Review of existing decision support systems for rabbit management

Landcare Research
Manaaki Whenua

Review of existing decision support systems for rabbit management

Aaron McGlinchy

Landcare Research

DOI:10.7931/J2V40S46

Prepared for:

Internal report

June 2011

Landcare Research, Gerald Street, PO Box 40, Lincoln 7640, New Zealand, Ph +64 3 321 9999, Fax +64 3 321 9998, www.landcareresearch.co.nz

Reviewed by:	*Approved for release by:*
Bruce Warburton Programme Leader Landcare Research	Phil Cowan Science Team Leader Wildlife Ecology & Epidemiology
Landcare Research Contract Report:	LC 246

Telarc SAI registered

ISO 14001

Contents

Summary

Project and Client

- Internal Landcare Research report

Objective

- To inform future development of DSS tools for rabbit management in New Zealand

Methods

- Five existing decision support systems for rabbit management were reviewed:
    - MAF 'Rabbit' DSS (NZ)
    - Rabbit Control Simulation Model (Australia)
    - Fox and Rabbit information kit (Australia)
    - Economic decision model for rabbit control to conserve native vegetation (Australia)
    - Rabbit Management Adviser – 'RabMan' (UK)

Conclusions

- Much could be gained by updating elements of the old MAF 'Rabbit' DSS to incorporate new research findings, and make these more accessible to end-users.
- Time, budget, and knowledge constraints may currently limit the extent to which overseas modelling work (in particular cost-benefit) can be pursued; however, approaches used overseas may warrant further consideration for future work.

Recommendations

- Update the information sheets from the MAF 'Rabbit' DSS, and the associated 'Rabbit Managers Factpack'.
- Document the expert knowledge contained in the MAF 'Rabbit' DSS expert system, and incorporate new research knowledge and any changes in best practice.
- Update the MAF 'Rabbit' DSS rabbit control costing facility in line with modern practice and operational costs.
- Evaluate end-user demand for rabbit population models, and farm affordability capability before deciding whether to pursue (either within current programme, or in future should funding be available).

1 Introduction

The objective of any DSS is to provide a vehicle for structuring complex decision problems to enhance the *likelihood* of producing good outcomes (Gough & Ward 1996 – cited in Walpole & Thompson 1997).

The potential benefits of computer decision support systems (DSS) for management of pest rabbits have been recognised for many years. One of the first systems, if not the first, was developed in New Zealand in the early 1990s. Since then, several countries have developed DSSs to assist land managers and/or management agencies to effectively manage rabbits.

Five DSSs are summarised below:

- MAF 'Rabbit' DSS (NZ)
- Rabbit Control Simulation Model (Australia)
- Fox and Rabbit information kit (Australia)
- Economic decision model for rabbit control to conserve native vegetation (Australia)
- Rabbit Management Adviser – 'RabMan' (UK)

While the above all involve computers to a greater or lesser degree, it is important to recognise that DSS tools need not be computerised models. Published information, decision tree diagrams and flowcharts, stakeholder workshops and site visits are all valid mechanisms for developing an understanding of the system and thereby aiding the process of decision making (Walpole & Thompson 1997). Nevertheless, today's computers and the Internet are a primary means of communication and information dissemination, and it is likely that they would have a role to play in any future DSS.

2 Objective

- To inform future development of DSS tools for rabbit management in New Zealand.

3 Findings

3.1 'RABBIT' DSS (MAF – New Zealand)

The Semi-Arid Lands Research group of MAF, led by Dr Jim Bell, constructed the first (to my knowledge) computerised DSS for rabbit management in New Zealand. The program was released in 1991, and complemented publication of hard-copy fact sheets which made up the 'Rabbit Managers Factpack' (MAF 1991).

The DSS was envisaged as six modules, brought together with a linking front-end menu system (Bell 1991a). The modules are able to be run individually, or linked through the front menu. The original concept identified the following modules:

1. Knowledge base and expert system – when to control, and by what method
2. Fact sheets – drawing together the wide array of rabbit management knowledge
3. Population model – to increase awareness of the dynamics of rabbits, show effects of different control strategies on recruitment and mortality
4. Economic model – ability to pay/cash flow spreadsheet to run 'what if' scenarios to explore rabbit control and land management decisions for optimum benefit at farm scale.
5. Database – record of control effort over time
6. GIS – recording soils/landscape information, control effort and efficacy.

Bell (1991a) noted that the DSS was not intended to replace the skilled field operators; rather the aim was to provide an integrated set of tools to help the user make better decisions. From the initial six modules proposed, four have been implemented (with the database and GIS components not being present):

- *Rabbit Facts*: Information sheets on a range of rabbit-related topics, e.g. costs, control methods, repellents, rabbit biology, population assessment, predators, diseases, legal responsibilities. There are 35 topics in all, with cross-referencing between topics to other relevant information in the fact library.
- *Rabbit Expert*: 'The distilled experience of field practitioners in a small expert system'. Jim Bell interviewed field experts from three regional councils (Canterbury, Otago, Nelson-Marlborough), and four farmers. In all, the expertise of 18 people was collated (Bell 1991b).

  The expert system is in three parts:

  - Determine whether control is needed
  - Choose which method of control to use
  - Estimate costs of the control

The rules of the expert system are quite transparent, and can be viewed at any time to evaluate how a decision has been recommended. It should be possible to recreate the decision-making process using similar modern-day software, and/or to document the decision framework in a flow diagram (or series of diagrams).

- *Rabbit Population Model*: The model was developed by Nigel Barlow (AgResearch) in 1993, and allows users to vary parameters of current population (rabbits/ha), K (carrying capacity), and birth and death rates. Control can be applied, either as poisoning, and/or shooting. Results are presented in a graph which allows users to play 'what if' games, and look at the effects of differing control strategies on rabbit recruitment and mortality over time.

  The model incorporated in the DSS (1991) pre-dates the arrival of RHD (1997); however, although not linked to the front menu, there is among the DSS files a revised model from 1993 that incorporates disease (e.g. myxomatosis or RHD), predation, and allows for sterilisation as a control tool as well as poisoning and shooting. The 1993 model handles disease relatively simply (e.g. no accounting for immunity of juveniles) and subsequently Barlow and colleagues (including John Parkes and Mandy Barron from Landcare Research) focused attention on more detailed modelling of RHD (aka RCD) and rabbits, publishing papers on this in 1998 and 2002. These later models were aimed at better understanding the general behaviour and impact of RHD on rabbit populations, rather than modelling the integration of RHD into on-farm rabbit management.

- *Rabbit Costs*: A spreadsheet costing model, tailored to a degree to the Rabbit and Land Management Programme (RLMP), which looks at the affordability of rabbit control given inputs on the effects of rabbits on stocking rates, Government grants received and borrowing required, and cashflow. The model allows the land manager to explore 'what if' scenarios around their land management and rabbit control decisions for optimum benefits on their property.

The program runs on MS-DOS, and is somewhat temperamental to run under the modern Windows environment.

