USDA

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Modeling Alternative Control Strategies for HPAI

What is the Issue?

Controlling a highly contagious disease such as highly pathogenic avian influenza (HPAI) requires a multifaceted approach, leveraging changes in animal movements and depopulation strategies to limit disease spread while eliminating the virus in domestic poultry populations. Many tradeoffs exist during the emergency response process due to limited resources and the availability of personnel, and it is important to consider the overall epidemiologic and economic impact when implementing any control strategy. Veterinary Services (VS) has evaluated a variety of control options for HPAI, should the disease return in fall 2015 in a widespread outbreak involving multiple States and production sectors.

What Did the Study Find?

- Improvements in depopulation capacity alone offer limited reductions in disease spread, unless delays in bird disposal are also addressed. Under the baseline depopulation and disposal times, depopulation capacity was only inadequate for the largest simulated outbreaks (greater than the 75^{th} percentile for number of infected flocks) and resulted in significant delays in depopulation. All enhanced depopulation capacities explored in this analysis allowed most farms to be depopulated within 24-48 hours.
- Strategies that target multiple aspects of the disease control process—depopulation, disposal, detection, and prevention—showed the greatest impact on reducing outbreak size and duration.
- In order to reach a marked reduction in producer losses due to HPAI, depopulation and disposal capacities must both be at the current outbreak's highest implemented level combined with improved detection and biosecurity in each of the poultry sectors. Producer losses with these improvements could decrease by 37 percent compared to the base outbreak, and indemnity costs decrease by 78 percent.
- U.S. consumers may reduce purchasing poultry and poultry products due to concerns about disease control methods employed to double depopulation and disposal capacity relative to current best capabilities. However, if only a 5 percent decline in poultry and poultry product purchases occurs due to concerns about depopulation methods, producer returns fall to levels similar to the scenario with current best depopulation and disposal capacities and consumer surplus is at its lowest levels.
- While vaccine efficacy of just 50 percent greatly reduces the potential spread of HPAI in epidemiological model scenarios, the economic losses caused by resulting national trade embargoes are not offset until production losses equal the percentage of domestic

production exported. These percentages were attained in the modeling work to date for layers and in limited cases for turkeys. Further modeling work of vaccination strategies is pending availability of additional data from on-going vaccine trials.

How Was the Study Conducted?

Geographically specific population files were simulated for poultry with 18 distinct farm types based on the 2012 Census of Agriculture. The conceptual model provided by Interspread Plus v.5 (ISP) (Stevenson et al., 2013) was used as the framework for developing a national-scale HPAI model for the United States. ISP provides a framework for creating epidemiologic simulation models and is a stochastic, state transition model incorporating spatial and temporal information to simulate the spread of highly contagious animal diseases.

Twenty sites across the United States were selected to model for successful introduction of HPAI into the domestic poultry population over a 50-day period (figure 1). Sites were chosen based on areas identified as high risk for AI infection in wild birds (Naller et al, 2015; USDA, 2015) and on the density of poultry operations in order to simulate a large, multifocal outbreak spanning multiple States. For each control alternative evaluated, the number of farms and birds infected and the overall duration of the outbreak were compared. Median and 75th-percentile outbreaks were selected for each strategy, and resulting economic impacts were identified using a quarterly, partial equilibrium economic model of the U.S. livestock and feed economy.

Figure 1. Start locations, labeled by day of modeled disease introduction, used for model simulations.

