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DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT SCIENCE DIVISION

TELEPHONE: (08) 9334 0333

TTY: (08) 9334 0456

ADDRESS:
17 DICK PERRY AVENUE
TECHNOLOGY PARK, WESTERN PRECINCT
KENSINGTON WA 6151

POSTAL:
LOCKED BAG 104
BENTLEY DELIVERY CENTRE
WESTERN AUSTRALIA 6983

<http://science.calm.wa.gov.au/cswajournal>

Volume Five
Number Two
December
2004

Conservation Science Western Australia



Recommended abbreviation:
Conservation Science W. Aust.

Published by the Science Division, Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, Western Australia 6983.

AIM

To foster awareness, understanding and support for the science on which the Department of Conservation and Land Management's nature conservation and natural resource management activities in Western Australia are based.

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Conservation Science Western Australia publishes papers by scientists and technical officers employed by the Department of Conservation and Land Management. Submissions from outside the Department are not accepted, except when the research was funded by the Department.

The policy of the Science Division of the Department of Conservation and Land Management is for its scientists to publish in mainstream national and international science journals; however, some research is of 'parochial' interest only or results in papers of monographic length. *Conservation Science Western Australia* is intended to ensure that such material is publicly available after it is peer reviewed by scientists external to the Department.

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Contributions and enquiries should be addressed to The Editor, *Conservation Science Western Australia*, Science Division, Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre WA 6983, Australia.

SUBSCRIPTION ENQUIRIES

Only limited printed copies of the journal are produced. Access to the papers published in the journal is freely available on the Internet at:

<http://science.calm.wa.gov.au/cswajournal>

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ISSN 1447-3682

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FRONT COVER PHOTOGRAPHS: [taken by Babs and Bert Wells]

Clockwise from top left: western ringtail possum (*Pseudocheirus occidentalis*),

dibbler (*Parantechinus apicalis*), quenda (*Isodon obesulus fusciventer*),

European red fox (*Vulpes vulpes*), feral cat (*Felis catus*) and woylie (*Bettongia penicillata*).

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Advice to authors



A review of the *Western Shield* program

by

Hugh Possingham (*Panel Chair*)

Professor of Mathematics and Ecology

Director of The Ecology Centre

The University of Queensland

Peter Jarman

Emeritus Professor, Department of Ecosystem Management

The University of New England

Allen Kearns

Deputy Chief, Sustainable Ecosystems

CSIRO, Canberra

in February 2003

Edited by

Tony Start and Peter Mawson

Department of Conservation and Land Management
Locked Bag 104, Bentley Delivery Centre, WA, 6983

Foreword—*Western Shield* review

Western Shield has been one of Australia's most visionary and effective native fauna conservation programs. It also is one of the largest and boldest.

The program had its genesis in scientific research in the 1970s and 1980s that clearly demonstrated a link between predation by the European fox and the decline of small to medium size native mammals in the south-west of Western Australia. Further work showed that feral cats, too, were implicated in the decline of many species, especially in the arid zone.

While this research provided the science on which recovery measures could be based, there was one other key factor that came into play to enable *Western Shield* to be implemented on an operational scale.

This was Western Australia's 'natural advantage' - the toxin that occurs naturally in native plants of the genus *Gastrolobium* (the 'poison peas'). In the mid-1970s, Western Australian scientists discovered that the toxin in poison peas was almost identical to the commercially-manufactured pesticide known as 1080 (monosodium fluoroacetate). Because native animals in the south-west of Western Australia had evolved alongside the poison peas, they had developed a relatively high tolerance to its toxicity.

Implementation of *Western Shield* on a large scale also hinged on technical improvements such as cost-effective fox baits, captive breeding, translocation and management of threatened fauna, training of field officers, development of monitoring programs, risk management assessments and effective community education and communications.

Consequently, *Western Shield* is arguably the biggest example of an adaptive management program for the conservation of biodiversity at an operational scale in Australia. Scientific research and experience from field operations have created the synergy that has enabled the project to succeed.

This synergy was further strengthened with sponsorship by the private sector, particularly Alcoa World Alumina (Australia), Cable Sands (WA) Pty Ltd, Iluka Resources Ltd, the Australian Bush Heritage Fund, the TiWest Joint Venture and the Wind over Water Foundation.

The program already has had significant success: three native mammals—the woylie, quenda and tammar wallaby—have been removed from the threatened species list, many populations of native animals have recovered or been re-established in their former ranges, and the restoration of ecological processes has been initiated. However, not all species have responded so emphatically to fox control and further research is needed to better understand this.

An independent review of *Western Shield* was initiated as part of CALM's adaptive management approach. The review process included the appointment of three eminent scientists, selected for their complementary skills in conservation management and scientific disciplines.

It also involved the preparation of 12 papers covering all aspects of *Western Shield* that were presented at a forum to which representatives of key stakeholders, including community conservation groups, were invited. The Review Panel's report was released for public comment before being presented to the Minister for the Environment, Dr Judy Edwards MLA.

This special volume of *Conservation Science Western Australia* contains the Review Panel's report, the summary of public comments, and all 12 papers. It is important for conservation in Australia and elsewhere that programs such as *Western Shield* are well documented, and reviewed periodically, so that we can share what we have learnt as well as provide a benchmark against which to measure future change.

The Review Panel's report says:

'We believe that *Western Shield* is a world-class predator threat abatement program that is strategically targeted at the recovery of a wide range of threatened fauna'.

It is pleasing that the Panel believes that the success of the program has been a consequence of—among other things—'dedicated and competent staff'.

On behalf of CALM, I thank the members of the Panel: Hugh Possingham, Professor of Mathematics and Ecology, Director of the Ecology Centre, The University of Queensland (chairman); Peter Jarman, Emeritus Professor, Department of Ecosystem Management, The University of New England; and Allen Kearns, Deputy Chief, CSIRO Sustainable Ecosystems.

I also thank the authors and editors of the papers for their contributions to the review.

Our challenge now is to respond to the review's findings and ensure that *Western Shield* fulfils its potential to expand across larger areas of Western Australia and reverse the decline of much of our native fauna and ecosystems.



Keiran McNamara
EXECUTIVE DIRECTOR
Department of Conservation and Land Management
December 2004

Independent review of *Western Shield*—February 2003

HUGH POSSINGHAM¹ PETER JARMAN² AND ALLEN KEARNS³

¹ Panel Chair. Professor of Mathematics and Ecology, Director of The Ecology Centre, The University of Queensland, St Lucia, Queensland, 4072. Email: hpossingham@zen.uq.edu.au

² Emeritus Professor, Department of Ecosystem Management, The University of New England, Armidale, New South Wales, 2351. Email: pjarman@pobox.une.edu.au

³ Deputy Chief, CSIRO Sustainable Ecosystems, GPO Box 284, Canberra. 2601. Email: Allen.Kearns@csiro.au

THE WESTERN SHIELD FAUNA RECOVERY PROGRAM FOR WESTERN AUSTRALIA

Australia's native fauna have not fared well in the past 200 years due to environmental changes, including clearing of native vegetation, altered fire regimes and the introduction of predators such as the fox. This is particularly true of its medium-sized mammals. Twelve species of mammal that once occurred in Western Australia are now extinct and many more that were once widely distributed across much of the nation, or large parts of Western Australia, are now confined to a few isolated populations or a small number of offshore islands.

Research conducted in Western Australia over the past 30 years has shown that the most important current threatening process affecting these species is predation by foxes and feral cats. Similarly, research has shown that if these introduced predators can be controlled then many native species can recover in suitable habitats. In 1996 the Department of Conservation and Land Management (CALM) commenced a major fox control program called *Western Shield*. The program is now applied to nearly 3.5 million hectares of land (primarily in national parks, nature reserves and State forest), mostly in the southwest of the State. The fox control program is designed to reduce fox numbers enough to allow the affected native fauna to survive and recover. Fox numbers are controlled by laying dried meat baits containing the poison 1080 (sodium monofluoroacetate) at least four times per year.

Western Shield has five objectives. The first has been to maximise the recovery of sustainable populations of vulnerable native fauna by reducing the impact of fox and cat predation. In those areas where populations of native fauna have become locally extinct but suitable habitat remains, fauna are translocated to establish new populations. Preference is given to species that are currently considered threatened with extinction, but at specific sites the aim is to reconstruct entire suites of native fauna and associated ecological processes. The animals used in translocations are obtained from extant wild populations wherever possible. In those cases where extant populations can not presently sustain the removal of even small numbers of animals for translocation or where the costs and logistics of collecting them from the wild are

prohibitive, then animals are bred in captivity specifically for the purpose of release into the wild at sites protected from introduced predators. Indicator species are monitored at selected locations across the geographic extent of the *Western Shield* program to measure the recovery of extant populations of native fauna and the establishment of translocated populations. The successes of the program to date have enabled four species to be supplied to other States for re-establishment.

While foxes are the main threat in many areas of the State, in particular the higher rainfall areas of the southwest, it is also recognised that feral cats are a major threat to some species in more arid environments. The second objective of the *Western Shield* program has been to develop cost efficient and effective control techniques for foxes and feral cats. The success of this element of the program will largely determine the technical capacity of CALM to expand predator control efforts and fauna re-introductions into arid environments. The extent of the implementation of these techniques will depend on the availability of financial resources necessary for such an expansion.

The third objective relates to CALM's ability to conduct the program. The community's acceptance of the program is largely dependent on the development and conduct of an education and public relations program to increase awareness of the effect of fox and feral cat predation on native fauna and what can be done to mitigate this effect. The Department also has a responsibility to ensure that adjacent landholders are aware of the risk to domestic dogs and that any people visiting baited areas understand the implications of taking dogs into those areas.

The fourth objective has required that the *Western Shield* program makes the best use of new and existing research to enhance its recovery programs. It is important that vital and effective links be maintained between research and management to maximise the returns gained from available funds and staff resources.

The final objective has been to provide opportunities to develop and maintain partnerships with groups and organizations (e.g. universities, non-government conservation organizations, commercial businesses) to maximize the efficiency and effectiveness of fauna recovery across Western Australia, and where possible Australia.

The *Western Shield* program has been running for seven years and it is appropriate that the program be reviewed to determine how successful it has been, what aspects of the existing program should be changed, and in which direction those changes might take the program. It also provides an opportunity to examine resource allocation to the program, whether there is scope for savings, or an opportunity to build on the successes and invest additional resources to maintain or enhance the program.

The direct annual cost of *Western Shield* as of 2002 is about \$1.25 million with indirect costs that increase that amount at least two-fold. Only one staff member is directly employed under *Western Shield*, most of the costs are for on-ground work (see Wyre, this issue).

REVIEW METHOD

The terms of reference of the review panel are detailed in appendix 1. The formal part of the review took place over seven days, from 24 February to 2 March 2003. The schedule for the seven days was:

DATE	ACTIVITY
24 Feb	Review Panel arrived in Perth, visited captive breeding operations at Perth Zoo (Dr Terry Fletcher host), met the Minister for the Environment and Heritage and the Acting Executive Director, and met senior CALM staff involved in the review of <i>Western Shield</i> .
25 Feb	The panel attended a full day workshop at which twelve papers describing aspects of the program were presented. The workshop concluded with a general discussion. The invited audience included a wide array of people representing interstate and Commonwealth sister agencies, tertiary institutions, public interest groups, collaborating organisations, agencies and individuals, and CALM staff involved in <i>Western Shield</i> .
26 Feb	The panel met members of the Conservation Council of Western Australia before attending a full day, in-depth discussion of the subjects covered in the workshop. Other participants included review paper authors, senior CALM officers, including the Acting Executive Director and representatives from interstate and Commonwealth sister agencies.
27 Feb	The panel and senior CALM staff travelled to Harvey where they inspected the CALM bait factory and discussed practical issues associated with bait production with the local staff before travelling to Dryandra Forest. At Dryandra Forest, the panel was shown captive breeding facilities and the Barna Mia educational and public night-viewing facility. Local officers and Science Division staff involved in fauna recovery work at Dryandra hosted the visit.
28 Feb	The panel returned to Perth and met with the Acting Executive Director. Hugh Possingham returned to Brisbane late that night.

DATE	ACTIVITY
1 Mar	Peter Jarman and Allen Kearns, together with the Acting Director Nature Conservation and Director Science Division and other senior CALM officers flew to Denham (Shark Bay) via Geraldton, including a low level over-pass of Dirk Hartog, Bernier and Dorre Islands. Local staff hosted a visit to the Project Eden captive breeding pens and release sites in Francois Peron National Park.
2 Mar	The party returned to Perth Airport where Peter Jarman and Allen Kearns caught flights.

The Review panel used information gathered during the formal part of the review, other information, and their own experience in Australia and overseas, to formulate this report. The Review Panel provided a draft report to the Acting Executive Director on 16 March 2003, and following discussions with the Department finalised its report in August 2003.

Review

We believe that *Western Shield* is a world-class predator threat abatement program that is strategically targeted at the recovery of a wide range of threatened fauna. The success of the program has been a consequence of:

- south-west Western Australia's natural advantage in having 1080-tolerant native fauna, while introduced mammals remain susceptible
- implementing a scientific research and management framework that exploits that natural advantage
- a clear vision of the scale of the predation control challenge and the potential rewards in terms of reintroductions and *in situ* recovery of native fauna
- dedicated and competent staff
- operational efficiency, particularly with respect to baiting operations.

More specifically, the program has achieved:

- formal improvement in the listed conservation status of the woylie, tammar wallaby and quenda, and improvements in the abundance and distribution of many other critical weight range mammals. This has been achieved within a remarkably short timeframe. Few Australian fauna have improved their conservation status through direct action—most improvements in threatened species status have been through discoveries of new populations or changes in taxonomy.
- increases in the number of 'viable' populations of several critical weight range mammals.
- broad-scale, although not always quantified, improvement in the status of a broad spectrum of other species—e.g. reptiles and ground nesting and/or foraging birds.

- a recovery of certain, but poorly defined, ecosystem services associated with fauna recovery. For example soil turnover of 6 tonnes/yr/woylie, has improved soil water penetration and enhanced seed dispersal (see references in Mawson, this issue).
- development of skills and knowledge relating to the intensive and extensive captive-breeding of several threatened mammal species, and their translocation and release to the wild
- advances in baiting methods including the prospect of successfully baiting cats
- growing public awareness about Western Australia's threatened native fauna, and the role of feral predators as threats to native fauna.

The Department is to be commended for initiating an external and transparent review that will include the publication of 12 background papers. Independent and external reviews are all too rare in Australian conservation. The terms of reference given to authors included instructions to document successes, problems, threats and opportunities, as well as technical aspects of the program (Appendix 2).

During the course of the review, and as part of the review terms of reference, many issues were discussed. The purpose of this review is not to rehash those discussions in detail, but to provide clear recommendations with succinct justification. These recommendations are listed below.

Recommendations

1. **Future of *Western Shield*.** We believe that *Western Shield* should continue. It is a world-class and iconic threat-abatement program that has delivered real conservation outcomes with high efficiency at a time when most of Australia's fauna and flora is still in rapid decline. In addition, we believe that *Western Shield* should be expanded to focus more effort into feral cat research and management. Particular attention needs to be focussed on cat-fox-dog-native fauna interactions at the whole-landscape level of ecosystem management.
2. **Scope of *Western Shield*.** Exactly what activities are, or are not, classified as part of *Western Shield* has evolved through a sequence of historical events. At one extreme *Western Shield* could be expanded to encompass all threats and recovery activities to do with rare and threatened fauna, or it could be contracted to deal with issues of fox control in the State's southwest forests. There is merit in retaining focus from both a strategic science and targeted marketing perspective. We believe that an appropriate and well-contained scope for *Western Shield* is:

Feral predator control (where predators include foxes, cats and in particular cases rats and maybe even pigs) for the purpose of recovering remnant, and re-establishing new, populations of critical weight range mammals and associated terrestrial vertebrates (e.g. reptiles, ground-nesting birds).

Where re-establishment requires various forms of captive breeding then these operations should be included in *Western Shield* in an integrated and effective manner, using a network of captive breeding facilities and operators. We recommend CALM clarifies the focus and develops a concise form of words that leaves the public and CALM in no doubt about what is, or is not, in *Western Shield*. It would be simplest if there were no anomalies (e.g. *Project Eden*) that some people currently consider to be in, and others out, of *Western Shield*. Based on the definition of *Western Shield* above, *Project Eden* would be part of *Western Shield*.

3. **Management structure and strategic direction.**

Western Shield has now reached a point of complexity in its organisation and operations where it needs one clear leader, whose task will be defined as the scope identified above. Ideally, that leader will be both the strategic science and business director and the public 'face' of *Western Shield*. CALM should consider whether *Western Shield* is of sufficient scale and complexity to warrant the appointment of a Director level position similar to the Director, Nature Conservation. If not, then a *Western Shield* Manager reporting to the Director, Nature Conservation, should have the resources and authority to commission management-oriented research, and review actions and advice from within and outside CALM. It is important that the *Western Shield* leadership and management structure recognises the need for, and empowers, both strategic leadership and managerial (operational) leadership. The *Western Shield* Manager will need to have a clear line of effective management and strategic direction. The person should also have access to independent science, economic and social advice from the Conservation Council of Western Australia or other appropriate bodies. The current management structure (1999–2003) places too much emphasis on the *Western Shield* Strategic Committee to co-ordinate activity between the Director, Nature Conservation, and the management committees for the South West, Project Eden and the future Arid Zone. It would be preferable to have clearly assigned Project Managers in each of these geographic zones taking advice from local advisory committees, made up of CALM staff and representatives from community and other science and Natural Resource Management based organisations in WA. The central co-ordinating role of the *Western Shield* Manager needs to be adequately resourced and organised to integrate cross-geographic synergies and learning for staff involved in baiting operations, communication, field research, monitoring, scientific advice and review, captive breeding and community involvement. At present

communication between some groups, especially those more geographically isolated, is not adequate. An annual meeting of CALM staff and stakeholders, similar to that initiated for the *Western Shield* Review would provide a great opportunity to build social capital for future challenges, develop program cohesion and enhance shared learning.

4. **Community involvement** in *Western Shield* could be enhanced by building on the goodwill already generated by *Western Shield* and by moving from efficient consultation and publicity to genuine dialogue and real partnerships. Mechanisms for effective community involvement are needed at different scales of operation of *Western Shield*. For example, high-level community representation, reporting and partnering could be developed through the Conservation Commission of Western Australia, or a similar body. More focussed local level participation could be developed by further fostering local community groups in project areas, along the lines of the Mallee Fowl Protection Group model. Some technology transfer should be part of that process. The *Western Shield* manager would interact frequently with these groups, and report those interactions annually to CALM. The Conservation Commission, or similar body high level reference group, should provide broad strategic and stakeholder advice and not be involved or concerned with day-to-day issues on local projects where local community groups are operating with CALM.
5. **Full-cost accounting.** Choosing between different management options requires an understanding of the full costs and risks of those options. For example whether or not to embark on a new baiting application, a captive breeding program, a breeding facility such as the one at Dryandra, or use an island to develop a new population means the full costs of these activities need to be determined. This information, along with the careful application of risk assessment, will enable the program to maximise its expected benefits (Appendix 3). Full cost accounting must include direct costs, salary costs, infrastructure costs and discounting, and organisational infrastructure costs. For example, normal multipliers for full cost recovery are between 2 and 3 times salary costs.
6. **Bait Development, Procurement and Delivery.** Both CALM and the Agricultural Protection Board of WA have made impressive advances in the development and delivery of baits as well as the wise use of 1080 for predator control in WA. The Review Panel also consider that there is an interdependence between the two organisations and their different approaches to 1080 bait development using Dry Meat Baits (APB) and Probait sausages (CALM). There was some discussion during the review about the need for full-cost accounting to be used to make sure that decisions that could affect the Agricultural Protection Board of WA are made on an equitable basis. Importantly, the loss of one department's future capacity to prepare baits could lead to the unintended

consequence of poorer predator control in WA because both departments serve different land jurisdictions and stakeholders. The concern is that the loss of either DMB or Probait could lead to a 'brittle monopoly' for the sole supplier of baits not having the capacity to adequately deliver enough baits to both production and protection interests in WA. It is recommended that the departments consider a co-operative approach to meeting bait development needs and community involvement in bait delivery in the future. A more open process of scientific, community and technological review of bait development and delivery techniques would greatly enhance co-operation in this area that is of vital importance for the future of *Western Shield*. The bait factory developments at Harvey, and the development of long-life baits and alternative toxins to 1080, are strongly supported by the panel. In addition, because baiting operations are such a costly part of *Western Shield* it was felt that consideration should be given to modifying the actual baiting operations themselves in order to reduce costs. For example, as part of an active adaptive management approach consideration could be given to reducing the number of annual baiting cycles from four to three by dropping the winter operation or by reducing the number of baited areas after evaluating the monitoring information.

7. **Monitoring.** Monitoring in wildlife management can have one of four purposes:
 - a. Provide information for public relations. Much of the monitoring for *Western Shield* and associated programs provides important material for public relations. The recovery of local populations and increases in the number of local populations of key fauna are important and compelling information that engages community support and justifies continued public and private investment. We recommend that some of the indirect benefits of *Western Shield* (e.g. recovery of non-target fauna and complete communities) and the recovery of ecosystem processes (soil litter turnover and seed dispersal) are used more in future publicity.
 - b. Provide information with respect to performance targets – an auditing function. This is not always a very profitable function.
 - c. Trigger pre-specified actions and inform management about opportunities to change the management program to test new ideas and/or reallocate funds to other priorities. For example one might wind-back monitoring once a population has an $x\%$ trap success for five consecutive years, or increase bait frequency if a particular population shows no response after y years.
 - d. Monitoring needs to be seen, and enabled, as the critical feedback loop for information flow in an active adaptive management framework, see recommendation 8.

Monitoring has also engaged CALM District operational staff in *Western Shield* and has provided valued and valuable skills training.

We recommend that management review the purposes of monitoring and the extent to which the present techniques, distribution, and staff input effectively and efficiently fulfils these purposes. Issues of data management and analysis are in the next recommendation on research needs.

8. Research needs.

- a. *Basic questions.* *Western Shield* research purchased by the proposed business manager (recommendation 3) should be targeted at solving critical problems. Certain critical problems are already under active investigation—including the problem of cat control and appropriate baiting, and the question of pre-release predator training for captive-bred stock. These specific management-based research questions appear to be well thought out and carefully targeted. In all management there is a trade-off between actions that enhance learning and actions that are most likely to achieve management goals. There are a few questions where existing management actions could be reformulated in an experimental framework to deliver knowledge that will improve future management— for example, alterations in the frequency and intensity of fox baiting, including pulse baiting or even no baiting in a few sites where species like woylie, quenda and brush-tailed possum populations appear to have recovered.
- b. *Research partners.* Expand interaction with universities (inside and outside WA), CSIRO and others to deliver research outcomes in peer-reviewed and broadly accessible literature (cf New Zealand Department of Conservation model).
- c. *Quantitative ecology in CALM.* Build critical in-house capacity for modelling population and community dynamics and ecological statistical expertise in CALM, or acquire the expertise in a strategic manner from research partners. More specifically, one of the largest data sets presented to the Review Panel is that presented by Peter Orell (this issue). Whilst the lack of control site data is a problem, the capture data could be analysed with advanced time series methods to disentangle information about the effects of baiting, rainfall, density-dependence and interaction between species. Such analysis is a first step towards designing experimental management regimes.
- d. *Data storage.* Where the community is involved in data collection, very basic data storage using common packages (e.g. ACCESS) and delivery through the Web may be the best option. One person must be nominated as data custodian to ensure quality and consistency before web-based delivery. Attractively presented web-based deliver

can be a good community communication device and may attract research partners.

Overall we recommend enhancing the experimental aspects of *Western Shield* management within an active adaptive management framework.

9. **Dingoes.** There is healthy debate within CALM, and more broadly, on the role of dingoes in Australian ecosystems. From a broader perspective, it is probably true that dingoes deliver cat and fox control benefits, a form of ecosystem service, in areas where they retain their numbers and social organisation. The Department could take a leadership role in Australia by reviewing the role of dingoes in the restoration of ecosystems and drawing together national and international expertise in multi-species predator systems. This would be the step towards determining a long-term management position for dingoes in different ecosystems. As CALM scientists know, there is a considerable international literature on the management of predator systems and the problems of meso-predator release from removal of top predators.
10. **Cats.** The control of cats, and the likely competitive release of cats following the loss of other predators in the arid zone (see recommendation 8 above), is a significant issue that *Western Shield* is actively addressing. We strongly support and expanded effort on cat research and management which could be the focus for reinvigorating the original vision of *Western Shield* and the next phase of its implementation. Such a program would have implications across Australia and partnerships with other state agencies and research groups should be developed further to address this nationally significant problem.
11. **Moving outside the southwest forests and *Project Eden*.** CALM could consider developing action research and active adaptive management projects along the interior edge of the wheatbelt, working from the outset in negotiated projects in partnerships with private conservation organisations and community groups in farming areas. This might address some of the current disparities between CALM Regions in their involvement in translocation and faunal reconstruction programs. The interior edge of the wheatbelt may be a logistically simpler place than more central WA deserts to reconstruct unfenced, semi-arid, critical weight range fauna. However, the bold and visionary strategy implemented by CALM in the southwest forests and *Project Eden* would need to be fully revitalised and scaled up to tackle the world-class conservation challenge faced in overcoming cat predation effects and small mammal reintroductions in the arid zones and rangelands of WA. In order to meet this visionary challenge, there needs to be research into how large areas of the arid zone of Australia could sustain viable populations of native fauna in largely unfenced ‘mainland islands’.

12. The role of islands and marooning. The costs of island-based work are high, but can deliver more secure populations if successful eradication of cats, black rats and rabbits is possible. The rationale for continued work on islands needs to be fitted within a cost-benefit analysis (Appendix 3). Opportunities exist on islands for harbouring and marooning endangered fauna, as well as for experimental trials of novel baiting techniques and other pest animal control techniques with an emphasis on ecosystem management, for example, habitat manipulation and recovery. Recent developments on the eradication of cats on Faure Island, close to Peron Peninsula, and the eco-tourism centre at Monkey Mia, offers new opportunities for the use of islands to encourage fauna recovery in WA.

13. Public relations. The active program of public relations needs to continue to maintain community profile and support. However, a strategy needs to be developed to best communicate and report on failures in order to educate the community more broadly that success in ecological restoration is highly uncertain. Indeed failures are a necessary part of a risk-weighted management system that intends to maximise expected benefits rather than be excessively risk-averse. Openly discussing disappointing news will build community trust and a better understanding of the reality of predator control and the difficulty of implementing native mammal recovery in Australia.

14. Captive breeding. A network of CALM staff, and research and community collaborators, needs to be developed to more effectively capture and transfer the valuable science management knowledge being developed within the different captive breeding programs providing animals for reintroductions. There is an extraordinary level of commitment and ingenuity being practised within the different captive breeding and intentional release projects and the different groups would benefit from a facilitated network, with both virtual exchanges of knowledge and actual exchanges of personnel. A systems analysis of the currently fragmented captive breeding programs is essential input for choosing between management options and maximising the benefits of working with interested partners.

15. Co-ordination between projects at Shark Bay. The current program on the Peron Peninsula involves intensive management of animals in small pens with consequent high husbandry requirements, likely undesirable modifications to animal behaviour, and higher disease risks. The facilities appear to require significant upgrades to overcome some inherent problems with the incursion of large numbers of house mice and occasionally snakes. The current facility is clearly a significant investment in terms of the costs of maintaining even the existing inadequate infrastructure and the amount of staff effort required to maintain the animals and the facilities at Peron. The current program needs to be reviewed in terms of what critical

role the facility plays in the reintroduction of animals and the role it could achieve in terms of public education, along the lines of the Barna Mia model at Dryandra. For example, the existing Peron captive breeding facility could be replaced by one of two alternative models: Large semi-free range yards similar to the 17-hectare yards used on Heirisson Prong. This model is likely to work best on Peron if integrated with ecotourism (nocturnal viewing like the Barna Mia facility), or Replacement of captive breeding entirely by establishment of free-range populations at smaller and more secure nearby sites (Faure Island and/or Heirisson Prong). These sites allow extensive breeding of wild populations at the scale of 1200–5000 ha. Faure Island provides a cat-free site, while Heirisson Prong's smaller size makes it easier to guarantee effective cat control. Both of these sites could become sources for reintroductions elsewhere (note that burrowing bettongs from Heirisson Prong have already been used to start new populations at Roxby Downs and Faure Island). Both sites could support secure populations of species known to be highly sensitive to cat predation that are unlikely to be effectively established on Peron in the short to medium-term.

