Epidémiol. santé anim., 1997, 31-32

A MODEL OF WARBLE FLY INFESTATION (HYPODERMOSIS) IN SPACE AND TIME

French N.P. [1]

Après une campagne d'éradication du varron réussie, la question de son retour au Royaume Uni par des bovins importés se pose maintenant. Un modèle de simulation spatiale et temporelle a été développé pour mesurer l'impact éventuel d'un tel retour. Le but du modèle est aussi d'améliorer les connaissances sur le système hôte-parasite et d'identifier de nouveaux domaines de recherche. Il s'appuie sur les quelques données acquises concernant la dynamique de population de l'hypoderme et quelques autres mouches parasites. Les paramètres essentiels du modèle sont la distance de dispersion médiane, le taux de reproduction, la mortalité larvaire, densité-dépendante et la mortalité des pupes et des adultes, densité indépendante. La dispersion est modélisée selon une distribution de Cauchy sur une grille. Les variations spatiales et temporelles des effectifs de la mouche servent à estimer les taux d'infestation sur la grille et à calculer la prévalence du varron sur des bovins sensibles. Le modèle simule la dispersion d'une épizootie pendant 5 ans sur une zone de 30 km de côté au sud-ouest de l'Angleterre et peut servir pour comparer les stratégies de lutte. Une première analyse de sensibilité par la méthode de l'hypercube latin a montré que les paramètres les plus sensibles sont la mortalité des pupes et le taux de reproduction.

INTRODUCTION

The warble fly (*Hypoderma spp.)* is a parasite of major welfare and economic importance in cattle. A successful campaign of eradication was initiated in 1978 in the UK and resulted in major decline in cases of warble fly. In 1991 no cases of warble fly infestation were notified and no animals were identified as sero-positive. Since then there has been some concern that the disease could be reintroduced into the UK through imported cattle. A simulation model of warble fly infestation is currently being developed to describe the distribution of hypodermosis in space and time. The model enables us to understand and describe the host -parasite system, to highlight weaknesses in our understanding of the ecology of the parasite and to compare the possible impact of simple control measures. It is constructed using our understanding of the spatial distribution and population dynamics of the fly and draws heavily on models developed for other myiasis flies.

POPULATION GROWTH

In order to simulate the population dynamics of the fly the life cycle was divided into two parts: adult gravid female to 3rd stage larvae (warbles) and pupa to adult. The number of warbles arising from a single gravid female in the absence of density dependent constraints was assumed to be 28 (Minar 1984). However this part of the life cycle contains several density dependent stages (Weintraub 1978) that were modelled using a limited population growth model with a mean equilibrium population density of 4 warbles per host (this was estimated after assuming that the prevalence of infestation rarely exceeds 75% and the distribution of warbles follows that described by Burrilion and Messean (1982)). The sex ratio was assumed to be 50:50 and the mortality from pupation to gravid female flies was assumed to be density independent (Weintraub 1978) and was estimated to be 80% (Minar 1984). Only one generation was allowed per year and the model simulated the population growth over 5 years.

DISPERSAL

There appears to be little detailed information about the dispersal of *Hypoderma spp* although it is clear that dispersal distances are relatively short Gregson (1958). It was decided to use the Cauchy distribution to simulate the dispersal of the adult flies using one parameter; the median dispersal distance (this technique has been used to describe the dispersal of other myiasis flies (Mayer and Atzeni 1993)). A median dispersal distance of 500m was adopted for the final models. In order to model the spread in two dimensions, the distance and direction of 250,000 flies was simulated. The distance was obtained by selecting 250,000 random numbers from a Cauchy distribution with a median of 0.5 . The direction was obtained from random numbers from a uniform distribution spanning 0 to 360. The pattern of dispersal was then transposed onto a 5x5 cell window consisting of 25 grid cells each with a dimension of 1.5 x 1.5 km (Mayer et al 1993, Stinner et al 1983). As each generation of flies emerged they were dispersed from a central cell into each of the surrounding cells according to the Cauchy distribution. As the populations increased and dispersed, the flies emerging from each cell were allocated into the surrounding 24 cells and added to those already present in those cells. The cell allocations were then further weighted according to the square of the number of cattle in each grid cell (Mayer et al 1993). This would therefore attract flies into areas with more cattle and prevent flies from being dispersed over water or urban areas.