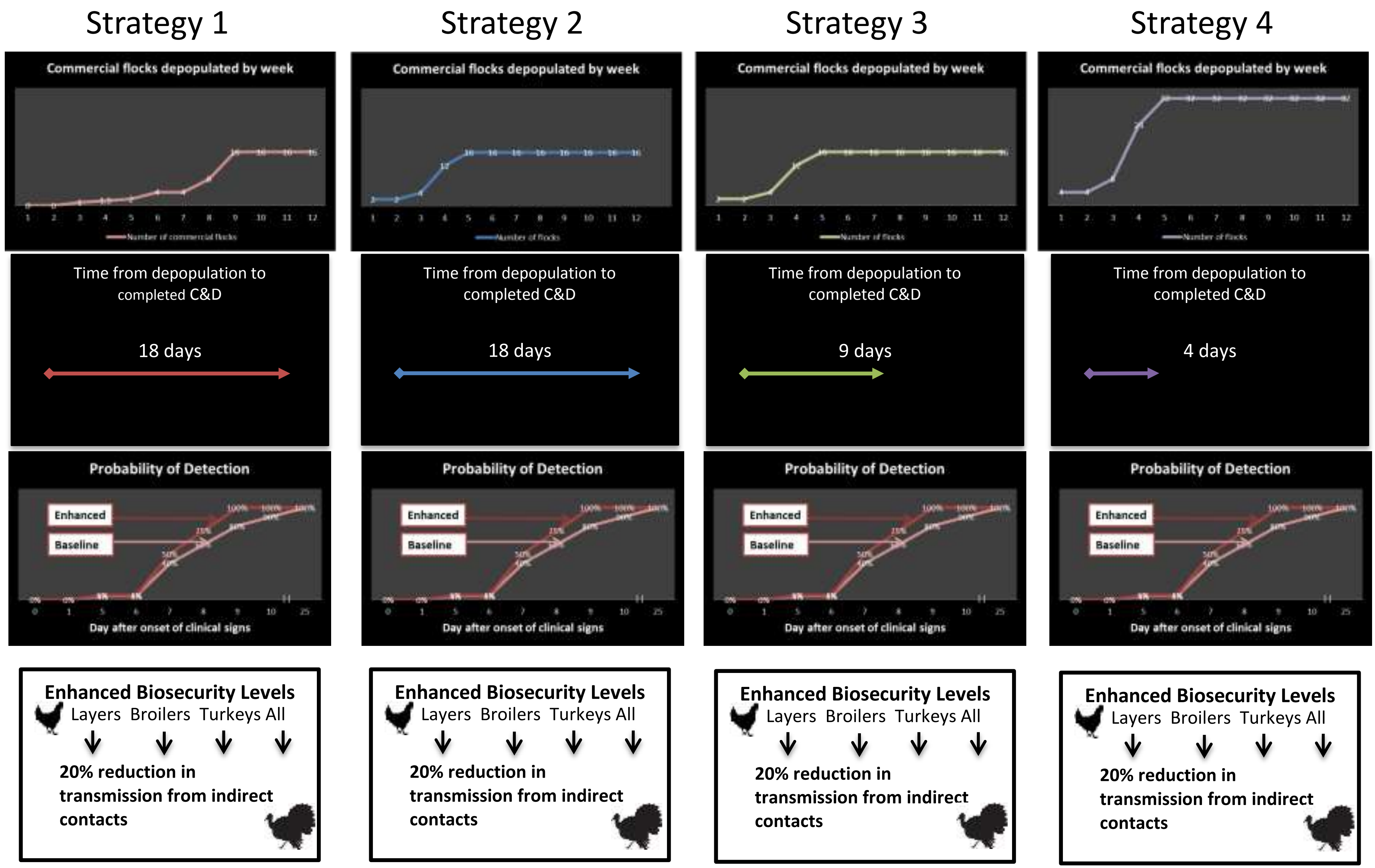
Strategies Examined:

Among the factors influencing disease spread and control were (a) depopulation capacity and time required for cleaning and disinfection (C&D); (b) detection and reporting of disease by poultry producers; and (c) biosecurity. These factors were examined independently and in combination. Figure 2 illustrates the assumptions made for each of these factors.

Depopulation capabilities were varied from a current average baseline capacity with an average time estimated at 18 days from depopulation to completion of C&D (Strategy 1), to an enhanced depopulation capacity based on the best capacity seen in the current outbreak with average or best case C&D times, 18 and 9 days, respectively. (Strategies 2 and 3, respectively), and to double the best depopulation capacity with 4 days for completing C&D (Strategy 4).

Within each strategy, we varied the likelihood that producers would detect disease across two levels. One level assumes 100 percent of reporting occurs up to 25 days after onset of clinical signs, and the second level assumes 100 percent of reporting occurs up to 10 days after onset of clinical signs. Finally, improved biosecurity was modelled as a 20 percent decrease in the probability of disease transmission related to indirect contacts such as vehicles and personnel, which was varied in each strategy by application to the layers, broilers, and turkey operations individually or to all three simultaneously.

Figure 2. Nested strategies examined during this study. Four primary strategies were defined based on depopulation capacities and disposal times. Within each strategy, changes in outbreak size and duration were examined based on improved detection and/or improved biosecurity in industry sectors.