3.2 Rabbit Control Simulation Model (CARE/BRS Australia)

The Centre for Agricultural and Regional Economics (CARE) in Australia developed a DSS on rabbit control for the Bureau of Rural Sciences (BRS) and Landcare Research in 1998/99. This DSS differs from the MAF system in that it does not feature the information/expert system aspects. It is a bioeconomic model that allows users to simulate the financial outcomes of alternative rabbit control and sheep stocking rate scenarios. The key measure used to evaluate rabbit control decisions is whole-farm gross margin (the change in revenue less costs, with and without rabbit control).

The authors state: 'This DSS should not be used to provide prescriptions on the best rabbit control option to follow for a particular farm business', and that 'The main purpose of this DSS is a means of better understanding the rabbit control system, and getting a feel for the relative importance of system variables' (Thompson 2000a).

The CARE/BRS model, unlike the Barlow MAF DSS population model, incorporates stochasticity through rainfall, pasture growth, wool growth, and effectiveness of rabbit control. The model is based on 3 years of data collection (by Dave Choquenot now of Landcare Research) and is specific to the Bathurst region of Australia. The model's underlying data requirements are relatively high, and there are also a number of system variables able to be adjusted by the user (Figs 1 and 2).

While the DSS can give some insights on control options and the important factors (variables) in the systems when choosing between control options, the authors note different results are likely in other regions.

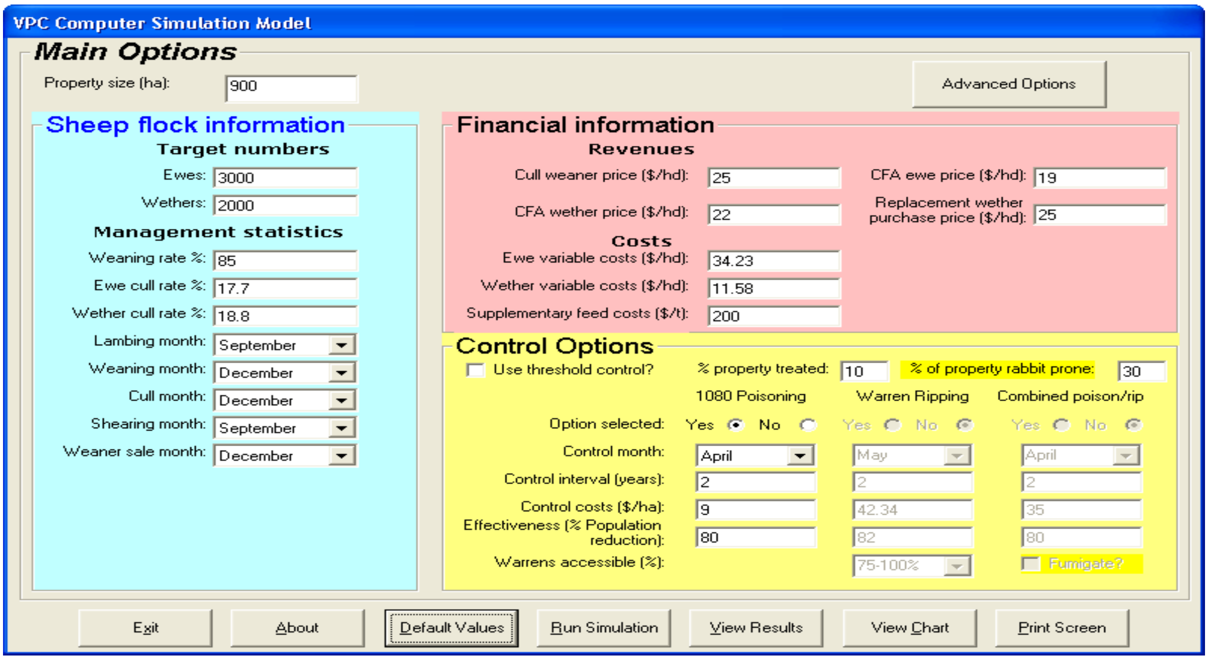

Figure 1 Basic input variables.

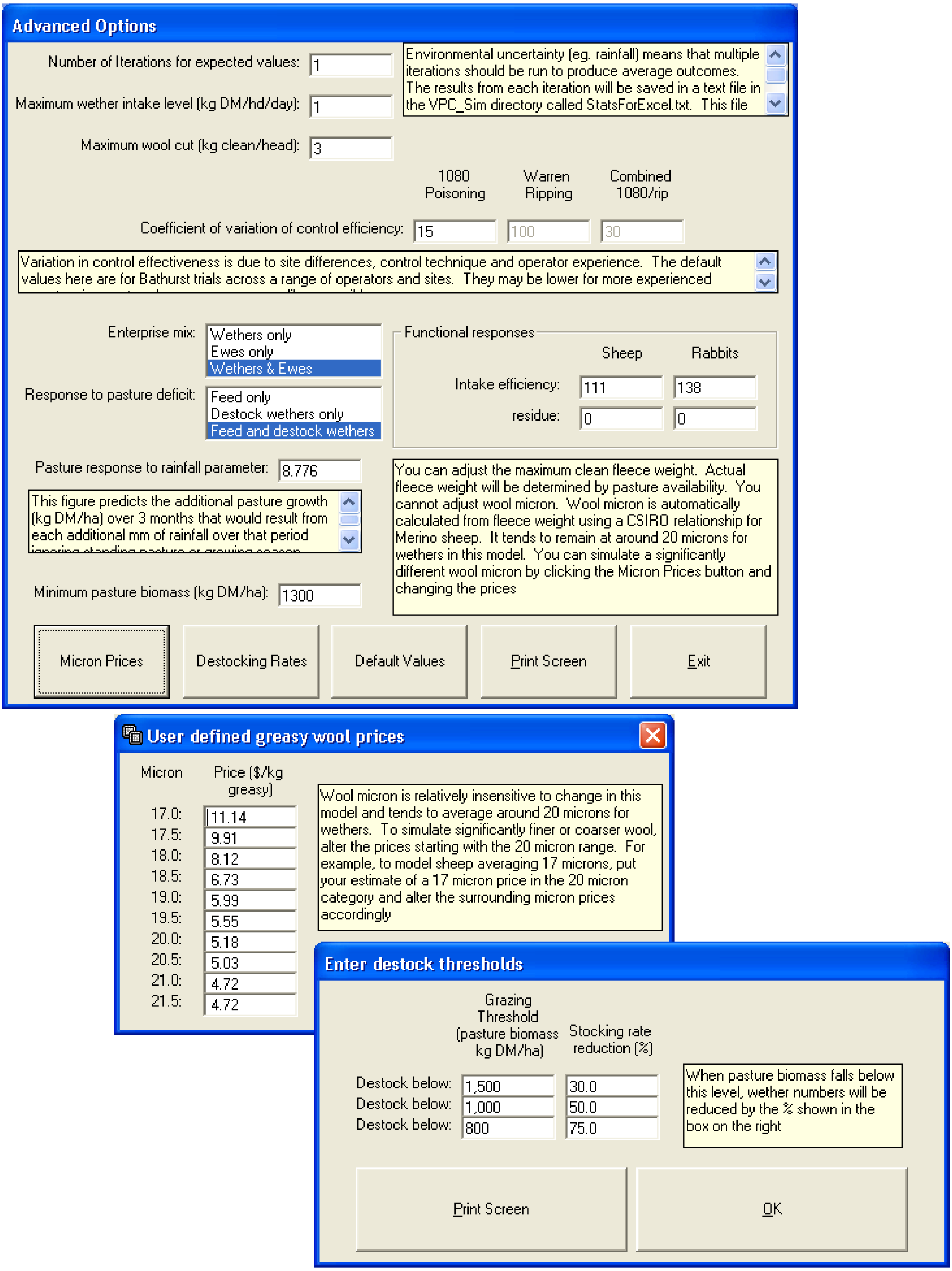

Figure 2 Additional 'advanced' input variables.

