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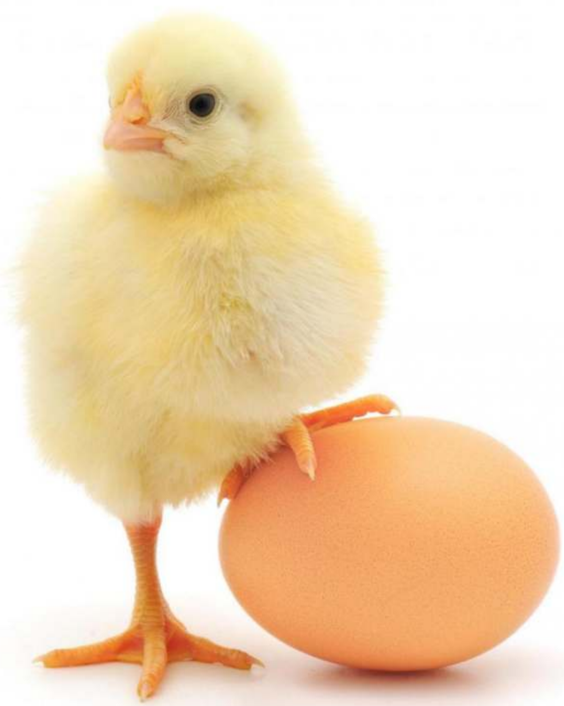

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Wind-Borne Transmission of Infectious Laryngotracheitis Between Commercial Poultry Operations

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Abstract: Infectious Laryngotracheitis (ILT) is an acute respiratory disease of poultry and causes significant economic losses due to increased mortality and decreased productivity. First described in 1925, ILT has been extensively studied, but little is known about the epidemiology of the disease. In the past 15 years, there have been severe ILT outbreaks in several poultry-producing states. The spread of ILT in outbreak situations is typically quite rapid, and then in an ever-widening arc around the initial case. The mechanism of this spread is not well understood, and many hypotheses are currently in existence. Several risk factors that have been identified are indicative of wind-borne transmission. A case-control study of 18 case and 122 control flocks was conducted. A GIS database of poultry operations and meteorological data from local weather stations were employed to analyze the risk of clinical ILT associated with prevailing wind patterns. Case farms were 9.9 times more likely located within the wind vector of a clinical ILT flock during the 14 day incubation period for ILT than control flocks ($p < 0.001$). House orientation and proximity to a backyard flock or a commercial flock were not significantly associated with case status. The control-to-case flock distance was significantly greater than the case-to-case flock distance ($p=0.03$). House ventilation system, wind vector, and distance from another case flock were presented to a backward eliminating logistic regression model. Only wind vector variable was retained in the model. The point estimate for the odds ratio was 0.110 (95% confidence interval 0.038 - 0.322).

Key words: Infectious laryngotracheitis, epidemiology, geographic information systems, windborne,

Introduction

Infectious Laryngotracheitis (ILT) was first described as tracheolaryngitis in 1925 (May and Tittsler, 1925). In 1932, ILT became the first major avian viral disease for which an effective vaccine was developed (Cover, 1996). ILT typically presents clinically with signs of respiratory distress accompanied by gasping and expectoration of bloody exudates. The causative agent of ILT is the alpha herpes virus, infectious laryngotracheitis virus (ILTV) (Hanson and Bagust, 1991). Over the past fifteen years there have been severe outbreaks in many poultry-producing areas: California (Linares *et al.,* 1994), the Delmarva Peninsula (Keeler *et al.,* 1993), Georgia (Andreasen *et al.,* 1989), North Carolina (Guy *et al.,* 1989) and Pennsylvania (Davison and Miller, 1988; Keller *et al.,* 1992). Mortality in these outbreaks has been variable, from 12-16% in pullet and layer flocks to as high as 50% in broiler flocks. As an acute respiratory disease of poultry with a global distribution, ILT results in large economic losses due to increased mortality, decreased productivity, and lost international markets (May and Tittsler, 1925). Therefore it is a disease of serious economic importance to the poultry industry.