16. Publication and communication. *Western Shield* is an exemplary program, at the forefront of Australia's conservation effort. It already influences conservation opinion and practice in other Australian States, more often than not through word of mouth. *Western Shield* could well be seen as an international exemplar of strategic cost efficient conservation management. To serve Australian and international conservation most effectively, its activities and outcomes need to be transparently and promptly reported. We suggest that CALM designs and implements means for the rapid and accurate dissemination of *Western Shield* data and their interpretation, in addition to timely publication in peer-reviewed journals of science and management. Journals like *Bioscience* or *New Scientist* would be appropriate venues to overview the science-management interaction within the program. Publishing some of the more rigorous papers from the review in the international peer-reviewed literature would be worth the effort. There is an exploding suite of conservation journals to which this applied research could be submitted: *Ecological Applications*, *Conservation Biology*, *Biological Conservation*, *Journal of Applied Ecology*, *Animal Conservation*, *Oryx*, *Pacific Conservation Biology* and *Biodiversity and Conservation*.

17. The wise use of 1080. *Western Shield* builds on 15 years of research by the Agriculture Protection Board in WA (particularly Denis King) and CSIRO Wildlife and Ecology in Canberra (John McIlroy) to establish the respective tolerances of native and pest species to 1080. This research established the generally far higher tolerances of native species in WA when compared with native species in eastern Australia and

non-native pest species such as rabbits, foxes and cats. These differences were linked to the co-evolution of native species in the west with native peas (*Gastrolobium* spp.). These peas contain sodium monofluoroacetate as a secondary compound to deter herbivory. This compound is the same active ingredient as in 1080. *Western Shield* also built on the observations of:

- Faunal decline following the phasing out of extensive use of 1080 'one-shot' oat baiting for rabbit control in wheatbelt areas with the introduction of a new vector for myxomatosis, the rabbit flea.
- The coincidence of surviving remnant populations of mammals in south-west WA and dense forest or woodland understoreys containing thickets of *Gastrolobium*.

- Initial successes by CALM (Jack Kinnear) in the management of remnant populations of threatened mammals in the late 1980s and early 1990s. These include the resurgence of numbats at Dryandra and of populations of black-footed rock wallabies on isolated rock stacks in the WA wheatbelt following the introduction of fox management.

Clearly, the success of *Western Shield* is underpinned in large part by the availability of 1080, its natural occurrence in native vegetation and the tolerance of a wide range of native mammals in WA to 1080. The 1080 toxin plays a fundamentally important role in the conservation of the biodiversity and natural heritage of WA. Based on the WA experience, and while viable alternatives to 1080 are not available, it would be prudent, if not essential for Australian nature conservation, to retain the wise use of 1080 in Australia.

APPENDIX 1

Terms of Reference of Review Panel

The members will:

- Act collaboratively as a Review Panel

The Panel will:

- Prepare and submit a report to the Acting Executive Director. The report will be available for public comment before presentation of the final report to the Minister for the Environment and Heritage.

The report will address strengths and weaknesses in:

- The concept and parameters of the project
- The geographical distribution of operational programs throughout the State
- The operational implementation of feral predator control procedures from bait procurement and deployment to public awareness of baiting operations
- The operational implementation of fauna management procedures from captive breeding and translocation to monitoring (and response to monitoring results)
- The direction and methodology of research programs, particularly in regard to cat control
- Management of the project at all levels, particularly integration of the various components as well as monitoring and reporting
- Allocation of resources
- The cost-effectiveness of the project
- Public awareness and acceptance of the project, including the use of 1080 baits

- Any other issues that the panel deems significant to the improvement or future implementation of the *Western Shield* project.

The report will comment on proposals for future directions and make recommendations for:

- Improvement to existing components
- Varying (increase or decrease) the current funding allocations
- New initiatives.

Responsibilities of the Department of Conservation and Land Management

The Department will make available to Panel members pertinent information through:

- Presentation of papers at a workshop
- Opportunity for in-depth discussion with key people in all areas
- Opportunity to visit a range of sites where components of the project are carried out
- Facilitating access to further information that the panel deems desirable or necessary to its task.

Duration

The Panel's function will cease after it has reported to the Department to the satisfaction of the Acting Executive Director.

APPENDIX 2

Terms of Reference for CALM authors assigned the task of writing background papers for the *Western Shield* review process

Authors were asked (where relevant) to:

- consider their topic in relation to the 1996 *Western Shield* proposal and the *Western Shield* Strategic Plan (July 1999 to June 2004)
- provide sufficient background, detail and budget information to allow independent assessment and review
- address specific terms of reference (detailed below)
- provide a summary that addressed objectives, achievements (against targets), difficulties, potential economies and potential improvements.

They were also advised that the papers would be published in *Conservation Science Western Australia* as a useful landmark against which future work can be judged.

Financial analysis—Gordon Wyre

- Provide an overview of total costs of *Western Shield* (including staff time) and discuss cost-effectiveness in relation to the objectives set in 1996.

Baiting—Roger Armstrong

- List all areas being baited with dates of commencement and costs of each operation, overall and per hectare.
- Consider the results of the ‘Foxglove’ research conducted by Paul de Tores into baiting intervals and protocols, and any other relevant research, and discuss what the results mean for future baiting plans.
- Discuss issues relating to bait production and past and future costs.
- Discuss the development of Pro bait and the steps needed to obtain registration.
- Discuss whether all programmed baitings have been conducted, and if some have not occurred, state the reasons.
- List any changes made to baiting protocols at any site, state why the decision to make changes were made and by whom, and any evidence suggesting that changed baiting regimes may be more or less effective.

Monitoring and staff training—Peter Orell

- Present all monitoring data for all sites in a summarised and analysed format that allows easy comparison between sites.
- Discuss where monitoring data suggests that baiting has not produced any, or produced only limited, species recovery.

- Discuss locations where species numbers have declined after an initial increase.
- Discuss any problems in monitoring, including failures to meet monitoring targets and problems with data being received or data being inadequate.
- Describe past and current staff training programs, list all staff who have graduated from the mammal conservation course and whether they have used the skills they developed. Provide any feedback from staff who have attended the courses.
- Discuss options for future training programs.

Community support and education—Ron Kawalilak, Liz Moore and Nigel Higgs

- Provide an overview of work done to present *Western Shield* and its progress to the general public.
- Provide an overview of programs aimed at school pupils and describe how successful they have been.
- Discuss what changes in public perception and attitude have resulted from the community support and education programs carried out.

Translocations and fauna reconstruction sites—Peter Mawson

- Provide a list of all fauna translocations that have taken place under *Western Shield* since 1996 together with information on the success or failure of each translocation. Provide an overview of the reasons for each translocation and what monitoring has been undertaken.
- For each species translocated, present information on its conservation status at the time of the translocation and its conservation status now.
- Discuss how the translocations have helped achieve *Western Shield* targets.
- Discuss how translocations have been integrated to achieve targets for Fauna Reconstruction Sites.
- Where translocations have occurred of species that are not critically endangered or endangered, state why the translocation occurred.

Captive breeding and coordination—Peter Mawson

- Provide an integrated overview of breeding programs being run at Shark Bay, Dryandra, Two Peoples Bay, Kanyana, and Perth Zoo, including founder numbers, breeding success and death rates within the colonies, costs per animal produced.

- Present information on costs of captive breeding at departmentally-operated sites and elsewhere.
- Discuss why captive breeding was chosen as a strategy for each species and what alternative strategies were considered.
- Discuss whether the Department should be involved in captive breeding at each or any of these sites or whether captive breeding would be more effectively and efficiently carried out at Perth Zoo or other specialist captive-breeding facilities.

Feral cat control—*David Algar and Neil Burrows*

- Provide an overview of all research aimed at developing broadscale control technology for feral cats.
- Present results of cat control experiments across various climatic/habitat types.
- Discuss any current obstacles to broadscale implementation and timelines for overcoming them.
- Discuss how and when bait registration can be achieved and the likely cost of feral cat baits.

Threatened fauna issues not covered under *Western Shield*—*John Blyth and Andrew Burbidge*

- Provide an overview of threatened fauna recovery projects not included in the *Western Shield* umbrella.
- List critically endangered and endangered fauna species for which there are no or limited recovery programs and state whether these species have an approved or draft recovery plan. List what recovery actions are underway or needed for each of them.
- Discuss the pros and cons of including additional or all fauna recovery projects under *Western Shield*.

Return to Dryandra—*Tony Friend and Brett Beecham*

- Provide an overview of the project against original targets.
- Present results from breeding and a critical analysis of viability of the Dryandra site for the project.
- Discuss management of the project in relation to the involvement of staff from different departmental divisions.
- Present an overview of future plans.

Project Eden—*Keith Morris, Nigel Sercombe and Colleen Sims*

- Provide an overview of *Project Eden* against original targets.
- Discuss breeding plans, translocation results and timelines and future resource requirements.
- For each species translocated, discuss whether it is likely to establish without any additional translocations.
- Present an overview of future plans.

Montebello Renewal—*Andrew Burbidge*

- Provide an overview of the project against original targets.
- Discuss feral animal eradication methods and results, with justification for any new methods introduced.
- Discuss translocations, why they took place before eradication of introduced animals had been achieved within the whole archipelago.
- Present an overview of future plans.

Western Shield as a fauna management tool. Case studies using the western ringtail possum and the quokka—*Paul de Torres*

- Outline the distribution, changes in status over time and probable causes of change for each species
- Identify the components of *Western Shield* being used in the management of each species (e.g. predator control, translocation) and the populations being managed.
- Identify all the people (and their roles) involved in the management of each species
- Describe or tabulate the implementation of *Western Shield* actions with respect to each managed population and the process for modifying prescriptions
- In consultation with key people from each involved Region, assess the efficacy of the implementation of *Western Shield* actions and decision making procedures

APPENDIX 3

Adopting a decision-theoretic approach to choosing between management options for *Western Shield*

While developing a decision-theoretic approach to threatened species management is a research program in itself - we present a crude model of the application of decision theory to choosing between different management options largely as a tool to introduce this way of thinking.

At any point in time a program like *Western Shield* must decide how to allocate resources across a range of possible management options. For example we may be considering a captive breeding program for Gilbert's potoroo, expanding fox baiting to a new area or marooning a population of Bilbies on an island from which they are currently absent. Here is an example of how a structured decision-making tool might help us to make, *not make*, that decision.

Assume the value of a new population of species i is

$$V_i = \sqrt{(1/N_i)},$$

where N_i is the current number of extant relatively viable populations of that species. Hence establishing the second population of a species gets us 1 point, the third population about 0.7 points and the 10th population about 0.3 points. This (or a similar formula) places more weight on establishing populations of species that have fewer extant relatively viable populations.

The benefit of any management action can now be evaluated as a combination of its cost, 'value' as defined above, and probability of success. For example if V_j is the 'value' of action j (which is the sum of the V_i values because any action could help more than one species), P_j is the probability of success and C_j is the cost (in \$ - add recurrent annual expenses to capital cost divided by ten) then the net expected value of action j is

$$\text{Net expected value per million \$ to conservation} = 1000000V_jP_j/C_j$$

Three management actions are evaluated in the table below and their 'value' per million dollars is assessed. Actions with a significantly higher value per million dollars are probably better choices all else being equal.

On which basis we would conclude that option 2 seems significantly better than options 1 and 3, and that options 1 and 3 are indistinguishable. NB these numbers are hypothetical.

MANAGEMENT ACTION (HYPOTHETICAL)	VALUE	PROBABILITY OF SUCCESS	COST PER ANNUM FOR 10 YEARS	NET BENEFIT
Captive breeding Gilbert's potoroo	1	20%	\$125,000	1.60
Maroon bilbies and western-barred bandicoots on island	1/2+1/3	30%	\$ 62,500	4.00
Fox bait a new site for woylies and chuditch	1/5+1/6	90%	\$ 25,000	1.56

Note: these numbers are hypothetical.

Summary review of public submissions on the 2003 independent review of the *Western Shield* program

P. R. MAWSON¹ AND A.N. START²

¹ Department of Conservation and Land Management, Wildlife Branch, Locked Bag 104, Bentley Delivery Centre WA 6983. peterm@calm.wa.gov.au

² Department of Conservation and Land Management, Wildlife Research Centre, PO Box 51, Wanneroo, WA 6946. tonys@calm.wa.gov.au

The independent panel appointed to review CALM's *Western Shield* program provided its final draft to the Executive Director of CALM in September 2003. The Minister for the Environment made the report available to the public and invited public comment through a media statement on 10 October 2003 (Appendix 1). The closing date for submissions was 21 November 2003. Advice on making submissions (Appendix 2) was provided to enquirers at CALM offices and on CALM's website (www.naturebase.net).

Sixteen submissions were received; five from private individuals, one from a non-government organization and 10 from government agencies or individuals within government agencies (Appendix 3). One private respondent has requested identity confidentiality. Three of the respondents provided general comments about the *Western Shield* program and the review process but did not offer specific comments on any of the 17 recommendations made in the review panel's report.

Not all respondents commented on each of the Review Panel's 17 recommendations. However, 118 comments referred to specific recommendations (Table 1). The number of comments made on any one recommendation ranged from 11 (Recommendations 1, the future of the *Western Shield* program and 2, scope of the program) to as few as three (Recommendation 14, Captive Breeding issues). Of the 118 assigned comments, 101 (86%) were supportive and a further 11 (9%) gave qualified support. Six (5%) were dissenting comments. In some cases, distinction between qualification and dissent was, necessarily, subjective. The editors take responsibility for assignments to those categories. However, the nature of all qualifications and dissensions are described in the following text.

The submissions, will be available to CALM officers who are responsible for considering the implementation of the Review Panel's recommendations.

Recommendation 1. Future of *Western Shield*

Eleven responses were received. All supported the recommendation. Three more did not specifically address the recommendation but endorsed the continuation of the program.

Recommendation 2. Scope of *Western Shield*

Eleven comments were received. Nine respondents supported the recommendation, three with qualifications, as follows:

- Two respondents felt that it was logical and appropriate to expand the scope of the program to include the control of a wider range of feral predators and that fauna recovery within a landscape restoration context, including habitat management, should be the focus of the work.
- One respondent cautioned that CALM needs to be careful about selection of projects for inclusion in *Western Shield* to ensure adequate funding for all aspects of the program.
- One respondent suggested that the program should include monitoring of introduced predators and that the program should not be restricted to any particular geographical area, but should encompass all introduced predator/native prey interaction.

Two respondents did not support the Panel's recommendation. One considered the scope of the program, with a heavy emphasis on mammals, is too narrow. The other considered it important to expand the scope to include reference to translocations involving both wild-caught and captive-bred animals.

Recommendation 3. Management structure and strategic direction

Nine comments were received. Eight respondents supported the recommendation, one qualified as follows:

- The future strategic direction needs to incorporate animal health programs that include preventative medicine and effectively address and manage the impact of disease.

One respondent, who did not support the Panel's recommendation, suggested that the *Western Shield* program should have not one but two leaders; one to oversee business aspects and the other to oversee the science aspects of the program. The rationale was to ensure that scientific quality was not compromised by a single manager placing undue emphasis on business and management issues. This respondent agreed with the rest of the recommendation.

Recommendation 4. Community involvement

Seven comments were received. All respondents were supportive.

Recommendation 5. Full-cost accounting

Seven comments were received. All respondents were supportive.

Recommendation 6. Bait development, procurement and delivery

Six comments were received. All respondents were supportive, two with the following qualification:

- They both strongly opposed the reduction of baiting frequency to off-set rising bait costs without first obtaining scientific justification for such an action.

Recommendation 7. Monitoring

Seven comments were received. All respondents were supportive.

Recommendation 8. Research

Eight comments were received. All respondents were supportive, one with the following qualification:

- The respondent was concerned that, as yet, there is insufficient evidence to justify research and development of a cat bait. This respondent did not have access to all the material presented to the Review Panel. Research undertaken by CALM scientists as part of *Western Shield* goes some way to mitigating the concern. Nevertheless, this comment reinforces the need for CALM to publish its research results in a timely manner and in a variety of fora.

Recommendation 9. Dingoes

Six comments were received. Five respondents were supportive. One respondent considered that a single-species (i.e. fox) approach to predator control is not holistic and so successful control of foxes in isolation of other feral predators may induce new problems.

Recommendation 10. Feral cats

Seven comments were received. All respondents were supportive, one with the same qualification raised under Recommendation 8 with regard to feral cats.

Recommendation 11. Moving outside the southwest forests and *Project Eden*

Four comments were received. Three respondents were supportive, one with the following qualification:

- The research and operational priorities for the *Western Shield* program need to be determined by the new manager (Recommendation 3) and his/her support team. If these decisions are not made within an overall framework, the implementation of specific actions become increasingly *ad hoc*.

One respondent did not support the Panel's recommendation, suggesting that *Western Shield* should concentrate on smaller areas of land where predator control or eradication can be managed economically and where wildlife translocations are more likely to succeed (compare the manageable size of Heirisson Prong with the much larger area of Peron Peninsula).

Recommendation 12. The role of islands and marooning

Five comments were received. All respondents were supportive, one with the following qualification:

- Noting that the reviewers identified the values of islands in terms of translocating threatened fauna, novel control methods etc, but made no recommendations about *Western Shield's* direction in this regard, it was suggested that several criteria need to be satisfied (e.g. impact on local wildlife) before any island is used as a testing ground. Moreover an objective cost-benefit assessment of island work would be useful.

Recommendation 13. Public relations

Ten comments were received. All respondents were supportive.

Recommendation 14. Captive breeding

Three comments were received. All respondents were supportive.

Recommendation 15. Co-ordination between projects at Shark Bay

Five comments were received. Four respondents were supportive, one with the following qualification:

- Captive breeding facilities not capable of producing genetically, physiologically and behaviorally sound animals for translocation should close.

One respondent disagreed with the Panel's view that the existing captive breeding infrastructure is 'inadequate' and considered that the two potential replacements that were canvassed would not provide satisfactory alternatives. Arguments in support of those views were provided.

However, the respondent did agree that the current program needs to be reviewed, its priorities and objectives re-set and the potential of an increased role in public education investigated.

Recommendation 16. Publication and communication

Five comments were received. All respondents were supportive.

Recommendation 17. The wise use of 1080

Seven comments were received. All respondents were supportive.

TABLE 1

Summary of comments that addressed the Review Panel's recommendations. (N = 16 submissions).

RECOMMENDATION #.	COMMENTS	SUPPORT	QUALIFIED SUPPORT	DISSENT
1. Future of <i>Western Shield</i>	11	11 (100%)	Ø	Ø
2. Scope of <i>Western Shield</i>	11	6 (55%)	3 (27%)	2 (18%)
3. Management structure and strategic direction	9	7 (78%)	1 (11%)	1 (11%)
4. Community involvement	7	7 (100%)	Ø	Ø
5. Full-cost accounting	7	7 (100%)	Ø	Ø
6. Bait development, procurement and delivery	6	4 (67%)	2 (33%)	Ø
7. Fauna monitoring	7	7 (100%)	Ø	Ø
8. Research needs	8	7 (88%)	1 (12%)	
9. Dingoes	6	5 (83%)	Ø	1 (17%)
10. Feral cats	7	6 (86%)	1 (14%)	Ø
11. Moving outside the south-west forests and <i>Project Eden</i>	4	2 (50%)	1 (25%)	1 (25%)
12. The role of islands and marooning	5	4 (80%)	1 (20%)	Ø
13. Public relations	10	10 (100%)	Ø	Ø
14. Captive breeding	3	3 (100%)	Ø	Ø
15. Co-ordination between projects at Shark Bay	5	3 (60%)	1 (20%)	1 (20%)
16. Publication and communication	5	5 (100%)	Ø	Ø
17. The wise use of 1080	7	7 (100%)	Ø	Ø
TOTAL	118	101 (86%)	11 (9%)	6 (5%)

APPENDIX 1

Text of the Ministerial press release announcing the availability for public comment of the independent panel's review. Advice on how to submit comment is shown in Appendix 2.

10-10-2003

Conservation program hailed a success

Western Australia's native fauna recovery program—*Western Shield*—has been hailed by a review panel of independent scientific experts as a world-class and iconic predator control program that has delivered real conservation outcomes.

Environment Minister Judy Edwards today released for public comment the review panel's assessment of the Department of Conservation and Land Management's comprehensive fauna recovery initiative

"The report clearly recommends the continuation and expansion of *Western Shield*, which aims to conserve native animals at a landscape level by controlling introduced predators the European fox and feral cat," Dr Edwards said.

"The three-member review panel has found the program to be extremely successful in strategically targeting the recovery of a wide range of threatened native fauna in a short time frame.

"In particular, it commends the department on implementing scientific research and a management framework that exploits the advantage of the naturally occurring toxin, 1080."

Dr Edwards said the review was conducted by three independent scientists with relevant expertise in the field of fauna conservation and program management.

Panel members were Professor Hugh Possingham, from the Departments of Zoology and Mathematics at Queensland University; Emeritus Professor Peter Jarman, from the Department of Ecosystem Management at the University of New England, NSW; and Mr Allen Kearns, from the CSIRO's Sustainable Ecosystems Division.

The Minister said the review panel's report sets out a number of recommendations for future management of the program including:

- expanding the program to provide for more effort into feral cat research and management
- appointing a *Western Shield* manager to provide a clearer management structure that can be both strategic science and business orientated; enhancing community involvement to build on the goodwill already generated by *Western Shield*
- reviewing the purposes of monitoring and the extent to which the present techniques, distribution, and staff input effectively and efficiently fulfill these purposes
- a co-operative approach between CALM and the Department of Agriculture in the production of 1080 meat baits; and enhancing the experimental aspects of *Western Shield* to provide greater scope for research needs.

"The report also strongly recommends the continued wise use of 1080, stating that it played a fundamental role in the conservation of the biodiversity and natural heritage of WA," Dr Edwards said.

The report is available for public comment for six weeks and copies are available at CALM's State Operations Headquarters, 17 Dick Perry Avenue, Technology Park, Kensington or from the department's website - <http://www.naturebase.net>

The closing date for comments is Friday, 21 November, 2003.

Minister's office: 9220 5050

APPENDIX 2

Text of the background information on the Independent Review Panel's Report on the *Western Shield* program and Advice on how to submit comment on it. This text was provided to people requesting copies of the report and it was available from CALM's NatureBase website www.naturebase.net.

WHAT DOES THE DRAFT INDEPENDENT REVIEW OF *WESTERN SHIELD* INCLUDE?

The draft *Independent Review of Western Shield* is a report compiled by three independent scientists commissioned by the Executive Director of the Department of Conservation and Land Management to undertake a review of the Department's Western Shield fauna recovery program. The review panel was asked to report on all aspects of the project's management, implementation and outcomes and make recommendations for improvements.

The terms of reference of the review panel are included as an appendix to the panel's draft report.

To assist the panel in undertaking the review, the Department of Conservation and Land Management commissioned the writing of twelve review papers on a range of topics associated with the *Western Shield* program. The authors of those papers were given specific instructions on the scope and detail that their papers were to include. The terms of reference for the authors of the review papers are also set out in an appendix to the review panel's report.

To further assist the review panel the Department also organised a one-day public workshop at which a summary of each of the twelve papers were presented orally. The Department also organised a one-day closed workshop attended by the authors of the review papers and invited senior Department staff, representatives from sister conservation agencies in other parts of the country.

Field trips were arranged to the captive breeding facilities at the Perth Zoo, to the Department's experimental bait production facility at Harvey, the captive breeding facilities (Return to Dryandra) and the public fauna viewing facilities (Barna Mia) located at Dryandra Forest, and to the captive breeding facilities at Francois Peron National Park. At each of these venues the review panel members were able to meet and question Perth Zoo and local Department staff involved in those aspects of the *Western Shield* program.

What do you think?

We want to know what you think of draft *Independent Review of Western Shield*.

Why write a submission?

It is an opportunity to provide information, express your opinion, suggest alternatives and have your say on how you think the *Western Shield* program has performed and what changes, if any, should be made to the program. If you prefer not to write your own submission you could make a joint submission with others.

What makes an effective submission?

To ensure your submission is as effective as possible:

- Make it concise and clear.
- List your points according to the subject sections (and page numbers) in the draft *Independent Review*.
- Describe briefly each subject or issue you wish to discuss.
- Say whether you agree or disagree with any or all of the objectives or parts within each of the draft *Independent Review* or just those of specific interest to you; clearly state your reasons (particularly if you disagree) and give sources of information where possible.
- Suggest alternatives to deal with any issue with which you may disagree.

It is important to indicate those parts of the draft *Independent Review* you agree with as well as those with which you disagree.

Each submission is important in its own right but those that give reasons for concerns, give support where appropriate and offer information and constructive suggestions are most useful.

What happens to your submission?

All submissions will be summarized according to the topics discussed. The draft *Independent Review* will then be considered in the light of submissions, according to established criteria (see below). A summary of the

submissions will be published (together with the final version of the Independent Review and the 12 review papers). Your submissions will not necessarily result in changes to the Independent Review since that is the product of the review panel, however it may well influence how the Department responds to the issues raised in the Independent Review. If a submission is marked 'CONFIDENTIAL' the author will remain anonymous in the summary submissions.

Deadline

Submissions are welcome for six weeks. The closing date for submissions is 5:00 p.m. Friday 21 November 2003. For enquiries please telephone (08) 9334 0333.

Where do you send your submission?

Written submissions should be sent to:

Executive Director
Department of Conservation and Land Management
Locked Bag 104
BENTLEY DELIVERY CENTRE, WA, 6983
Attention: Senior Zoologist, Wildlife Branch

APPENDIX 3

Summary of public submissions and an indication of the respondents' support for or opposition to each of the Review Panel's 17 recommendations. Y = support; Y* = qualified support; N = dissent. In some cases, distinction between qualification and dissent was, necessarily, subjective. The editors take responsibility for assignments to those categories. However, the nature of all qualifications and dissents are described in text.

RESPONDENT	STATUS	REVIEW PANEL RECOMMENDATION #																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Kim Anderson	Private	Y	Y*	Y	Y	Y	Y*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Confidential	Private	Y	N		Y	Y	Y	Y	Y*	-	Y*		Y	Y				Y
Dr Jack Kinnear	Private																	
Kanyana Rehabilitation Centre Inc.	Private	Y	Y	Y*		Y							Y					
Dr Dorian Moro, Edith Cowan University	Private	Y	N					Y				N	Y	Y		Y		Y
Conservation Council of WA	NGO	Y	Y	Y									Y					
Conservation Commission of WA	Govt																	
WA Dept. of Agriculture	Govt	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y			Y	
WA Dept. of Health	Govt												Y					
SA Dept. of Environment & Heritage	Govt																	
Dr Jeff Short, CSIRO Sustainable Ecosystems	Govt	Y	Y	Y	Y			Y	Y		Y					Y	Y	Y
Project Eden Mgmt. Committee (CALM)	Govt	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Exmouth District (CALM)	Govt	Y	Y	Y	Y	Y	Y	Y	Y	N			Y	Y		Y	Y	
Dr Tony Friend (CALM)	Govt		N															
Kelly Gillen, Regional Mgr. Midwest (CALM)	Govt	Y	Y*						Y	Y								
Fauna Conservation and Recovery Program staff (CALM Science Division)	Govt	Y	Y*	Y	Y	Y	Y*	Y	Y	Y	Y	Y*	Y*	Y	Y	Y*	Y	Y
TOTAL	Y	11	6	7	7	7	4	7	7	5	6	2	4	10	3	3	5	7
	Y*	0	3	1	0	0	2	0	1	0	1	1	1	0	0	1	0	0
	N	0	2	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0
Sum		11	11	9	7	7	6	7	8	6	7	4	5	10	3	5	5	7

Introduction to the papers

The reasons for reviewing *Western Shield* and the process that was adopted for the review are described in the Foreword and the Review Panel's report, elsewhere in this special volume of *Conservation Science Western Australia*. Nevertheless, understanding the nature of the papers published here requires some understanding of the circumstances under which they have been written.

To provide the Review Panel with comprehensive background information and expose its members to airing of that information in both public and in-house environments, the Executive Director commissioned twelve papers that were chosen to embrace all aspects of *Western Shield*. Each author was provided with specific terms of reference for his/her paper to ensure adequate coverage of topics, relevance to the review process and to avoid replication (Appendix 2 In Possingham *et al.* this issue). Authors were also required to comment on strengths, shortcomings and opportunities for improvements to aspects of the program that they implemented. This volume contains the papers that were originally presented to the Review Workshops and Review Panel members (but subject to minor revisions in the light of the workshop discussions and referee comments).

Collective publication of the papers is important because the set provides a snap-shot of *Western Shield* in 2003 that will become the historical benchmark against which progress is measured in future¹. A special volume of *Conservation Science Western Australia* is an appropriate publication vehicle because its content format allows all the papers, despite their wide array of subject matter, to be published in a stand-alone volume of a journal that requires all manuscripts to be subject to the rigour of external (to CALM) refereeing. Moreover, in order to ensure important material that is pertinent to conservation and natural area management is publicly available, the journal accommodates papers that are too parochial or unacceptably long for mainstream journals. However, publication here has presented several challenges to scientist and non-scientist authors alike.

Scientist authors writing papers for publication in refereed scientific journals are usually able to choose their subject parameters and follow more or less conventional formats. However, addressing an imposed set of tightly-defined terms of reference while, nevertheless, presenting scientifically rigorous information that will be subject to external refereeing, requires departure from the comfort zone of normal scientific writing.

