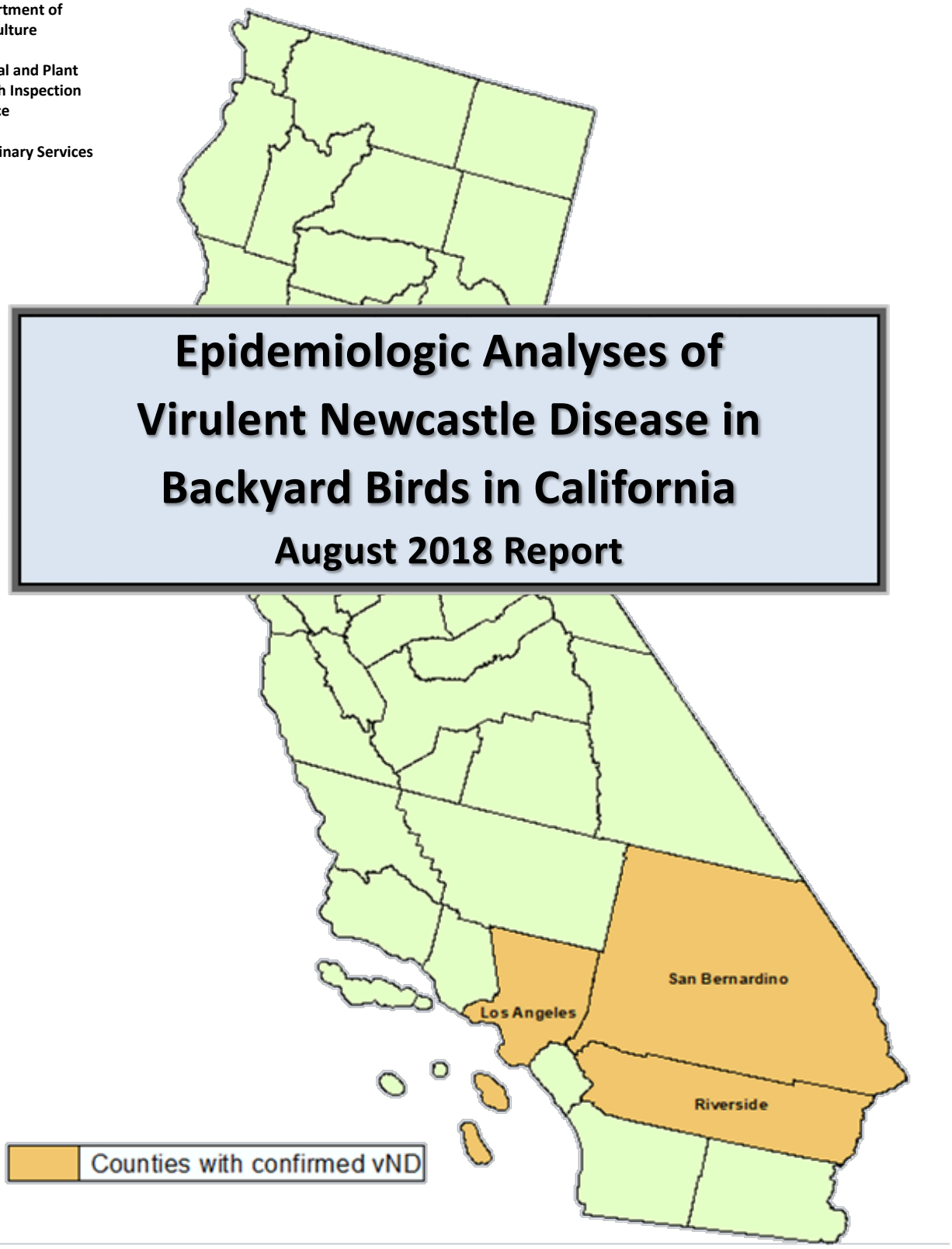
United States
Department of
Agriculture

Animal and Plant
Health Inspection
Service

Veterinary Services

Epidemiologic Analyses of Virulent Newcastle Disease in Backyard Birds in California

August 2018 Report



Suggested bibliographic citation for this report:

USDA-APHIS (2017). Epidemiologic analyses of virulent Newcastle disease in backyard birds in California (August 2018). USDA:APHIS:VS:STAS:Center for Epidemiology and Animal Health. Fort Collins, CO. August 2018. M&M Doc #447.0718. 27 pgs.

For more information, contact:

Amy Delgado, DVM PhD
Director, Monitoring and Modeling
Center for Epidemiology and Animal Health
USDA:APHIS:Veterinary Services
Science, Technology, and Analysis Services
Center for Epidemiology and Animal Health
2150 Centre Avenue, Bldg. B-2E7, Fort Collins, CO, 80526-8117
Phone (970) 494-7276 | Mobile (970) 420-2567 | Fax (970) 494-7228
Email: Amy.H.Delgado@aphis.usda.gov
Web: http://www.aphis.usda.gov/animal-health/ceah

USDA–APHIS–VS–STAS–CEAH
NRRC Building B, M.S. 2W4
2150 Centre Avenue
Fort Collins, CO 80526-8117
(970) 494–7000

Email: vs.ceah@aphis.usda.gov
http://www.aphis.usda.gov/about_aphis/programs_offices/veterinary_services/ceah.shtml

M&M Document #447.0718

Contents

Executive Summary **2**

Introduction **3**

A. Disease Overview 3
B. Description of Outbreak 4
C. References 4

II. Phylogenetic Analysis and Diagnostics **7**

A. Virulent Newcastle Disease Virus 7
Methods 7
Results 7
B. Comparison to Other Viruses/Lineages 8
C. Diagnostics 8

III. Population at Risk **9**

A. Predicting Areas of Backyard Bird Ownership 9
Methods 9
Results 9
Summary 11
B. References 12

IV. Epidemiologic Risk **13**

A. Case Control Study 13
Methods 13
Results 13
Summary 15
B. Summary of Historical Epidemiologic Risk Factors 15
C. References 15

V. Estimating Disease Spread **17**

A. Overview 17
B. Summary of Epidemiologic Analysis 17
C. References 19

VI. Acknowledgements **20**

Appendix A: Questionnaire **21**

List of Figures and Tables

Figure 1. Counties with confirmed findings of virulent Newcastle Disease from 17 May 2018 to 31 July 2018 in the United States. 5

Figure 2. California vND case detection curve based upon the date the case definition was met for a presumptive positive flock by day from 17 May 2018 to 31 July 2018. 6

Figure 3. Preliminary socio-demographic variables used in the model to predict the presence of backyard poultry in a census block in southern California. 10

Figure 4. Predicted number of backyard flocks by census block group in southern California. 11

Table 1. Number of vND confirmed positive premises by California counties and dates of earliest confirmation in each county as of 31 July 2018. 6

Table 2. Characteristics of backyard premises that are cases (confirmed/presumptive positive for vND) or dangerous contact (DC) premises or control premises (C). Odds ratios (OR) and p-values calculated by univariate logistic regression (dangerous contacts excluded). 16

EXECUTIVE SUMMARY

In May of 2018, virulent Newcastle Disease (vND) was reported in backyard exhibition chickens that had clinical signs. An owner presented sick chickens to a California veterinary clinic; samples were sent to the California Animal Health and Food Safety (CAHFS) Laboratory where vND virus (vNDV) was detected. The National Veterinary Services Laboratories (NVSL) confirmed vND on 17 May 2018. As of 31 July, seventy-two premises had been confirmed with the virus.

