APPENDIX A: Epidemiology Modeling Addendum

Scenario Description

Table A1. Summary of differences between the scenario with business continuity measures and the scenario without business continuity measures implemented.

Activities in the Control Area	Scenarios	
	Business Continuity	Non Business Continuity
Movements of nest-run shell eggs to locations outside of the Control Area	Permitted for premises determined to not be infected following daily testing (consistent with SES[1] Plan) and following a 2-day holding period.	Prohibited. Any premises located within a Control Area must maintain a stop movement order whether or not infection has been detected on the premises.
Movements of other egg products to locations outside of the Control Area	Permitted for premises determined to not be infected following daily testing by rRT-PCR (consistent with SES Plan) and following a 2-day holding period.	Prohibited. Any premises located within a Control Area must maintain a stop movement order whether or not infection has been detected on the premises.
Movements from premises of other poultry sectors to locations outside the Control Area	Low risk and high risk indirect contacts permitted.	Low risk and high risk indirect contacts permitted.
Detection of infected premises	Daily testing by rRT-PCR (consistent with SES Plan) for layers. Every other day testing for other sectors inside the Control Area. Detection by mortality threshold outside the Control Area.	Every other day testing by rRT-PCR in the Control Area. Detection by mortality threshold outside the Control Area.
Probability of transmission (biosecurity effectiveness)	Reduced to reflect compliance with biosecurity measures outlined in the SES Plan.	Reduced (but to a lesser extent than the business continuity scenario) to reflect increased producer awareness and education following detection of infection of HPAI in the United States

[1]Secure Egg Supply

Population Dataset

Disease spread in InterSpread Plus is simulated at the flock level. Each flock in the population dataset has an associated geographic location, production type, and number of birds. This study uses actual commercial flock locations and numbers of birds derived from a database of registered flocks obtained from the Minnesota Pollution Control Agency (MPCA). A total of 895 flocks, representing approximately 55.7 million birds, are included in the dataset. Data from MPCA came with information that could be used to classify the operations into general categories of broiler, layer, and turkey operations. Subclasses within those groups were determined through subject matter expert consultation to determine the numbers of each commercial production type (Table A2). Simulated outbreaks begin in one layer flock which is selected at random.

Table A2. Descriptions of the production types assigned to premises in the HPAI simulations.

Production Type	Description
Broiler breeder pullet	Pullets 1 day of age to 18 weeks of age which replace broiler breeder parent stock
Broiler breeder	Parent stock 18 weeks to 60 weeks of age which supply fertile eggs to be hatched for grow-out
Broiler	Meat chickens 1 day of age to 50 days of age being raised for slaughter
Layer pullet	Pullets 1 day of age to 18 weeks of age being raised to replace egg laying stock
Layer	Birds 18 weeks to 2 years of age laying infertile eggs
Turkey breeder brooder	Parent stock age 1 day to 6 weeks which supply turkey breeder grow-out
Turkey breeder grow-out	Parent stock age 6 weeks to 30 weeks which supply turkey breeders
Turkey breeder	Parent stock age 30 weeks to 60 weeks which supply fertile eggs to be hatched for grow-out
Turkey brooder	Meat-type turkey poults one day of age to six weeks of age to be moved to a turkey grow-out operation
Turkey grow-out	Meat-type turkeys 6 weeks of age to 20 weeks of age being raised for slaughter

Disease Spread Parameters

InterSpread Plus is a state transition model; therefore, each flock exists in a particular disease state (i.e., susceptible, infected, depopulated) at a given time step in the model. A flock transitions through the disease states over the course of a simulation based upon user-defined input parameters (Stevenson et al. 2013).

The model simulates disease spread via movement of birds (direct contact), movement of people, vehicles, and other fomites (indirect contact), and local area spread (i.e., spread associated with distance between premises not attributable to a specific mechanism). Due to all-in/all-out management practiced by the commercial poultry industry, only three forms of direct contact occur in the model: movement of spiking roosters between broiler breeder premises, movement of layer pullets to layer premises, and movement of turkey brooders to turkey grow-out premises.

To define indirect contacts, 27 types of visitors to commercial poultry operations were identified and classified into low-risk (i.e., visitors to premises that are unlikely to enter poultry barns), high-risk (i.e., visitors to premises that may enter poultry barns), movement of nest-run shell eggs, and movement of other egg products. Low-risk and high-risk indirect contacts are defined separately to reflect differences in probabilities of transmission. Nest-run shell eggs and other egg products were defined separately so that their impact on the outcomes could be examined.

Movements in the simulation model are stochastic, following Poisson distributions with user inputted means (Table A3). The mean contact frequencies are defined by determining the number of production cycles per year and the number of times each type of contact would occur

during a production cycle through a combination of subject matter expert consultation and literature review.