Similarly, non-scientist authors are exposed, often for the first time, to the concept of refereeing and to being required to revise their papers to accommodate the (sometimes anonymous) referees' comments. In many cases, formatting papers to the journal's editorial prescriptions is also a new experience. Thus, they too have departed from the comfort zone of more familiar creative or administrative writing styles.

Finally, but (under the circumstances) understandably, many referees were faced with new or unfamiliar requests. For example, some scientists who were invited to referee papers with scientific content were critical of unconventional formats that were sometimes dictated by the terms of reference given to author(s). Similarly, it was necessary to invite people who were familiar with a paper's subject matter, but not necessarily with the process of refereeing, to referee papers dealing with non-scientific subjects such as public relations and administration.

The labours of referees and authors, alike, in coming to grips with the processes has been commendable and has resulted in substantial improvements to the papers without compromise to the underlying information that was presented at the workshops and to the Review Panel. In the light of the unusual circumstances outlined above, as editors of this special volume, we accept full responsibility for interpretation of some referee comments and author responses and we take this opportunity to acknowledge the hard work, tolerance and willingness to work through issues that both referees and authors have afforded us.

TONY START AND PETER MAWSON
8 OCTOBER 2004

¹ To preserve the integrity of the papers as a benchmark, they have not been updated to reflect developments between February 2003 and publication, except to provide full references to papers that were 'in press' at that time.

Management of the *Western Shield* program: *Western Shield* review—February 2003

GORDON WYRE¹

¹ Acting Director of Nature Conservation, Department of Conservation and Land Management,
Locked Bag 104, Bentley Delivery Centre, WA, 6983. gordonw@calm.wa.gov.au

INTRODUCTION

This paper has been prepared to give an overview of the management of the Western Shield Program in terms of budget and technical planning, coordination and resourcing. In so doing it provides a background to the development of the program, the current management arrangements and some thoughts for the future on possible variations to the current management model. The thoughts for the future are based on experiences gained through the initial 6 years the program has been operating. They take into account the desirability of balancing the need for minimizing overhead costs, so as to maximise operational resources, while also providing sufficient management control to avoid waste of public and community resources.

INITIAL CONCEPT FOR WESTERN SHIELD

Targeted recovery of fauna

The initial proposal for the *Western Shield* Program (Burbidge *et al.* 1995) was essentially to take the experience gained from successful feral predator (fox) baiting projects and translate this into a broad scale baiting program that would recover a wide range of fauna species. A number of projects had been undertaken with fox baiting coinciding with population recovery of a range of native fauna species including black footed rock wallabies (*Petrogale lateralis lateralis*), numbats (*Myrmecobius fasciatus*) and woylies (*Bettongia penicillata*).

A particular focus of the proposal was the Critical Weight Range mammals (35 g to 5.5 kg; Burbidge and McKenzie, 1989) that had been significantly reduced in range and abundance in a pattern believed to be caused by fox predation. The broad scale of the program would allow economies of scale to maximise benefit/cost ratios. The program would include re-establishment of species that were locally extinct, where fox predation was considered to be the major cause of target species

population decline. This re-establishment would be achieved primarily through translocations.

Another key feature of the initial plan for *Western Shield* was its expansion to incorporate broad scale operational feral cat control once a proven technique that elicited population recovery in native fauna had been proven.

The essential elements of the initial *Western Shield* proposal were to recognize that the Department of Conservation and Land Management was in a unique position to conduct a broad scale fauna recovery program in the south-west and west of the State due to the following four key features of Western Australia.

- The very significant and largely contiguous system of State forests managed for conservation and other conservation reserves.
- The ready availability of a poison bait that was:
 - guaranteed for supply through the State's Agriculture Protection Board;
 - equivalent to a naturally occurring toxin that did not pose a threat to native fauna; and,
 - proven to be effective in fox control in a range of habitats such that Critical Weight Range mammals exhibited rapid population recovery in baited areas.
- The availability of source native mammal populations for restocking of areas depleted of natural biodiversity.
- A community that would not only tolerate, but embrace and support such a broadscale wildlife recovery project.

The 1995 proposal (Burbidge *et al.* 1995) had the following vision.

The fauna of south-western Australia has been severely fragmented. At the community level, many ecological communities have been virtually destroyed. At the species level some animals are extinct, some have been lost from the region and many others are endangered, surviving only as relict populations. The CWR mammals have been most affected. Almost all of this has happened during this century. However in the last decade CALM has turned the tide. We have been successfully recovering the endangered species. Now we have the ability and the will to reconstruct the fauna (excepting the species that are totally extinct).

In doing so we will be rescuing our heritage, re-starting the ecological processes that were driven by the 'lost' fauna, and setting Western Australia at the forefront of fauna conservation on a global scale. Ecological knowledge of threatened species has increased enormously as a result of the many scientific projects that have taken place in recent years. Scientific research into the causes of the extinctions and operational fox control are now both sufficiently advanced for a major coordinated program of fox control and animal re-introductions to commence. Such a program will lead to the reconstruction, as far as is possible, of much of the original fauna of the south west of Western Australia, and ultimately, the rest of the State. For the first time in many decades, people will again be able to see almost extinct mammals, such as the Western Barred Bandicoot and Boodie, without having to travel to remote, fragile island nature reserves. Other threatened species, such as Western Ringtail Possums and Malleefowl should also increase in abundance.

Western Shield will lead to a major improvement in the conservation status of many animal species. It will dovetail with many other Western Australian nature conservation and economic initiatives - initiatives such as Landcare (embracing better management of remnant vegetation), and ecotourism and environmental education, including the Hills Forest and Landscape Expeditions. Spotlighting expeditions to view the south-west's native mammals can become a major tourist attraction, adding a further draw card for visitors to the State. Additional fox control will benefit farmers on adjoining agricultural lands through increased lamb survival and more effective and cheaper fox control will be possible on a regional scale.

In the largely agricultural south west of the State, where the great majority of the land is privately owned, the success of virtually all conservation programs, including the control of feral predators and the maintenance of remnant vegetation, will depend upon the support and involvement of landholders. Coordinated community programs to control feral predators have the potential to eliminate, or greatly reduce, target species, and so result in larger, more visible populations of threatened species over entire regional areas. These results provide great benefits both for nature conservation and for the landholders themselves.

The proposal (Burbidge *et al.* 1995) also listed the following principles to be followed in developing and implementing *Western Shield*:

1. Additional fox control projects will be based on a system of Fauna Reconstruction Sites (FRS) and

Species Recovery Sites (SRS) (CALM Policy Statement No 29) designed to provide protection for existing threatened mammals and to allow the re-introduction of species that are locally extinct. Fauna reconstruction sites are not only an effective means of achieving nature conservation; they are also the most cost-effective means of doing so. Costs for baiting, fire management and measuring species density will be minimised when many species are being managed in the one area.

2. Current fox control projects will be reviewed and those that are clearly beneficial to threatened species will be provided security of funding.
3. The involvement of local communities in fox control, and in reconstructing the fauna, will be promoted and facilitated, with the aim of eventual joint community / CALM ownership of *Western Shield*.
4. With some special exceptions, widespread fox control will be limited to areas of the south-west with an annual mean rainfall greater than 350 mm, where cats are not expected to present a significant problem. The 350 mm rainfall isohyet is set as a guide only; areas outside it may be considered for fox control if their vegetation is of a type in which cats are judged likely to have little effect on native prey species, and areas within it may not be suitable for species recovery.
5. Translocations will take place only after the approval of Recovery Plans or Interim Recovery Plans for the threatened species involved, and the approval and funding of Translocation Proposals, as laid down in CALM Policy Statement No. 29.

The proposal (Burbidge *et al.* 1995) also identified the following aims for fox control under *Western Shield*

1. To conserve those elements of the Western Australia fauna that are declining because of fox predation.
2. To reduce fox density on conservation lands and private property in Western Australia to a level that will allow the reconstruction of fauna that has become locally extinct because of fox predation.
3. To involve rural communities in fox control and in achieving the first two aims.

Recognising the need for government accountability and for measures of success or failure of the investment of considerable public funds, the initial proposal incorporated a fauna recovery monitoring program to involve:

1. Routine trapping and animal recording procedures carried out by CALM District operations staff as part of their normal work load.
2. Special monitoring undertaken by CALM scientific staff as part of the implementation of Recovery Plans, particularly where monitoring requires special techniques (e.g. the numbat).

The ambitious initial monitoring plan involved up to 40 fauna reconstruction and species recovery sites being incorporated in ongoing monitoring operations through the first 5-year phase of the program. These sites would

be areas where management priority is given to the reconstruction of a nominated suite of native fauna species, and in species recovery sites to nominated threatened fauna species.

As stated in the 1995 proposal:

Species Recovery Sites will complement the system of Fauna Reconstruction Sites, allowing particular mammal species to be conserved in areas that are either too small or have an insufficient range of habitats for the reconstruction of the original fauna, or where the special needs of Critically Endangered species take priority. Community involvement and ownership will be facilitated.

The initial proposal was very much focused on recovery of species that were already *in situ*, given that many species were still extant, but at very much reduced population densities. Where stocks were not available for recovery in local areas, priority would be given to natural recolonisation where possible, along with wild-to-wild translocation style reintroductions, where local populations did not exist.

The *Project Eden* proposal for reconstruction of the terrestrial fauna of Shark Bay had a focus of translocation of a range of mammal species found on nearby Bernier and Dorre islands, but extinct on the mainland including boodies (*Bettongia lesueur*), banded hare-wallabies (*Lagostrophus fasciatus fasciatus*) and western barred bandicoots (*Perameles bougainville bougainville*). There was a clear potential for these species to also be translocated to former habitat areas elsewhere in the State under the *Western Shield* program and indeed this was proposed in the initial list of Species Recovery Sites/Fauna Reconstruction Sites.

Initial resourcing and management

The initial resourcing concept for *Western Shield* was for the bulk of resources to be expended ‘on the ground’ and so minimal new resources were to be put into administration or staff positions. Instead the program was to incorporate a range of existing operations and staff resources, with a re-focus and re-direction under the overall umbrella of *Western Shield*. The existing operation in the northern Jarrah forest *Operation Foxglove* was to be totally incorporated into *Western Shield* along with the baiting operations for *Project Eden* (reconstruction of the mammal fauna of Peron Peninsula in Shark Bay) and Montebello Renewal (reconstructing the fauna of the Montebello Islands).

The key new position proposed was the fauna ‘monitoring coordinator’ to coordinate monitoring activities undertaken by regional staff in ‘fauna reconstruction sites’ and ‘species recovery sites’.

The initial proposal also included the incorporation of feral cat control research as an ongoing CALM Science Division commitment and component of *Western Shield*, with expansion of this research as resources became available.

The initial management concept for *Western Shield* was as follows:

- Management coordination, including budget accountability by the Director of Nature Conservation with all coordinating positions in Nature Conservation Division.
- Fox baiting to be managed by Environmental Protection Branch, responsible to the Director of Nature Conservation.
- Monitoring and translocations to be coordinated by the new Monitoring Coordinator within Nature Conservation Division, responsible to the Director of Nature Conservation.
- Monitoring of population responses to baiting through Regional Services staff.
- Specialist monitoring by Science Division staff.
- Community baiting facilitation to be coordinated by the possible establishment of a new community fox control coordinator within Nature Conservation Division, responsible to the Director of Nature Conservation.
- Program implementation monitoring through a proposed Western Shield Steering Committee.

The initial budget proposal was as listed in table 1.

TABLE 1

Initial proposed budget.

EXPENDITURE ITEM	COST
Baiting costs	\$886,960
Monitoring/success criteria costs	\$93,950
Cat research (Algar; ANCA FPP money not renewed)	\$120,000
Community Fox Control Coordinator	\$63,500
TOTAL	\$1,164,410

THE APPROVED WESTERN SHIELD PROGRAM—1996

Overview

Western Shield was, from the outset, a grand plan developed under the personal guidance of the then Executive Director of the Department, Dr Syd Shea. The approved *Western Shield* program commenced in 1996. It was determined by the department’s Corporate Executive that the program would essentially be as proposed by Burbidge *et al.* 1995, with the only full new position being that of the Western Shield Zoologist’ (monitoring planning and coordination). Funding for the program was provided in the form of \$1,150,000 from the Department’s budget, with an additional \$120,000 from the ALCOA funds provided under the CALM ALCOA Forest Enhancement (CAFE) agreement relating

to bauxite mining in the northern jarrah forest. This gave an initial budget package of \$1,270,000.

It was determined that the component funding of the above for feral cat control research would total \$418,000 over the first three years of the program. It was further decided that liaison with community groups undertaking fox control programs would be facilitated at the regional level and through overall baiting planning and management undertaken by Environmental Protection Branch, as well as direct cooperation with the Agriculture Protection Board.

Overall management control of the program was the responsibility of the Director of Nature Conservation, with the Western Shield Steering Committee facilitated by the Manager of Wildlife Branch and the Senior Environmental Officer (Western Shield Manager) in Environmental Protection Branch.

The reporting arrangements for 1996 in Western Shield Management are presented in Figure 1.

Key reporting relationships and duties were as follows.

- Overall Program Direction, Coordination and Management
 - Director of Nature Conservation
- Program Implementation Monitoring, Standards and Procedure Specifications
 - Western Shield Steering Committee
- Program Implementation
 - Western Shield Manager, Operations Officer, Zoologist, Science Researchers and Field staff.

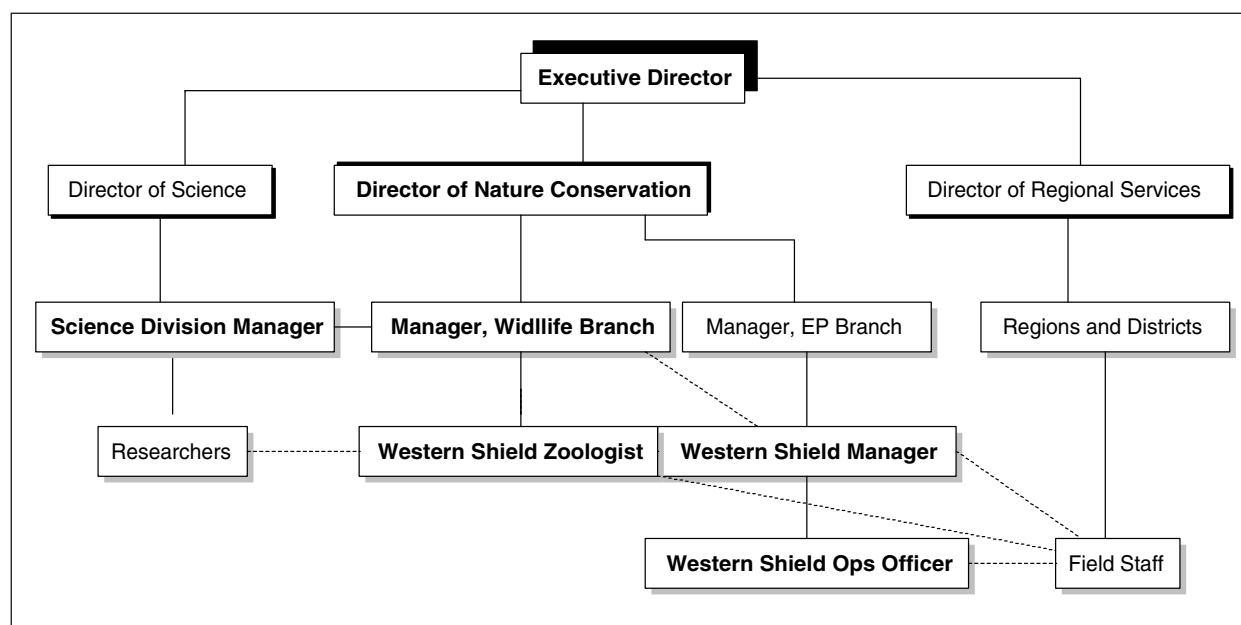
The initial Western Shield Steering Committee involved the following personnel:

- Director of Nature Conservation (or proxy, Manager, Wildlife Branch), overall program management.
- Manager, Fauna Conservation Research (Science Division), Science Division's aspects of monitoring and translocation programs and standards.
- Senior Environmental Officer (Environmental Protection Branch), Western Shield Manager, Western Shield baiting and regional services coordination.
- Corporate Relations Officer, public notices, publications and publicity.
- Regional Services (operations) Representative.
- Other specialist staff as required for translocation planning etc.

A south-west operations management committee was also established. This committee involved regional and district staff engaged in planning field operations, with a particular focus on baiting. A key feature of the program has been the provision of some central *Western Shield* program funds to assist with such operations (c. \$150,000 p.a.). Coordination at this level has been consistently good throughout the entire operation of Western Shield.

The approved budget for 1996 is listed in Table 2. It is noteworthy that several existing positions were significantly changed with the advent of Western Shield. The most significant changes occurred in Environmental Protection Branch, where two staff took on the roles that became 'Western Shield Program Manager' and 'Western Shield Operations Officer' in addition to (and indeed in replacement for, their duties for feral animal control coordination and other related duties). These positional changes were not reflected in the Western Shield budget.

The budget also did not include significant resources for field site monitoring, the costs for which were borne by regions and districts through refocusing their nature conservation activities.



Note: key components in bold.

Figure 1. Initial Western Shield Program management structure.

TABLE 2

Western Shield initial approved budget and expenditure by operation categories; 1996–97 financial year.

OPERATIONS CATEGORY	BUDGET \$	ALLOCATION \$
Western Shield Source of Funds		
Departmental funds	1,150,000	
CAFE	120,000	
TOTAL	\$1,270,000	
Western Shield Operations		
Baits and bait production		440,150
Aircraft hire and fuel		242,500
Advertising and printing		61,500
Materials/services		151,950
Plant/vehicle		27,980
Staff training		3,000
Flying allowance		6,010
Travel allowance		9,630
Airfares		6,000
Radio		0
Overtime		0
TOTAL core baiting related activities		\$948,720
Other Operations		
Cat Research		158,000
Wildlife Zoologist & Monitoring		73,280
Monte Bello Renewal		64,000
Contingency		26,000
TOTAL	\$1,270,000	\$1,270,000

DEVELOPMENTS 1996–1999

Initial success

After the launch of the *Western Shield* Program, a review was completed on the populations and conservation status of the woylie. This review was completed in 1996 and concluded that the species was at that time no longer under significant threat. Soon after the completion of this review, the woylie was delisted from the State and national threatened species lists and also from the international IUCN Red Book list. It was officially ranked as Lower Risk, on the basis of demonstrated recovery (including re-established populations in South Australia) and ongoing fox control operations.

In 1998 the quenda and tammar wallaby were removed from the State's threatened species list on the basis of recovery under *Western Shield*.

The initial success set a benchmark for the program and has led to widespread expectation that not only will a range of fauna species be protected from further population declines, but that further species will also be removed from threatened species lists in the future. This has placed some pressure on the program to focus on selected species and to target areas where specific species can be recovered, which was a key part of the original plan.

A significant early initiative under the program was the development of the concept for a field-breeding centre at Dryandra Woodland. This was linked with the development of the Peron Captive Breeding Centre and

intensive breeding of numbats and chuditch at Perth Zoo in a plan to give the overall fauna recovery operations of the Department a full suite of animal source options. These were:

- on-site recovery, where the species persisted
- wild-to-wild translocation for species that were readily trappable in remote areas but unlikely to spread naturally to baited areas
- field breeding for species that could be kept in artificially high densities at the Dryandra Field Breeding Centre, with minimal intervention as a source for wild re-establishment
- intensive captive breeding at Peron and Perth Zoo for species which could tolerate such intervention and still have reasonable wild survival chances, or for which there was some urgency of recovery or significant difficulty in wild harvests or field breeding.

The expansion of breeding options provided a greater ability for the program to again target key threatened species and to also focus on species recovery.

Corporate Sponsorship

It was recognized by the department's Corporate Executive at the time of establishment of the Program that it would be attractive to corporate sponsorship and so from 1996 efforts were made to attract such sponsorship to fund additional operations or to meet cost pressure increases. These initiatives were coordinated by the Director of Nature Conservation and pursued by the Manager, Wildlife Branch, with assistance from the Manager, Environmental Protection Branch.

In addition to the CAFE/ALCOA funds, direct cash sponsorship was negotiated in the period 1996 to 1999 with Cable Sands Pty Ltd, and Westralian Sands (Iluka Resources) Pty Ltd. In addition non-cash/in kind assistance has been negotiated with a number of companies over the years of operation of the program.

Corporate sponsorship provided for initiatives within specific areas that were related to the interests or area of operation of the sponsors. It also allowed for further central funds to be expended in research and development initiatives related to baiting, including the establishment of field and captive breeding populations.

Budget review 1998

The initial budget was very significant for a wildlife recovery operation and in planning the ongoing expenditure it was hoped that advances with feral cat control would be achieved within three years. For this reason it was determined that the cat research budget component would cease in 1998–99. This would progressively release the cat research budget component, which was \$158,000 in 1996–97, for use in operational baiting or to meet cost increases in other areas.

In 1998 the first detailed budget review was undertaken. This highlighted cost increase pressures and

also pressures being applied both from within the Department and externally for expansion of the baited areas and species to be targeted. Further details of these aspects are presented in other papers. These cost pressures have required very careful and deliberate targeting of expenditure and a greater level of budget support for basic field operations from regional and specialist Branch budgets, not necessarily allocated under the *Western Shield* budget.

Key cost pressures from 1997 have been attributed to increasing bait and aircraft costs, along with vehicle fleet costs. This is discussed further in Armstrong, this issue.

Bait prices have risen dramatically in response to full cost recovery requirements of the Agriculture Protection Board (APB), while aircraft costs have increased in keeping with fuel and general aviation charges. There has therefore been, from the very beginning, a strong incentive for the Department to develop means to reduce bait costs and streamline aircraft operations. The Department has also had an ongoing objective of 'increasing bait delivery precision', to ensure the effectiveness of baiting operations, and also to avoid wastage.

A specific focus of the program has been expansion of baiting to key target areas where continued economies can be reached or where specific priority outcomes have been identified. In 1998 key target areas for future baiting expansion were the northern sandplains (north of Perth to Geraldton), Avon Valley and Walyunga National Parks (immediately north of Perth, and retaining rock wallaby habitat) and expansion of operations for rock wallabies at Cape Range (by 2003, these areas have largely been included in the baiting operations).

The principal result of this review was to raise awareness of the budget pressures on *Western Shield* and to provide a priority focus on what areas should be targeted in future. It reinforced the need for external funds for feral cat control program development and provided the incentive for a review of operational areas for baiting and species recovery over the next two years.

MANAGEMENT OF OPERATIONS: WESTERN SHIELD STRATEGIC PLAN 2000–2004

Operations 2000–2003

A number of major developments occurred for the Department over the period late 1999 through to mid-2001 that had impacts on the operations and management of the *Western Shield* Program. These included the departure of Dr Shea as Executive Director in 1999, the splitting-off of the commercial aspects of forest logging operations to the Forest Products Commission in 2000–01, the introduction of Output Purchaser Provider (OPP) budget management as an initiative of the new Executive Director, Dr Wally Cox in 2000–01, and the reductions in the departmental overall base budget over the period

2001–02 and 2002–03. Ongoing changes in plans for the APB's bait factory in terms of possible privatization, closure and cost structures, have also significantly influenced *Western Shield* planning. These issues are covered in Armstrong, this issue.

The change to OPP budgeting in place of program budgeting provided for greater central control of nature conservation budgets through the position of the Director of Nature Conservation. This initiative provided scope for the Director of Nature Conservation to set priorities for the new Nature Conservation Output expenditure across the Department (other outputs are Parks and Visitor Services, Sustainable Forest Management and the Perth Observatory). One positive feature of this move was the greater integration of *Project Eden* funding into the overall *Western Shield* planning as these projects were under more direct budget control of the Director. There will be further discussion on the *Project Eden* component of *Western Shield* elsewhere during this review. It will suffice to state here that there is further scope for integration of *Project Eden* into the *Western Shield* Program.

Under cost cutting initiatives of government the department's Nature Conservation Output was subjected to a 7.4% budget cut over the period 2001–02 to 2002–03. This equated to a total of a \$2,430,000 reduction in funding for nature conservation activities per annum from 2002–03. While the specifically identified Western Shield budget was 'quarantined' from the cuts, the resultant cuts to Regional Services, CALM Science and Nature Conservation Division activities and staffing inevitably impacted on the program.

In tandem with these cuts and changes in Departmental operations a number of key positions in the Department, including that of the Director of Nature Conservation and Manager, Wildlife Branch were filled only in an acting capacity (this continues). Also, the Environmental Protection Branch Manager's position was abolished and the Branch has since been amalgamated with another area of the Department (Wildlife Protection). Currently the part time positions of 'Western Shield Program Manager' and 'Western Shield Operations Officer' are effectively undertaken by a single officer, with direct assistance from other staff, including the Director of Nature Conservation. This is a temporary measure while a recent vacancy is filled, but is still having an impact on coordination of the program.

Western Shield Strategic Plan 2000–2004

As a result of the budget review in 1998 and ongoing pressures from a range of areas into 1999, the Western Shield Program Manager, prepared a Draft Western Shield Strategic Plan in 1999. This plan was considered internally within the then departmental management structure. It was unfortunate that the development of the plan coincided with the very significant changes to the Department outlined above. Nevertheless the strategic plan has proven to be a very significant document and one that can be a basis for the overall review of the management structure for the program for the next five

years. It has been accepted by the Director of Nature Conservation as an operational draft and has formed the basis of management of the program since 2000. It is anticipated that a revised strategic plan will be prepared for more widespread consideration following this review.

The draft strategic plan is an update of the original Western Shield proposal document (Burbidge *et al.* 1989) and has specific objectives and targets, performance indicators, a clarified management structure and associated roles and responsibilities.

In essence, the draft strategic plan brings the initial project proposal or 'blueprint' for the program forward by recognizing the progress made in fauna recovery and planning. Significantly, the draft plan has more specific operational guidelines. The key features of the draft strategic plan 1999–2004 are summarised in Table 3 and Figure 2.

Western Shield mission

- To conserve and enhance those elements of the Western Australian fauna that have declined as a result of predation by introduced predators (foxes and cats) and rats where applicable e.g. islands.
- To reconstruct the fauna that has become locally extinct because of predation by reducing the density of foxes and feral cats on conservation lands, and encourage their reduction on private lands.
- To inform the community of Western Australia of the aims and progress of *Western Shield* and involve them in its implementation.

Western Shield principles

- Controlling introduced predators for fauna conservation is a long-term commitment that cannot be diminished or abandoned once begun.
- Our fauna heritage belongs to all Western Australians and every effort should be made to involve them in its conservation.
- While much is known about introduced predator control and predator/fauna interaction, continuing research is needed to refine and add to the knowledge enabling cost effective operations to be developed and improved.

Western Shield priorities

Introduced predator control:

- Control of introduced predators will be undertaken in those areas where it can be demonstrated to be effective.
- Those areas with extant fauna vulnerable to predation will be given first priority for introduced predator control.

- Those areas that no longer contain fauna vulnerable to predation but which have suitable habitat will be given second priority for introduced predator control.

Fauna Translocations:

- Translocations of native fauna will only be undertaken in situations where the native fauna species are not present and/or cannot colonize the treated area by natural spread.
- Species listed as 'threatened' will have a higher priority for translocation than other non-threatened species.
- The focus for translocations should be on fauna reconstruction sites.

Captive breeding:

- Only species that cannot be readily translocated from existing wild populations will be bred in captivity.
- Threatened species will be favoured over non-threatened species for captive breeding.
- Species will only be bred in captivity if release sites with suitable habitat are available.
- Captive breeding facilities will be maintained at several sites to manage risk of failure or loss.
- Species will be bred for release in Western Australia unless required by a species recovery plan to be released elsewhere.

Monitoring:

- Monitoring of translocated threatened species will continue until they are established.
- Monitoring of indicator species will be undertaken across the geographic extent of the *Western Shield* program.
- There will be a balance of long term monitoring of indicator species and short term monitoring of re-introduced species.

Objectives and targets:

- Maximise the recovery of sustainable populations of vulnerable native fauna by reducing the impact of predation by foxes and feral cats.
- Develop cost efficient and effective control techniques for foxes and feral cats.
- Through education and public relations programs increase the awareness of the effect of fox and feral cat predation on native fauna and what can be done to mitigate this effect (best practice).
- Link predator control and fauna recovery to complementary research projects.
- Develop and maintain partnerships with groups and organisations that maximise the efficiency and effectiveness of fauna recovery across Western Australia.

TABLE 3

Draft Key Performance Indicators for *Western Shield* (Draft Strategic Plan).

KEY PERFORMANCE INDICATOR	EFFECTIVENESS INDICATOR	EFFICIENCY INDICATOR
Establish and maintain predator control over CALM-managed lands where predation is a threatening process.	Hectares of CALM-managed lands that are subject to predator control operations.	The cost per ha per annum of undertaking such operations.
Recovery of fauna threatened by predation.	Extent to which indicator species recover in terms of percentage trap success or other appropriate measure. Number of threatened species allocated to more secure conservation categories under IUCN criteria.	The cost per ha per annum of undertaking predator control and fauna monitoring operations, per species down-listed.
Awareness of WA public to the threat that predation poses to native fauna.	Extent to which market research polling indicates public awareness.	Cost per annum of public relations and education programs.