Once initial response efforts were in place, a series of epidemiologic investigations and studies were initiated. This is a report of the findings available to-date, and these analyses are intended to assist in understanding disease introduction and transmission pathways. These studies were undertaken collaboratively with bird owners, state agriculture personnel, and the Animal and Plant Health Inspection Service.

The outbreak predominantly affects chickens in an area that crosses three counties in Southern California: San Bernardino, Riverside, and Los Angeles counties. Preliminary genetic analysis supports a single introduction followed by secondary spread. Lack of epidemiologic data regarding the index premises, and temporal and geographical gaps in available genetic data contribute to the uncertainty surrounding the origin of the outbreak.

This area has a high density of backyard bird ownership, but such flocks are not typically registered and their locations are unknown. Using a Bayesian hierarchical model, previously identified socio- economic and demographic variables found to be associated with urban poultry ownership were used to estimate the probability of backyard flocks in this area. Results suggest that a single 10-km zone could have as many as 4,000 backyard flocks, and that the greater Los Angeles area may have over 11,000 backyard poultry premises. These modeled backyard ownership maps will help inform ongoing surveillance and response efforts.

Analysis of surveys conducted at case, control, and dangerous contact premises identified flock size, ownership of exhibition birds, a high proportion of roosters in the flock, and housing that allows contact with other domestic and wild birds as risk factors for vND in this population. The percent of premises reporting the use of Newcastle vaccine was low overall.

Initial results from disease spread and control simulations suggest that local area spread is likely to become more important as the outbreak increases in size. This type of disease spread is distance-dependent and represents mechanisms of spread that are difficult to trace, such as movement of free ranging birds, wildlife, or fence-line contact. Good biosecurity practices and measures are the best way to reduce local spread, but completely preventing this type of spread is difficult. Overall, the likelihood of spillover into commercial flocks is low, but spillover was observed in 7% of simulated outbreaks.

INTRODUCTION

USDA-APHIS and the State of California have initiated epidemiologic and genetic investigations in response to the virulent Newcastle disease (vND) outbreak in backyard premises in southern California. These investigations will provide a better understanding of factors associated with vND virus transmission among backyard chickens and other susceptible species. These investigations include the following:

- Analysis of the phylogenetic characteristics of the virus,
- Estimation of the probability of homes in southern California owning backyard birds,
- A field-based study of backyard case and control premises using data collected through site visits and interviews with backyard chicken owners, and
- An epidemiologic disease spread simulation model of vND spread among bird-owning households in southern California.

This report includes the preliminary results from these investigations, in an effort to provide producers, industry, and other stakeholders with current epidemiologic information. The report will be updated as more information becomes available in the future.

A. Disease Overview

Newcastle disease (ND) is the cause of regular, frequent poultry epizootics throughout Africa, Asia, Central America, and parts of South America. The disease is caused by strains of avian paramyxovirus-1, also known as Newcastle disease virus, which can be classified into three pathotypes based on their virulence in chickens. The World Organization for Animal Health (OIE) defines ND as infection caused by highly virulent strains of APMV-1 viruses. This virulent form of ND (vND) is considered a Foreign Animal Disease (FAD) in the United States.

Clinical signs vary and can include respiratory, neurological, reproductive, and intestinal signs. Clinical signs seen in chickens during this outbreak include loss of appetite, difficulty breathing, nasal discharge/ocular discharge, swelling around the eyes, diarrhea, blue combs, and death. Morbidity of unvaccinated chickens infected with vNDV strains can reach 100 percent, and mortality ranges from 70-100 percent. The severity of disease produced varies with the host species and the strain of the virus. Many other avian diseases present with clinical signs similar to vND; therefore, laboratory testing is necessary to distinguish between diseases.

Newcastle disease is transmitted by inhalation or ingestion, and birds shed the virus in both feces and respiratory secretions. The virus can infect many species of domestic and wild birds. Chickens are highly susceptible; other gallinaceous birds such as turkey, quail, and guinea are also susceptible. There are two species-adapted viruses that are genetically distinguishable from those found in poultry in the absence of direct transmission: one is maintained in pigeons and doves, and another in double-crested cormorants (Brown and Bevins, 2017). Parrots have been reported to be infected with virulent viruses and have the potential to shed virus for long

periods of time without clinical signs; however, data supporting virus maintenance in these species is lacking. A detailed summary of susceptible wild bird species is available in Appendix A.

Vaccination of commercial poultry against ND is common in the Americas, including the United States. The classical vaccine strains are distinguishable from other viruses by genome sequencing. Widespread vaccination of poultry was implemented in Mexico and several Central American countries in the early 2000's, and since this time divergence of subgenotypes circulating in vaccinated poultry has been documented (Susta et al., 2014; Garcia et al., 2013). Outbreaks of vND occurred in California, Nevada, and Arizona in 2002-2003 and in Texas in 2003.

B. Description of Outbreak

16 May 2018 to 31 July 2018

On 16 May 2018, the California Department of Food and Agriculture (CDFA) reported vND in sick backyard exhibition chickens presented to a veterinary clinic in Los Angeles County (Figure 1). The National Veterinary Services Laboratories (NVSL) confirmed vNDV on 17 May 2018. This was the first case of vND, formerly referred to as exotic Newcastle disease, in the U.S. since 2003. An owner presented sick chickens to a California veterinary clinic; samples were sent to the California Animal Health and Food Safety (CAHFS) Laboratory where vNDV was detected. CDFA responded to the incident by creating 3km control areas around the premises associated with the index case and began targeted surveillance and outreach including to feed stores and known exhibition bird premises. On 24 May 2018, NVSL confirmed vNDV in a backyard premises in San Bernardino County. On 26 May 2018, a USDA-APHIS incident management team joined the unified incident command in California. By this time, seven premises had been confirmed in San Bernardino County and two in Los Angeles County. On 30 June 2018, a premises in Riverside County was confirmed. Between 16 May 2018 and 31 July 2018, 72 confirmed premises were identified in three California counties (Figure 2, Table 1).

C. References

Brown V.R., Bevins S.N., A review of virulent Newcastle disease viruses in the United States and the role of wild birds in viral persistence and spread. Vet Res. 2017; 48: 68.

Garcia S.C., Lopez R.N., Morales R., Olvera M. A., Marquez M. A., Merino R., Miller P. J., Afonso C.L., Molecular epidemiology of Newcastle Disease in Mexico and the potential spillover of viruses from poultry into wild bird species. Appl. and Environ. Microbio. 2013; 79:4985-4992.

