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# Decision Support Systems for Improving Invasive Rabbit Management in Australia

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**ABSTRACT:** European rabbits threaten ecological, agricultural, forestry, and production assets in Australia, New Zealand, and many oceanic islands where they have become established as invasive pests. Managing rabbits in conservation lands often requires managers to prioritise allocation of funding, while managing them in production lands often requires farmers to know what the benefits and costs are of undertaking control. We aimed to design two Decision Support Systems (DSS) to aid various rabbit management decisions in both conservation and agricultural settings. We describe how our approach: 1) engaged stakeholders to gain their thoughts on the type of decisions that needed support, the issues that they thought were important regarding rabbit management, and the scale and shape of the decision tool they wanted; and 2) produced DSS that were user-friendly, open-sourced, and, most importantly, able to evolve beyond our involvement, which ensures that they stay relevant and current, and are able to improve as new knowledge becomes available. Our approach also placed the DSS within the wider context of rabbit management which highlighted other steps necessary to achieve the ultimate objective of the DSS tool: effective rabbit management to protect and enhance conservation, social, and economic assets. This approach should increase acceptance of the DSS and their limitations but, more importantly, should increase the probability of achieving effective rabbit management.

**KEY WORDS:** Australia, decision support systems, invasive species, rabbit management, theory of change

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## INTRODUCTION

European rabbits (*Oryctolagus cuniculus*) threaten ecological, agricultural, forestry, and production values in Australia, New Zealand, and hundreds of oceanic islands where they have become established pests (Williams et al. 1995, Vere *et al.* 2004, Lees and Bell 2008). Even at low densities, rabbits pose a heavy cost to native flora and alter plant community composition by inhibiting regeneration of some species through ring-barking and selective over-browsing, and by removing some species entirely through selective over-grazing (Moseby et al. 2005, Lees and Bell 2008). Rabbits also affect native fauna by competing directly for habitat and food (Williams et al. 1995, Lees and Bell 2008), or indirectly by supporting high densities of invasive predators that hyper-predate on native prey (Pech et al. 1995).

Rabbits were introduced to Australia in the mid-19<sup>th</sup> century where they quickly spread (Lees and Bell 2008). By the early 1900s, rabbits reached plague proportions over vast areas of conservation and production lands, becoming one of the most common invasive prey (Williams et al. 1995). For much of the 19<sup>th</sup> century, rabbits were controlled with limited success using trapping, shooting, poisoning, and fencing (Williams et al. 1995). During the mid-20<sup>th</sup> century, large reductions in rabbit numbers were achieved in semi-arid areas with the release of mosquitoes and fleas carrying the myxoma virus, but not in arid and high rainfall areas (Ratcliffe et al. 1952, Williams et al. 1995, Fenner and Fantini 1999). In the late-1990s, Rabbit Haemorrhagic Disease (RHD) escaped quarantined field trials in Australia (Cooke 2002), reducing rabbit populations by more than 90% but, like myxomatosis, RHD efficacy proved geographically patchy (Mutze et al. 1998, Cooke 2002). More than a decade later, the efficacy of RHD is now also waning,

and rabbit numbers are once again on the rise (Cooke 2012). This history of rabbit management reminds us that there are no “silver-bullet” solutions for managing rabbits and that effective, long-term management requires an integrated management approach (Williams et al. 1995, Cooke 2012).

Effective management of rabbits and other pests is challenging and requires a broad range of knowledge and coordinated actions across a range of stakeholders. While operational managers make the ultimate management decisions on-the-ground, other stakeholders can influence those decisions by creating or modifying the context (e.g., positive or negative support), thereby influencing whether management is effective and sustainable. Stakeholder collaboration broadens the scope of action and improves problem solving beyond the capacity of an individual manager.

Decision Support Systems (DSS) can facilitate integrated knowledge transfer and collaboration amongst multiple stakeholders to support pest managers with decision making (Jakku and Thorburn 2010). DSS have evolved in recent times, providing not only interactive (often computer-based) end-user tools that provide information access, model analysis, and decision guidance for managers (McCown 2002, Hung et al. 2007), but also a process that actively engages stakeholders at all stages of development (Parker and Sinclair 2001, Hayman and Easdown 2002, Diez and McIntosh 2009, Van Meensel et al. 2012). The ideal development process aims to facilitate communication (Hearn and Bange 2002, Volk et al. 2010) and collaboration between stakeholders (Hearn and Bange 2002, Jakku and Thorburn 2010), support learning (Parker and Sinclair 2001, Hayman and Easdown 2002, Hearn and Bange 2002, McCown 2002, Walker 2002),

