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Evaluation of Two Systems for Managing Emergency Poultry Diseases in Intensive Poultry Production Regions

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Abstract: This paper provides an overview of two systems used for the management of infectious disease within the poultry industry on the Delmarva Peninsula. The first system is a paper-based Grid system that was developed in the 1970's. This system divides the peninsula into a total of 3420 unique locations, each covering approximately 5 square miles. The second system is a Geographic Information System (GIS) database that is currently under construction. Each system is critiqued with respect to several of the criteria established by Klaucke *et al.* (1998) for the evaluation of a surveillance system: simplicity, flexibility, acceptability, representativeness and timeliness. In addition, the objectives of a disease management system in an intensive poultry production area are discussed. A grid-based system is most appropriately used in situations involving a small, easily managed population or geographic location, especially when funding and geographic resources are limited. When multiple diseases or large geographic areas are the focus of a surveillance and monitoring system, or when several different risk factors are to be examined and funding and adequate resources are available, the use of a GIS-based system provides additional flexibility. The database management component of GIS allows for rapid updating of demographic and disease information, and the linkage of the database component with the spatial coordinates of a GIS provides the ability to examine the effects of several risk factors at the same time.

Key words: Geographic information system, disease management, epidemiology, disease surveillance

Introduction

Disease management is a critical tool for the continued improvement of health and productivity of the nation's livestock. Ensuring the future health and productivity of the nation's livestock requires: determining the prevalence, distribution and economic impact of endemic disease; setting priorities for the use of resources for disease control activities; planning and implementation of disease control programs; rapid response to disease outbreaks; and the ability to demonstrate disease status to trading partners (Cameron, 1999).

The Delmarva Peninsula, the fifth largest broiler production area in the United States (Delmarva Poultry Industry, 1997), currently employs a paper-based grid system to monitor disease progression in outbreak situations. A committee composed of company veterinarians, industry representatives, poultry producers, regulatory officials, extension specialists, diagnostic laboratory veterinarians and others determines responses to outbreaks of infectious diseases.

The objective of this paper is to compare and contrast a computer-based GIS system to the existing paper-based grid system used by the commercial poultry industry on the Delmarva peninsula. The paper-based grid system was conceived in the early 1970's to facilitate the response of the poultry industry to outbreaks of Avian Influenza, and if necessary with outbreaks of other disease of concern, such as ILT. In 1998, it was decided that a GIS database of the poultry industry on the Delmarva Peninsula would be developed, with the intent of developing a disease management program that would include the database. The goal of this endeavor is to create a completely integrated tool for surveillance; disease control and prevention; conduction of epidemiologic studies; and planning and decision support functions. Upon completion, the Delmarva Poultry GIS will assist in the management of diseases of importance on the Delmarva Peninsula. In the event of an outbreak of an infectious disease, the GIS will facilitate outbreak management decisions such as quarantine, no-movement and vaccination zones. It will also serve as a resource for emergency management agencies when creating response plans for natural disasters.

Description of the two systems.

The Grid system (Fig. 1).

Design: The Delmarva Peninsula was manually divided into thirty-six horizontal sections (1-36) and nineteen vertical sections (A-S), to form a total of 684 grid

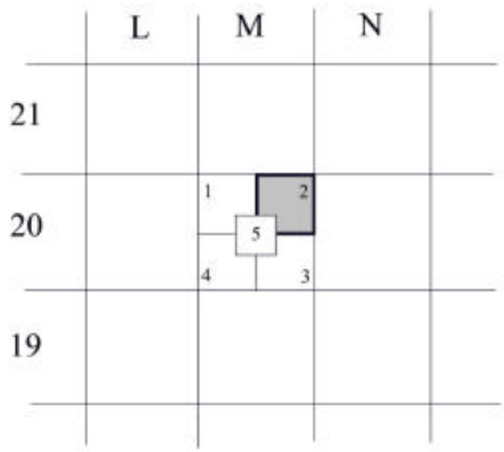

Fig. 1: Example of the Delmarva Grid Square system. The shaded grid represents grid square M-20-2.

