Towards an integrated sheep parasite decision support system. Part I. Sheep Blowfly Strike

R. W. Sutherst[1], G.F. Maywald[1] and K. Wardhaugh[2]
CSIRO Entomology
[1]Long Pocket Laboratories, 120 Meiers Rd, Indooroopilly, QLD, 4068.
[2]Black Mt, GPO Box 1700, Canberra, ACT, 2601
Email Robert.Sutherst@ento.csiro.au

Summary

An outline is provided of a proposed integrated Decision Support System (DSS) for arthropod sheep parasites (initially). The DSS would include multiple parasite species. The first component will describe the likely timing of emergence of blowflies in spring around Australia, and the effects on blow fly populations and incidence of fly strike of multiple protective products. It will address a number of performance criteria including population suppression, profitability, and sustainability as affected by resistance and effects on non-target species, and complementarities of management actions. The DSS will enable a holistic assessment of options to optimise returns on parasite control and increase the sustainability of sheep production in Australia by minimising risks from resistance and chemical residues in sheep products. Examples are given to illustrate the use of the DYMEX modelling package, which has formed the basis of the Australian IPM Modelling network. This network provides a mechanism for facilitating national approaches to Australia's pest and disease problems, and is recommended as a vehicle for a collaborative effort to develop and apply the proposed Decision Support System.

Keywords

DYMEX, modular model, Networks, *Lucilia*, decision support, *Haematobia*

Introduction

Sheep arthropod parasites continue to cause losses of production and increases in costs of production of wool and meat in Australia. The use of protective and treatment products can cause residue problems and there is an ever-present risk from the development of resistance. A knowledge-based approach to the Australian sheep blowfly (*Lucilia cuprina*) and lice management could exploit knowledge of the ecology and behaviour of the parasites to increase the effectiveness of treatments (McKenzie & Anderson, 1990). Improved prediction of the spring emergence of sheep blowfly is one example where an opportunity exists to select timing of prophylactic treatments to maximise their effectiveness. In addition, there are advantages in being able to identify those climatic conditions that are conducive to an increase in the susceptibility of sheep to fly strike. At a later time the incidence of scouring that results from nematode infections or specific pasture conditions could be obtained from linked nematode and pasture growth models and be included in the flystrike predictive model.

Past research by CSIRO Entomology and others has collected a substantial amount of unpublished and published data on the dynamics of sheep blowfly populations and on the susceptibility of sheep to blowfly strike (Wardhaugh, *these proceedings*). Wardhaugh and Morton (1990) related fly abundance and strike incidence to rainfall, cloud cover and the lushness of pastures, so providing a promising basis for a dynamic model for predicting impending high-risk periods. Morley *et al*. (1976) related breech strike to scouring in response to helminth infections, and to a much lesser extent to weaning of sheep onto dry pastures, drought feeding with wheat or moving sheep onto pastures which had been grazed by cattle.

Computer simulation models are now widely accepted as having an important role to play in the management of biological systems because they enable managers to take account of non-linear responses and to account for negative feedback effects, and the dynamic nature of biological processes in varying environmental conditions. The aim of this paper is not to act as a primer on modelling, but to point to one possible way ahead for the sheep and wool industry to improve its management of parasites, and sheep blowfly in particular. Sutherst *et al*. (1979), Norton *et al*. (1983) and Floyd *et al*. (1995) provided extensive evidence of the value of models in making many different decisions related to control of cattle tick in Australia, so they are not repeated in detail here. The lessons from that modelling are equally applicable to management of sheep blowfly. In essence, the tick modelling showed that the tick's lifecycle was driven more by its relationship with cattle than by climate as previously believed; dynamic models help to foresee the *delayed* effects of many events; considerations of resistance and economics alter outcomes substantially; and that models can themselves be a powerful means of communication with policy makers looking for ways of weighing up the implications of adopting different approaches to tick management.

There have been a number of attempts to build models of varying complexity, ranging from the FlyAlert model to predict spring emergence times of flies (Foster *et al., unpublished*), to a management model for the control of flystrike (Wardhaugh *et al*., 1994). Other groups have been exploring approaches to predict the seasonal occurrence of the flies (Ward, 2000). These data and models provide a basis for a new, more holistic and reliable decision support system that could also be used to conduct scenario analyses of options for management of blowfly strike in sheep in different parts of Australia.