Estimating Capacity

Disease spread associated with indirect contacts such as vehicles and shared equipment was assumed to occur from the time a flock becomes infected until cleaning and disposal are complete. To estimate baseline capacities for this timeline, outbreak data from EMRS2 were examined for key time points in outbreak response related to depopulation: the first day that clinical signs were reported, the day that HPAI confirmation was returned from the National Veterinary Services Laboratories, the day that the VS 1-23 was signed by a VS official, the day that depopulation was complete, and the time to disposal. Time required for each step varied by State and type of operation. The number of farms completing disposal by week were used to calculate a daily depopulation capacity for each week of the outbreak. This capacity was then scaled to the national level based on the assumption that similar capacities could be seen in six regions simultaneously. Although we suspect that data gaps, particularly early on in the outbreak, influenced these capacities, we felt that using available data would result in the most reasonable baseline.

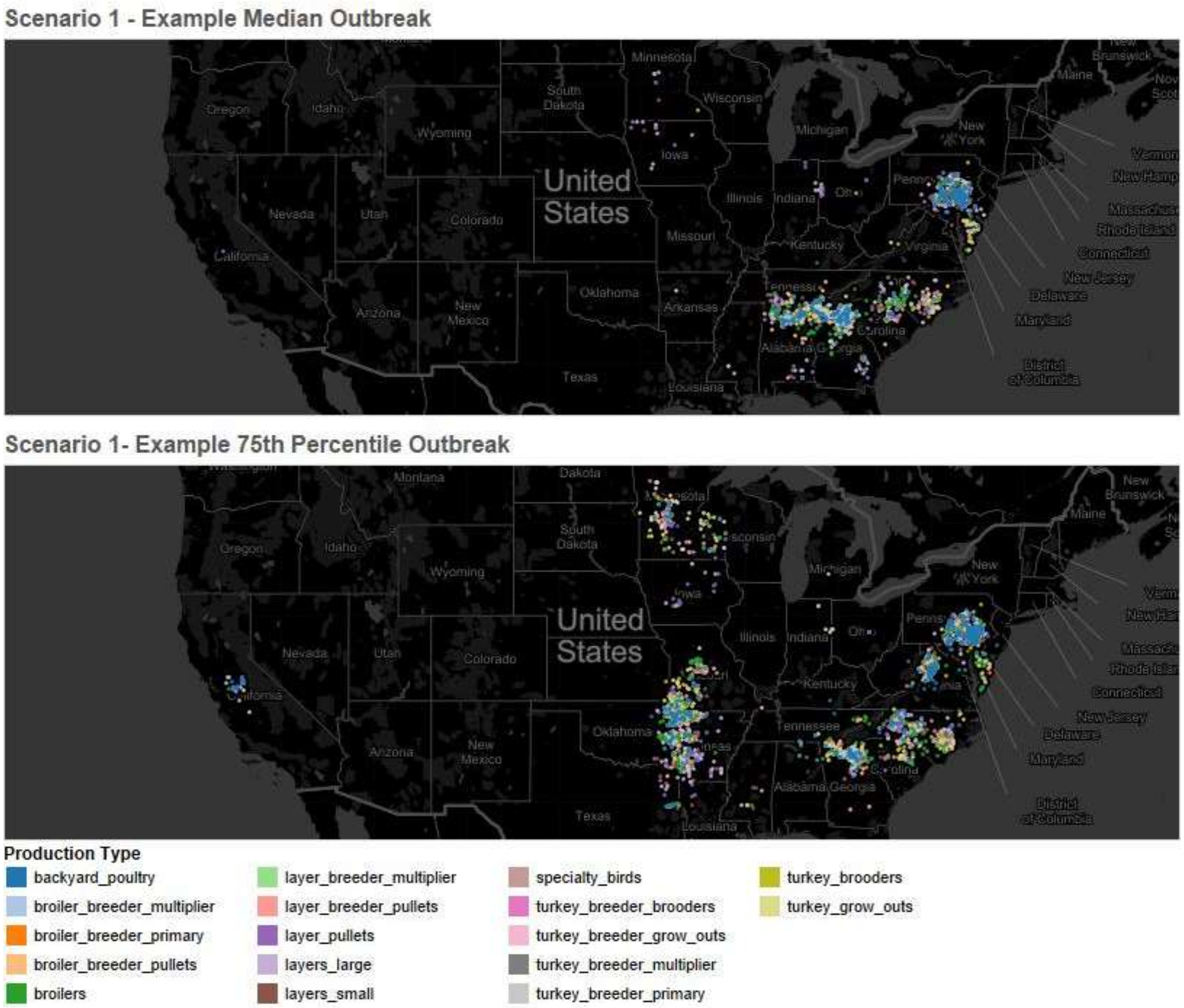
Next we examined depopulation capacity levels representing the best case from the 2015 Minnesota and Iowa outbreak data. However, time delays for disposal remained the same as the baseline. The best case capacity levels resulted in a shift in peak depopulation capacity (16 farms/day) to 5 weeks earlier in the simulated outbreaks For the third alternative, we set both depopulation and disposal times to the best times achieved during the current outbreak. In the fourth alternative, we modeled depopulation capacity as double the best case scenario from the 2015 outbreak data, with half as much time required for disposal. Depopulation capacities for layers were modeled as 600,000 birds per day nationwide for the baseline, increasing to 1,386,000 birds per day for the enhanced baseline nationwide, followed by 2,772,000 birds per day for the enhanced depopulation (projected). Graphs of each depopulation capacity over time are shown in figure 2.

