MODELS FOR PREDICTING THE DYNAMICS AND CONTROL OF CONTACT-SPREAD DISEASES IN FERAL PIGS (Sus scrofa) IN AUSTRALIA

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Abstract: Feral pigs (*Sus scrofa*) are a major pest in Australia because of the agricultural and environmental damage they cause and because they have the potential to form a significant reservoir of exotic diseases such as foot and mouth disease (FMD) and classical swine fever. To address the second issue, two types of epidemiological models have been used. Simple deterministic models have been used to predict the threshold density of feral pigs for the persistence of FMD, the rate of spread of FMD and the effectiveness of control and surveillance techniques. In addition a user-friendly software package (AUSPLAGUE) has been developed around a spatial model for contact-spread diseases in feral pigs. The model places in a landscape context management techniques for containment and eradication of disease and aspects of feral pig ecology relevant to epidemics, such as movements and social behaviour. AUSPLAGUE will be used as a training and decision-support tool for planning the eradication of disease in feral pigs and could serve as a prototype for other diseases of feral animals and native wildlife.

Keywords: Feral pig, *Sus scrofa,* Suidae, Epidemiology, Model.

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1. Introduction

Feral pigs (*Sus scrofa*) are distributed widely through much of eastern and northern Australia (Wilson *et al.*, 1991). They are considered a pest of agriculture and the environment and a variety of techniques are used to control them (McIlroy, this volume). Also of major concern is the potential of feral pigs to harbour endemic or exotic diseases. This paper reviews the results from epidemiological models for diseases spread primarily by direct contact, for example foot and mouth disease (FMD) and classical swine fever (CSF) and describes a new computer simulation model, AUSPLAGUE, for the spatial dynamics and control of disease in feral pigs.

2. Results from conventional mathematical models

Non-spatial models and spatial diffusion models have been used to predict the conditions for establishment and forecast the subsequent progress of FMD and CSF in feral pigs in south-eastern Australia. For example, estimates of threshold densities (K_T) for epidemics of FMD in wild pigs are 7 pigs/km^2 (range 2 - 14) in semi-arid floodplains (Pech & Hone, 1988) and < 0.1 pigs/km^2 in Namadgi National Park (NNP) in the south-eastern tablelands of New South Wales (Pech & McIlroy, 1990). The differences in K_T partly reflect differences in the capacities of feral pigs to transmit disease in the two contrasting habitats, as well as the generally poor quality of data on contact rates and transmissibility of infectious doses of FMD under field conditions. For comparison, estimates of K_T based on data from Pakistan suggest that CSF might establish only in some wetlands and river systems of Australia which have very high densities of feral pigs (Hone *et al.*, 1992).

The models have been used to assess the likely effectiveness of control procedures (Pech & Hone, *op cit.*) as well as preventative actions such as surveillance or pre-emptive reduction of feral pig densities (Pech *et al.*,1988). Currently there is no systematic surveillance of disease in feral pigs in Australia. Hone and Pech (1990) showed that relying on opportunistic reporting by hunters could result in widely dispersed, and difficult to manage, epidemics of exotic diseases. This conclusion was supported by the estimate from a diffusion model of a relatively rapid rate of spread, 2.8 km /day, of FMD in feral pigs in NNP (Pech & McIlroy, *op cit.*).

Despite the availability of quantitative predictions from models such as those outlined above, exotic disease contingency plans can be difficult to formulate because the generality of predictions is unknown, their associated errors are often large, and the published studies may not apply to the particular conditions of a disease outbreak. A computer simulation model, AUSPLAGUE, is being developed to address some of these problems.

3. Structure and design of AUSPLAGUE

AUSPLAGUE has been designed to: (a) simulate the dynamics of a contact-spread disease by modelling the behaviour of pigs within habitats (because this determines the rate of spread of disease between individual pigs), and the time spent by pigs in each type of habitat (because this affects the rate of spread of disease across a landscape); (b) simulate the effects of a range of control methods on disease dynamics; (c) place the epidemiological and control models in spatially realistic settings; (d) enable non-specialists to use the models interactively to explore ways of managing exotic diseases. AUSPLAGUE employs a four-stage procedure of setting up a scenario, introducing a disease, then using a range of techniques to trace and control an epidemic (Pech *et al.* 1992; Pech, 1992).