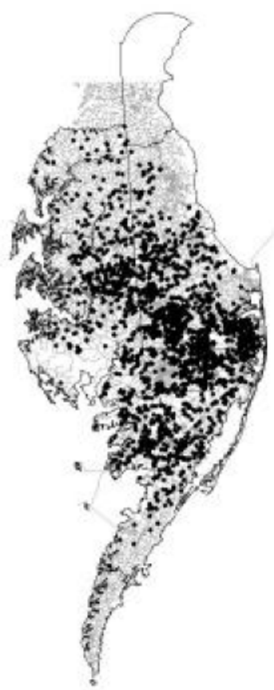

Fig. 2: Example of the Delmarva Geographic Information System. Each black dot represents a poultry farm.

squares. Each grid square represents twenty-five square miles of land on the Delmarva Peninsula. Each grid square is further subdivided into 5 numbered squares (1-5) which are used to indicate whether a farm is in the northwest (1), northeast (2), southeast (3), southwest (4) or center (5) of the grid square. This system results in a total of 3420 unique location designations, with each covering approximately five square miles. Each farm is assigned a three or four digit grid location based on its approximate location on the grid-map.

Utilization: By providing fellow integrators with the three or four digit grid square location of an infected farm, integrators are able to assist in control efforts without revealing the exact location of the diseased operation. Cases are typically mapped by placing colored pins or dots on individual copies of the grid map, the exact placement of the marker within the designated grid square left to the discretion of whoever is performing the mapping. This grid map was successfully used by the Poultry Health Committee (PHC), a working committee of the Delmarva Poultry Industry, Inc. to develop vaccination zones to combat the spread of infectious diseases for many years (Ritter, 2000). The PHC is composed of veterinarians from the poultry integrators; state veterinarians from Delaware, Maryland and Virginia; faculty from the University of Delaware, the University of Maryland and the Virginia-Maryland Regional College of Veterinary Medicine; veterinarians from the poultry diagnostic laboratories; contract growers and other representatives of the poultry industry. After examining the location of diseased flocks on the map, the PHC determines the grid squares in which all flocks at risk should be vaccinated. Most frequently, the boundaries of these vaccination zones consisted of major roadways or bodies of water. The most common predictor of success was cooperation and communication between the poultry companies in the area of the outbreak. Decreases in disease incidence were most evident when all companies complied with the recommendations of the PHC (Ritter, 2000). When some or all companies failed to follow the recommendations of the PHC or to work in a coordinated manner, disease continued to spread and incidence of increased (Stewart-Brown, 1999).

The Geographic Information System (Fig. 2 and 3). Design: Producers, poultry companies, veterinarians, government officials and epidemiologists from Delaware, Maryland and Virginia are cooperating to build a GIS database that will eventually integrate information on poultry production: locations of poultry farms, processing plants, feed mills, truck routes with other geographical and environmental data. A complete GIS database of commercial poultry operations on the entire Delmarva Peninsula (which includes the state of Delaware and the Eastern Shore of Maryland, and Virginia) was compiled during the summer of 2000 (Colby *et al.*, 2000; Johnson *et al.*, 2000). Poultry operation data and locations, roads, waterways and orthophotographs were layered into the database using the ArcView software system and ArcView software was used to generate longitude and latitude coordinates for

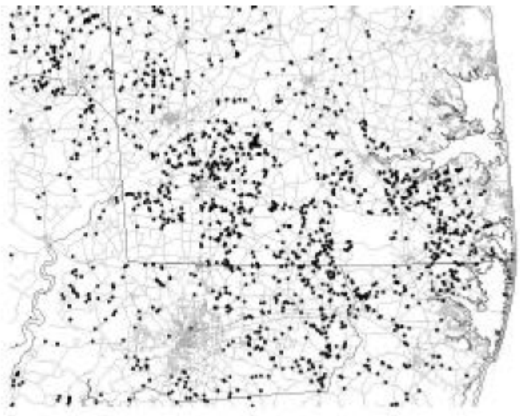

Fig. 3: Another example of the Delmarva Geographic Information System. A closer view with more detail.

visible poultry operations. For those poultry operations not visualized on the orthophotographs, site visits were conducted and longitude and latitude readings were taken with a Magellan Map 410™ (Anonymous, 1999) or Garmin eTrex (Anonymous, 2000b) hand held GPS unit.