Susta L., Hamal K.R., Miller P.J., Cardenas-Garcia S., Brown C.C., Pedersen J.C., Gongora V., Afonso C.L., Separate evolution of virulent Newcastle Disease viruses from Mexico and Central America. J Clin Micro. 2014; 52:1382-1390.

Figure 1. Counties with confirmed findings of virulent Newcastle Disease from 17 May 2018 to 31 July 2018 in the United States.

Table 1. Number of vND confirmed positive premises by California counties and dates of earliest confirmation in each county as of 31 July 2018.

County	Confirmed Premises	Earliest Confirmation Date in County
Los Angeles	5	17 May 2018
Riverside	7	30 June 2018
San Bernardino	60	24 May 2018
Total	72	

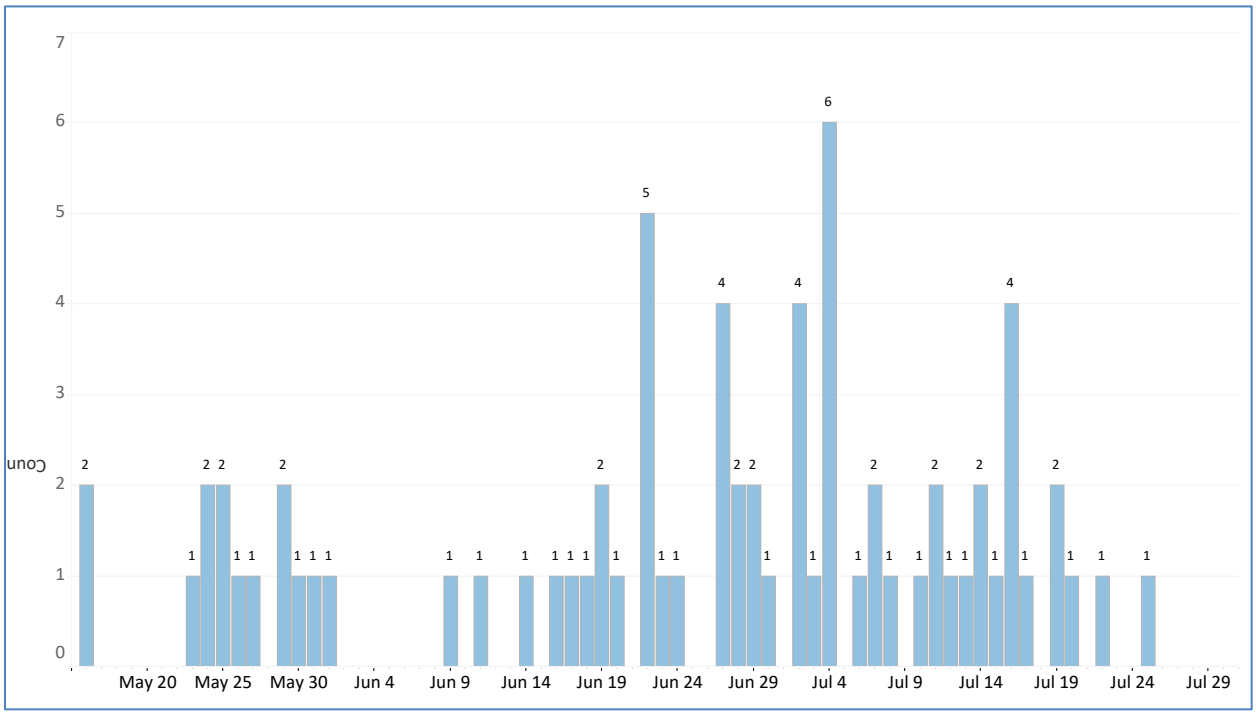


Figure 2. California vND case detection curve based upon the date the case definition[1] was met for a presumptive positive flock by day from 17 May 2018 to 31 July 2018.

[1] Case definitions

- Suspect case: domesticated bird or flock having clinical signs compatible with vND; or detection of APMV-1 by rRT-PCR; or epidemiological information indicating exposure to vNDV
- Presumptive positive case: a suspect case with detection vNDV by the fusion-target rRT-PCR test at a laboratory designated by the Secretary of Agriculture
- Confirmed positive case: domesticated bird or flock from which vNDV has been identified at the NVSL as presumptive positive with confirmation of multiple basic amino acids (either directly via protein or by deduction through sequencing) in the fusion gene at the C-terminus of the F2 protein and phenylalanine at residue 117, which is the N-terminus of the F-1 protien. The term 'multiple basic amino acids' refers to at least three arginine or lysine residues between residues 113 and 116; and/or the vNDV has an intracerebral pathogenicity index (ICPI) in day-old chicks (Gallus gallus) of 0.7 or greater.

II. PHYLOGENETIC ANALYSIS AND DIAGNOSTICS

A. Virulent Newcastle Disease Virus

This section describes viruses characterized from the 2018 vND events in California (CA2018). The index case is chicken/California/18-016505-1/2018, which has an amino acid cleavage site of PGGRRQKR/FVGAII. The intracerebral pathogenicity index (ICPI) conducted on selected isolates in accordance with OIE guidelines ranges confirms virulence and ranges from 1.67-1.75[2]. Chickens have been predominantly affected; other species from which the virus has been recovered include turkey, peafowl (peacock), duck, goose, and pigeon. Preliminary studies with the CA2018 index virus at the Southeast Poultry Research Laboratory suggest that it is highly chicken adapted and very infectious for chickens.

Methods

Genetic sequence data from the virus is used to determine the cleavage site, which serves as disease confirmation. Additionally, full genomic sequence data are generated and analyzed to monitor virus evolution and to inform epidemiologic investigations. Genetic data are also used to confirm that diagnostic assays are fit for purpose.

Results

The CA2018 virus (genotype Vb) is related to older Mexican-lineage viruses from Central American village poultry (Belize 2008, Honduras 2007), and the U.S. (smuggled parrot 1996, CA2002), which represent viruses from birds with low or no vaccine coverage. Preliminary genetic analysis of CA2018 virus isolates supports a single introduction followed by secondary spread based upon the high identity among available sequences from 41 chickens and 1 each from duck, goose, peafowl, pigeon, and turkey, representing 41 premises. Lack of epidemiologic data regarding the index premises, and of contemporary sequence data (the most recent available related sequences are from 2008) contribute to the uncertainty surrounding the origin of the outbreak. Evolutionary analysis of available sequences with the CA2018 and CA2002 viruses suggest ongoing circulation of the virus; however, where and in what population remains unclear.

NOTE: The outcomes of phylogenetic analysis should be interpreted in context of all available virus and epidemiologic information and should not be used directly to infer transmission.

[2] The World Organization for Animal Health (OIE) defines Newcastle disease as an infection with a virulent APMV-1 virus (vNDV) characterized by either an intracerebral pathogenicity index (ICPI) of 0.7 or greater in day-old chickens, or the presence of multiple basic amino acids at positions 113- 116 of the C-terminus of the fusion (F2) protein (either arginine (R) or lysine (K)), plus phenylalanine (F) at residue 117 of the F1 protein.

