Generic Modelling for Integrated Pest Management

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Abstract A modular approach to modelling the population dynamics and management of biological organisms is described. In order to enable rapid and reliable development of deterministic models of many species of pests, diseases and weeds a new modelling software package, *DYMEX*, has been developed. The target audience for the package is biologists with the need for a model but unable to write computer code or unable to fund a computer programmer. *DYMEX* consists of a model *Builder* for constructing the model plus a *Simulator* that runs the models. Modules are assembled interactively using icons and dialogs and there are in-built data formatting, graphics and table generating facilities. DYMEX enables models to be built on the fly during intensive Workshops that involve users, such as managers, and researchers with the necessary understanding and data for the system to be modelled. *DYMEX* is written in C++ using the language's object oriented features. The package provides a means by which Australia's pest, disease and weed management community can exchange information in a common language to facilitate cooperation and build the synergy that is needed if the country is to harness its scarce and widely distributed scientific expertise. It is planned to continually expand the *DYMEX* program to add new modules and include spatial features and some data interpretation and analysis capability.

1.1 INTRODUCTION

There are a large number of pests, diseases and weeds that affect a wide range of stakeholders in agriculture, the natural environment and public health. Australia's expertise in these areas is thinly spread across the continent and resources are not readily available for the development of computer models. Such models help to summarize our understanding of the species' population dynamics, identify gaps in knowledge and enable rapid evaluation of management options. The *DYMEX* package is designed to overcome the bottleneck caused by inadequate computer programming resources and modelling expertise. It was made possible by the advent of object oriented programming languages. This paper describes the design and application of *DYMEX*.

1.2 *DYMEX*

DYMEX is a modular modelling package that runs under Microsoft Windows 3.1 and 95. It uses icons and dialog boxes to guide the user in the development and running of population models of biological organisms. Both the layout and descriptive language used for *DYMEX* components were designed for use by biologists. The package consists of two major components:

Builder

The *Builder* consists of a user interface that makes use of bitmaps, icons and dialog boxes to present the user with a friendly method of assembling components into a model. A hierarchy of components is used in this assembly. High level modules such as a "Lifecycle" or "Soil Moisture Model" are configured using lower level modules such as processes or functions. Functions, in turn, are selected from a library of functions and supplied with a user-defined range of parameters. The modelling paradigm that is used to describe populations and ecological processes in DYMEX is a cohort based approach, with provision for each cohort to have characteristic properties.

The *Builder* translates the screen representation of a completed model into a model description (GMD) file, ready for transfer to the second part of the package – the Simulator. The Builder has been designed so that new modules and functions can be added easily in future, both to the basic program and as program libraries (DLLs).

Simulator

The *Simulator* reads the GMD files prepared in the *Builder* in the form of a model description. It runs the model after the user has defined the required conditions for the particular simulation, entered the necessary information to run the model, such as meteorological data, and then presents the results in the form of tables or graphs. Additional facilities allow for automatic multiple runs of models to explore, for example, optimal timing of pesticide applications or to perform sensitivity analyses on parameters. Model results can be saved in standard spreadsheet format for further analyses using other software.

Model Applications

The models created using the Builder are the product of value to a particular user. They can be enhanced by manually editing GMD files, or the parameter values can be tuned without the need to return to the Builder. Models can range in complexity from the simplest model run with no age structure and no use of environmental inputs, to multi-species, multi-trophic models with complex environmental drivers. Currently models are deterministic.

User Documentation

There is a comprehensive User's Guide, a Reference System and a context-sensitive Help system. In addition, there is extensive provision for documentation of the

models created by the user in order to enable quality assurance standards to be reached.

Examples

Two models will illustrate the capacity of this generic approach to assemble and use dynamic simulation models of biological systems.

A multi-species tick population model describes the population dynamics of three African species of ticks with one or multiple generations per year. The model is climate driven, and describes the dynamics of the ticks on cattle with a defined level of host resistance in a paddock at a given stocking rate. Tick survival depends on climate, host availability and host suitability and on a range of tick control methods. The outcome of a simulation is the number of ticks of each species, the impact that they have on cattle productivity and its economic value. Automatic multiple runs of the model can be used to determine optimum times for application of acaricide (Figure 1).

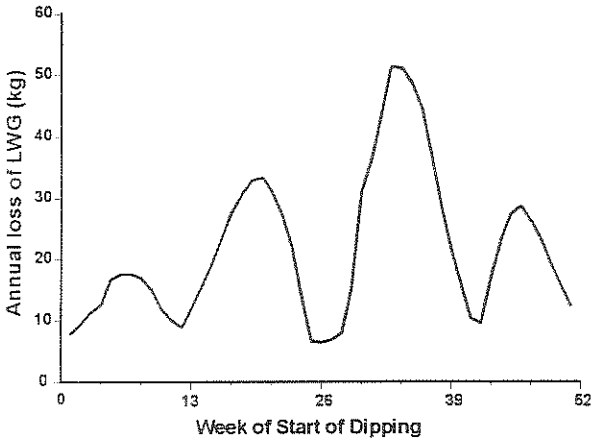

Figure 1: *DYMEX* prediction of the combined loss in liveweight gain (LWG) caused by the ticks *Rhipicephalus appendiculatus* and *Boophilus decoloratus* at Gulu Farm (South Africa). Control treatments consisted of eight weekly dippings in acaricide with starting times on each week of the year.

The second model describes the population dynamics of herbivorous insects on a simple wheat-rice rotation, with a range of control measures. It is also climate driven and illustrates the capability of DYMEX to model plant growth as well as insect population dynamics, insect plant interactions and management.

Together, the examples illustrate the ability to develop models of communities of crop and livestock pests. This in turn will facilitate the adoption of an Integrated Crop Management (ICM) approach with the integrated pest management component being described as a whole rather than with a number of independent models as has been the case in the past.

Model Building Workshops

The advent of *DYMEX* has transformed the way in which models of use to biologists, ecologists and managers can be developed. It is now possible to assemble a model during a model development workshop in close association with the intended user. In this way, it is possible to generate outputs with multiple benefits:

(i) a model that workshop participants understand and have ownership in,

(ii) training in the modelling process,

(iii) an analysis of the problem to the level that the data allows, with pointers to the most effective future research priorities to fill any gaps,

(iv) a designed set of management options, and

(v) the establishment of national 'interest groups' around the particular model application, such as 'Queensland fruit fly' and 'plant diseases under global change'.

1.3 DISCUSSION

DYMEX is cost effective and has been developed in close collaboration with potential users to ensure that it meets market needs and it is flexible in terms of its range of applications. Its open ended architecture will allow ready incorporation of new features. *DYMEX* should provide the language and tools with which to encourage collaboration between Australia's experts and managers of pests, diseases and weeds, in order to improve management of these costly species in different sectors. Major beneficiaries will be the customers of ecological modelling groups as they will be able to achieve much more rapid model development and analysis. It is intended that *DYMEX* will receive ongoing support for extensions and user support.

DYMEX provides a much needed modular modelling capability for population ecologists. It complements the modular models being developed for plant growth (Reynolds & Acock 1997) and offers the opportunity to link models with different trophic levels.

1.4 ACKNOWLEDGEMENTS

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1.5 REFERENCES

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