PREDICTING CANTERBURY GRASS GRUB OUTBREAKS: THE ROLE OF TEMPERATURE

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ABSTRACT

Probability (Markov) matrices and graphical analysis suggest that inclusion of mean summer temperature (Dec - Feb) significantly improves predictions of grass grub (*Costelytra zealandica*) outbreaks in Canterbury based on current density and disease levels. Outbreaks tend not to occur (7% chance) following a warm/dry summer. If the summer is cool, outbreaks are most likely if the density is currently high (irrespective of disease), or if both the current density and the disease level are low (43% chance if any of these conditions are met). The fact that high current density is one of the predisposing conditions suggests that with favourable summers, grub densities may stay high for more than one year or at least decline only slowly from very high levels.

Keywords: *Costelytra zealandica*, grass grub, population dynamics, model, temperature

INTRODUCTION

Forecasting pest density is a vital part of any integrated pest management strategy. For example, Barlow and Jackson (1993) showed that the use of the bacterial insecticide *Inovade* against grass grub (*Costelytra zealandica*) in Canterbury could give a 400% rate of return if applied in advance of an outbreak, but would be a net cost to the farmer if the outbreak never eventuated or if currently high grub densities inevitably declined. These authors further demonstrated that outbreaks were inherently unpredictable, and that even in young paddocks there was only a 44% chance of a grub outbreak within the first 5 years after sowing. Using a probability (Markov) model, Barlow and Jackson (1993) attempted to predict grub density from the previous year's density and proportion of grubs infected with the bacteria *Serratia* spp., but found that this left considerable unexplained variation. Barlow and Jackson (1993) suggested that the inclusion in the Markov model of factors such as the current level of pasture damage or summer temperature (related also to summer rainfall) could improve predictions of grub density. A possible effect of summer temperature was indicated by its appearance as a significant variable in a previous regression analysis of the Canterbury data (Barlow and Jackson 1992).

This paper, therefore, has two aims. First, it tests whether the inclusion of temperature improves predictions of May grub densities using Markov transition matrices. Second, it investigates the likely shapes of the relationship between current density and previous density, disease level and temperature in order to develop more appropriate equations for mathematical models of grass grub population change in Canterbury.

METHODS

Markov matrix

The matrix was developed from 110 data points from Canterbury, including paddocks in the foothills, mid-plains and coastal zones of Ashburton County, sampled from 1981-1986, paddocks in trials at Winchmore and Fairton sampled in 1983 and 1984, and those in a trial at Ashbury sampled from 1983-1987. Each data point comprised grub density in May for a single paddock, percentage of grubs visibly

diseased at this time, the following summer (Dec - Feb) mean temperature, and the grub density in May of the following year. Meteorological data were taken from stations at Highbank (foothills), Winchmore (mid-plains, Winchmore and Ashbury trials) and Ashburton (coastal and Fairton trial). The matrix was drawn up in a different way to that of Barlow and Jackson (1993). The data were first partitioned into two ranges of the current year's grub density: low ($< 250/\text{m}^2$); and high or outbreak ($+ 250/\text{m}^2$). Each of these was divided into two according to the percentage of grubs diseased, namely low ($< 20\%$) and high ($+ 20\%$), and these groups were further split into two temperature categories, low ($< 16^\circ\text{C}$) and high ($+ 16^\circ\text{C}$). This gave a total of 8 categories for density/disease/temperature in the current year (temperature being for the summer following the current May sample), for each of which there was a probability of obtaining low or outbreak grub populations in the following year. These probabilities were obtained for each current-year category by dividing both the number of low and outbreak grub density outcomes in the following year by the sum of both. The mean square deviation (MSD) of these probabilities for each current-year category (column in the matrix, shown in Table 1) is a measure of predictability: the higher the MSD the greater the predictive power. An MSD of zero, for example, corresponds to both probabilities being 0.5, which is of no predictive value, and a MSD of 0.5 indicates maximum predictive ability with probabilities of 1.0 and 0 for the two outcomes. So the MSD averaged over all 8 current-year categories, compared with the same index calculated for only 4 categories omitting temperature, was taken as a measure of the increased predictive power, if any, attributable to its inclusion.

Relationships between density, previous density, disease and temperature

The problem with multivariate regression methods is that they do not show the actual shapes of the relationships between variables, so an approach was adopted similar to the matrix one described above, in which the data were grouped then plotted. In this case, the same 110 data points were first ranked according to summer temperature then partitioned into two equal groups (low and high temperature). Each of these was subject to the same procedure for disease level, giving low and high disease categories, and finally each of the four temperature/disease groups was ranked according to current density and subdivided into four current density groups, for each of which the mean density in the following year was calculated. This gave relationships (four points plus the origin) between current and subsequent densities for each of four combinations of disease and temperature.

