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ArboNet and the Arbonauts—Rapid Reporting Systems for Vector-borne and Zoonotic Disease

Introduction

Vector-borne diseases usually have complex life cycles. For any given system, the host(s) vector(s) and pathogen are each subjected to a variety of “pressures” within the ecosystem. Many environmental factors drive or constrain the system: weather and climate, food and space resources, predators and parasites. For example, food quantity and quality, availability of nesting sites, and exposure to predators or parasites affect the abundance and susceptibility of vertebrate hosts. The vector is affected by temperature, precipitation, humidity, food resources (which may differ between adult and immature stages), and by predators and parasites. Host immune status, the frequency and timing of contact between vector and host, and the mix of host species all affect the survival and transmission of the pathogen. Temperature has a major impact on development rate of the pathogen when it is developing in the vector. With the exception of vector-borne diseases that have humans as the primary or only vertebrate host (e.g., malaria, dengue, and bancroftian filariasis), humans often become involved in the transmission cycle by accident, and do not develop sufficient parasitemia or viremia to infect additional vectors; that is, they are “dead end” hosts. For these latter diseases, it is crucial to monitor the dynamics of the enzootic cycle if we hope to predict and prevent epidemics.

Vector-borne disease intelligence

One of the first things that strikes the entomologist or epidemiologist when looking at remotely sensed imagery is the enormous amount of information in comparison to the available data on the diseases we would like to prevent or control. For many diseases, such as cancer and birth defects, there are well-developed registries that give detailed information about cases. Such information allows the epidemiologist to search for associations between environmental indicators (from the remotely sensed data) and the location of cases. Unfortunately, reporting systems for vector-borne diseases are generally poorly developed or entirely absent. For example, dengue, which is responsible as many as 50-100 million cases each year, is not even reported in many countries—only the more severe cases being entered into the reporting system. Even in the United States, vector-borne diseases are generally grossly underreported. To apply new technologies such as remote sensing to the surveillance, prevention, and control of vector-borne and zoonotic diseases, we need well-designed surveillance systems to provide the “ground truth” data to validate the models that are being developed (Guptill and Moore 2004).

Development of rapid diagnostics and reporting systems

As recently as twenty years ago, it was unheard of to have near-real-time data on arbovirus activity (location, virus identification, identity of major vectors, numbers of cases, etc.) that could be used to predict and, perhaps, prevent or reduce epidemic virus transmission. Identification of the pathogen took weeks to months and, once identified, the information often sat in a laboratory notebook, without being returned to the submitting agency or the organizations responsible for prevention and control.

With current laboratory technology, it is possible to identify pathogens within days, or even hours (Shi et al. 2001). Widespread access to the Internet permits the rapid exchange of information between all levels of the public health system. The net result of these changes is that, potentially, we can now provide updated information that reflects events that occurred within a matter of days prior to their posting in a database.

A rapid reporting system has been developed for West Nile virus activity that serves as a model for other reporting systems. The system, called ArboNet, collects data from state and local health departments into a central database at the Centers for Disease Control and Prevention (CDC). The data is then made available to state health departments in near real time. In addition, the data are uploaded to the US Geological Survey (USGS) in Reston, VA, where they are used to update a set of maps showing current and past West Nile activity. One of the crucial features of ArboNet is that it records epidemiologic data for vectors, wild vertebrate hosts, and domestic animals, as well as for humans. This broad focus gives ArboNet its utility for disease prevention and control.

ArboNet's developers encountered many problems in the design, programming, and implementation process. Many states already had reporting systems, but these often were not compatible with one another, and frequently did not collect essential data (e.g., vectors, wild vertebrates, etc.). To comply with new federal guidelines, ArboNet had to be compatible with the HHS-wide National Electronic Disease Surveillance System (NEDSS) structure. Because data on humans is reported and stored by ArboNet, several legal and ethical issues had to be dealt with in the development of the database system. These issues included patient privacy, secure data transmission and retrieval, and related problems. Finally, several states wanted a process for double-checking data and giving a final "release" before posting to the national mapping site or other public access sites.

We will explore the structure of ArboNet, attempt to identify strengths and possible shortcomings, and suggest ways to improve the existing system.

Suggested readings

CDC. Epidemic/Epizootic West Nile Virus in the United States: Guidelines for Surveillance, Prevention, and Control. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Center for Infectious Diseases, Division of Vector-Borne Infectious Diseases Fort Collins, Colorado. 3rd Revision; 2003. Available on line at: http://www.cdc.gov/ncidod/dvbid/westnile/resources/wnv-guidelines-aug-2003.pdf

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Prior to his retirement from federal service, Dr. Moore was Supervisory Research Entomologist and GIS Coordinator in the Division of Vector-Borne Infectious Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention, located in Fort Collins, Colorado. He received his BS, MS, and PhD degrees from the University of California, Davis. He is the author/co-author of over 60 research papers or book chapters, and has received numerous government and professional society awards.

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Dr. Moore also is President of Vector Biology and Control International, an independent consulting firm that provides training and consultation on the biology and control of vector-borne diseases. VBCI provides on-site training, develops tailored training manuals and other material, and assists agencies in developing effective surveillance, prevention, and control programs. Emphasis is placed on rapid response and the use of current technology—such as GIS, GPS, and automated field data entry—to reduce personnel costs and speed up turnaround times.