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A mathematical model for the dynamics of digital dermatitis in groups of cattle

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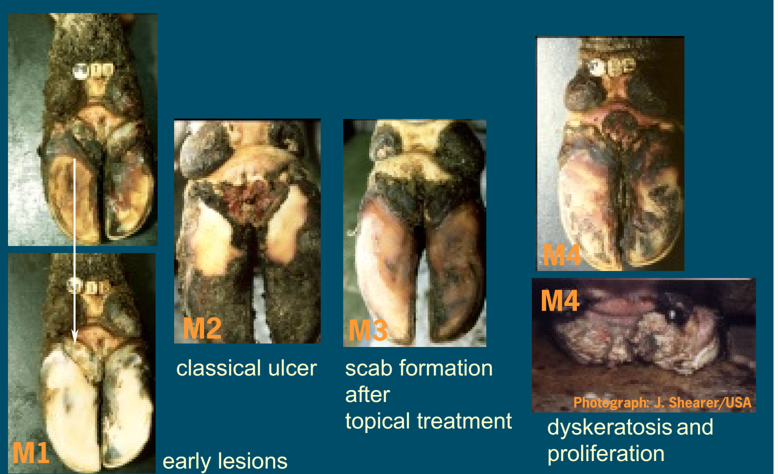
Introduction

(Papillomatous) Digital dermatitis, (P)DD, is an infectious disease in cattle that causes painful ulcerative lesions along the coronary band of the claws. Herd health managers have failed to eradicate this classical production disease of cattle and this may be due to the 'paradox of the modern animal health manager'. Dynamic modelling can help in developing preventive and therapeutic strategies with the aim to characterize the 'manageable endemic state' of disease. The evaluation of therapy and prevention is commonly accomplished by generic data analysis of incidence or prevalence data of lesions alone. The mathematical model presented in this study aims at providing a hierarchical transition model for the population transmission dynamics in closed groups of cattle.

Materials and Methods

Four stages of (P)DD were identified during the course of the disease: M1: the early stage, M2: the acute classical ulceration, M3 the healing stage covered by a scab, and M4 the chronic stage characterised by dyskeratosis and/or proliferations as illustrated in figure 1 (Döpfer et al. 1997).
The transitions between stages were described using ordinary differential equations (ODE) in a deterministic matrix SEIS model where two transition parameters were dependent on the infection pressure from the environment and the number of infectious stages M2 and M4 as shown in table 1 and figure 2. The model is used to test the efficacy of group management strategies aimed at preventing outbreaks of (P)DD.

Figure 1: course of the (P)DD lesions



Döpfer et al. 1997

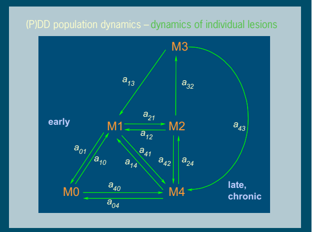
Table 1: (P)DD population dynamics – transition matrix

	M0	M1	M2	M3	M4
M0	$-(a_{10}+a_{40})(\mathbf{x_1})$	$+a_{01}$			$-a_{04}$
M1	$+a_{10}(\mathbf{x_1})$	$-(a_{01}+a_{21}+a_{41})$	$+a_{12}$	$+a_{13}$	$+a_{14}$
M2		$+a_{21}$	$-(a_{12}+a_{32}+a_{42})$		$+a_{24}$
M3			$+a_{32}$	$-(a_{13}+a_{43})$	
M4	$+a_{40}(\mathbf{x_1})$	$+a_{41}$	$+a_{42}$	$+a_{43}$	$-(a_{14}+a_{24}+a_{04})$

Figure 2: (P)DD population dynamics – SEIS model

- a_{40} and a_{10} depend on two infectious state variables:
- (M2 and M4)

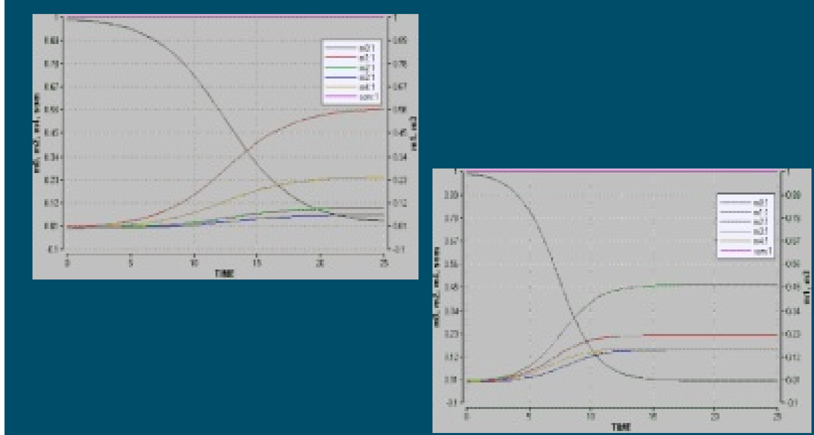
- M2 – highly infectious state (I_2)
- M4 – less infectious state (I_3)
- $a_{10} = f\,[h_2m_2(t) + h_4m_4(t) + h_ee(t)]$
- $a_{40} = (1-f)\,[h_2m_2(t) + h_4m_4(t) + h_ee(t)]$
- infection of the environmental compartment
- $de(t)/dt = f_2m_2(t) + f_4m_4(t) + be(t)$
- be(t) is the halflife of infectiousness



Results and Discussion

Many if not all intervention studies are aimed at eliminating (P)DD together with its risk factors and pathogens (the knock-out strategy) and not at modulating the population dynamics of disease to facilitate the manageable state of an endemic disease with a low percentage of M2 lesions at equilibrium (see figure 3).

Figure 3: time plot of the dynamic (P)DD model



Animal health managers are expected to confine animal husbandry systems to states defined by 'animal health and welfare' under economic constraints. The human brain on the other hand, has no intuitive insight into consequences of complex interactions because human cognition was conditioned by evolution in a partially predictable ecosystem at steady state (Vollmer 1986). This results in the 'paradox of modern animal husbandry'. Intensive animal husbandry systems are not balanced ecosystems and may not be predicted by intuition alone.

Applied mathematics may provide structures, which when interpreted in terms of real entities will result in a cognitive aid, that is a structurising algorithm, able to disentangle paradoxical situations and help to develop management strategies for animal husbandry.

References
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