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Participatory Modelling Workshops for Feral Animal Management in Kakadu National Park: May 2010

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1. FOREWARD

A key recommendation of the Kakadu National Park Feral Animal Management Strategy report (Whitehead et al. 2004) was that effective management of feral animals will require park managers to engage with Bininj and involve them in the definition and management of pest animal damage and methods of control. Since the adoption of that broad underpinning strategy in the Kakadu National Park Management Plan 2007-1014 (Director of National Parks 2007), the park has implemented a range of feral animal control programmes with the Traditional Owners that now need to be assessed.

The aim of the project is, therefore, to examine recent feral animal control programs and identify what worked well and what didn't, using a series of participatory modelling workshops involving park staff and Bininj. The workshops were to be conducted using an approach to planning and decision making called "participatory Agent-Based Modelling (ABM)". The modelling framework will be developed together with Bininj in a "bottom-up" approach, where social-economic and cultural values (& processes) are integrated with available biophysical knowledge on feral animals in the park. The results of the workshop were to be used to make recommendations for future feral animal control programs, including a conceptual model for future negotiations between park management and Bininj that will be trialled over a three year period.

Services to be provided by the project team

The project team was to conduct a series of five to six clan-based participatory modelling workshops on feral animal management. Workshops were meant to take place at up to five locations in Kakadu National Parks, with the exact number to be determined by the park. Interspersed with clan-based workshops, the project team was to meet regularly with the Feral Animal Working Group (FAWG) to contribute to the project. The group comprised Bininj, park staff and advisory experts.

2. SUMMARY

A key recommendation of the Kakadu National Park (KNP) Feral Animal Management Strategy report (Whitehead *et al.* 2004; Field *et al.* 2006) is that effective management of feral animals will require park managers to engage with Traditional Owners (Bininj) and involve them in the definition and management of pest animal damage and methods of control. Since the adoption of that broad underpinning strategy in the KNP Management Plan 2007-1014 (Director of National Parks 2007), the park has implemented a range of feral animal control programmes with that now need to be assessed.

Hence, the aim of this project is to examine recent feral animal control programs and identify what worked well and what didn't, using a series of participatory modelling workshops in May 2010 involving park staff and Bininj.

This report summarises the outcomes of those workshops and provides a positive foundation for the future development by Bininj and park staff of a partnership approach to the control of feral animals on KNP.

A Management Strategy Evaluation (MSE) tool (SimFeral) was developed jointly by workshop participants and demonstrated the potential benefits of an interactive approach to resolving conflicting objectives at both park-wide and local scales.

Section 3 (Introduction) provides background context for the project, and Section 2 (Methodology) introduces the concept of participatory Agent-Based Modelling (ABM) used to underpin Adaptive Management and MSE approaches to community-based natural resource management.

Section 5 (Consultative workshops) describes the approach used to elicit the issues and needs of all stakeholder participants in relation to the management of feral animal damage.

Section 6 (Model development) describes the development of the SimFeral agent-based model used in the final participatory workshop (Section 5) in May 2010. This tool integrates all available data, knowledge and stakeholder aspirations so that informed decisions and trade-offs can be made by all participants in the face of uncertainty and tight budgets.

Section 8 outlines in detail the following key recommendations from this project.

- Adopt an overarching MSE operational framework to facilitate the practice of Adaptive Management in relation to feral animal management.
- Jointly develop clear and explicit control objectives and performance criteria as necessary pre-requisites for an MSE approach. This will allow control programs to be continually assessed and improved (i.e. "Best Practice" - learning from both success & failure)..
- Revise and strengthen the current process for engagement with Bininj on feral animal issues. A more effective consultation and engagement process would require co-development of explicit operating guidelines for both park staff and Bininj. We recommend a "rules-based" operating manual based on the conceptual model developed here for future process-driven feral animal control programs, and which is compatible with the participatory ABM platform that employs a rules-based programming language (see

Section 6.2). That is, these operational "rules" can be embedded into the relevant cells of the ABM.

- Resourcing – a comprehensive strategic and operational planning process for feral animal control needs to be urgently implemented and supported by dedicated, adequate and sustained annual budgets that align strategically with the KNP Management Plan 7-year cycle.
- A dedicated full-time staff position is required to manage the Bininj engagement process and all other facets of the control program, particularly data management and knowledge integration that is currently "bottlenecked" due to lack of resourcing.
- A range of staff training needs should be immediately provided, such as (but not limited to): conflict resolution; workshop facilitation, effective communication and 360 degree feedback; database management and basic analysis skills; advanced GIS mapping skills; computer modelling and software visualisation skills; and advanced skills in vertebrate pest population management.
- Further SimFeral model development is needed because the workshop highlighted that two basic scales are required to resolve differences in feral animal control objectives between Bininj and park management. One scale is at the "park-wide" resolution and, hence, the 25km^2 grid cell should be adequate. The other scale needs to be fine enough to help resolve local issues and may require a 1 km^2 grid cell or less. Instead of developing SimFeral at two grid resolutions, we recommend one of the following options: (i) a software engineer is employed to couple the SimFeral model to Google Earth with its zoom-in/zoom-out capability, and with the park GIS; or (ii) SimFeral is transferred to an alternative ABM platform called "Repast-Simphony" (see North *et al.* 2006; North *et al.* 2007), which has the capability to link to GIS including remote sensing captures (with zooming facility) and, apparently, it requires little programming skills. This latter technique will be encompassed in a future Northern NERP project.

In the interim, however, users will be reliant on the Cormas modelling platform to underpin the MSE approach for feral animals, and this would require user skills at two different levels. For proficient use of Cormas during further participatory workshops we recommend that a few key park staff undertake the HEMA (www.hemaconsulting.com.au) five–day course, which includes training in participatory modelling skills. For more advanced model development, such as coding additional and more complex management scenarios, we recommend that Anne Dray (HEMA Consulting Pty Ltd) be retained as an external consultant.

Detailed appendices, A through to G, contain a review of feral animal monitoring and assessment data, a basic "Users Guide" to the SimFeral model and a summary of the relevant sections in the Kakadu National Park Management Plan 2007-2014).

3. INTRODUCTION

3.1 A short history of feral animals in the region

A major landscape-scale risk to areas of high conservation value in northern Australia, such as Kakadu National Park (KNP), is the impact of invasive species (both weeds & feral animals). On a global and national scale they rank equal with habitat loss, over-exploitation and anthropogenic climate change as being the greatest threats to biodiversity (Vitousek *et al.* 1996; Park 2004; Field *et al.* 2006), particularly in KNP, globally recognised for its biodiversity values (IUCN 2000).

The threat from feral animals to park values in isolation is serious enough and well documented (Whitehead *et al.* 2002; Bayliss & Walden 2003; Walden & Nou 2007; Field *et al.* 2006; Bradshaw *et al.* 2007; Petty *et al.* 2007; Jambrecina 2010). However, in combination with other landscape-wide threats such as weeds, unmanaged fire, mining and anthropogenic climate change, the cumulative risks are significantly much higher (Bayliss *et al.* in press). In particular, the future effects of climate change may increase the potential range and abundance of invasive species on the park (Australian Greenhouse Office 2005; Winderlich 2010).

Despite Australia's short period of European settlement, it has a remarkably diverse and abundant feral fauna (Bayliss & Yeomans 1989). The most conspicuous species are those derived from domestic ungulate stock: buffalo (*Bubalus bubalis*); camels (*Camelus dromedarius*); cattle (*Bos Taurus*); donkeys (*Equus asinus*); horses (*Equus caballus*); goats (*Capra hircus*); and pigs (*Sus scrofa*). Although the Alligator Rivers Region (ARR) in the Northern Territory (NT) was remote from the earliest settlements and its human population was small, it was not immune from this invasion. For example, spectacularly successful introductions of buffalo occurred at the NTs' original settlements of Port Essington and Fort Dondas (Letts 1962; Letts 1964; Bayliss & Yeomans 1989), and many species occur (or have occurred) at densities that often exceed abundances in their native ranges (Freeland 1990; Whitehead *et al*. 2002).

Whist Buffalo started to colonise the ARR from Cobourg Peninsula by the 1880s, historical accounts suggest that densities were low until the late 1950s after which populations rapidly increased within a decade to probably what was carrying capacity (Letts 1962; Petty *et al.* 2007). In the 1980s buffalo numbers declined dramatically due to harvesting for the regional pet meat industry and the National BTEC, with evidence of landscape-scale responses to ground cover vegetation and fire regimes Petty *et al.* (2007). Concomitant with the massive and sudden reduction in buffalo numbers was an explosion of pig numbers in the ARR (Fig. 1), suggesting that a strong competitive interaction may exist between the two species (Bayliss *et al.* 2006). This ecological interaction provides the current ecological setting, whereby the "pest status" of the two species has reversed since the mid-1980s. The environmental and cultural damage caused by pigs, and possibly unmanaged horses, are currently key threats to World Heritage and Ramsar park values (Whitehead *et al.* 2002; Bayliss & Walden 2003; Jambrecina 2010).

In addition to the above complex ecological interaction between two key pest species, the following three "human" factors combine to set the overall scene for the management of feral ungulates on KNP:

The underlying assumption of most pest control programs is that a reduction in pest density will result in a concomitant reduction in pest "damage". Hence, by default, the control objective usually becomes density reduction rather than damage mitigation (or some other index of derived "benefit"). However, Hone (1994) reviewed the literature for explicit damage-density relationships and found that it was demonstrated in only about half the studies, suggesting more complex relationships may exist. Needless to say, without clear control targets or objectives that are inextricably linked to pest damage, there is no way of measuring the performance of the control program and, hence, optimising or even justifying control costs. Caughley (1977) described this sort of approach as "idiotic culling", as exemplified by the history of deer control in New Zealand (Caughley 1983).

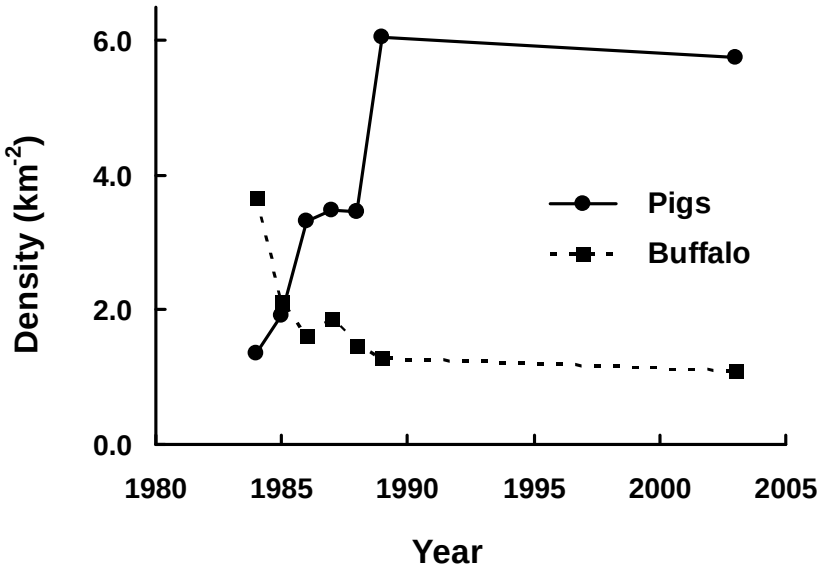


Figure 1 Trends in buffalo and pig density (1985-2003) on Kakadu National Park (after Bayliss *et al.* 2006).

Whilst feral animal management on conservation areas is often based on the proposition that introduced species threaten ecological values, that view is not necessarily shared by all stakeholders, including some Indigenous people who own and co-manage KNP (Robinson *et al*. 2005). A key issue that emerged in early consultations with Bininj is the importance of understanding the different values that Indigenous people attribute to feral animals, their perceptions of feral animal impacts, and the degree of convergence of these views with other park values (Robinson *et al*. 2005). The existence of complex multiple objectives that often conflict will inevitably involve making difficult tradeoffs.

The effort and associated costs to remove the last few remaining animals, in combination with immigration from surrounding uncontrolled areas, means that eradication or control to very low densities is prohibitive (see Figs. 17 a & b; Choquenot and Hone 2000). There has been no

successful program to eradicate a well-established mainland population of vertebrate pests in the world (Whitehead *et al.* 2002).

Hence, managing complex cultural/social-ecological systems such as feral animals on Kakadu will always be a very difficult task. Park managers want good environmental outcomes at least cost, but also need to include Bininj values and aspirations as an obligation of co-management, and all in the face of knowledge uncertainty and limited budgets.

3.2 Feral animal control strategy & recent control programs

As historical background to the present consultancy this section provides an overview of: (i) the co-management governance structure on KNP in relation to strategic planning and operational decision making by park managers and Bininj; (ii) the relevant sections of the Kakadu National Park Plan of Management (2007-2014) in relation to feral animal management; (iii) recommendations found in the consultancy report by Charles Darwin University consultants (Field *et al.* 2006; Feral Animals in Kakadu National Park: A Management Strategy for the Future); and (iv) an examination of recent control programs as elicited from the workshops.

3.2.1 Co-management governance structure on Kadadu National Park

Kakadu National Park is listed as a World Heritage park because of its outstanding natural and cultural values (IUCN 2000). Robinson *et al.* 2005 and Field *et al.* (2007) provide summaries of the hierarchical co-management governance structure on KNP that are relevant to feral animal management, outlined below.

The park is governed under the Commonwealth Environmental Protection and Biodiversity Conservation Act 1999 (EPBC 1999), and jointly managed by the Director of National Parks and the Kakadu National Park Board of Management. Land on Kakadu owned by Traditional Aboriginal Owners (Bininj) is leased to the Director for the purposes of a national park. Under the terms of the lease and the legislation, the Board of Management is primarily responsible for drafting the Park's Plan of Management and making important decisions on its implementation, such as feral animal control. The Board of Managements' (BoM) Indigenous majority allows for strong representation of the views of Bininj in important decision-making processes, particularly in framing general principles of the management plan. The Director is assisted by Parks Australia staff, now a part of the new Commonwealth Department of Sustainability, Environment, Water, Population and Community (DSEWPaC). Parks Australia manages daily operations of the Park in consultation with Bininj.

However, whilst the Kakadu Board may make decisions that are consistent with the KNP Plan of Management (Director of National Parks 2007), under customary law and practice Indigenous members of the Board are reluctant to make decisions that directly affect the rights and obligations of other Bininj on their country (Field *et al.* 2006). Hence, the Board is constrained in making detailed operational decisions that specify how feral animals should be managed locally across the Park.

The Park Manager is responsible for implementing the KNP Plan of Management under directions from the Board and the Director. The Park Manager is therefore responsible for the implementation and performance of feral animal control programs, and for regularly reporting progress to the Board. Field *et al.* (2006) highlight that, because feral animals are controlled to mitigate damage to natural and cultural values, the Park Manager is also primarily responsible for reporting on damage mitigation. At the next level down the five Districts are responsible for the local management of park regions, and is where detailed interactions with Bininj in relation to feral animal management is expected to occur, particularly in relation to the definition and monitoring of damage.

Irrespective of the above governance structures outlining the chain of responsibilities, Field *et al.* (2006) argued that the most effective strategy for the park would be through the creation of a dedicated feral animal management team that is similar in purpose and structure to the Weed Management Teams. They argued also that, whilst such teams should provide a more efficient Park-wide approach to feral animal control, it will also facilitate Bininj engagement through Country-Based Decision Making (CBDM) programs.

Pahl-Wostl (2009) suggested that governance failures are at the heart of many resource management problems. She argued that climate change and the concomitant increase in extreme weather events in particular has already exposed the inability of current governance regimes to deal with present and future change. She argued also that our knowledge about resource governance regimes and how they change is limited. This may also be true in the context of feral animal management on KNP because we understand little about the nature of multi-level cross-cultural interactions and the relative importance of bureaucratic hierarchies. In short we lack basic knowledge on the adaptive capacity, and hence ability, of the existing governance systems on KNP to solve complex socio-ecological issues such as feral animal management, which is characteristically dynamic and uncertain.

3.2.2 Kakadu National Park plan of management

Kakadu National Park is currently operating under its 5th Plan of Management, which covers the period 2007-2014. The new plan aims to conserve natural and cultural values, 'whilst protecting the interests of the park's traditional owners and providing for safe and enriching experiences for visitors.'

The KNP Management Plan is required to take account of the interests of Traditional Owners and other relevant Aboriginal people as identified under Section 368 of the EPBC Act. This is reflected in one of the four vision statements of Kakadu National Park: that the Park is recognised internationally as a World Heritage area where: 'Bininj guide and are involved in all aspects of managing the Park'

The guiding principles for the management of Kakadu National Park, as identified in the Plan, are also informative in shaping the development of a feral animal management and control strategy.

They are, that:

- Culture, country, sacred places and customary law are one, extend beyond the boundaries of Kakadu, and need to be protected and respected;
- Bininj and Balanda keep joint management strong by working together, sharing decision making, learning from and respecting each other;
- Young Bininj have opportunities to learn about culture and country;
- Bininj and Park management share obligations to look after the natural and cultural values of the Park;
- Tourism is developed at a pace and level determined by Bininj, and strong partnerships are maintained with the tourism industry, and
- Visitors are provided with opportunities for safe, enriching and memorable experiences.

The Plan also states that: 'To ensure that effective control programs are in place (to manage feral and domestic animals), there is a need for a strategic integrated regional approach. Control programs need to consider:

- How the priority of protecting the Park's natural and cultural values can be achieved while respecting the range of values that Bininj place on some introduced animals;
- The range of habitats, differing sensitivities to disturbance, susceptibility to weed invasion, and feral animal populations in adjoining country;
- What levels of damage to country caused by feral animals are seen as unacceptable to Bininj and Park staff;
- Analysis and implementation of each control operation in close consultation with Bininj from the different clan estates (p80).'

Appendix E more comprehensively identifies the approach to feral animal management taken in the current Kakadu Plan of Management (Director of National Parks 2007).

The Plan identifies that 'monitoring programs will be directed at indicator species identified in regard to major threats and management issues such as fire, weeds and feral animals', although no such monitoring programs have been implemented to date.

Such monitoring would appear particularly important in measuring how well the Park is achieving its aims in feral animal control and management. The overall aim of the Plan being:

'Through control programs developed and implemented in consultation with Bininj, the adverse effects of domestic and feral animals on the natural and cultural values of the Park, and on human safety, are minimised.'

The Park has identified in the Plan of Management that they will measure their success according to the:

- Extent to which **values** within identified management areas have recovered from feral animal impacts, and
- Bininj satisfaction with their level of involvement in the planning and management of feral animal programs.

Again, in the absence of clear programs for monitoring and evaluation, the Park is currently not able to measure success against their aims. As a first step toward developing monitoring and evaluation programs, there is a need to identify some of the values that could be used as indicators when measuring recovery from feral animal impact.

3.2.3 Kakadu National Park Animal Control Strategy Report (CDU)

Charles Darwin University (CDU) was contracted in 2002 to develop a strategic management plan for feral animals on KNP. In the early years the main research focus was on the importance of understanding the different values that Indigenous people attribute to feral animals and perceptions of their impacts (Whitehead *et al*. 2002; Robinson and Whitehead 2002; Robinson *et al*. 2005). In the latter years the main research focus switched to Excel spreadsheet modelling of feral animal density reductions (see STAR in Field *et al.* 2006; McMahon *et al.* 2010).

The report 'Feral Animals in Kakadu National Park: A Management Strategy for the Future' (Field *et al.* 2006) contains recommendations to park managers in the "design and implementation of effective and sustainable feral animal control programmes within an adaptive management framework". The report is divided into the following three main sections: (i) a review of current and potential threats (Chapter 1); (ii) spatial modelling of feral animal density reduction (Chapter 2); and (iii) Management framework and implementation (Chapter 3).

Whilst Chapter 3 explores the complex problems associated with feral animal management within a cross-cultural setting, and provides an adaptive management strategy framework as a solution, no operational guidelines are provided although the accompanying text shows that this was the intention. The report states that the priority-setting advice of Chapter 1 should be used as a starting point for action, action that is based on their 7-step Feral Animal Management (FAM) strategy and, which draws on the Country-Based Decision-Making tool (CBDM). With respect to the latter action statement Field *et al.* (2006) recommended strongly that Bininj be engaged to monitor the performance of control programs as part of a "caring for country" land management program (CBDM) similar to those successfully implement on Aboriginal land across Australia. Unfortunately, their detailed recommendations to establish a CBDM program for feral animal management on KNP have not been tabled in their final report (see their Appendix D with 62 blank pages in a 337 page report!). The conspicuous absence of critical details and linkages to Bininj values and perceptions of feral animal damage in the Field *et al.* (2006) report is surprising given the resources devoted to this component of their consultancy in the early stages. Nevertheless, they make well considered and practical recommendations to better engage Bininj in feral animal control on KNP, given that under the joint management agreement it is a shared responsibility. For example:

There can be few more fundamental interests and related decisions than those concerning the values that require protection, the levels of change in values that are acceptable, and the resources that should be invested in mitigating change. However, there is presently no clear statement of the values important to Traditional Aboriginal Owners that might be affected by feral animals or how far they are prepared to trade off other values or investments to manage

the impacts of the feral animals. This is why such emphasis has been placed on sound processes of negotiation through the CDBM (as detailed above and in Appendix D).

Whilst the participatory-Indigenous values component of the research was always meant to be fully integrated with the development of population modelling tools, this unfortunately never happened and, needs an independent review to ensure that we learn from this apparent failure.

3.2.4 Examination of recent feral animal programs

Feral animal management that has been undertaken most recently in the Park occurred as a response to a discrete funding event that was not underpinned by strategic planning or program development. The most recent funding came from a discretionary pool not specifically allocated in the budget to feral animal control. This is not the most effective way in which to implement a program of control, but staff interpreted the funding as a 'start-up' bucket of money that would precede more funding for further feral animal control work. The staff appeared keen to make as much impact to feral animal numbers as possible, and to respond relatively quickly to the unexpected opportunity.

The Park decided to spend the majority of their resources on a significant aerial shoot, undertaking two weeks of aerial shoots focusing on the north and east of the Park, and predominantly targeting pigs. These aerial shoots are viewed as being successful by the Park.

The participatory workshops raised some discussion about recent feral animal management and the following comments are informative in revealing the current situation in regards to feral animal management in the Park:

- The last shoot they did was over 14 days -2 weeks on weekdays. Two shoots per year is best as you can target the pigs in June/July when the floodplains are drying up but the pigs haven't yet started to created lots of damage, and then again at the end of the year when pigs are congregating around water holes – but before the first rains as the pigs scatter. The timing of control is important, which needs to be considered in sourcing and securing funding
- They can get 400 pigs per day from the chopper. On a really good day (at the right time of year and in the right place) they could get 90 pigs operating from the ground. Most of the pigs are found on the floodplain margins in the north of the Park
- Weed control work seems to be the priority, and receives the funding for aerial work (ID and plotting distribution etc). The ferals group use this airtime to also check out where the heavy concentrations of feral animals are.
- The ferals group records ground disturbance where possible – wallows, fire-scars, pig damage. The quality of this information, along with the feral counts depends heavily on the skills of the spotter or other people in the chopper
- Most important, Park staff have been operating programs according to annual funding cycles; there are not enough resources and the timeframes for resourcing are inadequate.

4. METHODOLOGY

4.1 Adaptive Management & Management Strategy Evaluation (MSE)

Managing any complex socio-ecological system such as co-managed KNP is a very difficult task and cannot be underestimated (Gunderson *et al*. 2008; de la Mare 2006; Stepp *et al*. 2003; Costanza *et al*. 1993). For example, parks want good environmental outcomes at the least cost and, at the same time, there is an obligation to be inclusive of all stakeholder interests and needs. Hence, there are complex and often conflicting objectives, particularly when we consider cultural, social, political and economic objectives. Some objectives can be vague or difficult to measure (e.g. we want to protect KNP from invasive species), and multiple stakeholder groups will often have different mandates. An additional challenge is that more often that not we have incomplete and variable information. Hence, managers are often required to achieve high level goals in the face of uncertainty and limited resources.

The Adaptive Management (AM) framework helps us understand 'where we are' and 'where we want to be' with respect to the system we want to manage and, whilst few would disagree that it's the solution, it does not come with guidelines about how to make the approach operational. Figure 2a is a representation of the AM cycle in a very popular form. However, taken at face value, it begs quite a few questions (de la Mare pers. comm.):

- What is the management meant to achieve?
- How do we measure progress?
- How fast do we have to go around the loop?
- How much do we need to understand?
- What do we need to learn and how can we go about it?

Figure 2b is another version of AM called "Management Strategy Evaluation" (MSE). In terms of making AM principles operational it's a major advance. Now we have objectives, targets and performance indicators linked to decision making by managers. This operational framework for the management of a natural resource was originally designed to assess alternative fisheries management regimes in the face of uncertainty (see Fig. 2c adapted to feral animal management on KNP; de la Mare 2005; Punt 2001; Sainsbury 2000; Smith 1994), but has also been used in the coastal zone (McDonald 2006). In the context of fisheries management, Gavaris (2009) defines management planning as a hierarchical process that translates objectives to strategies ('what' will be done), and strategies to tactics ('how' it will be done"), and we use those definitions here. By his "control systems" definition a strategy specifies also what will be done.

With this more applied view we are now focussing on comparing outcomes with objectives, in essence a negative feedback system. Feedback systems in the engineering world need to be designed and, hence, MSE is a design system for Adaptive Management. Put another way it's a "flight simulator" for natural resource managers (Meadows 2007), as not everything we need to learn has to take place in the real world. MSE uses computer simulation models to assess the

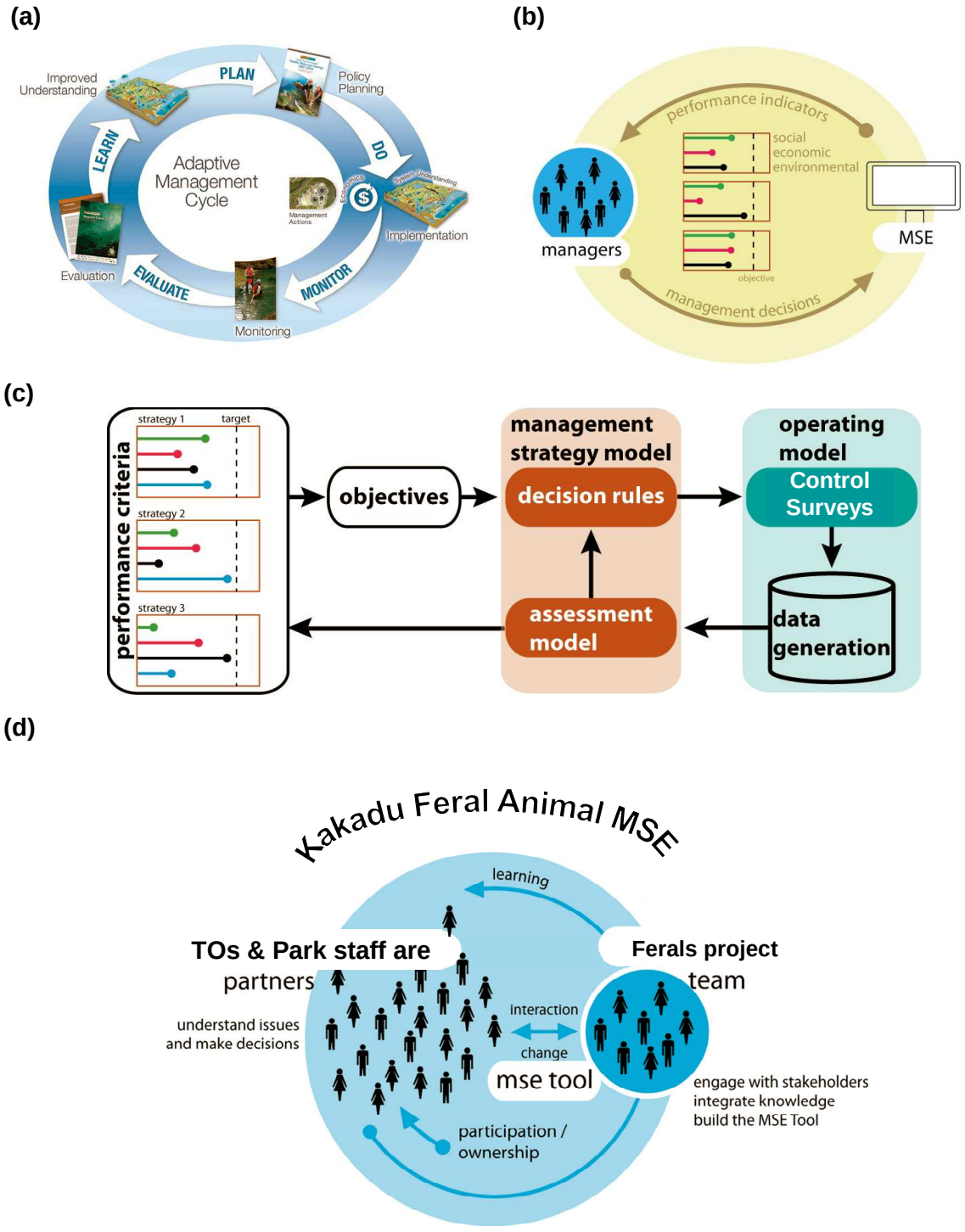


Figure 2a-d (a) Adaptive Management Cycle (South East Queensland Healthy Waterways Partnership 2010; (b) Adaptive Management approach incorporating a Management Strategy Evaluation (MSE) framework; (c) Traditional operational MSE framework developed for fisheries based on Kell et al. (2007) and Dichmont et al. (2006), modified for feral animal management on Kakadu; and (d) the adopted MSE approach whereby the MSE Tool (SimFeral) is used to mediate interactions between the project team and stakeholders (Bininj & Park staff, modified from Dutra et al. 2010).

consequences of a range of management strategies, presenting the results as a set of trade-offs in the performance measures of selected indicators across a range of management objectives

(Dutra *et al.* 2010; Smith 1994). The evaluation of management strategies is made against user-orientated and resource-orientated objectives that are set by managers, but which also needs to account for stakeholder views and needs (Butterworth 2010).

A management strategy is characterised as a set of rules that transform the results of an assessment into explicit management actions, thereby closing the AM loop (Fig. 2a). MSE basically adopts control system principles (de la Mare 2006) and so requires the representation of two coupled systems to assess management strategies; the natural system and the management system. The natural system is represented by an operating model that essentially simulates the world to be managed. The operating model represents plausible hypotheses about the world and is intended to test the robustness of management strategies to what we don't know and cannot control, and to what we do know and can control. The management system is represented by the management model, which includes an assessment model to derive estimates of performance measures from simulated observations. Based on outputs from the assessment model, the management model decides what management actions to implement (Kell 2007; Dichmont 2006). However, the MSE approach is not without criticism. Whilst Rochet and Rice (2009) suggested that a simulation-based MSE approach is, without question, a significant step forward in fisheries management because it provides a tool to help make the precautionary approach operational, it can sometimes be ignorance disguised as mathematics.

Whilst the MSE simulation approach was originally developed by fisheries scientists for testing the effectiveness of proposed management plans and their robustness in meeting objectives under a wide range of uncertainties, it now has application to terrestrial conservation issues (Milner-Gulland *et al.* 2010). In contrast to standard fisheries MSEs, however, we used participatory methods to engage with stakeholders at the outset in order to integrate cultural knowledge and to develop the specifications of the computer simulation model (SimFeral), ensuring ownership and control. Stakeholder perceptions and expectations about the MSE tool were hopefully kept at realistic levels (i.e. it is NOT a highly predictive tool under all circumstances, but a tool to help communicate & resolve differences). There has been much investment in developing highly predictive population models to help design management actions at any given time, and these need to be the best available. Whilst MSE is complementary to this approach, its main purpose is to help us decide whether or not we have an AM system that can provide us with enough information to track if our management actions are having the expected effect. If so the AM system has the ability to implement a course correction to reach our objective.

In summary MSE helps you (de la Mare pers. comm.):

- Try before you buy (i.e. choose an expensive management option)
- Make your mistakes quickly and without adverse consequences (it's safe)
- Check whether your objectives are reachable, at what cost, and when you might get there
- Collaborate with other stakeholders as partners
- Make trade-off between multiple objectives
- Design monitoring strategies and evaluate assessment methods (what to measure, how often & where?)