Wind-borne transmission of disease is not new to livestock industry. In cattle, the importance of airborne transmission of Foot and Mouth Disease (FMD) has been documented since the 1970's (Donaldson, 1979; Gloster *et al.*, 1981; Montou *et al.*, 1987). Several incidences of airborne spread of FMD have been documented over great distances such as between France and England or Denmark and Sweden (Donaldson *et al.*, 1982; Gloster *et al.*, 1981). Several risk factors that have been identified for clinical ILT in commercial poultry flocks may be indicative of wind-borne transmission. These include: proximity to backyard flocks (Mallinson *et al.,* 1981; McNulty *et al.,* 1985; Johnson *et al.,* 2004); proximity to vaccinated flocks (Andreasen *et al.,* 1989; Churchill, 1965; Hilbink *et al.,* 1987; Samberg *et al.,* 1971); and houses with North-facing ventilation systems (Zellen *et al.,* 1984). Airborne transmission has also been recognized in several other poultry diseases, including *Salmonella enteriditis*(Holt *et al.,* 1998) and Newcastle Disease (Hopkins and Drury, 1971, Hugh-Jones *et al.,* 1973). However, no studies on the epidemiology of ILT have been conducted that use real-time meteorological data in an effort to assess the risk of wind-borne ILT between commercial poultry flocks. The objective of this study is to quantify the risk associated with wind-borne transmission of infectious laryngotracheitis based on prevailing wind patterns during the 14-day incubation period.

Hypotheses: The following hypotheses were tested:

- Mean case-to-case farm distance is less than the mean case-to-control farm distance.
- Case farms are more likely to be located within the wind vectors of other case farms than control farms.
- Poultry houses on case farms are more likely to be oriented in a North-South direction than poultry houses on control farms.
- Poultry houses on case farms are more likely to have conventional ventilation systems than poultry houses on control farms.

Materials and Methods

A case control study was conducted using commercial poultry operations located within a 10-mile radius of the University of Delaware weather station in Georgetown, Delaware. An ILT case flock was defined as a commercial poultry flock in which:

- Diagnosis was confirmed via virus isolation or histopathology at the University of Delaware Laboratories in Georgetown or Newark Delaware.
- Diagnosis occurred between November 1, 1998 and November 1, 2001.
- The flock was not vaccinated for ILT.

There were 24 case flocks located within the study region that met the case definition. Control flocks were defined as commercial poultry flocks located within the study region with no reported clinical signs of ILT during the study period. There were 196 control flocks within the study region. The types of ventilation systems in use on the farms and the orientations of the poultry houses were recorded by visiting each farm. The orientation of the house was determined using a Garmin eTrex personal navigator (Garmin Corp. Olathe, Kansas).

Data on prevailing wind patterns for the study period were collected from the local weather station at the University of Delaware Research and Education Center, Georgetown, DE. The station is equipped with a Model 05103 RM Young wind monitor and a Model 21X data logger (Campbell Scientific Inc. Logan, Utah). The primary variables of wind speed and wind direction are retrieved from a low threshold press ion air velocity sensor employing a fast response helicoid propeller that responds to a component of airflow that is parallel to the axis of rotation. This process measures horizontal wind speed and direction thereby closely approximating a cosine of a curve. There are three out puts that are retrieved from the weather station: mean horizontal wind speed, unit vector mean wind direction, and standard deviation of wind direction. The process instruction and algorithm used to produce these data complies with US Environmental Protection Agency guidelines for use with a straight-line Gaussian dispersion model known as the Industrial Source Complex Plume Rise Model Enhancement (Paine and Lew, 1997).

An ArcView (ESRI Inc. Redlands, CA) software script initially establishes a bearing point using the pre projected latitude and longitude coordinates of a poultry farm. This location is used as a point of departure. The script will then read a list that contains date, wind speed and direction data. The program then generates vectors representing the wind pattern from the poultry farm during the dates of interest. These vectors will be used to determine a high-risk area around each case farm (Fig. 1). The number of case flocks and control flocks falling within these "high risk" areas were determined. A binary variable was then created to indicate whether or not the farm was located within a “high risk” area.

Statistical analysis: Data analyses were conducted with SAS Version 8.2 (SAS Institute, Inc. Cary NC). Chi-square, odds ratios and t-tests were calculated for categorical and continuous variables respectively. Logistic regression was used to model the relationship between the probability of clinical ILT and the risk factors of interest. The independent variables include: location within a high risk wind polygon, house orientation, house ventilation system, distance from a case farm, distance from nearest commercial poultry flock and distance from nearest backyard flock. Independent variables with a $p < .08$ were introduced into the full model. A backward eliminating approach was used for model building.

Results

There were a total of 24 case farms and 196 control farms located within the study region. A total of 80 farms were eliminated from the study due to missing data (6 case farms and 74 control farms). The study population consisted of 18 case farms and 122 control farms. Results of the univariate analyses are summarized in Tables 1 and 2. Proximity to the nearest backyard flock and commercial flock were not significantly different between case flocks and control flocks. The case-to-case flock distance was significantly less than the control-to-case flock distance. Flocks with tunnel ventilation were one-third as likely to be case flocks than those with conventional ventilation systems. House orientation was not significantly associated with case status.

