Quantification of this difference in risk between layer and meat sectors is severely limited by the lack of understanding about transmission of Australian AI subtypes H5 and H7 and mutation of AI viruses in general. Thus the estimates of relative risk of HPAI outbreak from this work should only be viewed as an indication of difference. This finding does not absolve the meat sector from responsibility to contribute to collective efforts on biosecurity education, adoption and monitoring.

Consultation about our research findings with industry and government stakeholders identified that this work can inform changes to the generic biosecurity manual, and that these changes should then be applied to biosecurity manuals and QA programs utilised by the respective chicken layer and chicken meat industry sectors, and also the duck and turkey industries.

This work, focused on the commercial chicken industry, did not consider the non-commercial chicken industry with smaller size flocks. Thus no comment can be made regarding comparative risk for HPAI outbreak between these industries. Previous work by Hernandez-Jover at al. (2010) that did compare commercial (over 1,000 birds) and non-commercial (100 to 1,000 birds) poultry farms in Australia estimated a higher risk for LPAI introduction to non-commercial farms, but similar risk of AI virus spread for the first infected farm to other farms for commercial and non-commercial farms.

For the Australian chicken industry to obtain precise estimates of AI risk, rather than the relative assessment provided by this work, it is essential that knowledge about Australian LPAI subtypes be improved particularly their ability under realistic conditions to infect chickens and to spread between chickens, and factors that foster mutation to HPAI. Currently, while the modelling results and the history of HPAI outbreaks in Australia indicate that periodically Australian commercial chicken flock/s are LPAI infected but that the virus does not establish, there is no surveillance to estimate LPAI infection of commercial flocks due to implications of H5 or H7 identification and notification under state legislature.

Response to AI outbreak

Current policy under the AUSVETPLAN (Animal Health Australia (AHA) 2011) is to destroy all birds on a farm where there is clinical disease or evidence of active HPAI infection, and undertake sanitary disposal of culled birds and avian products to eliminate infection sources on farm. The extent of infection on a HPAI infected farm at the point of detection using standard industry mortality levels demonstrated by the branching process model supports this policy. With almost absolute certainty, by the time mortality levels trigger investigation, HPAI will be present on multiple sheds on a HPAI infected farm, and destruction of all birds on the farm is definitely the most appropriate action to eliminate infection and halt spread.

Recommendations

There are recommendations from this project for consideration by the industry at large, by individual farmers, and by specialist research providers.

Revision to National Farm Biosecurity Manual Poultry Production[3]
This project recommends revision of the DAFF (2009) biosecurity manual for the poultry industry and provides as a specific output detailed recommended revisions that will provide an updated, contemporary manual that reflects the changing poultry industry structure and current understanding of biosecurity relevant to AI risk in the midst of other poultry health and food safety risks (Appendix E). The revised generic manual would be suitable for the industry sectors to use to revise their specific manuals.

It is understood that the recommended revision will be considered during 2017 by AHA and the peak industry bodies in the consultation process to prepare and publish a new version of this generic biosecurity manual.

Consultation and collaboration to address shared risk
This project, having identified biosecurity non-compliance across all farm types and estimated a level of HPAI outbreak risk for all farm types, recommends that this shared risk be viewed as a shared responsibility and responded to through an ongoing process of consultation and collaboration. While this work considered only the chicken industry, the susceptibility of ducks and turkeys requires that collaborative action should also involve these poultry industries.

Collaboration is needed on biosecurity manuals (as stated above) and on education programs to support enhanced on-farm biosecurity for farmers. Animal Health Australia has a role to facilitate such collaboration.

It is recommended that the standard industry mindset, in relation to recognition of this shared AI risk, be that:

- Waterfowl are assumed to be LPAI infected and farmers act to minimise water fowl presence on farm
- Chicken flocks are viewed as potentially LPAI infected and farmers adhere to biosecurity practices to prevent virus spread.

This mindset and the subsequent biosecurity implemented will also protect flocks from other endemic infectious diseases.