B. Comparison to Other Viruses/Lineages

The CA2018 virus is not related to classic Newcastle disease vaccine strains, nor to available strains from vaccinated poultry in Mexico (2000-2010). The virus is also unrelated to the species-adapted virus from columbids (pigeons, doves), and is not closely related to virulent viruses endemic to double-crested cormorants.

C. Diagnostics

Testing avian swabs/tissues for APMV-1 involves screening assays (real time reverse transcription polymerase chain reaction [rRT-PCR]), virus isolation, and characterization of the virus (sequencing and in vivo tests). The National Animal Health Laboratory Network (NAHLN) tests swab/tissue first by the APMV-1 matrix-target rRT-PCR test[3], best suited to detect Class II viruses that contain low and highly virulent pathotypes, including vaccine viruses. Detections by the matrix-target test are subsequently tested by a fusion gene-target rRT-PCR test, which is designed to allow rapid identification of virulent viruses reportable in poultry. This approach does not provide the genetic or geographic lineage of the virus. Sequence analysis of the virus compared to the assay primers and probes confirmed high identity between the CA2018 virus sequences and the fusion gene-target rRT-PCR test. A negative fusion gene-target test in the face of clinical signs requires further testing including virus recovery, sequence and/or ICPI testing.

Under normal surveillance, all poultry samples with a non-negative test result by APMV-1 PCR or virus isolation are forwarded to NVSL for confirmatory testing; for the current CA vND event, the NAHLN laboratory is using the highly matched fusion-target assay. The NVSL uses Sanger sequencing protocols to generate partial fusion gene sequence directly from the sample for virulence determination, where sufficient viral RNA is present. Whole genome sequencing is conducted on all isolated viruses, and select viruses are further characterized by ICPI in specific pathogen-free chickens.

The NVSL confirms the virus lineage and virulence through molecular sequencing. Where no virus can be recovered nor sequence obtained directly from sample(s), the virulence is determined by the clinical presentation of the flock compared to the USDA vNDV case definition.

[3] PCR results from the NVSL are reported as “detected” or “not detected” and include the cycle threshold (Ct) value. The lower the Ct value, the more viral nucleic acid was detected.

III. POPULATION AT RISK

A. Predicting Areas of Backyard Bird Ownership

The distribution of backyard bird flocks in the United States is currently unknown. However, statistical modeling can be used to estimate the likely locations and densities of backyard flocks in a given geographic area using socio-economic and demographic variables that have been shown historically to be related to bird ownership. This approach was used to develop neighborhood-level, spatial data to facilitate the creation of risk maps to identify and prioritize areas for surveillance during the 2002-2003 outbreak of vND in the United States (Freier et al., 2004, Freier et al., 2007). Building on that historical work, we aimed to identify areas with increased probability of backyard poultry ownership to inform surveillance response efforts for the current outbreak.

Methods

A Bayesian hierarchical model for spatial areal unit data was used to analyze socio- economic and demographic variables that have previously been found to be associated with urban poultry ownership. Census block groups were used as the unit of analysis. The number of backyard flocks identified during the previous vND outbreak were tallied for each census block group. During the 2002 outbreak all homes within 1 mile of an affected premises were queried about backyard poultry ownership resulting in a near census of backyard poultry ownership for some census block groups. Census block groups within 1 mile of affected premises were then assumed to have all flocks identified, and the total number of households reported in the census data was used as the total sample size. These census block groups were then used as data to fit the Bayesian model.

The Bayesian model used a binomial likelihood conditional on historical socio- demographic and economic risk factors. The factors examined are listed in Figure 3. The model included a spatial random effect using a convolution model that allows for both weak and strong spatial autocorrelation with neighboring census block groups. Prior to model fitting 5% of the data was randomly withheld for out-of-sample model validation. The withheld data was identified using conditional Latin hypercube sampling. Models were fit using JAGS in R.

Results

Human population size, home value, education level, housing density, household income, and household size were all significant predictors. Figure 3 presents the predicted coefficients for the socio- demographic and economic predictors used in the model. Based on the model's predictions, a single surveillance zone (10km) could have almost 4,000 premises with backyard poultry, while the greater Los Angeles area is predicted to have over 11,000 backyard poultry premises. Figure 4 presents the predicted distribution of backyard flocks by census block group within the current surveillance zone and control areas.

The model performs generally well explaining 79.9% of the deviance in the spatial distribution of backyard poultry ownership during the 2002 outbreak. Comparison of the predicted number of households with backyard poultry with the out-of-sample data found a Pearson's correlation of 0.67 indicating the model has good predictive capacity.