Like the model in the MAF DSS, graphs of rabbit numbers over time can be viewed. However, the time frame of the two models differs (due to the different aims of the models). The CARE/BRS model is long term, running at monthly time steps over 50 years – you confirm/specify system variables, pick a control strategy, then run the model to see the economic impact over 50 years (Fig. 3). The MAF model is focused on shorter intervals and allows varying of control strategies over time, i.e. you set the initial control option, run the model for *x* months and observe the predicted result. You can then adjust the strategy (e.g. implement sustained shooting after an initial poison) and run the model for *y* more months to observe the predicted impact on rabbit numbers.

In addition to rabbit numbers, the CARE/BRS DSS also graphs pasture biomass, and gross margins with and without control over the 50 years.

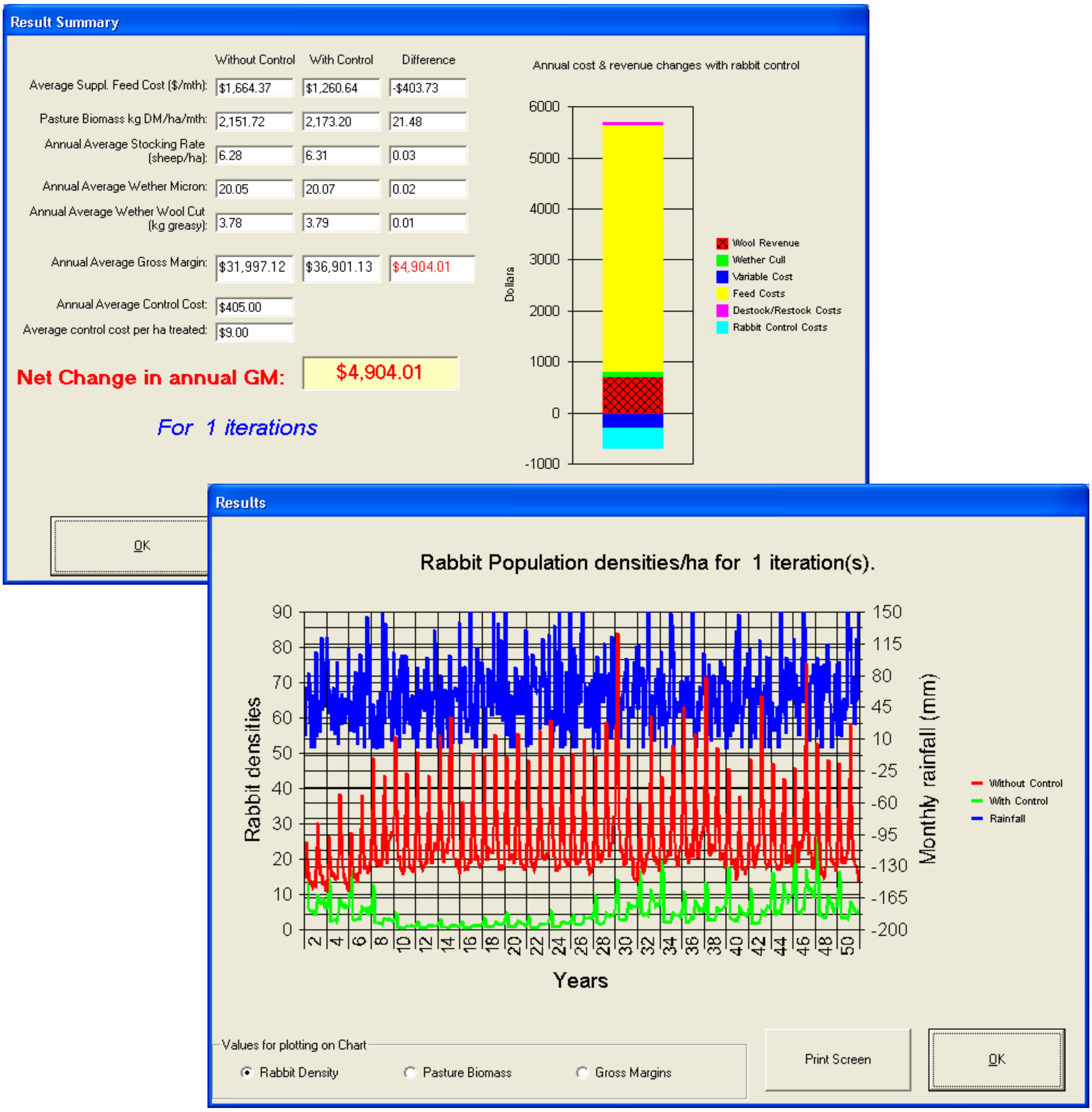

Figure 3 Output from the CARE/BRS model.

3.3 Foxes and Rabbits (NSW Agriculture/BRS Australia)

In 1998, New South Wales Agriculture, funded by the Bureau of Resource Sciences, produced a kit to assist Agricultural Protection Officers and Rural Lands Protection Board rangers when talking to landholders about managing pest animals, particularly rabbits and foxes in NSW.

The kit consists of hard-copy and electronic materials. Included are:

- A checklist to assist in arranging and giving a talk
- A presenter's guide with the background information, a structure for talking to a group of landholders, and frequently asked questions and responses
- PowerPoint slide presentation, split into three levels of detail to suit different audiences
- Video clips
- Detailed guidelines for managing vertebrate pests (one for rabbits (284 pp.); one for foxes (147 pp.)). These are in pdf format, with a structured set of bookmarks (essentially electronic table of contents) which allows readers to click quickly to sections of interest. The video clips are linked to the guidelines.

The information is in-depth, and covers a wide range of topics relating to the pests and their management. It is based on the (then) recently produced national guidelines for managing rabbits and foxes and on two studies by NSW Agriculture aimed at refining and demonstrating how best to manage the damage caused by foxes and rabbits on the Central Tablelands of NSW.

