EARLY WARNING, DATABASE, AND INFORMATION SYSTEMS FOR AVIAN INFLUENZA SURVEILLANCE


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ABSTRACT: Early warning systems rapidly detect the introduction or sudden increase in incidence of any disease of livestock which has the potential to develop epidemic proportions and/or cause serious socioeconomic consequences or public health concerns. Early warning activities, mainly based on disease surveillance, reporting, and epidemiological analysis, are supported by information systems that enable integration, analysis, and sharing of animal health data combined with relevant layers of information such as socioeconomic, production, and climatic data. Information systems represent the backbone of early warning systems. Disease analysis and integration provide better understanding of underlying ecological and epidemiological mechanisms responsible for the maintenance and spread of a given disease. This also leads to the definition and implementation of cost-effective control strategies. The FAO Early Warning System for worldwide monitoring of avian influenza highlights the potential for better integration and exchange of information among key stakeholders, and better understanding of the disease. It also provides member countries the tools necessary to protect national flocks of domestic poultry and to keep the disease out of their national boundaries.

Key words: Avian influenza, early warning, EMPRES-i, Geographical Information Systems, information systems.

In the aftermath of the avian influenza (AI) crisis triggered by the spread of the highly pathogenic avian influenza H5N1 (HPAI H5N1), the world has been on alert to curb the spread of the disease and mitigate the risk of a potential human pandemic. Existing international early warning systems, including the World Organization for Animal Health (OIE), the European Union, the World Health Organization (WHO), and the Food and Agriculture Organization (FAO), actively monitor the avian influenza situation worldwide. FAO, through its Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases program (EMPRES) and the Global Animal Health Information System (EMPRES-i), played a key role in collecting, recording, and analyzing data on AI, both in wild bird populations and domestic poultry. The system aims at delivering timely and accurate situation updates as well as relevant risk analysis in electronic format (AIDE News, HPAI Updates, EMPRES Watch Messages, Disease Tracking List) distributed to member countries and partner institutions.

The magnitude of the crisis and the epidemiological features of HPAI H5N1 prompted the scientific community to adopt a multidisciplinary approach through the immediate mobilization of competencies and skills of veterinarians, wildlife specialists, ornithologists, virologists, molecular biologists, data managers, and GIS specialists working in the same spirit. The AI crisis is a unique opportunity for developing new collaborative links among groups and institutions that share knowledge. The information leads to better understanding of the underlying epidemiological and ecological factors responsible for emergence and spread of the disease. However, in light of the recent spread to new continents and the threat posed to disease-free areas, it is clear that more integration and data sharing are needed to feed existing global early warning systems and to ensure dissemination of current and accurate knowledge to animal disease decision makers through-
out the world. The international scientific community should join efforts to streamline integration and exchange of large amounts of surveillance data, harmonize surveillance protocols, increase data sharing, carry out joint risk assessments, and coordinate all surveillance efforts with the use of state-of-the-art information systems and technologies.

In 1994 FAO launched the EMPRES program. To support the Early Warning and Early Reaction component, a Web-based Global Animal Health Information System called EMPRES-i was developed. EMPRES-i provides a platform to share information among animal health officers in FAO headquarters and in the field as well as with consultants, experts, and institutions involved in disease-outbreak management and emergency response. The core of the system is a secured Internet-based database using Oracle. Users are granted different levels of access to the system (guest, manager, administrator) and different levels of privileges (view, edit, analyze). EMPRES-i aims at recording, analyzing, and monitoring data on major transboundary animal diseases (TADs). Priority diseases are highly pathogenic avian influenza (HPAI), foot-and-mouth disease (FMD), rift valley fever (RVF), contagious bovine pleuropneumonia (CBPP), African swine fever (ASF), and rinderpest (RP).

From the beginning of the avian influenza crisis in 2003/2004, entry of all available information on occurrences of avian influenza in domestic poultry and wild birds was emphasized. Information is gathered from various sources. Official Web sites such as the OIE, WHO, and Ministry of Agriculture (MoA) are screened on a regular basis. Furthermore, some information is provided directly by the European Commission or by governments. In addition to these official sources, data are drawn from mailing lists such as ProMed, GPHIN, or AI-watch, and news items on avian influenza are traced through Internet research. Important sources of information also include the FAO field offices and contact points as well as OIE/FAO reference laboratories.

The main outputs of EMPRES-i deliver timely and accurate situation updates as well as relevant risk analysis on TADs. The Disease Tracking List (DTL) is one example of disease information generated by EMPRES-i. The DTL is a bimonthly summary of the avian influenza epidemiological situation in space and time. All confirmed outbreaks and pending investigations worldwide from the foregoing 2 wk in domestic poultry and wild birds are listed. The DTL also displays the temporal evolution of daily incidence for a 1-yr period. This list is shared with national and regional field staff as well as key partner institutions, which are requested to verify and validate the unconfirmed events, and to follow up and search for reliable sources of information.