Three variables met the criteria for presentation to the multi variate logistic regression model: distance to the nearest case farm in meters, tunnel ventilation system (0,1), and location within the wind vector of a case flock (0,1). The results of the logistic regression model are

Table 1: Univariate Analysis of Continuous Risk Factors*

Risk Factor	Case Flocks Mean (meters)	Control Flocks Mean (meters)	p-value
Distance to Nearest Backyard Flock	7662.78	3413.27	0.239
Distance to Nearest Case Flock**	3029.35	4774.92	0.031
Distance to Nearest Commercial Flock	2335.24	1855.60	0.542

*Null Hypothesis: Mean Distance for Case Flocks is less than the Mean Distance for Control Flocks. **Statistically significant at $p<0.05$ level.

Table 2: Univariate Analysis of Categorical Variables

Risk Factor	Chi^2 (p- value)	Odds Ratio	95% Confidence Interval
Wind Vector*	22.99 ($p<0.0001$)	9.905	3.44, 28.53
Tunnel Ventilation System*	Fisher's Exact ($p=0.038$)	0.288	0.079, 1.047
North-South House Orientation	0.005($p=0.9424$)	0.964	0.354, 2.624

*Statistically significant at $p<0.05$ level.

Table 3: Final Logistic Regression Model Results

Parameter	Estimate	Standard Error	Wald Chi^2	Odds Ratio Point Estimate (95% Confidence Interval)	p-value
Intercept	-1.595	0.2734	34.060		$p<0.0001$
Wind	-1.103	0.2734	16.278	0.110 (0.038, 0.322)	$p<0.0001$

summarized in Table 3. Wind vector was the only variable retained in the model. The odds ratio for wind vector indicates that case flocks are approximately 10 times more likely to be located within the wind vector of another case flock than control flocks.

Discussion

Six variables were analyzed as risk factors for clinical laryngotracheitis during several clusters of cases on the Delmarva Peninsula between November 1, 1998 and November 1, 2001. Distance to the nearest case flock, backyard flock, and commercial flock were assessed with the aid of GIS databases of commercial and backyard poultry flocks in the region. To quantify the role of wind-borne transmission in the spread of clinical ILT between commercial flocks, meteorological data from the University of Delaware Research and Education Center weather station in Georgetown, Delaware was used to establish prevailing wind patterns from each case farm during the 14 days after a diagnosis of clinical ILT. The univariate analyses indicated that location within the wind vector of a clinical flock, proximity to an ILT clinical flock, and use of a conventional ventilation system were all significantly associated with increased risk of clinical ILT.

The lack of an association between proximity to a backyard and clinical ILT is inconsistent with previous work by the authors (Johnson *et al.,* 2004). However, the cluster of cases studied in this investigation is significantly different from the cluster of cases in the previous study. The previous cluster of ILT cases studied by the authors occurred between May and June 1998. The spring 1998 cluster were the first clinical cases in commercial poultry reported in the region since December 4, 1995 (Colby *et al.,* 2001). Prior to the spring 1998 cluster of cases, commercial integrators were not routinely vaccinating broiler flocks against ILT. The series of cases that occurred between November 1998 and November 2001 were subsequent to a widespread ILT vaccination campaign in which several (but not all) flocks in the area were vaccinated against ILT. The relative importance of geographic and spatial risk factors can be expected to change in response to implementation of outbreak control measures such as intensified biosecurity, vehicle re-routing, and vaccination.

Lack of available data on which control flocks were vaccinated against ILT prohibited analysis of proximity to a vaccinated flock as a risk factor. Previous reports have cited proximity to a vaccinated flock as a risk factor for clinical ILT (Andreasen *et al.,* 1989; Churchill, 1965; Hilbink *et al.,* 1987; Samberg *et al.,* 1971). This is a potentially important limitation of this study. The strength of the association between risk factors in question and clinical ILT may have been underestimated because some of the flocks exposed to the risk factor were not susceptible to clinical ILT because they had been vaccinated. If windborne transmission of ILT virus from vaccinated flocks poses a similar risk of spread as observed in this study from clinically infected flocks, vaccination of only a portion of the susceptible flocks in a geographic region may serve to enhance disease transmission to the unvaccinated flocks.

The multi variate model assesses the impact of each risk factor while holding the others constant. This allows us to evaluate the impact of wind vector while holding constant the impact of proximity to a case farm. While proximity to another case flock was a statistically significant risk factor, its importance is removed from the model when the variable of wind vector is also present.