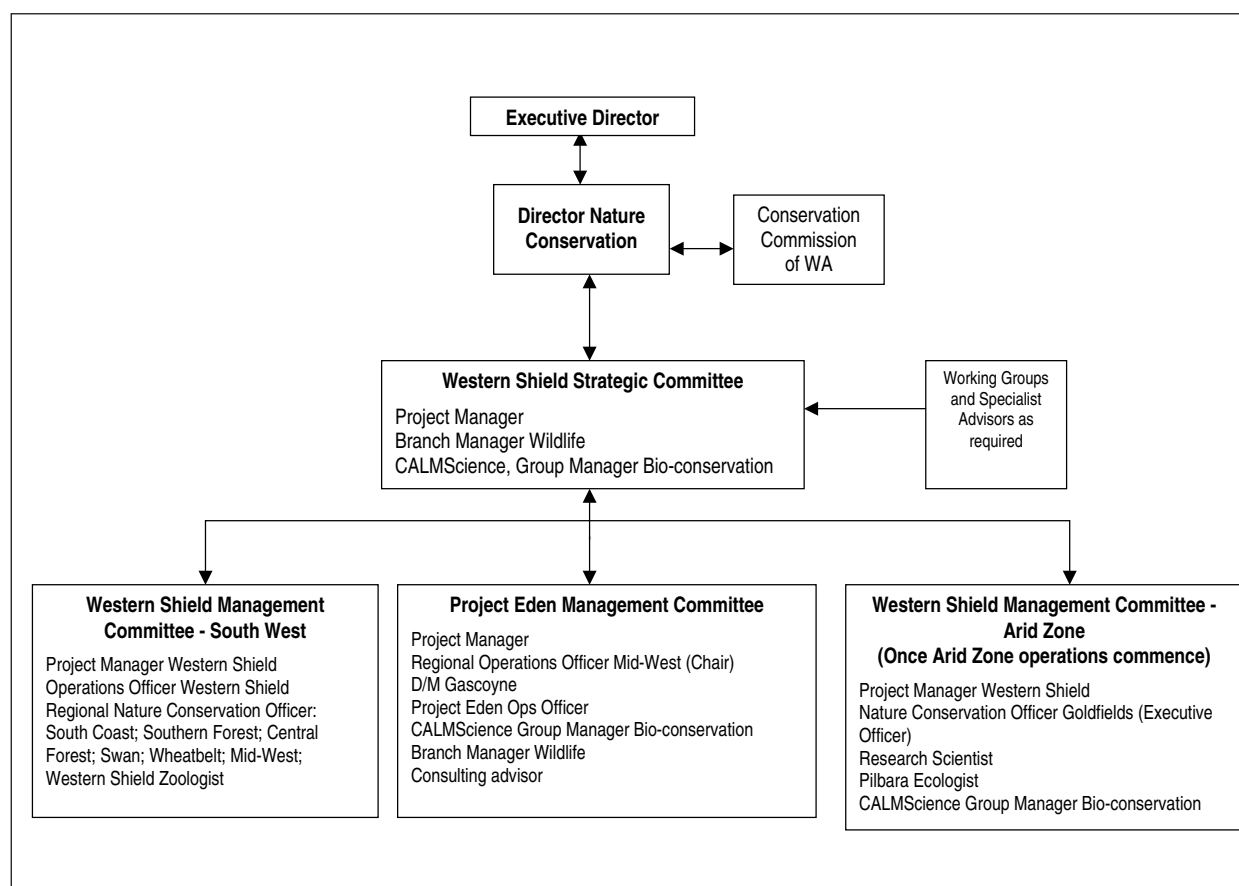


Figure 2: Management Structure 1999–2000 to 2003. Detailed responsibilities of the various parties are listed in the Appendix.

Current *Western Shield* management structure and budget

The overall direction and guidance of the draft strategic plan is an improvement on the original blueprint for the program. In particular, it has addressed problematic issues of resource allocation, while also maintaining faith with the original vision of an integrated broad scale program delivering demonstrable native fauna recovery.

The draft plan also proposed a minor reworking of the management and organisational structure for the entire program, including *Project Eden*. This is presented in Figure 2. The responsibilities of the various parties to this management structure are listed in the Appendix.

Budgeting has been a very significant management concern over the past six years, as outlined earlier. Over recent years cat control research has been funded under a very generous sponsorship package from the Wind over Water Foundation.

Along with cost cutting and the sponsorships received, essential budget requirements for the Program have been met, including increases of around 48% in the combined cost of baits and aircraft. This is demonstrated in Table 4.

TABLE 4

Comparison of budget expenditure for *Western Shield* from central funds 1996–97 and anticipated 2002–03.

WESTERN SHIELD OPERATIONS	1996–97 \$	2002–03 (ANTIC) \$
Baits and bait production	440,150	640,000
Aircraft hire & fuel	242,500	364,000
Advertising & printing	61,500	35,000
Materials/services/assistance	151,950	167,000
Plant/vehicle	27,980	15,000
Staff training	3,000	2,000
Flying allowance	6,010	0
Travel allowance	9,630	10,000
Airfares	6,000	1,000
Radio	0	500
Overtime	0	0
WS Zoologist	73,280	101,500
SUBTOTAL core baiting related activities	1,022,000	1,336,000
Other (cat research and contingency etc.)	248,000	18,000
SUBTOTAL	1,270,000	1,354,000
Project Eden	n/a	420,000
Grand Total	1,270,000	1,774,000

Possibilities for future management

The ongoing reviews of Western Shield, including the 1998 budget review and the preparation of the draft strategic plan in 1999, have identified a series of management issues for the program. These can be listed as follows:

- Planning and management of program budget and resources (day-to-day and overall)

- Ongoing monitoring and review of performance towards targets and objectives
- Review of appropriateness of targets and objectives
- Development of annual and bi annual works programs
- Reporting to the Executive Director and Corporate Executive on significant issues for the program

It is clear that the on-ground delivery of the program has been very successful and that the management of the program at that level has been good. The program has been managed within budget, with innovative developments realised in terms of management and refinement of aircraft contracts. Baiting and translocations have been well planned and conducted along with the required monitoring programs.

What has been lacking, however, is the high-level critical review and analysis of priorities. This has been partly due to a lack of a rapid and smooth two way transfer of information on the program between operational areas, specialist areas of the Department and senior management. This problem has largely arisen through inadequacies in the operation of the Western Shield Strategic Committee, which has not met as frequently as it should over the past four years. This has not been surprising given the resource and organisational changes experienced by the Department over this time.

The lesson learnt from this period is that a truly robust management system should be able to cope with organisational change and uncertainties. This requires both a clear statement of priorities and duties of those involved and a system to alert parties to any failures to meet these requirements.

Day-to-day program management and reporting

Over time the *Western Shield* program has become more clearly defined and its real resource requirements better known. Yet, six years after its commencement the true budget and resource costs of the program are not easily identified. The true costs of the program, taking into account sponsorships and related activities in Science Division and Regional Services areas, is well in excess of \$2 million per annum. With this operational expenditure it would seem appropriate to allocate a core full time management unit that would have the responsibility of ensuring that all communication channels operate and that there is adequate business and operational planning and review for the program. In this regard, the current part time positions of 'Western Shield Program Manager' and 'Western Shield Operations Officer' could be replaced with permanent counterparts. At the very least a full time 'Western Shield Program Business Manager', or the equivalent would seem to be appropriate. Full costs for a single permanent management position would be in the order of \$90,000 to \$100,000 per annum. An assistant position would add another \$50,000 or so to this cost.

This could be achieved within existing budgets by amalgamating the non Western Shield duties of the existing part time management positions and a relatively minor reallocation of existing Western Shield and other departmental budgets.

The Western Shield Business Manager and/or Business Management Unit would prepare and monitor annual business plans for the program, schedule and service meetings of the Strategic Committee and other coordination/operational committees and prepare an annual report on program performance for public consumption. This person/group would also have responsibility for ongoing review of the Program targets etc. as approved under the Strategic Plan.

As far as is possible, all Western Shield management, standard setting and training staff should be in the same administrative unit of the Department, and at least within the same Division.

Overall program management

The key improvement here would be to introduce a clear reporting and meeting schedule for the Strategic Committee, including reports to Corporate Executive and the community. Audited requirements for business planning and annual reports to Corporate Executive would help to refocus work plans of the various members of the Strategic Committee which should meet at least twice per year. This group would recommend to Corporate Executive any significant changes proposed for the program. Its task would be much easier once a clear position was established on activities and resources expended in areas within a true (and all inclusive) budget for the program.

Responsibility for this should continue to rest with the Director of Nature Conservation.

Review of appropriateness of targets and objectives

Now is an opportune time for the Department to undertake a review of Western Shield targets and objectives. The results from the *Western Shield* review should therefore include a definitive statement of the targets and objectives of the program (and also budget requirements) for the next five years. This would be the framework around which a new 5-year strategy for the program could be prepared. There should be ongoing minor annual reviews of targets and objectives, with major reviews scheduled for every 3–5 years.

Development of annual and biennial works programs

Annual and biennial works programs would be the responsibility of the Business Manager/group, as proposed above. While we currently prepare annual budgets and works programs, there is scope to extend the framework for such planning with a series of ‘what if’ scenarios linked to specific measurable targets under the overall Nature Conservation Output budget planning process.

Reporting to the Executive Director and Corporate Executive on significant issues for the program

There should be endorsement and auditing by Corporate Executive of the requirement for an ongoing reporting timetable, as discussed above. This would include as a minimum review of annual reports on targets and performance of the program.

Other management issues

There is a series of other management target issues that have been raised in papers prepared for this review. A key question among these is the relative priority between reconstruction of fauna in numerous areas and a more standard threatened species recovery focus. The management requirement relating to such issues is to ensure that there are mechanisms to adequately consider improvements to program delivery and to implement these efficiently. The structure and processes outlined above should provide this framework.

REFERENCES

- Burbidge AA, McKenzie NL (1989) Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* 50, 143–198.
- Burbidge AA, Start AN, Morris KD, Armstrong R (1995) ‘Western Shield—Bringing back our wildlife’. Department of Conservation and Land Management, Perth.

APPENDIX

Responsibilities of personnel in Figure 2

Director of Nature Conservation

- Supply guidance to Strategic Committee.
- Approve annual budget allocation to *Western Shield*.
- Approve *Western Shield* Strategic Plan.
- Approve major operational changes to *Western Shield*.
- Consider and endorse as appropriate recommendations from Strategic Committee.
- Report to Corporate Executive.

Western Shield Strategic Committee

- Advise on the target areas for predator control.
- Advise on priorities for *Western Shield*.
- Seek resources from sponsors.
- Allocate funds to Western Shield projects.
- Manage the *Western Shield* budget.
- Maintain a current Strategic Plan for Western Shield.
- Ensure best practice and CALM policy is applied to Western Shield operations.
- Recommend major changes to operational prescriptions or *Western Shield* programs to Director Nature Conservation
- Approve minor changes to operational prescriptions or *Western Shield* programs.
- In consultation with relevant CALM managers, recommend the re-introduction of fauna to Western Shield baiting areas.
- Ensure fauna monitoring protocols and reporting procedures are in place and utilised.
- Ensure appropriate training is available for personnel involved in *Western Shield*.
- Make recommendations to Director Nature Conservation regarding research requirements or research proposals affecting Western Shield operations.
- Report periodically to Director Nature Conservation

Western Shield Management Committees

- Determine the annual resource requirements to undertake Western Shield projects and inform the Western Shield Strategic Committee.
- Allocate available resources to undertake Western Shield projects.
- Coordinate the utilisation of CALM resources for baiting, fauna management and educational components of the *Western Shield* program.

- Ensure best practice is applied to Western Shield operations and CALM policy and procedures are complied with.
- Schedule operational components of Western Shield projects to achieve optimum effectiveness and efficiency.
- Vet proposals for changes to prescriptions and make recommendations to Western Shield Strategic Committee.
- Vet proposals for additions or deletions to the *Western Shield* program and make recommendations to Western Shield Strategic Committee.
- Identify opportunities for public education and public relations and convey these to the Project Manager.
- Determine training needs of personnel involved in Western Shield operations and communicate them to the Project Manager.
- Identify research requirements and comment on research proposals affecting Western Shield operations. Make recommendations to the Strategic Committee.
- Report periodically to Western Shield Strategic Committee.

Western Shield Project Manager

- Attends Strategic Committee and Management Committee meeting and acts as a communication bridge between them.
- Ensures Management Committees function to identify and resolve issues affecting the implementation of Western Shield projects.
- Ensures relevant training opportunities are available to personnel involved in Western Shield projects.
- Prepares, monitors and controls the Western Shield budget.
- Coordinates and integrates the implementation of *Western Shield*.
- Liaises with Director Nature Conservation, Strategic Committee, Management Committee and other relevant managers to implement Western Shield projects.
- Coordinates all introduced feral predator control operations.
- Encourages process improvement and productivity improvement in Western Shield operations.
- Facilitates opportunities for public relations and education.
- Prepares reports on behalf of Strategic Committee.

Baiting operations: *Western Shield* review—February 2003

ROGER ARMSTRONG¹

¹Senior Environmental Protection Officer, Department of Conservation and Land Management, PO Box 1693, Bunbury, Western Australia 6231. rogera@calm.wa.gov.au

Introduction

Introduced predators have been identified as a significant threatening process to the conservation of native wildlife (Environment Australia 1999, Braysher 1993). *Western Shield* is an initiative of the Department of Conservation and Land Management (CALM) targeted at reducing the predation of native fauna by introduced foxes and cats. The program reduces predation pressure to a level that ensures the continued persistence of native fauna and particularly those within the critical weight range (CWR) of 35 to 5500 gm (Burbidge and McKenzie, 1989). The program involves the regular delivery of 1080 fox baits to approximately 3.4 million ha of conservation estate in the southern half of Western Australia.

This paper addresses aspects of the *Western Shield* baiting operations. The terms of reference are set out in Appendix 2 in Possingham *et al.* (this issue). Essentially, they require the paper to address:

- The areas being baited, their progress and cost
- The outcome of operational research and its implications for future baiting plans
- Bait production and costs
- The development of Probait
- The history of baiting programs and
- Changes made to baiting protocols.

The task is covered in four sections headed:

- Procuring bait material
- Management and use of the 1080 toxin
- Contracts for supply and management of aircraft and navigation technology and
- Coordination and management of baiting operations.

For each, problems, potential economies and potential improvements are summarized in subsequent sections.

PROCURING BAIT MATERIAL

Current bait supply contract

Dried meat baits (DMB) have been the preferred bait for most *Western Shield* fox-control programs, particularly aerial baiting. Dried meat baits are manufactured using 200 gm chunks of fresh kangaroo meat that are dried to

a weight of approximately 45 gm. Supplies of DMB for *Western Shield* are purchased from the Western Australian Department of Agriculture (DAWA), which is the only commercial supplier in this State.

The current annual DMB requirement for *Western Shield* for both aerial and ground based operations is 780 000 baits. To facilitate production scheduling, CALM advises DAWA of its anticipated annual DMB requirements in advance and submits firm orders quarterly. Baits are collected from the DAWA Bait Production Unit (BPU) at Forrestfield by CALM staff in a custom-built freezer truck and distributed to departmental storage facilities throughout the State where they are held in locked freezers on departmental premises (Table 1 and see section Bait Management below).

TABLE 1
Departmental bait storage facilities.

LOCATION	NUMBER OF FREEZERS	STORAGE CAPACITY (DMB)
Karratha	1	7 000
Exmouth	3	21 000
Denham	2	14 000
Kalbarri	3	21 000
Jurien Bay	2	14 000
Wanneroo	1	7 000
Mundaring	2	14 000
Jarrahdale	2	14 000
Dwellingup	4	28 000
Collie	2	14 000
Harvey	2	14 000
Busselton	2	14 000
Manjimup	6	42 000
Pemberton	1	7 000
Walpole	1	7 000
Albany	2	14 000
Jacup	6	42 000
Esperance	2	14 000
Katanning	2	14 000
Pingelly	3	21 000
TOTAL	49	343 000

Dried meat baits are manufactured manually. The method is slow, wasteful, unreliable expensive and production capacity is limited.

- The meat preparation process is time-consuming and drying meat pieces to their final form requires four days per batch

- Bait production is limited by the production capacity of the meat driers (currently 4000 baits/week)
- Because 200 gm chunks are required, only the large muscles of a kangaroo carcass can be utilized
- The quality of meat delivered to the BPU is variable and wastage in excess of 20% is not uncommon
- Reliability of supply is often jeopardized by field conditions precluding kangaroo shooters from harvesting. *Western Shield* operations have, at times, needed to be modified because the BPU has been unable to obtain sufficient quantities of kangaroo meat. For example a shortfall of 55 800 baits for the June 2001 baiting program had to be accommodated by reduced bait-density in a number of cells. The uncertainty of supply and the long lead times required by the manufacturer are significant threats to the effectiveness of routine baiting operations
- The quality of the DMB can be affected by micro-organisms causing spoilage. Rotten ('puffy') baits are extremely unpleasant to handle and are of questionable effectiveness and often have to be discarded. For example, in 2000, spoilage required the destruction by deep burial of \$9000 worth of baits that had been delivered to Manjimup
- The per-bait cost (which is the DAWA factory-door cost-price) has steadily increased (Table 2) in line with cost increases and progression to government full cost recovery principles. At current bait requirements, every one-cent rise increases the annual program cost by \$7800.

TABLE 2
Change in cost of DMB from 1994 to 2003 (excluding GST).

YEAR	PER-BAIT COST	ANNUAL COST OF 780 000 DMB
1994	\$0.650	\$507 000
2003	\$0.964	\$752 000
Increase	\$0.314 (48%)	\$245 000 (48%)

The 1996 central budget for *Western Shield* was \$1.15 million (excluding resources allocated by other cost centres and resources provided by corporate sponsors). As the central budget has not changed from 1996 to 2003, the increased cost of baits has reduced central budget funding for other components of the project by \$245 000 (21%). Any reduction in bait cost would constitute a significant saving to the project. Indeed, bait procurement and aircraft hire for deployment is currently equivalent to 99% of the central budget.

Future bait supplies

There have been several attempts to find new manufacturers. In 1999 the Agriculture Protection Board (APB; a component of DAWA) attempted to outsource the manufacture of all 1080 bait products by inviting

proposals to lease the BPU at Forrestfield for up to three years. Four proposals were received. The preferred proponent was unwilling to proceed without a commitment by CALM to purchase baits. CALM agreed, subject to guaranteed pricing which was unacceptable to the proponent. The APB repeated its invitation in 2001 but all four responses were unacceptable.

In 2002 the APB advised CALM that the BPU would cease to manufacture 1080 baits as of the 30 June that year. As a result CALM called a tender for the manufacture and supply of dried meat baits. The feasibility and cost effectiveness of the tenders received were assessed and the cheapest tender found to add 75% (\$566 200 per annum) to bait procurement costs. As this was considerably in excess of the current bait price and considerably above the costs of CALM producing in house, the tender was withdrawn. On receipt of this advice the APB/DAWA advised CALM that the BPU would continue to manufacture and supply baits to CALM.

In view of the precarious bait-supply situation, in 1998–99 CALM (with advice from the small-goods processing industry) developed a sausage-bait (Pro bait) based on the salami manufacturing process. Advantages were:

- an automated process
- large production runs
- minimal wastage
- improved shelf-life
- an estimated factory-door cost of \$0.45 per bait (less than 1994 prices).

Moreover, the product's uniform shape and size allows

- improved packaging efficiency
- reduced transport and storage costs
- automated bait-laying procedures (see below).

Finally, there would be an opportunity to supply baits commercially, returning a profit to the Department, or subsidizing the cost of *Western Shield*.

A business plan was developed and submitted (in 2000) to the Director of Nature Conservation who referred it to a project team for review. The team endorsed the proposal and recommended an injection of \$400 000 for the first step, construction of a pilot plant. Although the capital has not yet been committed, opportunistic savings have financed some progress. At Harvey, south of Perth, plant and equipment capable of producing 200 000 Pro bait units per week has been installed and small scale, bench-top production and drying experiments have been undertaken over the past two years. The factory is now licensed to manufacture trial baits incorporating 1080 toxin. The National Registration Authority (NRA) registered Pro bait for manufacture and use in September 2002 (Product No. 53187). However, production of sufficient Pro bait units for *Western Shield* will require additional investment in drying equipment.

While the capacity to produce Probait proceeds, work is progressing on testing its efficacy as a fox bait, and its potential risk to non-target species:

- A captive fox population at CSIRO's laboratories in Canberra readily took and consumed both Probait and DMB without evident caching behavior but trial-design problems have hampered analysis of preference (R. Brazell, CALM, Collie personal communication).
- Feeding trials have investigated the palatability of (toxin-free) Probait and DMB to the native species thought most at risk from 1080 baiting operations. Results indicate that risks posed by Probait and DMB are approximately equal (Martin *et al.* 2002) and the risk to non-targets from DMB in the *Western Shield* operational area is acceptable.
- In trials involving a wild fox population near Yalgoo/Paynes Find, uptake of DMB was 11% greater than Probait. However, degradation by ants and/or the effect of inserting bio-markers may have reduced the persistence or palatability of Probait in the field (N. Marlow unpublished data).

Production of cat baits

In liaison with Science Division staff, development of an effective cat-bait has progressed in parallel with the development of Probait for foxes. The formulation and manufacturing process for cat baits is well advanced (Algar and Burrows, 2004). The NRA has registered operational-scale manufacture and deployment of the cat bait (incorporating 1080) for experimental purposes. Application for full NRA registration is progressing (D. Algar, CALM, personal communication). The ultimate aim is to produce a bait carrying a cat-specific toxin. In the meantime, a cheap and effective bait that can be deployed for simultaneous fox and cat control would be useful.

CONTROL AND USE OF 1080 TOXIN

Authority and procedures for use of 1080 bait products

Originally, the use of 1080 products was restricted to DAWA officers and persons they authorised under conditions they stipulated. However, DAWA officers were accustomed to using 1080 products for agricultural protection, not nature conservation. The frequent baiting of large areas of natural vegetation necessary for *Western Shield* fox control was outside their experience. The approval process required to utilize 1080 for nature conservation purposes involved a time consuming bureaucratic process between CALM and DAWA.

This inefficient arrangement was reviewed by CALM, DAWA and the Western Australian Department of Health.

As a consequence, the legislation has been changed. Pesticides containing 1080 are now controlled under the *Poisons Act of Western Australia 1964*. A Code of Practice on the Safe Use and Management of 1080, 2000 (the Code) has been developed under the provisions of 'Section 24, Poisons Notice of the Poisons Act. Registered Pesticide 1080'. The Code is the basis for CALM's standard operating procedures.

Accredited CALM officers can use 1080 bait products for nature conservation purposes. Accreditation requires successful completion of a training package approved by the Executive Director of Health. Currently, 179 CALM officers are authorised to use registered 1080 bait products. In addition, 38 officers are Authorised Risk Assessors. They are authorised to assess applications by landowners and managers to use 1080 bait products on any land for nature conservation purposes. Accredited departmental staff train and accredit CALM personnel as well as contract aerial baiting bombardiers in the use and possession of fox baits. All accreditations lapse after three years. Re-accreditation requires re-assessment of competence.

The Code requires that every *Western Shield* target area be subject to an application to bait. Approval requires (amongst other things) a satisfactory risk assessment. All approved programs are reviewed annually to ensure adherence to the Code and to accommodate circumstantial changes that may affect risk levels. This has been useful because changed circumstances (notably urban encroachment) at several target areas have affected risk levels and required prescription modifications. Baiting prescriptions are also reviewed after non-target incidents (notably, alleged dog poisoning).

Bait management

CALM maintains a register of all baits:

- collected from the BPU
- delivered to storage facilities
- issued from storage facilities for field use.

There are also quarterly checks of stored baits in each storage facility (Table 1). Bait numbers delivered to each facility take into account the requirements of approved prescriptions and the baits already on hand. Records are audited annually (as required by the Code) and audited records are made available to the Department of Health. They are also available on CALM files.

Orders are placed with the BPU under the authority of 1080 Authorisation Vouchers for *Western Shield* baiting cells. Issue and Receipt Vouchers are used to track all subsequent transfer transactions within CALM. Bait orders are released from the BPU into the custody of an 'authorised' driver of a CALM, purpose-built freezer truck who delivers them to the custody of 'authorised' district officers who secure them in departmental storage facilities. A Bait Register at each storage site records all deposits and withdrawals.

Recorded details are:

- the name of the person into whose custody baits are received or released
- the location where baits are to be used
- Issue and Receipt Voucher details.

National Registration Authority—1080 bait registration

The National Registration Authority (NRA) is currently reviewing the use of 1080 in Australia. Use and management practices vary considerably between State and Territory jurisdictions. Issues being examined include non-target impacts and the humaneness of 1080 as a vertebrate pest toxin. A whole of Western Australia government submission, including a comprehensive information package, has been provided to the reviewers. The written submission was supported by personal presentations and field trips for the NRA Board and its officers. The possibility of further restriction or prohibition of the use of 1080 is of great concern. This could restrict or abolish opportunities for economically feasible conservation of threatened fauna. Results of the review are expected in late 2004.

Irrespective of the NRA review, public tolerance of the use of 1080 is essential to its continued availability for conservation use. This reinforces the importance of proactive communication with the public and careful, conservative risk assessment for each baiting application. Selection of baiting targets near to urban or built up areas or areas of high public use could jeopardizes the future of the entire program. Protection of small populations of vulnerable fauna in these areas cannot be achieved using 1080 bait products if it puts the continued use of this tool at risk. Not all proponents of baiting operations appreciate this restriction and their lack of understanding is sometimes a cause of friction between portfolios within CALM.

MANAGEMENT AND COORDINATION OF BAITING OPERATIONS

Baited areas and baiting regimes

About 3.4 million hectares are baited under the *Western Shield* program. The baited areas (Appendices A,B,C and D) were selected in 1996 as the areas that best met the strategic aims of the original project proposal. The *Western Shield* program also incorporated a pre-existing experimental baiting program, *Operation Foxglove*, located in the northern Jarrah forest.

Operation Foxglove commenced in 1994 with corporate sponsorship from Alcoa World Alumina Australia under the CALM Alcoa Forest Enhancement

(CAFE) agreement. Its aim was to experimentally determine the most economically effective baiting regime required to meet fauna recovery objectives in the northern jarrah forest. The work was undertaken by Paul de Tores (CALM, Science Division). The experiment compared fauna response to baiting two, four and six times per year against an unbaited control. Fieldwork was completed in March 2002. The outcomes have been used to adjust baiting prescriptions on all Foxglove cells to four times per year. A plan to bait a 10 km strip along the eastern margin six times per year to reduce fox immigration from adjacent farmland has been developed and will be implemented if funds are available. The future of the unbaited control areas have not yet been determined. Ongoing support is being sought from CAFE.

The list of baited areas was reviewed in 2001 and several were discontinued for various reasons (Table 3). The review was undertaken in conjunction with the annual review of baiting applications and risk assessments. Given the large areas that are baited frequently each year and the degree of public access to baited areas, poisoning non-target domestic or working animals is inevitable and a few incidents are reported each year. Each incident is investigated and remedial action taken where risk of recurrence can be reduced. The risk is managed by proactive media advertising, articles in the popular press, direct neighbour notification (Kawalilak *et al.* this issue), conservative risk assessment and meticulous adherence to operational prescriptions.

TABLE 3

Areas deleted from active baiting since 2001.

CELL NAME	AREA (HA)	REASON FOR REMOVAL
Karroun Hill NR	40 000	Numbat – introduced to the area on a number of occasions - was found to be in continuing decline and baiting was not arresting decline.
Torndirrup NP	3 844	Baiting area immediately adjacent to populated town site. Continued baiting would not have met risk assessment guidelines.
Millbrook	1 484	Small size and isolation. Only quenda thought to be present. They are adequately represented elsewhere.
Helms Arboretum	3 778	Fauna monitoring since 1998 did not indicate any fauna response to baiting. Area is too small and isolated for re-introduction sites.
Capel NR	<15	Too small, isolated and disturbed to be of any nature conservation benefit to CWR mammals.
Ruabon NR	<15	Too small, isolated and disturbed to be of any nature conservation benefit to CWR mammals.
Fish NR	<10	Too small, isolated and disturbed to be of any nature conservation benefit to CWR mammals.

Management functions

From the outset, the project has been a high departmental priority. It was allocated a central budget of \$1.15 million but other resource needs have had to be found from existing programs. Thus, a substantial component of a CALM Environmental Protection Branch officer's time was assigned to co-ordinate and manage the project. Other personnel from Wildlife Branch, Regions and District-based Nature Conservation Officers provided significant additional support.