Utilization: As with the grid-based system, disease reporting within the GIS-based system originates with the flock supervisors; veterinarians employed by the poultry integrators and veterinarians in the poultry diagnostic laboratories. The PHC facilitates a coordinated response by bringing representatives from each integrator, as well as diagnosticians and epidemiologists, together. The GIS system can also be expanded to include data layers with additional types of information such as land cover, meteorological data, truck routes, and other information that may be useful in determining the source of an outbreak, or in controlling the spread of a disease.

Projects demonstrating the utility of the database are currently underway. Colby *et al.*, 2000 conducted a case-control study to examine several geographic risk factors (distance to four lane road, distance to nearest commercial poultry facility) for respiratory disease (Colby *et al.*, 2000). Another study examined the effects of prevailing wind patterns on transmission of respiratory disease. This case-control study utilized data on prevailing wind patterns to generate 14-day virus plume polygons to demonstrate a significant difference between the number of cases and the number of controls located within and without the virus plume (Johnson *et al.*, 2001). Both of these studies were conducted using the GIS database and historical disease information.

Potential actions of the two systems: The value of disease management systems is the generation of information that can be used to support strategic and operational decision-making. The system is more than simply a database of disease information. Rather, these systems should be used to generate information that is then applied towards the prevention and control of the diseases identified. Ideally, these systems will quickly identify outbreaks and allow appropriate responses to be carried out. Disease management systems should be designed with the crisis in mind, and plans should be in place and arrangements flexible enough to allow for rapid responses in emergency situations (Anonymous, 2000a).

Potential responses to an outbreak include: the development of vaccination and quarantine zones and/or the re-routing of vehicular traffic around infected areas to prevent the further spread of a disease. In response to the emergence of a new disease or an increase in the levels of an endemic disease, an epidemiologic investigation might be instigated to prevent future outbreaks.

Both systems are capable of providing assistance and or/guidance on the tasks mentioned above, however, the GIS-based system can perform additional tasks such as re-routing traffic based on criteria assigned by the user (Cheng *et al.*, 2001) and providing a list of all poultry farms within a given distance of an infected farm (McGinn *et al.*, 1996). Limitations of utilizing a GIS system to direct response actions include the knowledge and expertise of the user with respect to disease characteristics and risk factors, and with respect to the capabilities of a GIS system. Maps generated by GIS often appear more informative than the actual data they represent as a result of the advanced and not always well understood mapping capabilities available (Kitron, 1998). An example of this is when maps with contrasting colors that imply a large difference are presented, but no data on the statistical significance of this difference is supplied. It is up to the user to be aware of these potential limitations and know how to interpret the information obtained from a GIS. The grid-based system can provide a visual tool for the manual determination of routes around infected farms and vaccination zones, but its capabilities are limited by the inability to layer information in a paper-based system (Astudillo, 1983).

Evaluation of the two systems: According to Klaucke *et al.* (1998) the efficacy of a surveillance and monitoring program is influenced by the following attributes: simplicity, flexibility, acceptability, representativeness and timeliness (Table 1) (Klaucke *et al.*, 1998). Improved timeliness facilitates the initiation of control and prevention activities and surveillance and monitoring systems representative of the population being evaluated allow for more accurate epidemiologic characterization of disease in the defined population. Simple, flexible systems that are accepted by all

Table 1: Attributes of a surveillance system.

Attribute	Description
Simplicity	Refers to the structure and ease of operation of the system.
Flexibility	System's availability to adapt to changing needs without large increase in need for resources.
Acceptability	Reflects the willingness of individuals and organizations to participate in the surveillance system.
Representativeness	Indicates the accuracy of the system in describing the occurrence of a disease over time of the distribution of a disease by location and population affected.
Timeliness	Refers to the speed or delay between steps of the surveillance system.

participating parties also tend to be more useful. According to Klaucke, a "surveillance system is useful if it contributes to the prevention and control of adverse health events (disease)…[or] if it helps to determine that an adverse health event previously thought to be unimportant is actually important." The criteria established by Klaucke to evaluate surveillance and monitoring systems are also ideal criteria when evaluating disease management systems, and have been used to compare the grid-based system currently in place on the Delmarva Peninsula to the GIS-based system that is being developed.