This resource is of primary use to agency staff. The material may be too detailed for the average person's interest, but would provide valuable background knowledge to assist the Agricultural Protection Officers and Rural Lands Protection Board rangers in presenting and discussing management of foxes and/or rabbits with landholders. The kit contains some information on control techniques, but refers readers to other sources such as the NSW Agriculture *Vertebrate Pest Control Manual* (1996) and fact sheets for more detail of these practical aspects.

The kit mentions periodic updating of the information – intended through distribution of new files to replace existing ones on the CD, and potentially requiring burning a replacement CD. With the advances in technology and Internet speeds in the past 12–13 years, such a project being developed now might best be delivered via the Internet to enable seamless updating and widespread access to the information.

3.4 Economic decision model of rabbit control to conserve Australian native vegetation (Invasive Animals Cooperative Research Centre, Australia)

A recent paper by Cooke et al. (2010) describes a different modelling approach to identify the most cost effective combinations of control methods, and where you get most economic benefits from rabbit control. Unlike other models, Cooke et al. were interested in the rabbit problem from a vegetation conservation perspective, rather than agricultural production.

In Australia vegetation remnants are continuing to be lost, and rabbits are one of the major threats (in dry environments in New Zealand this is also likely to be the case). The aim of the research was to better define the rabbit problem, and to show how limited resources for ecosystem protection can be most effectively applied. They used existing data on effectiveness and costs of three rabbit control methods (1080 oats, fumigation, warren ripping), and supplemented this with new research to better understand the impacts of rabbit browsing on Australian native vegetation. From their research they came up with a scale which scored rabbit abundance 0–5, and estimated rabbit impacts on shrub and tree seedlings abundance and browse damage to determine a sites ‘regeneration capacity’, again on a scale of 0–5.

The monetary value of vegetation was determined using an ‘avoided costs’ approach – the rationale being that the value of improvement in the environment can be inferred from reduction in expenditure such as costs of replanting vegetation. In the model, value was assigned proportionally based on the apparent capacity of plant communities to regenerate and sustain themselves.

Uncertainty in the efficacy of control is incorporated, and Monte Carlo simulation is used to account for variability in rabbit population growth rates to enable assessment of the long-term impacts. Based upon rabbit numbers, and the vegetation’s regenerative capacity (low/medium/high), the model predicts the best combination of rabbit control methods for cost-effective rabbit control, and provides a framework for deciding how limited resources can be used to greatest benefit in protecting vegetation.

The authors noted that the model recommendations may vary if the resource to be protected was valued differently – and different sectors of the community may have different views – but the valuation chosen for their research was of use to people with an interest in vegetation conservation.

In applying a similar approach to the rabbit problem in New Zealand there would likely be considerable work required to parameterise the model and quantify the impacts of rabbits – be that on production, or on conservation values. Grant Norbury noted in 2000 that *‘rabbits clearly impose significant costs to production, but there is no way at present to assess the marginal costs and benefits of rabbit control’*. Some work has been done that relates rabbit and sheep densities to rates of pasture growth that will assist in cost–benefit analyses, but as yet it is not published (Scroggie et al. in prep) and the above statement still holds (G. Norbury pers. comm.).

3.5 Rabbit Management Adviser – 'RabMan' (DEFRA – UK)

Rabbits are a major agricultural pest in Britain, so much so that a report by CABI named the rabbit as Britain's most costly invasive species – the estimated 40 million rabbits in Britain cost £260 million in damage to crops, business and infrastructure (Meikle 2010). Over £5 million is spent each year to manage rabbit pests of agriculture (Smith et al. 2007).

As such, Britain has invested significantly in research into the rabbit problem. Between 1996 and 2004 DEFRA (Department for Environment, Food and Rural Affairs) spent £2.4 million on rabbit research, including £978,000 on development of a DSS for rabbit management (DEFRA 1999a–2004). This work built on considerable research done over the prior 20 years, and sought to extend and integrate the knowledge base that had been developed. The research programme aimed to develop an expert system to assist MAFF advisers to assess costs of rabbit grazing, and to determine when and how to control rabbits most cost efficiently. The researchers noted that prior to their work, the only comparable work done in the rabbit DSS area was the New Zealand (MAF) work – which used a more simplistic approach (DEFRA 2002a).

Central to the DSS is a deterministic population model that extended upon earlier work by including the effects of RHD and myxomatosis, and incorporating immigration and dispersal effects (so the model can be run as an open or closed population). The model has been validated in the field and generally found to give reliable predictions of future rabbit numbers under different control scenarios (DEFRA 2004). From a starting population and prescribing which control methods are used in which months at what intensity, the model is run for 2 years and compares the controlled population prediction, to a no-control option (Fig. 4). Up to five control strategies can be compared visually against the no-control option.

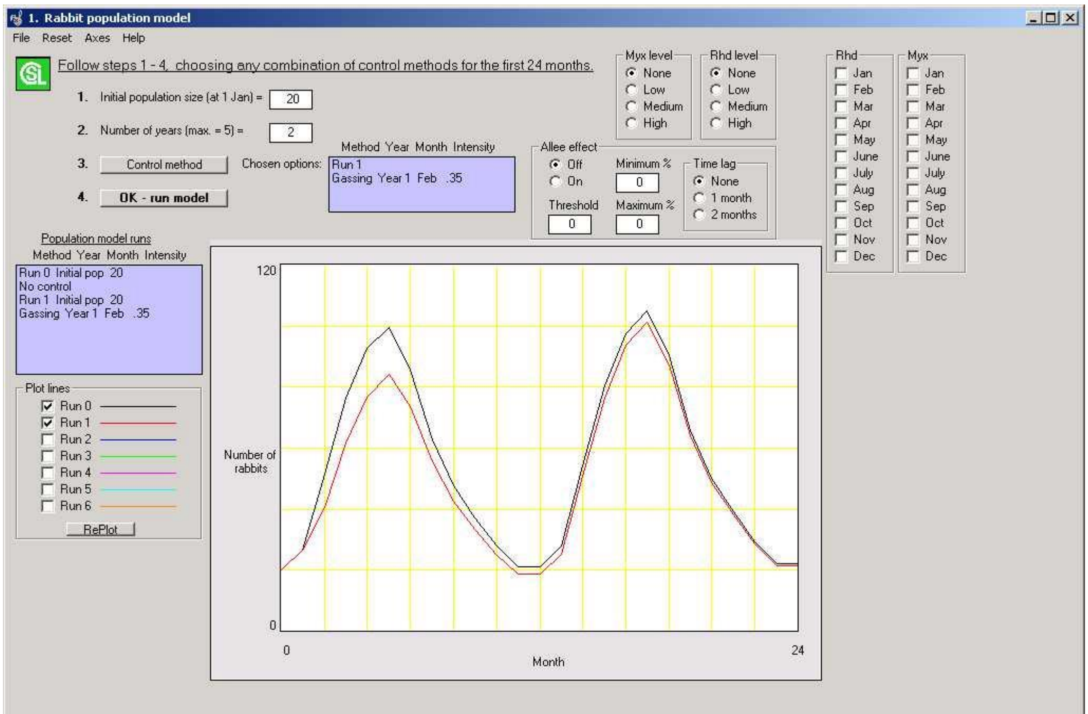

Figure 4 The population model output screen showing a comparison of a single gassing control with the uncontrolled population (source DEFRA 2002a).