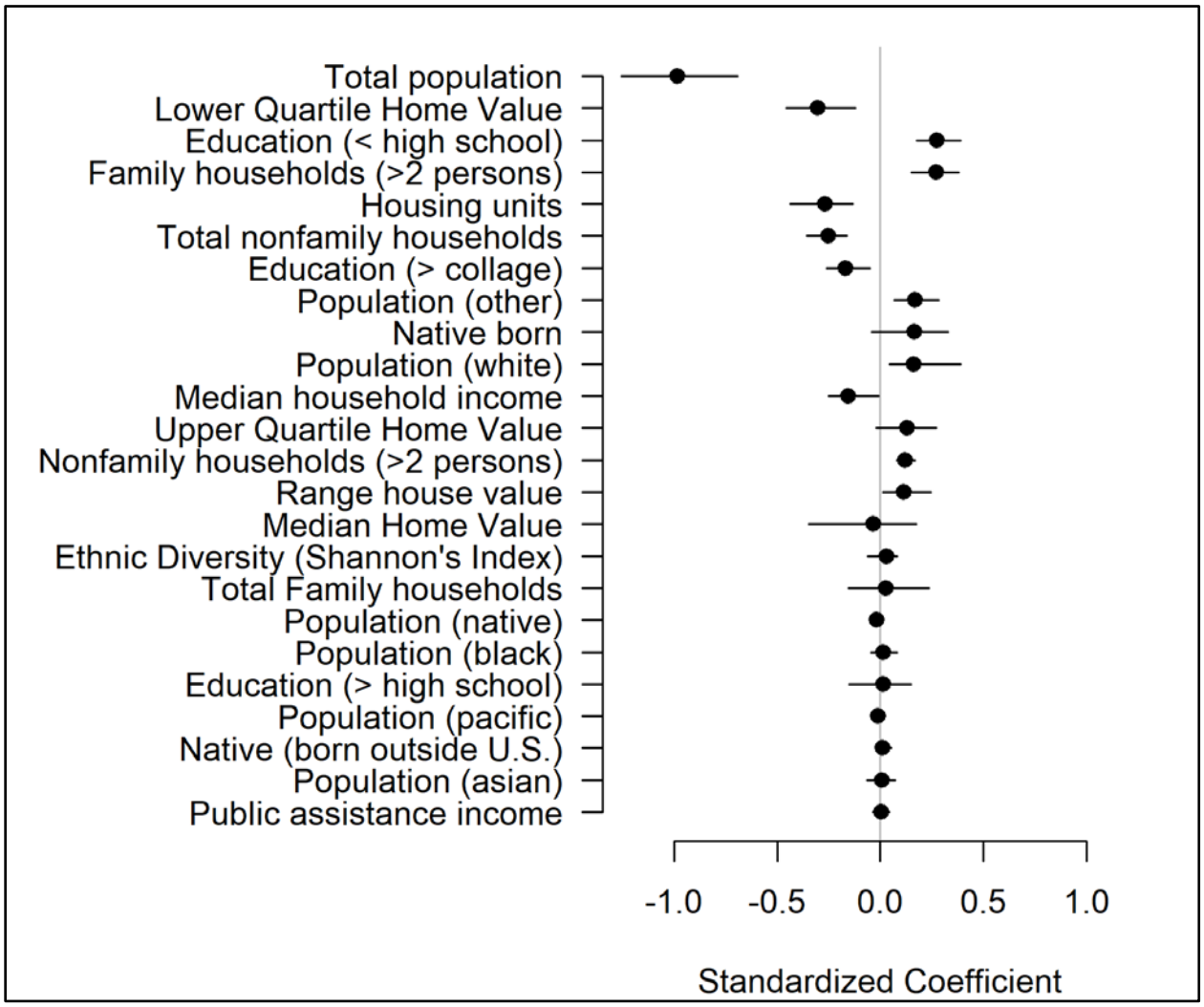


Figure 3. Preliminary socio-demographic variables used in the model to predict the presence of backyard poultry in a census block in southern California.

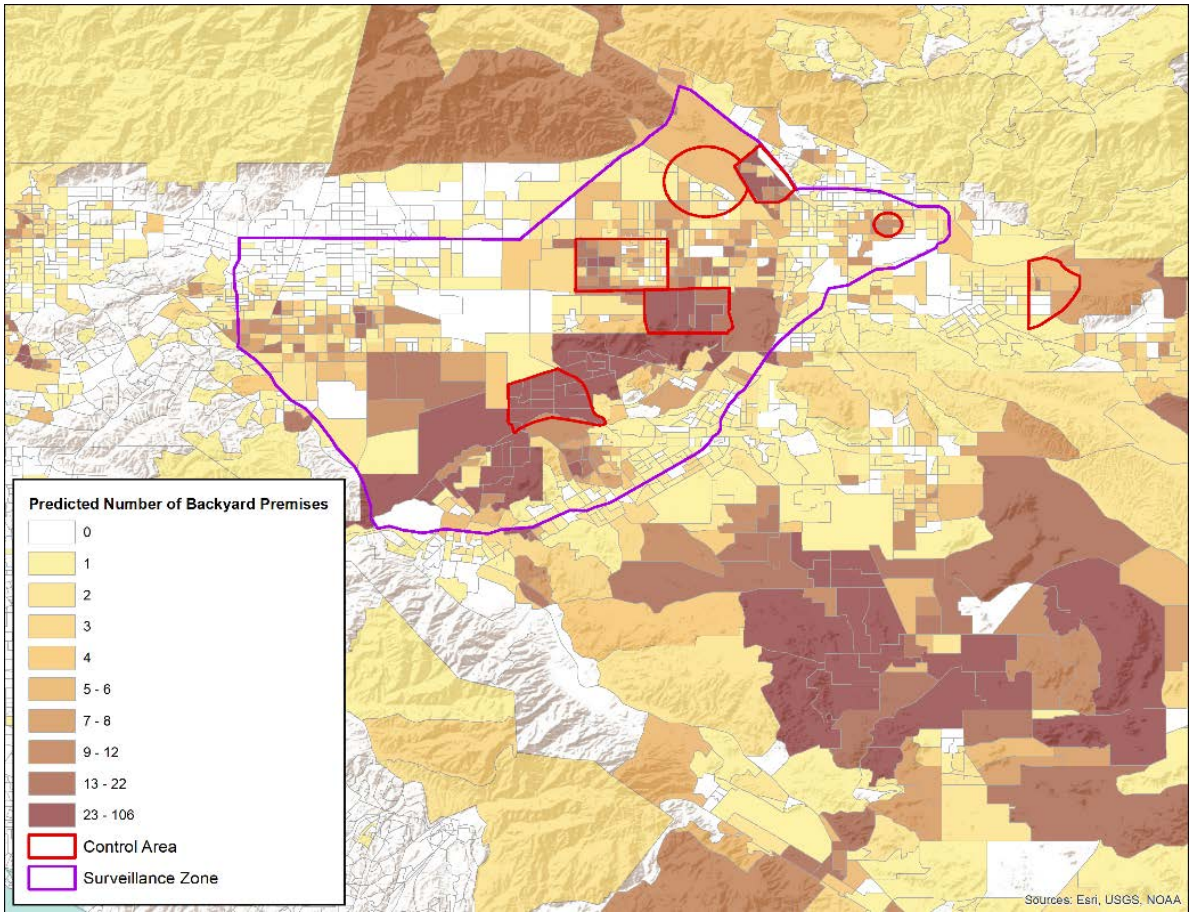


Figure 4. Predicted number of backyard flocks by census block group in southern California.

Summary

The area where the outbreak is occurring is likely to have a very dense population of backyard poultry. In addition, there was a strong spatial pattern to the distribution of backyard poultry ownership, indicating that a spatially targeted approach may improve surveillance efficiency. Work is ongoing to improve the model and incorporate data and predictors related to the probability of vND is present in the census block groups. Formal model selection has not been implemented yet but may improve the predictive abilities of the model. The data used to fit the model was restricted to block groups in southern California to facilitate model fitting (i.e. limit cpu time). However, data is available throughout California, Nevada, and Arizona for the 2002 vND outbreak. Including these data in the model may improve prediction and applicability to other regions of the United States.

B. References

Freier, J. E., et al. "Spatially-targeted surveillance for Newcastle disease in southern California." *Proc. GISVET* 4 (2004): 3-5.

Freier, J. E, Miller, R. S, & Geter, K. D. (2007). Geospatial analysis and modelling in the prevention and control of animal diseases in the United States. *Veterinaria italiana, 43*(3), 549-557.

IV. EPIDEMIOLOGIC RISK

A. Case Control Study

A case-control epidemiological analysis was performed on confirmed and presumptive positive virulent Newcastle disease (vND) backyard premises, dangerous contact premises, and non-infected premises. Data were obtained from in-person interviews that used the CDFA Non-Commercial Premises Virulent Newcastle Disease Epidemology Questionnaire, which were entered into the USDA's Emergency Management Response System (EMRS).

