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Treatment strategies for sheep scab: An economic model of farmer behaviour

Emily J. Nixon*, Hannah Rose Vineer, Richard Wall

Veterinary Parasitology and Ecology Group, University of Bristol, Bristol Life Sciences Building, 24 Tyndall Avenue, Bristol, BS8 1TQ, United Kingdom

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ABSTRACT

Ovine psoroptic mange (sheep scab) is a debilitating and damaging condition caused by a hypersensitivity reaction to the faecal material of the parasitic mite *Psoroptes ovis*. Farmers incur costs from the use of prophylactic acaricides and, if their sheep become infected, they incur the costs of therapeutic treatment plus the economic loss from reduced stock growth, lower reproductive rate, wool loss and hide damage. The unwillingness of farmers to use routine prophylactic treatment has been cited as a primary cause of the growing incidence of sheep scab in the United Kingdom (UK) since the disease was deregulated in 1992. However, if farmers behave rationally from an economic perspective, the optimum strategy that they should adopt will depend on the risk of infection and the relative costs of prophylactic versus therapeutic treatment, plus potential losses. This calculation is also complicated by the fact that the risk of infection is increased if neighbours have scab and reduced if neighbours treat prophylactically. Hence, for any farmer, the risk of infection and optimum approach to treatment is also contingent on the behaviour of neighbours, particularly when common grazing is used. Here, the relative economic costs of different prophylactic treatment strategies are calculated for upland and lowland farmers and a game theory model is used to evaluate the relative costs for a farmer and his/her neighbour under different risk scenarios. The analysis shows that prophylaxis with organophosphate (OP) dipping is a cost effective strategy, but only for upland farmers where the risk of infection is high. In all other circumstances prophylaxis is not cost effective relative to reliance on reactive (therapeutic) treatment. Hence, farmers adopting a reactive treatment policy only, are behaving in an economically rational manner. Prophylaxis and cooperation only become economically rational if the risk of scab infection is considerably higher than the current national average, or the cost of treatment is lower. Should policy makers wish to reduce the national prevalence of scab, economic incentives such as subsidising the cost of acaricides or rigorously applied financial penalties, would be required to make prophylactic treatment economically appealing to individual farmers. However, such options incur their own infrastructure and implementation costs for central government.

1. Introduction

Ovine psoroptic mange (sheep scab) is a debilitating and damaging condition caused by a severe hypersensitivity reaction in sheep to the faecal material of the parasitic mite, *Psoroptes ovis* (Burgess et al., 2012). Clinical signs include dermatitis, intense pruritus and self-trauma (Berriatua et al., 2001). Sheep scab infection leads to a lower reproductive rate (Fthenakis et al., 2000), weight loss or reduced weight gain (Kirkwood, 1980; Rehbein et al., 2000a), wool loss (Rehbein et al., 2000b), additional food and acaricide costs (ADAS, 2013) higher labour costs (ADAS, 2008) and, in some cases, stock mortality (Roberts et al., 1971).

Before its deregulation in the UK, it was compulsory to treat all sheep prophylactically and by 1988 when twice yearly immersion dipping was enforced, there were fewer than 40 reported outbreaks per year (French et al., 1999). Following deregulation in 1992, many farmers abandoned prophylactic treatment, particularly with organophosphate insecticides (French et al., 1994; Bisdorff and Wall, 2008). Subsequently, the prevalence of scab increased by two orders of magnitude (Bisdorff et al., 2006; Bisdorff and Wall, 2008). Within the headline figure for national prevalence, there are significant regional variations in scab prevalence, with a study by Rose, (2011) showing 13.9% of flocks experiencing at

Abbreviations: UK, United Kingdom; ML, macrocyclic lactone; OP, organophosphate.

* Corresponding author.
E-mail address: Emily.Nixon@bristol.ac.uk (E.J. Nixon).

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least one outbreak per year in the uplands of Great Britain and 5.2% in the lowlands. The uplands are comprised of Scotland (average scab prevalence 7.1%), Northern England (14.1%) and Wales (20.5%) while the lowlands include Central England (3.3%), East England (5.9%) and South West England (6.4%). The regional differences in scab prevalence have been attributed to the greater use of common grazing in upland areas, since unrestricted mixing of animals facilitates transmission from infected to uninfected animals and makes prompt disease management more difficult (Rose and Wall, 2012).

The cost of sheep scab in Great Britain was estimated at £8.3 million per year (Nieuwhof and Bishop, 2005), although the true cost is likely to be higher since this estimate did not include the cost of labour, subclinical disease, or ineffective treatments. Costs are incurred because farmers are legally obliged to treat flocks visibly infected with scab with approved acaricides and from the economic loss of the reduced reproductive rate, weight, wool and skin loss of their infected livestock. Farmers also incur costs if they treat their sheep prophylactically with acaricides to prevent scab. The rapid increase in the prevalence of sheep scab in the UK following deregulation and the apparent inability to control this disease in the UK has been attributed to the fact that many farmers are unwilling to use prophylactic management given a perceived relatively low probability of infection (ADAS, 2008). As a result various sheep scab management initiatives have been launched to attempt to encourage more proactive treatment approaches (ADAS, 2008).