- Identify the critical knowledge gaps
- Design around inevitable structural uncertainties

4.2 Participatory modelling with Agent-Based Models (ABM)

Use of simulation models in collaborative decision-making for the management of natural resources is one of the characteristics of adaptive management (Etienne *et al.* 2008; Holling 1978; Walters 1986). In contrast, the use of models to stimulate the participation of stakeholders in the definition and development of management scenarios is rare (Etienne *et al.* 2008 citing Costanza and Ruth 1998 and Bousquet *et al.* 2002). Etienne *et al.* 2008 argued also that any progressive shift from management plans based on an institutional command-control model towards tools for mediation based on participatory democratic approaches (e.g. as advocated by Van den Belt 2004), will require the development of new tools of co-construction and sharing of information and understanding.

Le Page and Bommel (2005) argued that Agent-based models (ABMs) are particularly well suited to represent ecosystems where contrasting human activities compete for the use of natural resources in space. They define an agent as a virtual entity, a computer component, such as a software (program) or a hardware (robot), that is driven by individual objectives, capable of perceiving its surrounding environment and capable of acting on its environment, and that can also communicate directly with other agents. Hence, park managers and Bininj can be represented as agents in the socio-ecological landscape, along with feral animals and other classes of human and environmental attributes. Individual-based models are a class of ABMs and had their origins in rules-based cellular automaton. The dynamical behaviour of agents is subject to rules that are determined by other interacting agents and the environmental properties of each cell and its neighbours. Many recent studies have emerged that demonstrates the power of a participatory modelling approach using ABMs (Bousquet *et al.* 2007; Dray *et al.* 2006; Becu *et al.* 2005; Bousquet *et al*. 2005; Promburom and Bommel 2005; Bousquet and Le Page 2005; Bousquet *et al.* 2001).

Montes de Oca Munguia *et al.* (2009) advocated the use of an Agent-Based Model (ABM) to represent Māori cultural values and is directly relevant to this project. He states that cultural values are integral to indigenous Maori culture in New Zealand and are pivotal to guiding a person's preferences and priorities. In particular, Maori cultural values reflect the strong relationship *tangata whenua* (people of the land) have with country. As has happened in Australia and in other places where Indigenous people manage their own country, a large amount of information and knowledge has been recorded onto GIS such that it now has become an important NRM planning tool involving cultural projects (e.g. recording cultural values, sacred sites & key foraging areas). Concomitantly, agent-based simulation modelling (ABM) has been increasingly used to help understand the complex interactions between coupled human and natural systems. Combined with a GIS and a participatory modelling process, ABMs have provided a powerful and spatially explicit planning and decision making tool for Indigenous communities (Montes de Oca Munguia *et al.* 2009). In particular, they may help bridge the gap between the two knowledge domains (western science & Indigenous ecological knowledge), and help facilitate tradeoffs between conflicting NRM goals.

Nevertheless, in a review of the role of computer modelling in participatory integrated assessments, Siebenhqner and Barth (2005) found that models played a mixed role in informing participants and stimulating discussions, primarily because no deeper reflection on values and belief systems could be achieved. They argued that, in terms of the risk management phases of an AM approach, computer models best serve the purposes of problem definition and option (MSE) assessment within participatory integrated assessment processes. Needless to say, the purpose of the participatory modelling approached used in this consultancy was exactly this, not to convert stakeholders from one belief system to another.

5. PARTICIPATORY WORKSHOPS

Participatory workshops were held in various locations in Kakadu National Park between the 11th and 22nd May 2010 with the purpose of engaging Bininj and Park staff in a discussion about feral animals. The requirements of the consultancy determined that the project team was to conduct a series of five to six clan-based participatory modelling workshops on feral animal management. Workshops were meant to take place at up to five locations in KNP, with the exact number to be determined by the Park.

Two workshops were held at Park Headquarters, the first targeting the Park's Feral Animal Working Group, although the workshop became a discussion with predominantly the Park's feral animal management operations team, and the second was an Open Meeting for all interested Bininj. Further workshops were held at the Mary River District Ranger Station, Jim Jim District Ranger Station and the East Alligator Ranger Station. The workshops were promoted through posters (see Appendix F), by Park staff and through word of mouth. On request by Gundjehmi Aboriginal Corporation, the Park arranged a meeting with the consultancy team at their offices in Jabiru. On request, the team also met with members of the Gagudju Association at Cooinda, where the purpose of the workshops was briefly discussed. Limited discussion about feral animal management occurred at this meeting and as such is not documented here.

5.1 Methodology

Drawing on previous reports and research the consultancy team was prepared for a range of opinions and differing, sometimes conflicting, values held by Bininj and Park staff about feral animals and their management in the Park. In order to move away from a point of conflict, the team initially focused participants' attention on identifying, on maps, those values that were important to them within their clan boundaries, or in the case of Park staff within District or Park boundaries.

Participants identified many sites within the Park that hold importance based on a range of both use and non-use values which are briefly outlined in Section 5.9.1.

Participants were then asked to identify any concerns people held for protecting those values. These concerns were discussed as a group and summarised on butchers' paper in full view of all present. Once all of the concerns were raised, those that received the most attention across

the group, and that were most relevant to feral animal management, were focussed on, with the audience asked to provide potential solutions or a way forward in dealing with identified issues.

The following sections focus on the key issues or concerns that were raised by participants at each of the workshops. The issues have been grouped under sub-headings and include concerns raised about threats that might impact upon or influence the management of feral animals within the Park. The editing or rewording of comments has deliberately been minimised, and addition information has been inserted in italics.

5.2 Workshop I: Park Headquarters 11 May 2010

The first workshop, held at Park Headquarters was aimed at Park staff involved in feral animal management. The following people were present: Natasha Nadji, Calvin Murakami, David Brown, Fred Hunter, Charlie Whittaker, Steve Winderlich, Mim Jambrecina, Mary Bligh, Ben Tyler, Andy Davies, Pascal Perez, Peter Bayliss and Emma Woodward.

The following issues that related to feral animal control were highlighted by Park staff.

5.2.1 Resourcing

- 'Perhaps money wasn't used as well as it should have' for feral animal control in the past
- Not enough air time for feral animal shoots – Expensive and resource intensive as rangers are borrows from Districts and the District Manager might have to cover that person
- Recording sightings and successful shoots – makes aerial shooting more expensive as you need to have the choppers with more seats *to accommodate the record keepers* – but also good as the shooters don't waste their time recording when they could be shooting
- Quality of data being collected about ferals damage (and shoot counts) highly dependent on the experience of the observer. Also – a qualified spotter can have a significant impact on shoot success as they can direct the shoot toward areas where it is thought ferals are – based on observations – for example sightings of specific birds known to hang around where pigs are
- Issue with shooters being chosen by Traditional Owners – it is thought by Park staff that these shooters are chosen because they are sympathetic to these specific TO groups and won't shoot certain species or will leave a group of pigs with the idea of coming back later on the ground and shooting them for food
- Some data isn't kept about feral control in some areas so as not to draw attention to the culls there. Although agreements have been reached between TOs and Park Staff about controlling ferals in priority areas – such as around mimosa plots – there is a strong concern that TOs will change their mind…the result being that data is being skewed by a perceived need to take a 'softly' approach with TOs
- Much more time efficient with aerial shoots over ground shoots – 400 pigs per day vs. 90 pigs
- Timing for aerial control is crucial – so notifications and consultations must be timely

- Weed control work seems to receive higher priority and receives the funding for aerial work (ID and plotting distribution). *The team takes the opportunity to note where the heavy distributions of ferals are when they are in the air*

5.2.2 Neighbours and a regional management approach

- The Park worked with TO groups and the Mount Bundy Defence Training area to identify a 10km buffer zone within which all ferals could be removed. This worked well until the pet meating contractor from the south of the park sidelined the process by contacting a TO - said they would pay per head for the TOs ferals – even though they don't have the capacity to reduce ferals in this area – and they are not targeting all ferals
- Contract for the pet meater needs to be renegotiated
- Issue with non-regional approach to management – e.g. pigs running over the boundary into Carmor Plains when Park staff were shooting the north-western corner of the Park, before heading back when the Safari operation starts up next door – although no data on numbers moving across borders (regional distributions of ferals – e.g moving from Arnhem Land and the plateau, and from the south and west).
- Issue with contractors not fulfilling the role of feral controller – but 'farming' animals to breed them up for pet-meating business. Parks staff – think 6oo horses per year very low – and sceptical whether the business is even taking their quota. Inefficient – could get 600 horses by air in a day. Contractors should operate under strict conditions - all agreements and negotiations to operate through Park processes. Reduce opportunity for them to play off TOs against the Park.
- Put contract out to tender – 2 year period in which the contractor can take as many animals as they can – needs to be an incentive to reduce the feral numbers and not just pick and choose and have limited effect
- Contractors – what are the obligations in their contracts and how are they being managed?
- Think that if the TOs could see the extent/degree of damage that ferals were causing then they would be more open to feral control. The thought that many TOs hadn't been on those areas of country that are most damaged for some time – so are unaware of the 'damage' ferals are causing
- Evidence of benefits of feral control – the regeneration of vegetation after the BTEC campaign. Noted that it would be interesting to get some history to perhaps assist in communicating feral animal impacts with TOs
- General consensus that pigs are the number one nuisance feral
- 'In an ideal situation the feral control team would have 6 weeks, twice a year in the chopper undertaking only feral animal management across the Park in all areas'. Once during May and June to get as many pigs as possible before they start digging and again in November or as late as possible before the rains of the Wet Season when the ferals are congregating around water holes

5.2.3 Poaching

- Management is currently reactive, disrupted. No ability to plan. Are they annual funding arrangements? Need 5-10 year arrangements
- Understand TOs want to keep some ferals near their properties to hunt. 'But not 20km radius'
- "We're not going to kill everything, that's impossible, so they'll always be there. People don't seem to understand that' (The model can show that to people – population recovery each year is high)

A key site for discussion was the Yellow Water area. Yellow Water is a major tourist site as well as supporting a high numbers of ferals, particularly horses. This is a very contentious area for management but there needs to be an agreement reached about management.

5.2.4 Management structures

- The Districts are acting as silos - like independent management units

5.2.5 Communications

- Parks avoids conflict - there is a role for dynamic role-playing. Get people skilled at facing and dealing with conflict. About dealing with partners and stakeholders, not just other Park staff members (which seems to be the current focus in training opportunities
- 'need to get all staff together for a staff meeting and be proactive in communication - get in before the rumour mill starts'. There should be greater focus on conflict resolution and negotiation skills training for staff – for many of the staff that undertakes consultations, this is their core business and they need simple methods for engagement.

5.3 Workshop II: Mary River Ranger Station 13th May 2010

The meeting at Mary River District Ranger Station drew together the following people: Rob Markham, Joe Markham, Rob Muller, Roy, Steve Winderlich, Mim Jambrecina, Andy Davies, Mary Blyth, Ben Tyler, Pascal Perez, Peter Bayliss and Emma Woodward.

Those present at the Mary River Workshop spent a considerable amount of time identifying, on maps, important area and changes they had noticed over time. The group spoke of the key tourist sites in the south of the Park and how TOs go there when they know no tourists will be there. There are numerous important rock art sites distributed throughout the rock country with some sites also regarded as sacred. A lot of the south of the Park is known as sickness Country, so people tend to opportunistically hunt from the road rather than spend a lot of time there.

There is a history of degradation from feral animals in the south of the Park, with damage having accumulated over the past 50 years. There is widespread erosion and loss of vegetation in this area, with some hardened pads the size of football fields. Gimbat was an active pastoral station until the southern area was included in Kakadu National Park in 1986.

The group felt that it is difficult to be accurate as to the extent of feral animal-related damage and whether it is increasing or decreasing in areas as there is no ongoing feral animal monitoring program.

The group were particularly interested in discussing the following issues:

5.3.1 Damage to springs and soaks

- There are a lot of springs throughout the south, and together with soaks, these sites are 'knocked around by animals during the dry season'. This damage can only be seen from the ground as they are small but important areas under tree cover. Important vegetation is associated with soaks, and ferns and animals are frequently trampled by ferals.
- Soaks and springs seemed to be getting damaged by pigs, horses and a few buffalo while waterholes were suffering from pig and buffalo damage at the end of the dry season.

5.3.2 Feral animal control

Pigs

- Controlling pigs (and to some extent buffalo) is a very important issue in the rocky country. Fouled or contaminated water prevents further water use is a water scarce country during the dry season. Algae will grow in springs once the buffalo get in and then you can't drink.
- Fencing off soaks and springs isn't a solution as native animals can't access resources. It is better that you get rid of what pigs you can at a particular site, even if you can't get them all, as having only 2 pigs is better than 15 or so
- In regards to controlling pig populations 'what we can do on the ground is inconsequential' (Mary River Park staff), need a big aerial shoot combined with baiting

Horses

- A contractor is currently shooting horses, as well as a few buffalo and donkeys, along the highway within a 5km buffer in the south of the Park – however not enough evidence to assess whether his current capacity is sufficient to control population

Donkeys

- Everyone agreed that donkey numbers are increasing in the south of the Park. Donkeys are an issue because they will chomp into woody vegetation and brows the trees, whereas horses will graze 'Donkeys also have the habit of standing in the road'

Cattle (red skin)

- TOs spoken to in the south of the Park do not want red skin cattle shot, as they feel that the numbers are limited in the Mary River District due to high interest in them as a food source

with ‘poaching occurring from Aboriginal people outside the Park’. However, sick or injured animals should be managed.

Buffalo

- Discussion about buffalo removal was complex. If buffalo are seen in sickness Country it is fine for them to be shot from the air, as no one can go into this area and utilise the resource
- In ground-accessible areas the buffalo should be left for the local rangers and the contractor to manage, unless the buffalo is creating a safety issue for tourists or locals. Where safety is threatened a ‘common understanding’ prevails whereby rangers control ferals as necessary and feedback this information to TOs afterwards.

Other ferals

- Other ferals that were mentioned briefly include feral bees, black rats, cats, dingo-domestic cross breeds. It was queried whether feral cats are the cause of small mammal decline (black-footed tree rats have disappeared form around the ranger station), while bees are an issue as they hassle birds around small soaks and compete for nesting space in hollow trees. Wild goats and deer were also briefly mentioned as requiring management.

5.3.3 Safety in the Park

A key concern of all present was the safety of tourists in the Park and their interaction with feral animals. Tourists have been bitten and kicked by horses and charged at by buffalo on the Jatbula Trail. Ferals wandering on the roads was discussed as a safety issue for everyone. ‘Bininj have been killed by ferals on the road, and are also a risk for tourists and others in the Park’.

At this meeting HQ Park staff attempted to seek confirmation from the group that if there was a feral animal threatening people, could they could go ahead and kill it and not have to seek permission from the TO first, even if that animal is valued for meat? The response from TOs was that if someone was in danger and something had to be done straight away, then it was reasonable to shoot the animal. However this understanding should extend only to common visitation sites and not a place like Dinner Creek that’s not a commonly used area. ‘It’s still good to consult, except if it’s urgent and time doesn’t allow for it’.

5.3.4 Ferals as a valued food source

While pigs, donkeys and horses are not eaten in the south of the Park, the red skin cattle (‘red meat’) are seen as a favoured food source and are preferred over buffalo.
The group definitely wants to keep the red skin cattle for hunting in the key hunting areas and perhaps elsewhere. ‘There is hunting pressure on red skin because everyone wants a cow…they come from Jabiru and Pine Creek (*to hunt*)’. *This hunting activity in the south of the Park is seen as illegal by local TOs even though it is likely there are family connections with the ‘poachers’*

5.3.5 Meat provided to communities from aerial shooting

The idea of providing some meat to communities after a big aerial shoot was considered by everyone at the meeting, and discussed as an idea worth pursuing.

- ‘When it’s practicable I think there’s some benefits’
- ‘If you drop the animal off on the way to do a fuel stop or something it might be feasible’ Making meat available can influence the way people feel about future shoots.
- ‘Slinging dead animals is probably a poor solution in terms of cost efficiency but it has a huge psychological impact’. ‘People would want red skin and not buffalo if you are going to make the effort to sling animals’
- ‘If there is information coming back from the shoot that they got heaps of red skin and none has come back to the communities then people will get pissed off’. ‘Community people should be notified so they can get the meat that is close to the roadside, easily accessible’.
- It could be a good negotiating point; organise meat for people and they let the aerial shoots go ahead. ‘One or two animals per community could be a reasonable gesture to change people’s perception of a control program’
- It was suggested that the term ‘cull’ should not be used in future, it should be ‘control and manage’. There needs to be better communication to let people know that it’s not eradication, and that some animals will be left.

There was also discussion about the role TOs could play in going up in the air with the shooters. One argument is that weight in the chopper is a crucial factor, and that heavy TOs will exclude shooters from getting in the air. The other argument is that weather plays a large role in the handling of the aircraft and that when it is cooler and less humid the chopper can take more weight –and therefore TOs. A suggestion was made that TOs should be trained as observers and shooters so that they can make decisions about what can be left (not shot) on the day.

5.3.6 Poaching

Poaching was also mentioned by this group as being a problem in the western part of the Park. ‘Piggers lose their dogs, spread weeds, light fires and you don’t know where or when they’re around’ creating a safety issue for TOs being on Country. There was a concern that they might be shooting other animals, not just pigs.

There was a discussion with Park staff about how the poachers could be controlled. There are plans underway but: they have a huge area to patrol with limited resources; poachers are hard to spot and catch by definition. Zero-tolerance isn’t the objective and the Park will focus on obvious presence as a deterrent.

Some other ideas to address the issue were:

- To establish a hunting permit system for invitees of TOs, as the current legal situation doesn’t make any distinction between poachers and invitees – hunting is illegal

- Take away the incentive to hunt by making a more concerted effort to clear the western boundary of pigs and also make new rules/legislation about the types of dogs allowed in the Park
- Make efforts to have the legislation strengthened. Currently there are difficulties in apprehending people as it is hard to make a case for illegal activity once the poacher is back in their car and driving through the Park – could argue they are just driving through. The legislation needs to clearly define under what conditions a person can be arrested in the Park. E.g. having a dog off the lead in the Park or bringing large knives into the Park. Also, rangers aren't trained to deliver and instruct court orders.

5.3.7 Protecting cultural sites

During 2010 there were plans to fence an archaeological site (a stone arrangement) that had been knocked around by horses. There are also concerns for sacred sites and art sites with buffalo throwing up dust and rubbing against them.

Figure 3 Participants at the Mary River District Workshop

5.4 Workshop III: Open Bininj meeting, Park Headquarters 14th May 2010

At the Open Bininj meeting held at Park Headquarters there were 17 attendees, of which 7 were Park staff and project consultants. Participants present included: Terry Hill, Peter Mabin, Ian Conroy, Ollie Schiebe, Paddy Cahill, Victor Cooper, Dennis McCarthy, Mark Cahill, Anna Cahill, Colin Cahill, Andy Davies, Steve Winderlich, Mary Blyth, Ben Tyler, Pascal Perez, Peter Bayliss and Emma Woodward.

An overview of the research consultancy was given, before attendees were encouraged to either form groups or work alone to identify on maps of the Park key areas of value, interest and concern.

The key issues that were highlighted during this meeting are summarised as follows:

5.4.1 Park Resourcing

- 'The resources available for feral management don't match the size of the problem'. There are big issues but not much money available to manage them e.g weeds
- Park staff want clear direction on how to use the resources available for control and management programs
- The management programs in place now are working for pigs, but there is a need to prioritise specific areas to get effective results

5.4.2 Horse management

There were some strong comments made about horses in the Park and their current and future management. These comments were followed by a discussion about ferals and safety in the Park:

- ‘At Yellow Water horses have been there for years. Some areas are out of bounds to everyone for feral animal control. How should these animals be dealt with? Shut down the area and then conduct a shoot?’
- ‘Why are the horses still there? As far as I know this is a National Park, people shouldn’t be letting ferals run around.’
- ‘A lot of ferals have an economic value for people – that’s why they want them to hang around’.

There was a suggestion that road corridors should be prioritised for donkey and horse control in the north of the Park, and that rangers could shoot animals that they see close to the road.

5.4.3 The interaction between feral management and saltwater inundation

Comments were made about the need to get feral weeds and animals under control before the problem was exacerbated by saltwater intrusion driven by climate change. There was also some discussion about options for keeping saltwater from moving inland, including ‘barrages to let freshwater flow in and keep saltwater out and let the fish breed’. Some comments made include:

- If barrages are to be built to stop the saltwater intrusion the buffalo might trample and allow the mixing of fresh and saltwater as they did 20 years ago
- Buffalos currently ‘making the channels too deep and letting the water in’
- Mangroves are growing further inland, following along the buffalo channels which are 4-5 metres deep
- Where the saltwater comes up on the floodplain it keeps the country moist, so pigs do a lot of damage, when the rest of the floodplain dries out.

5.4.4 Threats from ‘outside’ forces: poaching, fishermen and neighbouring cattle

There was considerable concern expressed for the perceived impacts of poachers, commercial fishermen and large boats entering Park waters and causing bank erosion.

- ‘There should be more controls related to the size of boats and engine power.’ ‘Currently there’s no size restrictions, legislation or speed limits – there’s supposedly a no-wash zone but it’s not enforced.’
- ‘Poaching is going on all over the place: pigs, buffalo, geese, turtle…people taking bigger catch and breaking Park regulations’.
- ‘Commercial fishers are coming into river mouths within the Park, and onto the mudflats where they shouldn’t…taking more fish and breaking regulations.’ *There was recognition that defining the Park boundary at the coast was difficult.*

There was also discussion about cattle from neighbouring properties wandering into the Park, and confusion over ownership of the cattle once it crossed over the border. It was suggested

that there needs to be clear direction on processes of action to take, for example calling the pastoralist to muster and collect the animals within a certain timeframe.

- ‘Lots of cattle from the pastoral property to the west come across the boundary. Has to be made clear – when the cattle move into the Park who owns the animals?’
- ‘Park legislation is weak. There is a grey area about who owns them’
- ‘Need to change legislation so that Parks can remove them by law.’

5.4.5 Sacred sites

There was clear agreement between those present that all sacred sites should be protected, and Parks staff suggested the idea of having a zero tolerance area and a buffer zone around sacred sites in which all feral animals could be shot. The rules of such an idea would have to be made clear to all.

5.4.6 Communication

There was also a concern about lack of consultation with TOS around planned shoots.

- ‘There is little feedback from Parks staff about planned shoots. One shoot was stopped at the last minute after all of the consultations took place – but there was a perception that no Park staff had communicated why the shoot had been stopped.
- “Senior staff should be engaged in consultations, not junior staff’

Figure 4 Participants at the Open Bininj workshop held at Park Headquarters

5.5 Workshop IV: Jim Jim Station Ranger Station 17th May 2010

The meeting at Jim Jim district station attracted a lot of interest with 22 attendees (including a significant proportion of Park staff). Participants present included: Alan Harbour, Fred Baird, David Cahill, Tom Conroy, Lizzie Pedersen, Charles Whittaker, Jeff Lee, Sylvia Badari, Rosie Lungguy, Mercy Maralngurra, Hilda Maralngurra, Jason Ledingham, Dennis McCarthy, Janice Mitchell, Anna Conroy, Jason Koh, Buck Salau, Kathy Wilson, Steve Winderlich, Andy Davies, Mary Blyth, Mim Jambrecina, Pascal Perez and Emma Woodward.

Again the group was asked to identify places within the Park of special interest to them. This mapping exercise led to the identification and discussion of numerous Park values including fishing and hunting, cultural (including art and shell midden) sites, and tourist/visitor attractions.

Issues highlighted include the following:

5.5.1 Wild dogs

There is a concern that wild dogs/cross-breeds need to be controlled as they are becoming increasingly dangerous to staff, residents and tourists. They are frequently seen near people at Cooinda and Jim Jim Station and having taken items form people's tents and packs.

5.5.2 Ferals at high visitation sites

Special attention was given to the need to control feral animals around high-visitation areas including Nourlangie and Yellow Water. There was a comment made that Park rangers should be allowed to control ferals as required to protect important art sites, to ensure the safety of

staff and visitors and to maintain aesthetics, and that this should be supported as core business and therefore staff 'should be able to deal with ferals without consultations'.

- 'We shouldn't tolerate buffalo here…where visitors come to see a world heritage site.'
- 'Buffalo and pigs shouldn't be around Yellow Water. Risk is too high – even with one or two buffalo or pigs'
- Horses around Cooinda and Warradjun visitor centre are a danger to people and tourists. Although a fence has gone up around Warradjun visitor centre there is no spring on the gate and the horses can wander in. A cattle grid at the entrance to the centre costs between $3000 and $4000 and needs to be suitable for coaches to cross.
- Safety of motorists on the highway is a concern, with multiple horses having been hit by cars.
- The top and bottom areas of Jim Jim and Twin Falls: Ferals should be removed as they are ruining the natural springs. At Umbrella Springs ferals are a danger to tourists. However some red skin cattle on the plateau 'should be left for meat'

One observation by a staff member at Jim Jim station was that they couldn't find pigs to use in their crocodile traps as easily since the aerial shoot. There also seemed to be less damage and pig sightings at Nourlangie Rock since the most recent aerial shoots. Staff expressed frustration at seeing buffalo in a clear and 'safe area' to be shot, such as on the banks of Yellow Water, but not being able to take action quickly due to the need to seek permission/consultation to shoot. The result being that the buffalo is left to do more damage to the banks and potentially wander off to cause a threat to people.

5.5.3 Distributing culled meat

There was some discussion about making meat readily available to TOs after large culls. The culling of ferals might be more readily accepted if there is a distribution of meat organised afterwards. There was conflicting views between Park staff of the validity of slinging animals into outstations for TOs at the end of an aerial shoot. One view is that the cost of slinging an animal by air would be better put toward 'management of the Park' while the other view is that 'people don't see the slinging cost, but they see animals running around as meat they could eat and see it going to waste when it is shot and not eaten'.

A suggestion was made to have a chiller at Jim Jim to have meat on hand for people as well as be able to store pigs as bait for croc traps.

5.5.4 Communication about Park feral control operations

There were come notable instances of either a lack of communication in regards to feral animal control, or miscommunication between Park staff and TOs. One comment from a staff member 'we rely on people to spread the news (*about future culls*) so we don't have to go around and see everyone' raises the question of whether people are aware of this or whether this is the best option. Other comments about communication include:

- Need improved communication of feral animal cull numbers and shoots back to TOs.

- TOs and community people should feel free to call the Ranger station to get information about what's going on.
- Perhaps a community notice board at each of the ranger stations could help.

5.5.5 'Poaching'

There was concern expressed about people coming into the Park on the western boundary and hunting illegally. This is a hot-spot for weeds, so there is a concern that they might be spreading them, and there are many tracks which are contributing to erosion. Many of them were thought to bring dogs and firearms into the Park and it was reported that they have been creating damage to government property: to signs, fences and gates. There were a few responses to this news:

- 'It is against the law'.
- 'Need to reduce feral numbers and this will reduce the attraction to poachers'.
- A permit system is being proposed to allow TOs to give people they know permits to hunt on their country.

5.6 Workshop V: East Alligator Ranger Station 18th May 2010

There was a strong turn-out to the meeting at East Alligator Ranger Station, with the Park organising transport for Bininj from Gunbalanya. Participants present included: Michael Bangalang, Connie Nayinggul, Natasha Nadji, Adriana Nayinggul, Anita Nayinggul, Nicole Nayinggul, Katie Nayinggul, Greg Sattler, Mick Gorst, Jimmy Marrimowa (?), Mabiyarra, Walter Nayinggul, Josh Taylor, Jane Christophersen, Gabrielle O'Loughlin, Andy Davies, Steve Winderlich, Mim Jambrecina, Mary Blyth, Buck Salau, Peter Bayliss, Pascal Perez and Emma Woodward.

As with other meetings the participants were asked to highlight on maps areas of value as well as concerns

The key areas of discussion included:

5.6.1 The protection of sacred sites

Sacred sites were acknowledged as needing protection, but staff were reminded that there are restrictions on who can go to some of these places to manage them, and to shoot for ferals.

- Near the Merl Campground there is a very powerful site that Balanda (non-Aboriginal people) should avoid from the air and ground. Only the right initiated Bininj can go there. *It was suggested that the right people (including brothers of those present) should shoot that area for ferals.*

Rock art sites and shell middens were also identified on maps as needing protection, with people unsure of the level of damage that has occurred to shell middens.

5.6.2 Impacts of pigs

The negative impacts of pigs were discussed by this group in terms of their destructive rooting, competition for natural resources, degradation of rock art sites and ability to carry diseases. Comments include:

- '…always pigs rubbing on rock sites…competition with pigs for yams, turtle, bulbs, water lilies..' 'Pigs also eat green plum off the ground'
- The pigs eat important 'yellow and brown colour root for dying pandanus', which is then used for weaving baskets and mats
- 'Pigs carry disease…want them controlled in key hunting areas on the border of the Park to the east

While pigs are seen as having many detrimental impacts on socio-cultural values, they are also considered a valuable food source alongside native plants and animals. It was suggested that Park staff let TOs know where they have undertaken a pig shoot so that TOs can come in and take some of the pigs for meat.

Several control methods for pigs were suggested and discussed by the group. These include:

- Trapping. Could TOs and communities be involved in checking pig traps that are set and claiming the meat? It was acknowledged that baiting and checking traps is very time consuming and that this method is only really used where there have been complaints by tourists. There was interest by a TO in trapping pigs in the wet season when there are pockets of pigs trapped on the high ground.
- Poisoning/baiting. This idea was received with caution by TOs as the poison 'might kill natives'. But there was some interest in investigating the poisoning option further (and receiving further information).

There were concerns about people with dogs (outsiders) shooting indiscriminately for pigs – but there was interest in Park residents being contracted to reduce pig numbers.

5.6.3 Horses

A number of concerns surrounding horse management and safety concerns were raised at the East Alligator Meeting. This included questions about how animals that were a nuisance in tourist areas could be put down safely. There was a concern about tourists seeing dead horses as well as shooting near where tourists frequent. One comment was made about TOs wanting 'royalties' for horses that are shot by Park staff and not used for pet-meating etc. This comment was followed by an idea to fence some horses and have them 'broken-in', with the view of 'managing the horses' better.

Other comments made include:

- Perhaps the Park staff could fire warning shots to scare animals from tourist areas, and if that doesn't work then the animals can be shot.
- The Park rangers need to know what to do…need to be able to protect tourists.

- If TOs are busy with ceremony etc and the Park Manager isn't around to consult – it's the Park's responsibility to protect the tourists.
- I want more signs on the roads to warn of horses.

Everyone agreed that if there are sick or diseased horses then they should be put down.

5.6.4 Coordinating feral control with neighbours

Coordinated management of ferals across the Park boundaries was an issue that was raised. Park staff said they would arrange a meeting with the coordinator from the Adjumarllarl Rangers based at Gunbalanya. It was also mentioned that the Park had participated in a workshop with regional ranger groups, but that the group bordering to the east of the Park, the Adjumarllarl Rangers, had not participated.

TOs raised the idea of a clan-based land management program being set up within the Park. Park staff responded by saying that while there is a Kakadu Indigenous ranger program that is funded, the Park struggles to find participants, and there are issues with providing accommodation for those not living in the Park. It was suggested that the Park needs to provide accommodation within the Park to…'keep the workers here. If they go back over to Gunbalanya you won't find that person again'.


Figure 5 Participants at the East Alligator District workshop

5.7 Workshop VI: GAC Meeting 19th May

This meeting was held at the Gundjeihmi Aboriginal Corporation (GAC) in Jabiru. The following people were present at the meeting: Geoff Kyle, Yvonne Margarula, Nida Mangarrbar, May, Valerie, Tony, Sandra, Raelene, Stephanie, Melanie, Ruth, Stevan, Michelle Ibbett, Andy Davies, Ben, Steve Winderlich, Peter Bayliss, Pascal Perez and Emma Woodward

The group wasn't interested in undertaking the planned mapping component of the meeting, so discussion turned directly to the impacts of different ferals and the issue of meat being distributed following an aerial shoot. Pigs were highlighted as the biggest issue: 'Too many pigs everywhere…around Mamukala, Mudginberri, Munmarlary, Bindji area'.