Parallel with these developments there have been major advances in the tools to build and operate computer models. The advent of a new approach to building simulation models that describe biological systems has opened opportunities for more efficient and cost-effective ways of building models. The DYMEX system (Maywald *et al*., 1997; Maywald *et al*., 1999; Sutherst *et al.*, 2000; http://www.ento.csiro.au/dymex/dymexfr.html) is one such approach that was developed in Australia and is being used as a tool to build collaborative research networks around key pests, disease and weeds (http://www.ento.csiro.au/research/pestmgmt/IPMModellingNetwork/index.html).

The approach of using workshops to enable researchers and managers to articulate their problems in order to develop model specifications, pool their knowledge and expertise to jointly develop, test and apply the resulting models, is a proven approach to building national, collaborative teams with the capability to implement best practice management of the species concerned.

Thus, it is proposed to build a national, collaborative team of researchers, advisers, managers and agrochemical companies to jointly build a model of sheep blowfly population dynamics and the susceptibility of sheep to fly-strike. The model would then be made available to the group to test in different environments and then to use it to analyse local situations and to design more cost-effective management strategies.

Methods

A workshop and network approach to synthesise expertise from a diverse group of people was described by Sutherst *et al.* (1998) as indicated above. The aim is to adopt a consensus approach to design, then build and use simulation models in different environments around Australia in order to develop national approaches and to make best use of Australia's pool of research providers. Participants agree to make their data available on the understanding that their ownership is protected. The modellers then use that data to develop mathematical functions that describe the processes in the lifecycle of the species. The prototype model that results from the initial workshop is then made available to participants to test in their environments and report back at a future date so that an iterative process of model improvement can be followed. An attraction of this process is that participants automatically receive training in the concepts of modelling simply by being involved in the process. They learn that the type of data needed to build predictive systems is quite different to the data that is produced by traditional experimental studies aimed at describing states rather than processes.

DYMEX is a modular modelling package that was designed by biologists for biologists (http://www.ento.csiro.au/dymex/dymexfr.html). It enables models to be built using dialogue boxes and graphics, makes the structure of the model explicit and has in-built charting and table generating functions for presentation of results. DYMEX uses the cohort based paradigm for modelling and our preference is to make most population models climate driven so that they can be run for different habitats using the climate to remove a large amount of the site-related variation. The emphasis in DYMEX is on facilitating the design of management strategies, so it has functions to enable optimisation of animal health products for example, and sensitivity analyses are possible with minimal effort. We also adopt the approach by which economic relationships are incorporated by defining a relationship between productivity losses and parasite numbers, and another between productivity loss and the market price.

Results

As we did not have access to a functional DYMEX population model of sheep blowfly with associated risk of flystrike, to illustrate the power of DYMEX, two examples are given. The first, a simple development predictor for sheep blowfly, initially developed as *FlyAlert* by Foster *et al.* (*unpublished*) and ported to DYMEX with some improvements including a better soil temperature calculator to drive development until adult emergence, is shown as a modular DYMEX model in Figure 1. Results from the model's results for Birchip in Victoria over a period of 4 years are shown in Table 1.

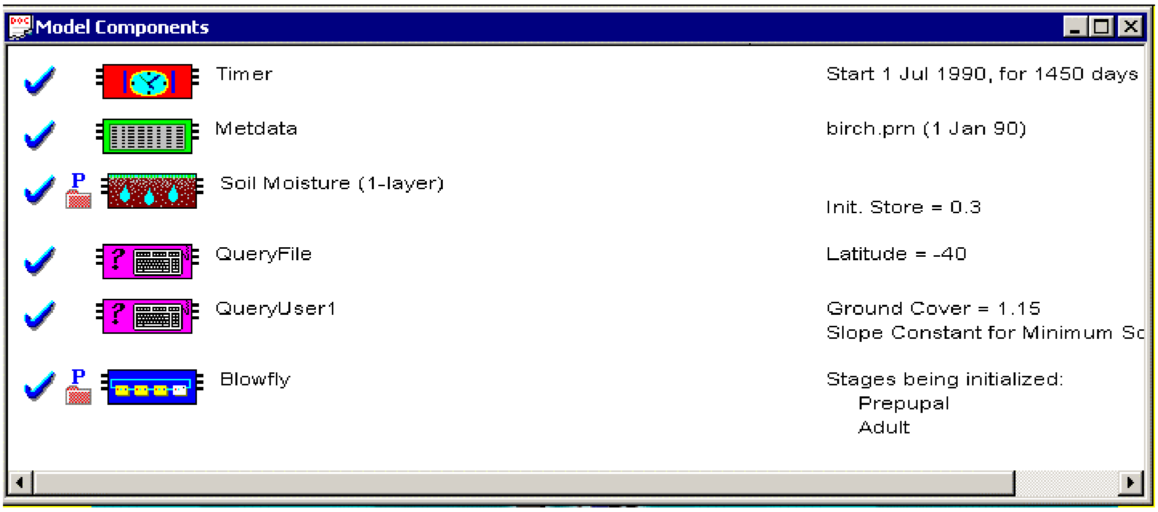

Figure 1. A view of the DYMEX modular *FlyAlert* blowfly development predictor.