Currently, a Project Manager and an Operations Officer, located in the department's Environmental Protection Section, manage the baiting program. Their salary is met from the normal Branch budget and, although *Western Shield* is the largest component of both officers' workload, they also have other duties. A new position of Western Shield Zoologist was created with a salary drawn from the *Western Shield* central budget to work full time on *Western Shield* monitoring and field-staff training (Orell, this issue).

While the Operations Officer coordinates baiting operations, District staff undertake the roles of Aircraft Baiting Coordinators (ABC) and bombardiers. District resources cover most of the costs but there is modest assistance from project funds. Where it is needed, Districts resource all additional ground baiting.

The project manager developed a five-year strategic plan for 1999–2004 that defined an organizational structure and identified areas of responsibility. Although the plan was submitted to the Director Nature Conservation for approval the Corporate Executive has not formally ratified it. Nevertheless, many components of the document are used informally. Four groups have been formed to provide direction.

1. A Strategic Committee comprising the Project Manager, Director of Nature Conservation and the Manager, Biodiversity Group, Science Division was formed to maintain the strategic direction of the program. It served a useful purpose in early days but it has not met regularly and has been ineffectual at achieving its intended role.
2. A Management Committee was formed to prioritise operational aspects of the program in the State's southwest. It met periodically but should have met more regularly. It did achieve most of the role for which it was established.
3. A Management Committee was formed to guide implementation of Project Eden because it is a large program that integrates predator control with fauna reconstruction in a geographically discrete area, Shark Bay. Membership is drawn from people involved in that project and the Western Shield Project Manager who provides a link to the *Western Shield* program. It works well.
4. Similarly, an effective Management Committee guides implementation of Montebello Renewal.

SUPPLY AND MANAGEMENT OF AIRCRAFT AND NAVIGATION TECHNOLOGY

Aerial baiting operations were first outsourced in 1994 for Operation Foxglove. The contractor used a single engine aircraft and navigation technology designed for aerial photography. The aircraft was flown at 1000 ft AGL at 90 knots and baits were laid at 200 m intervals along parallel flight lines 1 km apart (5 baits per km²). The aircrew consisted of a contract pilot and a departmental bombardier from the local District. An incident involving an engine failure in this aircraft over forest near Dwellingup in 1996 resulted in the Department stipulating the use of twin-engine aircraft when there are CALM officers on board.

A twin-engine aircraft contracted to the Department for controlled-burn ignition and equipped with Department-owned navigation equipment and software was used for six months. This interim arrangement allowed time to establish a dedicated aerial-baiting contract.

The contractor was required to provide GPS navigation equipment that met departmental specifications for accuracy, inputs and outputs. A non-differential GPS with a maximum error of 90 m was allowed. Unbaited buffers adjacent to private property were set at 1000 m to accommodate GPS (and possible human) error as well as wind drift while baits were falling. The new contract performance specifications required:

- recovery from an engine failure under full fuel and useful load burden and the maintenance of a climb gradient of 1.5% on one engine to 3000 ft ASL
- endurance of 270 minutes
- minimum safe operating speed of 150 knots
- cruising speed of 180 knots
- ability to operate from 900 m gravel airstrips.

Besides the safety factors, the specifications permitted four hours of useful baiting on each sortie, minimised ferry times and enabled use of local airstrips for re-fuelling and reloading. These specifications were used for two years.

Meanwhile, bait-drop trials indicated that DMB were not particularly aerodynamic. At an altitude of 500 ft AGL and an airspeed of 160 knots with a 10-knot tailwind, baits carried forward no more than 77 m. These results, combined with the accuracy achievable with a differential GPS, led to the opportunity to reduce the unbaited buffers alongside private property to 500 m and the operational flying altitude to 500 ft. New tenders were called.

Digital navigation files are prepared for each baiting cell. They specify flight lines designed to minimise unnecessary turns and unproductive time. They incorporate un-baited buffers adjacent to private property boundaries and baiting exclusions over internal high-risk areas (e.g. recreation sites in national parks). The contractor uploads the files into the aircraft's navigation system. Whilst in the air, the location at which any object

leaves the aircraft via the bait-drop tube is recorded to within ± 10 m by infrared sensors at the bottom of the tube. The information is subsequently plotted on a map of the baited cell and used as an audit tool.

Originally, a digital LED display on the instrument panel allowed the pilot to fly along the flight line and to count down the distance to the entry and exit from the cell along each flight line. A flashing green light indicated to the bombardier that the aircraft was within the prescribed baiting area and a red light indicated that the aircraft was outside it. A timer calibrated to the aircraft speed controlled the flashing intervals informing the bombardier when to drop baits down the bait tube. This ensured an inter-bait distance of 200 m. An audible alarm sounded if the infrared sensors were triggered when the aircraft was outside the prescribed baiting area. Baiting halted immediately and the aircraft circled until the cause of the alarm was determined and recorded in the flight log. Common causes included flies, bait chips, pieces of ice, packaging material from bait bags and vomit.

An automated baiting machine now eliminates the risk of dropping baits outside the prescribed area because of human error. It consists of a carousel (loaded by the bombardier in flight) that rotates under the control of the navigation equipment and, being linked to the DGPS, releases baits at 200 m intervals, irrespective of air and ground speeds. When the aircraft is not over the prescribed area, the carousel locks. If 'free flying' (e.g. following the edge of a gorge) is required, a timer can over ride the navigation control of bait release to maintain 200 m bait intervals.

In 2002, a new five-year aerial baiting contract was awarded. A Memorandum of Understanding between the Department and the contractor provides guidelines for the operational implementation of the contract. The contractor provides the flight crew (pilot and bombardier). Payment is based on area baited, not aircraft flying time. Aircraft specifications are not defined so that the contractor can choose the number and type of aircraft (including single or twin-engine, fixed or rotary-wing) best suited to the job and resources available. However, the baiting specifications are narrowly defined and the contractor has to provide post-operational plots depicting bait locations, aircraft track and altitude. Moreover, daily flight diaries detail the cells baited, the number of baits dropped, wind speed and direction, and the incidence of any alarms for objects leaving the aircraft outside the prescribed baiting areas. These are auditable documents. The contract specifies completion of each baiting cycle within 56 days.

DIFFICULTIES

Bait procurement

- DMB production methods are slow, wasteful and expensive and DMB are prone to spoilage.

- DMB supply problems sometimes cause insufficient bait for routine operations
- Outsourcing attempts by DAWA have created uncertainty and pose future potential supply risks to *Western Shield*.
- Lack of funds for development and production of Pro bait has delayed securing an alternative (and superior) long-term bait supply.
- Operational production of cat baits will also be affected if the Harvey bait factory is not completed and staffed.
- The durability of 1080 in meat baits is an issue (that is not helped by technical difficulties associated with assay methods). Degradation could lead to sub-lethal dosing and consequently bait-shy foxes. Nevertheless, there is no evidence of widespread bait shyness in Western Australia to date.

Control and use of 1080 toxin

- There is no departmental policy or guideline on managing vertebrate pests. *Western Shield* is setting the direction for predator control but it operates in isolation of other pest management priorities. It is also an issue where urban encroachment impinges on baited areas causing conflict of opinion among staff wanting to protect fauna and those who have to refuse permission to use 1080 baits because of risk assessment outcomes.
- There are perennial problems associated with small but inevitable incidents of non-target poisoning, particularly domestic animals.
- Not all proponents of baiting operations appreciate the risk that public backlash to non-target incidents poses to the continued authority to use 1080 baits for conservation. This lack of understanding has caused debate within CALM on operational priorities. This debate, if not appropriately resolved, could lead to operations with an unacceptable risk to non-targets and consequent restrictions on the use of 1080 in this State.

Management and coordination of baiting operations

- Coordination and assurance that statutory and best practice requirements are met has been difficult because of limited time, the large number of people involved and their dispersed geographic locations.
- The same constraints have limited regular reporting on progress against stated objectives.
- The committee structure secured commitment in the program's establishment phase. However, it has become cumbersome in its operation as some committee members are not directly responsible or accountable for implementing decisions. It is also resource hungry and time consuming.

Supply and management of aircraft and navigation technology

- Any significant extension of the baited area may require further investment by the contractor in capital equipment.

POTENTIAL ECONOMIES

Bait procurement

- Development and application of Probait will reduce annual bait-procurement expenditure by about \$401 000, but will require a capital investment of approximately \$400 000 to establish manufacturing infrastructure. It would be possible to achieve this in a staged process that would spread the investment over a number of financial years.
- The irregular shape and size of DMB adds inefficiency to packaging and mechanized delivery. More efficient packaging of Probait will reduce handling, and distribution costs.
- Probait stability at room temperatures will eliminate the costs of purchasing, maintaining and running storage freezers.
- Automation of ground baiting operations may result in faster bait deployment and significant time saving for District staff.
- If DAWA continues to have a role in providing bait products to primary producers, a whole of government strategy to meet the State's bait production requirement should result in economic efficiencies.

Control and use of 1080 toxin

- This functions well now and no potential economies could be identified.

Management and coordination of baiting operations

- The cost effectiveness of *Western Shield* has probably been very high. However, real costs are not accurately captured because many cost centres absorb costs into routine operational budgets. Internal budgeting arrangements based on internal contracts such as Service Provider Agreements would contribute significantly to accurate and reliable identification of true costs, and potential economies.
- Sponsorship has been vital. More investment in the identification of potential new sponsors, development of sponsorship proposals and servicing the information requirements of secured sponsors could substantially improve the project's funding base. The fixed-term nature of most sponsorship agreements underlines the importance of this activity.

Supply and management of aircraft and navigation technology

- The efficacy of automated aerial bait laying can be improved by using standard-shaped baits (Probait). Standard baits could lead to automated carousel loading and reduction of crew to a pilot only.
- The Department of Agriculture uses aircraft to bait wild dogs in the pastoral areas of the State. Cooperative contracting arrangements have not been possible to date, but the issue should be re-examined.
- Fox baiting is gathering momentum in other States and South Australia is now undertaking aerial baiting trials for nature conservation. There are opportunities to assist their operations and offset some of the contract maintenance costs.

POTENTIAL IMPROVEMENTS

Bait procurement

There are many opportunities for innovative improvements to Probait. They need to be explored through an ongoing focus on research and development. For example:

- Incorporation of artificial scent and taste enhancers could improve attractiveness and palatability.
- Incorporation of an ant repellent compound could extend field life of baits and reduce the chances of sub-lethal dosing.
- Development of a water-resistant skin could improve the field-life of baits generally and become an alternative to buried egg baits (used in wetlands; they are costly to produce and deploy).
- Inclusion of chemical or physical markers in the Probait recipe would facilitate investigation of suspected non-target poisoning incidents.
- Tethering of baits may help to resolve some problems associated with baiting in high-risk areas. Building string loops into Probait should be investigated.
- Mechanisation of the bait laying operation. Ground baiting operations could utilise a 'mortar' device to launch baits from a moving vehicle to a safe distance from tracks, reducing staff time and other costs.
- Compact packaging and mechanised bait deployment from aircraft may reduce the number of aircrew required for baiting operations and hence baiting costs.
- Labelling of baits with warning markings could further reduce occupational health and safety risks to operators as well as any member of the public who may come into contact with Probait in the field.

Management and coordination of baiting operations

- A policy framework on management of vertebrate pests on Department-managed lands would provide operational guidance for the integration of vertebrate pest control across the Department
- *Western Shield* is now perceived as a generic name for any work dealing with introduced predator control and/or fauna recovery. A clear definition of its parameters is required.
- The Strategic Committee should be abolished and replaced by line-authority of an appropriate manager. This will ensure responsive and timely decision-making and clear lines of accountability, responsibility and reporting.
- Service Provider Agreements between the manager responsible for implementing *Western Shield* and managers responsible for providing the supporting services need to be established and clearly defined. This will ensure that project objectives, and the resources needed to achieve them, are incorporated into normal departmental operations.
- The Project Manager, Operations Officer and Zoologist should be dedicated positions within a management unit. The unit requires an additional L3/4 position to assist with routine management audit functions and administrative support.
- Closer integration of fauna recovery planning with the *Western Shield* program would resolve conflicts and enhance efficiency (many recovery actions have nothing to do with *Western Shield*, but membership of *Western Shield* personnel on relevant recovery teams might be useful).
- The productive and informed working arrangement between the Department of Health and CALM needs to be fostered
- Consistent size and long shelf-life of Probait offers the potential to develop and deploy automated bait stations in remote areas that now require expensive travel to regularly protect small, isolated prey populations (e.g. rock-wallabies in the deserts).

Supply and management of aircraft and navigation technology

- The current aircraft contract and arrangements are the result of eight years of experience and continual improvement. It will take time to evaluate the current system, but there may be opportunities for further improvements.

CONCLUSIONS

The development and implementation of the *Western Shield* program has demonstrated considerable initiative and innovation since its inception. The achievements to date have been nationally significant. These achievements have been made with the application of relatively few resources and the incorporation of skills and technologies not usually found in a land management agency. The opportunities for *Western Shield* to become more effective lie primarily in the areas of project management and bait product development.

The development and adoption of the Probait product has the potential to realise significant financial savings and operational efficiencies. A valuable adjunct to this work is the ability to contribute significantly to the development of an effective cat control technology that would have international implications for fauna conservation. To enable this work to proceed with confidence will require a consistent commitment to research and development, the establishment of manufacturing capacity and a whole of government approach to implementation.

The facilitation of effective project management requires a clear definition of agency policy on vertebrate pest management and the dedication of resources to ensure consistent operational processes and standards are set and adhered to. Organisational structures are required that clearly define lines of responsibility and accountability. Contractual arrangements within the agency are required to ensure effective financial management, operational execution, reporting and accountability. The inculcation of the *Western Shield* program into normal agency operations should be strived for and existing management structures utilised to achieve effective implementation.

The success of the program to date has been contributed to by effective cooperation and liaison between government agencies such as CALM, DAWA and the Health Department. Liaison and engagement of other stakeholders such as corporate sponsors, neighbouring landholders, aviation interests and community-based interest groups has also been vital to the programs ongoing success. This experience and knowledge has been confined to date to a small number of agency personnel involved in managing the program. This experience and knowledge needs to be spread across the agency to ensure effective managerial succession and continued improvement.

REFERENCES

- Algar D, Burrows ND (2004) Feral Cat control research: *Western Shield* review–February 2003. *Conservation Science W. Aust.* 5 (2),131-163. Department of Conservation and Land Management, Western Australia.

- Braysher M (1993) *Managing Vertebrate Pests: Principles and Strategies*. Bureau of Resource Sciences, Department of Primary Industries and Energy, Canberra.
- Burbidge AA, McKenzie NL, (1989) Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation*. **50**, 143-198.
- Environment Australia (1999) *Threat abatement plan for predation by the European Red Fox*. National feral animal control program, Biodiversity Group, Environment Australia. Canberra.
- Kawalilak R, Higgs N, Moore E (2004) Communications, community awareness and schools education programs: *Western Shield* review–February 2003. *Conservation Science W. Aust.* **5** (2), 96-107. Department of Conservation and Land Management, Western Australia.
- Martin GR, Twigg L, Marlow NJ (2002) The acceptability of three types of predator baits to captive non-target animals. *Wildlife Research* **29**, 489-502.
- Orell P (2004) Fauna Monitoring and Staff Training: *Western Shield* review– February 2003. *Conservation Science W. Aust.* **5** (2), 51-95. Department of Conservation and Land Management, Western Australia.

APPENDIX A

Aerial and ground baiting cell summary

Note: 'Area of the cell' is the total area approved for baiting. 'Approved number' of baits is the number of baits approved by the 'Risk Assessment and Baiting Approval' process for that baiting cell each year.

CELL NAME	TOTAL AREA OF CELL (HA)	APPROVED # BAITS PER YEAR	CELL NAME	TOTAL AREA OF CELL (HA)	APPROVED # BAITS PER YEAR
Argyle	10 412	1 320	Leeuwin National Park	500	3 300
Avon National Park	14 711	5 200	Leschenault	1 071	1 200
Bakers junction	1 090	960	Locke Nature Reserve	187	192
Batalling	45 754	8 400	Magenta	95 000	32 000
Bendering Nature Reserve	1 601	800	Manjimup	133 011	26 840
Boyagin Nature Reserve	4 903	12 350	Manypeaks	10 967	3 164
BramleyForest Block	4 260	640	Mehniup Hill	383	300
Burruup	8 494	1 200	Mt caroline	351	1 430
Cape Arid	205 246	48 400	Mt stirling Nature Reserve	224	845
Cape Le Grande	33 667	7 576	Mullalyup	6 624	640
Cape Range	70 966	14 400	Nambung	140 474	23 200
Corackerup	4 334	2 400	Nangeen Hill Nature Reserve	176	1 040
Creary and Channel islands	74	48	Nornalup	7 979	2 700
Creery Wetland	94	48	Nth Kalgarin	5 119	2 200
Crookes pp	64	546	Peniup	3 630	2 200
D'Entrecasteaux	9 3875	18 000	Peron	105 000	10 800
Denbarker	243 842	43 200	Porongorup National Park	2 621	1 880
Donelly	132 897	30 000	Ravensthorpe Range	25 647	3 900
Dongolocking	2 350	7 200	Roe Nature Reserve	1 246	800
Dragon rocks	32 200	10 600	Sales Rock	65	520
Dryandra	23 838	42 900	Scott National Park	1 920	640
Dwellingup	132 178	25 140	Shannon	312 921	67 600
Ellen Brook	30	60	Stirling Range	101 901	29 860
Fitzgerald River	344 682	78 000	Stokes National Park	18 686	8 160
Gardners pp	10	364	Sunklands	286 310	50 400
Giants	3 026	1 600	Thompsons Lake	509	200
Grimwade	53 757	7 800	Tuart Forest	4 000	2 460
Gull Rock National Park	2 104	520	Tutanning	2 309	9 425
Gundaring	127	455	Twin Swamps	155	90
Hadfield	6 660	800	Two Peoples Bay	5 836	5 120
Harold Holt Aerial Farm	300	540	Walyunga National Park	1 812	3 000
Hills	101 662	21 400	Wellington	58 713	9 200
Irwin	6 177	1 000	West Cape Howe	3 517	1 040
Jaloran	455	1 200	Wilga	14 256	4 400
Jarrahdale	147 607	36 996	William Bay	1 700	450
Jerdacuttup Lakes	14 598	3 900	Worsley	11 083	2 000
Julimar	35 700	7 200	Yalgorup National Park	2 240	3 840
Kalbarri	180 563	34 400	Yelverton	1 000	1 200
Lane poole	87 755	24 300	TOTAL	3 421 206	820 099

APPENDIX B

Aerial fox baiting cell details.

Note 'Area' is the navigation file area not the total area of the cell.

Fiscal Year 1993–94

AIR CELL	DATE COMMENCED	AREA	BAITING PER YR	TOTAL AREA BAITED/YR	BAITS	TOTAL BAITS/YR
Julimar	April 1994	18 400	4	73 600	1 420	5,680
Hills Forest	April 1994	20 000	4	80 000	1 400	5,600
Batalling	April 1994	45 754	4	183 016	1 870	7,480
Gervasse	April 1994	10 200	4	40 800	440	1,760
Hadfield	April 1994	3 000	4	12 000	200	800
Kelmscott	June 1994	66 700	2	133 400	3 350	6,700
Jarrahdale	June 1994	127 800	2	127 800	6 640	13,280
Dwellingup	June 1994	116 500	4	266 800	6 000	24,000
Worsley	June 1994	14 400	2	28 800	720	1,440
TOTAL		422 754		946 216	22 040	66,740

Fiscal Year 1994–95

AIR CELL	DATE COMMENCED	AREA	BAITING PER YR	TOTAL AREA BAITED/YR	BAITS	TOTAL BAITS/YR
Julimar	April 1994	18 400	4	73 600	1 420	5 680
Hills Forest	April 1994	20 000	4	80 000	1 400	5 600
Batalling	April 1994	45 754	4	183 016	1 870	7 480
Gervasse	April 1994	10 200	4	40 800	440	1 760
Hadfield	April 1994	3 000	4	12 000	200	800
Kelmscott	June 1994	66 700	2	133 400	3 350	6 700
Jarrahdale	June 1994	127 800	2	127 800	6 640	13 280
Dwellingup	June 1994	116 500	4	266 800	6 000	24 000
Worsley	June 1994	14 400	2	28 800	720	1 440
Lane Poole	Jan 1995	94 000	6	564 000	3 900	23 400
TOTAL		516 754		1 510 216	25 940	90 140

Fiscal Year 1995–96

AIR CELL	DATE COMMENCED	AREA	BAITING PER YR	TOTAL AREA BAITED/YR	BAITS	TOTAL BAITS/YR
Julimar	April 1994	18 400	4	73 600	1 420	5 680
Hills Forest	April 1994	20 000	4	80 000	1 400	5 600
Batalling	April 1994	45 754	4	183 016	1 870	7 480
Gervasse	April 1994	10 200	4	40 800	440	1 760
Hadfield	April 1994	3 000	4	12 000	200	800
Kelmscott	June 1994	66 700	2	133 400	3 350	6 700
Jarrahdale	June 1994	127 800	2	127 800	6 640	13 280
Dwellingup	June 1994	116 500	4	266 800	6 000	24 000
Worsley	June 1994	14 400	2	28 800	720	1 440
Lane Poole	Jan 1995	94 000	6	564 000	3 900	23 400
Cape Range	April 1996	75 000	4	300 000	3 400	13 600
Karroun Hill	April 1996	40 000	4	160 000	2 000	8 000
Lake Magenta	May 1996	116 921	4	467 684	5 020	20 080
Dragon Rocks	May 1996	32 546	4	130 184	1 380	5 520
TOTAL		781 221		2 568 084	37 740	137 340

APPENDIX B (continued)

Fiscal Year 1996–97

AIR CELL	DATE COMMENCED	AREA	BAITING PER YR	TOTAL AREA BAITED/YR	BAITS	TOTAL BAITS/YR
Julimar	April 1994	18 400	4	73 600	1 420	5 680
Hills Forest	April 1994	20 000	4	80 000	1 400	5 600
Batalling	April 1994	45 754	4	183 016	1 870	7 480
Gervasse	April 1994	10 200	4	40 800	440	1 760
Hadfield	April 1994	3 000	4	12 000	200	800
Kelmscott	June 1994	66 700	2	133 400	3 350	6 700
Jarrahdale	June 1994	127 800	2	127 800	6 640	13 280
Dwellingup	June 1994	116 500	4	266 800	6 000	24 000
Worsley	June 1994	14 400	2	28 800	720	1 440
Lane Poole	Jan 1995	94 000	6	564 000	3 900	23 400
Cape Range	April 1996	75 000	4	300 000	3 400	13 600
Karroun Hill	April 1996	40 000	4	160 000	2 000	8 000
Lake Magenta	May 1996	116 921	4	467 684	5 020	20 080
Dragon Rocks	May 1996	32 546	4	130 184	1 380	5 520
Jerdacuttup Lakes	Sept 1996	17 746	4	70 984	730	2 920
Corackerup	Sept 1996	4 325	4	17 300	150	600
Peniup	Sept 1996	6 318	4	25 272	200	800
Collie	Oct 1996	31 944	4	127 776	1 360	5 440
Wilga	Oct 1996	14 256	4	57 024	530	2 120
Grimwade	Oct 1996	53 757	4	215 028	1 950	7 800
Fitzgerald	Oct 1996	377 641	4	1 510 564	18 300	73 200
Mullalyup	Oct 1996	6 624	4	26 496	160	640
Argyle	Oct 1996	10 412	4	41 648	330	1 320
Manjimup	Nov 1996	133 011	4	532 044	4 560	18 240
Shannon	Nov 1996	312 121	4	1 248 484	14 610	58 440
Denbarker	Nov 1996	243 842	4	975 368	11 000	44 000
Millbrook	Nov 1996	1 484	4	5 936	40	160
Kalbarri	Nov 1996	180 563	4	722 252	8 600	34 400
Stirling	Nov 1996	113 331	4	453 324	6 100	24 400
Two Peoples Bay	Nov 1996	9 274	4	37 096	300	1 200
Manypeaks	Nov 1996	13 393	4	53 572	550	2 200
Porongurup	Dec 1996	2 747	4	10 988	50	200
Irwin	Dec 1996	6 177	4	24 708	230	920
Giants	Dec 1996	3 026	4	12 104	70	280
Nornalup	Dec 1996	7 979	4	31 916	260	1 040
Stokes Inlet	Dec 1996	24 948	4	99 792	1 500	6 000
Cape Le Grande	Dec 1996	33 667	4	134 668	1 750	7 000
Cape Arid	Dec 1996	213 872	4	855 488	12 100	48 400
TOTAL		2 603 679		9 857 916	123 170	479 060

APPENDIX B (continued)

Fiscal Year 1997–98

AIR CELL	DATE COMMENCED	AREA	BAITING PER YR	TOTAL AREA BAITED/YR	BAITS	TOTAL BAITS/YR
Julimar	April 1994	18 400	4	73 600	1 420	5 680
Hills Forest	April 1994	20 000	4	80 000	1 400	5 600
Batalling	April 1994	45 754	4	183 016	1 870	7 480
Gervasse	April 1994	10 200	4	40 800	440	1 760
Hadfield	April 1994	3 000	4	12 000	200	800
Kelmscott	June 1994	66 700	2	133 400	3 350	6 700
Jarrahdale	June 1994	127 800	2	127 800	6 640	13 280
Dwellingup	June 1994	116 500	4	266 800	6 000	24 000
Worsley	June 1994	14 400	2	28 800	720	1 440
Lane Poole	Jan 1995	94 000	6	564 000	3 900	23 400
Cape Range	April 1996	75 000	4	300 000	3 400	13 600
Karroun Hill	April 1996	40 000	4	160 000	2 000	8 000
Lake Magenta	May 1996	116 921	4	467 684	5 020	20 080
Dragon Rocks	May 1996	32 546	4	130 184	1 380	5 520
Jerdacuttup Lakes	Sept 1996	17 746	4	70 984	730	2 920
Corackerup	Sept 1996	4 325	4	17 300	150	600
Peniup	Sept 1996	6 318	4	25 272	200	800
Collie	Oct 1996	31 944	4	127 776	1 360	5 440
Wilga	Oct 1996	14 256	4	57 024	530	2 120
Grimwade	Oct 1996	53 757	4	215 028	1 950	7 800
Fitzgerald	Oct 1996	377 641	4	1 510 564	18 300	73 200
Mullalyup	Oct 1996	6 624	4	26 496	160	640
Argyle	Oct 1996	10 412	4	41 648	330	1 320
Manjimup	Nov 1996	133 011	4	532 044	4 560	18 240
Shannon	Nov 1996	312 121	4	1 248 484	14 610	58 440
Denbarker	Nov 1996	243 842	4	975 368	11 000	44 000
Millbrook	Nov 1996	1 484	4	5 936	40	160
Kalbarri	Nov 1996	180 563	4	722 252	8 600	34 400
Stirling	Nov 1996	113 331	4	453 324	6 100	24 400
Two Peoples Bay	Nov 1996	9 274	4	37 096	300	1 200
Manypeaks	Nov 1996	13 393	4	53 572	550	2 200
Porongurup	Dec 1996	2 747	4	10 988	50	200
Irwin	Dec 1996	6 177	4	24 708	230	920
Giants	Dec 1996	3 026	4	12 104	70	280
Nornalup	Dec 1996	7 979	4	31 916	260	1 040
Stokes Inlet	Dec 1996	24 948	4	99 792	1 500	6 000
Cape Le Grande	Dec 1996	33 667	4	134 668	1 750	7 000
Cape Arid	Dec 1996	213 872	4	855 488	12 100	48 400
Sunklands	July 1997	286 310	4	1 145 240	12 560	50 240
Ravsthre Range	Sept 1997	18 140	4	72 560	1 290	5 160
D'Entrecasteaux	Oct 1997	93 875	4	375 500	3 940	15 760
Donnelly	Oct 1997	132 987	4	531 948	5 200	20 800
Burru Peninsular	Oct 1997	8 494	1	8 494	245	245
Scott	Mar 1998	1 053	2	2 106	100	200
TOTAL		3 144 538		11 993 764	146 505	571 465

APPENDIX B (continued)