Some suggestions were made to the Park including:

- When a buffalo has to get shot because it's wandering on the road or if one gets hit by a car and Parks knows about it, GAC would like to know so they can consider recovering some meat
- When Park staff are going to undertake any shooting can they please let GAC know so they can send someone out to bone some meat for the TOs
- There should be more on-ground shooting of pigs and on quad bikes, not just aerial shooting
- Important to keep ferals out of art sites areas. It's ok to shoot from helicopters in these areas as long as the shooters don't miss
- Leave the buffalo, we don't need Parks shooting them. Bininj can shoot that buffalo for meat. The buffalo are coming up from Nourlangie –the buff farm
- There is a big mob of horses at Mudginberri, but they have been hanging around for a long time, it'd their home now. Don't want these animals shot. Maybe in the future if their numbers get bigger they might become a problem. Bog mob of horses all over the country.

5.7.1 Safety

There was a suggestion of putting up more road signs to warn people of animals on the road. There was also concern that tourists are driving too fast and also driving at night when they hit animals.

Other issues and threats were also raised including wild dogs, cane toads and salvinia. Wild dogs have been seen around the dump, but the participants didn't know what the solution is, and shooting them seems cruel.

5.8 Meetings external to the formal workshops

5.8.1 Cooinda/Yellow Water

The consultancy team was asked to attend a Gagudju Association meeting at Cooinda in order to explain the feral animal workshops and the model to a group of people that did not attend the formal workshops organised within the Park. The team waited for an hour to be seen by the group and spoke briefly to those at the meeting, who did not wish to participate in any values mapping.

5.8.2 Meeting with Cannon Hill residents

Park Staff facilitated discussions with residents of Cannon Hill as they did not attend the formal workshops organised within the Park.

5.8.3 Meeting with Buffalo Farm residents

Park staff attempted to arrange a meeting for the consultancy team with a long-time resident in the Park – Dave Linder, who operates the buffalo farm near Yellow Water. Due to time restrictions the team did not meet with Mr Lindner, who shortly after forwarded a letter to the team though Park staff outlining his observations on a range of Kakadu issues.

5.9 Information from the workshops

5.9.1 Values mapping

In undertaking the values mapping component of the workshop, participants identified many sites within the Park that hold importance based on a range of use and non-use values. The resulting values were grouped into the following categories for ease of inserting them into the model: hunting (including fishing and other resource harvesting), sacred sites (including rock art sites), historic sites, springs (and soaks featuring sensitive vegetation), high visitation (dominated by tourist sites but also those visited by Bininj and other Park residents), conservation areas (including jungle patches and endangered plants and their habitats) and

commercial hunting. The values identified on the maps in the different workshops were condensed onto one broad-scale topographic map, to provide a simple but informative overview of the scale and diversity of social, cultural and ecological values within the Park. This was created to report findings back to the participants in the final modelling workshop –whilst avoiding the identification of confidential information. While the map can be viewed in Appendix G, it should not be considered to be representative of all values within the Park, nor has the information provided by workshop participants been mapped with any accuracy.

When the participants were then asked about the potential concerns people held for protecting those values, a discussion about feral animal impacts, as well as weeds and other threats was raised and discussed by the group.

A summary of key values and threats identified by participants in the mapping exercise were translated into Excel Spreadsheets – with map cells of 25km2 (see Figures 23a-d for examples of these layers). These data layers for natural and cultural values are contained in the SimFeral values and damages.xls file (Appendix D). They were imported into the SimFeral_april2011.ev environmental file and are loaded automatically into the SimFeral_april2011.st model during the initiation process.

Identification of values is a particularly important step in determining how to measure success of any feral animal management plan. Although the short nature of the consultancy didn't allow for it, future engagement with Bininj around feral animal management might focus on those indicators that Bininj recognise for the health of Country. This could provide a good starting point for a participatory community-based monitoring program.

5.9.2 Key messages from the workshops

The purpose of bringing people together in the participatory workshops was to first determine what people thought had worked well and what hadn't worked well in regard to recent feral animal control programs.

Because of the diverse and varied perspectives of workshop participants in regards to which feral animals are regarded as problematic, which ones are tolerable, which are considered a resource and which are valued for social or cultural reasons, the perceptions of recent feral animal control programs are necessarily varied. Some of the key messages that emerged from participants are:

- Many participants thought that the aerial shooting had resulted in a noticeable reduction in pig populations which was recognised as being a positive outcome (and had worked well) at several of the workshops;
- There were some concerns with the level of consultation that occurs in relation to feral animal management programs, both in the notification of potential availability of meat from shoots and feedback in regards to decisions made about aerial shoots and the success of programs. This was seen as an area of the program that could be improved;
- There was concern raised about the safety of Bininj, Staff and tourists in the Park and their interaction with feral animals. There was discontent raised by many staff and Bininj about the protection of people from feral animals, and the lack of rules or guidelines for Staff to

act in accordance with. This emerged as an area that has not worked well in the Park recently;

- The creation of a buffer zone between the Park and Mt Bundy Defence area, in which the neighbouring organisations were both responsible for clearing the area of feral animals worked well for a time and was seen as a successful program. Unfortunately that arrangement has been put on hold due to a breakdown in agreements with Bininj on the Park, and
- While the engagement of a private contractor to pet meat horses and other ferals is a positive step to reducing feral animal densities in the south of the Park, it is questionable as to whether the business has the capacity to create a significant/noticeable impact on population densities and therefore warrant their exclusive use of certain areas. This contract might actually be counter-productive by preventing others, including the Park, contributing to the reduction of feral populations. Therefore this aspect of the Park's feral animal control program, particularly in the south of the Park, may have not worked as well in recent times.

5.9.3 Recommendations for change from workshop participants

The following recommendations and key concerns were taken directly from workshop discussion and have not been prioritised or edited by the author.

- The process of consultation with TOs should involve senior Park staff, not junior staff (Bininj perspective)
- When conducting workshops, meetings or consultancies be clear as to why the information is being collected and how/for what it will be used
- Aerial shooters should focus on shooting, not recording data also (separate person for that work)
- Feral shooters should not being doing consults with TOs about shoots. Need some distance – other Park staff should do consults
- Ensure the right people are entering and shooting within specific sacred sites
- Consider options for TOs to be involved in setting and checking pig traps – particularly in the East alligator District
- The idea of clan based ranger programs operating within the Park – based on a similar model as the Caring for Country
- Seek further information about the safety and feasibility of pig poisoning and provide feedback to TOs (East Alligator District)
- Investigate options for residents within the Park to take on pig reduction contracts
- Investigate opportunities for TOs to be involved in feral shoots alongside rangers
- Concern for tourists and locals hitting animals – particularly horses – more road signs warning of danger
- Feral dogs need to receive greater attention

- The core business of the Park should be to ensure staff and visitor safety, and that where a feral animals threatens that safety - there need to be effective systems in place to ensure Park staff can respond in a timely manner.
- Explore options for meat distribution after a cull – as a good faith measure that could constitute part of an agreed package
- Protection of sacred sites from ferals – need adequate fencing, and written into Park Staff work plans (not just opportunistic control)
- Improved communication around planned culls – and feedback after the culls, how much was shot, where the animals were seen in dense numbers (need to complete the communication – feedback loop)
- Trial the use of 'community notice boards' at each Ranger Station – to communicate upcoming feral animal control programs etc
- Feral monitoring program in the south of the Park
- Resumption of feral buffer zone and coordinated effort of feral removal on the western boundary of the Park – to remove the incentive for illegal hunting in this area – at the same time Legislation needs to be strengthened and capacity of rangers built to deal with illegal hunting and illegal use of firearms in the Park – particular focus on the western boundary
- Terminology change – from 'culling' to control and manage. Communication and terminology is vital
- Conduct trial vegetation monitoring program in the south of the park – fenced/exclusion areas – see what the recovery rate is like (in different habitats and with varied degradation)
- Any contractual arrangements for private removal of ferals…streamlined process managed by the Park with strict reporting requirements (numbers hot, areas worked) and control plan - to add to feral management database. Short-term contracts or with clause to dissolve contract on non-performance. Seek examples from other National Parks
- Pet-meating – conflict of interest? Limit to how many horses can be shot and boned in one day. Use of meat important to TOs, but need to gauge how many horses are being shot vs. how many are being boned (which is time-consuming).
- Consider the training of TOs in aerial observation, data collection, as well as shooting – take some TOs up in the chopper for aerial shoots so they can monitor a big shoot being implemented
- Reduce speed limits within the Park.
- Increase signs – to warn motorists of wandering animals

6. MODEL DEVELOPMENT

The workshops were conducted using an approach to planning and decision making called "participatory Agent-Based Modelling (ABM)". The modelling framework provides an opportunity for social-economic and cultural values (& processes) to be included together with available biophysical knowledge on feral animals in the Park. This model can be used to test management/feral animal control scenarios and see what the outcome is in a controlled and safe

environment. The model was used as a tool to facilitate greater engagement by participants at the workshops, first by eliciting participant's values and incorporating them in the model, and second by providing participants with the opportunity to test control scenarios chosen by the individual, that reflected their personal values and interests.

6.1 SimFeral model and Cormas

The MSE simulation tool for feral animal management is called **SimFeral** and was developed in Cormas. Cormas (Common-pool resources and multi-agent systems) is a computer simulation environment that has been developed in Smalltalk programming language using VisualWorks software (Bousquet *et al*. 1998). Smalltalk is an object-oriented programming language (Byrne *et al.* 2001) that was created as the language to underpin the "new world" of computing exemplified by "human–computer symbiosis, and has been advocated as a UML (Unified Modeling Language) by Le Page and Bommel (2005). Bousquet *et al*. (1998) argued that such a simulation tool would be useful to better understand the complex interactions between natural and social dynamics in renewable resource management, and has been successfully applied to local community-based and regional NRM issues around the world that required decisions to be made in a spatial context and multiple use (e.g. Le Page and Bommel 2005; Le Page *et al.* 2001).

The Cormas modelling environment is big on integrating spatial dynamics of multiple interacting agents, and visualising both temporal and spatial outputs. Whilst it has many strengths it is difficult to use without undertaking a specialist training course. It is even more difficult for non-programmers to code, which may constrain stakeholder participation in model development. Another constraint of the Cormas platform is that spatial resolution and simulation speed will be limited when confronted with a large number of agents and interactions. Ideally we would want to eventually link the SimFeral modelling tool described below to the park GIS. Hence, up front, we recommend investigating other ABM-GIS modelling platforms that have fine spatial resolution, are easier to use and require little training (see Section 6, Recommendations).

Appendices A, B and C provide detailed descriptions of all data classes used in the SimFeral model, as outlined below.

6.1.1 Cultural knowledge

Two knowledge domains exist on KNP; one is associated with Indigenous ecological knowledge reflecting cultural beliefs, values and deep connections to family and country, and the other knowledge domain encompasses western science and its associated and often hidden values. Both knowledge domains are considered by stakeholders to be complimentary, not mutually exclusive, and their combined use in land management has been advocated by many Indigenous communities across northern Australia as the "Two Tools Box" approach (as adopted by Working on Country programs, see May 2010). The SimFeral model attempts to integrate both knowledge domains with respect to feral animal damage in order to help resolve potentially conflicting objectives.

The participatory feral animal workshops conducted in May 2010 (Section 5 above) were designed to help elicit the issues and needs of all stakeholders (Bininj & park managers) in relation to protection of natural and cultural values from damage, including the performance of the last big control program both in terms of process and reaching clearly defined objectives. The elicitation by workshop process is outlined in Figure 6. Six workshops were first conducted to map natural and cultural values, and perceived damages, in all clan areas and park Districts. These data were transferred individually to Excel spreadsheets and colour coded as being recorded/not recorded for each 25 km^2 cell (see Appendix D; p94). All spatial information elicited at these workshops was also combined onto one topographic map (1:100K) covering the park (see Appendix G). A final workshop was held (21st May 2010) with all stakeholders from across the park to integrate all knowledge and data during a participatory MSE modelling exercise (see Section 7). Prior to the simulation exercises however, all elicited information was checked as much as possible before being imported into the Cormas SimFeral model (data imported into a companion "environmental file"; see Appendix C).

Despite the dependence on eliciting critical information from workshops, little information is available on how it should be conducted, what the most relevant methods for elicitation are or how the knowledge gained can best be used to inform the decision making process (see Kuhnert *et al*. 2010 with respect to eliciting expert opinion for qualitative risk assessments).

6.1.2 Ecological knowledge

For convenience ecological knowledge is here defined as knowledge and information acquired by western scientific means, although much ecological knowledge resides in the cultural domain. Environmental data (e.g. vegetation, topography & hydrology) were derived from medium to high resolution maps and re-formatted to the 25 km^2 grid (see Appendix C; p90 & Appendix D). Aerial survey data (Tracey *et al.* 2009) describing the distribution and abundance of pigs, buffalo, cattle and horses, and their associated ground disturbance damage (e.g. pig rooting, wallows, tracks, fouled water) across KNP were re-formatted to the 25 km^2 grid (see Appendix A, Appendix C; p90 & Appendix D). Although the recent 2008-2009 survey data are stored in a GIS, there has been no pre-processing of information to easily facilitate the drafting of distribution and abundance maps (see Appendix D; p99). Unfortunately the GPS data had to be downloaded from the GIS then transferred by hand to topographic maps with a 25 km^2 grid pencilled in, and finally cell data derived for import into Excel spreadsheets and eventually the Cormas environmental file.

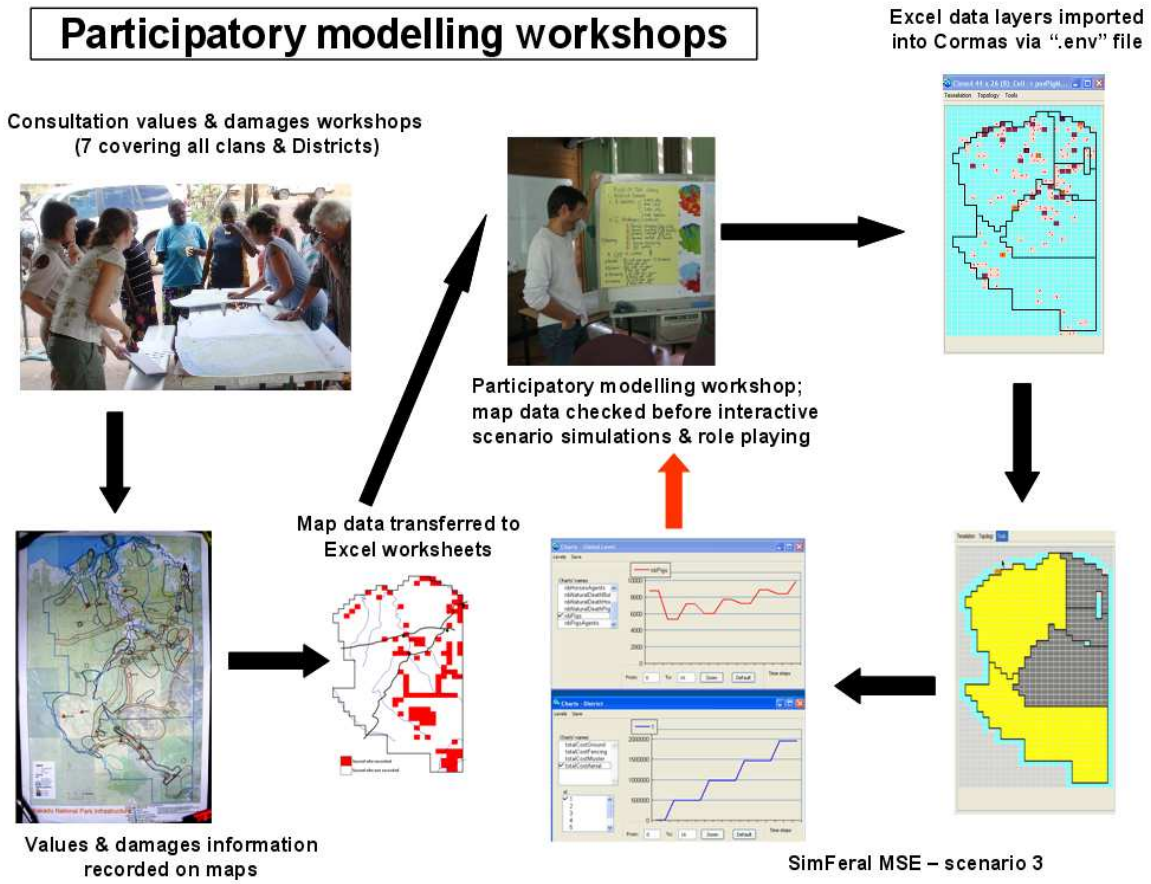


Figure 6 The participatory and elicitation modelling approach adopted by the project team for the feral animal workshops in May 2010.

6.1.3 Knowledge integration

The SimFeral ABM integrates all available data when simulating MSE scenarios last 3 boxes in Fig. 6 above; Fig. 7). Information on the cost of different control methods (see Appendix D; p105), and potential damage-density relationships (see p108), are also integrated into the SimFeral model when simulating scenarios to evaluate a range of management strategies. These settings are "hardwired" into the program code.

6.2 Model structure and dynamics

To develop an ABM we commence with a conceptual model of how the system works, and then design and simulate this in a computer using a specific programming language (the source code). Given the huge diversity of programming languages available, early developers of ABMs recognised the need for a rigorous and standardised methodology of programming. UML (Unified Modelling Language; Bergenti and Poggi 2002) is one such language. Le Page and Bommel (2005) outline in detail a methodology for designing an ABM with Cormas through a formal ULM representation of the conceptual systems model.

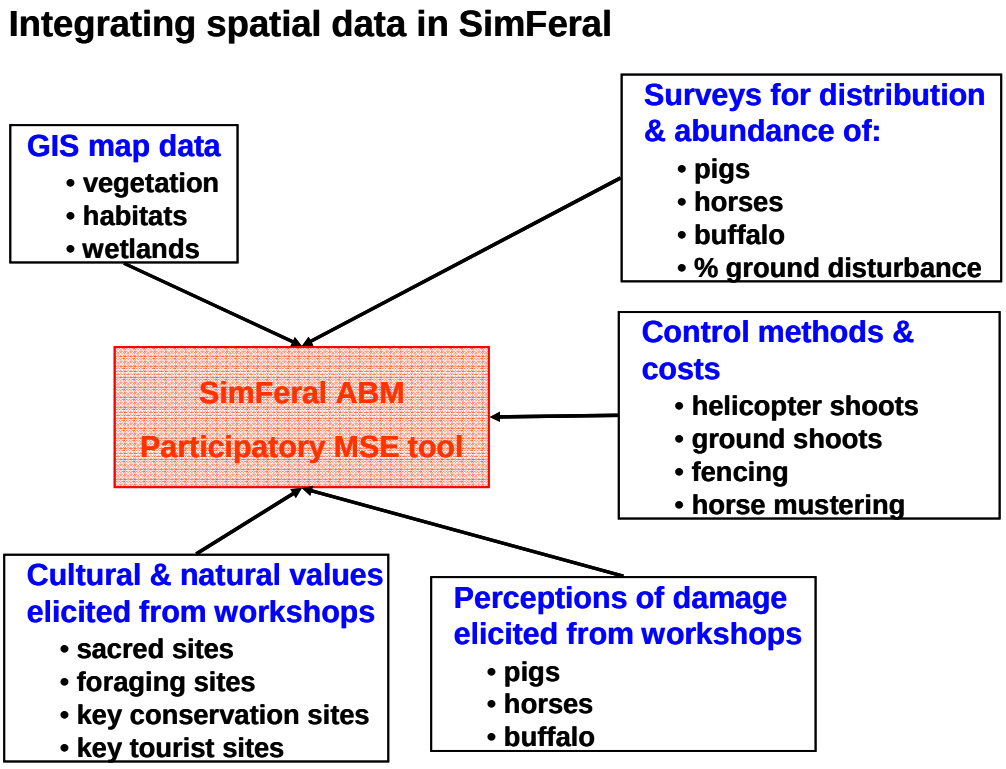


Figure 7 Integrating all classes of spatial data and knowledge in SimFeral.

UML is a graphically-based modelling language, basically a universal object-oriented language. UML diagrams are used to describe the structure and dynamics of the model system independent of the computer platform and language. Because the UML is based on simple graphical notations, an ABM described by UML diagrams should be understandable even to non-modellers. The UML is seen as a dialogue tool that facilitates communication among scientists, modelers and stakeholders (Le Page and Bommel 2005). The UML class diagram is the basic building block for agent-based modelling, and shows all the classes (or a sub-set of classes) and their relationships with each other. Drawing a class diagram is the first and main stage of the modeling process, and is particularly useful when it occurs during participatory sessions with stakeholders.

The first step consists of identifying the relevant real-world types of entities and then mapping out each of them using the concept of “class”. A class is a description of objects that have a similar structure and behaviour, generally sharing a common semantic (e.g. feral animals). In practice a “class” is defined by a list of characteristics called “attributes”, and a list of behaviours called “operations”. Attributes represent the static component of the model and operations represent the dynamic component. A class can also be viewed as the “generator” of the objects (called “instances” of the class). Hence, a class describes a structural model for a set of similar objects called “instances of this class”. A Cormas UML flow chart connecting feral animal agents with their class attributes (per spatial grid cell) is illustrated in Figure 8.

There are three basic modelling components (or programmes) represented in Cormas: (i) agents and their interactions (in space or by communication); (ii) control of dynamics; and (iii) observation viewpoints ("pov" or "Points of View"; see Section 11.1, Fig. 24). Bousquet *et al.* (1998) provided a detailed description of each of these components of the Cormas modeling platform, briefly summarised below.

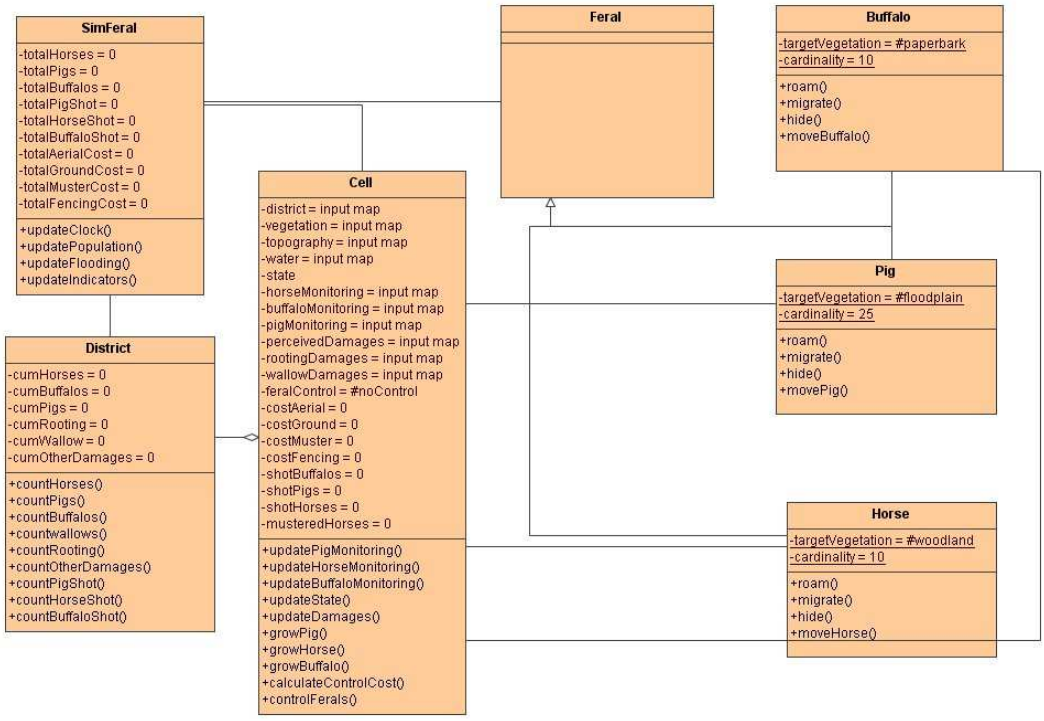


Figure 8 Cormas UML model flow chart connecting feral animal agents with their class attributes (per spatial grid cell).

6.2.1 Agents and interactions

There are three types of agents. The first is the "situated" agent, where the position of an entity is declared relevant. The situated agent has a spatial reference and is characterized by its field of perception. The second is the "communicating" agent, which is said to be communicating when it can communicate with another entity that is not located in direct proximity. Communication is not only the exchange of information because, in the context of renewable resource management, such things as agreements (e.g. the co-management agreement on KNP) and exchanges and contracts are all situations that involve communication between entities. The third type of agent is the "situated" and "communicating" agent, which corresponds to the sum of effects of the two previous classes of agents. Obviously you can have as many types of agents as the situation demands.

There are two modes of "interaction". The first concerns the way in which space is accounted for. We have created a spatial environment containing the "situated agents". By space we mean physical space (e.g. territory, zone or region). The space is divided into "cells" or "patches"

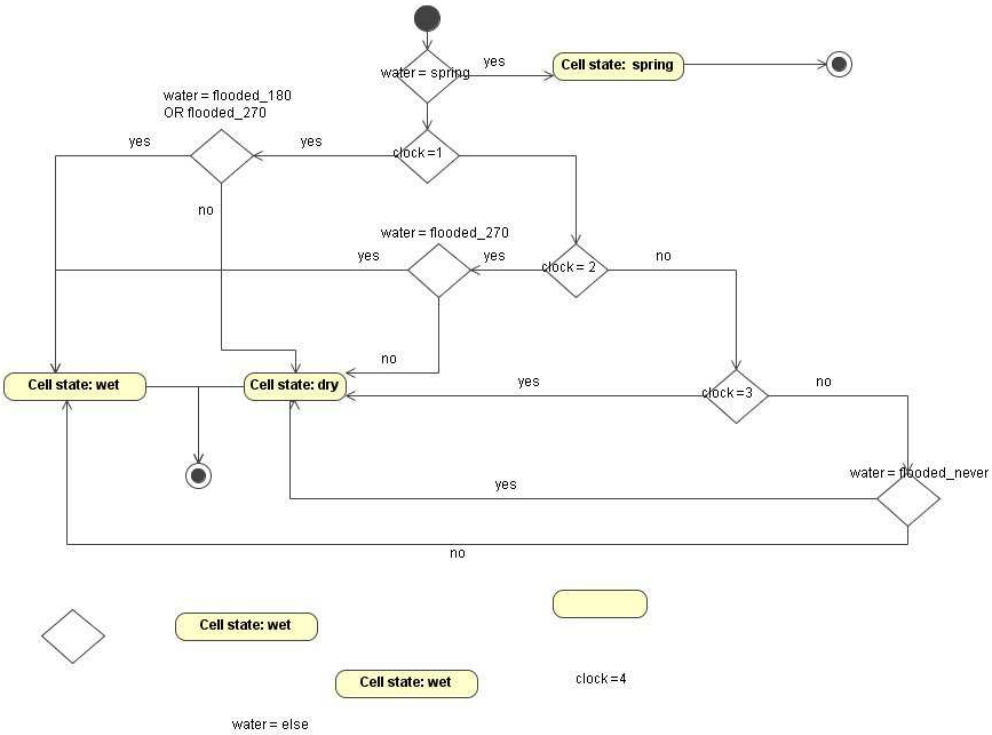
linked by relations of proximity. The cell is the smallest referenced spatial unit. To play its role as a medium, as an intermediary between agents, the "patch" has a list of its occupants and implements "primitives" that enable communication to take place. It also provides "primitives" for access to its vicinity (immediate or extended). The second type of interaction involves the notions of a "message" and "transmission" channel. Communicating agents can send each other messages through channels. The channel models a communication path between agents who are not necessarily neighbours. The channel implements message transmission primitives between connected agents.

6.2.2 Controlling model dynamics

Agents, space cells and channels are the basic components that comprise a multi-agent simulation. They are used to create an artificial world with a given configuration or design to perform simulations. A space is first created and its dimensions defined, along with the number of agents required and their initial state. The time dynamics of interactions between agents must also be scheduled and, for this reason, the "control" part of the simulation dynamics is isolated. It is just as important to define the control as it is to define the behaviour of agents, because the different types of control determine the sensitivity of simulations.

The structure and controlled dynamics of the SimFeral ABM is exemplified in Figures 9 and 10. Figure 9a is the UML diagram (flow chart) that characterises and schedules the seasonal inundation patterns of floodplain habitat on KNP, which in turn (another UML diagram not shown here) modifies the behaviour of feral animal agents in each cell by forcing them to move to adjacent terrestrial habitats at the peak of wet season floods (see Appendix D & Fig. 26). Figure 9b is the UML flow chart that characterises and schedules the underlying population dynamics of pigs in each cell in the absence of control (reduction in density) using the Theta-logistic population growth model, and is the same model applied to all other feral animal species but with different parameter settings (see Field *et al.* 2006 for parameter values). UML flow charts were developed also to characterise and schedule the random dispersal dynamics of each species into adjacent cells (i.e. in contrast to the seasonal movements described above). Figures 10a-d are UML flow charts that characterises (in terms of numbers & $costs) and schedules reductions in density of feral animal agents in each cell depending on the method of control and vegetation type. For example: Figures 10 a & b are UML diagrams for aerial and ground control of pigs per cell based on vegetation cover, respectively; and Figure 10c-d are those for fencing exclosures per cell and horse mustering, respectively.

(a) UML for seasonal inundation of floodplains



(b) UML for population dynamics of pigs

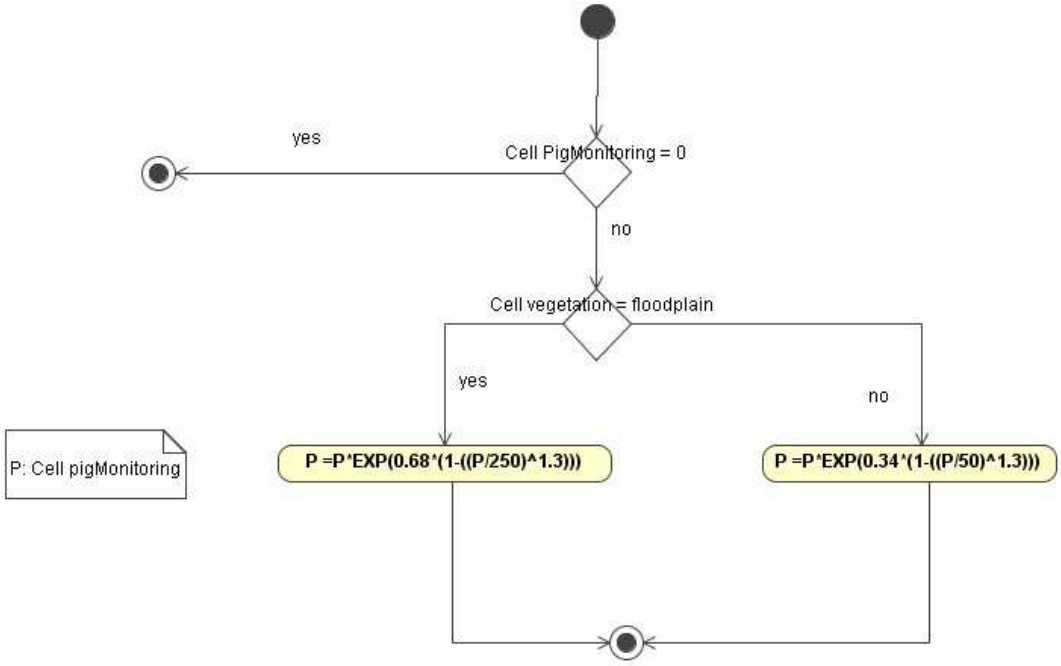
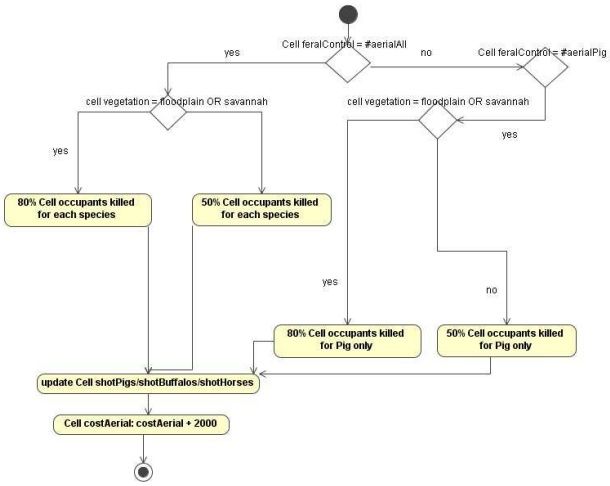
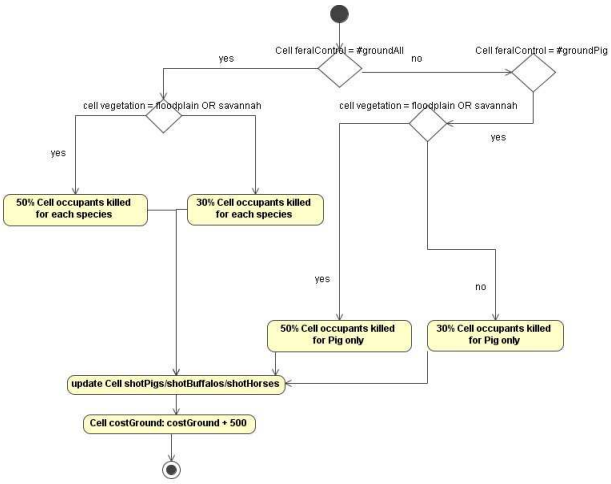


Figure 9 Cormas UML flow chart for (a) seasonal inundation of floodplains and (b) population dynamics (logistic model) of pigs per spatial grid cell.