encourage best practice (Parker and Sinclair 2001, Walker 2002, McCown et al. 2009), and influence management processes (Hayman and Easdown 2002, McCown et al. 2009). Meanwhile, the ideal end-user tool should be fit for purpose to ensure its relevance (Parker and Sinclair 2001, Walker 2002, Volk et al. 2010); well-designed, with software that is easy to access and use, and with minimal data requirements (Hayman and Easdown 2002, Volk et al. 2010, Shtienberg 2013); adaptable, so that new information can be easily incorporated as science advances (Parker and Sinclair 2001, Walker 2002, Voinov and Bousquet 2010); and supportive to the end-users' decision making process, aiming to address end-users' needs and wants (Hayman and Easdown 2002, Hearn and Bange 2002, Walker 2002).

This paper aims to describe two DSS that were developed to support rabbit management in agricultural and conservation lands in Australia. We developed the DSS by coupling good practice for DSS development (described above), with a larger outcome-focused framework termed "Theory of Change" (TOC) (Anderson 2005, Vogel 2012a). We describe this process briefly before outlining details of the two DSS.

#### **OUR DSS DEVELOPMENT APPROACH**

A review of the DSS literature was used to guide our DSS development process. This also highlighted that previous rabbit-management DSS were seldom used or updated (McGlinchy 2011). Additionally, while conducting initial workshops with stakeholders, it also became apparent that stakeholders had a whole-system view of the problem, with a focus on achieving management outcomes (i.e., protecting environmental and economic assets from rabbits) rather than on the outputs of the DSS (e.g., what control tool to use). A framework was needed to allow stakeholders to work through all the elements that were required to achieve their ultimate goals, and to highlight where a DSS could contribute. These workshop sessions highlighted that ignoring the wider context that the DSS must be used in was likely to result in "yet another DSS" of little value and use. To address these potential hurdles, we used a Theory of Change approach, which helped us to place the DSSs into their wider decision-making context and also provided a platform for project planning and evaluation (Morra Imas and Rist 2009, Rogers 2008, Vogel 2012).

Theory of Change is an outcomes-based approach that guides developers and stakeholders during the planning stage – defining the project elements (inputs, activities, outputs, and outcomes), and during the evaluation stage – defining criteria to measure project performance. This outcomes-based approach (or TOC) can be used to consider: 1) the "big picture," or ultimate outcomes wanted from pest management; 2) how the DSS contributes to those outcomes; and 3) what other critical components of the system must also be considered alongside the DSS to achieve those ultimate outcomes, and what assumptions underlie this view of the system. This big picture was developed with stakeholders to identify the required activities, outputs, intermediate, and final outcomes that are the elements necessary to achieve

effective pest management. The success of applying this approach to DSS development will be assessed in the next phase of the project using evaluation criteria identified during the development of the TOC.

#### **CONSERVATION LAND DSS: PRIORITISING FUNDING FOR RABBIT MANAGEMENT**

The Australian Capital Territory (ACT) Parks and Conservation Service manage rabbits on conservation lands, generally to minimise their impacts on biodiversity and soil assets, but also in peri-urban and urban parks to minimise their impacts on amenity and economic assets. As with most management agencies, funding available is never sufficient to do the required control everywhere, so the land manager (viz. vertebrate-pest coordinator, VPC) has to allocate available funding to priority areas, to ensure that maximum benefits are delivered. The request to develop a DSS for conservation lands was made by the vertebrate-pest coordinator's line manager to capture the experience, knowledge, and decision process used by the current vertebrate pest coordinator to ensure it was not lost, if and when the VPC left the position.

With this aim in mind, we developed a conservation land DSS in close collaboration with Parks and Conservation Service staff, particularly the VPC. We used a series of workshops to ascertain their objectives (i.e., outcomes) for rabbit management, the decision steps followed by the VPC to make funding-allocation decisions, and the type of DSS tool that would be most useful to them.

The workshops were important for capturing the steps of the decision-making process, which resided solely in the head of the VPC. The steps identified were used to create a decision tree that clarified the sequence of questions, answers, and decisions the VPC addressed when allocating funds. The decision tree was iteratively validated with the VPC, and after several iterations, and agreement that it captured the critical steps, it was turned into a final decision tree that guided the structure of the DSS tool.

This iterative process highlighted gaps in knowledge required to reach the final decision. These gaps in knowledge were addressed by the development of two methods: 1) a method for rapidly assessing the abundance of rabbits, as rabbit abundance was unknown for most conservation lands, and 2) a method for assessing and scoring the relative importance of conservation, social, and economic assets of an area (i.e., management unit).