Fiscal Year 1998–99

AIR CELL	DATE COMMENCED	AREA	BAITING PER YR	TOTAL AREA BAITED/YR	BAITS	TOTAL BAITS/YR
Julimar	April 1994	18 400	4	73 600	1 420	5 680
Hills Forest	April 1994	20 000	4	80 000	1 400	5 600
Batalling	April 1994	45 754	4	183 016	1 870	7 480
Gervasse	April 1994	10 200	4	40 800	440	1 760
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Collie	Oct 1996	31 944	4	127 776	1 360	5 440
Wilga	Oct 1996	14 256	4	57 024	530	2 120
Grimwade	Oct 1996	53 757	4	215 028	1 950	7 800
Fitzgerald	Oct 1996	377 641	4	1 510 564	18 300	73 200
Mullalyup	Oct 1996	6 624	4	26 496	160	640
Argyle	Oct 1996	10 412	4	41 648	330	1 320
Manjimup	Nov 1996	133 011	4	532 044	4 560	18 240
Shannon	Nov 1996	312 121	4	1 248 484	14 610	58 440
Denbarker	Nov 1996	243 842	4	975 368	11 000	44 000
Millbrook	Nov 1996	1 484	4	5 936	40	160
Kalbarri	Nov 1996	180 563	4	722 252	8 600	34 400
Stirling	Nov 1996	113 331	4	453 324	6 100	24 400
Two Peoples Bay	Nov 1996	9 274	4	37 096	300	1 200
Manypeaks	Nov 1996	13 393	4	53 572	550	2 200
Porongurup	Dec 1996	2 747	4	10 988	50	200
Irwin	Dec 1996	6 177	4	24 708	230	920
Giants	Dec 1996	3 026	4	12 104	70	280
Nornalup	Dec 1996	7 979	4	31 916	260	1 040
Stokes Inlet	Dec 1996	24 948	4	99 792	1 500	6 000
Cape Le Grande	Dec 1996	33 667	4	134 668	1 750	7 000
Cape Arid	Dec 1996	213 872	4	855 488	12 100	48 400
Sunklands	July 1997	286 310	4	1 145 240	12 560	50 240
Ravsthrpe Range	Sept 1997	18 140	4	72 560	1 290	5 160
D'Entrecasteaux	Oct 1997	93 875	4	375 500	3 940	15 760
Donnelly	Oct 1997	132 987	4	531 948	5 200	20 800
Burru Peninsular	Oct 1997	8 494	1	8 494	245	245
Scott	Mar 1998	1 053	2	2 106	100	200
Avon	June 1999	14 711	4	58 844	730	2 920
TOTAL		3 159 249		12 052 608	147 235	574 385

APPENDIX B (continued)

Fiscal Year 1999–2000

AIR CELL	DATE COMMENCED	AREA	BAITING PER YR	TOTAL AREA BAITED/YR	BAITS	TOTAL BAITS/YR
Julimar	April 1994	18 400	4	73 600	1 420	5 680
Hills Forest	April 1994	20 000	4	80 000	1 400	5 600
Batalling	April 1994	45 754	4	183 016	1 870	7 480
Gervasse	April 1994	10 200	4	40 800	440	1 760
Hadfield	April 1994	3 000	4	12 000	200	800
Kelmscott	June 1994	66 700	2	133 400	3 350	6 700
Jarrahdale	June 1994	127 800	2	127 800	6 640	13 280
Dwellingup	June 1994	116 500	4	266 800	6 000	24 000
Worsley	June 1994	14 400	2	28 800	720	1 440
Lane Poole	Jan 1995	94 000	6	564 000	3 900	23 400
Cape Range	April 1996	75 000	4	300 000	3 400	13 600
Karroun Hill	April 1996	40 000	4	160 000	2 000	8 000
Lake Magenta	May 1996	116 921	4	467 684	5 020	20 080
Dragon Rocks	May 1996	32 546	4	130 184	1 380	5 520
Jerdacuttup Lakes	Sept 1996	17 746	4	70 984	730	2 920
Corackerup	Sept 1996	4 325	4	17 300	150	600
Peniup	Sept 1996	6 318	4	25 272	200	800
Collie	Oct 1996	31 944	4	127 776	1 360	5 440
Wilga	Oct 1996	14 256	4	57 024	530	2 120
Grimwade	Oct 1996	53 757	4	215 028	1 950	7 800
Fitzgerald	Oct 1996	377 641	4	1 510 564	18 300	73 200
Mullalyup	Oct 1996	6 624	4	26 496	160	640
Argyle	Oct 1996	10 412	4	41 648	330	1 320
Manjimup	Nov 1996	133 011	4	532 044	4 560	18 240
Shannon	Nov 1996	312 121	4	1 248 484	14 610	58 440
Denbarker	Nov 1996	243 842	4	975 368	11 000	44 000
Millbrook	Nov 1996	1 484	4	5 936	40	160
Kalbarri	Nov 1996	180 563	4	722 252	8 600	34 400
Stirling	Nov 1996	113 331	4	453 324	6 100	24 400
Two Peoples Bay	Nov 1996	9 274	4	37 096	300	1 200
Manypeaks	Nov 1996	13 393	4	53 572	550	2 200
Porongurup	Dec 1996	2 747	4	10 988	50	200
Irwin	Dec 1996	6 177	4	24 708	230	920
Giants	Dec 1996	3 026	4	12 104	70	280
Nornalup	Dec 1996	7 979	4	31 916	260	1 040
Stokes Inlet	Dec 1996	24 948	4	99 792	1 500	6 000
Cape Le Grande	Dec 1996	33 667	4	134 668	1 750	7 000
Cape Arid	Dec 1996	213 872	4	855 488	12 100	48 400
Sunklands	July 1997	286 310	4	1 145 240	12 560	50 240
Ravsthrpe Range	Sept 1997	18 140	4	72 560	1 290	5 160
D'Entrecasteaux	Oct 1997	93 875	4	375 500	3 940	15 760
Donnelly	Oct 1997	132 987	4	531 948	5 200	20 800
Burru Peninsular	Oct 1997	8 494	1	8 494	245	245
Scott	Mar 1998	1 053	2	2 106	100	200
Avon	June 1999	14 711	4	58 844	730	2 920
TOTAL		3 159 249		12 052 608	147 235	574 385

APPENDIX B (continued)

Fiscal Year 2000–01

AIR CELL	DATE COMMENCED	AREA	BAITING PER YR	TOTAL AREA BAITED/YR	BAITS	TOTAL BAITS/YR
Julimar	April 1994	18 400	4	73 600	1 420	5 680
Hills Forest	April 1994	20 000	4	80 000	1 400	5 600
Batalling	April 1994	45 754	4	183 016	1 870	7 480
Gervasse	April 1994	10 200	4	40 800	440	1 760
Hadfield	April 1994	3 000	4	12 000	200	800
Kelmscott	June 1994	66 700	2	133 400	3 350	6 700
Jarrahdale	June 1994	127 800	2	127 800	6 640	13 280
Dwellingup	June 1994	116 500	4	266 800	6 000	24 000
Worsley	June 1994	14 400	2	28 800	720	1 440
Lane Poole	Jan 1995	94 000	6	564 000	3 900	23 400
Cape Range	April 1996	75 000	4	300 000	3 400	13 600
Karroun Hill	April 1996	40 000	4	160 000	2 000	8 000
Lake Magenta	May 1996	116 921	4	467 684	5 020	20 080
Dragon Rocks	May 1996	32 546	4	130 184	1 380	5 520
Jerdacuttup Lakes	Sept 1996	17 746	4	70 984	730	2 920
Corackerup	Sept 1996	4 325	4	17 300	150	600
Peniup	Sept 1996	6 318	4	25 272	200	800
Collie	Oct 1996	31 944	4	127 776	1 360	5 440
Wilga	Oct 1996	14 256	4	57 024	530	2 120
Grimwade	Oct 1996	53 757	4	215 028	1 950	7 800
Fitzgerald	Oct 1996	377 641	4	1 510 564	18 300	73 200
Mullalyup	Oct 1996	6 624	4	26 496	160	640
Argyle	Oct 1996	10 412	4	41 648	330	1 320
Manjimup	Nov 1996	133 011	4	532 044	4 560	18 240
Shannon	Nov 1996	312 121	4	1 248 484	14 610	58 440
Denbarker	Nov 1996	243 842	4	975 368	11 000	44 000
Millbrook	Nov 1996	1 484	4	5 936	40	160
Kalbarri	Nov 1996	180 563	4	722 252	8 600	34 400
Stirling	Nov 1996	113 331	4	453 324	6 100	24 400
Two Peoples Bay	Nov 1996	9 274	4	37 096	300	1 200
Manypeaks	Nov 1996	13 393	4	53 572	550	2 200
Porongurup	Dec 1996	2 747	4	10 988	50	200
Irwin	Dec 1996	6 177	4	24 708	230	920
Giants	Dec 1996	3 026	4	12 104	70	280
Nornalup	Dec 1996	7 979	4	31 916	260	1 040
Stokes Inlet	Dec 1996	24 948	4	99 792	1 500	6 000
Cape Le Grande	Dec 1996	33 667	4	134 668	1 750	7 000
Cape Arid	Dec 1996	213 872	4	855 488	12 100	48 400
Sunklands	July 1997	286 310	4	1 145 240	12 560	50 240
Ravsthrpe Range	Sept 1997	18 140	4	72 560	1 290	5 160
D'Entrecasteaux	Oct 1997	93 875	4	375 500	3 940	15 760
Donnelly	Oct 1997	132 987	4	531 948	5 200	20 800
Burru Peninsular	Oct 1997	8 494	1	8 494	245	245
Scott	Mar 1998	1 053	2	2 106	100	200
Avon	June 1999	14 711	4	58 844	730	2 920
TOTAL		3 159 249		12 052 608	147 235	574 385

APPENDIX B (continued)

Fiscal Year 2001–02

AIR CELL	DATE COMMENCED	AREA	BAITING PER YR	TOTAL AREA BAITED/YR	BAITS	TOTAL BAITS/YR
Julimar	April 1994	18 400	4	73 600	1 420	5 680
Hills Forest*	April 1994	20 000	4	80 000	1 400	5 600
Kelmscott*	June 1994	66 700	4	133 400	3 350	6 700
Batalling	April 1994	45 754	4	183 016	1 870	7 480
Gervasse	April 1994	10 200	4	40 800	440	1 760
Collie	Oct 1996	31 944	4	127 776	1 360	5 440
Hadfield	April 1994	3 000	4	12 000	200	800
Jarrahdale***	June 1994	127 800	4	511 200	6 640	26 560
Dwellingup	June 1994	116 500	4	266 800	6 000	24 000
Worsley***	June 1994	14 400	4	57 600	720	2 880
Lane Poole***	Jan 1995	94 000	4	376 000	3 900	15 600
Cape Range	April 1996	75 000	4	300 000	3 400	13 600
Karroun Hill	April 1996	40 000	4	160 000	2 000	8 000
Lake Magenta	May 1996	116 921	4	467 684	5 020	20 080
Dragon Rocks	May 1996	32 546	4	130 184	1 380	5 520
Jerdacuttup Lakes	Sept 1996	17 746	4	70 984	730	2 920
Corackerup	Sept 1996	4 325	4	17 300	150	600
Peniup	Sept 1996	6 318	4	25 272	200	800
Wilga	Oct 1996	14 256	4	57 024	530	2 120
Grimwade	Oct 1996	53 757	4	215 028	1 950	7 800
Fitzgerald	Oct 1996	377 641	4	1 510 564	18 300	73 200
Mullalyup	Oct 1996	6 624	4	26 496	160	640
Argyle	Oct 1996	10 412	4	41 648	330	1 320
Manjimup	Nov 1996	133 011	4	532 044	4 560	18 240
Shannon	Nov 1996	312 121	4	1 248 484	14 610	58 440
Denbarker	Nov 1996	243 842	4	975 368	11 000	44 000
Millbrook	Nov 1996	1 484	4	5 936	40	160
Kalbarri	Nov 1996	180 563	4	722 252	8 600	34 400
Stirling	Nov 1996	113 331	4	453 324	6 100	24 400
Two Peoples Bay	Nov 1996	9 274	4	37 096	300	1 200
Manypeaks	Nov 1996	13 393	4	53 572	550	2 200
Porongurup	Dec 1996	2 747	4	10 988	50	200
Irwin	Dec 1996	6 177	4	24 708	230	920
Giants**	Dec 1996	3 026	4	12 104	70	280
Nornalup**	Dec 1996	7 979	4	31 916	260	1 040
Stokes Inlet	Dec 1996	24 948	4	99 792	1 500	6 000
Cape Le Grande	Dec 1996	33 667	4	134 668	1 750	7 000
Cape Arid	Dec 1996	213 872	4	855 488	12 100	48 400
Sunklands	July 1997	286 310	4	1 145 240	12 560	50 240
Ravsthrpe Range	Sept 1997	18 140	4	72 560	1 290	5 160
D'Entrecasteaux	Oct 1997	93 875	4	375 500	3 940	15 760
Donnelly	Oct 1997	132 987	4	531 948	5 200	20,800
Burru Peninsula	Oct 1997	8 494	1	8 494	245	245
Scott	Mar 1998	1 053	2	2 106	100	200
Avon	June 1999	14 711	4	58 844	730	2,920
Nambung	Mar 2001	113 282	4	453 128	6 000	24, 000
TOTAL		3 272 531		12 729 936	153 235	605 305598 385

* Amalgamated to Perth Hills March 2002 & converted to 4X per year

** Amalgamated to Walpole Sept 2001

*** Converted to 4X per year from March 2002.

APPENDIX B (continued)

Fiscal Year 2002–03

AIR CELL	DATE COMMENCED	AREA	BAITING PER YR	TOTAL AREA BAITED/YR	BAITS	TOTAL BAITS/YR
Julimar	April 1994	18 400	4	73 600	1 420	5 680
Hills Forest*	April 1994	20 000	4	80 000	1 400	5 600
Kelmscott*	June 1994	66 700	4	133 400	3 350	6 700
Batalling	April 1994	45 754	4	183 016	1 870	7 480
Gervasse	April 1994	10 200	4	40 800	440	1 760
Collie	Oct 1996	31 944	4	127 776	1 360	5 440
Hadfield	April 1994	3 000	4	12 000	200	800
Jarrahdale***	June 1994	127 800	4	511 200	6 640	26 560
Dwellingup	June 1994	116 500	4	266 800	6 000	24 000
Worsley***	June 1994	14 400	4	57 600	720	2 880
Lane Poole***	Jan 1995	94 000	4	376 000	3 900	15 600
Cape Range	April 1996	75 000	4	300 000	3 400	13 600
Lake Magenta	May 1996	116 921	4	467 684	5 020	20 080
Dragon Rocks	May 1996	32 546	4	130 184	1 380	5 520
Jerdacuttup Lakes	Sept 1996	17 746	4	70 984	730	2 920
Corackerup	Sept 1996	4 325	4	17 300	150	600
Peniup	Sept 1996	6 318	4	25 272	200	800
Wilga	Oct 1996	14 256	4	57 024	530	2 120
Grimwade	Oct 1996	53 757	4	215 028	1 950	7 800
Fitzgerald	Oct 1996	377 641	4	1 510 564	18 300	73 200
Mullalyup	Oct 1996	6 624	4	26 496	160	640
Argyle	Oct 1996	10 412	4	41 648	330	1 320
Manjimup	Nov 1996	133 011	4	532 044	4 560	18 240
Shannon	Nov 1996	312 121	4	1 248 484	14 610	58 440
Denbarker	Nov 1996	243 842	4	975 368	11 000	44 000
Kalbarri	Nov 1996	180 563	4	722 252	8 600	34 400
Stirling	Nov 1996	113 331	4	453 324	6 100	24 400
Two Peoples Bay	Nov 1996	9 274	4	37 096	300	1 200
Manypeaks	Nov 1996	13 393	4	53 572	550	2 200
Porongurup	Dec 1996	2 747	4	10 988	50	200
Irwin	Dec 1996	6 177	4	24 708	230	920
Giants**	Dec 1996	3 026	4	12 104	70	280
Nornalup**	Dec 1996	7 979	4	31 916	260	1 040
Stokes Inlet	Dec 1996	24 948	4	99 792	1 500	6 000
Cape Le Grande	Dec 1996	33 667	4	134 668	1 750	7 000
Cape Arid	Dec 1996	213 872	4	855 488	12 100	48 400
Sunklands	July 1997	286 310	4	1 145 240	12 560	50 240
Ravsthrpe Range	Sept 1997	18 140	4	72 560	1 290	5 160
D'Entrecasteaux	Oct 1997	93 875	4	375 500	3 940	15 760
Donnelly	Oct 1997	132 987	4	531 948	5 200	20 800
Burru Peninsular	Oct 1997	8 494	1	8 494	245	245
Scott	Mar 1998	1 053	2	2 106	100	200
Avon	June 1999	14 711	4	58 844	730	2 920
Nambung	Mar 2001	113 282	4	453 128	6 000	24 000
		3 231 047		12 564 000	152 195	597 145

* Amalgamated to Perth Hills March 2002 & converted to 4X per year

** Amalgamated to Walpole Sept 2001

*** Converted to 4X per year from March 2002.

APPENDIX C

Summary of aircraft baiting by fiscal year.

FISCAL YEAR	CELL AREA (HA)	TOTAL AREA PER YEAR (HA)	BAITS	TOTAL BAITS/YR
1993-94	422 754	946 216	22 040	66 740
1994-95	516 754	1 510 216	25 940	90 140
1995-96	781 221	2 568 084	37 740	137 340
1996-97	2 603 679	9 857 916	123 170	479 060
1997-98	3 144 538	11 993 764	146 505	571 465
1998-99	3 159 249	12 052 608	147 235	574 385
1999-00	3 159 249	12 052 608	147 235	574 385
2000-01	3 159 249	12 052 608	147 235	574 385
2001-02	3 272 531	12 729 936	153 235	605 305
2002-03	3 231 047	12 564 000	152 195	597 145

APPENDIX D

Total aerial baiting costs (to October 2001)

AIR CELL	DATE COMMENCED	BAITING PER YR	TIMES BAITED	TOTAL FLYING HOURS	TOTAL BAITS USED	TOTAL COST (APPROX)
Julimar	April 1994	4	30	84	43 290	\$59 000
Hills Forest	April 1994	4	30	78	43 050	\$56 500
Batalling	April 1994	4	30	90	56 910	\$71 000
Gervasse	April 1994	4	26	26	13 000	\$18 000
Hadfield	April 1994	4	30	18	6 300	\$10 500
Kelmscott	June 1994	2	16	67.2	52 992	\$60 000
Jarrahdale	June 1994	2	16	160	107 424	\$130 000
Dwellingup	June 1994	4	30	228	180 720	\$204 500
Worsley	June 1994	2	16	16	8 016	\$11 000
Lane Poole	Jan 1995	6	41	205	165 025	\$185 000
Cape Range	April 1996	4	22	68.2	74 800	\$79 000
Karroun Hill	April 1996	4	22	88	44 000	\$66 000
Lake Magenta	May 1996	4	22	101.2	110 792	\$117 500
Dragon Rocks	May 1996	4	22	52.8	30 624	\$42 000
Jerdacuttup Lakes	Sept 1996	4	21	50.4	16 863	\$32 000
Corackerup	Sept 1996	4	21	10.5	3 171	\$6 000
Peniup	Sept 1996	4	21	10.5	4 200	\$7 000
Collie	Oct 1996	4	18	43.2	25 398	\$35 000
Wilga	Oct 1996	4	21	31.5	12 852	\$21 500
Grimwade	Oct 1996	4	21	58.8	41 286	\$52 000
Fitzgerald	Oct 1996	4	21	399	376 047	\$420 000
Mullalyup	Oct 1996	4	21	8.4	3 549	\$6 000
Argyle	Oct 1996	4	21	12.6	7 014	\$10 000
Manjimup	Nov 1996	4	20	142	91 200	\$120 000
Shannon	Nov 1996	4	20	294	292 200	\$320 000
Denbarker	Nov 1996	4	20	236	214 440	\$243 000
Millbrook	Nov 1996	4	20	5	1 000	\$3 000
Kalbarri	Nov 1996	4	20	144	169 000	\$175 000
Stirling	Nov 1996	4	20	116	129 300	\$136 000
Two Peoples Bay	Nov 1996	4	20	12	7 280	\$10 000
Manypeaks	Nov 1996	4	20	18	11 420	\$15 000
Porongurup	Dec 1996	4	20	10	2 400	\$5 500
Irwin	Dec 1996	4	20	18	4 392	\$10 000
Giants	Dec 1996	4	19	9.5	1 900	\$5 500
Nornalup	Dec 1996	4	19	19	5 985	\$11 500
Stokes Inlet	Dec 1996	4	20	40	30 000	\$37 000
Cape Le Grande	Dec 1996	4	20	40	29 880	\$37 000
Cape Arid	Dec 1996	4	20	272	210 840	\$254 500
Sunklands	July 1997	4	18	216	225 342	\$246 500
Ravsthorpe Range	Sept 1997	4	17	42.5	12 325	\$26 000
D'Entrecasteaux	Oct 1997	4	17	76.5	66 980	\$78 500
Donnelly	Oct 1997	4	17	113.9	88 400	\$109 000
Burru Peninsula	Oct 1997	1	5	12.5	1 325	\$6 000
Scott	Mar 1998	2	5	2.5	500	\$1 500
Avon	June 1999	4	10	10	5 790	\$8 500
Wellington	Dec 2000	4	4	12	8 240	\$11 500
Nambung	Mar 2001	4	3	18.6	18 000	\$22 000
Walpole	Sept 2001	4	1	1.5	392	\$1 000
Total					3 055 854	\$3 593 000

Fauna monitoring and staff training: *Western Shield* review—February 2003

PETER ORELL¹

¹Zoologist, Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, Western Australia 6983. petero@calm.wa.gov.au

SUMMARY

Objectives

The objectives of *Western Shield* for fauna monitoring and staff training were to develop a methodology and establish monitoring sites in key areas under fox control and to ensure Department of Conservation and Land Management (CALM) staff were given appropriate training and guidelines to undertake the monitoring. The methodology and monitoring was to be of a standard to be able to demonstrate recovery or otherwise of extant and translocated fauna.

Achievements

Forty monitoring sites have been established in the south-west of Western Australia from Kalbarri National Park north of Geraldton to Fitzgerald River National Park on the south coast. Recovery of at least one of the mammal species present has been demonstrated at 22 of these sites. Increases of some reptile species has also been demonstrated.

A database (the Fauna File) for the recording and management of monitoring data has been developed and distributed to 16 work centres. Though further development is required, it has been readily adopted by these work centres and has facilitated the collation and presentation of data in this review.

A Fauna Management Course was evolved and has developed to facilitate the training of CALM staff to undertake fauna monitoring and other fauna management activities. Since 1997, 97 CALM staff (70 men and 27 women) have completed the course.

Difficulties

Limited resources have restricted the establishment of monitoring surveys using spotlighting, nest boxes or other techniques to monitor fauna not readily trapped. Poor fauna recovery and high staff turnover in some districts has reduced staff exposure to fauna and consequently limited the development of fauna survey competencies of staff in these districts.

Other than two species recovery plans there have been no generic criteria for successful recovery of fauna

populations (see Mawson, this issue) and hence assessment of recovery may be subjective for some sites.

The development and maintenance of the Fauna File has been limited by time constraints on the custodian and some districts have experienced problems with bugs in the database or delays in acquiring updates on the database software. Time constraints on the *Western Shield* Zoologist have also made it difficult to service remote centres.

Incorrect or inconsistent use of *Western Shield* account codes has made it difficult to track expenditure on *Western Shield* fauna monitoring activities.

Potential economies

Survey effort at some sites has been above *Western Shield* requirements and some savings could be made by reducing the survey effort (e.g. number of traps or survey frequency) to within *Western Shield* standards. Reduction of monitoring sites could also achieve some savings but is not recommended on account of the high variation in monitoring results across sites.

The sharing of resources between neighbouring districts has the potential to create savings as well as enhancing the development of district staff.

Potential improvements

Formal annual reporting and reviewing of monitoring results from all sites is recommended now that a functional data collection and management system is in place and several years of data have been collated for the majority of sites. Integration of environmental data is also recommended. This activity will help to identify successes, problems and failures and aid the decision-making process for the 'adaptive management' of areas and species under *Western Shield*.

The capacity for district staff to be able to manage and use the data collected during monitoring activities is very important for maintaining the momentum for the *Western Shield* program. Further development of the Fauna File with particular emphasis on GIS functionality will greatly increase the capacity of districts to manage and use data and will increase monitoring efficiency. Improvements to the physical performance of the CALM intranet system could greatly increase the efficiency of central data management.

More resources are needed to further the development of The Fauna File database, the completion of accreditation requirements for the Fauna Management Course and the development and implementation of a field accreditation system for fauna survey skills.

INTRODUCTION

Western Shield is a predator control and fauna recovery program initiated by CALM. It covers 3.6 million hectares of state forest and conservation estate in the southwest of Western Australia, primarily covering the area from Kalbarri south and east to Cape Arid, with additional sites in Shark Bay, Cape Range and isolated locations of rock-wallaby populations in arid regions.

Fox control is achieved through the distribution of dried meat baits containing 4.5mg of monosodium fluoroacetate (1080) either by ground or aerial delivery, or a combination of both. The control of foxes by this method has facilitated the recovery of a number of mammal (and one bird and one reptile) species that remain extant in the southwest of WA. Five mammal species have become extinct in the south-west but have surviving populations elsewhere. The recovery of these species, and other species that have become locally extinct, can be further enhanced by translocation to suitable areas where fox control is being implemented.

An internal CALM document that outlined the objectives and the implementation of *Western Shield* was first prepared in 1995 (Burbidge *et al.* 1995). This document identified a network of 'Fauna Reconstruction Sites' and 'Species Recovery Sites' that would 'ensure both the conservation of currently existing threatened mammals and the reconstruction...of the original mammal fauna'. It also provided a list of the species that would benefit from this recovery program.

The mission, principles, priorities, objectives and strategies of *Western Shield* have since been formalised in the 'Western Shield Fauna Recovery Program Strategic Plan July 1999 – June 2004' (CALM 1999). There is a focus on the recovery of extant fauna and on fauna reconstruction through translocation. The document provides an expanded list of proposed fauna reconstruction sites and species recovery sites by species and by CALM region.

The *Western Shield* program was formally launched in 1996 and has now been operating for over six years. Fauna monitoring sites have been established in southwest districts and translocations of fauna to some of these sites have been undertaken. Six training courses have been conducted to support the program by providing the appropriate skills to undertake these tasks. This report reviews the progress, efficiency and results of the fauna monitoring and staff training operations within the Nature Conservation Division following the terms of reference established by the CALM Corporate Executive.

OBJECTIVES OF WESTERN SHIELD FAUNA MONITORING

The key objective of *Western Shield* is to 'maximise the recovery of sustainable populations of vulnerable native fauna by reducing the impact of predation by foxes and feral cats' (CALM 1999).

At the time of this review, only foxes have been controlled at an operational scale and this has been achieved by the distribution of 1080 dried meat baits at a density of 5 baits/km². The baits are distributed by fixed-wing aircraft at a standard frequency of four times per year over the forest areas and larger reserves, and more frequently from the ground in smaller isolated reserves (up to once a month).

The objective of *Western Shield* fauna monitoring is to measure population trends of native fauna, whether extant or translocated, in areas subject to fox control to assess whether recovery is being achieved. There are two main aspects to consider: (1) have there been changes in population density; and (2) have there been changes in population distribution. A recovering population may be expected to show an increase in the number of individuals as well as spread into unoccupied areas of suitable habitat. This requires the use of repeatable techniques that can measure the relative changes in abundance over time and area. Fauna monitoring may also enable an assessment of the importance of factors other than fox predation. These include climate effects, predation by native predators, competition between native species and habitat choice in species that have been reintroduced to areas outside their current distribution.

Fauna targeted for recovery under *Western Shield*

The species of fauna that have suffered the most decline in Australia are primarily mammals ranging in weight from 35 g up to 5500 g, the 'critical weight range' (Burbidge and McKenzie 1989). Also included are some reptiles and ground-nesting birds. The species occurring in WA that fall into this category are listed in Table 1. Most of these species are particularly vulnerable to predation by introduced predators, mainly foxes, and several have shown remarkable recovery where foxes have been controlled.

Those species that are readily observed via simple survey methods, and have shown clear positive responses to fox baiting are targeted by *Western Shield* monitoring programs to measure the effectiveness of fox baiting at selected sites. These species are referred to as 'indicator species' (Table 1). Further recovery of the species listed in Table 1 will be achieved through their translocation to suitable fox baited sites. Species with a mean adult body weight of 500 g up to 2500 g are herein referred to as 'medium-size mammals'.

TABLE 1

Species that form the focus of *Western Shield* recovery activities. (Cons status = Conservation status: Schedule 1 = species listed as 'rare or likely to become extinct' under the *Wildlife conservation Act*; Priority = species listed on CALM's Priority Fauna list. Ind = Indicator species. Tran = Species subject to translocation proposals: CB = captive bred for translocation; WC = wild-caught for translocation; B= both CB and WC; CI= incubated in captivity for translocation).