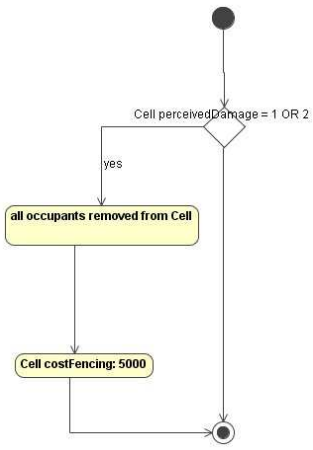
(a) UML for aerial control of pigs by vegetation type



(b) UML for ground control of pigs by vegetation type



(c) UML for fencing



(d) UML for horse mustering

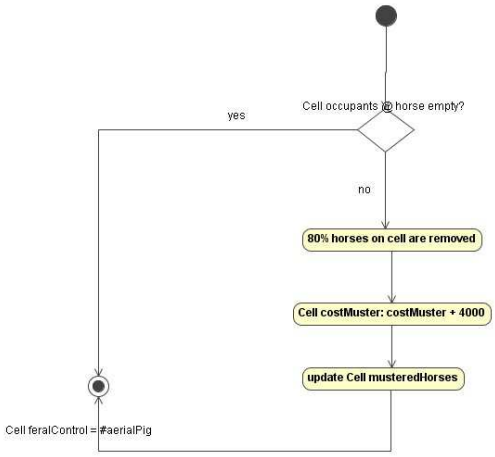


Figure 10 Cormas UML flow chart for cost of (a) aerial control and (b) ground control of pigs per cell based on vegetation cover, (c) fencing exclosures per cell, and (d) horse mustering.

6.2.3 The observer's viewpoints

Emergence is an underlying property of multi-agent systems, and involves simulating behaviours and interactions at the microscopic level in order to observe the emergence of complex behavioural patterns at the macroscopic level. However, "observation" is also a key property of multi-agent systems and is gaining more attention. The *Cormas* environment is equipped with several tools to define the "observation" of simulations such as the notion of "viewpoint", whereby a portion of space or an agent can be observed from different viewpoints (see Appendix D; p100 & "pov" or "Points of View" in Fig. 24). Hence, the *Cormas* user is both a modeller and an observer and must therefore define the observation of interest and implement it in the same way that agents and control dynamics are programmed.

6.2.4 Implementation

Once the model structure and dynamics have been defined and developed in UML, the ABM can then be implemented. Implementation mainly involves the preparation of Smalltalk language classes inheriting predefined classes. Appendix D contains detailed instructions how to implement a Cormas ABM to simulate different management scenarios.

6.3 Model calibration - trial simulations for pigs

Feral animal distribution and abundance data obtained during aerial surveys in 2008-09 on KNP (Tracey et al. 2009) were used to calibrate starting values in the SimFeral model as seen in the visualisation grid. The fidelity, or proximity of the model to reality, was assessed by examination of trial simulation results for pigs. Although the main aim of the modelling exercise was to facilitate participation by Bininj and park staff in order to increase communication and interaction between them, model outputs still need to be in the right "ball park" to be believable.

6.3.1 Pre-set control scenarios

The pre-set control scenarios used in the SimFeral model are described in detail in Appendix D, along with the costs of four different control methods applied to different feral species and areas. Appendix D provides a step by step set of instructions on how to load and open the SimFeral model using Cormas software, and how to initialise and simulate the four following control scenarios using pigs as an example.

- Scenario 1: no control baseline.
- Scenario 2: broad-scale aerial control (shoots from helicopters) in the South Alligator River and Mary River districts (1 & 7 respectively) during the early dry season.
- Scenario 3: Scenario 2 aerial control in districts 1 and 7, plus ground control in sensitive eastern districts (East Alligator River, Headquarters & Jim Jim districts) during the early and late dry seasons. Ground control is not broad-scale but localised within cells.

- Scenario 4: selective control based on habitat comprising ground control in dense vegetation and helicopter control in open floodplain and savannah habitats in the South Alligator River, East Alligator River and Mary River districts.

The cost-of-control rules for shooting pigs from helicopters and on the ground are $2000/cell and $500/cell, respectively.

6.3.2 Simulation results

Figure 11 shows the simulated Park-wide ("Global") trend in total pig numbers for each of the four management scenarios described above. Simulations were run over 16 quarterly time steps or four years. The percentage difference between Scenario 1 (no control) and all other control Scenarios is a measure of performance when matched to total control costs. Table 1 shows that Scenario 3 was the most efficient Park-wide strategy, with a 76% potential reduction in pig numbers compared to a population that has increased without control.

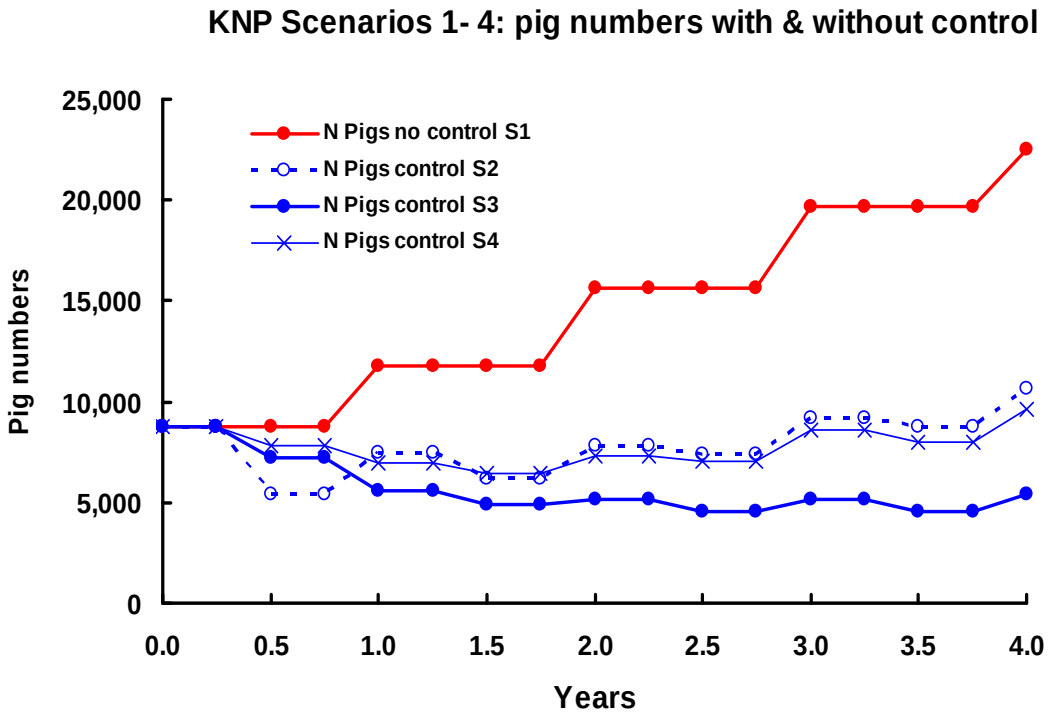


Figure 11 Trend in simulated park-wide pig numbers for control scenarios 1-4 (Scenario 1 is no control, see text for others).

Table 1 Percentage difference in simulated pig numbers on Kakadu National Park between no control (S1) and control scenarios (S2-S3) at each time step (see Figure 11). Populations increase annually at the start of the wet season, and are controlled in the early and late dry season (see text).

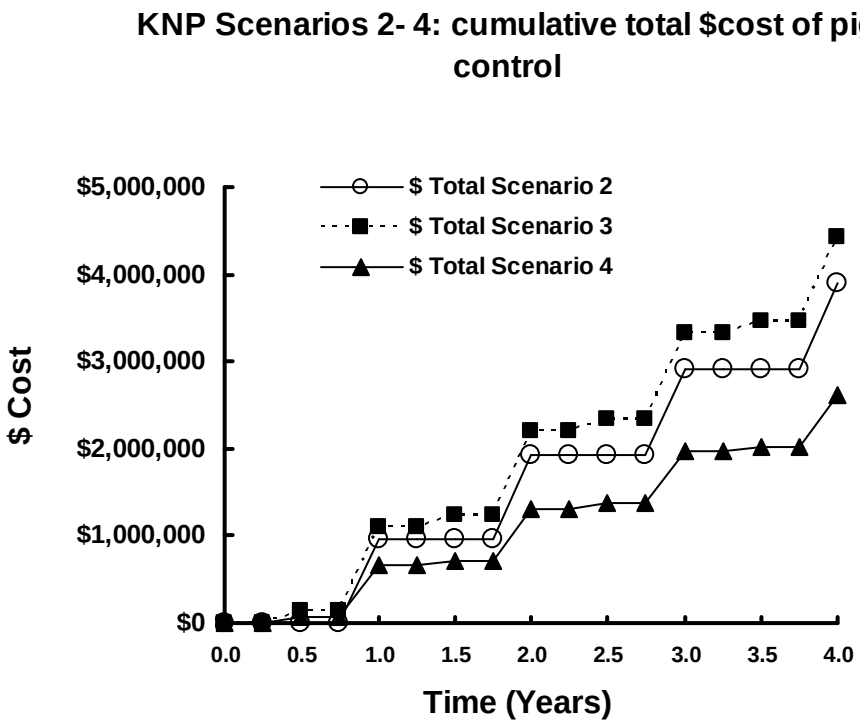
Time step	Years	% difference S2	% difference S3	% difference S4
0	0	0	0	0
1	0.25	0	0	0
2	0.50	38	17	10
3	0.75	38	17	10
4	1.00	37	53	41
5	1.25	37	53	41
6	1.50	48	59	45
7	1.75	48	59	45
8	2.00	50	67	53
9	2.25	50	67	53
10	2.50	53	71	55
11	2.75	53	71	55
12	3.00	53	74	56
13	3.25	53	74	56
14	3.50	56	77	60
15	3.75	56	77	60
16	4.00	53	76	57

However, Scenario 3 incurred the greatest overall total cost (Fig. 12a) because of the more extensive use of helicopters (Fig. 12b). Whilst scenario 3 was 21% more effective in reducing potential pig numbers than Scenario 4, it cost 41% more ($1.8M).

If this scenario was run in a participatory modelling workshops park managers and Bininj would have a realistic simulation outcome that could be discussed and assessed in terms of a range of performance criteria, not just the number of beasts killed or the percentage reduction. This interactive “what if” simulation process occurs in a “safe” and “friendly” environment and, therefore, has the potential to defuse strong emotions attached to unsatisfactory stakeholder outcomes; it is “learning by doing” in an imaginary world. For example, Scenario 3, whilst slightly less efficient in terms of density reduction is about half the control costs, and yet could be more effective in protecting park values because it is more targeted (prioritised) to sensitive areas with respect to natural and cultural park values. Evaluating the performance of different simulated management strategies under different settings or scenarios is Management Strategy Evaluation (MSE) as described in Section 3, and supports the principle of Adaptive Management.

Invasive species management embraced a “damage focus” over 15 years ago. Hence, today, density reduction is rarely used in isolation as the performance criteria for control (Hone 1994). It was a major paradigm shift because by focussing on perceptions of “damage” pest control managers had to focus on people’s values, which were generally ignored by biophysical scientists because they involved the cultural and sociological domains and so outside their skills set.

(a)



(b)

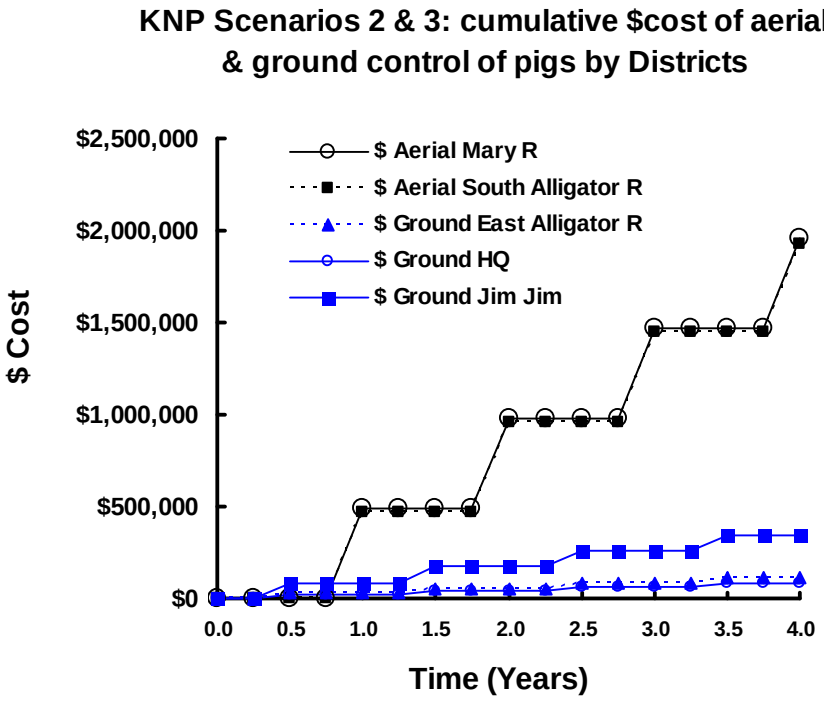


Figure 12 a & b (a) Total combined cumulative cost ($) of aerial and ground control for pigs for Scenarios 2-4, and (b) cumulative cost ($) of pig control by District for Scenarios 2-4.

7. PARTICIPATORY MODELLING WORKSHOP

7.1 Description

Following the set of participatory workshops held around the Park to illicit values and concerns related to feral animal management, participants were invited to a final participatory modelling workshop.

The aim of the modelling workshop was to allow participants to propose feral animal management scenarios that could be tested in the SimFeral agent-based model. This 'role playing' would create an opportunity for participants to: play the role of the feral animal manager, providing some insight into the decisions that have to be made about feral animal; test their preferred methods of control within a budget, and see what kind of impact the controls might have on feral population numbers.

Participants were first asked to check over the map layers that had been created from the values mapping exercise completed by individuals and small groups throughout the previous weeks' workshops. All of the areas and sites identified as being either of value or showing 'damages' (which includes threats to key values) were pulled out from the individual maps and recreated as separate map layers, combining all of those identified areas that fell into each of the following categories:

Value Layers:

- Springs (including soaks/areas with ferns)
- Conservation
- Sacred sited (including rock art sites)
- Historical (sites of old buildings, planes)
- Hunting (including fishing and other resource harvesting)
- High visitation (tourists and Bininj)

Damages layers:

- saltwater intrusion
- dogs and cats (presence/sightings)
- buffalo
- pigs (rooting and wallowing)
- horse activity
- boat erosion
- 'wet' weeds: (including salvinia, paragrass, mimosa)
- 'dry' weeds: (dryland weeds)
- poaching

– commercial hunting

These data layers for natural and cultural values, and threats/damages had map cells of 25km2 (see Figures 23a-d for examples of these layers) and broad enough that different people's information could be shared and be relatively unidentifiable.

Participants were then provided with some 'rules of the game' and asked to come up with ideas for managing ferals in their Country, or in the case of the Park staff participating, either in their District or Park-wide. The following four control methods for pigs, horses and buffalo were offered for consideration, with the associated cost ($) of control on a cell (25 km^2) basis estimated by Park staff before the modelling workshop started.

i. Aerial shooting ($2000/cell or $200/km^2)
ii. Ground shooting ($500/cell or $80/km^2)
iii. Fencing ($5000/cell or $200/km^2)
iv. Mustering (horses) ($4,000/cell or $160/km^2)

The purpose of providing costings was to make people aware of limitations to certain control methods rather than provide a strict budget to be spent.

A couple of scenarios were run at the workshop so that participants could see how the model worked, and also to show simplistically how the feral animal populations change over time following the implementation of a control method as well as how the population moves within the landscape through the wet and dry seasons.

7.2 Outcomes

The participatory agent-based model proved to be very effective in engaging participants in thinking about on-ground feral animal management. The range of options, in regards to control methods available for people to choose from, provided the opportunity for all participants to engage and test ideas, even if some of the control methods didn't appeal to some participants.

Participants were particularly thoughtful throughout the process, appearing to carefully consider their options, and for at least one group, there was animated discussion about what might be the best methods to employ at intricate scales, and for different animals, across their Country.

The option to run scenarios in a model that looks for all purposes like a computer game is effective in diffusing any conflict between participants, and is empowering in that it allows participants to determine their own preferred methods for control. At no point during the workshop were concerns raised by any party when a control scenario was run that in 'real life' may have caused heat or conflict, even to discuss. These simulations provide the opportunity to test ideas in a safe environment, in this case feral animal control measures, before implementing them in the real world. This allows for potential problems or issues to be identified and rectified before being undertaken in a real sense.

8. RECOMMENDATIONS

8.1 Conceptual model for future negotiations

The team is aware of the efforts already made by Park staff to undertake effective consultation with Bininj living both within and outside Kakadu National Park. There are however issues with the current process of engaging Bininj in feral animal control – which is why Kakadu National Park has sought, through a consultancy, the development of a conceptual model for future negotiations in the Park.

A conceptual model will serve several purposes. Its overarching aim is to build trust in the construction and delivery of a feral animal management operations manual that responds directly to both the values and interests identified by Bininj, and the identified natural and cultural values of Kakadu National Park.

The consultations undertaken for this consultancy revealed that many Bininj are not happy with current consultation and engagement by the Park in regards to feral animal management. Future negotiations should evolve to provide opportunities for Bininj to drive feral animal management, including monitoring, within the Park. This might facilitate buy-in to the process of feral animal management and lead to more positive engagements between Park staff and Bininj around this contentious issue. This conceptual model supports the participatory development of feral animal management strategies with Bininj, tailored to individual sites of high value, and the participatory development of clear communication and consultation guidelines, backed by a comprehensive communications database.

1. The development of a feral animal management operations manual will be based on information gathered through a series of workshops and consultations with Bininj from each clan group as well as Park staff. These consultations will seek to:

a) Identify the key values and assets that Traditional Owners would like to see protected, retained or recovered from feral animal damage or presence, and

b) Identify the key values and assets KNP has obligations to protect as a World Heritage park.

Values identification and their mapping is likely to have been undertaken on several other occasions, including for the consultancy report by Robinson *et al* 2005. Previously gathered information should be used wherever appropriate to ensure duplication of effort is minimised. This concern was raised by a participant in the workshops undertaken for this consultancy.

2. This information will be recorded and documented in a multi-stage process that involves the spatial mapping of key sites to be protected– and a description of the concern or damage at each of those sites. This information will be used further by Bininj in identifying key indicators that will measure the success of the management

program. These indicators will be used to measure 'health' of the values and assets in a participatory monitoring program which will be discussed further.

3. Following the identification of keys sites of value, a process of prioritisation of sites for animal management should occur. This is a good opportunity for both Park staff and Bininj to recognise that there are limited resources both now and in the future for the control of feral animals – so management efforts will have to be strategic and focussed. It is important for everyone to recognise that the new way of managing feral animals in the Park will be via an adaptive management framework whereby management efforts will be monitored and regularly reviewed jointly by Bininj and Park staff. Changes to management efforts will be made according to a predetermined time-frame (possibly annually to begin with to build trust in the process) based on the performance of indicators and whether objectives are being met.

4. After revealing the range of options and cost of each option, each stakeholder (both Bininj and Park staff) will identify the preferred methods for protecting/managing these sites through feral animal management and control, clearly identifying:

a) Which animals are to be targeted at each of those sites;

b) How those animals are to be managed at that site, and

c) Unacceptable modes or methods of management.

5. A GIS database, linked to the agent-based model, should be built that clearly sets out the process of engagement for each individual management/value site. The following information should be recorded in close partnership with each of the custodians identified for each of the management sites. Such a database might include, but is not limited to:

a) The name of the Traditional Owner or KNP staff member who is identified as the 'custodian', who makes decisions for that site;

b) Details about the best way of communicating with that custodian:

- Method of contact (phone, in-person etc);
- Who that custodian prefers to be contacted by (e.g. Senior staff member only; specific staff member who they have a good relationship with);
- Specifics relevant to that custodian that are often lost with Park staff turn-over ('corporate knowledge') e.g. best times of the day for contacting that person; where people might be found if not at home; other people that can be contacted to find out where they are;
- The extent to which Parks staff will continue to attempt to contact each custodian under different scenarios and the chain-of-command the decision making process should follow under each scenario. For example, the decision of feral animal control might fall to the Park Manager if there is perceived to be immediate danger to life or infrastructure at a particular site. If the Park Manager is not available immediately, the delegation for decision-making moves to the identified feral animal operations manager;

- The identification of a back-up contact might be appropriate if a decision has to be made with urgency. Such instances will need to be carefully listed and agreed upon by all parties, and
- The time frames for contacting and reporting should be identified in the database. For example: What time-lag for reporting back to custodians is appropriate for different scenarios? In what instance does the custodian want immediate reporting?

It is crucial that this database is regularly reviewed and updated as information changes, for it forms the crux of all negotiations in regards to feral animal management in the Park.

6. A central point should be identified that is used by all Park staff to lodge details of communications and attempts to communicate with custodians about feral animal management. This idea should be progressed through discussion with custodians, to ensure they are aware of the steps the Park is taking to ensure future consultations and communications about feral animal management are prioritised. A template within the communications database might be appropriate – and should be readily accessible to all staff involved in the feral animal management program. The Park might also wish to consider designing a calling card or something similar that can be left at a place of residence when a custodian is not home. This should provide details of who called, in reference to what, and a number to contact.
7. A participatory monitoring program will be an integral part of new feral animal control and management. The monitoring program will be developed in close coordination with custodians, with a two-fold aim:

a) To ensure the custodians are engaged consistently in the feral management and control program and in doing so create a sense of ownership and control over the process, and

b) To provide an opportunity for custodians to be actively involved in assessing the success or otherwise of management strategies for their specific sites and be best placed to make recommendations in the adaptive management cycle.

c) The participants will be encouraged to develop their own indicators to measure the health of a site over time, as well as the objectives, targets and performance criteria that will measure the success of site-specific management and control methods.

8. Annual adaptive management workshops will form a key part of the management cycle, providing opportunity for custodians and Parks staff to reflect on what they think has worked well, and how management techniques at each site might be improved. These workshops will also provide an opportunity for KNP to directly measure how well they are meeting their ‘feral management’ aim in the Kakadu Plan of Management 2007-2011. That is: through control programs developed and implemented in consultation with Bininj, the adverse effects of domestic and feral animals on the natural and cultural values of the Park, and on human safety, are minimised

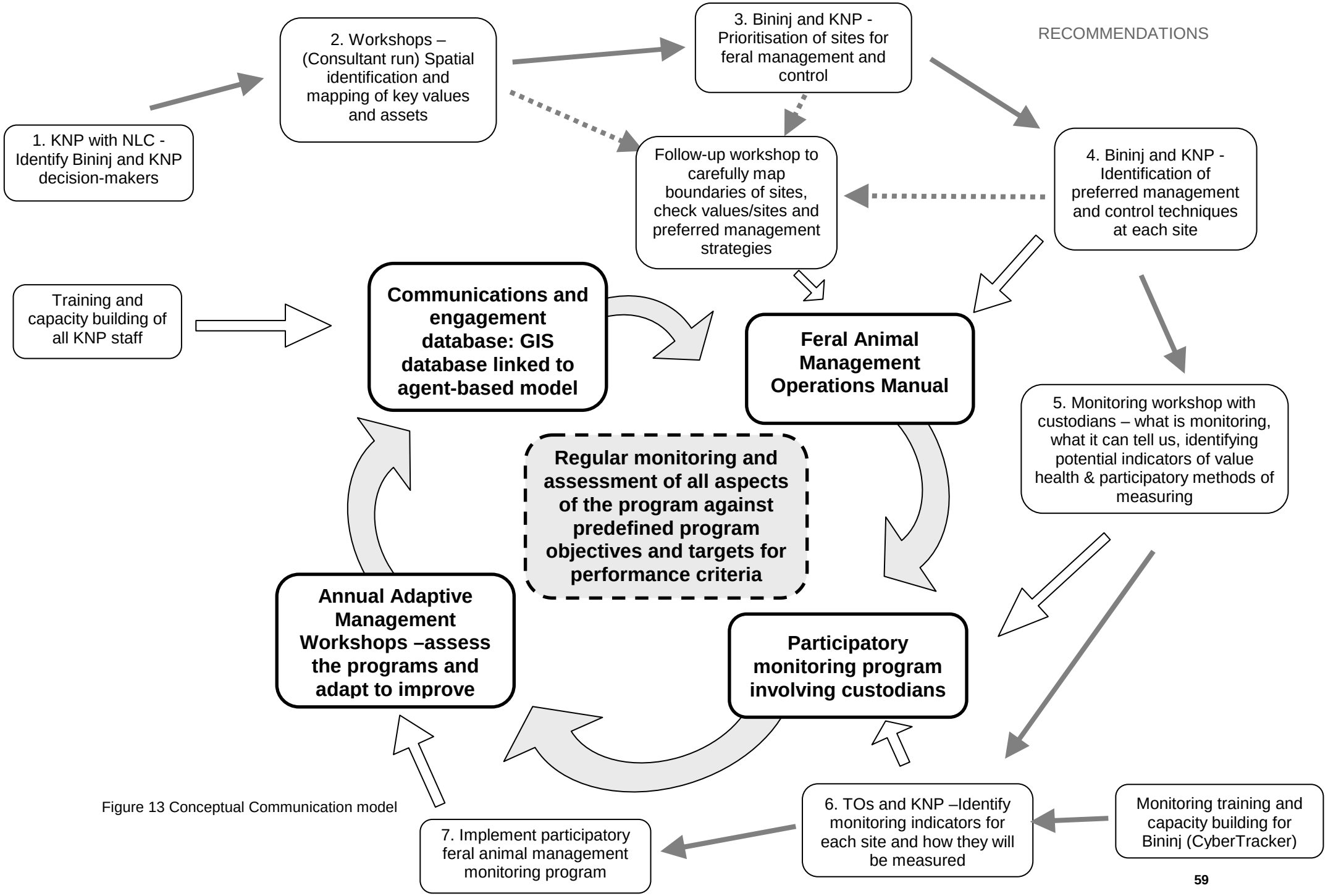


Figure 13 Conceptual Communication model

8.2 Secure a specific and strategic allocated budget for feral animal management

Sustained funding is a necessity to allow for strategic planning, engagement, consultation, management and control, monitoring, evaluation and reporting on feral animal management in the Park. There should be a minimum 3 year investment to undertake the initial phase of developing a feral animal management operations manual. Following this start-up phase, funding should be allocated on seven year cycles, reflecting the duration of each Kakadu Plan of Management.

Specific, strategic funding should be dedicated to both 1) the process of stakeholder engagement and participation and 2) feral animal management and control activities.

There should be an annual review of the feral animal management program, with the aim of ensuring an adaptive management framework is being followed.

Spending on feral animal management in the Park should be strategically reviewed every 3 years, in the middle and before the end of each Plan of Management.

8.3 Develop and implement an operations manual for undertaking feral animal control and management in the Park.

Kakadu National Park's Plan of Management (2007-2014) covers information about feral animal threats and issues, but is not supported by operational detail. The development of an operations manual specific to feral animals will be a significant undertaking that will require an initial start-up investment over a 3 year period. This would be a dynamic document for directing and informing all future feral animal operations in the Park. The expertise of the Kakadu Regional Advisory Committee (KRAC) should be drawn on extensively during the development and ongoing implementation of the manual.

The development of an operations manual will involve all stakeholders in a participatory way. The current Feral Animal Strategy could be reviewed and rewritten to include the following key elements to make it useful in an operational sense:

i. The relationship between feral animal densities (numbers) and damages. This information is key to determining what management and control effort is required to reach the acceptable level of damage for a certain value. If this research information is not available it should be prioritised by the Park.

ii. The goals and objectives of identified feral animal management and control activities. These activities will have been identified through a series of four participatory workshops run by external consultants with Bininj, as identified by the Northern Land Council, and Parks representatives. All stakeholders will participate in a process of 1) identifying priority sites for management; 2) identifying the values at each of these sites that require protection from damages, 3) appropriate management and control activities at

each site, and 4) indicators for measuring change at each site. Damages can be measured and monitored in a number of ways, and the Kakadu Research Advisory Committee (KRAC) should be engaged throughout this process to provide scientific expertise and advice.

iii. The performance criteria that will be used to measure success of feral management activities including 'engagement'

Integrated within the new operations manual will be:

i. Directions on the process of engaging and communicating with stakeholders within and/or external to the Park, and

ii. A rules-based approach to dealing with complex issues in the park, including but not limited to:

- Hunting in the Park by external parties
- Contractual arrangements for engaging feral animal control businesses and individuals
- Human safety and the protection of infrastructure from feral animals
- Clear guidelines on the chain of command and points of escalation when Staff are dealing with issues of complexity or uncertainty

A rules-based approach clearly sets out how key issues, which have caused contention in the past, will be approached and dealt with by the Park. The rules will be formulated together, by Bininj and Park staff in a facilitated process.

Currently the process and guidelines for Park staff to make decisions about feral animal management in diverse situations are weak, uncertain or non-existent. In contrast all Park staff should feel safe and confident when working according to clear guidelines agreed on by all relevant Park stakeholders.

8.4 Develop and implement a Park-wide participatory monitoring program

Bininj should be encouraged to monitor the results of feral animal management control on their country, to build a sense of ownership in the process. A consultant-run workshop should be delivered on community-based monitoring programs. Bininj should be encouraged to identify the indicators they will use to measure change at their management and control sites. Methods for measuring change will be identified by participants with assistance from monitoring specialists engaged by the consultant. Participatory methods might include the construction of 'photo points' and other non-onerous ways of measuring change. The use of I-Tracker is on the rise by Indigenous land and sea management groups in Northern Australia and should be investigated as an option for recording spatial information as part of an integrated Park-wide program (Ansell and Koenig 2011; http://www.nailsma.org.au/projects/i-tracker.html).

8.5 Three year investment in a 'new' dedicated full time (equivalent) position

This position is necessary to assist in: 1) the development of an operations manual for feral animal management in the Park, 2) the implementation and facilitation of a community-based park-wide monitoring program, and to 3) build and maintain a feral animal management communications and operations database. The candidate should operate at an AO5/6 level. There should be a focus on appointing someone with proven performance in working with Indigenous people in a joint-management arrangement.

8.6 Staff training and skills development

The capacity of Park staff needs to be built in negotiation and conflict-resolution. Training should be sought from operators qualified in dealing with complex multi-stakeholder negotiations and not work-place conflict (which tends to be the focus of internal Government training programs).

Skills in workshop facilitation should also be strengthened. The consultant engaged to run the series of 4 workshops should have included as part of their brief – to provide a training component for junior and mid-level staff.