The other key aspect of the DSS is estimation of rabbit damage to crops. Using specialist facilities at CSL (now Food and Environment Research Agency – FERA) in York (six enclosures approximately 1 ha each in size) data were gathered in order to produce yield loss models for crops (spring barley, and winter wheat) and grass (DEFRA 2002a). In the first stage, static 'damage estimation models' were developed based on fixed populations of rabbits (ranging from 11 to 35 per hectare, plus control of no rabbits). Subsequently the models were extended to handle complex dynamic situations where rabbit numbers could fluctuate naturally, and the rabbits had choices in terms of where they foraged.

As well as direct use of the population model (as above), the DSS integrates monthly population estimates from the population model with the damage estimation model to predict losses (for up to 4 years) from different rabbit management options. The system can then assist in calculating the cost of control. A series of questions relating to the costs of the method chosen are put to the users, with default values as answers, which the user can accept or modify. On completion of the questions, the system calculates the costs of control, compares it with the damage costs, and displays a cost–benefit analysis (see Figs 5 and 6; DEFRA 2004).

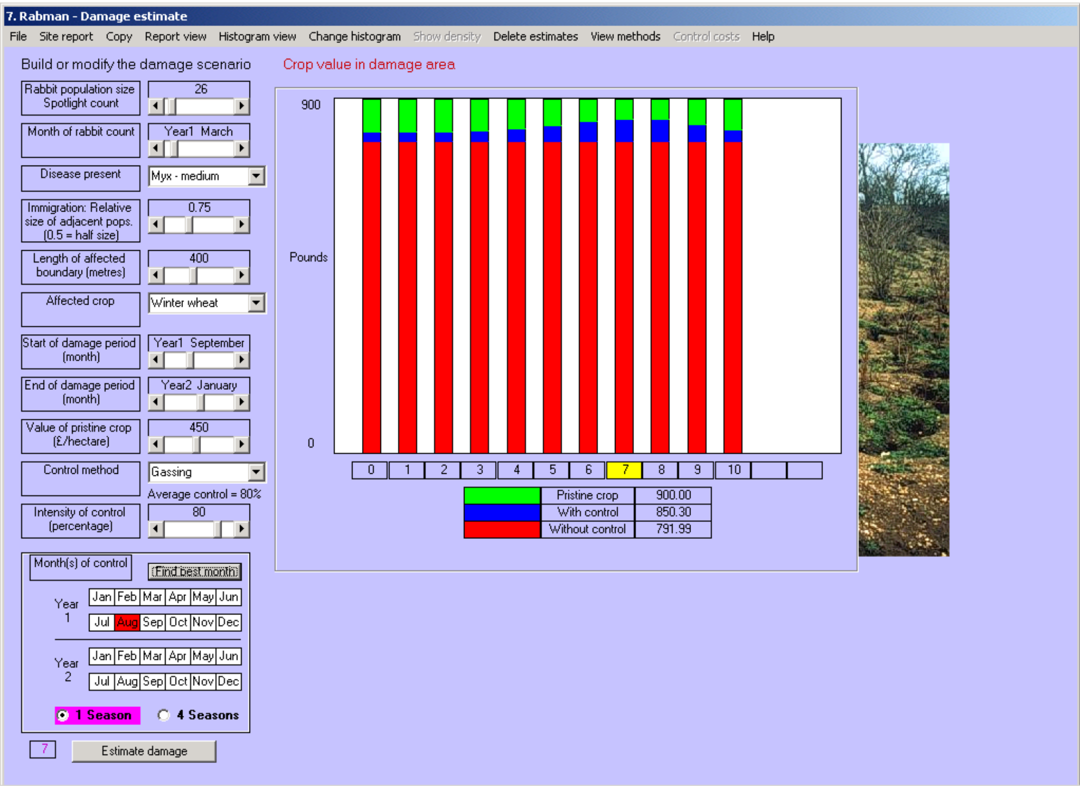

Figure 5 Graphical output showing crop yield with and without application of a specific management approach (source DEFRA 2004).

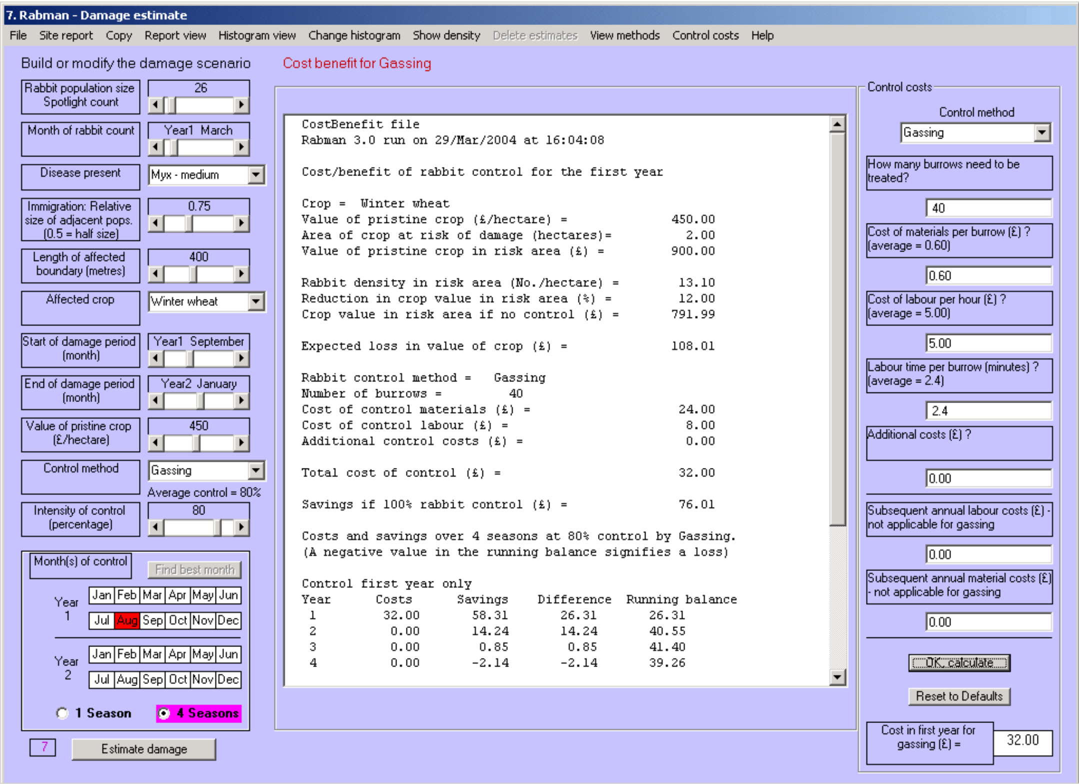

Figure 6 Cost–benefit analysis text output (source DEFRA 2004).