Simplicity: Simplicity refers to the structure and the ease of operation of the system (Klaucke *et al.*, 1998). Disease management systems should be as simple as possible while still meeting their stated objectives, and should be well documented with sufficient staff resources and training opportunities to allow the data to be utilized effectively (Blood, 1995).

The grid-based system is inherently simple; in its simplest form it may consist of pins in a map to record the geographical spread of disease. Little expert knowledge is necessary to compile information and examine disease based on geographic location. This system provides for the visualization of disease patterns, and facilitates the determination of vaccination and restricted movement zones.

Full utilization of the capabilities of a GIS system may require advanced training. Basic GIS user training program will usually require about 40 hours of a potential user's time (Korte, 2001). Such training courses are available from ESRI, the manufacturer of ArcView 3.2, for approximately $2000 per participant. The construction of the Delmarva GIS database is based on a simple spreadsheet program. Additional layers including environmental and meteorological data can be added as desired, which may increase the complexity of both the design and the analysis capabilities. The simplicity or complexity of a GIS-based system varies, as it is quite dependent on the needs and demands of its users (Paterson, 1995). Users wishing only to monitor the spread of the disease and generate vaccination and quarantine zones will find the system fairly easy to utilize with minimal training, while those wishing to examine disease patterns and conduct cluster analysis will find that more advanced training might be required (Sanson *et al.*, 1991b).

Flexibility: Flexibility refers to the ability of a disease management system to accommodate changes in information needs or operating conditions without additional expenditures of time, personnel or funds (Klaucke *et al.*, 1998). Flexibility allows for a comprehensive plan of disease management that might include tracking hazards, exposures and health outcomes; as well as indicators for a variety of environmental factors; host characteristics, risk factors, disease agents, and expression of disease (Bush *et al.*, 1999).

In the grid-based system, the actual location of poultry farms are not recorded, thus, accuracy is limited to the five square miles represented by the 3 or 4 digit grid location. The lack of latitude and longitude coordinates makes georeferencing, the assignment of an exact location or geographic position to data items, impossible (Bernhardsen and Viak, 1999). While the grid system can be used for any number of infectious diseases without much increase in time or funds spent, it's capabilities are limited to tracking and visualizing disease occurrence. Tracking hazards, such as potential windborne spread of a disease; exposures, such as visits by the feed truck and/or utility companies; and environmental factors including tree cover and proximity to wetlands are not possible with the current system.

Like the grid-based system, the GIS system has the flexibility to address any number of diseases of importance; with little effort additional information on new diseases may be incorporated to the database. The functionality of the GIS-based system can be rapidly enhanced with minimal investment of time or effort, by the inclusion of additional data layers. GIS databases developed for surveillance and monitoring programs have been utilized for epidemiologic studies of pseudorabies (Marsh *et al.*, 1991; Norman *et al.*, 1996) and disease modeling of Foot and Mouth disease (Paterson *et al.*, 2000; Sanson *et al.*, 1999; Moutou *et al.*, 1994).

The incorporation of GIS into existing disease management programs provides users with the opportunity not only to utilize the geographic capabilities in the management of current disease problems, but also to conduct epidemiologic studies on diseases of concern that have been a problem in the past and have the potential for recurrence. In addition to monitoring patterns of endemic disease and surveillance for foreign animal diseases; other issues of vital importance to the commercial poultry industry on the Delmarva peninsula that might be assisted by a GIS include: developing environmentally sensitive plans for litter disposal, application, and processing; disaster planning; evaluating the capacity of local infrastructure on poultry production and processing; and making recommendations for the location, orientation, and ventilation systems for newly constructed poultry houses to minimize disease transmission and odor.

Acceptability: The acceptability of a system refers to the willingness of individuals and organizations to participate and carry out their designated roles within the system (Klaucke *et al.*, 1998). The phrase “garbage in, garbage out” holds true for surveillance and monitoring systems. The better, more representative and more complete the information and effort put into the development and maintenance of such a system, the better, and more useable, the information coming out (Bartlett *et al.*, 2001).