8.7 Progress participatory agent-based modelling as a key communications and data management tool

Further SimFeral model development is needed because contrasting scales are required to resolve differences in feral animal control objectives between Bininj and park management. One scale is at the "park-wide" resolution and, hence, the 25km^2 grid cell should be adequate. In contrast the other scale needs to be fine enough to help resolve local issues and may require a 1 km^2 grid cell or less. Instead of developing SimFeral at two different grid resolutions, however, we recommend one of the following options: (i) employ a software engineer to couple the SimFeral model to Google Earth with its zoom-in/zoom-out capability, and with the park GIS; or (ii) transfer SimFeral to an alternative ABM platform called "Repast-Simphony" (see North *et al.* 2006 & North *et al.* 2007), which already has the capability to link to GIS including remote sensing captures (with zooming facility) and, apparently, it requires little programming skills.

Until these enhancements are undertaken, however, users will be reliant on the Cormas modelling platform to underpin the MSE approach for feral animals, and this would require user skills at two different levels. For proficient use of Cormas during further participatory workshops we recommend that a few key park staff undertake the HEMA (www.hemaconsulting.com.au) 5–day course, which includes training in participatory community-based modelling skills. For more advanced model development, such as coding the systematic inclusion of additional and more complex management scenarios, we recommend that Anne Dray (HEMA Consulting Pty Ltd) be retained as a consultant. Suggested budget elements to fulfil these recommendations:

- Engage Anne Dray (ex-CSIRO) as an expert and reliable consultant for further model development (programming up to 60 control scenarios), to be undertaken via email/phone with Mim Jambrecina (estimated cost $5,000).
- Peter Bayliss (CSIRO) to provide training to a few Park staff in use of the SimFeral model to a standard sufficient for further participatory feral animal workshops.
- A follow-up participatory modelling workshop at KNP facilitated by Emma Woodward and Peter Bayliss (CSIRO), and to commence co-development of an operational manual (estimated cost $11,500).
- Presentations to the Kakadu National Park Board of Management and Kakadu Research Advisory Committee (estimated cost $9,800 including salary & travel). Costs can be minimised by timing this with future NERP Northern Australia Biodiversity Hub (NABH) projects on KNP.
- Transference of the SimFeral ABM to a more sophisticated modelling platform with GIS capability. This could be achieved as part of future NERP Northern Australia Biodiversity Hub (NABH) projects on KNP.

Total budgeting requirement for modelling: approximately $26,300 (or less).

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APPENDIX A – INTEGRATION OF EXISTING DATA AND MODELS

Background

Considerable investments have been made by Park management over the last ten years to develop effective planning tools for feral animal management at both strategic and operational levels. For example, the development of a Management Strategy Evaluation (MSE) modeling tool to simulate and compare alternative control scenarios, the implementation of systematic aerial surveys to monitor the distribution and abundance of large ungulate pest species and their associated ground disturbance damage, and the use of data loggers linked to GPS trackers during helicopter shoots across the park. However, the integration of existing tools and data systems into an effective overall assessment tool, such as the participatory Agent-Based Modeling (ABM) framework, is currently severely constrained by a number of incompatibilities resulting in bottlenecks and fatal delays. The planning tools were designed independently of each other and, hence, their lack of integration means that the overall performance of current control programs cannot be adequately assessed. Therefore the aim of this section of the report is to identify the technical constraints to effective integration and to recommend solutions. Specifically we examine: the STAR model; the aerial survey monitoring program; and the helicopter-based culling program. Minimal investment would be required to address each of the recommendations.

The STAR model

The STAR (Spatio-Temporal Animal Reduction) ExcelTM spreadsheet model was developed by Charles Darwin University (McMahon et al. 2010) to underpin the operational management of large ungulate pests, and was part of a broader contract to help implement a strategic management plan for feral animals on KNP (Whitehead et al. 2002). The model is a simple and spatially coarse MSE tool based on scenario simulation, yet unlike more sophisticated MSE tools used in fisheries and wildlife management, it does not address model uncertainties. It comprises the following two linked sub-models for pigs, buffalos and horses; a theta-logistic population growth model as a first approximation to capture population dynamics after density reduction (i.e. recovery rates); and a negatively exponential control-cost function ($ cost/kill vs. density). However, a complete bio-economic model would include a linked damage-density function used to establish control targets based on social-cultural values and acceptable levels of damage to those values.

McMahon et al. (2010) attempted to address the lack of explicit pest abundance-damage relationships by incorporating a relative “management vexation index” for each cell, whereby control can be spatially prioritized based on a combination of perceived damages and stakeholder sensitivities to culling (e.g. in areas of high tourist visitation). This priority layer apparently then modifies the cost-benefit scores on which their optimization routines are based, although they do not explain how this is done. They state also that “an index of landscape-scale damage caused by feral animal populations within KNP (e.g., spread of weeds, over-grazing,

soil compaction, topsoil disturbance) was compiled from various consultations with KNP rangers, administrators, Traditional Owners and others familiar with the Park". Unfortunately, in both versions of the STAR model, cells in the "vexation index" map layer have all been set to 1 (medium), indicating that no link has been made to the information that they and others in their project team (see Whitehead et al. 2002; Robinson and Whitehead 2002; Robinson et al. 2005) compiled on damages. Additionally, the coarse level of spatial resolution used (10km x 10km cells; 100km2) in their model may be insufficient to adopt this approach as it would likely encompass a huge diversity of damages and sensitivities to different control methods. Until the present consultancy, however, the critical and explicit link between social-cultural values and feral animal abundance has been lacking, as highlighted by Bradshaw et al. (2007).

Key model parameters such as maximum rate of population increase (rm) and habitat-specific carrying capacity for the three species of interest were derived from the literature. Hence, whilst the general modeling approach and parameter values were reviewed in detailed by Hone (2007) and found to be adequate, the model has never been calibrated to local conditions and, no assessment has been made of its operability (apart from the fact that it's currently unusable). Hence, although not explicitly part of this contract, park management asked that the model be evaluated.

Evaluation

- The STAR model is potentially a very useful addition to the participatory ABM approach adopted in the current contract to manage feral animals on KNP. However, its utility is severely constrained due to current technical problems highlighted below, some of which have already been addressed in the ABM developed here.
- There appear to be two 'official' versions of STAR and each gives very different results using the same model inputs. One version (v1) was delivered to KNP at the completion of the CDU feral animal contract, and the other (v2) is a version published on a web site by the model developers (McMahon *et al*. 2010). Using pigs as an example and Scenario 1 (no cull), v1 estimates 93,000 park-wide at carrying capacity. In contrast v2 starts off with 12,000 pigs which increase to 90,000 after 15-20 years. There appears to be no connection between carrying capacity and initial density in v2, and initial density is where one would expect to incorporate current values. The initial value of 12,000 pigs, while possibly a more realistic park value, suddenly appears from within the program and without explanation. Additionally, buffalo and horses have the same imposed no-cull starting value of 12,000 as that for pigs, which doesn't make sense.
- The version left with park managers (v1) is probably the correct version because the starting population sizes of each species can be determined by habitat-density settings, even though they are likely inaccurate by a factor of 10 (see Table 4 below). Unfortunately v1 is locked so the habitat-density estimates based on the 2008-2009 aerial survey results cannot be incorporated. Hence, v1 cannot be calibrated or revised with new information, which is a fatal constraint.
- The unlocked version (v2) is the one posted on the web, but unfortunately gives nonsensical results as described above. I've examined the program code and cannot determine how the 12,000 starting value is derived.

- If the above technical problems can be resolved the model would be more useful as an operational and strategic planning tool if it allowed managers more realistic options, such as:
    - Culling at different time intervals rather than annually, which is unrealistic given budget constraints.
    - Incorporating multi-species helicopter shoots (realistic) and/or alternative ground-based control methods (e.g. mustering, exclusion fences, trapping in forest habitats etc).
    - Visualising control at a finer spatial scale. Operationally the broad 100 km^2 cell size is almost useless except as an iconic symbol of KNP. The 25km^2 cell size used in the ABM model is probably a more practical operational scale at District and Park-wide levels (although a 1 km^2 cell size would better suite local issues).
    - Assessing control performance against the condition of spatially-explicit natural and cultural values, and/or the extent of visible ground disturbance damage. Whilst an attempt has been made to address this critical management need via the "vexation" index it appears to be unfinished.

These options would not require cost-prohibitive re-programming and could be something to aim for. In its current form the STAR model has limited utility.

- The models' utility would be greatly improved if the following were also addressed:
    - Uncertainties are not accounted for in any form, hence simulation results could be misleading. This is standard practice in fisheries and wildlife MSE modeling.
    - The model is underpinned by habitat-specific carrying capacities obtained from the literature and attributed to four main habitat classes (Floodplain, Paperbark woodland, Savanna woodland & Forest). The proportions of these habitats on the park were re-estimated (see Table 6 below) using a high resolution vegetation map, and the model should be re-calibrated with these local estimates of habitat-specific densities.
    - Seasonal shifts in distribution and abundance between floodplain and adjacent terrestrial habitats should be explicitly incorporated (as done in the ABM).

Recommendations

- The two versions of the STAR model should be reconciled. The correct version would need to be thoroughly 'road-tested' and verified for utility by park staff. If necessary an independent review of the utility/operability of the spreadsheet program should be obtained (i.e. in contrast to the Hone 2007 review of model parameters – note that he did comment the model was locked & so code could not be checked).
- The STAR model developers should be approached to rectify the problems identified above, and to calibrate the model to local conditions using more appropriate starting values (e.g. the latest survey data). That is, they should be encouraged to finish model development, particularly the apparent ability to link to perceptions of damage, or provide park staff with clear instructions on how to do this.
- The suggestions in the last two dot points of Evaluation above should be adopted in order to improve the models' capability before use.

- Future consultancies involving model and software development should incorporate detailed specifications and performance criteria in contract deliverables.
- Hone (2007) suggested that the r_m value of 0.34 p.a. for pigs is grossly underestimated and we agree. Whilst this value approximates what would be expected based on body weight (Bayliss and Yeomans 1989a), the literature values cluster around 0.60 - 0.80 p.a. Hence, the STAR model most likely underestimates recovery rates for pigs and therefore overestimates control efficiency in simulations (see Hone 2007). We recommend that r_m values specific to KNP for each feral species be estimated as part of an integrated design of the monitoring surveys and control operations (i.e. post-control recovery rates).

Aerial surveys

The standardised fixed-wing and helicopter aerial survey methodologies are described in detail by Tracey et al. (2009) and are generally consistent with methodologies used in previous surveys on KNP and across the NT (Bayliss and Yeomans 1989 a&b; 2001-2003 Saalfeld & Bayliss unpubl.). All fixed-wing surveys used the same basic survey design (systematic sample transects flown east-west) and same aircraft altitude and speed. Observers counted on opposite sides of the aircraft and their counts are summed to provide total counts along transects. Sampling intensity (& hence precision or standard error of estimates) depends on transect spacing and for KNP surveys fall between 8% and 20%. Visibility bias and associated correction factors (CFs) to convert observed counts to absolute counts were estimated for each species using the "double count" technique. However, there are important differences between all surveys in the method used to record and process data, and are detailed below because they explain the current survey data "bottleneck".

Evaluation

- Observers in the Bayliss and Yeomans (1989a&b) fixed-wing aerial surveys across the Top End of the NT, including KNP, continuously recorded the following information onto data sheets on a transect-unit basis: counts of species groups; their group sizes; and the habitat they were observed in (open floodplain, & open & dense woodland). Transect units along transects were defined by an electronic timer-beeper, and were the same distance as transect spacing facilitating the mapping of distribution and abundance on a uniform grid (e.g. a 2 km transect spacing yields a 2 km 2 km = 4 km^2 grid). Data were stored on a database and analysed immediately after each survey, with results available within days. Habitat-specific detection probabilities (visibility bias) could be directly estimated for each species because habitat class (based on percentage canopy cover) associated with each observation was recorded (see Table 2). Visibility correction factors were applied to groups and the corrected number of groups multiplied by mean group size. Bayliss and Yeomans (1989a) argued that this procedure is equivalent to applying CFs to individuals, although groups are the actual 'sighting entities' used in the double count model.
- Observers in the Saalfeld and Bayliss 2001 and 2003 (unpubl.) fixed-wing aerial surveys on KNP recorded data onto continuously running tape recorders with a time stamp (e.g. species, group size & habitat sighted in). The location of observations along transects was determined by an algorithm that matched the time stamp with mean aircraft speed (developed by K. Saalfeld). Data transcription took one person approximately six months

part-time, with transcription time being more than three times that of actual survey time (~200 hrs). However, for management purposes, only distribution and abundance maps and population estimates for District strata were required. Hence, despite the massive amounts of location information capture on tape and the huge amount of processing time involved, only counts summarised on a transect-unit basis were necessary. Nevertheless, habitat-specific visibility bias and associated CFs could be estimated directly, and were most likely slightly more accurate than using transect-unit data because of the instantaneous nature of tandem observer counts. Regardless, the long delay between survey and application of results due to processing and filtering superfluous information was a much greater issue.

- Observers in the Tracey *et al.* (2009) fixed-wing aerial surveys on KNP used data loggers (a laptop with a custom key pad) or continuous tape recorders connected to a GPS. However, whilst this system provided the greatest location accuracy of observations along transects, only a limited amount of information could be collected. The critical omission is that habitat data associated with observations could not be recorded and, hence, habitat-specific CFs could not be directly estimated for each species, affecting accuracy of results. This is an important issue when comparing pre- and post-cull surveys if surviving animals use denser cover as it would result in an overestimate of reductions. The current data recording system trades-off critical habitat occurrence data for location accuracy of observations along sample transects that are simply not required and of dubious value. For example, feral animals are highly mobile and would not occupy exactly the same position at different times of day and between days. The real location accuracy of observations is also in-determinant as the observer field of view is 200m or more regardless of the accuracy of the GPS, and this on top of animals flushing. In summary it's a mystery why precise location data are collected on 'sample' observations at a sacrifice to collecting more relevant information, and with the associated burden of greatly increased processing time. In conclusion, observed counts from these surveys can only be corrected for visibility bias averaged across habitats (see Table 3).
- The use of multiple transect width markers by Tracey *et al.* (2009) on the aircraft wing struts to improve the accuracy of double count estimates of visibility bias would not compensate for the lack of habitat data. Additionally, even slight variations in aircraft bank, tilt or roll would introduce unknown classification errors in whether or not observers see the same or different animal groups, nullifying any possible advantage of this complex methodology.

Table 2 Summary of visibility correction factors (CFs) derived from the probability (P) of detecting feral animal groups (buffalo, cattle, horse & donkey) during fixed-wing aerial survey in habitats varying in canopy cover across the 'Top End' of the NT (from Bayliss & Yeomans 1989a&b). Cattle, horses and donkeys were not seen in dense woodland. Detection probabilities for pigs apply to Kakadu National Park (Bayliss et al. 2006 & unpubl. data).

Habitat	Canopy cover (%)	Buffalo		Cattle		Horse		Donkey		Pig	
		P	CF	P	CF	P	CF	P	CF	P	CF
Floodplain	0	0.79	1.27	0.71	1.40	0.68	1.48	-	-	0.50	2.00
Woodland	1 - 75	0.39	2.57	0.53	1.89	0.56	1.78	0.50	2.00	0.20	5.00
Dense woodland	76 - 100	0.13	7.69	-	-	-	-	-	-	0.05	20.00

Table 3. Summary of visibility correction factors (CFs) derived from the probability (P) of detecting feral animals on Kakadu in 2008 and 2009. Estimates were visually derived from Figure 1a on page 19 of Tracey et al. (2009). Values are averaged across habitats and pre- and post culling surveys. Estimates for cattle and donkeys not given.

Buffalo		Horse		Pig	
P	CF	P	CF	P	CF
0.53	1.89	0.48	2.08	0.2	5.0

- In contrast to previous survey designs Tracey *et al.* (2009) did not use a fixed counting transect width (e.g. 200m/observer) but recorded observations in 50m increments out to 200m, then from 200m to 500m, and 500m+ (i.e. essentially boundless). Whilst the precision of the estimates should theoretically be greater with a greater sample area, the bias would be much greater at greater distances from the aircraft, particularly for dense cover habitats. For example, from 200m out the probability of detection would more often than not be zero, meaning that there would be no observed counts to correct. Tracey *et al.* (2009, their pages 15-17) used a modified version of Horvitz-Thompson equations to estimate feral animal abundance, which still requires that the area of the sample unit be defined (in their analysis variable-length transects). However, it is not clear from their report which of the many transect widths available was chosen to define the area of the sample unit (transect). Whilst the complex array of transect widths superimposed on data collection appears more suited to estimating animal abundance using conventional line transect models, this was not done. Hence, it appears that their main purpose was to increase the accuracy of the double count model and, as discussed above, this may be better achieved longitudinally along the transect rather than laterally out from the transect.
- Tracey *et al.* (2009) acknowledged that aerial survey techniques and high-tech data recording methods can be complex and time-consuming activities, both during the survey and in subsequent collation and analysis of survey data. They hoped to overcome these disadvantages by coupling data loggers with a GPS system. Whilst the main advantage of their system is that data can be downloaded rapidly into a GIS and visualized, the assumption that this also equates to rapid analysis for management purposes is misconstrued as is currently the situation. For example, it would be possible to overlay the GPS stamped logged survey data onto a high resolution vegetation map in a GIS and classify double-count observations according to habitat. However, this would be a massively time consuming and complex GIS exercise, and not without new associated errors. This may explain why they did not do this although they undertook other useful

detailed habitat analyses on total observations using the medium resolution Schodde *et al.* (1987) vegetation map of KNP.

- The Tracey *et al.* (2009) GIS habitat analysis of aerial survey observations (Pie charts in their Figure 8 page 27, summarized here in Table 4) was used to derive estimates of buffalo, horses, cattle and pigs after culling in May 2009 based on habitat (Table 5) to compare with post-cull aerial survey estimates. Despite all the technical issues identified above the post-cull results are similar and can be used as 2010 starting densities in a corrected version of STAR. In contrast, estimates derived by v1 of the STAR model are 10 times greater than the pre-cull estimates derived here (post-cull estimate + numbers shot). However, the Pie chart appears to lump all observed data (helicopter & fixed-wing - although difficult to tell from the text) and, ideally, the analysis reported here should only use data for the fixed-wing aerial surveys, and for the left and right rear observers out to 200m. Hence, results need to be verified by a detailed GIS analysis.
- Results in Table 5 were used also to revise the proportion of main habitats used in the STAR model (Table 6) to make them consistent with the Schodde *et al.* (1987) vegetation classification used in the aerial surveys in 2008 and 2009 by Tracey *et al*. (2009).

Table 4. Summary of the percentage of horses, buffalo, cattle, pigs and their associated damage observed in 11 vegetation communities defined by Schodde *et al.* (1987) in Kakadu National Park (from Tracey *et al*. 2009, their Figure 8 on page 27). The area of each habitat and its proportion of the total area of Kakadu (19,109 km2) are shown.

Species	Total N observed	Woodland	Floodplain sedge land	Broad-leaf Shrub	Coastal RF	Pandanus savanna	Open Forest	Paperbark forest	Sandstone	Mixed shrub	Mangroves	Samphire	Total
Proportion		**0.34**	**0.08**	**0.02**	**0.01**	**0.11**	**0.22**	**0.03**	**0.15**	**0.02**	**0.01**	**0.01**	**1.00**
Area km^2		**6,497**	**1,529**	**382**	**191**	**2,102**	**4,204**	**573**	**2,866**	**382**	**191**	**191**	**19,109**
HORSE	737	52	1	0	0	31	12	1	3	0	0	0	100
BUFFALO	142	47	0	1	0	3	5	13	31	0	0	0	100
BUFF DAMAGE	122	36	6	1	1	17	11	3	25	0	0	0	100
CATTLE	74	58	0	0	0	1	15	0	26	0	0	0	100
PIG	115	17	23	0	0	45	3	11	1	0	0	0	100
PIG ROOTING	259	11	47	0.3	6	15	8	11	2	0	0	0	100

Table 5. Comparison between the numbers (N) of feral animals on Kakadu National Park after culling estimated by fixed-wing aerial surveys by Tracey et al. (2009), and that estimated by the numbers observed in different habitats and corrected for habitat-specific visibility bias using the correction factors in Table 3. The pre-cull population estimates were derived by adding the number shot to the post-cull survey estimates. A comparison of numbers estimated by habitat for the STAR V1 model is shown also.

Species	N before cull	Numbers shot	% Reduction	N estimated by survey	N estimated by habitat	STAR
Pig	11,779	7,029	60	4,750	4,183	93,000
Horse	9,917	2,312	26	6,605	9,717	94,000
Buffalo	2,664	840	32	1,824	2,653	219,000
Donkey	314	167	53	147	-	-
Red cattle	1,717	78	5	1,639	-	-
Braham cattle	406	18	20	388	-	-
Total cattle	2,192	96	25	2,027	1,054	-

Table 6 Revised proportion of main habitats used in the STAR model that is consistent with the Schodde et al. (1987) vegetation classification used in aerial surveys of feral animals in 2008 and 2009 by Tracey et al. (2009). Colour codes match those in Table 4.

STAR	Habitat	Revised
0.13	Floodplain	0.10
0.11	Paperbark	0.03
0.71	Savanna Woodland	0.86
0.05	Forest	0.01
1.00	**Total**	**1.00**

Recommendations

- With the notable exception of pigs (see next section), the current fixed-wing aerial survey design is a cost-effective means of mapping the distribution and abundance of horses, cattle and buffalos on KNP, different classes of visible ground disturbance damage (e.g. wallows, pig rooting, fouled water etc) and monitoring the performance of control programs on a District and park-wide basis. Additionally, these surveys are compatible with previous surveys, particularly those conducted relatively recently by Saalfeld and Bayliss (unpubl.) in 2001 and 2003, facilitating long-term trend analysis.
- Nevertheless, the methods used to record data are unnecessarily complex resulting in time-consuming processing, and could be greatly simplified to speed up analysis and application of results for management purposes. For example, observers could use traditional pencil and paper recording methods on a transect-unit basis without any loss of critical survey information. In fact, critical information such as habitat occurrence could now be collected. Results could be presented in a matter of days compared to several months of highly specialised GIS formatting, given that no-one would be dedicated full-time to this task. More importantly, the complex data re-formatting required in both Excel and GIS is superfluous because, at the end of the day, the basic management requirements still remain relatively simple, comprising: population estimates of species on a District and park-wide basis; distribution and abundance maps at a reasonable level of resolution as determined by transect spacing (e.g. 2, 3 or 5km cells, the latter being compatible with the resolution of the ABM framework); and a change analysis of visible ground disturbance damage. The high-tech data processing constraints identified above became immediately obvious during the present consultancy when all that was required for the ABM framework were up-to-date distribution and abundance maps of feral animals and their damage. These maps were unavailable despite the cost of the aerial survey consultancy, and to complete our work we did them by hand (i.e. by transferring data from a GIS file after much processing onto a 1:250K topo map, then into an Excel file & finally the ABM).
- However, there may be justifiable reasons to stick with the high-tech methods of data recording and, if so, a GIS specialist should be contracted to ensure that the analysis and presentation of survey results are as automated as much as possible. As highlighted above, this additional cost does not seem to be justified.
- Another simplification would be to abandon the complex array of variable transect widths markers and revert back to using a fixed transect width of 200m/observer, which would be

consistent with previous standardized surveys. However, overall use of the double count method applied to sample units along transects to estimate observer-survey-habitat specific visibility biases should be retained.

- A major constraint to effective evaluation of previous analysis, or even new analysis, was the lack of access to the raw 2008 and 2009 survey data, which were apparently not lodged with the Park at the completion of the consultancy. It is strongly recommended that the consultants be approached to lodge all raw data and analysis notes so that they can be used in future assessments.

The existing survey data should be re-formatted in a GIS to be compatible with the participatory ABM framework developed here that captures other critical spatial information needed for overall assessment (e.g. sensitive habitats, sacred sites, damage not recorded during aerial surveys etc). A start has been made and initial results are presented in Figures 14 to 16. Figure 14a shows the 25 km^2 grid (5 x 5km) over Kakadu and roughly aligns with the grid used in the ABM (slight differences due to curvature of the earth). Figure 14b is the same grid with unique number codes shown. As an example, Figure 15a shows the number of horses observed per grid cell during the 2008-09 fixed-wing aerial survey (data culled to both left & right rear observers & a maximum 200m transect width/observer), and is point-source data extracted from the GPS-linked data loggers. In contrast, Figure 15b shows the estimates of absolute number of horses per grid cell and comprise the distribution and abundance maps needed for the ABM framework. Data were corrected for habitat-specific visibility bias using the correction factors of Bayliss and Yeomans 1989a (Table 2) and adjusted for sampling intensity (either 8% or 16%, depending if 1 or 2 transects spaced 3 km apart traversed the 5km x 5km grid). The GPS survey point data illustrated in Figure 15a were converted in GIS to a polygon layer in Figure 15b by joining with the Grid polygon layer in Figure 14b and choosing the sum option to combine observer counts. Data ranges in both maps were derived by the Jenks algorithm in ArcMap™, which uses natural breaks in the frequency of spatial observations/cell. However, any density class range can be used. Figure 16 shows the distribution of pig sightings and rooting damage observed during the 2008-09 fixed-wing aerial surveys (data culled to left & right rear observers, & to a 200m transect width per observer).

(a) 25 km^2 GRID Kakadu National Park **GRID cell codes**

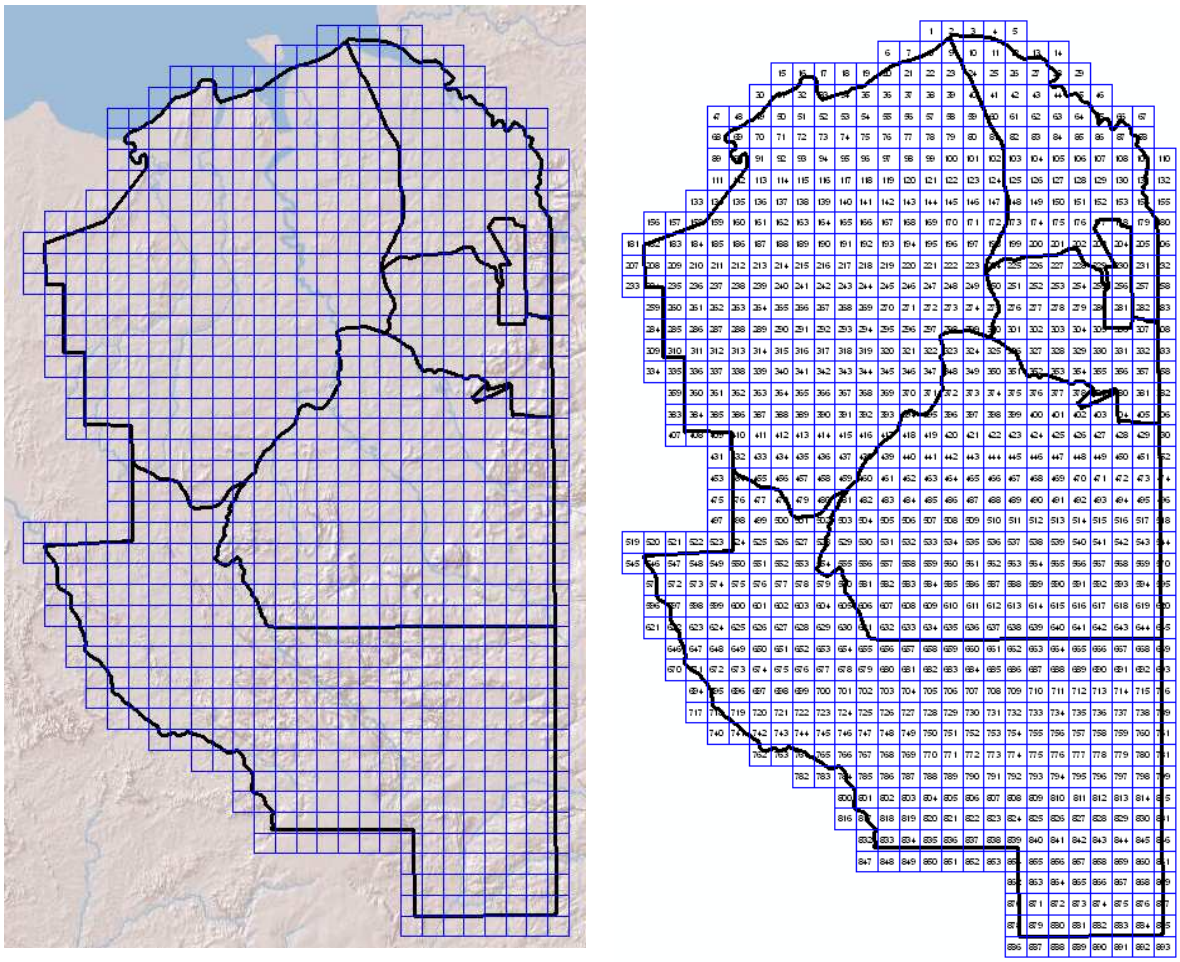


Figure 14 (a) 25 km2 grid over Kakadu National Park and (b) unique number codes for each grid cell. District boundaries and the Ranger Project Area (RPA) and Koongara mineral leases are shown.

(a) Observed number of horses/grid cell 2008-2009

(b) Absolute number of horses/grid cell 2008-2009

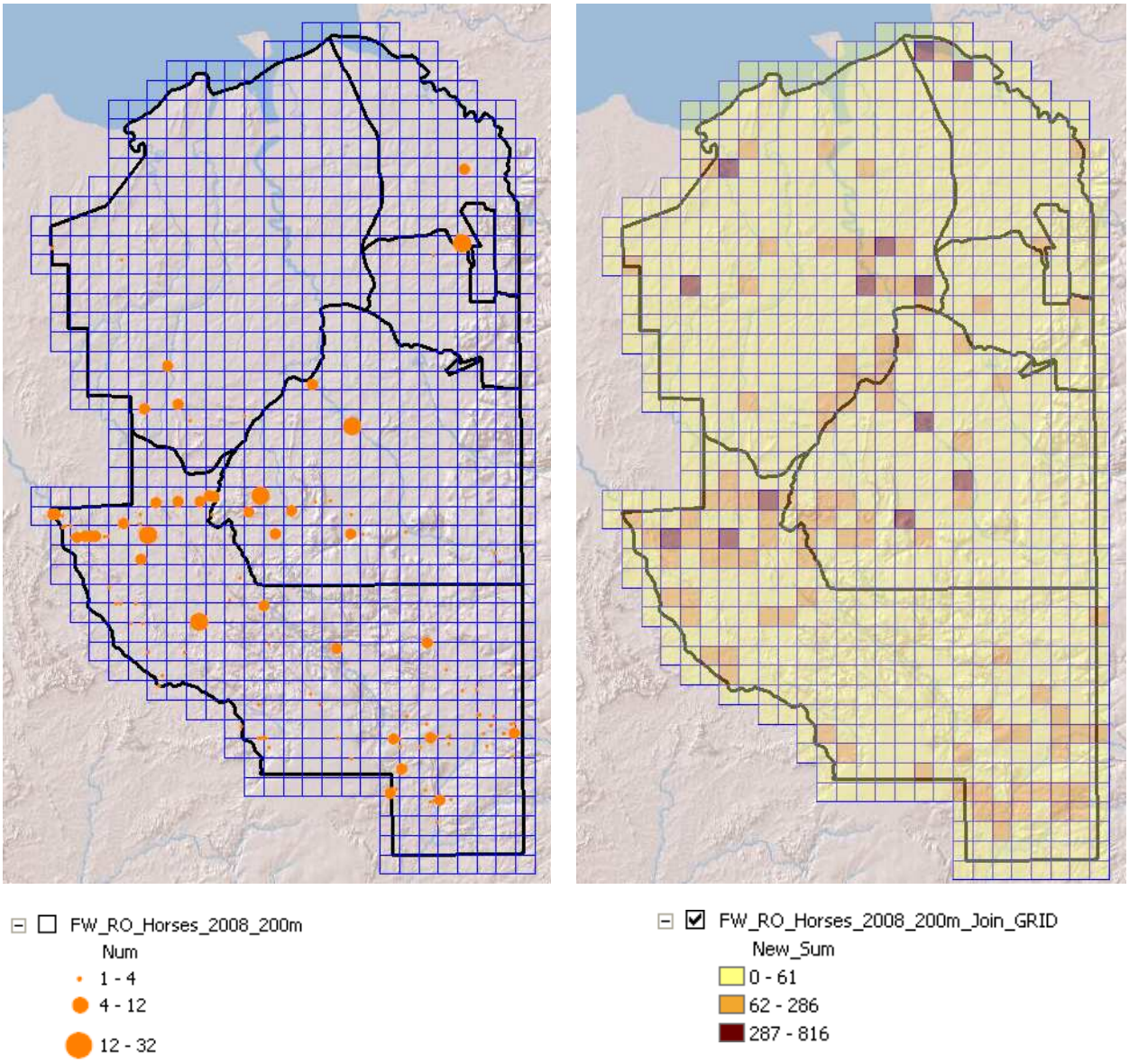


Figure 15 (a) Number of horses per grid cell observed during the 2008-2009 fixed-wing aerial survey (data culled to both left & right rear observers & a maximum 200m counting transect width/observer). (b) Corresponding estimate of the absolute number of horses per grid cell (data corrected for habitat-specific visibility bias using the correction factors in Table 2 and adjusted for an 8% or 16% sampling intensity).