Table A3. Mean number of contacts per day moving off of source premises. Parameter values for movement frequencies reflect the characteristics and producer practices in the study region.

Production Type	Movement frequency off of premises (movements/day)				
	High risk indirect contacts	Low risk indirect contact	Nest-run shell eggs	Other egg products	Direct contacts
Broiler breeder pullet	0.16	0.28	n/a	n/a	n/a
Broiler breeder	0.58	0.27	n/a	n/a	0.005
Broiler	0.19	0.37	n/a	n/a	n/a
Layer pullet	0.18	0.30	n/a	n/a	0.007
Layer	0.32	0.49	0.32	0.114	n/a
Turkey breeder brooder	0.45	0.24	n/a	n/a	n/a
Turkey breeder grow-out	0.46	0.42	n/a	n/a	n/a
Turkey breeder	0.58	0.41	n/a	n/a	n/a
Turkey brooder	0.45	0.24	n/a	n/a	0.02
Turkey grow-out	0.46	0.42	n/a	n/a	n/a

n/a denotes not applicable.

Biosecurity/Probability of Transmission

The probability of transmission in InterSpread Plus represents the combined likelihood that contacts leaving infected premises are infectious and the likelihood of transmission to susceptible birds. In these simulations, the probability of transmission in Control Areas was varied to reflect biosecurity effectiveness. Enhanced biosecurity measures described in the SES Plan are represented in the model by decreasing the probability of transmission given indirect contact. The probability of transmission was also reduced following detection of infection in the nonbusiness continuity scenario, but to a lesser degree. This reduction represents improved biosecurity effectiveness that is assumed to take place as awareness increases following detection of infection in the area. Data are scarce to quantitatively develop parameters to represent the

probability of transmission/biosecurity effectiveness and to estimate the degree to which enhanced biosecurity measures would affect the probability of transmission.

To address this uncertainty, three levels of reduction in the probability of transmission were developed for business continuity and no business continuity scenarios (Table A4). For example, the probability of transmission for nest-run shell eggs contact was based upon the estimates from Ssematimba et al. (2013). The scenarios for the level of reduction in the probability of transmission in a Control Area were then selected based on informed judgment and considering the mitigation risk measures qualitatively evaluated in proactive risk assessments. The impact of this uncertainty on transmission model results was explored by simulating scenarios with the three levels of probability of transmission and visually comparing the resulting number of infected farms at the end of the simulations (Figure A1). Based on Figure A1, the three variations in probabilities of transmission within each of the business continuity and no business continuity scenarios did not appear to have a large impact on the number of infected farms.

Table A4. Percent reduction in probability of transmission for contacts originating from premises located in Control Areas with business continuity measures and with no business continuity measures implemented.

Movement type	Percent reduction from baseline probability of transmission					
	Business continuity			No business continuity		
	Low	Medium	High	Low	Medium	High
High risk indirect	83%	87%	91%	79%	83%	87%
Low risk indirect	67%	72%	76%	61%	66%	70%
Nest-run shell eggs	80%	90%	100%	10%	20%	30%
Other egg products	90%	95%	99%	10%	20%	30%