In general, all enhanced depopulation capacities explored in this analysis allowed most farms to be depopulated within 24-48 hours. However, disease spread (local area spread) within 3km of an infected farm could still occur until C&D was completed. No farm was infectious for longer than 28 days.

Results

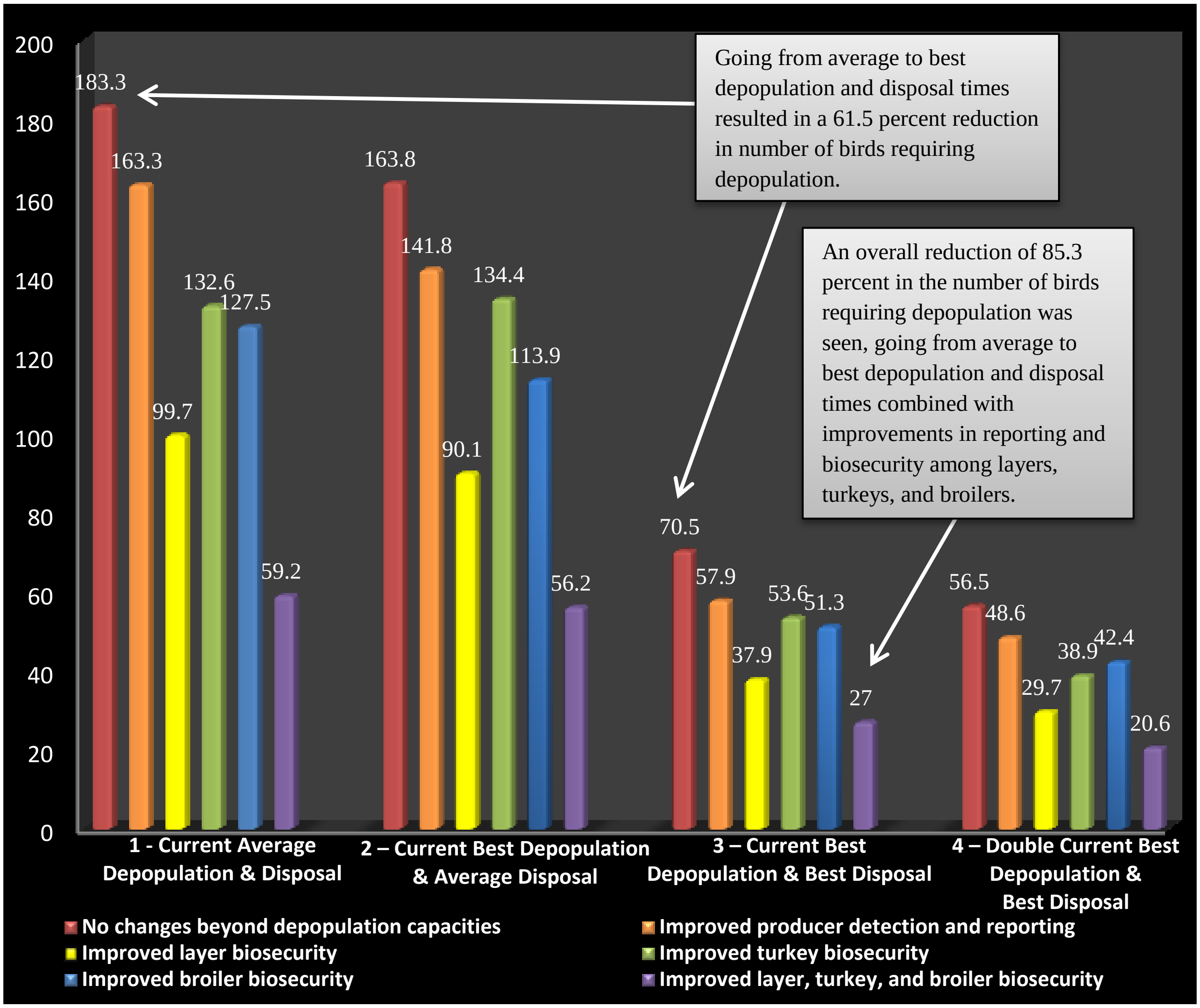
Epidemiologic results

Figure 3. Example maps of simulated outbreaks representing median (upper map) and 75th percentile (lower map) outbreak size, based on number of infected bird, across 200 different simulated outbreaks for the baseline depopulation and disposal capacities (Strategy 1).



The baseline observed depopulation capacities modeled under strategy 1 resulted in a median outbreak affecting 183 million birds on 2,561 farms. Under this baseline strategy, 25 percent of simulated outbreaks had a maximum of 1,951 infected farms, and 75% of had a maximum of 3,375 infected farms. Improving producer reporting by 1-2 days resulted in an 11% decrease in outbreak severity (2,347 flocks infected containing 163 million birds), while improving sector-specific biosecurity related to indirect contacts resulted in a 28 to 46 percent decrease in outbreak severity, depending on the sector. Reductions in indirect transmission among layer farms had the largest effect in the model, most likely due to the longer delays associated with control activities on layer facilities. Improved biosecurity in layers, broilers, and turkeys resulted in a 68 percent reduction in outbreak severity (921 infected flocks containing 59 million birds) without improvements to the baseline depopulation capacity. Under the baseline depopulation and disposal times, depopulation capacity was inadequate only for the largest simulated outbreaks (greater than the 75th percentile for number of infected flocks) and resulted in significant delays in depopulation. The largest simulated outbreaks under this strategy could not be controlled within one year.

Figure 4. Comparison of effects of improved depopulation and disposal capacity (strategies 1-4), and control options within strategy on the median number of birds requiring depopulation.