Table 1. Predicted pupation and adult emergence dates for sheep blowflies in 4 years at Birchip in Victoria.

Year	Pupation Date	Adult fly emergence date
1990	19th October	3rd November
1991	3rd October	21st October
1992	16th October	8th November
1993	30th September	25th October

This example does not do credit to the power of modeling or to DYMEX because it is so simple. In order to illustrate the potential of a DYMEX blowfly population model to generate useful information for the sheep and wool industry, two examples are given for the buffalo fly (*Haematobia irritans exigua*) on cattle in northern Australia. In the first, a simulation, using the (unpublished) CSIRO Entomology buffalo fly model, is run to find the best time to spray cattle at Rockhampton (3 times at 5-week intervals) with a hypothetical product that kills buffalo fly larvae in dung. The results in Figure 2 show that treatment schedules, which start in spring are much more effective than ones that start later in the year. This decision is not obvious for a parasite with a very short lifecycle of 3 weeks.

The buffalo fly model is relatively untested since being developed. One test that we are keen on is to run the model using the geographical database of meteorological data from CLIMEX. Aside from the complications that are inherent in the use of long-term average meteorological data, results from running the model and mapping the results provide good insights into the veracity of the model on a broad scale.

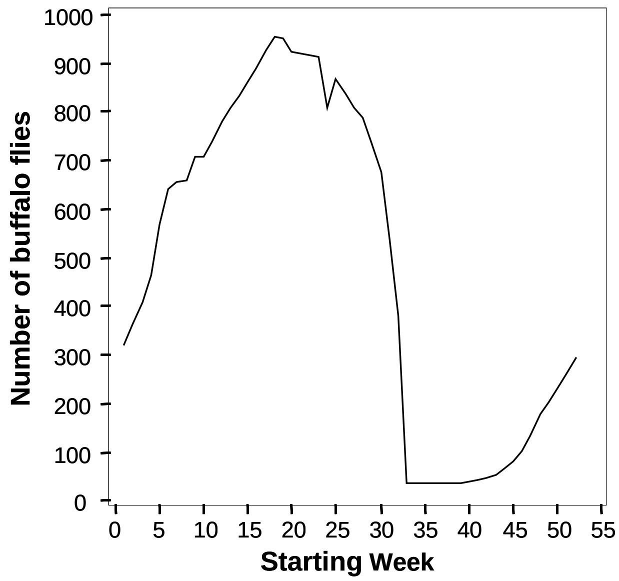

Figure 2. Annual averages of the numbers of adult buffalo flies per day (simulated using DYMEX) on cattle treated with a hypothetical product starting on each week of the year.

In Figure 3 the annual average numbers of buffalo fly per day that may be expected on cattle in different parts of Australia are shown. Note that, in this prototype version of the model, the buffalo fly numbers are significantly greater than would occur in the field.