Pig sightings & rooting damage 2008

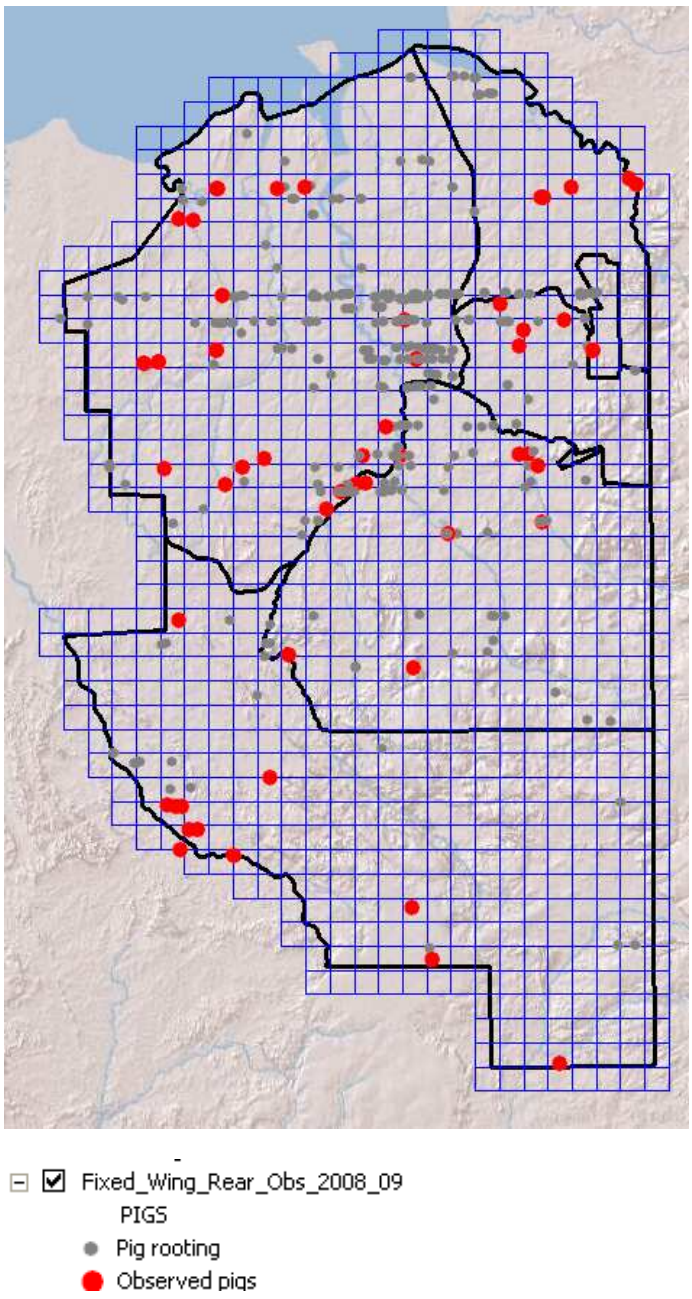


Figure 16 The distribution of pig sightings and rooting damage observed during the 2008-09 fixed-wing aerial survey (data culled to both left & right rear observers using a maximum 200m counting transect width/observer).Culls from helicopters.

Helicopter shooting data

Evaluation

Data collected systematically during helicopter culls of feral animals provide some of the most critical information used to assess the performance of control programs (kills/hr & associated costs, & the distribution of searching & shooting effort). For example, Figure 17 a & b illustrates the control cost functions for shooting buffalo and pigs from helicopters, respectively, and underpin the control scenarios in the STAR model (McMahon et al. 2010). The buffalo shoot data were obtained during a 1986 disease control exercise (Bayliss 1986) in the East Alligator River headwaters in western Arnhem Land, adjacent to KNP, and the pig shoot data apply to the East Alligator River catchment on Kakadu in 1999. Similar cost functions can be derived for any invasive species control program such as weeds (see Bayliss et al. 2006), or for any control method such as ground shooting, trapping or poisoning, or a combination of methods.

Park rangers are now using more sophisticated methods to collect control data during operations, such as the use of data loggers and GPS tracking devices. This is a clear example of beneficial application of new technology, and can only increase the performance of the control program. However, no systematic data processing or analysis procedures were indentified.

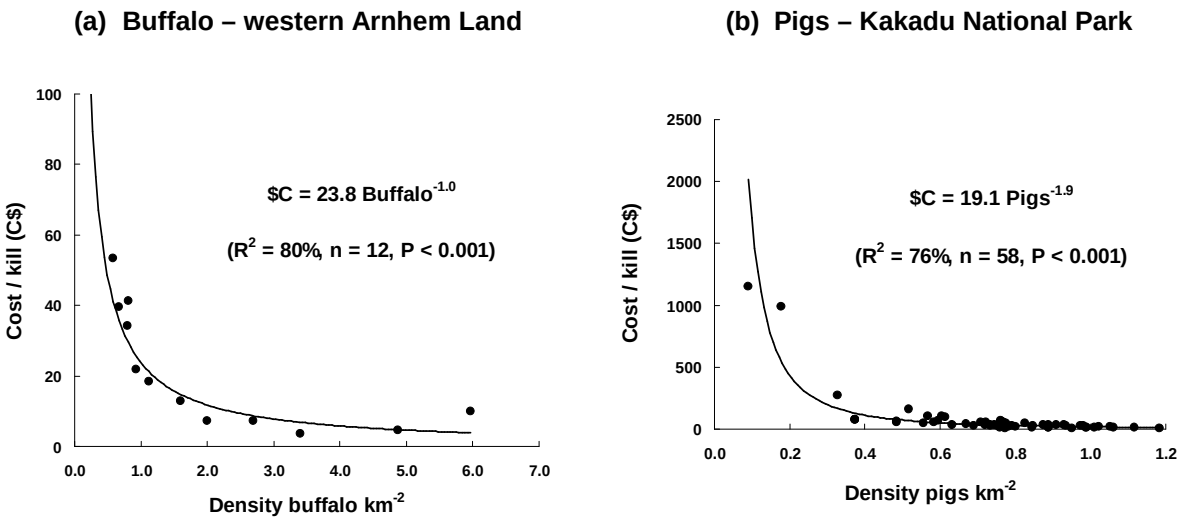


Figure 17 a & b Control cost functions for helicopter shooting of (a) buffalo in western Arnhem Land (Bayliss 1986) and (b) pigs on Kakadu National Park (Bayliss et al. 2006).

Such data can also be used to estimate both the pre-cull numbers of animals in a shooting zone and a more applicable estimate of recovery rate since the last culling operation, providing a better approximation of rm for use in the STAR model. The method is called the 'Leslies catch-out' method (Caughley 1977) and is applicable for closed populations where the rate of new kills is approximately constant (see Fig. 18 below using the same data in Figure 17b above). This method would be particularly useful for cryptic species that are difficult to survey by conventional methods, such as pigs during standard fixed-wing surveys (see above). However, because surviving animals are constantly harassed and shot at their behaviour can rapidly

change in response to culling. When this occurs the rate of new kills stops being constant (linear) and nonlinearity creeps into the relationship between the rate of new kills and cumulative kills. Nevertheless, given sufficient data the nonlinear portion of the catch-out curve can often be discarded. Bayliss (1986) compared the estimates for buffalo and pigs in a valley in western Arnhem Land using a variety of methods, including: fixed-wing aerial surveys corrected for visibility bias; low-level helicopter surveys similar to that used by Tracey et al. (2009); index-manipulation index using pre- and post-cull helicopter and fixed-wing surveys; and the Leslie's catch-out method applied to helicopter shooting and ground shooting data. All methods produced very similar results. Hence, the most cost-effective method was the 'catch-out' method because there were no additional survey costs.

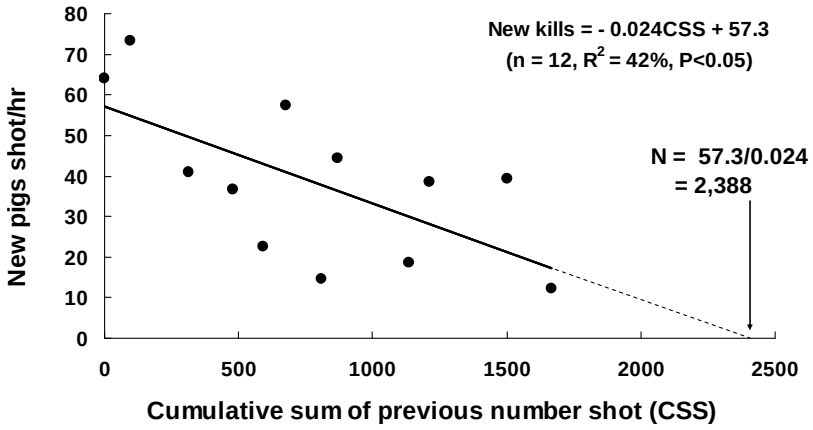


Figure 18 The Leslies "catch-out" method applied to helicopter pig shooting data in the East Alligator River catchment, Kakadu National Park, in 1999. Regression between the number of pigs shot/hour and the cumulative sum of the previous number shot.

Recommendations

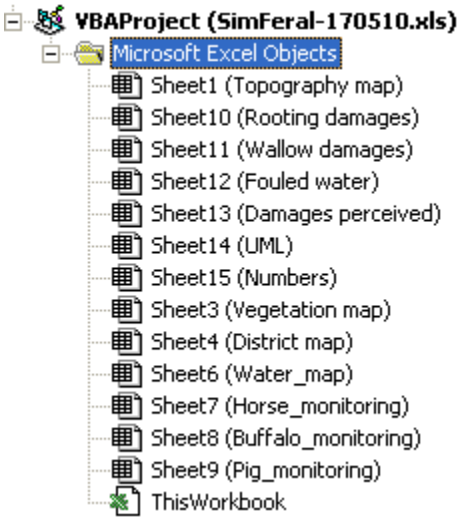
- That a standard data processing and analysis procedure be established so that relevant information can be immediately extracted for assessment purposes, and for incorporation into future iterations of the ABM.
- That the control-cost functions for feral species at Districts/catchment scales are continuously updated with additional new data, and that these are incorporated into a corrected version of the STAR model.
- That both control and survey data are integrated into the participatory ABM framework on a continuing basis.
- Tracey *et al.* (2009) recommended use of helicopters as a pre- and post-culling survey platform, particularly for pigs, because they yielded more accurate population estimates. However, this recommendation should be reviewed in light of the above evaluation of the Leslie's catch-out method.

APPENDIX B – ATTACHMENTS (DATA FILES & SIMFERAL MODELS)

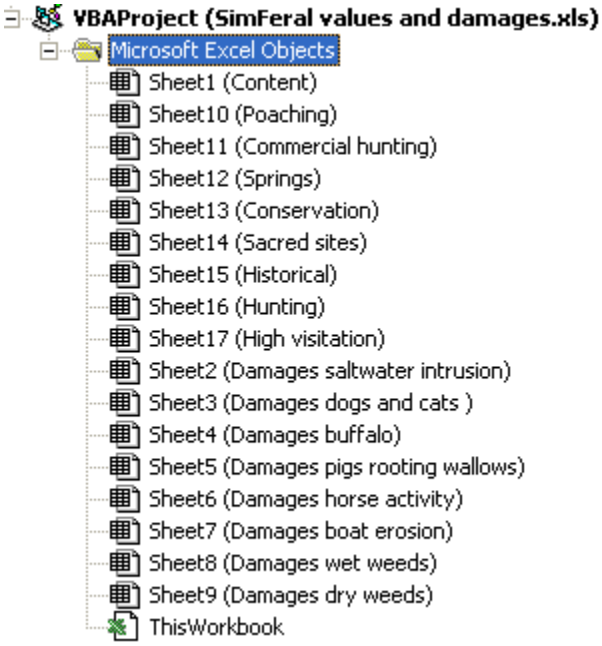
Model input data and custodianship

There are two Excel files attached to this report that summarise existing environmental and survey data, and data elicited during several consultation workshops in May 2010. All data have been consolidated, processed and reformatted as 5km by 5km ($25km^2$) grid cell maps for input and integration into the SimFeral model. These are:

File 1: SimFeral-170510.xls. Data layers on the distribution and abundance of feral animals and their associated 'visible' damage were derived from aerial surveys undertaken in 2008-09 (Tracey *et al.* 2009). Other data such as topography, vegetation and water type were derived from maps and other sources (see below for a list of all spreadsheet names in this file). Sheet 14 (UML or Unified Model Language is the programming code for the SimFeral model developed in Cormas). Sheet 15 is a test of the population and culling models used in the SimFeral model (basically the logistic growth models for pigs, buffalo & horses as described in McMahon *et al.* 2010 for the STAR model).



File 2: SimFeral values and damages.xls. This file contains maps of cultural and natural assets across the Park, perceived damages from feral animals and other threats such as weeds and poaching. See below for a list of all spreadsheet names in this file. This information is confidential and is the Intellectual Property of the Traditional Owners and the Park.



Location of SimFeral model files

Folder: C:\VW7.4.1\cormas\Models\SimFeral

File names: SimFeral_april2011.st

SimFeral_april2011.ev

APPENDIX C – SPATIAL GRID AND COLOR CODES USED IN SIMFERAL MODEL MAPS

Park boundary, Districts and the 5km^2 grid

The spatial domain of the SimFeral model is illustrated in Figure 19a, which shows borders and the five management districts. All up there are seven spatial entities on the park, two of which are mining leases. A 5km x 5km grid (25km^2) is overlaid across the Park, and all environmental and cultural values and assets are characterised using existing data and information elicited through the workshop consultation process. One such data layer is topography (Figure 19b), and exemplifies the spatial resolution of the grid. A total of 766 grid cells encompass the Park (~19,150km^2). The SimFeral model uses a one cell (5km) buffer around the Park to simulate movements of feral animals across a porous park boundary, comprising 146 grid cells (3,650km^2).

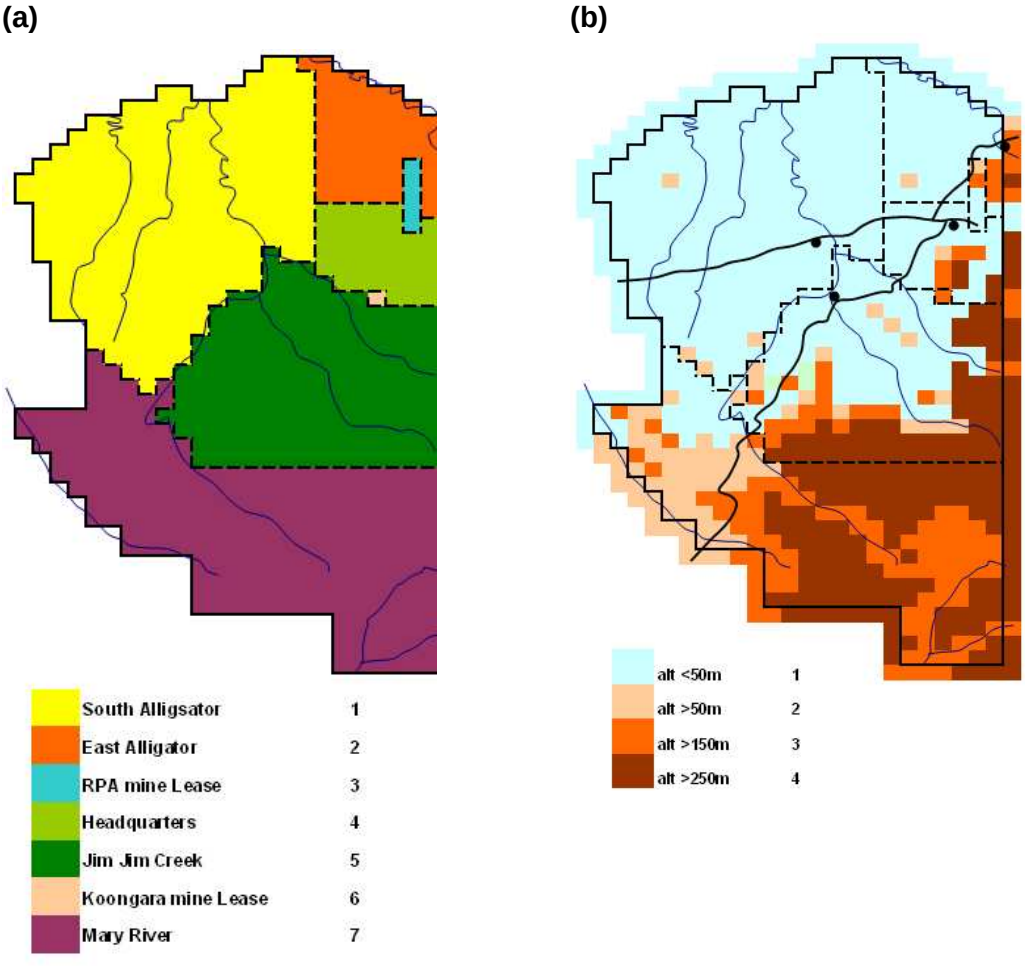


Figure 19 a & b (a) Park boundaries and Districts (mineral leases shown also); (b) topographic map illustrating the 5km x 5km (25km2) grid resolution.

Feral animal distribution, abundance and associated ground disturbance damage

All data layers for feral animal distribution and abundance, and their associated ground disturbance damage, that are contained in both the “SimFeral-170510.xls” and “SimFeral values and damages.xls” files (See Appendix B; p88) were incorporated into the SimFeral_april2011.ev environmental file and are loaded automatically into the SimFeral_april2011.st file when users initiate the model. Figure 20 a-f (photos) show the type of ground disturbance damage associated with pigs (a & b-rooting), buffalo (c & d-wallows & fouled water) and horses (e & f-fouled water & tracks). Figure 21 a & b shows the distribution and abundance of pigs and visible pig rooting damage with colour codes that reflect high, medium and low abundances to aid communication and facilitate participation by users. Figure 22 a & b illustrates the same for horses.

(a) Pig

(b) Pig damage

(c) Buffalo

(d) Buffalo damage

(e) Horse

(f) Horse damage – Mary R District

Figure 20 a-f (photos) (a) Feral pig and (b) rooting damage on seasonal floodplains; (c) buffalo and (d) extensive wallow-erosion damage at Yellow Water in the early 1980s when densities were highest (photo from internet); and (e) horses and their (f) damage to riparian habitats such as tracks, wallows and water-fouling.

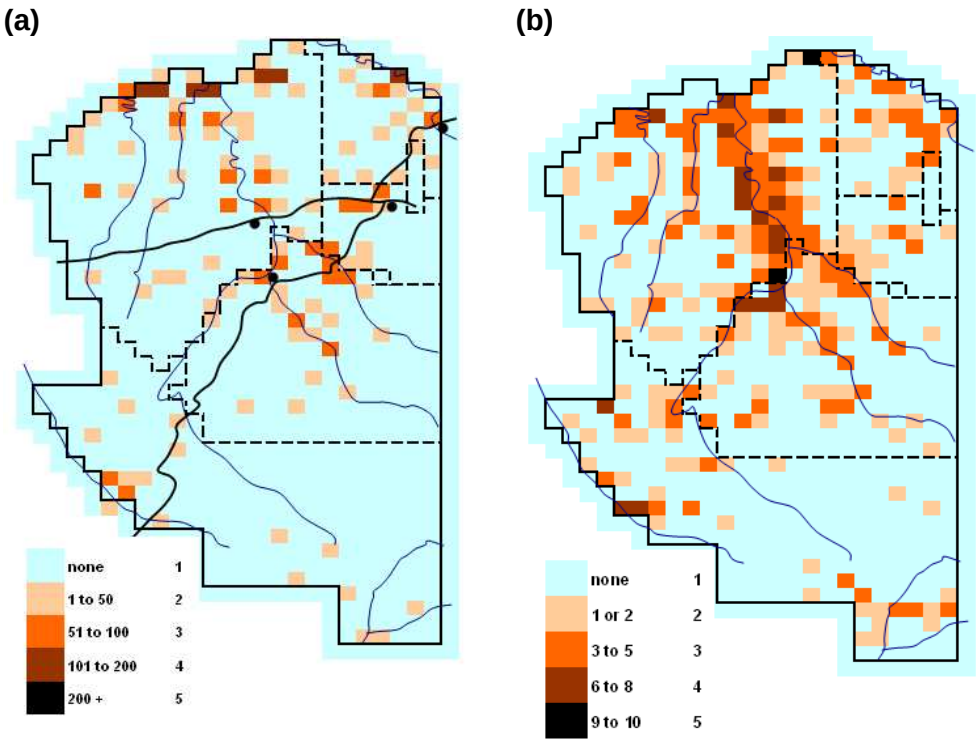


Figure 21 a & b (a) Distribution and abundance of pigs and (b) percentage cover of visible pig rooting damage (aerial surveys in 2008-2009; Tracey et al. 2009 & Saalfeld & Bayliss 2006 unpubl.).

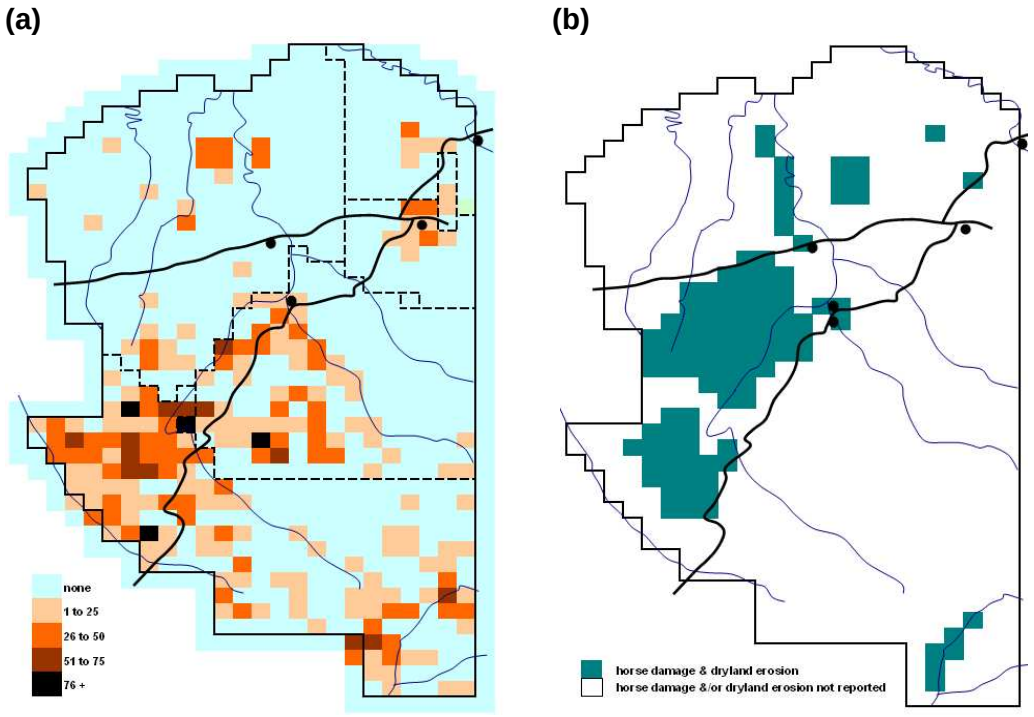


Figure 22 a & b (a) Distribution and abundance of horses and (b) perceived horse damage as elicited during park-wide consultations with Bininj and park staff (this report).

Natural and cultural values

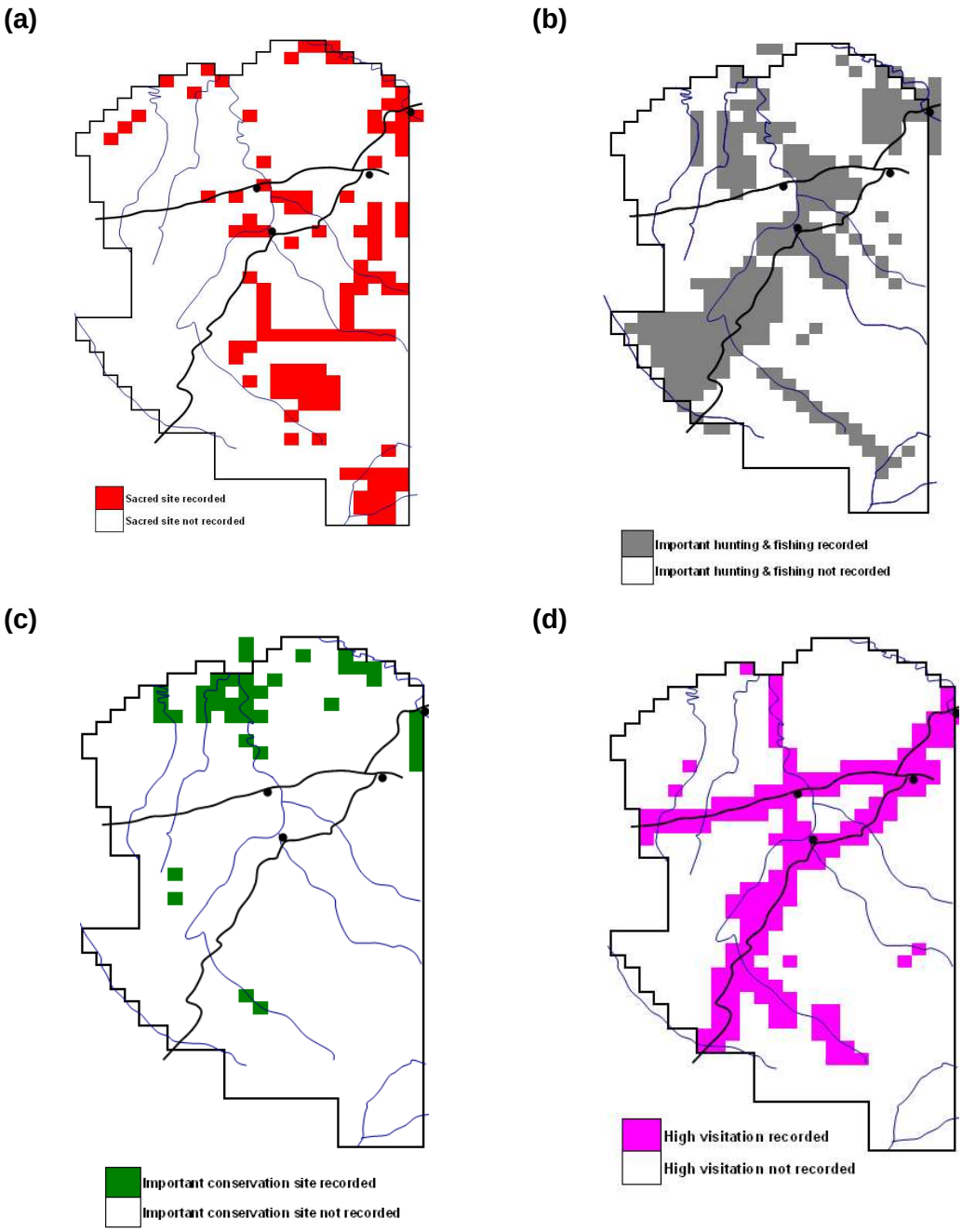


Figure 23 a & d Maps illustrating where: (a) sacred sites have been recorded and not recorded, and similarly for (b) important hunting/fishing sites, (c) important conservation sites and (d) high tourist visitation sites. Data were elicited during consultation workshops in May 2010 (this report). The first two maps are confidential.

All data layers for natural and cultural values that are contained in the "SimFeral values and damages.xls" file (See Appendix B; p88-89) were imported into the "SimFeral_april2011.ev" environmental file, and are loaded automatically into the "SimFeral_april2011.st" model during the initiation process (i.e. selecting the "ini" option). Figure 23 a & d shows where sacred sites have been recorded and not recorded (a) and, similarly, for important hunting and fishing sites (b), important conservation sites (c) and high tourist visitation sites (d).

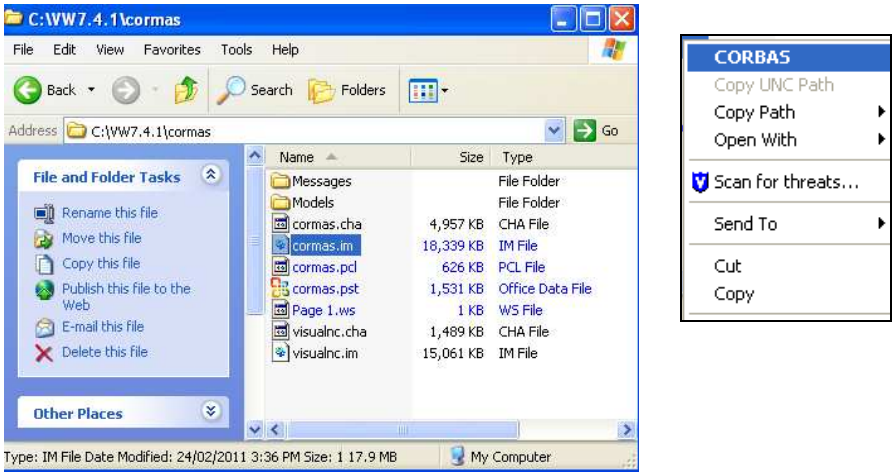
APPENDIX D – SIMFERAL USER INSTRUCTIONS

Installing and initiating Visual Works and Cormas software

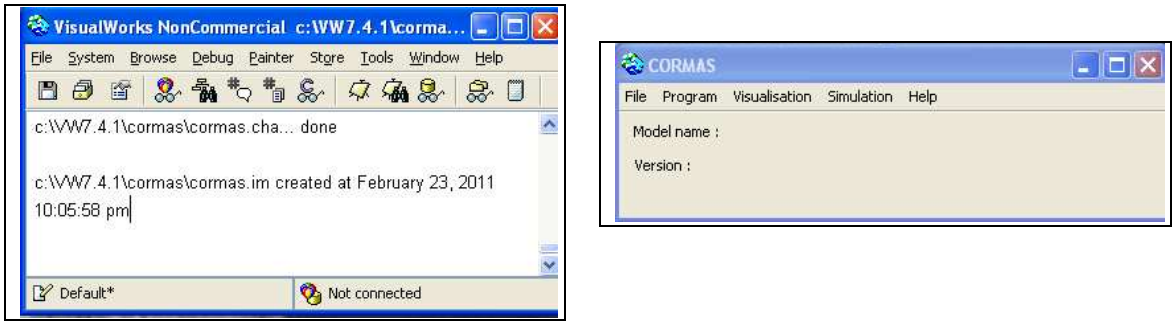
Two companion software (free downloads from web sites) run the model simulations: Visual Works (version 7.4.1, Cincom Smalltalk VisualWorks® 2006) and Cormas (version Cormas2007), are both are freely available as downloads from the following web sites (http://www.cincom.com/smalltalk & http://cormas.cirad.fr respectively). Whilst there is much training material in the VW folder attached to this report, readers will only use the "Cormas" folder. The VW 7.4.1 and Cormas folders, and the Kakadu feral animal folder (SimFeral) with all relevant files, must be located in the C-Drive with the following structure: C:\VW7.4.1\cormas\Models\SimFeral. Create a Cormas short-cut folder located on your desktop for easy access.