The other modules of the DSS are:

- An 'Information Centre' providing access to information on rabbit biology, standard operating procedures for population assessment, abstracts of key scientific references, current research, and leaflets on rabbit management
- A Rural Development Services (RDS) Rabbit complaint form (RDS Wildlife Advisers are the primary audience for this DSS).

This DSS appears quite comprehensive in its coverage, with not only rabbit populations modelled, but also the impacts of the rabbits. Cost information then enables cost–benefit analysis to be undertaken. The DEFRA DSS is applicable to 'lowland agricultural landscapes' and is broader in scope than the CARE/BRS Australian DSS both in terms that its underlying models are less location specific, and that it adds the Information Centre module.

Smith et al.(2007) showed an example of the use of the DSS and reported that the system was currently being field tested by UK agricultural advisers.

4 Conclusions

In the design of any DSS, a clear understanding of the intended use of the tool, including consideration of the target audience, is critical in deciding its design and level of complexity (Walpole & Thompson 1997). There are trade-offs between DSS development costs, complexity, accuracy of information, and the usability of the system. Cacho (1997, p. 2. cited in Walpole & Thompson 1997) describes the DSS model-building dilemma well:

> *… an all-encompassing model runs the risk of becoming as complex as the real system, defeating the purpose of the model as a simplified representation of reality*.

Walpole and Thompson (1997) prepared a useful summary of key issues in DSS development – see Appendix 1. Among the factors to consider in determining the approach to take they listed:

- The client for the DSS (e.g. landholders, researchers, government agencies)
- The budget available for developing the DSS
- The time available to develop the DSS
- The desire to create a learning tool as opposed to a prescriptive tool, and
- The level of 'black box' type features that are acceptable (i.e. how transparent does the DSS have to be).

Further, they suggested that perhaps the most useful way to decide what type of DSS is required is to match the product to the end-user (or client) needs. Landowners, and management agencies who undertake control on behalf of landowners, are considered our research programme's primary audience for a rabbit DSS.

Of the suggested needs/issues relating to a DSS focused on landowners identified by Walpole and Thompson, I consider the following to be most relevant:

- Requirement for a 'recipe' approach that is credible
- Simple framework
- Low data requirements
- Low cost
- Flexibility to cater for local variation in production systems
- Flexibility to cater for variations in goals and objectives
- Ease of interpretation of DSS output

All the DSSs reviewed appear to have useful application to the problem areas they target. Weighing up the budget and time available, the target client for a DSS, and their associated needs/issues, I have reached the following conclusions:

1. Elements of the MAF 'Rabbit' DSS are still likely to be relevant, and may still be largely representative of current best practice.

   The Information and Rabbit Expert knowledge remains highly relevant, as does costing of control operations. These elements could be readily updated based upon findings of the current rabbit research project.

   The population model that includes RHD impacts is probably still applicable. If the detailed information on the model is available, then within Landcare Research we would have staff with the skills required to bring the model into a modern software platform.

   In a 2001 paper, Fa et al noted that with regards to the Barlow models:

   > *Although these models produced a good fit to the wild rabbit population data used to determine the population parameters, they are not able to represent processes of spatial movement, local interactions, and social behavior that may be critical to the dynamics of a disease in a population.*

   If the Barlow model is still found to accurately portray rabbit populations at a farm level, then modifying the model to account for spatial factors may not be necessary (although at a regional level this may be of interest). However, a spatial model and/or database could be a future consideration, especially with the free availability of open-source GIS packages, which may make the original concept of including a GIS more achievable. This would be outside the scope and resources of the current project.

   The costing spreadsheet module that looks at longer term affordability of rabbit control is in a format that prevents users seeing the underlying logic and formulae. To recreate a similar tool, a farm economist would need to be contracted.

   The end of the RLMP subsidies, and likely changes to taxation rules etc. since the 1990s, means the spreadsheet would require some modification.

2. The detailed modelling encompassed in the CARE/BRS DSS is too complex and site specific for our immediate purposes.

3. The informative nature of the Fox and Rabbit DSS is likely to be valued by landowners; however, the focus of the material would be different for a landholder compared with agency staff. Given developments in Internet speeds, electronic distribution of material to allow easy access and updating is now best directed to the Internet (e.g. can now cope with video files).

   Video clips may be useful in engaging users (providing the clips add value to the information being presented).

   It would be useful to consult regional council staff to see if they see a need for additional, more-in-depth material for their staff, to sit alongside general information targeted at landowners.

4. The Invasive Animals CRC modelling approach provides a new approach to quantifying the benefits of rabbit control; however, it is currently oriented to assisting State agencies in determining where best to allocate resources for pest control over numerous competing projects rather than determining the best control options on an individual property.

   Most rabbit control in New Zealand is undertaken on pastoral farmland. From the landowner's perspective it is likely that production-value impacts (along with enforcement from regional councils) are the primary driver rather than conservation values. As such the IA CRC approach does not lend itself to our immediate issue, but nevertheless it is an interesting approach that could in future be considered for application to agencies' needs for prioritising control of various pests for biodiversity protection.

5. The British 'Rabman' DSS is perhaps the 'Rolls Royce' version of a rabbit DSS. It has taken the basic components contained in the New Zealand 'Rabbit' DSS and enhanced them with detailed modelling of rabbit populations, their impacts, and the benefits of control. While the underlying nature of the rabbit problem is different between New Zealand and the UK, the general framework that 'Rabman' provides is impressive, and could equally be applied to New Zealand.

   However, the amount of time and money that has been invested in developing this DSS is beyond the scope of our research programme.

5 Recommendations

With regards to the existing New Zealand MAF 'Rabbit' DSS:

- Update the Information Sheet section, and the associated Rabbit Manager's Factpack and make them available on the Internet. This is in line with a recommendation from the 'Lough report' (2009) which noted that the fact pack was *'…an excellent publication… no updates on rabbit management since 1992…'* and recommended that the fact pack be updated with current information on RHD (recommendation 12). Note – the NPCA updated the best practice guidelines for rabbit control in 2011. The primary audience of their document is *'council field staff and contractors'* – I would envisage more generally targeted information delivered in a modular format as the fact pack was (the NPCA guide is a single document).
- Attempt to document the Expert System and produce a flow chart or similar to get a concise view of the state of knowledge at that time and compare it with current practice to provide a framework that the current research programme can look to improve.
- Seek review from current pest control experts of the knowledge documented above, and identify any areas no longer regarded as best practice. Update Expert System to current best practice, and incorporate new knowledge generated by the research programme.
- Document and update the control costing facility in line with modern practice and operational costs. Incorporate this into new DSS alongside information sheets, and Expert System/best practice advice.
- Seek end-user input as to whether population models (including potential spatial aspects) and affordability spreadsheet are priorities, and if so at what level of detail. Based upon this feedback, and bearing in mind time and resource constraints, determine what work (if any) can be undertaken within the current programme and what work should be ear-marked for the future should funding be available.