On-farm biosecurity

On the basis of the findings of this project, the on-farm biosecurity practices that are particularly recommended to mitigate AI risk are the following.
To prevent AI virus entry to flock

- Ensure that all water used for drinking and for environmental control is adequately treated to ensure that viable AI virus is not present.
- Minimise waterfowl presence on farm such as on and around water sources that are used by the farm, and presence on the range on free range farms, and around feed storage areas on all farms.
- Prevent wild bird entry to sheds.
- Clean up feed spills immediately to avoid attracting wild birds.
- Do not return chickens that have escaped from shed or range to the flock.
- No other poultry species aside from chickens kept on farm.

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[3] DAFF (2009) National Farm Biosecurity Manual Poultry Production. DAFF, Canberra. Available at: http://www.agriculture.gov.au/pests-diseases-weeds/protect-animal-plant/bird-owners/poultry_biosecurity_manual

To prevent AI virus spread from an infected shed to other sheds on farm

- Equipment should not be shared between sheds.
- Shared equipment must be cleaned and disinfected prior to use in another shed.

To prevent AI virus spread from an infected farm to other farms

- Thorough decontamination of trucks and chicken crates used for live bird and dead bird collection.
- Trucks used for dead bird disposal should not enter onto the farm.
- For layer farms only, egg trays and egg pallets should be dedicated to the farm and where this is not possible should be made of materials that can be effectively decontaminated and routinely cleaned and disinfected, or made of new disposable materials with only single use.

To support farmer awareness and understanding of these recommended on-farm biosecurity practices, draft posters will be provided to Animal Health Australia for further development, publication and distribution in consultation with peak industry bodies.

Research

This project provides substantial justification for further research on specific issues.

1. Cost-benefit analysis to evaluate alternate approaches to deter wild bird presence (particularly waterfowl) on water bodies, and on range and feed storage areas on farm.

2. Investigate of current biosecurity practices implemented on layer farms and of the factors motivating and hindering biosecurity adoption. This is to address the notably higher levels of noncompliance on layer farms identified by this project.

3. Exposure scenario tree model to be used to investigate the impact on LPAI exposure of variation in flock size and number of sheds on-farm.

4. Branching process model to be used to investigate the impact on HPAI outbreak probability of variation in production-cycle length.

5. AI risk models developed in this project should be further developed to investigate risk for duck layer and duck meat farms in Australia.

6. LPAI introduction and transmission rates in chickens for LPAI H5 and H7 subtypes present in Australia
   Approaches to investigation of this issue that should be considered include the following.

   - Extend on the work done by East et al (2010), by investigation of data from sentinel flocks in Victoria and New South Wales to improve understanding of LPAI introduction, virus subtype (H5 and H7) transfer probabilities, and within flock transmission rates. If there is inadequate data available on LPAI spread between chickens in sentinel flocks due to current management and testing protocols, collaborate with Health and Agriculture to implement modified protocols that enables monitoring of serological status of a sentinel flock after identification of LPAI exposure.

   - Establish a serum bank of samples collected at slaughter from chickens belonging to higher exposure risk flocks (such as free range layer flocks) and at an agreed time post-sample collection investigate the LPAI serological status of these samples. Ensure an adequate number of birds sampled per flock to enable prevalence estimate to be calculated for any flock found to contain birds exposed to LPAI. For sampled flocks, collect information on flock size, production and management that will support investigation of factors associated with LPAI flock status.

7. Review and evaluation of systems for LPAI surveillance in commercial flocks and non-commercial flocks in other countries with equivalent poultry industries (such as The Netherlands, Canada, USA).

Acknowledgements

This project was conducted within the Poultry CRC with support from Woolworths Limited.

Sincere thanks to egg and chicken meat companies and producers, and to the experts for their participation. The guidance of the Steering Committee throughout all stages of the project was essential and is acknowledged with sincere appreciation.

For aspects of the Phase 1 research, specialist knowledge was generously provided by Frank Ball, Iain East, Jose Gonzales, Tiggy Grillo, Sam Hamilton, David Phalen, Andrew Robinson and Frank Wong. Further we were fortunate to be provided with access to relevant data for New South Wales by NSW DPI and by the National Avian Influenza Wild Bird program.

This Final Report was written by Jenny-Ann Toribio and reviewed by Peter Groves, Clive Jackson and Angela Scott.

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List of appendices

The following appendices were submitted to Smartsheet with this Final Report.