The grid-based system has been in place for almost 30 years. This system allows for the coordination of efforts without the disclosure of exact farm locations or other farm specifics to other integrators and/or state health officials. Little effort is required to gather information on recent cases from integrators.

A major problem with the acceptance of GIS-based systems is the trend towards more geocoding and large volumes of information in such systems. The inclusion of georeferenced locations connected to demographic information is viewed as having the potential to undermine privacy (Curry, 1999). The limited demographic information collected on each poultry operation will be extremely useful in disease analysis. In some cases individual grower and/or company concerns about data confidentiality may result in difficulty obtaining additional information that would further improve the capabilities of the system (Croner *et al.*, 1996). Other limitations to the acceptance of GIS systems include skepticism over the user of a “new” technology, and concerns with accuracy and quality of data contained within the systems (Tim, 1995).

Representativeness: A system is considered representative if it accurately describes the occurrence of disease over time and the distribution of disease in the population both geographically and demographically (Klaucke *et al.*, 1998). Quality of data is an important part of representativeness. In addition to adequately representing the population being monitored, to be fully effective, disease management programs need to take an integrated approach, collecting information throughout the production chain from hatchery to processing plant (Anonymous, 2000a).

The grid-based system is limited by the accuracy of the grid itself. Four farms located adjacent to one another may be placed anywhere within a five-mile square grid based on their grid location. With respect to the distribution of disease within a population, the grid system, containing no information on the base population, cannot adequately represent such information. This system is further limited by its inability to incorporate or display information on additional production steps, such as flock mortality, feed conversion, outside farm visitors, feed delivery, etc.

The GIS system has the ability not only to accurately describe the occurrence of disease over time, but also to describe the distribution of disease in the population, as it contains a standard set of information on every farm on the peninsula. Another advantage of using a GIS database rather than traditional database with the information from the grid system is that the data can be displayed, organized, and summarized visually in a graphical environment (Sanson *et al.*, 1991a). Because the exact latitude and longitude coordinates of each farm are included in the database, the accuracy of farm locations is approximately 25 meters rather than five square miles (Harrington, 2000). The fact that information on all farms is included in the database, greatly improves the accuracy of the GIS system, but also increases the time and effort necessary to maintain and update the records in the database. With additional effort, information on other steps in the production system can be incorporated as layers in the GIS system. Flock supervisor, feed delivery, and utility routes as well as processing plant and feed mill locations can all be included in the system if desired. In addition, with the inclusion of more demographic and flock information in the database, much more information about the pattern of disease spread can be visualized, aside from just location.

Timeliness: The speed or delay between steps in disease management systems reflect the timeliness of the system, and in many cases the timely dissemination of information to those involved in planning response measures is critical to the prevention of disease spread (Bush *et al.*, 1999). This attribute should be evaluated in terms of the availability of information for disease control, depending on the objectives of the system (i.e. immediate response vs. long-term control efforts) (Klaucke *et al.*, 1998). In relation to disease eradication programs, monitoring systems need to detect infection at an early state of the disease (Graat *et al.*, 2001), while surveillance programs need to have systems in place to allow for rapid response and control in an outbreak situation(Veterinary surveillance - what will be the role of the practitioner? Anonymous, 2000c).

With a grid system, especially on paper, it is difficult to convey or visualize information in a group setting which may lead to a delay in response time. The grid system has been used primarily during disease outbreaks and is not designed as a database to record locations of all the poultry farms on the Delmarva Peninsula. When a poultry operation is diagnosed with a disease, integrators must decide which farms to vaccinate and/or quarantine based on the grid square location rather than the actual location. This may affect the timeliness of a response in certain areas and contribute to the continued spread of disease, unless the vaccination zones are sufficiently large enough to account for the uncertainty as to the exact location of the farm.

With the GIS system, the time between detection, distribution of information and the use of that information to initiate control measures can be much more rapid and accurate than that of the grid-based system. The speed and accuracy of these steps is highly dependent on those responsible for disseminating the information and initiating the control measures. Once an occurrence of disease is reported, it can theoretically be entered into the database and the new information distributed electronically within a matter of minutes.

