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STUDIES IN THE THEORY OF THE SPREAD OF THE HANTAVIRUS

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Our recent work in the theory of the spread of epidemics is described. The work provides possible explanations for the formation of spatio-temporal patterns related to observed refugia, diffusion of infection-spreading animals in confined areas (home ranges) and involves description via Fokker-Planck treatments, Master equations, and extended random walks. Applications to observations in several locales, including in Panama and in New Mexico are also be mentioned.

INTRODUCTION

Health concerns constitute an obvious reason for carrying out the study of the spread of epidemics. The fundamental interest in a general understanding of how excitations in spatially resolved interacting systems propagate on a macroscopic scale provides another motivation for such a study. Among the epidemics we studied, the Hantavirus appears especially convenient for starting one's investigations into the subject because of its simplicity from a conceptual viewpoint. The Hantavirus is characterized by a few main features as follows. Infection is carried by mice that move from location to location, and is transmitted to other mice through mutual encounters. It is not known but is sometimes supposed that these encounters that lead to infection transmission involve aggression. The mice do not die, nor are otherwise impaired, from contraction of the virus. Mice are never born infected irrespective of infection status of the parent. Humans get the virus from the mice but have no feedback effects on the mice in the infection process. Our work has been based for the last few years on a simple model that can be constructed from these four features to describe the time evolution of the mouse populations. The mathematical details of the model may be found in the original references below. The model may be regarded from the ecological viewpoint as a so-called SI model extended to include spatial resolution and diffusive transport, and from the mathematical point of view as a system obeying the Fisher equation (a reaction diffusion equation with logistic nonlinearity) with internal states representing infection or its absence, respectively. The success of our model, in the short time since it was proposed for Hantavirus, has included qualitative and semiquantitative success in explaining observations such as spatio-temporal patterns in the epidemics. These patterns are associated with (1) correlations between periods of precipitation and epidemic outbreaks and (2) spatial location of refugia regions of the landscape in which infection persists during off-periods of the epidemic. Other applications of the model include a detailed understanding and control of traveling waves of infection, other effects related to the finite size of the populations and the environment, and event extensions to unrelated systems, e.g., bacteria in Petri dishes. Led by this success, we began an investigation to extract the parameters of the model from field observations.

DIFFUSION CONSTANT OF THE MICE AND FURTHER WORK

Of all the parameters of the model perhaps the most important is the mouse diffusion constant D. Under the simple assumption that mouse movement is a random walk, it first appeared straightforward to obtain D from records of the movement through the use of the well-known proportionality of the mean squared displacement to D. Detailed studies of extensive mark-recapture data for mice in Panama and NM led us to deduce D directly in this manner but also yielded as a byproduct a length scale in the random movements of the mice. This length scale turns out to be a combination of the home range of the mice and the grid size of the probe (trapping region) used in the field observations. To disentangle these two components of the length scale was an important undertaking. We succeeded in providing for this purpose a practical prescription on the basis of an extensive theoretical analysis. We deduced explicit values of the home ranges of two different kind of mice in Panama and NM respectively, through the application of this technique, e.g., 60 to 90 m for Zygodontomys brevicauda and about 100 m for Peromyscus maniculatus in the two respective locales. This information is in itself important. Furthermore it also led us to generalize our earlier model to incorporate home ranges. We have undertaken such investigations in a variety of ways. One simple way uses Fokker-Planck equations, another uses Volterra-type memory equations and a third considers the dynamics of two types of mice, stationary and itinerant, in each category with the additional label, susceptible or infected. While the itinerant mice are the subadults that must leave to find their own home ranges, the stationary mice are the adults that move within their home ranges and do not stray far from the burrow. Our studies, which employ a combination of nonlinear analysis and simulations, have led to unexpected new insights into the spread of the Hantavirus. These are being reported elsewhere.

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