As seen in figure 4, when only the depopulation capacity available in the model was increased from the current average capacity to the level of the best capacities seen during the outbreak in Minnesota and Iowa (Strategy 2), the median outbreak size decreased to 2,327 farms containing 163.8 million birds, a 10 percent reduction compared to the baseline. Improvements in producer reporting and biosecurity resulted in similar relative reductions in outbreak size, as they did under Strategy 1.

In the third strategy explored, depopulation capacity remained the same as during strategy 2, but the time required for the effective disposal of flocks was decreased by 50 percent (from 18 to 9 days for commercial farms). This change resulted in a 61.5 percent reduction in the number of birds requiring depopulation and decreased the median number of farms infected to 922 farms containing 70.5 million birds. Model improvements in producer reporting decreased the median number of infected farms to 810 farms, and improved biosecurity among layers, broilers, and turkey farms decreased the median outbreak size to 349 farms with 27 million birds affected.

Further enhancements in depopulation capacity and shortening the time to effective disposal resulted in a further decrease in the size of an outbreak. This doubling of depopulation and disposal capacity—twice what was estimated for the 2015 outbreak in Minnesota and Iowa—resulted in a 69.2 percent reduction in the number of birds to be depopulated and decreased the median number of farms infected to 686 with 56.5 million birds affected, when compared with the baseline (Strategy 1). Strategy 4 resulted in a 20 percent reduction in the number of birds requiring depopulation in comparison with Strategy 3, and these two strategies differed significantly ($p<0.01$).

Results indicate that improvements in depopulation capacity alone offer limited reductions in disease spread unless combined with reducing delays in disposal of birds to shorten the overall exposure time. Strategies that target multiple aspects of the disease control process—depopulation, disposal, detection, and prevention— showed the greatest impact on reducing outbreak size and duration.