The first step in creating a scenario is to select a study area from a digital map of a region familiar to the user. Superimposed on this is a habitat map for feral pigs and demographic data including birth and death rates, age distribution, the average density of pigs, the relative density in each type of habitat and seasonal variation in the use of habitats by pigs. AUSPLAGUE uses an estimate of the average density of feral pigs for the entire study area then scales the density in each habitat type within the selected area using either the relative frequency of observations from prior telemetry studies, or expert assessment of pigs' relative affinity for types of habitat.

Diseases are characterised by a standard set of parameters: case mortality, duration of the latent period, duration of the infectious period, duration of immunity (if any), and the transmission rate. For contact-spread diseases, the transmission rate combines the rate of contact between animals and the probability of transfer of an infectious dose when contact is made. In AUSPLAGUE, the pathogen is introduced into the feral pig population by selecting and "infecting" one or more animals. The "infected" pigs are assumed to be at the beginning of their infectious period and are immediately capable of naturally infecting nearby susceptible animals. AUSPLAGUE provides an opportunity to explore a wide range of methods of disease introduction by enabling the user to choose the size, location and timing of the initial infection.

In AUSPLAGUE, the progress of an epidemic can be traced with counts of the numbers of animals in each disease class, or by a convex polygon which delimits the infected area. As well, the disease status of individual pigs can be displayed at each time step during a simulated epidemic. A range of control methods including trapping, poisoning, hunting and aerial baiting, can be initiated by the user at any time. Although AUSPLAGUE can show explicitly the impact of each technique, simulations can be made more realistic by displaying only the information gathered from techniques, such as trapping or shooting, where live animals or carcases can be retrieved.

Because AUSPLAGUE is a stochastic model, repeated runs from the same initial conditions will not give identical results. AUSPLAGUE is designed to save and retrieve the values of all parameters and the locations and disease status of all pigs at any time during a run. The user can repeat the run several times to assess the variability in the outcome.

4. Sub-models within AUSPLAGUE

4.1. Movements of feral pigs

In the absence of disease or other control methods, the relative density of feral pigs in each habitat type should be maintained at the appropriate levels for each season. AUSPLAGUE achieves this by relating the speed of each pig's movements to the habitat type at its current location. At present, insufficient data are available to characterise the distribution of movements for each habitat in NNP. For each age/sex class of pigs, AUSPLAGUE uses a single reference distribution of movements which has been amalgamated from sequences of radiotelemetry records in all types of country. At each iteration in the computer simulation, the next movement for each pig is assigned firstly from the reference distribution then rescaled for each habitat type.

Preliminary analysis suggests that the social structure of feral pigs in NNP comprises mainly solitary adult males with fluid groups of juveniles of both sexes and adult females (McIlroy, unpublished data; Pech *et al.*, 1993). The observed group structures have been modelled using a modified version of the tendency-distance interaction models described by Warburton and Lazarus (1991). These models are biologically plausible and are particularly suitable for computer simulation techniques because they rely only on the positions of nearby pigs to calculate the next movement for each individual.

4.2. Control techniques

AUSPLAGUE includes three categories of control techniques to evaluate the timing and allocation of resources required to prevent, contain or stamp-out an epidemic. Spot controls such as traps and spot baiting have a point location but may have associated catchment areas. Linear controls such as bait lines or fences are represented as connected straight line segments and may also have associated catchments. The third category which includes hunting teams and broad scale aerial baiting, is applied across areas and is represented by a mosaic of rectangles. Each control technique has a prescribed effectiveness and duration.
Methods used to trace the progress of an epidemic are similar to that for pig control and could include sampling techniques such as "Judas pigs" and traps "baited" with sows in oestrus (McIlroy, this volume). In AUSPLAGUE, disease surveillance information can be flagged specifically; in training exercises, all other sources of information can be hidden from the user to allow an assessment of exotic disease control strategies using a realistic knowledge base.

5. Conclusion

The management of native and feral animals is a significant component of Australian contingency plans for exotic animal diseases. This is partly because some feral species are abundant, and partly because surveillance, eradication or containment of disease in wild animals differs substantially from that in confined herds or flocks of domestic animals. Conventional epidemiological models have provided useful but limited guidelines for plans to eradicate exotic diseases in feral pigs. A computer simulation model, AUSPLAGUE, is being developed to integrate disease dynamics, host population dynamics, control and surveillance methods and landscape data. The software is portable, interactive and user-friendly and will be useful as a training tool for testing and developing management strategies.

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