Methods

Data were analyzed for a total of 202 premises: 60 confirmed or presumptive positive premises, 13 dangerous contact premises and 129 non-infected premises. The analysis included questionnaires that were completed between May 16, 2018 and July 16, 2018 and includes all confirmed and presumptive premises with questionnaires entered in to the EMRS as of July 19, 2018. The questionnaire form was updated in July 2018 with additional questions; 70 respondents completed the original questionnaire and 132 completed the updated questionnaire. Questionnaires were not complete for all premises, such as in cases when owners refused to provide answers to certain questions. The number (n) of responding premises is noted in Table 1 that summarizes the results. Odds ratios, p-values and 95% confidence intervals for flock characteristics and other risk factors were calculated by univariate logistic regression using confirmed/presumptive premises as cases and non-infected premises as controls. Dangerous contacts were excluded from the regression analysis.

Results

Premises characteristics

The reported flock sizes ranged from 1 to 800 birds (mean=59, median=14 birds). 33 percent of all backyard flock owners had multiple bird species on their premises. These premises primarily had backyard chickens (86 percent). Fewer premises had exhibition birds (13 percent), and ducks/geese (14 percent). Other types of birds were reported on 32.5 percent of premises; the most commonly reported species were pigeons, turkeys, parrots, and cockatiels. Besides birds, 35 percent of owners had other livestock species on their backyard premises, 83 percent had dogs/cats, and 18.5 percent reported other non-bird species.

Housing types

Five percent of premises reported housing birds indoors. Forty-three percent reported housing birds outdoors in open top pens or enclosures, and 79.6 percent reported housing birds outdoors in cages or coops. Less than 2 percent reported keeping birds individually tethered, and 37.6 percent reported having free-range birds.

Illness and mortality

Over 70 percent of cases reported bird illness, and 71.2 percent reported mortality. The mean time between onset of illness and presumptive detection was 10.69 days (median=8.28, range

2-91 days). The mean time between onset of mortality and presumptive detection was 6.91 days (median=4.85 days, range 1 to 30 days). As an indicator of background morbidity and mortality, the percent of control premises reporting illness was 15.7 percent and mortality was 13.2 percent.

Risk factors

- Flock size

  Case premises reported larger flock sizes than control premises. The odds of being a case were significantly greater for flock sizes greater than 100 birds (OR = 6.69, 95% CI: 2.70-16.58) or from 20 to 99 birds (OR = 4.24, 95% CI: 2.03 – 8.86) when compared to flock sizes of less than 20 birds.

- Bird types

  Case premises were more likely to report having flocks that included exhibition birds or other non-chicken bird species than control premises. The odds of being a case were significantly greater for flocks reporting exhibition birds (OR = 3.69 , 95% CI: 1.47-9.20) or the presence of other bird species (OR = 2.2, 95% CI: 1.14-4.25).

  The odds of becoming a case were also higher when roosters comprised more than 50% of the adult birds in the flock (OR=5.7, 95% CI 2.12-15.14).

- Bird housing

  Premises with free-roaming birds have significantly greater odds of being a case (OR = 3.24, 95% CI 1.27-8.22). There were no other significant differences in housing types between cases and controls.

- Contact with other domestic and wild birds

  Both cases and controls reported high percentages of neighbors with birds (79 percent and 66 percent, respectively); however, premises that reported that their birds visit neighboring properties (OR = 4.98, 95% CI 1.38-17.97) or had contact with wild birds (OR = 5.57, 95% CI 1.84-17.94) had greater odds of becoming a case.

- The use of Newcastle vaccine

  The percent of premises reporting the use of Newcastle vaccine was low overall (10.2 percent total). The percent of case premises that reported using Newcastle vaccine was more than double the percent of controls that reported using Newcastle vaccine (16.1 percent vs 7.6 percent, respectively); however, the risk of disease was not statistically greater among flocks which reported use of Newcastle vaccine (OR=2.6, p=0.061).

- Common sources of feed

  Thirty-one local businesses were identified as a source for feed for 90 premises (32 cases, 54 controls, 4 and dangerous contacts). Six businesses were reported as the

feed source for more than one case premises. One business was a common source for 12 total premises, 10 of which were cases.

Summary

These results suggest that flock size, ownership of exhibition birds, a high proportion of roosters in the flock, and housing that facilitates contact with nearby domestic and wild birds are risk factors for vND infection in this population. Some of these practices have been shown to be risk factors in other studies or previous vND outbreaks in the U.S., as summarized below. However, not all epidemiology questionnaires were complete, and it is likely there is misclassification bias for some of these results, such as the type and number of birds on premises, the number of owners, and use of Newcastle vaccine; therefore, results should be interpreted with caution. This analysis will be updated when additional information is available.

B. Summary of Historical Epidemiologic Risk Factors

An epidemiological study of backyard premises in the 2002-2003 California vND outbreak identified the following risk factors for vND infection on premises: presence of game fowl, presence of feral chickens on premises, flock sizes larger than 40 birds, and multiple owners of a flock. Epidemiological descriptions of infected backyard premises in the 1971-1974 outbreak identified contact with infected commercial layer farms as the primary source of infection, followed by active trading of birds among backyard flocks and purchases of infected exotic birds from dealers. Infection among commercial premises in the 1971-1974 outbreak, the severity of the outbreak was attributed to the high density of egg-laying premises and extensive contact among those premises. In both the 1971-1974 and 2002-2003 California vND outbreaks, a suspected risk factor for vND infection in commercial premises was movement of contaminated equipment such as egg carts.

C. References

Bulaga, L.L., Dargatz, D., Garber, L., Miller, R., Rhoads, G. (2004). Risk Factors for exotic Newcastle disease infection in non-commercial flocks, California. Unpublished Report

Burridge, M. J., Riemann, H. P., Utterback, W.W. (1975). Methods of spread of velogenic viscerotropic Newcastle disease virus in southern California. Avian Diseases, 19(4), 666-678.

Speers, R., Webb, M., Grund, M, Howell, B., Hughes, C., Myrus, E., and, Silverman, J. (2004). Reconstruction of response operations to eradicate exotic Newcastle disease in 2002-2003. Technical report produced for USDA by the CNA Corporation.

USDA-APHIS (1978). Eradication of exotic Newcastle disease in southern California 1971-1974. APHIS-91-34 Technical Report

Utterback WW, Schwartz, J.H. (1973) Epizootiology of velogenic viscerotropic Newcastle disease in southern California, 1971-1973. J Am Vet Med Assoc. 163(9), 1080-1088.

Table 2. Characteristics of backyard premises that are cases (confirmed/presumptive positive for vND) or dangerous contact (DC) premises or control premises (C). Odds ratios (OR) and p-values calculated by univariate logistic regression (dangerous contacts excluded).