[1] University of Liverpool, UK

ESTIMATING PREVALENCE, INFESTATION RATE AND THE DISTRIBUTION OF LESIONS

In common with other macroparasites, the distribution of warble fly larvae in the host population is aggregated - some individuals carry large numbers of warbles, whilst the majority of them carry only a few. The relationship between infestation rate and prevalence was assumed to follow a modified negative binomial distribution in which the degree of aggregation decreased with increasing prevalence (Burrillion and Messean 1982). Each successive generation of gravid female flies was therefore dispersed into the surrounding area and allowed to strike the cattle in each cell, thereby producing a pattern of warble infestation consistent with the above distribution.

HOST POPULATION

For the final models a 30x30km area in the south west of England was chosen and a single cow carrying 30 warbles was seeded into a central grid cell. This area was chosen because it is densely populated with cattle and was the destination of a large proportion of the warbled cattle imported in 1993 (Tarry 1994). The cattle numbers in each cell were estimated from a map of the distribution of cattle in England and Wales.

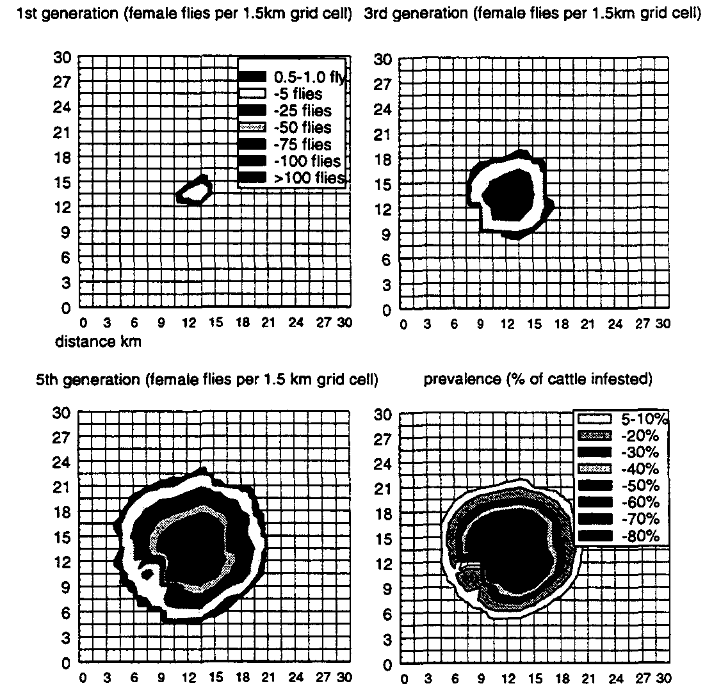
SENSITIVITY ANALYSIS

A preliminary analysis of the sensitivity of the model to changes in parameter estimates was conducted using the Latin Hypercube method (Blower et al 1991). Median dispersal distance, basic reproduction number (fly to 3rd stage larvae), equilibrium population density, pupal mortality and host density were all varied according to random samples from 10 equal intervals of a uniform distribution. A stepwise multiple regression model was then used to examine the independent associations between each of the varying parameters and a number of outcomes. The model was developed using programming language.

RESULTS: SIMULATION 1, assuming no control methods were used

Figure 1. After 5 years the maximum population increased to over 100 flies per cell (67 per km^2) and the area has a radius of 8.5km. The final graph shows the estimated prevalence of infestation after 5 generations. In the areas with the highest number of flies, the model estimated that approximately 70-80% of cattle will be infested.