COMMON NAME	SCIENTIFIC NAME	CONS STATUS	IND	TRAN
Chuditch	<i>Dasyurus geoffroii</i>	Schedule 1	X	CB
Dibbler	<i>Parantechinus apicalis</i>	Schedule 1		CB
Brush-tailed phascogale	<i>Phascogale tapoatafa</i>	Priority 3		
Red-tailed phascogale	<i>Phascogale calura</i>	Schedule 1		WC
Numbat	<i>Myrmecobius fasciatus</i>	Schedule 1		B
Bilby or dalgyte	<i>Macrotis lagotis</i>	Schedule 1		CB
Quenda	<i>Isodon obesulus fusciventer</i>	Priority 4	X	WC
Western barred bandicoot or marl	<i>Perameles bougainville bougainville</i>	Schedule 1		CB
Woylie	<i>Bettongia penicillata ogilbyi</i>	Priority 4	X	WC
Boodie	<i>Bettongia lesueur lesueur</i>	Schedule 1		CB
Gilbert's potoroo	<i>Potorous gilbertii</i>	Schedule 1		CB
Rufous hare-wallaby or mala	<i>Lagorchestes hirsutus</i>	Schedule 1		CB
Banded hare-wallaby or mernine	<i>Lagostrophus fasciatus</i>	Schedule 1		CB
Black-flanked rock wallaby	<i>Petrogale lateralis lateralis</i>	Schedule 1		WC
Quokka	<i>Setonix brachyurus</i>	Schedule 1		
Tammar wallaby	<i>Macropus eugenii derbianus</i>	Priority 4	X	WC
Western brush wallaby	<i>Macropus irma</i>	Priority 4	X	
Brushtail possum	<i>Trichosurus vulpecula</i>	Not listed	X	
Western ringtail possum	<i>Pseudocheirus occidentalis</i>	Schedule 1		WC
Greater stick-nest rat	<i>Leporillus conditor</i>	Schedule 1		WC
Shark Bay mouse	<i>Pseudomys fieldi</i>	Schedule 1		CB
Western ground parrot	<i>Pezoporus wallicus flaviventris</i>	Schedule 1		WC
Noisy scrub-bird	<i>Atrichornis clamosus</i>	Schedule 1		WC
Western bristlebird	<i>Dasyornis longirostris</i>	Schedule 1		WC
Malleefowl	<i>Leipoa ocellata</i>	Schedule 1		CI
Western swamp tortoise	<i>Pseudemydura umbrina</i>	Schedule 1		CB

SURVEY METHODOLOGY

There are a number of different survey methods that can be used to measure relative changes in abundance. Some key aspects to consider in choosing the most appropriate methodology are:

1. **Sampling/observation technique:** The choice of physical methods of capturing or observing fauna will depend largely on the target species, the information required, the resources available and the availability of the appropriate skills. Methods that accommodate the widest range of species will provide the greatest return for effort. The choices appropriate for Western Shield include:

Trapping – various trap designs available to target different species

Nest boxes – suit arboreal species that nest in hollows

Hair tubes – suit species with unique hair characteristics

Sighting surveys including spotlighting – suit species that are conspicuous when active

Call surveys – suitable for birds and frogs

Searching for scats, tracks and other traces.

2. **Survey design:** The layout or distribution (design) of the sampling/observation effort will influence the quality and quantity of information gained. The most appropriate design will depend on the area of interest and the area utilisation by target species. *Western Shield*

is largely concerned with medium size mammals, most of which generally occupy home ranges of more than 2 ha, and the recovery of these species at the landscape level. The two main choices applicable to mammal sampling are grids and transects. While grid designs allow intensive sampling of small sites and provide detailed information on population densities and demographics of the species present, transects allow the sampling of a wider variety of habitat types and provide information on species occurrence and abundance at the landscape level. Transects are also better suited for detecting species that occur at lower densities across a range of habitats. Clearly, transects are the preferred choice to meet the objectives of Western Shield.

3. **Sampling time and frequency:** The most appropriate timing and frequency of sampling or observations is dependent partly on availability of resources and partly on the life histories and ecologies of the target species. Whilst it is acknowledged that the activity of some species vary between seasons and are more readily observed during particular times of the year it is the changes in abundance beyond seasonal influences that is of concern to the objectives of *Western Shield*. For the major indicator species, sampling once a year is sufficient to demonstrate any changes in abundance, however more than three years are required to demonstrate meaningful trends. It must be noted that seasonal variations in activity of some species is usually

associated with breeding and sampling should be avoided during the sensitive periods when it might interfere with the rearing of young. Where sampling targets shorter-lived species, for example rodents, small dasyurids, some reptiles and frogs, there is merit in sampling more than once a year.

4. **Data and statistical analysis:** Western Shield is firstly concerned with relative changes in the abundances of fauna as a measure of response to fox control. The most basic abundance estimate that can be applied to all methods is the number of samples or observations per unit effort. More complex abundance estimates can be applied to some sampling methods or combination of sampling methods where the appropriate data has been collected.

Using these factors, the most appropriate methods can be identified for each target species to reveal the most appropriate monitoring strategy for *Western Shield*. Table 2 shows the range of choices for each target species. Some sampling methods, particularly hair-tubes, trapping and spotlighting, are applicable to a range of species and are obvious choices for a monitoring strategy.

Most fauna monitoring for *Western Shield* was to be carried out by CALM district operations staff as part of their normal workload, but initially the pool of skilled and experienced operations staff was very limited. In addition, the nature of district operations is such that many tasks, especially in the field, are shared amongst several people depending on available resources and other district works. Therefore, limited skills, variations in individual abilities, and staff changes had to be considered along with training staff in the use of the survey methods within practical constraints of available resources and venues.

Hair-tubes

Hair-tubes are a low-cost method of surveying for the presence of a range of species that requires no animal handling in the field and has the potential to provide some limited abundance data. However, expertise is required to process and identify hair samples collected but such expertise is practically unavailable within CALM, or even Western Australia, on the scale that would be required to meet current monitoring program requirements. Even if training could be provided it is still beyond the practical limitations of most CALM districts to maintain a basic laboratory with suitably qualified staff. This would limit the degree to which individual districts could manage their own data collection which, in turn, has implications for motivating districts to maintain fauna monitoring activities when resources are limited. There is also a time lag between the collection and identification of hair samples that could lead to significant delays in data collation, especially if the availability of expertise is limited.

Despite limitations, hair-tubes are a useful method to employ for particular purposes. They have been used to survey for rare species in areas that are difficult to access (e.g. surveys for Gilbert's potoroo by CALM Science

Division) and also by community groups to survey local areas not monitored by CALM. Hair-tubes have not been considered appropriate for a broadscale monitoring method for *Western Shield*.

Trapping

Eleven of the twenty-one species listed in Table 2 can be caught in small cage traps (20 cm x 20 cm x 56 cm, Sheffield Wire Co) and eight of these can be caught with varying degrees of success using universal bait (a mixture of rolled oats, peanut paste and sardines) in cage traps placed at 200 m intervals. Four of these species – chuditch, brushtail possum, quenda and woylie – are relatively widespread in the southwest forests and parts of the wheatbelt and south coast and have shown good responses to fox control in pre-Western Shield monitoring sites. Trapping transects using small cage traps baited with universal bait and set at 200 m intervals has been adopted as the standard survey method for *Western Shield* and remains one of the most appropriate survey methods. The standard transects use 50 or 100 cage traps which equates to 10 or 20 km of transect respectively. This provides good area coverage as well as sampling a variety of habitats. Elliott (type A) traps (9 cm x 10 cm x 33 cm, Elliott Scientific Equipment) may also be used at the same trap locations or placed on smaller separate transects. Transects are trapped for three to five nights (usually four nights) at least once a year, generally in autumn as this is the period when most species of mammal are least likely to have vulnerable young.

Percent capture rate is used as the most basic measure of abundance from trapping data. In this review, capture rates have been calculated for each day by site and species and then averaged over each trapping period to give a percent mean daily capture rate with a standard error. This method does not distinguish between newly caught animals and recaptures. All medium-sized mammals caught are tagged to identify individuals. Where appropriate and where data on individual identification is of a sufficient standard, the number of individuals known to be alive (KTBA) is calculated and provided to supplement the information provided by mean daily capture rates. KTBA provides a better indication of population size and is particularly useful for analysing monitoring data from sites used to source translocations. However, KTBA figures can be altered by every subsequent survey if captures include previously caught individuals that have eluded capture during the last preceding surveys, thus adding to the number of individuals known to be alive for each survey since its last previous capture. Figures for the latest surveys can therefore be proven to be underestimates by the next survey.

Tagging of animals

There are some problems associated with ear tags. Some animals such as quenda have small ears and a tendency to lose tags. The loss and replacement of ear tags can cause

problems with retaining individual identification. The ear tags are small to suit the size of the animals caught and many people find them difficult to read, consequently errors occur in reading and recording ear tags and this often leads to problems when entering data into the Fauna File database. Microchip implants are the best alternative for individual identification but the cost of the implants and the scanners make their use on a large scale too expensive.

Small mammals, reptiles and frogs are not marked for individual identification. Small mammals are ear notched once to indicate capture and usually marked with a temporary dye or similar to identify recaptures from the same survey period.

Spotlighting

At least five of the species listed in Table 2 can be readily observed at night using a spotlight. This method is particularly useful for species such as brush wallaby and western ringtail possum that are not easily trapped but are reasonably conspicuous at night with the aid of a spotlight. The standard spotlighting survey design under the *Western Shield* program is a driven road transect of at least 10 km. The density of vegetation significantly affects the visibility of fauna during surveys and transects are generally located through more open habitat. Visible activity of animals is highly variable over time along given transects and at least two consecutive nights of spotlighting is considered necessary to provide more consistent or reliable data. A sighting rate given as the number of sightings of particular species per 10 km is used as a measure of relative abundance.

Nest boxes

Some species are difficult to trap and are rarely observed by spotlighting. Of particular interest in the south west forests is the brush-tailed phascogale. This species is arboreal and nests in tree hollows and nest boxes have been used successfully to survey for its presence. A phascogale monitoring project was initiated in 1993 by Susan Rhind of Murdoch University and Alcoa of Australia Limited. The project used nest boxes and aimed to survey the presence of phascogales and to monitor their response to fox control and the impacts of the rehabilitation of bauxite mine sites. Nest boxes were erected at ten sites in state forest and rehabilitated mine sites, and phascogales were recorded in some of these sites (Rhind and Nichols 2000). Some of these sites were inherited by CALM with the intention of incorporating them into the *Western Shield* fauna monitoring program. Only one site, Julimar State Forest (proposed Conservation Park), is still monitored and has not shown any evidence of the presence of phascogales.

CALM districts encompassing the south west forests have been encouraged to establish transects of nest boxes to monitor brush-tailed phascogales. Nest boxes have been

erected along *Western Shield* monitoring transects in the northern half of Donnelly District (formerly Manjimup District). To date they have not been successful in showing positive signs of phascogale presence although phascogales have been recorded extensively in the Kingston and Perup forest areas.

Recording of survey data

Standard data recording sheets have been developed by the Western Shield Zoologist for use by district personnel to record survey data. The data sheets assist by prompting the recording of standard and specific information, and also facilitating the transfer of data into a database. Generally the data sheets have been used effectively, and they are filed and stored in district offices. The manner of filing has varied between districts and some standardisation in the filing of data sheets is required.

Although data sheets provide a reliable back up for digital data, the technology is now readily available in the form of data loggers to record field data digitally. Data loggers significantly speed up the process of collecting data and transferring it into databases and may be far more efficient than the traditional method of recording data on paper. Future trials may be conducted in CALM's South West Region where data loggers are already used in survey and monitoring work.

CURRENT MONITORING SITES AND METHODS

Monitoring sites have been established in the southwest from Geraldton to Esperance (including the wheatbelt). The number of sites in each CALM district varies greatly depending on the extent of 1080 baiting, connectivity of baited areas and the resources available. Many sites were identified as 'fauna reconstruction sites' in Burbidge *et al.* (1995) and in the strategic plan (CALM 1999). Other sites have generally been selected on the basis of the habitats represented, accessibility, and any known fauna populations or historical data. The selection of these sites, as well as the location of monitoring transects and grids, was largely determined by district staff with assistance from Science Division and Wildlife Branch. Trapping has been adopted as the main method of monitoring fauna recovery and the current monitoring sites and the survey design used are summarised in Figure 1 and Table 3 by CALM regions.

DEVELOPMENT AND USE OF THE FAUNA FILE DATABASE

The development of a generic database to store and manage data collected from fauna surveys began in 1995 by the author in order to service current research projects and District fauna survey requirements. A relational

TABLE 2

Survey methodology applicable to *Western Shield* target species (mammals). Methods (listed in order of suitability): TR = trapping, HT = hair-tubes, NB = nest boxes, SL = spotlighting, DS = driven daytime sighting survey, DG = survey for diggings, TS = tracks, scats and other traces. Trap types in parenthesis: sc = small cage traps, lc = large cage traps, br = Bromilow traps (see Kinnear *et al.* 1988), me = medium Elliott traps. Bait types: U = Universal; A = Apple; B = Bread; C = Chaff, M = Meat offal, O = Oats, S = Special mix with essences. Design = survey design. Interval = distance intervals between sampling points (e.g. traps). Optimum time: indicates the most appropriate time of year for monitoring. Dependent young: this refers to the period of time when females have dependent young; ! indicates that trapping during this time period should be avoided.

SPECIES	METHODS	BAIT	DESIGN	INTERVAL	OPTIMUM TIME	DEPEND- ENT YOUNG
Chuditch	TR(sc), HT	U, M	Transect	200m	Dec-July	July-Nov !
Dibbler	TR(sc,me), HT?	U	Transect	20-100m	?	?
Brush-tailed phascogale	NBTR(sc,me), HT?	U	TransectTransect	200-300m 100-200m	Jan-June	July-Nov
Red-tailed phascogale	TR(me), HT?, NB?	U	Grid	20-100m	Feb-June, May best	Aug-Oct !
Numbat	DGDS		TransectTransect	200m	Oct-Dec	Nov-Dec
Bilby	TR(sc), DG, HT?	?	?	?	?	?
Quenda	TR(sc), HT, DG	U	Grid or Transect	50-200m	All year, April best	All year, low in April
Western barred bandicoot	TR(sc), HT?	U	Grid or Transect	50-200m	?	?
Woylie	TR(sc), DG, HT	U	Transect	100-200m	All year	All year
Boodie	TR(sc), DG, HT?	U	Transect	100-200m	?	?
Gilbert's potoroo	TR(sc), HT	S	Transect	20-50m	?	?
Rufous hare-wallaby	SL?, HT?		Transect		?	?
Banded hare-wallaby	SL?, HT?		Transect		?	?
Black-flanked rock-wallaby	TR(br)SL	A	TransectTransect	50-100m	?	?
Quokka	TR(lc)TS	A, O	Transect	20-50m	All year?	?
Tammar wallaby	TR(lc,br)SL	O, C	Transect	100m	Nov-April	May-Oct !
Western brush wallaby	SLTR(lc)	O, B	TransectTransect	100m	All year	?
Brushtail possum	TR(sc)SL, TS	U	Transect	100-200m	All year	Aug-Dec
Western ringtail possum	TR(sc mounted in trees) SL, TS	U	TransectTransect	100-200m	All year	Aug-Dec
Greater stick-nest rat	TR(me)	U	?	20-50m	?	?
Shark Bay mouse	TR(me)	U	?	20-50m	?	?

database to record all details of trapping surveys (i.e. trap locations, trap types, numbers of traps used, dates, species captured, morphometric details taken, etc.) was developed using Microsoft Access 2.0. It was made compatible with Geographic Information Systems (GIS) by accommodating geographic coordinates for survey sites and was also expanded to include spotlighting data and incidental observations of fauna. The design allowed some modest data manipulation and graphic report generation. This database application was named the Fauna File and the first version was distributed for use by District staff in 1997.

Distribution

The objective was to have a copy of the Fauna File available to each CALM district to record fauna monitoring activities and results, and to be able to utilise the data for management needs. Initially the distribution of the Fauna File involved setting it up on a single personal computer (PC) in each CALM district office. The district's coordinator for *Western Shield* fauna monitoring became the custodian of the district's database and was responsible for ensuring that data was entered and updated after each monitoring survey. The Fauna File was distributed in this way to fourteen district offices.

This system was cumbersome though it worked reasonably well considering the limitations. Data updates had to be transferred by disc to Wildlife Branch where all monitoring data is collated. This often resulted in delays in data updates though the graphic reports generated by the Fauna File allowed hard copies of monitoring results to be sent via facsimile to Wildlife Branch.

The more serious problems became evident when PCs were upgraded. Failure to make regular backups of data files left many districts vulnerable to the loss of entire data sets. In one instance, a computer upgrade resulted in the loss of over twelve months of monitoring data from St Johns Forest Block covering a crucial time following a woylie reintroduction that appears to have failed. Problems with the filing and storage of the original data have made it irretrievable to date. Districts have now been given instructions on making regular local backups of the Fauna File. A standard format for the filing and storage of original data sheets also needs to be implemented.

At the time when the Fauna File was first being distributed, the CALM office complex in Manjimup had a network link to Kensington. The Fauna File was installed on the network making it accessible to designated staff in the District, Region and Science Division as well as Wildlife Branch in Kensington. The easier access has facilitated faster data transfer and better maintenance of the database.

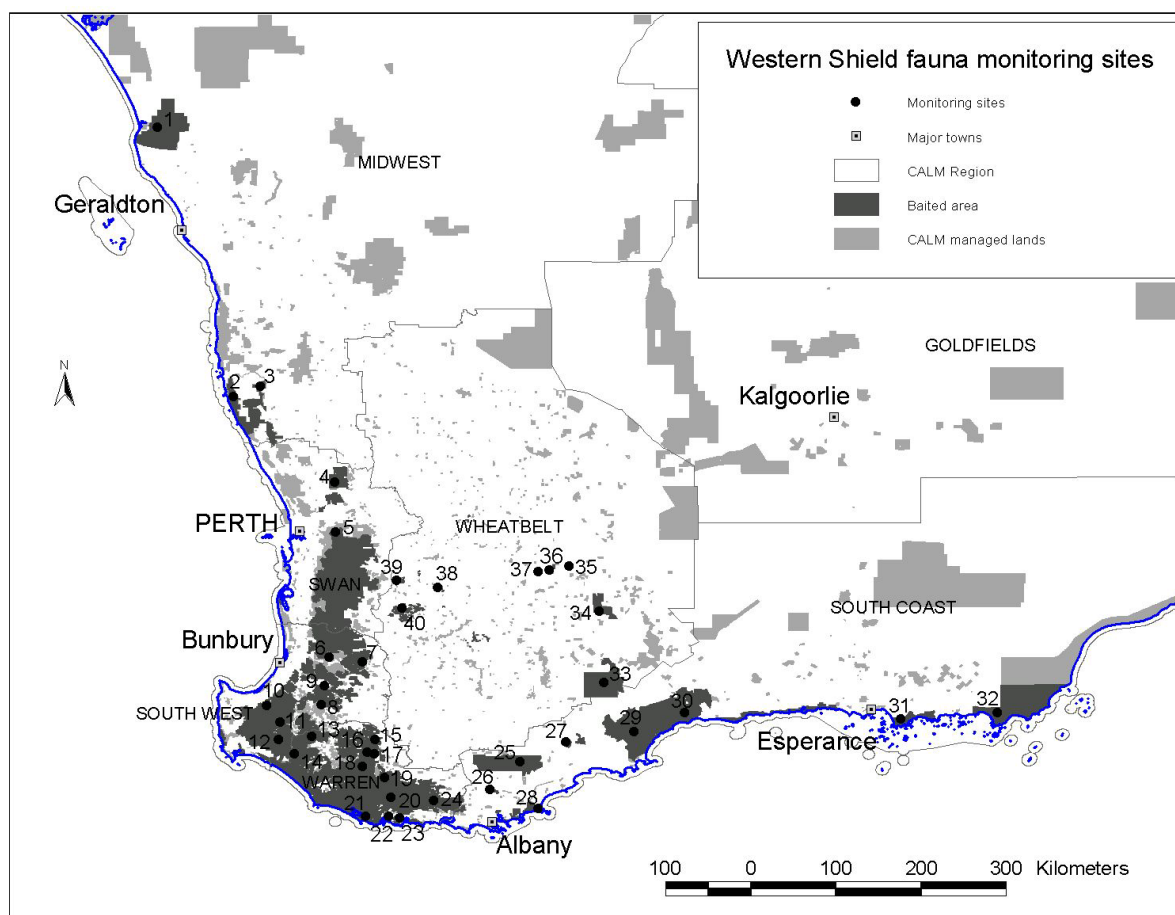


Figure 1. Map showing the location of Western Shield fauna monitoring sites and the extent of fox baiting in the south west of Western Australia. The number shown with each monitoring site correlates with the site ID number in Table 3.

As the CALM intranet has improved and expanded a number of districts have or are having the Fauna File transferred from PCs to the network. This will greatly improve the management of the Fauna File and the data recorded. Currently, the speed of data transfers via the network is too slow to allow the use of the Fauna File on-line from one central station, hence local databases are still required.

Improvements and significant changes to the Fauna File have been continually made since it was first distributed. Developing improvements and making changes is very time consuming and it has therefore been a slow process to distribute upgrades of the database. Bugs in the new versions often do not become apparent until the new version has been installed and used in a district. Debugging creates more delays in distributing the new versions to other districts. This has been a problem in the last two years since significant changes to the structure and front end of the database began in 1999 to improve the efficiency of the database and to allow for easier future expansion and improvement of the overall design. The current status of the Fauna File in CALM districts is summarised in Table 4.

Keeping abreast with upgrades in Microsoft Access has also been a problem as these upgrades have become more sophisticated and include some small but significant changes in programming code. Since the author's level

of programming knowledge has been limited, the causes of compiling errors during upgrades of the Fauna File have been difficult to find and has lead to significant delays in upgrading to later versions of Access. The current practice is to retain the version currently in use by the Western Shield Zoologist as the current standard version for operating the Fauna File, but upgrades with future versions of the operating software is unavoidable.

Functionality

The currently used version accommodates survey data from trapping, nest box surveys, spotlighting surveys and track count surveys. Other survey methods may be added in future versions. It also accommodates details of translocations and uses the same format as the CALM Threatened and Priority Fauna Database (TPFD) for recording incidental observations of fauna. This has greatly facilitated the collection of data from some CALM districts to add to the TPFD, providing a framework for the better management of threatened and priority fauna. It features standard reference data including a master species list with currently recognised nomenclature for nearly all terrestrial vertebrate taxa. This list is not yet complete for reptile taxa and only includes fish taxa that have been listed as threatened species or priority taxa. Data manipulations and graphic report generation include calculations of trap

TABLE 3

Western Shield fauna monitoring sites indicating site type, survey design and trap types used. NP = National Park; NR = Nature Reserve; SF = State Forest; FB = Forest block. ID = site identification number used in Fig 1. Type: ● = fauna reconstruction site, ○ = species recovery site (Burbidge *et al* 1995); ▲ = fauna reconstruction site (CALM 2000). Transect/Grid: sc = small cage traps, me = medium elliot traps, p = pit traps, nb = nest box, & = same transect or grid. Trap spacing on transects indicated by * is 100m, all other transects with sc have 200m trap spacing.

CALM REGION	SITE	ID	TYPE	TRANSECT	GRID
Midwest	Kalbarri NP	1	● ▲	100sc & 100me	(2x5p) x2
	Nambung NP	2	●	50sc & 50me	(2x5p) x2
	Badgingarra NP	3	▲	50sc & 50me	(2x5p) x2
Swan	Hills Forest	4	● ▲	55sc x2	
	Julimar SF	5	● ▲	125sc, 20nb	
South West	Centaur FB	6		100sc	
	Batalling Forest	7	●	120sc	
	Noggerup FB	8	●	173sc	
	Catterick FB	9	▲	200sc	
	Wicher FB	10		98sc & 98me	3x5p
Warren	St John FB	11	● ▲	192sc	
	Milyeannup FB	12		106sc	
	Wheatley FB	13	▲	50sc & 50me, 50nb	
	Gray FB	14		50sc & 50me, 50nb	
	Moopinup FB	15	●	50sc & 50me, 50nb	
	Boyicup FB	16	●	50sc & 50me, 50nb	
	Chariup FB	17	●	50sc & 50me, 50nb	
	Tone FB	18	●	50sc & 50me, 50nb	
	Lake Muir NR	19	●	50sc & 50me, 50nb	
	Mt Frankland NP	20	● ▲	100sc & 100me	
	Woolbales Track, D'Entrecasteaux NP	21	● ▲	100sc & 100me	
	Hilltop, Walpole-Nornalup NP	22		100sc & 100me	
	Valley of the Giants	23	▲	100sc & 100me	
	Denmark FB	24	● ▲	100sc & 100me	
South Coast	Stirling Range NP	25	●	50sc & 50me	
	Porongorup NP	26		50sc & 50me	
	Corackerup NR	27	▲	50sc & 50me	
	Waychinicup NP	28	○ ▲	50sc & 50me *	
	Twertup, Fitzgerald River NP	29	● ▲	50sc & 50me *	9sc & 15me & 15p
	Moir Track, Fitzgerald River NP	30	● ▲	50sc & 50me *	
	Cape Le Grand NP	31	▲	50sc & 50me	
	Cape Arid NP	32	● ▲	50sc & 50me	
	Lake Magenta NR	33	● ▲	100sc, 10me x10	(5x5p) x6
	Dragon Rocks NR	34	● ▲	100sc & 100me	
Wheatbelt	Roe NR	35		25sc, 20me x2	
	North Karlgarin NR	36			(9sc&16me&16p) x5
	Bendering NR	37		25sc, 20me x2	
	Tutanning NR	38	○	50sc	
	Boyagin NR	39	○ ▲	50sc x2	
	Dryandra Woodlands	40	● ▲	50sc	

success and sighting rates. The Fauna File can be linked to GIS software such as ArcView, allowing spatial viewing and interrogation of data.

To date development has focused mostly on designing the front end to facilitate data entry with as many error-reducing features as possible. It has taken a long time to identify sources of error and how to rectify them as some of these errors originate from the recording of data in the field. The database has also had to be flexible enough to accommodate a range of possibilities for various types of data and thus cannot screen for all possible errors. When errors have occurred it has taken time to clean up data to enable proper function of the database.

The development of data manipulation features has been slow as these are difficult to develop without clean and complete data sets to test the prototype features. Most of the current features relate to trapping data because this data is the most complete and useable. Data

manipulations for other survey methods are deficient due to the lack of useable data. Districts have also been slow to record geographic coordinates of trap locations or other survey points at *Western Shield* monitoring sites thus the development of GIS functionality has also been delayed. The recording of survey point locations has been further confused by an initial lack of awareness of the new geodetic datum, GDA94. Most existing data sets will need to be converted to the new datum.

Future development

Despite the problems associated with improving the functionality, the Fauna File has proven itself to be a valuable data collection and management tool. The collation of monitoring data on the scale of *Western Shield* and the generation of the figures presented in the following section detailing the results of monitoring has

TABLE 4

CALM district and regional offices in which *The Fauna File* software has been installed along with a summary of the status of fauna monitoring data input and type of installation (PC or N=network, (N)=network available) at each location.

DISTRICT/REGION (R)	FAUNA FILE VERSION	TRAPPING DATA	SPOTLIGHTING DATA	FAUNA RECORDS	PC OR NETWORK
Swan Coastal	2.1				PC
Swan Coastal, Mandurah	2.2	Yes			PC
Perth Hills	2.1	Yes			PC
Wellington	2.2	Yes			PC
Blackwood	2.1	Yes			PC
Donnelly	2.1	Yes	Yes	Yes	N
Frankland	2.1	Yes		Yes	N
Albany	2.1	Yes		Yes	N
Esperance	2.2	Yes			N
Merredin	2.1				PC (N)
Narrogin	2.2	Yes		Yes	N
Katanning	2.1	Yes	Yes	Yes	PC (N)
Geraldton	1.2	?		?	PC
Gascoyne	1.2				PC
Moora	2.1	Yes		Yes	PC
Goldfields (R)					
Pilbara (R)					
Exmouth					
East Kimberley	2.1				PC
West Kimberley					

been made considerably easier by its use. It has given district staff a sense of ownership and responsibility for their monitoring programs and the data they collect. It is becoming recognised as an important management tool and further investment in its development is warranted. The development of GIS functionality is a priority.

Its usefulness would be increased significantly if research data on all species could be included as this data is generally inaccessible in digital format and might otherwise be lost. Research data could significantly enhance the value of data collected by districts (and *vice versa*) and could help to generate long term monitoring data for the better management of threatened and priority fauna. There are issues of data ownership and data formatting to be resolved and there would also be an increased burden on the database custodian.

Currently, the Western Shield Zoologist is both the custodian and author of the Fauna File. The maintenance and development of the database program requires skills in database design and application as well as sound knowledge of fauna and fauna survey methodology. The combination of these skills within CALM is currently very limited and therefore the continued maintenance and development of the Fauna File is dependent on the skills and expertise of one person. Time constraints and the possibility of future staff changes leaves the database vulnerable and steps should be taken to ensure better security for its future. Consideration should also be given to migrating the Fauna File to a mainframe environment once the data set becomes too large for a PC or for Access, however this is not likely to be required within the next five years.

The creation of an additional dedicated position within the *Western Shield* program to provide support for the

Western Shield Zoologist is warranted. By directing less skilled tasks such as data validation and basic user support to this position, the Zoologist could direct more time to further develop the database and provide better quality of service and support to district and regional staff within the *Western Shield* program. The skills required to carry on the custodianship would gradually be passed on to the new position, thereby providing longer term security.