We worked with Parks and Conservation Service staff to field test and assess the value of adopting a rapid rabbit abundance assessment method used in New Zealand [viz. Modified McLeans Scale (<http://www.npca.org.nz/index.php/news/84-general/226-rabbit-control-training>)]. The second method was developed by Parks and Conservation Service as a draft conservation prioritising process (available as part of the DSS). Development of these two methods enabled the VPC to score each management unit for its conservation value, and to assess the relative abundance of rabbits in each unit – two critical information needs for prioritising resource allocations.

The methods developed provide an important step

toward improving current decision making by the VPC, but it was recognised that they would need further refinement beyond the life of the project. It was therefore agreed that the DSS tool would be developed using Visual Basic in Microsoft Excel, hiding the calculations in the background to make the tool user-friendly, but providing access to them when required by the end-user (VPC) to update the DSS tool beyond the life of the project. This allows a simple way of incorporating new information to refine the steps in the decision process in the future. It was also agreed that the tool would be made available online (i.e., open-sourced) in recognition that it could be used as a building block by government agencies elsewhere dealing with similar issues (available at: <http://www.pestsmart.org.au/pest-animal-species/european-rabbit/dss-for-rabbit-management/conservation-land-dss/>).

The DSS captured the steps in the decision tree by requesting user input for each management unit on: 1) previous government's commitment to rabbit control in the area, 2) number of rabbit-related complaints, 3) years of previous control, 4) rabbit abundance which could include data from three alternative measures: spotlight count data, warren count data, or a rapid assessment score (from the rapid method described above), 5) conservation score based on the proportion of native species and threatened species found in the area, 6) vulnerability score as a way of linking an area's ecosystem threats (from conservation scores) to the ecosystem's vulnerability to rabbits, 7) economic score to assess impacts of rabbits on economic assets, and 8) good neighbour score to acknowledge the government's responsibility to be a good neighbour, and the increased probability of successful control with increased community collaboration. Data were entered for each of the potential management units.

The answers to the first four steps determine whether an area is classified as one of the following: requiring control (i.e., priority list), not requiring control, or potentially requiring control (potential list). The areas in the potential list use scores from the last three steps in a Multi-Criteria Decision Analysis (MCDA) methodology (Kiker et al. 2005) to provide a prioritised list of management units that gets added to those in the priority list that were previously classified as requiring control. The VPC then estimates the costs of carrying out the required rabbit control in each area, and based on the prioritised list and each area's estimated control cost, develops a final list with a cut-off point at which the budget is no longer sufficient to apply control to an area (i.e., all areas below this point do not get rabbit control).

### **PRODUCTION LAND DSS: ECONOMIC BENEFITS OF RABBIT CONTROL**

Australian farmers are facing increasing rabbit abundances as the efficacy of RHD continues to wane (Cooke 2012). Unfortunately, experience with recognising rabbit impacts and applying effective management has been largely lost within the farming community as young farmers have not yet experienced high rabbit abundances. In an effort to equip farmers with tools to help them manage rabbits, the Invasive Animals Cooperative Research Centre (IA-CRC) commissioned the development team to create a DSS to help farmers with decisions

regarding rabbit management. Given limited funding and with knowledge that end-users were an essential part of the development process, the development team chose to target efforts towards wool production farms of the Centre Tablelands region of New South Wales (NSW), where knowledge of the rabbit-sheep system was available as part of an existing, but currently unused, DSS (developed by the late D. Choquenot). Choquenot (1998) collected ecological data at multiple wool production farms to estimate parameters for a seasonal herbivore-resource model in which rabbits and sheep interact through shared pasture biomass (which is driven by rainfall). The effects of alternative rabbit control techniques on rabbit abundance were also estimated, which allowed estimates of the flow-on effects on available pasture for sheep and, ultimately, on wool production costs.

As a first step, we organised a workshop, which brought together multiple stakeholders involved in rabbit management in wool production farms in the Centre Tablelands, including wool production farmers, Local Land Service (LLS) staff, NSW Parks and Service staff, Meat and Livestock Australia (MLA) representatives, and IA-CRC representatives. The aim was to collectively identify key issues of rabbit management in wool production farms in the area, and thoughts on how a DSS could be most useful. Collectively it was agreed that the DSS should aim to encourage effective rabbit management and best practice approaches by informing the end-users of the potential cost-benefits of various control specifications. It was agreed that if farmers are to invest in rabbit control, they need to ensure the cost of control will be offset by the benefits gained through increased pasture biomass and resultant wool production. The end-users of this production land DSS were therefore farmers, but also LLS staff, who are in charge of advising farmers on how to manage rabbits.