The benefits of the grid system are its simplicity and the fact that it is already widely accepted and used by the poultry industry on the Delmarva Peninsula. The grid map itself requires little or no maintenance, except during an outbreak situation when disease cases need to be displayed; is easy to use and requires little training. Maintaining up-to-date lists of poultry growers and grid locations does require some effort on the part of each integrator. While grid-based systems can be extremely useful and cost effective in outbreak situation, where financially feasible, a GIS-based system can quickly pay for itself in increased capabilities and decreased losses due to disease (Nath *et al.*, 2000).

A grid-based disease management system is most appropriately used in situations involving a small, easily managed population or geographic location, especially when funding and geographic resources are limited. Data on small populations should not require a large investment of time or manpower to keep up-to-date and in a relatively small, predefined, geographic area such as a city, gathering all the decision makers together presents less of a challenge than might be encountered in a larger area.

The advantages of the GIS system are its flexibility and versatility. In addition to flexibility and versatility, when used properly, the GIS system has the advantage of increased accuracy and efficiency in comparison to a grid system. It allows for a standard data format among poultry integrators and for visualization of the exact location of each farm. This system also provides a centralized storage space for all the information necessary to facilitate disease management decisions. While cost, the necessity of advanced training, and continuous maintenance of up-to-date information may be viewed as disadvantages, the increase in capabilities beyond a grid-based system provided by the additional investment of time and money also serve to increase the cost effectiveness and usability of the system. The benefit of having the exact location and demographic information for every farm in a given geographic area is accompanied by the need to devote time and resources to keep the information accurate and up-to-date.

When multiple diseases or large geographic areas are the focus for the development of a disease management system, or when several different risk factors are to be examined and funding and adequate resources are available, the use of a GIS-based system will provide the capacity for such management and the flexibility to introduce additional capabilities as desired. The database management component of GIS allows for rapid updating of demographic and disease information, and the combination of the database component with the geographical environment of a GIS provides the ability to examine the effects of several risk factors at the same time.

While the grid-based system currently in place on the Delmarva Peninsula has been used in past prevention and control measures, such as the determination of vaccination and quarantine zones, a GIS-based system would greatly enhance the information available to the Poultry Health Committee during the decision-making process. Pilot studies of the GIS system have been used to demonstrate that the direction of prevailing winds may have an impact on the transmission of respiratory disease, which in turn might have an impact on the determination of vaccination and quarantine zones (Johnson *et al.*, 2001). In addition to providing assistance in outbreak situations, a GIS database of the poultry industry on the Delmarva Peninsula would allow for the incorporation of an active surveillance program for diseases of economic importance (Maretto and Urcelay, 2000). While such a system is possible with the current grid-based system, the level of complexity required when focusing on more than one disease at a time could quickly overwhelm the capacity of the paper-based system. Epidemiologic studies of the geospatial aspects of diseases currently present on the Peninsula would contribute to the body of knowledge of these diseases and perhaps assist in the development of more effective control measures.

The centralization of information from all commercial poultry integrators on the Delmarva Peninsula does lead to issues such as data ownership, confidentiality and security that will all need to be addressed before the system is finalized. As more and more information is added to the system, these issues become more and more of a concern. Protection of both the integrators and the individual growers, as well as the trade capabilities of the Delmarva Peninsula are all priorities in ensuring that this information is well protected and used correctly. At the moment, all the data is stored on a secure computer in a centralized facility, which limits access to the data, but also ensures its security. Many options to effectively and fully utilize the GIS database are currently being explored, from maintaining the system in its current location with a designated technician to enter, analyze and report on disease status as well as maintain the database, to a non-integrated system where each integrator receives its own copy of the system which is updated each year through a private contract with the developer.

Cost and confidentiality are the two largest potential disadvantages of a GIS-based surveillance system. These are both surmountable disadvantages. Confidentiality can be ensured through strict security and by restricting access to the data to a few designated parties. Making use of the increased capabilities of the system can offset increased costs in development of the system.

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