Characteristic	Level	n			OR	p-value
		Case	DC	Control		
Number of birds	1-19	20/60	7/13	92/129	Ref	
	20-99	24/60	4/13	26/129	4.2	**<0.001**
	100+	16/60	2/13	11/129	6.7	**<0.001**
Bird species on premises	Backyard chickens	48/56	11/11	92/108	1.6	0.207
	Exhibition birds	13/56	1/11	9/108	3.7	**0.005**
	Ducks/geese	9/56	2/11	13/108	1.6	0.329
	Other species	24/56	3/11	30/108	2.2	**0.019**
Multiple bird species on the same premises		31/56	5/11	31/108	3.4	**<0.001**
Adult birds >50% roosters		16/47	2/9	7/84	5.7	**0.001**
Non-bird species or wildlife on premises	Livestock	23/51	5/10	38/128	1.94	0.0.51
	Dogs/cats	45/52	11/11	104/169	1.54	0.348
	Other animals	7/39	1/5	12/64	0.95	0.919
Housing	Inside home	1/23	0/6	4/74	0.8	0.842
	Outdoor open top	7/24	5/8	36/79	0.5	0.158
	Outdoor cage/coop	22/25	5/7	71/91	2.1	0.276
	Individual tether	0/22	0/6	2/74	1.0	NA
	Free range	14/25	5/6	22/78	3.2	**0.013**
Movement of new birds onto the premises within 30 days prior to the interview		9/57	2/12	11/108	1.8	0.21
Movement of birds off the premises within 30 days prior to the interview		6/58	0/12	11/123	1.2	0.76
Give/sell eggs		1/26	2/8	14/93	0.2	0.09
Neighbors have birds		19/24	7/8	61/92	1.9	0.23
Birds visit neighbors		6/26	2/8	5/88	5.0	**0.01**
Wild birds have contact with domestic birds		23/27	7/8	46/92	5.8	**0.003**
Newcastle disease vaccine	No	39/56	10/12	101/113	Ref	
	Yes	9/56	1/12	9/117	2.6	0.061
	Unsure	8/56	1/12	7/117	2.9	**0.049**

V. ESTIMATING DISEASE SPREAD

A. Overview

An epidemiologic scenario was developed in InterSpread Plus ® v. 6.01.44 (Stevenson et al., 2013) to model the introduction and spread of vND from confirmed premises in San Bernardino counties in California. Commercial and backyard farm units from the Western U.S. (17 states) were incorporated into the model. The Farm Location and Animal Population Simulator was used to generate likely farm locations based on geospatial characteristics, with backyard farm locations adapted from current and historic outbreak-related data. Model parameters were developed to reflect the impact of sustained outreach activities, to incorporate preliminary experimental data on viral pathogenesis in chickens, to include current strategies for active surveillance of commercial operations, and to describe the potential geographic extent of disease spread during the silent-spread period. The model is updated regularly in order to provide timely results back to the response.

B. Summary of Epidemiologic Analysis

Summary outcomes for a 300-iteration scenario were generated from ten seeded-sites. The seeded sites were based on the latitude/longitude of initial confirmed cases of vND in San Bernardino County. Simulations include control activities implemented in the current vND response, including outreach, quarantine, euthanasia/depopulation of detected premises, movement controls, tracing, and active and passive surveillance. Note: These outcomes are based on a completely naïve poultry population. The variable levels of vaccination applied within backyard farms is not explicitly modeled in this scenario.

The summary of results and their potential implications for the current vND outbreak are as follows:

- Initial disease spread commonly involves direct movements of infectious birds, but local spread becomes more prevalent as outbreaks become greater than 50 infected premises.

  Direct contacts associated with live animal movements accounted for 36 percent of spread for simulated outbreaks that resulted in less than 50 infected premises, and 27 percent of spread for simulated outbreaks that resulted in 50 or more infected premises.

  Local area spread became more prevalent as simulated outbreaks became larger, being responsible for 56 percent of disease spread for simulated outbreaks that resulted in 50 or more infected premises.

  Implications: As the number of detected premises continues to increase, outcomes from simulated outbreaks suggest that local spread of vND between premises may be responsible for additional infections. Local spread is associated with distance between infectious and susceptible premises and represents

mechanisms of spread that are difficult to trace such as movement of free ranging birds, wildlife, or fence-line contact. Good biosecurity practices and measures are the best way to prevent local spread (e.g., keeping outside birds in cages; moving cages away from neighboring fence lines; repairing damaged/missing fences; rodent control; covering/tarping cages to decrease wildlife/rodent/loose chicken exposure and the spread of vND viral particles into the environment).

- Small backyard operations[4] are the primary premises involved in outbreaks; large backyard operations or commercial poultry farms have a lower likelihood of becoming infected.

  Across all simulated outbreaks, large backyard operations represented slightly less than 1 percent of all infected premises, and commercial poultry farms represented 0.14 percent of all infected premises.

  Virulent ND infected small backyard operations in 100 percent of all simulated outbreaks, large backyard operations in 22 percent of all simulated outbreaks, and commercial poultry farms in 7 percent of simulated outbreaks.

  All spread to commercial operations resulted from indirect contact (e.g. people or vehicles moving from operation to operation) with infected, primarily small backyard operations.

  Implications: Unless generated by indirect contacts with infected backyard operations, outcomes from simulated outbreaks suggest a low probability of spreading vND to commercial farms.

- The extent of spread for simulated outbreaks is primarily in San Bernardino, Los Angeles, and Riverside counties.

  When considering disease spread within the silent period of the outbreak (three days prior to the first observation of clinical signs to the day of first detection), spread from infected premises in San Bernardino County to backyard chicken premises in Riverside County occurred in 66 percent of simulated outbreaks and to backyard chicken premises in Los Angeles County in 65 percent of simulated outbreaks.

[4] In the model operations are defined as follows:

1) Commercial poultry farms: more than 75,000 table egg laying chickens, or more than 100,000 meat-type chickens, or more than 30,000 meat-type turkeys
2) Large backyard operations: more than 1,000 birds but fewer than the number of birds described for commercial operations
3) Small backyard operations: fewer than 1,000 birds

In the current modeling scenario, 42 percent of simulated outbreaks involved 50 or more infected premises, and 19 percent of and outbreaks involved 100 or more infected premises.

Implications: Simulated outbreaks suggest future detections in other counties in Southern California, most commonly Riverside and Los Angeles Counties. In addition, some infected premises may not be detected due to natural viral elimination from these premises (i.e., birds die and go unreported) and/or no new, naïve birds being brought onto previously infected premises.

C. References

Burdett, C. L., Kraus, B. R., Garza, S. J., Miller, R. S., & Bjork, K. E. (2015). Simulating the distribution of individual livestock farms and their populations in the United States: An example using domestic swine (Sus scrofa domesticus) farms. PloS One, 10(11). doi: 10.1371/journal.pone.0140338

Stevenson, M.A., Sanson, R.L., Stern, M.W., O'Leary, B.D., Sujau, M., Moles-Benfell, N., Morris, R.S. (2013). Interspread plus: A spatial and stochastic simulation model of disease in animal populations. Preventive Veterinary Medicine, 109(1-2), 10-24. doi: 10.1016/j.prevetmed.2012.08.015

VI. ACKNOWLEDGEMENTS

We greatly appreciate the cooperation and support of the poultry owners for allowing us access to their properties, for providing information on their biosecurity and production practices, and for their cooperation with this investigation.

