Predictive Models for Integrated Pest Management of the Leaf Beetle Chrysophtharta bimaculata in Eucalyptus nitens Plantations in Tasmania

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and
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**Declarations**

This thesis contains no material that has been accepted for a degree or diploma by the University of Tasmania or any other institution. To the best of my knowledge and belief this thesis contains no material previously published or written by another person except where due acknowledgment is made in the text of the thesis.

Steven G. Candy

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ABSTRACT
The Tasmanian Eucalyptus leaf beetle, *Chrysophtharta bimaculata* (Coleoptera: Chrysomelidae) is the most important phytophagous insect pest of eucalypts in Tasmania regularly defoliating new season’s growth over large areas of forest. An integrated pest management (IPM) system is currently in operation to minimise economic losses from defoliation of *Eucalyptus nitens* plantations due to browsing by larvae. However, the utility of the IPM system has been limited by the lack of: (a) an efficient sampling scheme for population monitoring, (b) the ability to predict an ‘action threshold’ (i.e. the population density for which it is profitable to apply insecticide at a standard rate), and (c) the ability to predict *C. bimaculata* population phenology. This study attempted to rectify this situation by developing predictive models that were calibrated using data from a number of sources including that obtained from a caged-shoot, larval feeding trial and from stage-frequency sampling carried out by the author.

Sampling schemes for monitoring egg populations were investigated using (i) counts of the number of leaves occupied by one or more egg batches for a sample of shoots and trees where the total number of leaves on each shoot was unknown [‘occupied leaf count’ (OLC) sampling], (ii) counts of the number of occupied trees for a known total sample size (binomial sampling), and (iii) double sampling using a combination of both (i) and (ii). Novel statistical methods were employed in developing these sampling schemes. For OLC sampling, the current multi-stage technique for modelling the variance of the counts using either Taylor’s power law (TPL) or Iwao’s regression was compared to single-stage modelling using generalised linear mixed models (GLMMs). To do this, GLMMs were extended to incorporate a negative binomial variance function. Efficiency of estimation of TPL was improved by using a more accurate approximation to the variance of the marginal mean. For binomial sampling, William’s method III of handling over-dispersion in a binomial generalised linear model is shown to have theoretical and practical advantages over current methods that use simple linear regression.
Models of the growth of *E. nitens*, with and without browsing by larvae, were developed at the leaf, shoot, tree, and stand level. The models included (i) a leaf expansion model, (ii) a process model of the impact of larval browsing on total shoot leaf area incorporating (i) above and calibrated using data from the caged-shoot feeding trial, and (iii) a model of the impact of defoliation level on the growth of tree diameter and height calibrated using data from artificial defoliation trials. A method of predicting action thresholds for insecticide application from inputs of initial stand conditions, silvicultural regime, cost of control, stumpage value, and cash discount rate was developed. This involved the comparison of growth predicted from existing stand and tree growth models for *E. nitens* with that obtained by combining those models with the browsing and defoliation impact models (ii) and (iii).

Models of (i) egg and larval development rate as a function of ambient field temperature and (ii) the progression of the population through key life stages (egg to final instar larvae) were constructed. Maximum likelihood estimation was used for (i) based on interval-censored development times. Continuation ratio models for (ii), incorporating physiological time based on the models for (i) and calibrated using the stage-frequency data, were used to estimate time of peak occurrence of each of first, second, and third instar larvae. The models and estimation methods used are shown to have advantages over those currently used in population studies.

Finally, the practical application of this suite of predictive models for decision support within the leaf beetle IPM system was demonstrated. For a typical 15-year rotation pulpwood regime on a site of average quality with a discount rate of 8%, a cost of control of $35/ha, and a stumpage of $30/m$^3$, a value of 0.3 occupied leaves per shoot was the recommended action threshold. In addition, since approximately 90% of defoliation is caused by the last two (i.e. third and fourth) larval instars any application of insecticide should not be delayed past the time of the peak in the number of second instar larvae. The time from the start of mass oviposition to this peak was predicted to be approximately 175 DD[5] where DD[5] is the day-degrees calculated with a 5°C lower threshold.
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