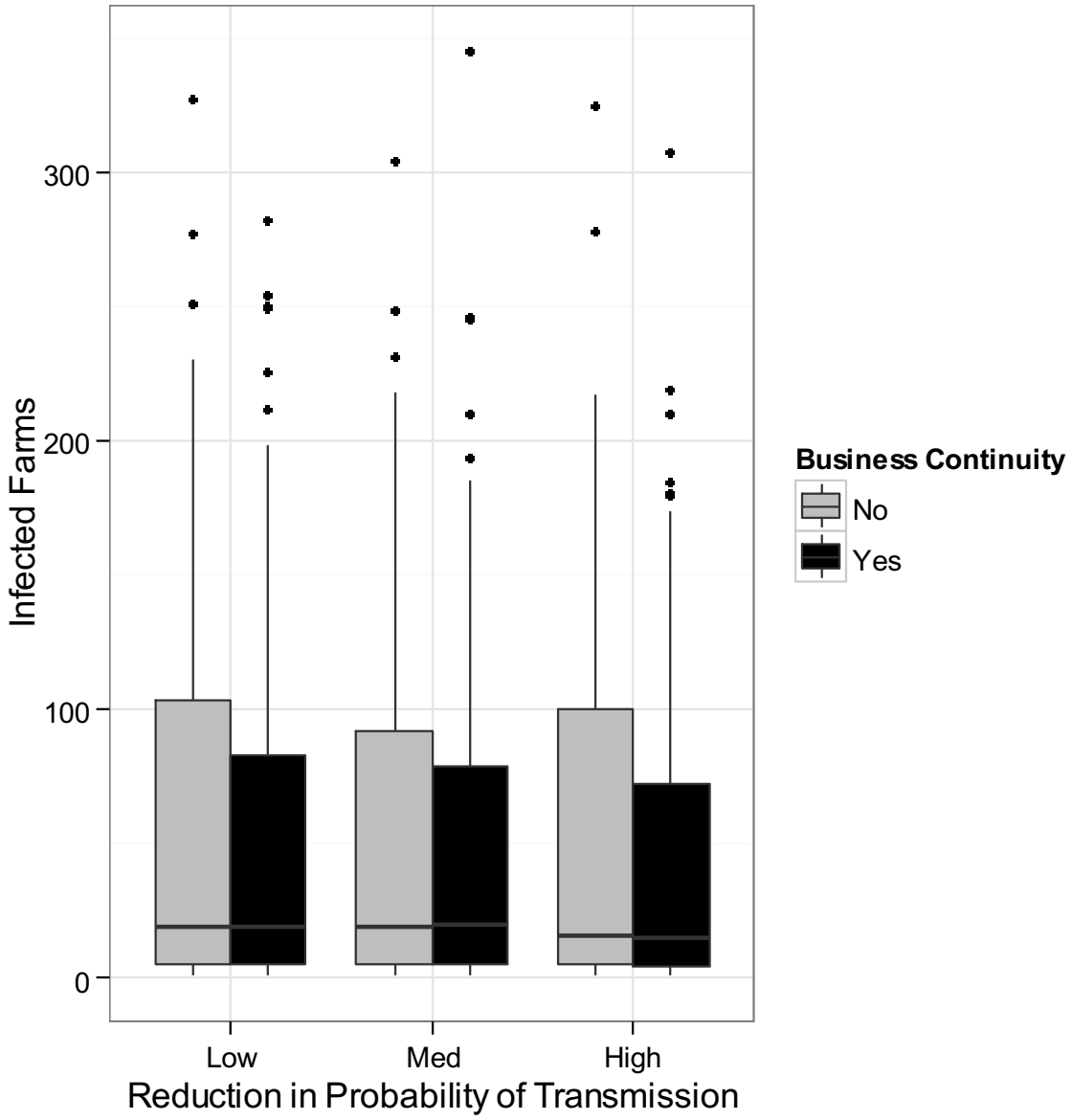

Figure A1. Distributions of the numbers of infected farms resulting from simulations with three levels of probabilities of transmission for both business continuity and no business continuity scenarios. The values for probabilities of transmission used in the scenarios are provided in Table A4.

Detection

Passive and active surveillance were simulated to detect infected premises. Passive surveillance applies to the entire study population during the period prior to initial detection of disease and to

premises located in the Free Area (i.e., outside a Control Area) after initial disease detection.

Active surveillance applies to premises located within Control Areas.

Table A5. The probability of detection of infected premises given the number of days since infection.

Surveillance	Probability of Detection	
Passive	Derived using a mortality threshold trigger (0.5%) applied to output from a separate within-flock disease spread model (Malladi et al. 2015). [1]	
Active	Derived from a within-flock disease spread model assuming testing by rRT-PCR (rather than a mortality threshold trigger) (Malladi et al. 2015) .[1]	
	Business Continuity Scenario Table-egg layer premises located within Control Areas: daily testing by rRT-PCR consistent with protocol outlined in the SES Plan. Premises from other sectors of the poultry industry located within Control Areas: every other day testing.	*No Business Continuity Scenario*[2] All premises located within Control Areas: every other day testing.

[1] Infectious and latent periods for the within flock model were based on the 1983 Pennsylvania HPAI H5N2 virus strain. An effective contact rate of Uniform (1-5) contacts per day was used.
[2] Consistent with protocols outlined in the USDA HPAI RedBook.

Control

With the exception of movement of egg products as explained above, the same control measures were implemented in both the business continuity and nonbusiness continuity scenarios with parameters following guidelines outlined in the USDA HPAI RedBook. Infected, detected premises were quarantined, and circular zones with 10-km radii were created around them. The frequencies of direct and indirect contacts for other premises located within these Control Areas were reduced. Trace investigations were simulated to identify other premises having had direct or indirect contact with infected, detected premises. Infected, detected premises were depopulated.

Works Cited

Malladi, Sasidhar, Kelly A. Patyk, Tim Boyer, J. Todd Weaver, and Jada Thompson. 2015. "Simulating the Spread and Control of HPAI among Poultry: Analysis of Intervention Options for Business Continuity Planning." In . Merida, Mexico.

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Stevenson, M. A., R. L. Sanson, M. W. Stern, B. D. O'Leary, M. Sujau, N. Moles-Benfell, and R. S. Morris. 2013. "InterSpread Plus: A Spatial and Stochastic Simulation Model of Disease in Animal Populations." *Preventive Veterinary Medicine* 109 (1): 10–24. http://www.sciencedirect.com/science/article/pii/S0167587712002899.