Another key publication is the ECTAD HPAI Situation Update, which compiles information on HPAI outbreaks, suspicions of outbreaks, or other relevant issues observed over the foregoing 2 wk. Information from the field or other organizations and institutions, as well as mission reports and news reports, are edited and summarized to give the reader a brief overview of important events regarding HPAI. The first page features a map showing locations of confirmed HPAI outbreaks in poultry or cases in wild birds over a period of up to 2 mo. The HPAI Update is produced and distributed in electronic format three times a week (Monday, Wednesday, Friday) and was originally created to regularly update FAO officers on the current HPAI situation in the world. In line with the increasing demand, its distribution has been expanded to FAO country offices, contact points in other international organizations, and partner institutions. As the HPAI Update includes suspicions and rumors, its distribution is limited. On the other hand, the monthly FAO Avian Influenza Disease Emergency (AIDE) News is designed
specially for public distribution. It includes a short situation analysis, country situations regarding confirmed HPAI outbreaks, and information on FAO missions and projects. Some of this information is posted on the EMPRES and FAO Avian Influenza Web site, depending on its relevance to the target audience and the potential sensitivity of the information.

EMPRES-i has been linked to a global information system (GIS) application to provide visual representation of the disease distribution patterns and to explore the relationships among location, environment, and disease. GIS environment offers spatial analysis and visualization capabilities, and can contribute significantly to understanding epidemiological and ecological factors responsible for TADs emergence and spread. In the GIS framework, AI observation data entered into EMPRES-i can be viewed as basic maps before being combined with additional geographical layers such as land use, poultry density, remote-sensed imagery, or other variables known to be relevant to the epidemiology of the disease (Fig. 1).

Exploratory spatial data analysis (ESDA) is used to seek patterns indicative of clusters of cases or areas with elevated incidence, or to highlight associations between the magnitude of disease and other risk factors. GIS supports ESDA through the calculation of spatial explorative measures, including the creation of smoothed surfaces derived from interpolation techniques applied to punctual variables (Fig. 2). Spatiotemporal density of events is another useful application of ESDA that gives insight into areas most vulnerable to a given disease and may help understand underlying spatial structures.

![Figure 1](image-url)  
**Figure 1.** Highly pathogenic avian influenza (HPAI) outbreak distribution from January to June 2006.
driving the spread of the disease. In Figure 2, an outbreak density map is represented as a moving window (or kernel) of a specified size passing through subsequent moves across the study area. At each location, a ratio is calculated between the area of the window and the number of outbreaks eventually falling within the window. Such a map helps identify areas of maximum outbreak density and shows the recent shift of the animal epizootic from southeast Asia toward central Europe and western Africa.

Three-dimensional representations also help uncover ecological and topographical features associated with the presence of the disease and its possible spread. GIS display of natural features such as topography may help outline obvious spatial patterns in the distribution of outbreaks. In Pakistan and Afghanistan (Fig. 3), outbreaks are dispersed along the valley surrounded by major relief and follow movements of people and animals across the border. Commerce commonly is carried out through valleys, suggesting that this might drive HPAI outbreaks in the area of interest. It also is apparent that outbreaks in both countries belong to the same ecosystem and that diseases do not recognize administrative borders.

These examples show the importance of GIS to identify spatial or spatiotemporal patterns that can be used in developing more rigorous causal hypothesis tests. Methods for identifying space–time clusters or hot spots of disease are among the most important exploratory methods for epidemiology. Maps also display significant clusters in proximity to hypothesized environmental risk factors for the emergence of HPAI, such as the presence of wetlands or rice fields. Several techniques explore the emergence, spread, and main-
Tenance of HPAI in Asia and contribute significantly to understanding disease epidemiology underlining the role of specific animal production systems and ecological conditions (Martin et al., 2006; Gilbert et al., 2007).

The independent multidisciplinary approach to surveillance programs and early warning systems for HPAI H5N1 does not necessarily capture the overall epidemiological picture required for combating the disease. For early warning and risk-assessment purposes, all data from domestic poultry and wild bird surveillance have to be managed, integrated, analyzed, and made accessible, preferably through a common platform where data can be viewed and exchanged. Data integration, analysis, and mapping represent a key step to understanding the distribution, behavior, source, and evolution of a disease, and to defining appropriate cost-effective disease response. Joint efforts of various disciplines within institutions and among international and regional organizations are required.

In conclusion, the ultimate goal of early warning systems is to make information and risk-assessment outcomes available to all relevant stakeholders and to provide the opportunity for timely reaction in the most cost-effective manner. To achieve this global challenge, we must strengthen collaborative opportunities across relevant disciplines and provide rapid access to surveillance data. Global national surveillance programs must be linked and connected to existing early warning initiatives such as the GLEWS, GAINS, Birdlife International, Wetlands International, CIRAD, and the European Union. Early warning, database, and information systems for avian influenza are essential tools in the global challenge to contain the current HPAI crisis. However, success depends on the willingness and commitment of all relevant stakeholders to join the challenge and create the necessary

Figure 3. Three-dimensional rendering of a digital elevation model and overlay of highly pathogenic avian influenza outbreaks in Afghanistan and Pakistan.
connection of all disciplines and people involved in the fight against the disease. This includes interconnection of information systems as well as public exchange and transfer of epidemiological information that can be used for risk assessment.

**LITERATURE CITED**


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