RESULTS

Markov matrix

The transition matrix predicting the probability of obtaining grass grub outbreaks, given current density, disease level and temperature, is shown in Table 1. The MSD averaged over all categories is 0.252, whereas that for an equivalent matrix disregarding temperature and with only four columns for different grub density/disease categories is 0.183. Thus the predictive value is improved by the addition of temperature. In particular, predictability is greatest when temperature is high. The MSD in Table 1 is then invariably high and a 'low' outcome in the following year is likely. In other words, outbreaks are unlikely to occur if the summer is warm, whatever the current grub density/disease situation. Conversely, the matrix indicates that the chance of an outbreak is greatest following a cool summer, unless the grub density is currently low and a high proportion are diseased. However, even given favourable predisposing conditions, on average there is less than a 50% chance of an outbreak occurring.

Relationships between density, previous density, disease and temperature

The relationships between grub density in one year and the previous density, disease and temperature are shown in Fig. 1. Because densities are grouped and averaged, those in the second year (vertical axis in Fig. 1) never reach high levels, but in practice an outbreak is most likely when the predicted average density is high. The key features of Fig. 1 are as follows. Firstly, there is strong density-dependence and an asymptotic relationship between densities in successive years (t and $t+1$) with an upper density limit of about $200/\text{m}^2$ on average. Secondly, this method confirms that

both disease and summer temperature are also important in determining density. Finally, these factors have the greatest effect when current density is low; at higher densities the density effect dominates and the outcome converges to the asymptote of 200/m² except possibly for the high temperature/high disease combination.

TABLE 1: Transition matrix in which the rows show the probabilities of obtaining low grub populations (<250/m²) or outbreaks (+250/m²), given the previous year's state represented by the columns. These are low or outbreak grub populations, low or high % diseased (< 20% and + 20%), and low or high summer mean temperature (< 16°C and + 16°C). The bottom row shows the mean square deviations (MSD) of the probabilities for that column.

Grub density % diseased Temperature	Low				High/Outbreak			
	Low		High		Low		High	
	Low	High	Low	High	Low	High	Low	High
Low density	0.57	0.91	0.94	1.00	0.67	0.83	0.43	1.00
Outbreak	0.43	0.09	0.06	0.00	0.33	0.17	0.57	0.00
MSD	0.009	0.328	0.394	0.500	0.056	0.222	0.010	0.500

FIGURE 1: The relationship between May grass grub density in year t+1 and May density in year t, for low levels of disease prevalence (solid lines, mean 7% diseased) and high disease levels (dashed lines, mean 42% diseased), and for low summer mean temperatures ('Low' on Figure, mean 14.3°C) and high mean temperatures ('High' on Figure, mean 16.6°C).

DISCUSSION AND CONCLUSIONS

Comparing the average MSD for the transition probabilities in Table 1 with the equivalent MSD for a matrix without temperature provides a basis for measuring its contribution to predictive ability. On this basis, increasing the MSD from 0.183 to 0.252 suggests that its inclusion improves predictions of Canterbury grass grub densities by 38%. A similar procedure comparing grub density plus disease with grub density alone suggests that the addition of disease increases predictive ability by 32% over grub density alone. The graphical approach shown in Fig. 1 also demonstrates the importance of summer temperature. Further support for a summer temperature influence comes from the separate Canterbury data set of Townsend *et al.* (1993, Table 1), which yields a significant relationship between January and February mean maximum temperatures (T) and the ratio of August grub densities (N) in successive years (t). Here each point is an average over many Canterbury paddocks for a single year and the data span 16 years. The relationship is:

$$N_{t+1}/N_t = 6.09 - 0.225T \quad R^2=0.18, \text{ df } 1,14, P=0.05$$

The low R^2 value is probably because disease and density-dependence are not included, the latter because the populations each year are averaged over many paddocks which largely obscures the density effect. Moreover, the August densities on which the relationship is based are naturally less variable than the May ones considered in the present paper, which makes it harder to detect causes for the variation. Nevertheless, it does confirm the relevance of temperature to grub dynamics, even when assessed over a different time scale using a different sampling occasion.

Kain (1975) and East *et al.* (1981) highlighted the importance of summer drought in causing grass grub mortality between the egg and second instar in Hawkes Bay and the Waikato respectively. In both cases the authors demonstrated relationships between the mortality and soil moisture deficit. This probably accounts for the relationships obtained here between population change and summer temperature, given that rainfall is inversely correlated with temperature in practice.

In conclusion, mean summer temperature (Dec - Feb) significantly improves predictions of grub outbreaks in Canterbury based on current density and disease levels. Outbreaks are unlikely after a warm summer (7% chance). If the summer is cool, outbreaks are most likely if the density is currently high (irrespective of disease), or if both the current density and the disease level are low (43% chance if any of these conditions are met). The fact that high current density is one of the predisposing conditions suggests that with favourable summers, grub densities may stay high for more than one year or at least decline only slowly from very high levels.

ACKNOWLEDGEMENTS

Our thanks to the Canterbury farmers who co-operated during the survey and Joan Pearson and Hamish MacNab for technical assistance.

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