General recommendations

- If rabbit impacts on farm production are identified as a future driver of when rabbit control is required (as opposed to compliance), give further consideration to the CARE/BRS approach from Australia (but at a more generic, less location specific level) and the UK 'Rabman' approaches.
- If regional biodiversity protection from rabbit impacts is identified as a priority, the Invasive Animals CRC approach warrants further investigation.
- Any cost–benefit modelling of rabbit control and impacts could be informed by the work of Scroggie et al. (in prep.) relating rabbit and sheep densities to rates of pasture growth.

6 Acknowledgements

I thank David Thompson (CARE) for providing copies of unpublished reports, and for permission to reproduce a section of a report in Appendix 1. Bruce Warburton and John Parkes reviewed a draft of this report, which was edited by Christine Bezar. The work was funded by the Ministry of Science and Innovation (MSI) *Control of small mammal pests* research programme (C09X0910).

7 References

Barlow N 1993. Modelling rabbit population dynamics. MAF Rabbit and Land Management Programme Newsletter March 1993, pp. 12–13.

Barlow N, Kean JM 1998. Simple models for the impact of rabbit calicivirus disease (RCD) on Australasian rabbits. Ecological Modelling 109: 225–241.

Barlow N, Barron M, Parkes J 2002. Rabbit haemorrhagic disease in New Zealand: field test of a disease-host model. Wildlife Research 29: 649–653.

Bell J 1991a. A Decision Support System for Rabbit Managers. 9th Australian Vertebrate Pest Control Conference: Handbook of working papers. Pp 47–49.

Bell J 1991b. “RABBIT” Decision Support System. Unpublished user manual for the RABBIT DSS. Ministry of Agriculture and Fisheries. Pp. 1–18.

Cacho OJ 1997. Systems modeling and bioeconomic modeling in aquaculture. Aquacultural Economics and Management 1: 45–64.

Cooke B, Jones R, Gong W 2010. An economic decision model of wild rabbit Oryctolagus cunniculus control to conserve Australian native vegetation. Wildlife Research 37: 558–565

DEFRA 1999a. Antigen delivery systems for the control of fertility in rabbits, Project OC9521. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=6154 (last accessed 13 May 2011).

DEFRA 1999b. Predicting damage to crops by rabbits (Previously VC0210), Project VC0215. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=5854 (last accessed 13 May 2011).

DEFRA 2000a. Improving the precision of estimates on the effect of warren based rabbit control, Project VC0223. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=9249 (last accessed 13 May 2011).

DEFRA 2000b. Development of breeding protocols for wild rabbits, Project VC0225. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=9446 (last accessed 13 May 2011).

DEFRA 2001a. Developing a visual scaring device to deter rabbits, Project VC0218. http://randd.defra.gov.uk/Document.aspx?Document=VC0218_221_FRP.pdf (last accessed 13 May 2011).

DEFRA 2001b. Developing a method for assessing the size of rabbit populations, Project VC0219. http://randd.defra.gov.uk/Document.aspx?Document=VC0219_222_FRP.pdf (last accessed 13 May 2011).

DEFRA 2001c. Rabbit behaviour and population dynamics at fenced hot-spots, Project VC0221. http://randd.defra.gov.uk/Document.aspx?Document=VC0221_223_FRP.pdf (last accessed 13 May 2011).

DEFRA 2001d. The impact of rabbit haemorrhagic disease on wild rabbit populations, Project VC0222. http://randd.defra.gov.uk/Document.aspx?Document=VC0222_3093_FRP.pdf (last accessed 13 May 2011).

DEFRA 2001e. Efficacy of CO as a rabbit fumigant, Project VC0229. http://randd.defra.gov.uk/Document.aspx?Document=VC0229_3094_FRP.doc (last accessed 13 May 2011).

DEFRA 2002a. Developing a rabbit management expert system, Project VC0220. http://randd.defra.gov.uk/Document.aspx?Document=VC0220_2360_FRP.doc (last accessed 13 May 2011).

DEFRA 2002b. Sperm-based contraceptive vaccine for the wild rabbit, Project VC0224. http://randd.defra.gov.uk/Document.aspx?Document=VC0224_1264_FRP.doc (last accessed 13 May 2011).

DEFRA 2002c. Incorporation of data on rabbit haemorrhagic disease and myxomatosis into the rabbit management decision support system, Project VC0226. http://randd.defra.gov.uk/Document.aspx?Document=VC0226_486_FRP.doc (last accessed 13 May 2011).

DEFRA 2002d. Towards ecologically sound rabbit management: impacts of critical threshold densities and migration on abundance, Project VC0227. http://randd.defra.gov.uk/Document.aspx?Document=VC0227_2361_FRP.doc (last accessed 13 May 2011).

DEFRA 2002e. Development of a simple daytime rabbit census method based on activity signs, Project VC0228. http://randd.defra.gov.uk/Document.aspx?Document=VC0228_487_FRP.doc (last accessed 13 May 2011).

DEFRA 2003. Developing a method for blocking rabbit burrows, Project VC0217. http://randd.defra.gov.uk/Document.aspx?Document=VC0217_1064_FRP.doc (last accessed 13 May 2011).

DEFRA 2004. Development of a decision support system for ecologically sound rabbit management, Project VC0232. http://randd.defra.gov.uk/Document.aspx?Document=VC0232_1722_FRP.doc (last accessed 13 May 2011).

Fa JE, Sharples CM, Bell DJ, DeAngelis D 2001. An individual-based model of rabbit viral haemorrhagic disease in European wild rabbits (*Oryctolagus cuniculus*). Ecological Modelling 144: 121–138.

Gough, J.D. and Ward, J.C. 1996 'Environmental Decision-Making and Lake Management, Journal of Environmental Management, 48, 1-15

Lough R 2009. The current state of rabbit management in New Zealand – Issues, options and recommendations for the future. MAF Biosecurity New Zealand. 100 p.

MAF 1991. Rabbit managers' factpack. Semi Arid Lands Research Group, Ministry of Agriculture and Fisheries.

Meikle J 2010 Rabbits named Britain's most costly invasive species. The Guardian, 15 Dec. 2010; www.guardian.co.uk/environment/2010/dec/15/rabbits-invasive-species-cost (last accessed 12 May 2011).

Norbury G 2000. Advances in New Zealand mammalogy 1990-2000: Lagomorphs. Journal of the Royal Society of New Zealand, 31: 1, 83–97

NPCA 2011. Pest rabbits – monitoring and control good practice guidelines. Wellington, National Pest Control Agencies. Downloaded from http://www.npca.org.nz/images/stories/NPCA/PDF/a5_201104_rabbitguide_web.pdf (last accessed 24 May 2011).

Scroggie MP, Parkes JP, Norbury G, Reddiex B, Heyward R. Effect of rabbits and sheep on vegetation growth in dry and mesic grasslands in Otago, New Zealand. In prep.