It was interesting that the stakeholder requirements matched the outputs of the DSS produced by D. Choquenot, but that the DSS was currently unused by them. This previous DSS had been produced without stakeholder involvement and was available via a CD as a stand-alone platform that could not be updated. Further, the DSS tried to simulate cost-benefits to an entire farm and therefore requested large amounts of inputs from the end-users. With the agreed aims in mind, and following guidelines of ideal DSS end-user tool and development from the literature (along with our TOC approach), we completely re-designed the DSS, while still taking advantage of the seasonal herbivore-resource model developed by Choquenot (1998).

The production land DSS was coded in the freely available R (v3.1.2, R Core Team 2015). A user-friendly and interactive web-based end-tool (front-end) was provided using Shiny (RStudio, Boston, MA). The DSS end-tool simulates scenarios with and without rabbit control and compares estimates in wool production revenue and in changes in rabbit abundance and sheep stocking rates through time, under these alternative scenarios. The scenarios can be adapted by the end user inputs, which are provided using easy to use radio buttons, sliders, and integer entries. The information that can be modified by the end users includes:

#### A. Farm characteristics

1. Size of the area to be assessed (ha)
2. Starting value of pasture biomass within this area (kg DM/ha)
3. Starting rabbit density (rabbits/ha)

#### B. Wool gross margin

1. Shearing month
2. Estimated average fleece weight per stock unit (greasy kg/SU)
3. Wool value (\$/greasy kg)

#### C. Which rabbit control method will be assessed

1. Ground-bait 1080 poison application
2. Fumigation
3. Warren ripping
4. Integrated approach (combining multiple methods)

#### D. Control costs and efficacy

1. Control costs (\$/ha)
2. Expected control effectiveness (%kill)
3. Control interval (yrs)
4. Month when control is applied

Estimates of cost and effectiveness of alternative control methods were obtained through a review of published and grey literature, along with an email survey of people involved in rabbit management operations around the country. These estimates were used to set default values. Additional pre-set values are also available for all other inputs to minimise the input changes required by end-users. The DSS is currently at the prototype testing stage and will be released free online later in 2016. R code will also be made available in an online code depository ([www.bitbucket.org](http://www.bitbucket.org)) to allow future updates beyond the life of this project, and for others to adapt it to their system. The project includes a future evaluation of the use and usefulness of the end-tool to farmers.

## CONCLUSIONS

We developed two DSS to assist land managers (government and farmers) to make informed decisions on where and how to control rabbits. Both DSS were designed to be user-friendly, open-sourced, and, most importantly, able to evolve beyond our involvement, which ensures that they stay relevant and current, and are able to improve as new knowledge becomes available.

The conservation land DSS captured the decision making process used by the vertebrate pest coordinator (as requested), but it also highlighted potential areas for improvement, which were jointly addressed by us (the DSS development team) and the ACT Parks and Services staff (the end-users). End-users had a say at all steps of development and hence have a real sense of ownership of the DSS tool. The DSS makes the prioritising process available to others (especially successors) so the prioritising process is not lost when current staff leave the organisation. The VPC acknowledged that the final list produced by the DSS not only guided where funds should be allocated, but could also be used as a way to highlight potential deficits in funding. Furthermore, the VPC acknowledged that the DSS provides an avenue for them to justify the decisions as coming from a transparent and

repeatable approach that takes into account several needs required for achieving effective rabbit management.

The production land DSS used the model of rabbit dynamics and the relationship between rainfall, pasture production, rabbit density, and wool production developed by Choquenot (1998). However, it was reformulated after discussions with stakeholders to make it more relevant to their wants and needs.

Several rabbit-related DSS had been developed with very little uptake (McGlinchy 2011), so we were cautious about developing additional ones that were also of little value. Consequently, we developed these DSS using a Theory of Change framework recognising that the outputs of the DSS need to be placed within the wider context of rabbit management. This wider context includes all relevant stakeholders and recognises that effective rabbit management requires coordinated actions across a range of stakeholder levels, from individuals to community, through regional and national governments.

We believe that developing a DSS within a TOC framework, and providing both the DSS and the elements of the TOC to the end-user, will improve the usefulness of the DSS. This is because end-users need to see the DSS not as a standalone tool that will achieve all the desired outcomes of effective pest management, but rather as one tool in a wider group of tools that are required to succeed. Further, we propose that the TOC approach facilitate a wider, outcomes-based approach to the evaluation of rabbit management; it should include looking at how the DSS contributes to the range of activities required. This will be done in the next stage of this project. Evaluating the use and usefulness of a DSS within a broader outcomes approach is an integral part of learning how to improve the DSS development process and end-tool.

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