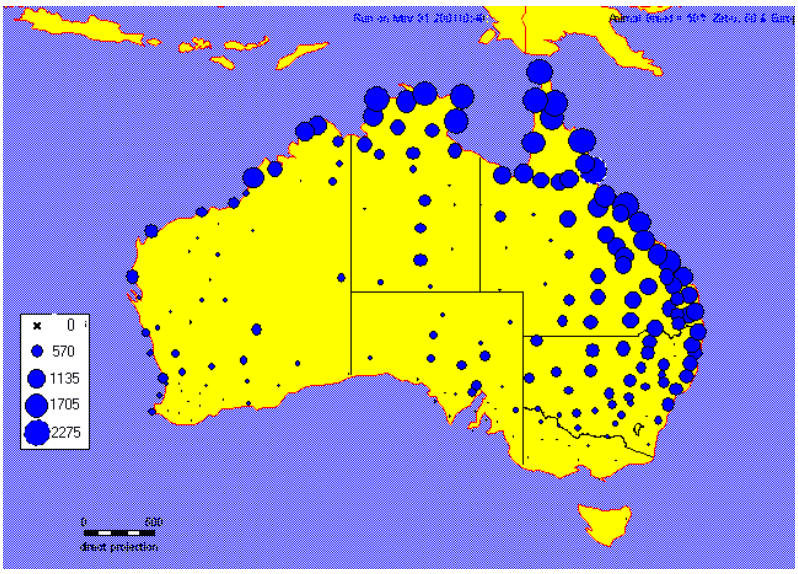

Figure 3. Map of the potential, annual average numbers of buffalo flies expected on cattle per day in representative locations in Australia, assuming immigration daily for 3 months in spring, as simulated using DYMEX.

Discussion

If Australia is to remain globally competitive it needs to move rapidly towards a knowledge-based approach to management of livestock and crop production, and the environment. The paucity of information with which recommendations are made for the use of many animal health products in different environments in Australia attests to that need. Most products are released with minimal efficacy data, and few field trials in different regions to measure the effects of the product on populations of the species, in whatever type of season exists at the time of the trials of the pre-release product. There is rarely an economic analysis with which to guide the grower, and guidelines are provided on the basis of a few field trials. This gives a very limited knowledge base from which to extrapolate to other situations. It emphasizes the benefits that will be gained from using simulation models to explore a wide range of options under a diversity of seasonal and management conditions, leading to more economically optimal and sustainable decisions on animal health.

Simulation modeling has the potential to add value to experimental data by enabling sensitivity analyses to look at the potential effects of rainfall, costs, failures in management, differences in strategies etc. However, the first step is to produce a model that is realistic enough to be able to simulate field numbers of the parasite and also the effects that they cause on livestock. In the case of *Lucilia cuprina*, Wardhaugh & Morton's (1990) analysis has provided a sound basis for relating fly abundance and the incidence of fly strike to weather and pasture conditions. Their statistical model explained 76% of the variance of body strike and 58% of the variance of crutch strike in the Southern Tablelands of New South Wales. Ward (2000) and Ward and Armstrong (2000) developed a predictive model based on the ENSO (El Nino Southern Oscillation) that was claimed to explain ~30% of the variance in numbers of blowflies. Sutherst (2000) found that the ENSO was neither sufficiently tightly correlated with rainfall in northern Australia, nor uniform enough in its spatial effects across Queensland to be able to form the basis of a reliable forecasting system. Thus our preference is for a climate-driven, process-based population model as an analytical and predictive tool, as illustrated above.

How then does one best go about building a population model of the sheep blowfly as a first step to producing a national '*Sheep Parasite Management Model'*? We suggest the following steps:

1. Hold a 3-day DYMEX Modelling Workshop to address the issues raised in the introduction, namely user expectations, resulting model specifications, a data sharing agreement and data synthesis, and model prototyping.
2. Build a prototype model based on the available data, and expert opinion where quantitative data do not exist.
3. Distribute the model to network participants in each State for testing against past and current field observations.
4. Hold a follow-up workshop one year later to provide feedback on performance of the model during the year.
5. Revise the model and repeat the above process if necessary prior to using the model for regional forecasting and calculation of costs and benefits of different control options.
6. Make the model available over the Internet (on terms to be decided) so that users are able to obtain the expected emergence times of flies in spring around Australia using real-time meteorological data.

Conclusion

If the Australian wool industry is to continue to make advances in productivity and sustainability, it needs to make better use of available or prospective parasite control treatments. One way to do that is to use computer models to increase the precision of timing of preventative treatments, to optimise the use of strategic approaches, and to maximise returns to growers, while minimising the risks to their markets and production systems from chemical residues, resistance and economic costs. Australia is unique in being able to develop national and continental scale approaches to our problems, that can help to support the '*Clean and Green'* image in export markets. The proposed first step is to address the issue of sheep blowfly strike *en route* to an integrated '*Sheep Parasite Management*' model that will provide a means of getting holistic advice on control of arthropod and Helminth infestations. Such a model will provide the sound foundation for sheep parasite management that the cattle tick model has provided for the northern cattle industry for 2 decades (Sutherst, 1987). During the period there has hardly been a year when the model has not been required to address an industry or policy-related question.

Acknowledgements

Mrs Anne Bourne rebuilt and modified the FlyAlert model using DYMEX and Dr Rick Bottomley assisted with the illustrations.

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