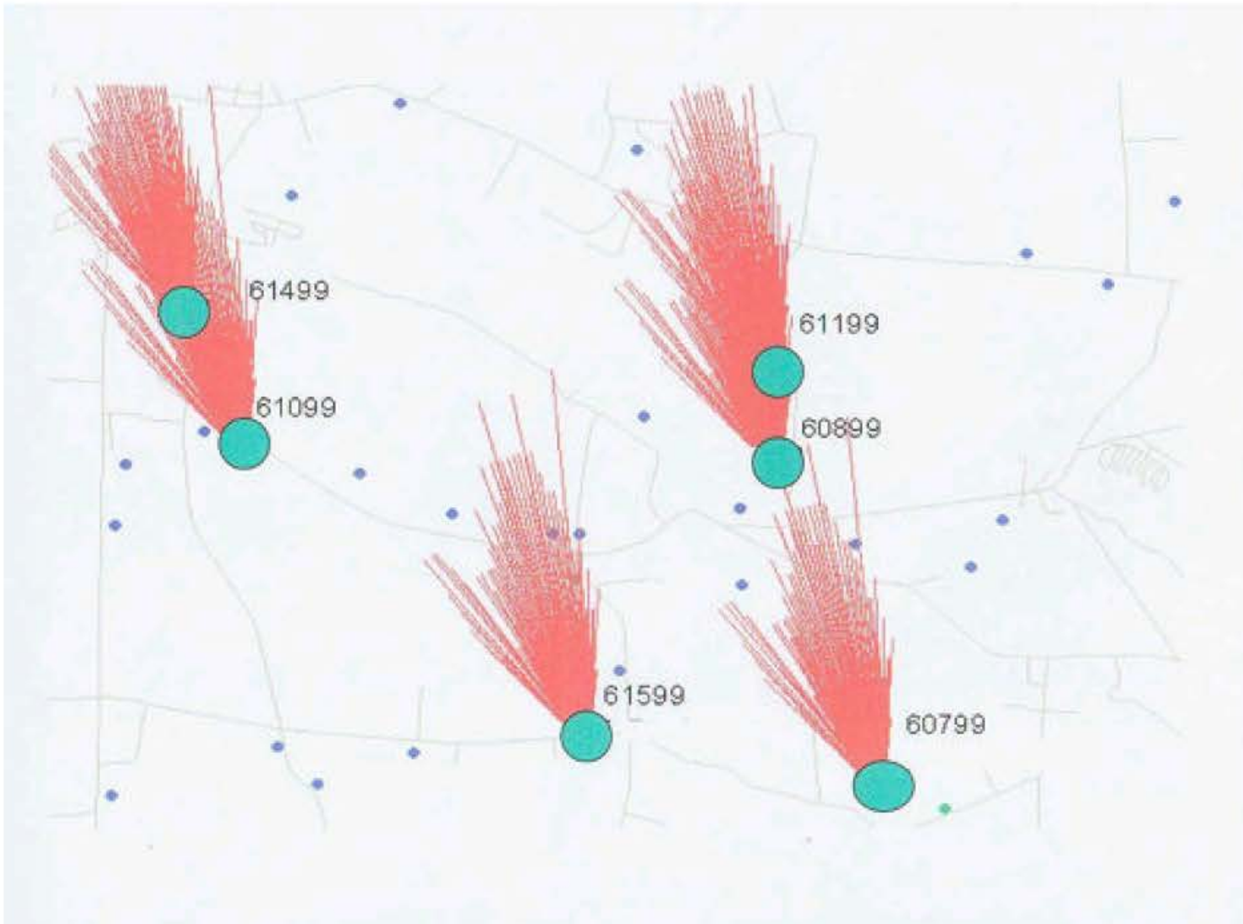

Fig. 1: Wind vector patterns from 6 ILT clinical case flocks diagnosed, June 7 - June 15, 1999 in Sussex, County, Delaware. Large green dots represent case flocks with their diagnosis dates. Small blue dots represent ILT negative commercial poultry flocks. Red lines depict the patterns of prevailing wind patterns during the 14 day period following diagnosis of the ILT clinical case flocks.

The findings from this study demonstrate the capability of GIS databases in addressing health issues in intensive livestock and poultry production systems such as epidemiological research, disease surveillance, and planning and decision support systems. The use of real-time meteorological data to identify farms at high risk for wind-borne transmission of infectious disease can be adapted to other diseases such as Foot and Mouth Disease, Avian Influenza or Newcastle Disease.

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