Vaccination

Previously, we examined the effect of vaccination, had it been employed in Minnesota, Iowa, Wisconsin, South Dakota, and North Dakota following the initial detection of HPAI on the West Coast. The immediate application of vaccination in turkeys following the first detections of AI allowed adequate time for flocks to develop immunity prior to simulated incursions of the virus in Minnesota and Iowa. At the time the work was completed, vaccine options were limited, and we simulated a 50-percent reduction in infectiousness as the effect of vaccination. The number of infected flocks was reduced by 76 percent, while the maximum number of birds vaccinated in those States was 34 million birds across all model runs. A second scenario modeled the effects of vaccinating turkey breeder flocks, turkey breeder brooders, turkey breeder grow-outs, turkey brooders, and layer pullets in the same five State area following detections on the West Coast. This strategy resulted in a 54 percent reduction in infected flocks and resulted in the vaccination of 36.4 million birds as a maximum across all model runs.

Improvements in vaccine matching and efficacy would result in even greater reductions in the number of infected birds among vaccinated sectors. However, reductions in bird numbers would need to be balanced with the negative trade implications of vaccination. Concerns have been raised that either (a) trade embargo responses to the use of vaccination may be national in scope or (b) trading partners may be unwilling to allow vaccination targeted by production type, such as for layers, without restricting exports of other production types' products, such as broilers and turkeys. Vaccination accompanied by these suggested national embargoes on all poultry and poultry products would only be indicated with certainty when domestic production losses exceed the percentage of that production exported, 20.4 percent of broiler production, 14.0 percent of turkey production, and 4.9 percent of egg production in 2014. These levels of production losses are reached for turkey and egg production in modeling work to date for 2% and 77% of simulated outbreaks, respectively. If feed industry losses were added to poultry industry losses, the reductions in poultry production necessary to trigger vaccination would be lower than the shares sited above. It is possible to think of these very large production impacts as tipping points where more focus goes to protecting our domestic production capacity to meet domestic demand (e.g. vaccination) than outbreaks in which we would focus on protecting our export markets.

Further modeling work examining vaccination options is pending the availability of data from vaccine trials currently in progress and is absolutely necessary to understand the complex interactions of the estimated production impacts of vaccination and trade responses.

Economic Impact Results

Analysis of median iterations for Strategy 1 indicate similar estimated producer losses for the current depopulation and disposal capacities and those incorporating earlier producer reporting and improved biosecurity by all three poultry sectors ranging from $3.3 billion to $3.5 billion. The broiler industry suffers the largest losses at $1.3 billion, while crop producers lose an estimated $956 million to $1 billion. The addition of earlier detection and improved biosecurity reduces the production shock to the poultry and poultry products sectors, meaning lower gains to consumers from previously exported product remaining in the domestic market. Indemnity costs drop 66 percent from $491.4 million to $165.9 million (table 3). However, trade shocks remain at similar levels, even with earlier producer reporting and improved biosecurity due to the number of States affected by the disease initially and the duration of the outbreak remaining at higher levels. The negative trade effects dominate the reduction in production achieved with the additional control measures. These economic impacts remain similar as well when only depopulation and disposal capacities are improved in Strategies 2 through 4.

To reach a marked reduction in producer losses due to HPAI, depopulation and disposal capacities must both be at the current outbreak's best levels and combined with improved detection and biosecurity in each of the poultry sectors. Producer losses decrease by 40 percent to $2.1 billion under Strategy 3. Indemnity costs are estimated at $110.4 million.

Further reductions in producer losses down to $1.3 billion are estimated, with a doubling of both the depopulation and disposal capacities from the current outbreak's best levels, together with earlier producer reporting and improved biosecurity. Indemnity payments are reduced to $57.3 million. However, these reductions must be weighed against the possibility of consumers reacting negatively to depopulation methods necessary to achieve a doubling of depopulation and disposal capacity. U.S. consumers may reduce purchasing poultry and poultry products due to concerns about disease control methods. Only 5 percent of consumers would need to stop purchasing poultry and poultry products for producer losses to return to levels under current best depopulation and disposal capacities and for consumer surplus to be at their lowest levels. That is, just a 5 percent reduction in consumer demand fully offsets the gains that may be achieved from reduced production losses as a result of the doubling of depopulation capacity.