These are not for public distribution with the Final Report as they either contain material that will be submitted for journal publication (Appendix A & B), have already been distributed in full or in part (Appendix C in full to participants of the National Forum, Appendix D in part to participants at regional workshops), or are to be submitted to Animal Health Australia for consultation process with industry stakeholders re biosecurity manual and communication tools (Appendix E & F).

Appendix A	Report – Scenario tree models – prepared by Angela Scott
Appendix B	Report – Branching process model – prepared by Belinda Barnes and Kathryn Glass
Appendix C	Report – AI Risk Mitigation National Forum 23 August 2016 – prepared by Clive Jackson, Jenny-Ann Toribio, Peter Groves and Michael Williams
Appendix D	Report – AI Risk Mitigation Workshops on Farm Biosecurity – prepared by Clive Jackson
Appendix E	Report – Recommended revision to DAFF 2009 National Biosecurity Manual – prepared by Clive Jackson
Appendix F	Communication tools – Brochure for APSS & APVA conferences + Posters for farmers – prepared by Clive Jackson

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POULTRY CRC

Plain English Compendium Summary

Sub-Project Title:	**Avian Influenza Risk Mitigation for the Free-Range sector of the Australian Poultry Industry**
Sub-Project No:	1.5.7
Researcher:	Sub-project leaders - Jenny-Ann Toribio & Peter Groves, University of Sydney
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Sub-Project Overview	
Background	The poultry industry in Australia faces a somewhat unique situation in relation to avian influenza (AI). Here, unlike the situation in Europe and North America, the threat of an AI outbreak arising from low pathogenic AI viruses circulating in native wild birds is considered higher than the threat due to introduction of an exotic highly pathogenic AI virus by migratory birds. Consumer demand has led to a change in industry structure with a substantial increase in the number of free range farms. This increase in free range management may increase the potential for AI outbreaks involving non-exotic AI virus. This project was undertaken to 1) Address gaps in current knowledge about likelihood of non-exotic AI virus introduction to commercial poultry kept under free-range and non-free-range management in Australia, 2) Consider on-farm biosecurity to mitigate AI introduction and spread, and 3) Consider how new knowledge may be incorporated into industry biosecurity guidelines.
Research	Phase 1, the research phase, involved conduct of an on-farm survey, wildlife camera surveillance on farm, expert opinion elicitation, and development of three models used to quantify the risk of AI virus introduction to a commercial chicken farm and spread from one infected farm to other farms. Phase 2 focused on extension of this new knowledge and included discussion of the Phase 1 findings and implications for industry with a range of industry players at a National Forum and regional workshops hosted by the project, and preparation of proposed revisions to industry biosecurity guidelines.
Sub-Project Progress	Completed
Implications	The work conducted by this project has implications for approach and action at farm and at industry level, and for future research. For these implications to be acted on requires stakeholders to view Phase 1 project findings as credible and Phase 2 activities and outcomes as worthwhile and a mandate for action. Consultation with industry regarding Phase 1 results found that the results were generally considered to agree with prior knowledge, and to add rigor to understanding of the relative differences between farm types in relation to the risk of avian influenza virus (AIV) introduction to a commercial chicken farm, and the risk of AIV spread from one infected farm to other farms. This work showed that all sectors of the Australian commercial chicken industry contribute to current industry risk of a highly pathogenic AI (HPAI) outbreak. Thus AI outbreak risk is a shared risk and AI prevention to protect the industry is a shared responsibility. Collaboration between industry sectors on efforts to educate farmers and support enhanced biosecurity on farm needs to be strengthened. The project produced detailed recommended revisions to the DAFF (2009) biosecurity manual for the poultry industry to provide an updated manual that reflects the changing poultry industry structure and current understanding of biosecurity relevant to AI risk. Model outputs were limited by a lack of knowledge on AI virus transmission. For the Australian chicken industry to obtain precise estimates of AI risk, rather than the relative assessment provided by this work, it is essential that knowledge about Australian LPAI subtypes be improved. Industry and government need to consider research and surveillance activities that will address this critical knowledge gap, given the existing implications of H5 or H7 identification on-farm under state legislature.
Publications	Jackson et al.(2016) Report of Stakeholder Forum “Avian Influenza Risk Mitigation for the Australian Poultry Industry – A National Forum”, 23 August 2016, Mascot, Sydney. Six journal papers in preparation for submission to international journals.