Of the two files needed to run simulations, one has a ".st" postscript (e.g. SimFeral_april2001.st) and contains the model codes, and the other has an ".ev" postscript (e.g. SimFeral_april2011.ev) and contains all relevant spatially-referenced environmental data automatically uploaded into the ".st" file and used in simulations. Again, they **must** be located in the **SimFeral** folder to work (see below).

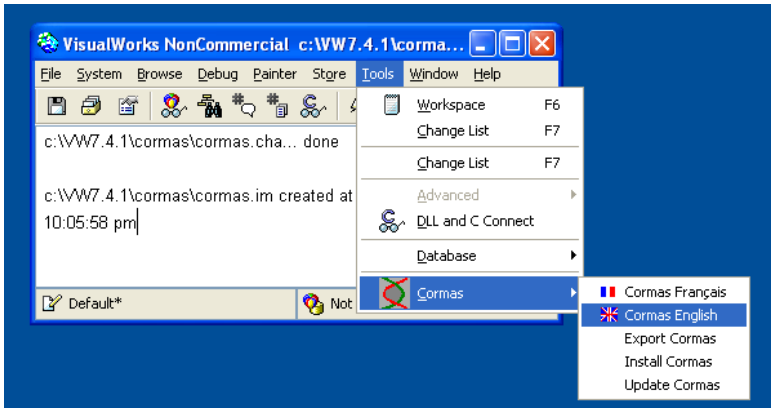
To initiate the Cormas software right click the "Cormas.im" file in the Cormas folder and left click the "CORBAS" command in the panel.



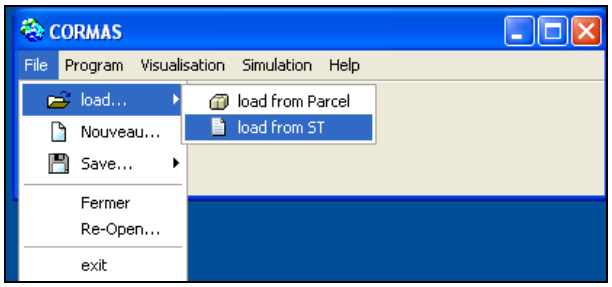
Two panels will open, one for VW (left) and the other for Cormas (right).



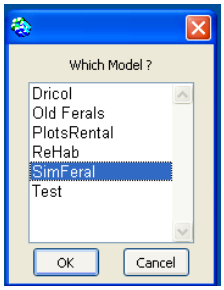
There is an English and French version of Cormas. The one you have opened is the default French version so reduce this by clicking "-" on the top right. On the VW panel select Tools, Cormas and then "English Cormas" and the English version panel will open. Reduce the VW panel.

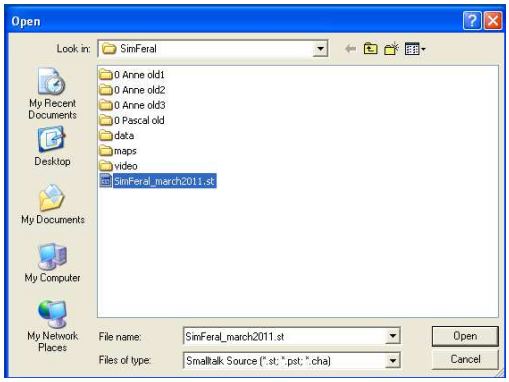


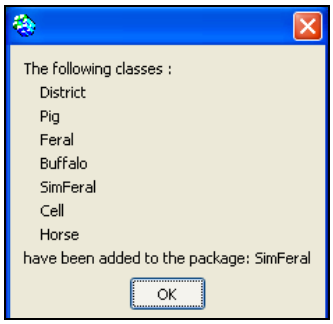
On the Cormas panel select File, Load then “load from ST”.



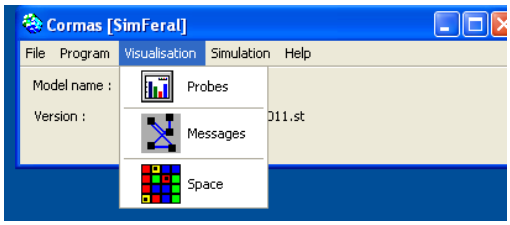
The following panel (left) will appear, choose the SimFeral folder, then the SimFeral_april2001.st file (middle) and click Open. Click OK on the right panel.

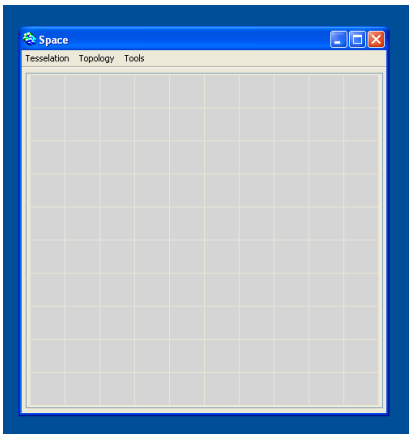




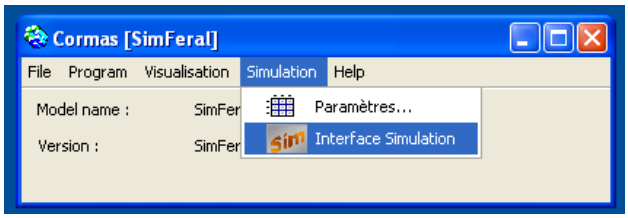


On the Cormas [SimFeral] panel select “Visualisation” then “Space”. A panel with a blank grid will open and now needs to be initialised with model parameters and control scenarios.

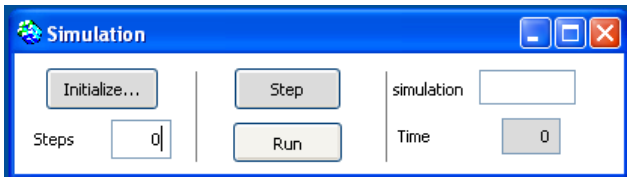




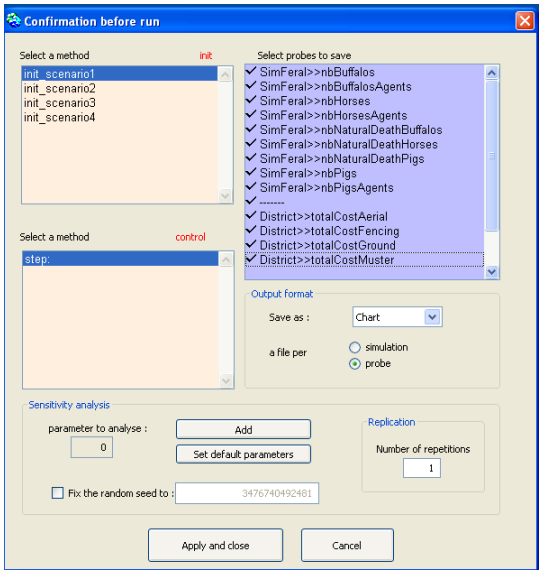
To initialise the model and commence simulations, choose “Simulation” on the Cormas panel, then “Interface Simulation”.



The Simulation panel will appear (see below). The SimFeral model runs on a quarterly (3 months) time step and, hence, 4 steps is a year and 16 steps 4 years (the maximum used in all simulations in this report). Note, however, that the user can choose as many time steps as needed.



Choose “Initialise” and the initialisation panel will open. In the upper LH “init” box click (highlight) on any one of the model scenarios to initialise it (e.g. init_scenario1 – no control), and also highlight “step” in the lower LH “control” box. Then click (tick) on “SimFeral>>nbBuffalos“at the top of RH “Select probes to save ”box (probes are the attributes/variables of interest). Hold the “Shift” button down, click on the bottom option (Districts>>totalCostMuster”), and all options will be ticked (chosen) if this is what you want. No need to modify any other part of the panel (for advanced users). The panel should look like the one below. Choose “Apply and close”.



The grid (cells = 5km x 5km = 25km^2) in the Visualisation “Space” panel (Fig. 24) are now filled with default data (here vegetation types & the park & district boundaries), and needs to be re-sized so that 25km^2 cells are square and not rectangular. The panel should look like the one below (colour codes

for all attribute maps are described in Appendix C above). To see a list of all available environmental and cultural data layers right click anywhere on the grid, then choose “Cell” and the attribute of interest. All attributes have a “pov” prefix meaning “Point of View”. This capability is a powerful visualisation tool for interactive and participatory engagements with Bininj and as a planning tool for developing long-term control strategies and operational plans.

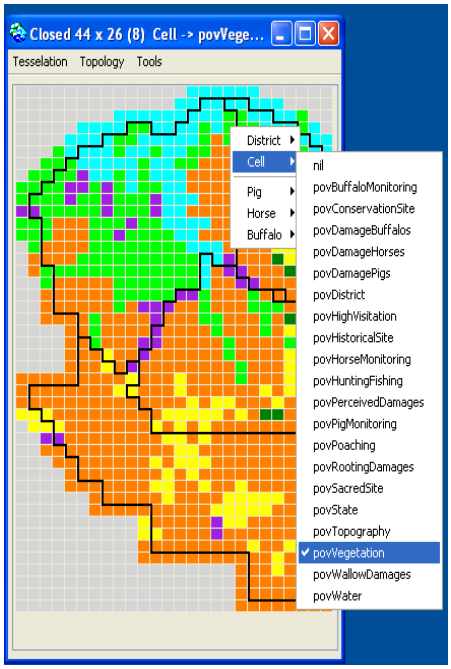


Figure 24 Displaying class attribute environmental data on the Cormas spatial panel. Right click and select the “Point of View” (pov) layer to display.

Additionally, you can activate initial model values such as the distribution and abundance of pigs, horses or buffalo as ascertained by the latest aerial surveys (2008 & 2009), either separately or in combination. If you choose all feral animals you would need to zoom in to discriminate symbols/colours for each feral species in cells where they overlap. For example, choose District and “povDistrict”, then Pig and “povPig”, then “Cell” first by “povPigMonitoring” then “povState”. By selecting “povPigs” (& not the default = “nil”) you can view the model starting values for each pig agent (here 1 red dot = 1 pig agent = 25 pigs; for all other species 1 symbol = 1 animal). The attribute “povPigMonitoring” shows that the cell starting values of the model were calibrated with the latest fixed-wing aerial survey data (Fig. 25) for pigs (using the Saalfeld & Bayliss unpubl. surveys), and similarly for buffalo and horses (using Tracey *et al*. 2009 surveys).

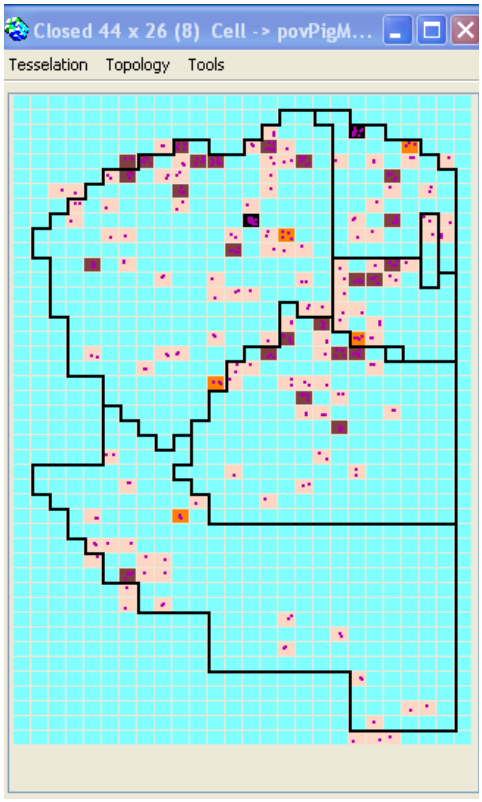


Figure 25 Calibrating initial cell starting densities for pigs (here pig agents where 1 red dot symbol=25 pigs) in the Cormas spatial panel with the 2003 survey data of Saalfeld and Bayliss (unpubl.)

To run a simulation go back to the Simulation panel (see page 98). You can choose to run simulations "step by step" (just keep pushing the Step button – here adjusted for 4 time steps or 1 year at a time), or for a set time period (e.g. choose steps = 16 for 4 years). There is a "Simulation run" and "step" counter at the right of the panel.

Seasonal floodplain dynamics and pigs

The attribute "povState" visualises the wet-dry seasonal spatial inundation dynamics on the floodplains at each quarterly time step (Step 1 early wet; Step 2 late wet; Step 3 early dry; Step 4 late dry). Pigs are simulated to shift their distribution to adjacent drier terrestrial habitats as the floodplains become flooded (see below). The map will initially appear all grey only showing park and district boundaries, but will display pig agents (red dots) and shifting seasonal flooding patterns when run (Figure 26 a & b below are the simulated wet & dry season distributions for pigs, respectively; yellow is for terrestrial habitats, blue for seasonal floodplains, & purple for location of springs/pools). See video file SimFeral_pigs_S1.

(a) Wet season **(b) Dry season**

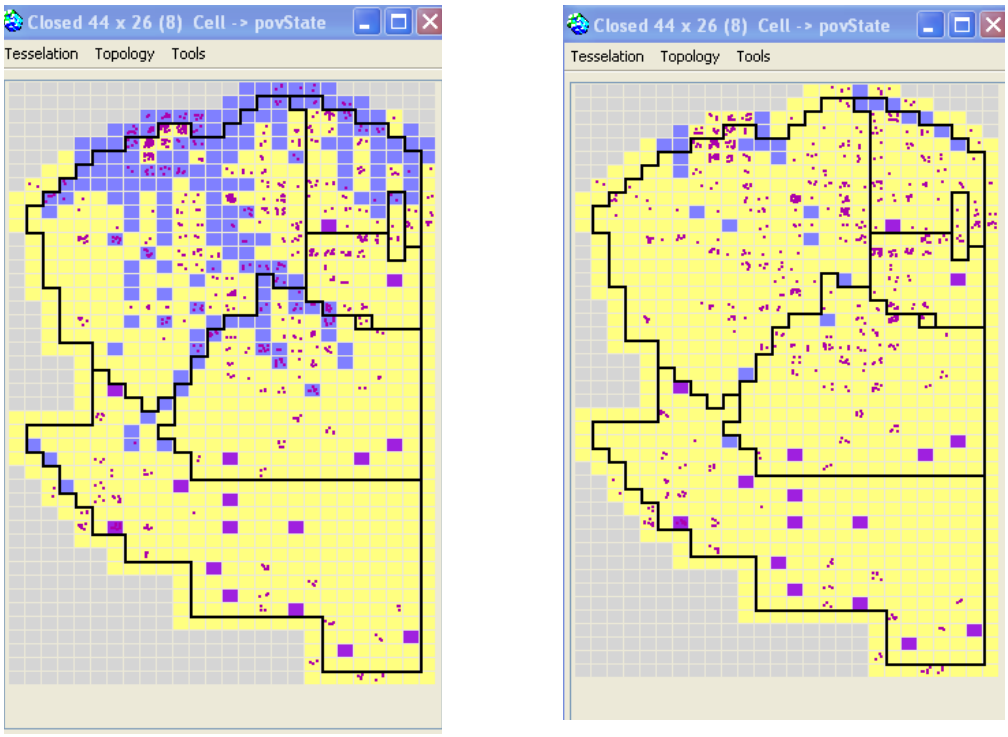
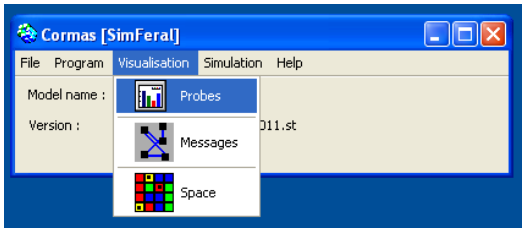


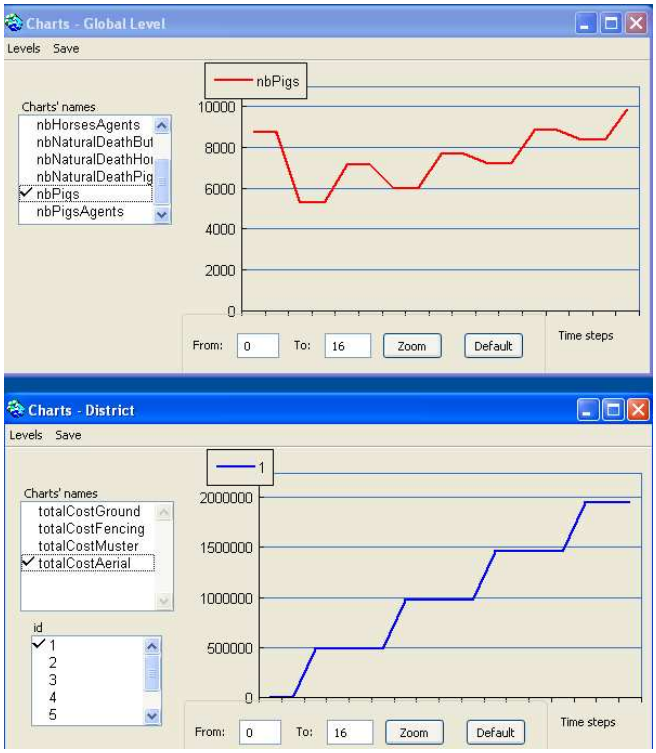
Figure 26 Simulated wet and dry season distributions for pigs, respectively; yellow indicates terrestrial habitats, blue indicates seasonal floodplains, and purple indicates location of springs/pools (see video file SimFeral_pigs_S1).

Graphing time trends of simulation outputs

In addition to the spatial visualisation panel Cormas allows users to graph time trends of attributes during simulations. For example, in the SimFeral model the total number of feral animals across the Park can be tracked over time in addition to control costs ($) by District for whatever culling method used (e.g. aerial shoots, ground shoots, mustering, fencing). The attribute “total numbers” has an “nb” prefix (e.g. nbPigs, nbHorses & nbBuffalo). In the Cormas model SimFeral panel choose “Visualisation” then “Probes”.



In the box that appears (below) select the feral species that you want to track park-wide abundance over time. You can view one species at a time or all species subject to a control scenario (see below).



In this example only the Park-wide (Level=Global) abundance of pigs (nbPigs) was selected and tracked over the time period chosen, here 4 years (culls are annual in the late dry season or after every 4th time step). The control strategy is Scenario 2 below (shooting pigs from helicopters in Districts 1 & 7, South Alligator River & Mary River respectively, see Section p106). To view the cost of control go to the Cormas SimFeral model panel and open another chart ("Probe"), but this time choose "Levels" then "Local" then "Districts". In the LH box "Chart's name" choose "totalCostAerial" ($s) by holding down the "Ctrl" button and left clicking the mouse button. In the "id" box just below choose the district of interest in similar manner and the cumulative costs will manifest (in this example only District 1 was chosen). Additionally, at this level, users can select the number of pigs, horses or buffalo by District (i.e. nbPigs, nbHorses & nbBuffalos). All simulated data can be saved to either a text or Excel file (see p112) for further analysis and plotting better graphs.

User selects sites (cells) for control and different culling strategies

This strategy is highly selective in that users can choose individual cells for control (species & method). Using pigs as an example, first select "init_scenario1" in the Simulation - Initialisation panel, as the "user select cell option for control" will only work within Scenario 1. Press ok to re-initialise. Click anywhere on the grid and select District then "povDistrict" (the map turns dark blue). Click anywhere on the grid and select Pig then "povPig", then "Cell" then "povPigMonitoring". The map now shows District boundaries and pig agent starting abundances/cell as calibrated to recent aerial survey results. Then select "Tools", click "Change attribute" and select 'feralControl_2' (see Fig. 27 below; large-scale aerial shoot of pigs, 80% reduction in open habitats, 50% in others). A box then appears asking for a "New value for attribute feralControl_2". Enter 'aerialPig' in the input field (note upper & lower case letters), and the white arrow pointer changes to a black pointer.

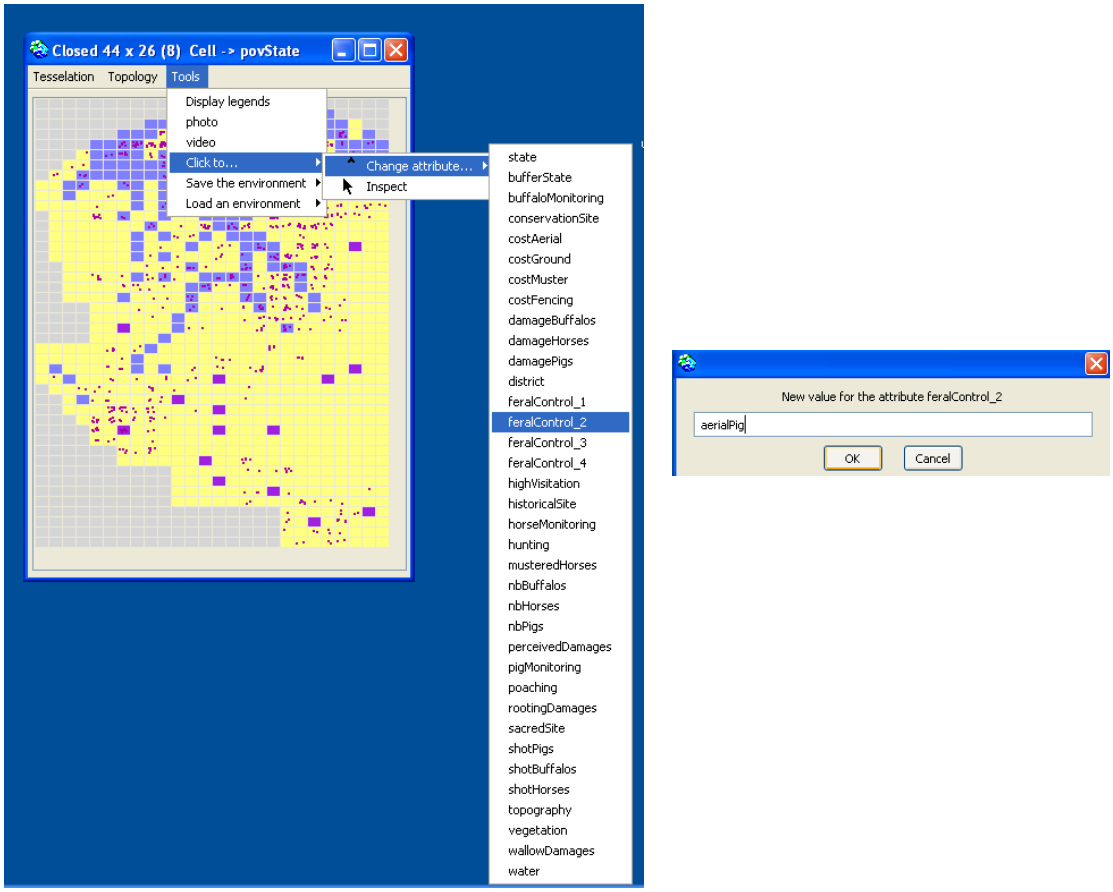


Figure 27 User selects sites for control and saves data to the "aerialPig" file location.

Click on as many cells as you or your audience wants. Each click corresponds to a cell that will be covered by a helicopter in the early dry season (in the example for pigs selected cells will change colour to yellow; Fig. 28 re-displayed to format used in Fig. 25). If a second shoot is required in the late dry season then select 'feralControl_4' instead. When you've finished go back to "Tools" and click the line under 'Click to change attribute' (i.e. "Inspect") and the white arrow pointer will return. Return to the Simulation panel and run the scenario simulation.

Other control methods for the "user selects cells" option of where to control (again note upper & lower case letters).

- aerialAll
- aerialPig
- groundAll
- groundPig
- horseMuster
- fencing

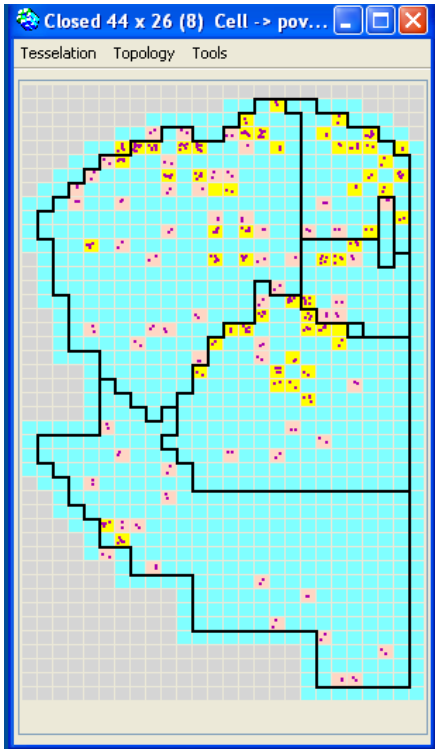


Figure 28 Cormas visualisation grid showing the "user selections sites option for where to control, using pigs as an example.

However, selecting individual cells manually by "pointing and clicking", in addition to checking that selected cells are attributed the correct control method (e.g. aerial/ground shoot, mustering, fencing), is a very tedious and time consuming process that would most likely inhibit its use as an interactive and participatory modelling tool. Nevertheless, the method has an obvious advantage in that users can be more effectively engaged in the planning process because they can select the aerial/ground shooting paths in their local area of interest (e.g. clan areas &/or site specific areas such as visitor hot spots &/or conservation areas). To scale-up to larger areas users can choose to select cells along linear pathways or in clusters. The modelling procedures are the same as that described in the following section broad-scale scenarios, up until the selections in the "Initialisation" panel. Here there is now only "init" to choose from in addition to and "control". Given the potential advantages that this site selection method has, we recommend that further software and model development is required to facilitate easy and rapid application. For example, by using the mouse to "drag and select" clusters of cells rather than using it to "point and click", given that there are 766 5km cells on KNP.

Hence, for demonstration purposes in this report, we have developed four broad-scale control scenarios for pigs only (p105-106). Further software coding is required for horses and buffalo, and/or for the inclusion of other control scenarios, and this would be a simple and rapid task for experts in Cormas programming (see Section 8 Recommendations).

Pre-set broad-scale control scenarios

Control methods and cost

The following four control methods for pigs, horses and buffalo were considered, and the associated cost ($) of control on a cell (25 km2) basis was estimated by park staff during the final interactive and participatory modelling workshop held on the 21st May 2010 (Section 7).

1. Aerial shooting ($2000/cell or $200/km^2)
2. Ground shooting ($500/cell or $80/km^2)
3. Fencing ($5000/cell or $200/km^2)
4. Mustering (horses) ($4,000/cell or $160/km^2)

Method 1 applies to the broad-scale shooting of pigs from helicopters to obtain an 80% reduction in open habitats (floodplain & savannas), and a 50% reduction in all closed habitats (e.g. paperbark & forest). Method 2 applies to shooting pigs on the ground in selected locations to obtain a 50% reduction in open floodplain and savanna habitats, and a 30% reduction in closed habitats. Method 3 applies to pigs in localised areas to obtain total exclusion (zero density), and Method 4 applies to broad-scale mustering of horses by helicopter to obtain an 80% reduction.

Whilst these cost values are preliminary and apply to specific control scenarios for pigs and horses, they can be refined with field data. For example, more precise control cost models exist for pigs and buffalo shot from helicopters (see Figs. 17 a & b, after Bayliss *et al*. 2006), and were derived from field data. The relationship between $cost/kill and feral density is best described by a negative exponential curve, indicating that as density is lowered towards zero, costs over a wide range are relatively constant but then dramatically increase, reflecting increased time searching at very low densities. Future modelling should incorporate such cost-density relationships to better predict the high costs of maintaining any successful control program.

The four control scenarios

Scenario 1

No control baseline.

Coding

Codes are the same as the previous current baseline simulation used for the site/cell selection method, with controlFeral_1, controlFeral_2, controlFeral_3 and controlFeral_4 (none, aerial, ground, mustering) recorded in the SimFeral#1.env file (with #none value for all cells).

Scenario 2

Aerial shoots for South Alligator River and Mary River districts (1 & 7 respectively) in the early dry season (Fig. 29a).

Coding

SimFeral#2.env contains the following:

All cells in District 1 have controlFeral_2: #aerialPig else #none;

All cells in District 2 aren't modified;

All cells in District 4 aren't modified;

All cells in District 5 aren't modified;

All cells in District 7 have controlFeral_2: #aerialPig else #none;

All cells in Districts 3 and 6 (mining leases) aren't modified.

Scenario 3

Scenario 2 aerial control in districts 1 and 7, plus ground control in sensitive eastern districts (East Alligator River, Headquarters & Jim Jim Districts) in both the early and late dry seasons (Fig. 29b).

Coding

SimFeral#3.env contains the following:

All cells in District 1 have controlFeral_4: #aerialPig else #none;

All cells in District 2 have controlFeral_2: #groundPig else #none;

All cells in District 4 have controlFeral_2: #groundPig else #none;

All cells in District 5 have controlFeral_2: #groundPig else #none;

All cells in District 7 have controlFeral_4: #aerialPig else #none;

All cells in Districts 3 and 6 aren't modified.

Scenario 4

Selective control method based on habitat comprising ground control in closed vegetation and aerial control in open floodplain habitats in the South Alligator River, East Alligator River and Mary River districts (Fig. 29c).

Coding

SimFeral#4.env contains the following:

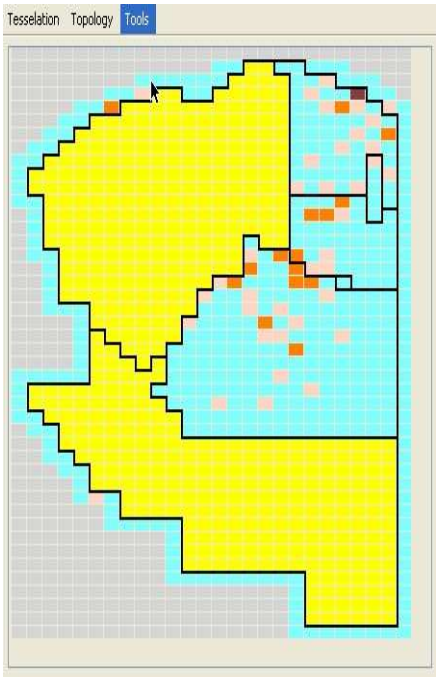
All cells with Vegetation 3, 4 and 5 have controlFeral_2: #groundPig else #none;

All cells with Vegetation 1 have controlFeral_4: #aerialPig else #none;

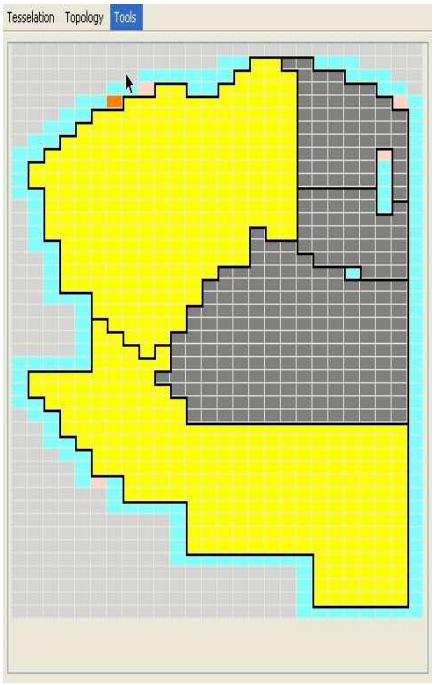
All cells in District 5 have controlFeral_4: #aerialPig else #none;

All other cells aren't modified

(a) Scenario 2



(b) Scenario 3



(c) Scenario 4

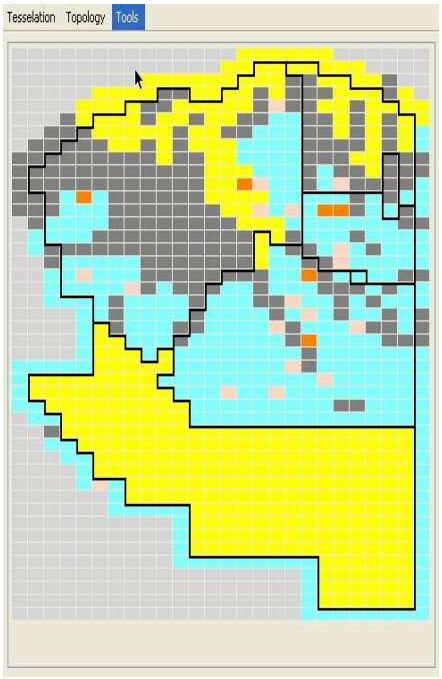
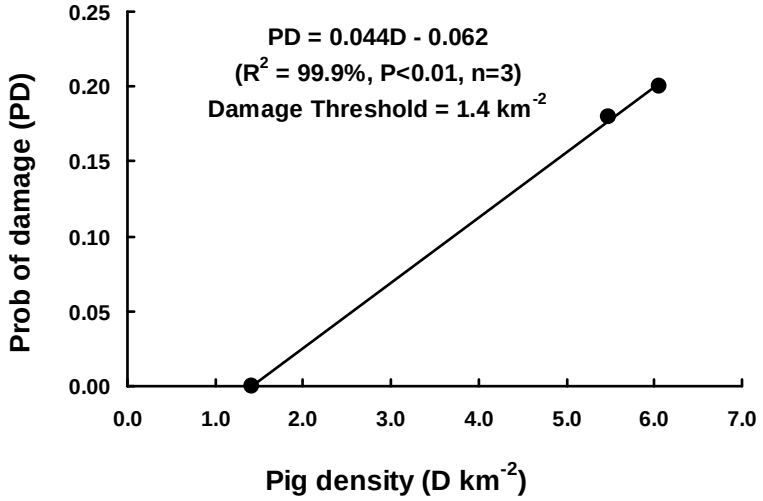


Figure 29 a - c. The three little pig control scenarios (2-4) illustrating where aerial (yellow) and ground control (grey) occurs.