Smith GC, Prickett AJ, Cowan DP 2007. Costs and benefits of rabbit control options at the local level. International Journal of Pest Management 53: 317–321.

Thompson D 2000a. Rabbit Control Simulation Model – users guide. Centre for Agricultural and Regional Economics (CARE) unpublished report to Bureau of Resource Sciences, Australia.

Walpole S, Thompson D 1997. Development of decision support guidelines for vertebrate pest management. Stage 1 – a review of economic applications. Centre for Agricultural and Regional Economics (CARE) unpublished report to Bureau of Resource Sciences, Australia.

Additional reading (not cited)

Thompson D 2000b. Rabbit control – economic guidelines. Centre for Agricultural and Regional Economics (CARE) unpublished report to Bureau of Resource Sciences, Australia.

Appendix 1 – Key issue summary for DSS development

[Excerpted (with permission) from Walpole & Thompson (1997)]

In addition to some general comments about DSS, this scoping study has essentially compared two approaches to developing frameworks which support decisions about the economics of vertebrate pest control. Those approaches are:

- The traditional benefit-cost analysis approach, which encapsulates a hierarchy of complexity ranging from an estimation of private costs and benefits through to a more comprehensive social analysis which includes the consideration of externalities and ideally, important non-economic factors. Both approaches may also contain stochastic elements and may be single or multi period (see Figure 5.1).

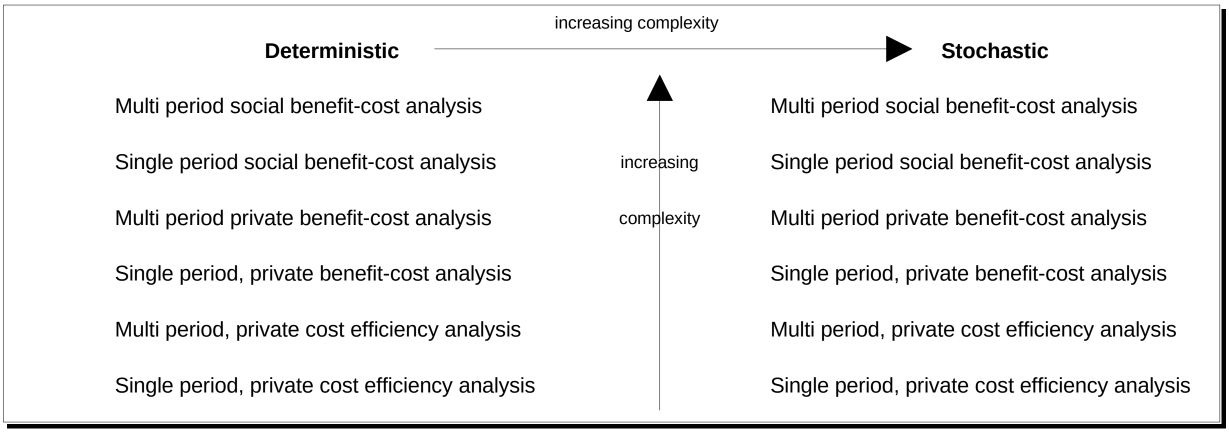

Figure 5.1 Hierarchy of benefit-cost approaches.

- Systems modelling (including bioeconomic modelling) also covers a range of levels of complexity and detail. However explicit attempts are made to separate out system components (e.g. biological, farm management and economic sub-systems). Systems modelling seeks to capture the pest management problem in a more realistic manner, by describing the links between system components, including dynamic (time) and stochastic elements as well as feedback loops. With this approach, there is more scope (relative to BCA) for plotting the path of important system variables over time. This may be important for a number of reasons. For example, if the bulk of the benefits from pest control occur early in the control strategy timeframe, and later elements of the control strategy provide little additional benefit.

In terms of a generic bioeconomic decision support framework for assessing the economic impacts of vertebrate pest control (as opposed to a species specific model), Cacho (pers. comm. 1997) has indicated that for many mammalian species, a generic framework would be suitable, with the only major changes being those to model parameters (such as parameters in population growth and damage estimation equations).

Contemporary thinking about economic modelling is at somewhat of a cross-roads with debate focusing on the relative merits of the neo-classical approach with which BCA is more aligned and the systems modelling approach which is more multi-disciplinary in nature and usually places far less emphasis on the importance of 'equilibrium' conditions.

The economic frameworks associated with both approaches have tended to lean toward traditional neo-classical approaches where high priority is given to factors which can be valued in monetary terms. Too little attention has been given to other important decision variables which are difficult or impossible to describe in monetary terms. In other words, outcomes which can be described in terms of markets have taken precedence over those related to the less tangible goals and objectives of the decision maker.

The final decision about which approach should be adopted depends on a range of factors including:

- The client for the DSS (e.g. landholders, researchers, government agencies)
- The importance of the decision to be made
- The budget available for developing the DSS
- The time available to develop the DSS
- The accuracy with which the real world situation is to be modelled (this is often constrained by the availability of data) which will influence model complexity
- Whether a descriptive (positive) or optimising (normative) model is required. Normative models seek to prescribe management options which will optimise a particular criterion (e.g. profit). Positive models simply indicate expected outcomes from alternative management strategies and are usually less expensive to operate than normative models (Cacho 1997)
- The desire to create a learning tool as opposed to a prescriptive tool, and
- The level of 'black box' type features which are acceptable (i.e. how transparent does DSS have to be).

Perhaps the most useful way to decide what type of DSS is required is to consider the end-user (or client) and match the product to their needs. For the case of vertebrate pest control, a range of issues for consideration are listed in Table 5.1

Table 5.1 Client analysis for a DSS on vertebrate pest control

Potential customer/client group	Suggested needs/issues
Landholders/Landholder groups (Private landholders)	Requirement for a ‘recipe’ approach which is credible Simple framework Low data requirements Low cost Flexibility to cater for local variation in production systems Flexibility to cater for variations in goals and objectives Ease of interpretation of DSS output May be interested in private assessments Information on externalities will influence their decision to take on pest control as individuals or as groups Will probably require adviser assistance either to assess the credibility of the tools or to help them use the tools and interpret results (i.e. landholders are unlikely to use these tools on their own)
Public landholders	Flexibility to cater for variations in goals and objectives (e.g. biodiversity, cost-effectiveness) Consideration of externalities, especially to private landholders Cost probably now more of an issue given current fiscal constraints Public image they wish to portray – setting pest management standards or just doing what is economically worthwhile
Advisory groups (public and private)	Generic DSS structure to provide advice under a range of scenarios for range of pests – may be a key element in the ‘extension’ of results Ability to present results in an easily understood format Flexibility to cater for local variation in production systems Flexibility to cater for variations in goals and objectives Incentives will be required (usually financial) to encourage advisers to become involved in the extension of these tools
Researchers	Ability to deal with increased DSS complexity Use as a learning tool Scope to manipulate the framework Will have access to more data which will evolve over time Ability to extend the DSS to new situations and pest species