We also appreciate the Federal and State animal health experts, as well as the many partners who assisted with this study while serving in the incident command for this outbreak.

This report would not have been possible without a large group of researchers, epidemiologists, laboratory staff, and data scientists who participated in the various analyses and drafting and review of this report. We appreciate their dedication and professionalism in providing the best information possible to help bird owners reduce the risk of Newcastle disease spread.

APPENDIX A: QUESTIONNAIRE

California Department of Food and Agriculture
CA VND 2018
Non-Commercial Premises
Virulent Newcastle Disease Epidemiology Questionnaire

Investigator name: _____Date of Investigation: _____/_____/_____

Investigator name: _____

Quarantine # _____ Date Quarantine Issued: _____/_____/_____

1. Name of **Premises Owner**:

_____
(First) (MI) (Last)

2. Premises Address (location of birds):

_____

_____

Latitude: _____ Longitude: _____

3. Premises Owner Telephone #:
   a. Mobile: _____
   b. Home: _____
   c. Other: _____

*If **Premises Owner** is the **Bird Owner** skip to Question 7*

4. Name of **Bird Owner**:

_____
(First) (MI) (Last)

5. Bird Owner Address: _____

_____

6. Bird Owner Telephone #: _____

7. Other than the interviewee, how many **other** owners with birds are on this premises: #_____

8. How many birds do you have on the premises today? # _____

9. What percent of the adult **chickens** are: a) Roosters %_____
b) Hens %_____

10. Which of the following birds are on the premises? *Complete table below.*

Type of Bird	**# Adults**	**# Young birds**	**Total**
Backyard Poultry	a	b	c
Exhibition Birds/gamefowl	d	e	f
Ducks/Geese	g	h	i
Other Specify j	k	l	m
Other Specify n	o	p	q

11. Which of the following animals are on the premises (potential fomites)?

a) Livestock (Horses, Cattle, Swine, Sheep, Goats) ☐1 Yes ☐3 No
b) Dogs/Cats ☐1 Yes ☐3 No
c) Other (specify _____) ☐1 Yes ☐3 No

12. Which of the following housing types are used to house birds?

a) Inside the home ☐1 Yes ☐3 No
b) Outdoor **open** top poultry pen or enclosure ☐1 Yes ☐3 No
c) Outdoor cages or coops - **fully enclosed** ☐1 Yes ☐3 No
d) Individually tethered ☐1 Yes ☐3 No
e) Free range ☐1 Yes ☐3 No
f) Other (Specify_____) ☐1 Yes ☐3 No

13. Has there been an increase in illness in your birds on your premises? ☐1 Yes ☐3 No

a) If yes, how many days ago did the birds first show signs of illness: _____days

Which of the following clinical signs of illness have you observed?

Check all that apply.

b) Not eating ☐1 Yes ☐3 No
c) Coughing/gasping ☐1 Yes ☐3 No
d) Depressed ☐1 Yes ☐3 No
e) Twisting of the neck ☐1 Yes ☐3 No
f) Paralysis ☐1 Yes ☐3 No
g) Diarrhea ☐1 Yes ☐3 No
h) Swellings around the eyes and neck ☐1 Yes ☐3 No
i) Sudden death ☐1 Yes ☐3 No
j) Other (specify_____) ☐1 Yes ☐3 No

14. Have there been any deaths in your birds on this premises during the past 30 days? ☐1 Yes ☐3 No

a) If yes, when did the first bird die? _____/___/_____

b) If yes, how many birds died in the first 7 days? # _____

c) If yes, how many birds have died in the past 7 days? # _____

15. Do you keep any birds at another premises? ☐1 Yes ☐3 No

a) If yes, where are the birds housed?

_____

_____

16. Have you brought new birds onto this premises during the past 30 days? ☐1 Yes ☐3 No

If Yes, list date and name the source and location of the new birds:

Date	Source/Location
___/___/___a	_____b
___/___/___c	_____d
___/___/___e	_____f

17. Have any of the following had contact with your birds, feed or water sources on your property in the last 30 days?

a) Wild birds (e.g., pigeons, doves, sparrows) ☐1 Yes ☐3 No
b) Neighborhood/community chickens ☐1 Yes ☐3 No
c) Wild animals ☐1 Yes ☐3 No

18. Have any of your **birds** left these premises during the last 30 days? ☐1 Yes ☐3 No

If Yes, for what purposes listed below were the birds moved?

Purpose	**Date**	**Destination (City/State)**	**# of birds**
Sale	a	b	c
Show	d	e	f
Competition	g	h	i
Veterinary care	j	k	l
Gift/trade m	n	o	p
Other Specify q	r	s	t

If Yes, did any birds leave and then return to these premises? ☐1 Yes ☐3 No

19. Do you give away or sell **eggs** from this premises? ☐1 Yes ☐3 No

20. Do your neighbors have birds? ☐1 Yes ☐3 No
*If **No**, skip to Question 23.*

*If **Yes**, please note location(s) on the map at the end of the questionnaire.*

21. When not cooped, do your birds ever visit the neighbor's property? ☐1 Yes ☐3 No

22. Do your neighbor's birds ever come onto your property? ☐1 Yes ☐3 No

a) If Yes, do the neighbors birds have contact with your birds? ☐1 Yes ☐3 No

23. Do you have **family members or close friends** who own/keep birds? ☐1 Yes ☐3 No

If Yes, do any of the following situations occur (evaluating direction of exposure):

a) Your family or friends handle birds when they visit. ☐1 Yes ☐3 No
b) When visiting family/friends do you handle their birds. ☐1 Yes ☐3 No

24. What is the name and location of the store(s) where you get feed and supplies for your birds?

Name	Location (City)
_____a	_____b
_____c	_____d
_____e	_____f

25. Have the birds on your premises **today** been vaccinated with Newcastle vaccine? ☐1 Yes ☐2 Unsure ☐3 No

Vaccine does not protect against disease!

a) If Yes, at what age(s) were your birds vaccinated with Newcastle vaccine?

26. Have you seen any dead wild birds on your premises in the last 30 days? ☐1 Yes ☐3 No

If Yes, what type of wild bird(s)?

_____a _____b

_____c_ _____d

Additional comments, observations and leads:

Insert Google Maps Image of the premises or draw a map and specify bird locations. Please indicate which neighbors, if any, have birds.

I _____certify that I have _____birds on / / @ _____
(owner signature) (number) (date and time)

Epidemiologic Analyses of Virulent Newcastle Disease in Backyard Birds in California

August 2018 Report

USDA ◆ APHIS ◆ VS

Science, Technology, and Analysis Services
Center for Epidemiology and Animal Health
2150 Centre Avenue, Bldg. B, Fort Collins, CO, 80526-8117
Web: http://www.aphis.usda.gov/animal-health/ceah