Damage-density relationships in SimFeral

A major assumption of feral animal control is that there exists a strong relationship between pest damage and pest density. Hence, reducing damage to socially acceptable levels is achieved by reducing density. However, Hone (1994) reviewed the literature and found that this was true in only half the studies examined because such a relationship was likely to be multivariate and hence more complex. Bayliss et al. (2006) re-examined historical aerial survey data for KNP over the time period that encompassed an explosion in pig numbers since buffalo were intensively culled (see Fig. 1). Although "visible" ground disturbance damage caused by pigs (PDam) was only systematically recorded in three of a dozen aerial surveys across the Alligator Rivers Region since 1985, they found that damage and density (PDen nos/km2) were positively correlated past an apparent threshold effects level (Bayliss et al. 2006; Fig. 30a; PDam = 0.14Ln PDen – 0.05; R2 = 99.9%, n = 3, P < 0.01; threshold = 1.43 /km2). Choquenot and Parkes (2001) argued that, given budgetary constraints, the use of threshold damage-pest densities to initiate pest control can increase control effectiveness by reducing opportunity costs. Such a pragmatic and defensible approach could be adopted on KNP for those feral animal species that exhibit threshold densities, and is a key knowledge gap.

(a)



(b)

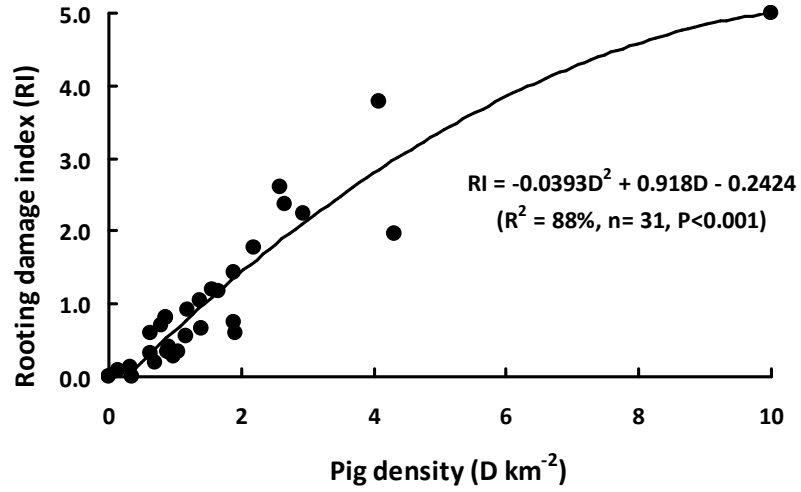


Figure 30 a & b (a) Damage-density relationship for pigs on KNP (probability or proportion of park sampled by aerial survey with visible ground disturbance vs. pig density) exhibiting a possible threshold relationship (after Bayliss et al. 2006). (b) Non-linear relationship between an index of feral pig rooting damage and their density in the Qld Wet Tropics (modified from data Mitchell & Dorney 2002).

Regardless, the damage-density relationship described above for pigs only applies to ground disturbance damage "visible" during fixed-wing aerial surveys, whereby a minimum amount of pig rooting damage in open habitats is required before being detected by observers. Such a detection threshold may be equivalent to the above "effects threshold". Given that pigs cause rooting damage in all other terrestrial habitats, especially forests, we adopted another approach. We searched the literature for data where pig rooting damage (between a perceived minimum & maximum score) was recorded during ground-based surveys in the tropics. The study by Mitchell and Dorney (2002) provided data to develop a "first-cut" damage-density function for pig rooting in the tropics. Although data were obtain to assess damage to agricultural values (e.g. banana & sugar plantations), their results based on measures of "ground disturbance" are directly applicable to conservation values on KNP. Their data were re-scaled with data from KNP, and the resulting non-linear function (quadratic polynomial; Fig. 30b) is coded into the SimFeral model in order to simulate, visualise and communicate potential reductions in pig rooting damage as a result of reductions in pig density. However, apart from pigs (& albeit with few data over time), there are currently no data for the park that defines horse and buffalo damage in terms of ground disturbance damage, let alone other perceptions of damage. Hence, derivation of simple species-specific damage-density functions (if they exist) are obvious areas of high priority targeted research, particularly for horses. Needless to say, ground disturbance damage alone does not necessarily encompass the additional, and potentially substantial, risks to KNP vertebrate wildlife from exotic diseases harboured and vectored by feral pigs (Bradshaw *et al.* 2007), and nor the impacts to native pasture biomass and plant biodiversity.

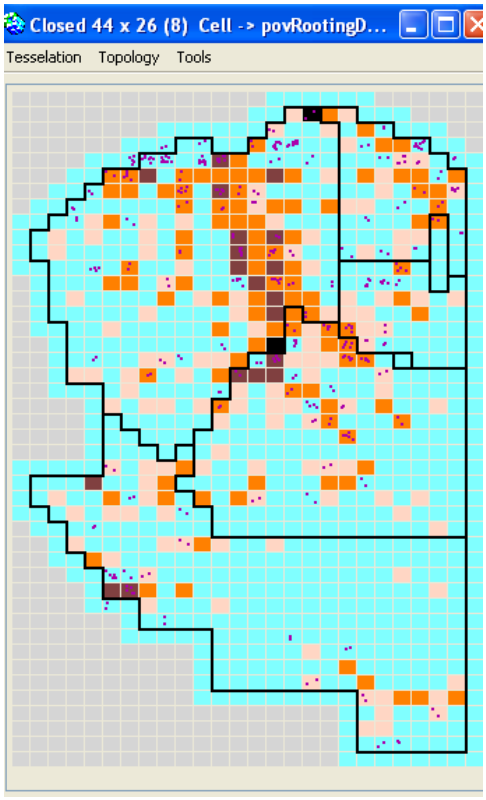
Code to simulate reduced pig rooting damage from density reduction of pigs

```
updateDamages

self vegetation = #none ifTrue: [^self].

(self theOccupants at: #Pig) size > 0 ifTrue: [^self updateRootingDamage].

self rootingDamages: 1.

updateRootingDamage

temp1: (self theOccupants at: #Pig) size.

temp1 = 0 ifTrue: [self rootingDamages: 0] ifFalse:[self rootingDamages:(((-0.393*(temp1^2)) +
(0.918*temp1)-0.2424) rounded)

[one #Pig agent represents 25 individuals]
```

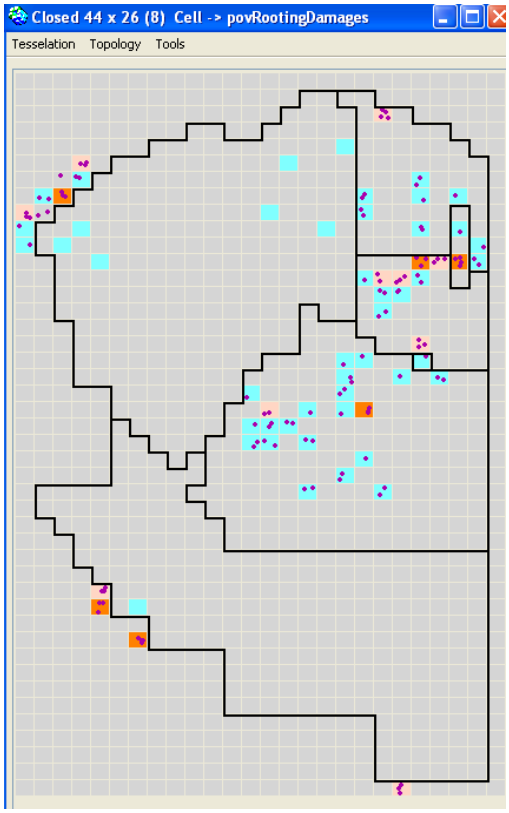
The above relationships between pig numbers/cell and pig rooting damage coded into SimFeral can be changed once better data becomes available. In the interim, however, they may suffice to visually demonstrate to users the expected spatial and temporal reductions in pig rooting damage as a result of different management scenarios and control strategies (see Fig. 31 a & b). The simulated reduction in pig rooting damage by Districts is illustrated in Figure 31c.

Figure 32 is another example of how to communicate the damage-density paradigm in the absence of hard data, and shows the results of simulated horse control by aerial shooting in the 1-South Alligator River and 7-Mary River Districts. In this scenario users selected or targeted cells that contained perceived horse damage (RH map, green cells) as elicited during the May 2010 feral animal workshops.

(a) Pig rooting damage Yr = 0



(b) Pig rooting damage Yr = 4



(c) Time trend in pig rooting damage by Districts

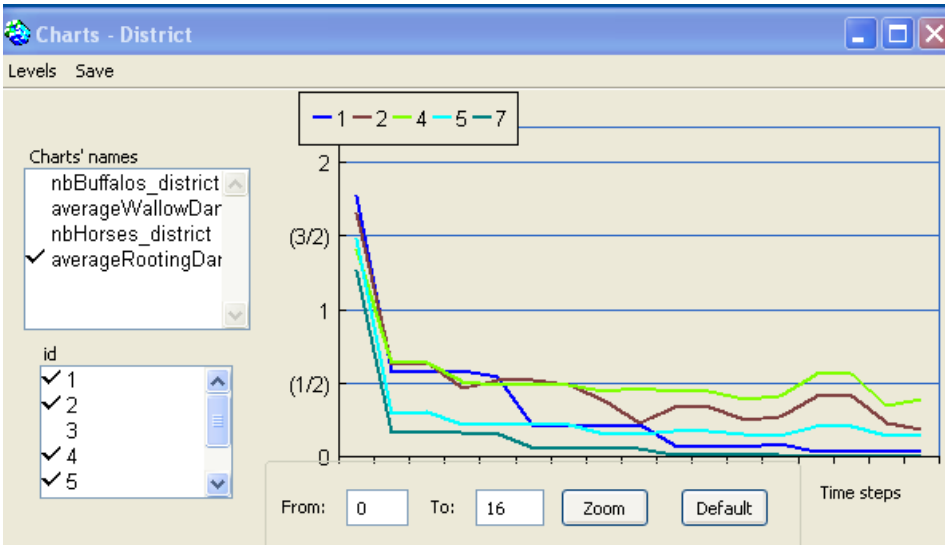


Figure 31 a-c (a) The distribution of high (dark brown), medium (light brown) and low (pink) occurrence of pig rooting damage, and pig density (1 dot = 25 pigs), across the park as ascertained by aerial survey (Saalfeld & Bayliss, unpubl.). (b) Simulated pig damage after four years of pig control (Scenario 3, init_feral3; aerial control in the 1-South Alligator River & 7-Mary River Districts, and ground control in all other Districts; see text for reduction details). (c) Time trend (n=16 steps or 4 yrs) in pig rooting damage (mean/cell) by District.

Control Scenario 2 and the "point and click cell selection" method were used (i.e. select init_feral2, 80% annual reduction in open floodplains & savannas, 50% in other habitats). Starting numbers for horses/cell were calibrated against aerial survey data (Tracey *et al*. 2009). The top LH panel shows the park-wide reduction in numbers after four years of control, and the bottom LH panel shows the reduction in numbers by District. Simulation results show that density reduction using this strategy occurred in areas with perceived damage (green cells). The red dots are horse agents (1 dot = 10 horses) after four years of control in Districts 1 and 7, and now mostly occur outside the control area.

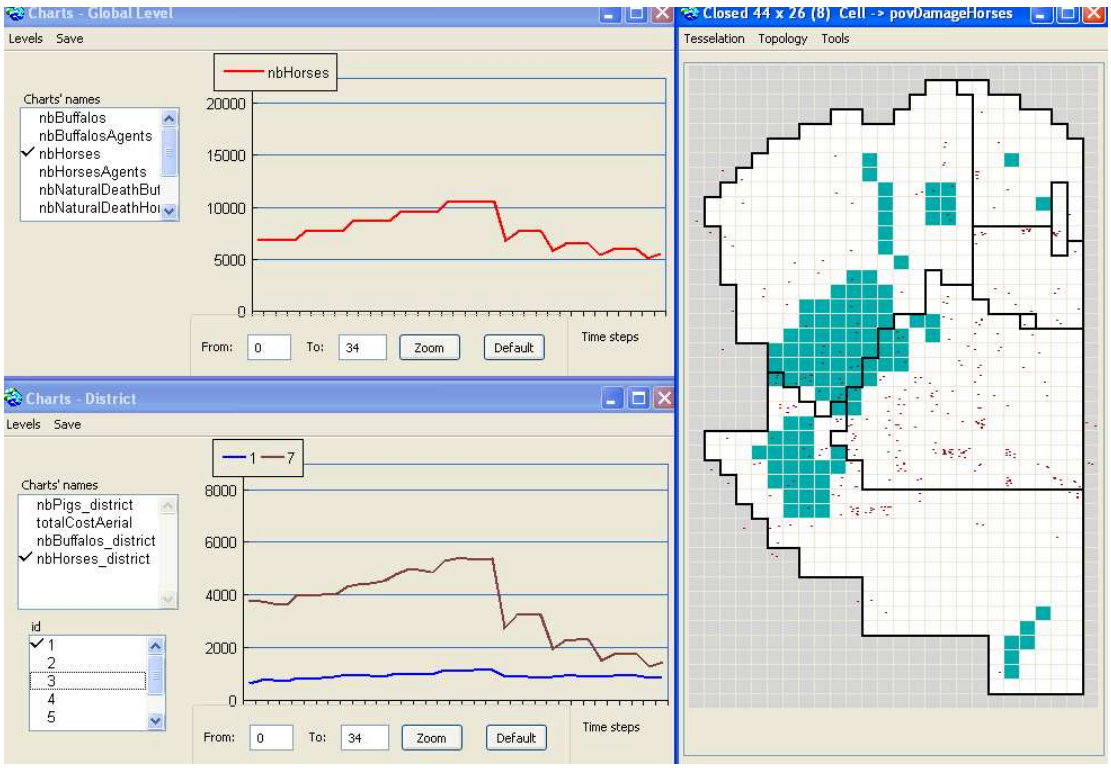


Figure 32 The distribution of perceived horse damage (RH graph, green) across the park as elicited during the May 2010 feral animal workshops in relation to simulated horse numbers/cell (1 dot = 10 horses) and after four years of control in Districts 1 (South Alligator River) and 7 (Mary River). The top LH panel shows the park-wide reduction in numbers and the bottom LH panel shows the reduction in numbers by Districts 1 (blue line) and 7 (brown line).

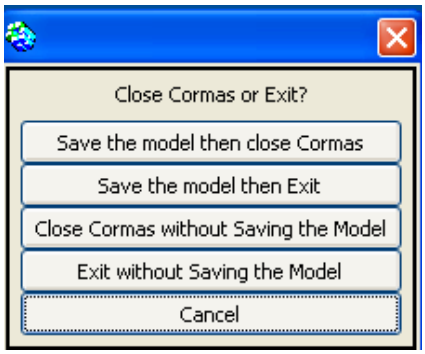
Saving models, simulation data, map images and videos of simulations

Temporal data from simulation runs can be saved as either Excel or Ascii text files. In the Chart panel (either Global park-wide or Local District options) select "Save". Data are saved by default in the SimFeral "data" folder. Unfortunately the Excel option doesn't work on our version of Cormas and,

hence, data must be save into a text file first and then imported into Excel by cutting and pasting using the Excel “Paste special” and “Transpose” functions.

Spatial data from simulation runs can be saved as jpeg picture files by choosing “Tools” then “Photo” on the Space panel. Videos of simulations can also be captured by selecting the “Video” option. All picture and video files are saved by default in the Cormas SimFeral “video” folder.

There are also various options for saving model simulations when exiting Cormas. You can discard all simulated data and model alterations by not saving, or save them (see panel below).



APPENDIX E - FERAL MANAGEMENT IN THE KNP PLAN OF MANAGEMENT

Taken from Winderlich, S (2010) Traditional Owner and stakeholder views on feral animal management in Kakadu National Park, Feral Animal Management Workshop, Kakadu Symposium series

What does the Kakadu National Park Management Plan (Director of Parks 2007) say about Feral Animal Management?

Management actions in KNP need to be consistent with the EPBC act and the Plan of Management (Director of Parks 2007). Discussion and actions relating to Feral Animals are found in section 5.12 of the current plan. The contents of this section are summarised below. Some of the sections of the plan considered less relevant to discussions at this symposium have been omitted.

Section 5.12 Feral and domestic animals

Our aim

Through control programs developed and implemented in consultation with Bininj, the adverse effects of domestic and feral animals on the natural and cultural values of the Park, and on human safety, are minimised.

Background

Feral animals can damage the cultural and natural values of country. They may impact on access, aesthetics and available food resources, and cause erosion, salt water intrusion, and the spread of weeds. Asian water buffalo, cattle, pigs, horses, donkeys, dogs, cats, European bees, cane toads and introduced ants are present in Kakadu. There are also risks that new species, such as crazy ants, will invade.

Issues

- To ensure that effective control programs are in place, there is a need for a strategic integrated regional approach. Control programs need to consider:
  - how the priority of protecting the parks natural and cultural values can be achieved while respecting the range of values that Bininj place on some introduced animals
  - the range of habitats, differing sensitivities to disturbance, susceptibility to weed invasion, and feral animal populations within adjoining country
  - what levels of damage to country caused by feral animals are seen as unacceptable to Bininj and Park staff
  - analysis and implementation of each control operation in close consultation with Bininj from the different clan estates.
- Some Bininj seek active involvement in conducting control programs and pursuing potential commercial and employment opportunities either jointly with the Park or independently through contracts between the Park and local Aboriginal associations.
- Preventing introductions of species that have the potential to establish unmanaged populations is the most important option available for reducing risk of additional damage caused by feral animals. At the time of writing this Plan, species that have the potential to enter the Park include banteng, sambar deer and crazy ants.

- Rules regarding restrictions on what animals may be brought into the Park are not always followed, either intentionally or accidentally through lack of knowledge. Some introduced fish and bird species could become pests or transmit disease to wild populations.
- The risks of some captive animals being released may increase when the population of Jabiru declines.
- Control programs must be conducted safely, effectively and with regard to animal welfare. There is a need to ensure that individuals undertaking control operations are appropriately trained and licensed.
- It is important to provide residents with good information prior to their arrival in the Park about the potential impacts of introduced animals on Park values.
- Programs for individual species need to be well designed to ensure that important values are protected and damage caused by individual species is reduced. Program effectiveness needs to be measured by the protection of values, not numbers of feral animals controlled.
- Pigs, buffalo, horses, cane toads and big-headed ants are regarded as the greatest threats to Park values by both Bininj and Park managers.
- Presently absent from the Park but important potential threats already established or present in the Top End include yellow crazy ants, mosquito fish and other aquarium fish. Invertebrates and smaller vertebrates, including fish, probably present the greatest mid-term threats that the Park needs to be prepared to control.

Issues for individual species

***Buffalo and cattle*:** Buffalo and cattle are abundant in neighbouring Arnhem Land and pastoral properties, and their numbers are increasing within the Park. Given the costs of culling, the Director may need to investigate cost recovery mechanisms through commercial activities. The future management of the Buffalo Farm needs to be considered. Some Bininj have indicated that they would like to have their own small domestic herds which would require intensive management to ensure they do not compromise control programs.

Pigs: Pigs cause noticeable widespread impacts around springs, floodplains and small rainforest patches. Bininj are concerned about the decline in the numbers of turtles and yams that may be related to the presence of pigs. The spread of weeds such as mimosa and olive hymenachne by pigs through foraging activities is of major concern. Pigs breed rapidly, so populations can quickly re-establish following control.

Horses and donkeys: Horses and donkeys cause erosion around water bodies, carry disease, and aid the spread of weeds such as mission grass, gamba grass and rattlepod. Horses near roads are a public safety issue. Information is required on seasonal distribution and survey techniques to help develop more effective targeted control programs.

Cane toads: Cane toads arrived in the southern regions of Kakadu in 2001 and populations are now well established throughout the Park. Cane toads have serious impacts on some wildlife populations. Toads eat a variety of invertebrate and vertebrate native animals (which not only impact on prey species but also reduces food resources for other native animals), and they have toxic defences that can result in the deaths of animals that eat toads. These impacts also affect the availability of some bush foods for Bininj. Following the arrival of toads in the Park, there has been a notable decline in the numbers of quolls and goannas. Large dragons, elapid snakes and other species are also likely to be affected.

Introduced ants: Introduced ants are capable of displacing other invertebrates such as green ants, therefore altering food availability for native animals. Introduced ants currently found in the Park include the ginger ant, pharaohs ant, Singapore ant, ghost ant and big-headed ant. Major costs have been associated with the control of big-headed ants in Kakadu since 2001. The possible introduction of the crazy ant is of major concern. Staff and residents need to be well equipped to quickly and reliably recognise introduced ant species.

Cats and dogs: There is a lack of information about the impacts and population of cats. However, cats are believed to prey on animals within all habitat types. Cats are also vectors of human and animal disease. To date, no effective cat control program has been developed. Feral dogs interbreed with dingoes, and in some locations hybrid dingoes may come to dominate dingo populations and place increased pressure on native wildlife within the Park. Dogs that are not looked after may pose health risks in Jabiru and in Aboriginal living areas.

Exotic aquatic animals: The introduction of exotic aquatic animals and aquarium plants into waterways within the Park would pose significant ecological risks. In addition exotic marine animals, such as the Black Stripped Mussel could pose significant threats to the coastal and estuary areas of the Park.

Exotic birds: Residents and visitors are not allowed to bring in pet birds, as they may introduce diseases and some species may become pests. Eradication of exotic birds is difficult if large populations become established over significant areas. Species accidentally introduced into Darwin, such as tree sparrows and spice finches, could become a problem in Kakadu if they become established on the Territory mainland.

European bees: European bees may adversely affect native insects and compete with native animals for nectar, pollen and tree hollows. Research is required to determine the abundance and level of impacts of European bees on wildlife within the Park. Control by Park staff does not presently extend beyond Park infrastructure and tourist areas.

Biological control agents: The *Cyrtobagous* weevil was introduced into the Park in 1983 to aid with salvinia control. The side leaf-feeding beetle (*Calligrapha pantherina)* is also present in the Park. No adverse ecological impacts of these agents have been reported. Research is currently under way into the development of a biological control agent for cane toads. Some mimosa control agents have been developed but not introduced to Kakadu as they are only viable where there are extensive stands of mimosa.

What we are going to do?

Policies

5.12.1 Recommendations from the Feral Animal Management Strategy for the Park will be implemented after public comments have been sought and following Board approval. Decision support tools will be used to help Park staff and Bininj to make joint decisions using current information about costs, reducing damage, generating income, monitoring populations over time and acknowledging the interest of some individuals in small populations being maintained.

5.12.2 Protocols for ensuring that animal welfare standards are met will be rigorously observed.

5.12.3 The Director will implement controls for the entry and movement within the Park of soils, pot plants, logs and other materials with a high potential for spreading feral animals and diseases.

5.12.4 The entry of dogs to the Park with visitors will be restricted to guide dogs for the vision and hearing impaired, or an assistance animal used by a person with a disability. Permits to bring dogs in for other purposes will only be considered in exceptional circumstances.

5.12.5 Park staff, and residents within lease areas may keep no more than two dogs per household without a permit issued by the Director. Cats or pet birds are not permitted to be kept, but exceptions may be made with the Director's approval for local, native birds that cannot be rehabilitated to the wild.

5.12.6 Park staff, Jabiru residents and residents within lease areas will only be permitted to keep fish native to the Magela Creek system in aquariums and permits may be issued to collect specimens for this purpose.

5.12.7 The Director may provide training in control techniques to enable Bininj not employed by the Park to obtain required licences.

5.12.8 Park staff will work with neighbours and cooperate with relevant Northern Territory authorities to develop regional approaches for feral animal management.

5.12.9 Opportunistic control will be undertaken for cats and dogs. Feral dogs and European bees will be actively controlled where they present particular health and safety risks to people or otherwise cause a significant nuisance.

5.12.10 Future proposals regarding the introduction of biological control agents will only be approved subject to rigorous research. This will help to ensure that the chance of any potential negative impacts on Park values caused by their introduction is minimised.

5.12.11 Non-native animals may be brought into or taken through the Park in accordance with a permit issued by the Director and where it is consistent with policies and actions in this Plan.

5.12.12 Managed herds may only be kept at the existing Buffalo Farm.

Actions

5.12.13 Develop and implement feral animal plans for districts which include identification by Park staff and Bininj of:

- the values to be protected
- sites suffering damage and hence requiring control programs
- methods to be adopted
- processes to measure and report on effectiveness of actions.

5.12.14 Develop decision support tools to assist in implementation of feral animal plans.

5.12.15 Develop contingency plans for managing introductions of particularly high risk feral animal species.

5.12.16 Cooperate with relevant agencies in pursuing a collaborative approach to the management and control of cane toads.

5.12.17 Provide regular reports to the Board that include information on Bininj participation, assessment of outcomes achieved and lessons learnt.

5.12.18 Park staff will work with Bininj to investigate the ecological, operational and safety issues associated with business and tourism proposals that involve the harvest of feral animals.

5.12.19 Review the future of the Buffalo Farm and prepare a rehabilitation strategy.

5.12.20 Work with landowners in Arnhem Land and on the western boundary and cooperate with relevant Northern Territory authorities to develop regional approaches for feral animal management and to help minimise cross border movement.

5.12.21 Liaise with the Jabiru Health Clinic to develop appropriate management programs for dogs kept in Jabiru and Aboriginal living areas.

5.12.22 Maintain awareness about national research into the development of biological and other control methods, and seek involvement with relevant decision-making committees regarding the introduction and keeping of exotic species in the Top End. Develop contingency plans as needed for particularly high-risk species.

5.12.23 Continue to monitor populations of *Cyrtobagous* weevil within *Salvinia* infested localities.

5.12.24 Work with relevant regional authorities to prepare public education programs. Prepare and distribute information about the recognition of feral animals, their known impacts and preferred management actions. Review the information annually.

5.12.25 Prepare and distribute an information kit to all Park residents, businesses, relevant tourism associations, freight companies and contractors to inform them of relevant EPBC Regulations and Management Plan requirements regarding the entry of plant, animal and soil material into the Park.

APPENDIX F - WORKSHOP POSTER

Kakadu Feral Animal Management

Workshops will be held around Kakadu National Park in May 2010 to discuss feral animal management in the Park.

Who is invited: Traditional Owners, Park staff, advisory experts

Where is the closest workshop:

When:

What will happen at the workshop:

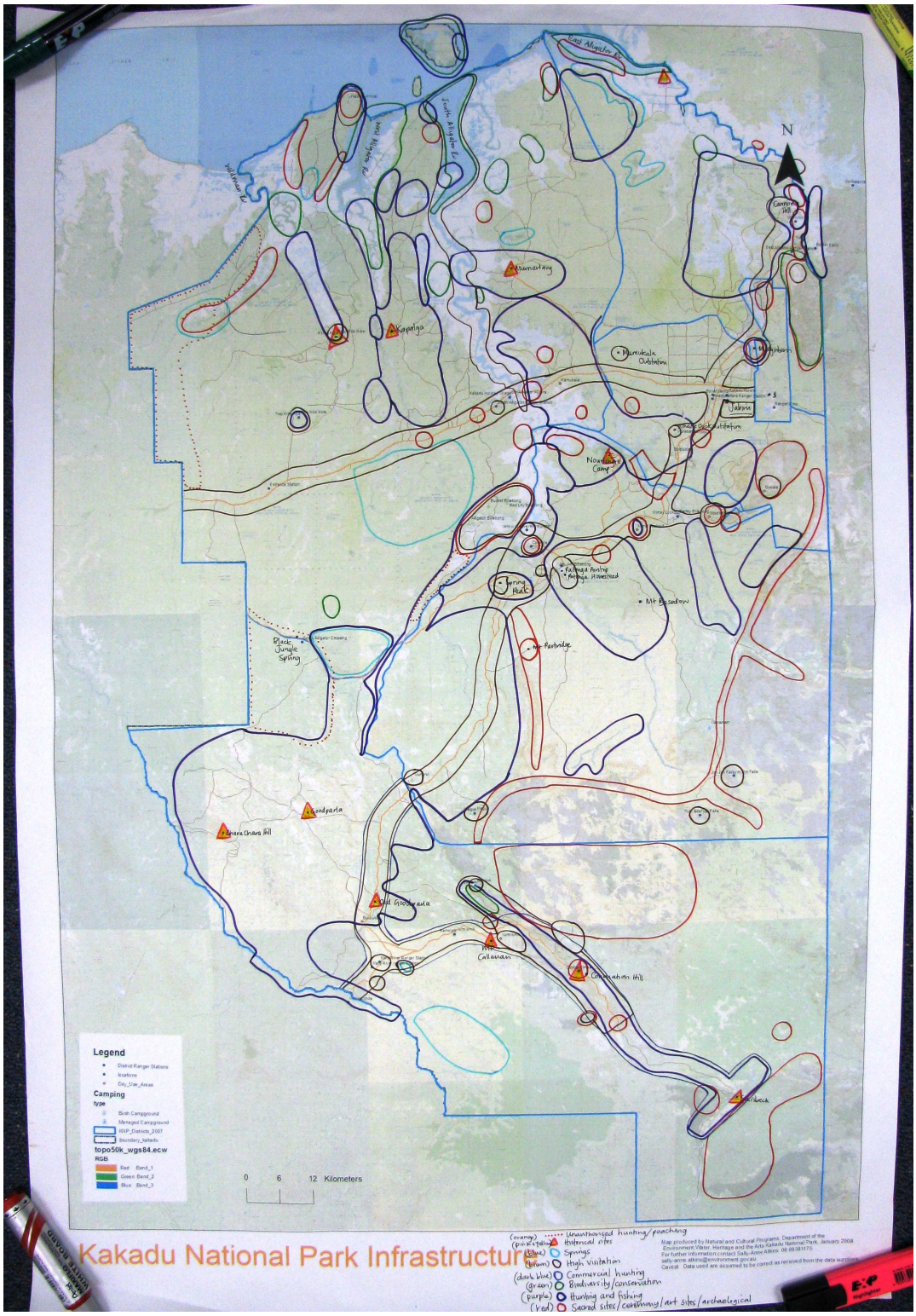
- Talk about what has worked well and what has not worked so well in recent feral animal control programs in Kakadu
- Make recommendations for future feral animal programs
- Discuss how negotiations between Traditional Owners and park staff, about feral animal control, might be improved in the future

Come and have your say about feral animal management in the Park. Transport and lunch will be provided.

Contact Mim Jambrecina at Park Headquarters for workshop dates and further details ph: 8938 1118



APPENDIX G: COMBINED PARK VALUES INDIVIDUALLY MAPPED IN THE WORKSHOPS



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