There are two primary prophylactic treatments for scab prevention currently licensed in the UK: a long-acting injectable formulation of the macrocyclic lactone (ML) moxidectin and the organophosphate (OP) Diazinon, used as a total-immersion plunge dip (Sargison et al., 2007). When used prophylactically, a single injection of long-acting 2% moxidectin can provide protection for up to 60 days (NOAH, 2014). Diazinon plunge dip confers protection for up to 63 days (Kirkwood and Quick, 1981). The same products can be used reactively to treat scab, as well as a range of other macrocyclic lactone products with relatively shorter periods of residual activity.

From a purely economic perspective, a farmer's optimum strategy for scab control depends on the balance between the cost of preventative treatment (if used) and the loss in production plus the cost of reactive treatment under different risks of scab. There may also be infrastructure costs, for example dip baths, for some approaches to scab treatment. This calculation is also complicated by the fact that the risk of infection is higher if neighbours have scab and lower if neighbours treat prophylactically; having neighbours with scab has been estimated to increase the chances of scab infection by 10 times in upland flocks (Rose and Wall, 2012). If a farmer's neighbour treats prophylactically for scab, this reduces the risk of the farmer's flock getting scab and reduces the need to use prophylaxis. In contrast, if the neighbour's sheep become infected with scab, the higher infection risk increases the benefits of prophylaxis. Hence, for any farmer, the risk of infection and optimum approach to treatment is contingent on the behaviour of neighbours, particularly when contact between flocks is likely, as when common grazing is used.

Farmers do not necessarily have access to information about their neighbour's strategy or about the costs and risks of scab to aid their decision-making process. However, the use of the mathematical Game Theory approach, as conceived by von Neumann and Morgenstern (1944), allows the determination of an economic optimum strategy for a farmer based on probability, without knowledge of the neighbour's strategy. Game Theory depicts two or more individuals (players) who will make choices that maximise their personal payoff, that is, they are rational (Myerson, 1991). The individual does not know what the other player (in this case the neighbour) will decide to do, however, the other player's actions affect disease incidence and infection risk (Shim et al., 2012). Game Theory in a human public health context has been used to model responses to a number of infectious diseases, for example Rubella (Shim et al., 2009) and Influenza (Galvani et al., 2007). In addition, it has been applied to epidemiological studies of animal health, for example toxoplasmosis in cats (Sykes and Rychtar, 2015). The aim of this study was to use a Game Theory model to explore the relative economic costs and benefits of different strategies when making individual decisions to treat prophylactically or reactively for sheep scab.

2. Material and methods

2.1. Model construction and assumptions

A deterministic Game Theory model was constructed in Microsoft® Excel (Microsoft Corporation, Redmond, WA, USA) to determine the optimum sheep scab control strategy (to treat or not treat prophylactically) for a farmer in relation to the behaviour of his/her closest neighbour. It is assumed that a farmer has only one neighbour and so the game involves two players, a farmer (known as Farmer) and his/her neighbour (Neighbour). Both players are assumed to be economically rational, that is, they are motivated solely by profit and not by any other factors. They simultaneously decide whether or not to treat their flocks prophylactically for sheep scab. Four scenarios of prophylactic treatment are possible: Farmer and Neighbour treat, Farmer treats and Neighbour does not, Neighbour treats and Farmer does not and neither treat. For all scenarios it is assumed that both farmers have the same flock size and that, if they both treat, they will use the same form of treatment. In all scenarios, both farmers apply a reactive, therapeutic treatment in the event of an infection. Every run of the model generates eight costs, one for each farmer during the four possible prophylactic treatment scenarios.

The cost to Farmer/Neighbour per year when both farmers treat prophylactically (C_{tt}) is the cost of prophylaxis per ewe (and her lambs) (PC) plus the product of the probability that a farmer's flock may get scab despite the fact that both farmers treat prophylactically (P_{tt}) and the costs and losses per ewe (and her lambs) incurred if the flock does get scab (L), all multiplied by the number of ewes in the flock (N_e).

$$C_{tt} = N_e \cdot (PC + (L \cdot P_{tt}) \quad (1)$$

The cost to Farmer/Neighbour per year when they do not treat prophylactically but the other player does (C_{ntt}) is the product of the probability that the flock gets scab when he does not treat prophylactically but his/her Neighbour does (P_{ntt}) and costs and losses per ewe (and her lambs) incurred if the flock does get scab (L) multiplied by the number of ewes in the flock (N_e).

$$C_{ntt} = N_e \cdot L \cdot P_{ntt} \quad (2)$$

The cost to Farmer/Neighbour when they treat prophylactically but the other player does not (C_{tnt}) is the prophylaxis cost per ewe (and her lambs) (PC) plus the product of the probability that a farmer's flock will get scab when he treats prophylactically but his/her neighbour does not (P_{tnt}) and costs and losses per ewe (and her lambs) incurred if the flock does get scab (L), all multiplied by the number of ewes in the flock (N_e).

$$C_{tnt} = N_e \cdot (PC + (L \cdot P_{tnt}) \quad (3)$$

The cost to Farmer/Neighbour when neither treats prophylactically (C_{ntnt}) is the probability that a farmer's flock gets scab when neither has used prophylaxis (P_{ntnt}), multiplied by the costs and losses per ewe (and her lambs) incurred if the flock does get scab (L) multiplied by the number of ewes in the flock (N_e).

$$C_{ntnt} = N_e \cdot L \cdot P_{ntnt} \quad (4)$$