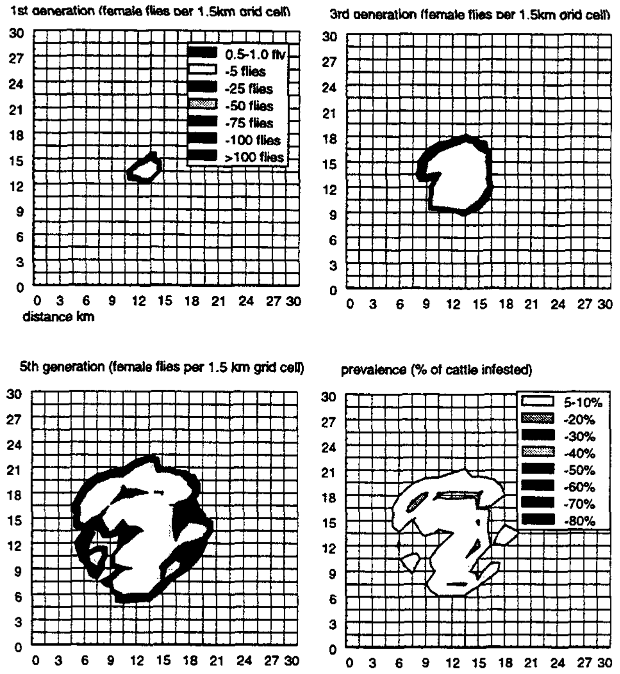
Warble fly dispersion (assuming no control measures are adopted)



SIMULATION 2. Farmers treat their cattle with an insecticide when more than 5% of the herd is infested.

Figure 2. The prevalence of infestation exceeded 5% in some cells after two years, resulting in an early and severe restriction in fly abundance and dispersal. The density of flies did not exceed 5 per grid cell, even after 5 years. The prevalence in year 5 was rarely above 10% although it was frequently above 5% in the centre of the outbreak.

Warble fly dispersion (cattle treated when prevalence>5%)



SENSITIVITY ANALYSIS

The variation in the number of adult flies emerging after 3 years from the starting population of 30 warbles was most influenced by pupal mortality, followed by the basic reproductive number (adult female to warbles in the back), host density, median dispersal distance and least of all by the equilibrium population density. The radius of the 'wavefront' of flies was also most influenced by pupal mortality, followed by the basic reproductive number, median dispersal distance, the equilibrium population density and least of all by the density of cattle in the area. The intensity of infection (number of warbles per host) was influenced in a similar way to the radius of the wavefront. These results suggest that improving our information on pupal mortality and basic reproductive ratio will have the greatest impact on our ability to predict future trends.

REFERENCES

Blower S.M., Hartel D., Dowlatabadi H., Anderson R.M., and May R.M. (1991) Drugs, sex and HIV: a mathematical model for New York City. Philosophical Transactions of the Royal Society of London Series B **321** 171-187

Burillon G. and Messean A. (1982) Comparison of two methods of estimation of the warble fly infestation rate. In Symposium on Warble Fly Control in Europe, Brussels 16-17th Sept. 131-140

Gregson J.D. (1958) Recent cattle grub life-history studies at Kamloops, British Columbia, and Lethbridge, Alberta. Proceedings of the Tenth International Congress of Entomology 3 (1956) 725-734

Mayer D.G., Atzeni M.G. and Butler D.G. (1993) Spatial dispersion of exotic pests - the importance of extreme values. Agricultural Systems **43** 133-144

Mayer, D.G., and Atzeni, M.G. (1993) Estimation of dispersal distances for *Cochliomyia hominivorax* (Diptera:Calliphoridae). Environmental Entomology **22** 368 - 374

Minar J. (1987) Studies on the population ecology of cattle warble flies as a model of the internal regulatorysystems in parasite and host population. In: Warble fly control in Europe IV. Puccini, V. and Tassi, P. (Eds), Bari, Italy. Italian society for Parasitology. 51-200

Stinner R.E., Barfield C.S., Stimac J.L. and Dohse, L. (1983) Dispersal and movement of insect pests. Annual Review of Entomology **28** 319-335

Tarry D.W (1994) Hypodermosis in Britain: a fragile success. Proceedings of COST 811 Workshops, 23-25th September 1993, Thun. Improvements in the Control Methods for Warble-Fly in Cattle and Goats. 3-9.

Weintraub J. (1978) Pilot test of sterile insect releases for warble fly control. Research Highlights 1977: Agriculture Canada Research Station, Lethbridge, Alberta. 48-53