RESULTS OF MONITORING OPERATIONS

A summary of species recorded in each designated *Western Shield* monitoring site by CALM Region is presented in Table 5 with an indication of whether significant recovery has been observed or no recovery has occurred and the species has declined to non-detectable levels. There have been no clear criteria established to determine successful recovery of fauna populations. For the purposes of this review data are only presented from sites that have been monitored for at least three years. Where species recovery plans have provided criteria for successful recovery, in the form of minimum capture rates, these have been used to assess recovery. More detailed results are presented below.

Recovery sites established pre-1996

Seven key fauna recovery sites were established by the implementation of fox baiting before *Western Shield* was launched in 1996. Monitoring of these sites has been undertaken in various forms since the commencement of baiting, however earlier monitoring data from sites where fox baiting was first implemented for research purposes has been unavailable for this review. While all of these

TABLE 5 (Part A)

Summary of monitoring results from *Western Shield* monitoring sites indicating mammal species recorded, whether recovery has been observed and major declines. C=Caught on monitoring transect; Co=Caught on other survey transects; S=Seen on monitoring transect; So=Seen at other locations; T=Translocated; R=Release of derelicts; dark shading=never recovered and declined to undetectable levels; light shading=recovered, may have subsequently declined.

SPECIES	MIDWEST REGION MONITORING SITES			SWAN REGION MONITORING SITES	
	KALBARRI NP	BADGINGARRA NP	NAMBUNG NP	JULIMAR CP	HILLS FOREST
Echidna (<i>Tachyglossus aculeatus</i>)	S			C S	
Chuditch (<i>Dasyurus geoffroi</i>)	T C			T C	C
Mardo (<i>Antechinus flavipes leucogaster</i>)					C
Dibbler (<i>Parantechinus apicalis</i>)					
Brush-tailed phascogale (<i>Phascogale tapoatafa</i>)					
Red-tailed phascogale (<i>P. calura</i>)					
Dunnart (<i>Sminthopsis</i> spp)	C	C			
Numbat (<i>Myrmecobius fasciatus</i>)					
Bibby (<i>Macrotis lagotis</i>)					
Quenda (<i>Isodon obesulus fusciventer</i>)				T C	C
Western barred bandicoot (<i>Perameles bougainville bougainville</i>)					
Woylie (<i>Bettongia penicillata ogilbyi</i>)	T			T C	T C
Boodie (<i>B. lesueur lesueur</i>)					
Mala or rufous hare-wallaby (<i>Lagorchestes hirsutus hirsutus</i>)					
Banded hare-wallaby (<i>Lagostrophus fasciatus fasciatus</i>)					
Black-flanked rock-wallaby (<i>Petrogale lateralis lateralis</i>)					
Quokka (<i>Setonix brachyurus</i>)					
Tammar wallaby (<i>Macropus eugenii derbianus</i>)				T S	
Western brush wallaby (<i>M. irma</i>)			S	S	
Brushtail possum (<i>Trichosurus vulpecula</i>)				T C	R C
Western ringtail possum (<i>Pseudocheirus occidentalis</i>)					
Western pygmy possum (<i>Cercartetus concinnus</i>)					
Honey possum (<i>Tarsipes rostratus</i>)	C	C	C		
Water rat (<i>Hydromys chrysogaster</i>)					
Greater stick-nest rat (<i>Leporillus conditor</i>)					
Shark Bay mouse (<i>Pseudomys fieldi</i>)					
Ash-grey mouse (<i>P. albocinereus</i>)	C	C	C		
Western mouse (<i>P. occidentalis</i>)					
Heath mouse (<i>P. shortridgei</i>)					
Mitchell's hopping mouse (<i>Notomys mitchelli</i>)					
Spinifex hopping mouse (<i>Notomys alexis</i>)	C				
Southern bush rat (<i>Rattus fuscipes</i>)		C	C		
Black rat (<i>R. rattus</i>)	C				C
Brown rat (<i>R. norvegicus</i>)					
House mouse (<i>Mus musculus</i>)	C			C	C

sites have supported recovery of at least one species, declines have occurred in at least one species in each site. All sites have been retained as monitoring sites under the *Western Shield* program and are important reference sites for other recovery and fauna reconstruction sites as fauna recovery and trends in populations can take years to manifest.

Data below are presented from Dryandra Woodland, Boyagin Nature Reserve, Tutanning Nature Reserve, Perup Forest, Batalling Forest, Hills Forest and Julimar State Forest.

Dryandra Woodland

Fox control using dried meat baits containing 1080 was first implemented in part of the main block of Dryandra Woodland in 1982 to investigate the response of the

numbat to the removal of foxes (Friend 1990). Substantial increases in the number of sightings along standard transects were observed within three years. Dramatic increases in numbers of woylies and brushtail possums were also observed (Friend 1996). Fox control was extended in 1989 to the whole of the main block and Montague block, and in 1998 to all nine 'satellite' blocks under *Western Shield*.

Trapping has been undertaken in Dryandra Woodland since the early 1990s for various purposes including translocation and assessment of abundance of woylies. Regular monitoring along a designated transect was implemented by Narrogin District in 1995 and results are presented in Fig 2. Whilst five different mammal species have been trapped along this transect only woylies and brushtail possums have been trapped consistently in sufficient numbers to show changes in abundance.

TABLE 5 (Part B)

Summary of monitoring results from *Western Shield* monitoring sites indicating mammal species recorded, whether recovery has been observed and major declines. C=Caught on monitoring transect; Co=Caught on other survey transects; S=Seen on monitoring transect; So=Seen at other locations; T=Translocated; R=Release of derelicts; dark shading=never recovered and declined to undetectable levels; light shading=recovered, may have subsequently declined.

SPECIES	SOUTH WEST REGION MONITORING SITES						
	BATALLING	CENTAUR	CATTERICK	MILYEANNUP	NOGGERUP	ST JOHN	WICHER
Echidna	C						
Chuditch	C	C	C	C	C	C	C
Mardo	C			C	C	C	
Dibbler							
Brush-tailed phascogale	C	C	C	C	C	C	
Red-tailed phascogale							
Dunnart (<i>Sminthopsis</i> spp)			C		C	C	
Numbat	T S						
Bibby							
Quenda	C	C		C		C	
Western barred bandicoot							
Woylie	T C	T C				T C	
Boodie							
Mala or rufous hare-wallaby							
Banded hare-wallaby							
Black-flanked rock-wallaby							
Quokka							
Tammar wallaby	T C						
Western brush wallaby	S						
Brushtail possum	C	C	C	C	C	C	C
Western ringtail possum							
Western pygmy possum				C			
Honey possum							
Water rat							
Greater stick-nest rat							
Shark Bay mouse							
Ash-grey mouse							
Western mouse							
Heath mouse							
Mitchell's hopping mouse							
Spinifex hopping mouse							
Southern bush rat			C	C		C	C
Black rat		C		C	C	C	
Brown rat		C				C	
House mouse		C				C	

Woylies recovered quickly following the implementation of fox baiting in the 1980s and had become the most abundant medium-size mammal in Dryandra Woodland by the time District monitoring commenced in 1995. Brushtail possums were consistently trapped but in comparatively low numbers. This pattern changed dramatically in 2001 when brushtail possums were trapped in higher numbers than woylies and the trapping figures for the two species were completely inversed by the following year. An additional trapping survey was undertaken on this transect shortly after the April 2002 survey using two traps at each trap point with similar results. The number of woylies known to be alive (KTBA) presented in Fig. 2 suggest that removal of animals for translocation may not be sustainable under the current population density.

Rainfall data from the Bureau of Meteorology for Narrogin and Pingelly indicate below average winter rainfall for the last three years, a trend evident in most of the south-west of WA including Perth (see Figs 24 and 25) and Albany (see Figs 26 and 27). The decline in winter

rainfall, suggesting a period of drought, appears to correlate with the decline in woylie numbers. Brushtail possums appear to have become more abundant with the onset of drought. An increase in foraging activity on the ground due to changes in quality and abundance of food supply as a result of drought may have contributed to the increase in possum captures. Woylie capture rates are still higher than the 7.5% trap success stipulated in the *Woylie Recovery Plan* (Start *et al.* 1995) as a criteria for successful recovery.

Boyagin Nature Reserve

Boyagin Nature Reserve consists of two disjunct blocks separated by a gap of approximately 500m. Fox baiting in the east block was first implemented in 1985 in preparation for a translocation of numbats from Dryandra Woodland. Baiting commenced in the west block in 1989 and has been maintained at a frequency of once monthly in both blocks. Woylies were reintroduced into both blocks from Dryandra in 1992. Results of monitoring by Science Division staff in Boyagin in the early years since fox control

TABLE 5 (Part C)

Summary of monitoring results from *Western Shield* monitoring sites indicating mammal species recorded, whether recovery has been observed and major declines. C=Caught on monitoring transect; Co=Caught on other survey transects; S=Seen on monitoring transect; So=Seen at other locations; T=Translocated; R=Release of derelicts; dark shading=never recovered and declined to undetectable levels; light shading=recovered, may have subsequently declined.

SPECIES	WARREN MONITORING SITES											
	GRAY	WHEATLEY	TONE	MOOPINUP	CHARIUP	BOYCUP	LAKE MUIR	HILL TOP	GIANTS	MT LINDESAY	MT FRANKLAND	D'ENTRE -CASTAUX
Echidna									C			
Chuditch			C	C	C		C			T C		
Mardo	C	C						C	C	C		C
Dibbler												
Brush-tailed phascogale						C						
Red-tailed phascogale												
Dunnart (<i>Sminthopsis</i> spp)								C			C	
Numbat												
Bibby												
Quenda		C	C	C	C	C		C	C	C	C	C
Western barred bandicoot												
Woylie	T C		C	C	C	C	T C		T C	T C		
Boodie												
Mala or rufous hare-wallaby												
Banded hare-wallaby												
Black-flanked rock-wallaby												
Quokka								C	C			
Tammar wallaby						S						
Western brush wallaby				S		S						
Brushtail possum	C	C	C	C S	C S	C	C	C	C	C	C	C
Western ringtail possum				C S	C S	C						
Western pygmy possum								C				
Honey possum											C	
Water rat								C				
Greater stick-nest rat												
Shark Bay mouse												
Ash-grey mouse												
Western mouse												
Heath mouse												
Mitchell's hopping mouse												
Spinifex hopping mouse												
Southern bush rat		C	C				C	C	C	C	C	C
Black rat	C	C					C	C	C	C		C
Brown rat		C										
House mouse		C	C	C	C		C	C	C	C	C	C

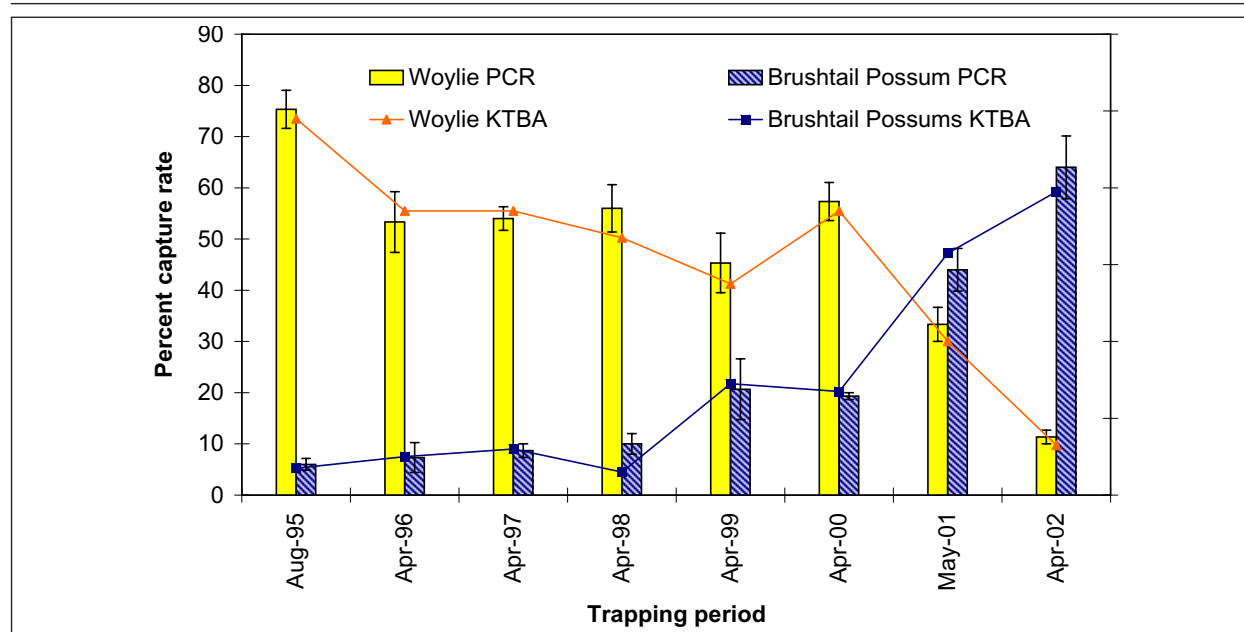


Figure 2. Mean daily percent capture rate (PCR, bars denote standard error) and number of individuals known to be alive (KTBA) for woylie and brushtail possum in Dryandra Woodland using small cage traps.

TABLE 5 (Part D)

Summary of monitoring results from *Western Shield* monitoring sites indicating mammal species recorded, whether recovery has been observed and major declines. C=Caught on monitoring transect; Co=Caught on other survey transects; S=Seen on monitoring transect; So=Seen at other locations; T=Translocated; R=Release of derelicts; dark shading=never recovered and declined to undetectable levels; light shading=recovered, may have subsequently declined.

SPECIES	SOUTH COAST REGION MONITORING SITES						
	STIRLING RANGE	PORONGORUP	WAYCHINNICUP	TWERTUP	MOIR TRACK	CAPE LE GRAND	CAPE ARID
Echidna					C		
Chuditch				C	C		T C
Mardo	C	C	C				
Dibbler				C	C		
Brush-tailed phascogale							
Red-tailed phascogale				C			
Dunnart (<i>Sminthopsis</i> spp)	C				C	C	C
Numbat	T So						
Bibby							
Quenda	C	C	C	C	C	C	C
Western barred bandicoot							
Woylie							
Boodie							
Mala or rufous hare-wallaby							
Banded hare-wallaby							
Black-flanked rock-wallaby						T	
Quokka	C						
Tammar wallaby							
Western brush wallaby							
Brushtail possum	C	C S		C	C		
Western ringtail possum		S					
Western pygmy possum				C			C
Honey possum			C	C	C	C	C
Water rat							
Greater stick-nest rat							
Shark Bay mouse							
Ash-grey mouse	C			C	C		
Western mouse	C			C	C		
Heath mouse					C		
Mitchell's hopping mouse				C	C		
Spinifex hopping mouse							
Southern bush rat	C	C	C	C	C	C	C
Black rat		C					
Brown rat							
House mouse	C	C	C	C	C	C	C

commenced have been published (Kinnear *et al.* 2002). A monitoring transect was established by Narrogin District in the east block in 1995, extended to the west block in 1996, and trapped annually as part of *Western Shield*. The results are presented in Fig 3 (the 1996 data shown were included in Kinnear *et al.* 2002).

Although woylies were reintroduced to both blocks at the same time there is a predominance of woylie captures (well above 7.5% trap success) on the west block with substantially fewer brushtail possums and the inverse pattern on the east block. Reasons for this difference are not known but possible contributing factors include baiting history, differences in carrying capacity or competition for traps (Kinnear *et al.* 2002). Numbers of both species on both blocks appear to be fluctuating about a mean though there is some indication of a decline in woylies on the west block and an increase in brushtail possums on both blocks. Such trends would be consistent with those observed in Dryandra Woodland. Quenda were reintroduced in 1995 from development sites on the Swan Coastal Plain and appear to be establishing very slowly.

The trapping transect may not traverse the best habitat for quenda and the monitoring results may therefore not be indicative of the success of the translocation.

Tutanning Nature Reserve

Fox baiting was implemented in this reserve in 1984. At this time the numbat, quenda and western ringtail possum had disappeared from the reserve and tammar wallabies and brushtail possums were seldom seen and woylies were not seen at all (Kinnear *et al.* 2002). Substantial recovery of woylies, brushtail possums and tammar wallabies was demonstrated within eight years. Quenda were reintroduced between 1991 and 1995 and numbats were reintroduced between 1987 and 1996.

A monitoring transect was established by Narrogin District in 1995 and has been trapped annually as part of *Western Shield* up until 2000 and from then on once every two years. The results are presented in Fig. 4.

The brushtail possum population is thriving and appears stable with capture rates ranging from 34.7% to

TABLE 5 (Part E)

Summary of monitoring results from *Western Shield* monitoring sites indicating mammal species recorded, whether recovery has been observed and major declines. C=Caught on monitoring transect; Co=Caught on other survey transects; S=Seen on monitoring transect; So=Seen at other locations; T=Translocated; R=Release of derelicts; dark shading=never recovered and declined to undetectable levels; light shading=recovered, may have subsequently declined.

SPECIES	WHEATBELT REGION MONITORING SITES							
	DRYANDRA	TUTANNING	BOYAGIN	BENDERING	NORTH KALGARIN	ROE	LAKE MAGENTA	DRAGON ROCKS
Echidna	C	C	C				C	
Chuditch	Co						T C	
Mardo								
Dibbler								
Brush-tailed phascogale								
Red-tailed phascogale	Co						C	
Dunnart (<i>Sminthopsis</i> spp)				C	C		C	
Numbat	So	T	T So					
Bibby	T Co							
Quenda		T C S	T C				C	
Western barred bandicoot								
Woylie	C	C	T C				T C	
Boodie								
Mala or rufous hare-wallaby								
Banded hare-wallaby								
Black-flanked rock-wallaby								
Quokka								
Tammar wallaby	C	S Co	S					
Western brush wallaby	S		S				S	
Brushtail possum	C	C S	C	C	C	C	C	C
Western ringtail possum								
Western pygmy possum					C		C	
Honey possum					C		C	C
Water rat								
Greater stick-nest rat								
Shark Bay mouse								
Ash-grey mouse					C	C	C	
Western mouse				C	C		C	C
Heath mouse							C	
Mitchell's hopping mouse				C	C	C	C	C
Spinifex hopping mouse								
Southern bush rat							C	
Black rat								
Brown rat								
House mouse	C			C	C	C		C

47.3%. Woylie numbers appear to have declined since the earlier recovery recorded by Kinnear *et al.* (2002) and the average capture rate from 1996 to 2000 has fallen below 7.5%. Quenda have established very well and appear to have been more abundant than woylies up to 2002 when capture rates declined to 2.7%. Capture rates of 3% or more along standard *Western Shield* transects is considered high for quenda. The changes in abundance may be a function of vegetation succession since the last fire as well as drought effects.

Perup Forest

The area of state forest about 35 km east of Manjimup is generally known as 'the Perup' and has been a proposed nature reserve for many years and is now a proposed national park. The area has long been known as 'special' since it supports populations of nearly all the species of medium-size mammals that were known to occur in the wider jarrah forests of the south-west of WA, including numbats, woylies and chuditch. The area has had a varied

history of 1080 baiting. Dog baiting was carried out in the 1980s and regular fox baiting first commenced in 1994. The area has been trapped and monitored for research purposes since the 1970s. Donnelly District (formerly Manjimup District) has undertaken regular monitoring in the area since 1998 as part of *Western Shield* and have two established transects: one in Chariup Forest Block and the other in Boyicup Forest Block.

Woylie, quenda, brushtail possum and western ringtail possum (*Pseudocheirus occidentalis*) have been trapped on both transects and chuditch have been trapped on the Chariup transect. Woylie captures at both sites have shown an increase to near saturation levels (about 70% capture rate coupled with additional trap disturbance), reducing or excluding other species from traps. This makes it difficult to interpret data for other species. Trials comparing standard universal bait and a meat-meal-based bait less attractive to woylies have shown that high capture rates of woylies significantly exclude chuditch from traps baited with universal bait (Wayne *et al.* in prep; Morris *et al.* 2003).

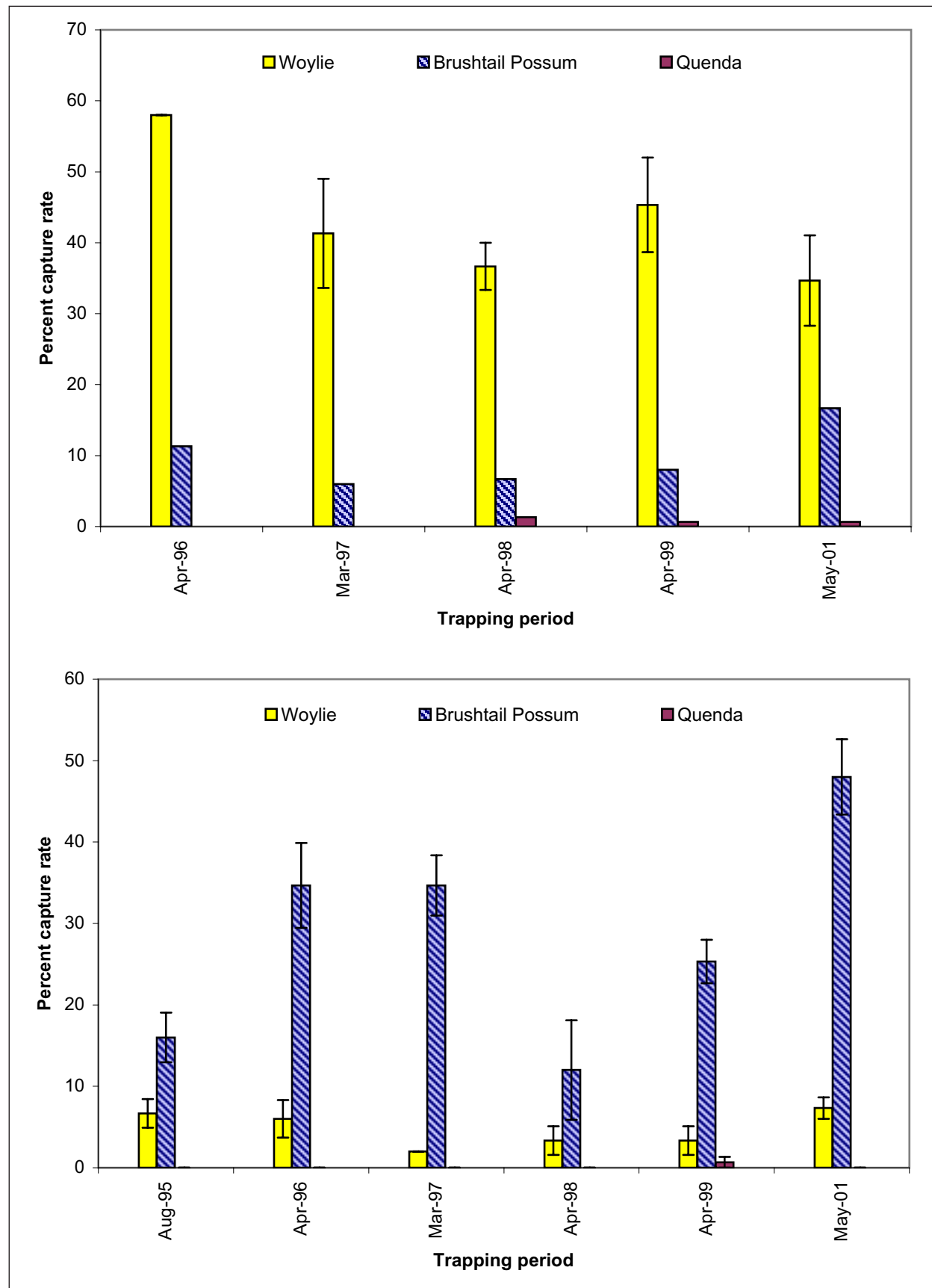


Figure 3. Mean daily percent capture rate (bars denote standard error) for medium-size mammals in (a) west and (b) east Boyagin Nature Reserve using small cage traps.

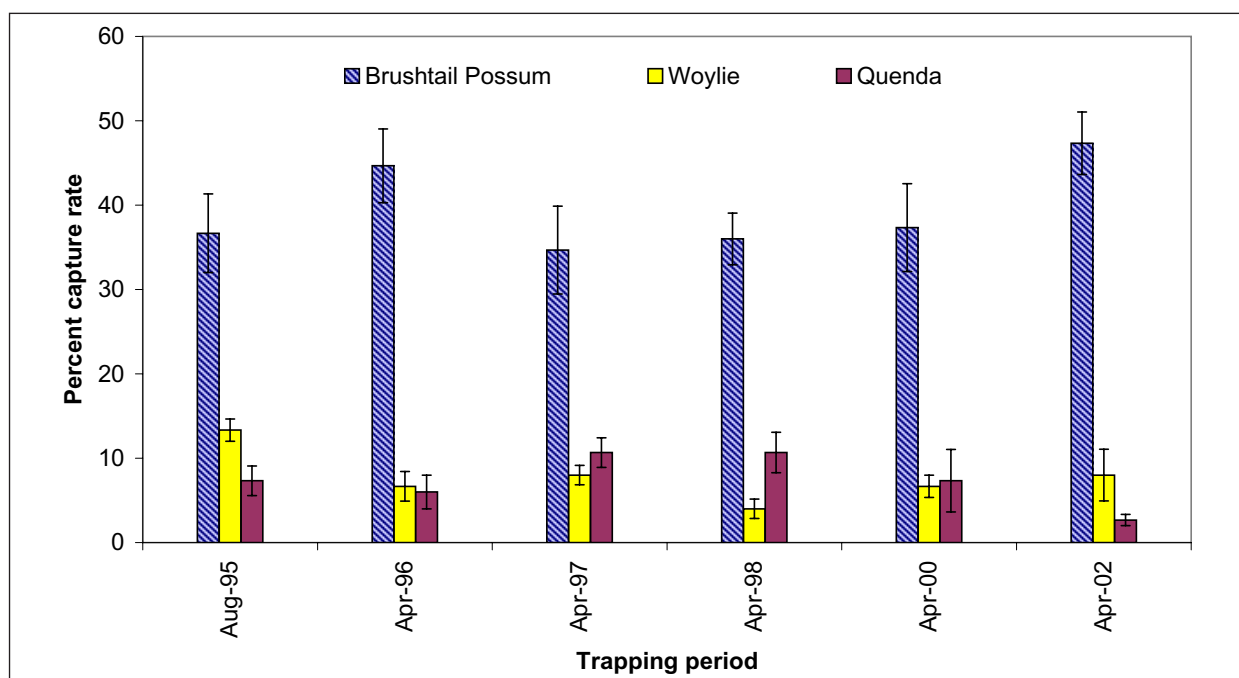


Figure 4. Mean daily percent capture rate (bars denote standard error) for medium-size mammals in Tutanning Nature Reserve using small cage traps.

Batalling Forest

This area on the eastern edge of the forest belt west of Darkan was the site of a woylie reintroduction in 1983. Some fox baiting was undertaken in the first two years after the release of woylies but it appeared that the population failed to establish. Surveys were undertaken in 1990 and found evidence that woylies were still present. Fox baiting at a frequency of four times a year was then implemented east of Don Road in February 1991. Aerial fox baiting west as well as east of Don Road was later implemented in 1994 as part of Operation Foxglove (a precursor to *Western Shield* that included aerially baiting 400,000ha of northern jarrah forest).

Extensive trapping was undertaken in the area to catch chuditch to monitor the impact of baiting on this species (see Morris *et al.* 2003). This necessitated trapping over different areas to catch sufficient animals for the study hence there was no consistently repeated trapping effort for several years. A woylie monitoring transect was established in 1995 which was then repeated annually as part of the department's Fauna Management Course and as part of Western Shield. This transect ran both east and west of Don Road.

Percent capture rates for medium-size mammals on the woylie monitoring transect east and west of Don Road are shown in Fig. 5.

Recovery of woylies is evident on both sides of Don Road, however recovery was faster on the east side than on the west side, presumably because the population was first established there and regular baiting started earlier. Recovery is more evident in Fig. 6 showing woylies known to be alive (KTBA). These figures also show that the population is large enough to sustain the removal of animals for translocation. There appears to be little

influence from low rainfall trends from 2000 (see rainfall data for Perth, Figs 24 and 25, and Albany, Figs 26 and 27).

Recovery of chuditch, brushtail possums and quenda is also apparent up until 1996. Chuditch capture rates on the east side of Don Road peaked at 21.8% in May 1995 and have been consistently higher than the minimum 1% given in the Chuditch Recovery Plan (Orell and Morris 1994) as one of the criteria for successful recovery. Capture rates for brushtail possums doubled within the first four years and quenda began to appear on the transect and peaked at 3.5% by 1996. It appears that when woylie capture rates reach about 40% there is a very noticeable decline in the capture rates of other species. Trap disturbance in addition to captures can further exclude other species from traps, and from the trapping data it is not possible to interpret population patterns in these species.

Hills Forest

This area of state forest was first baited with 1080 fox baits in 1993 and aerial baiting was later implemented over a wider area in 1994 as part of *Operation Foxglove*.

A monitoring transect was first established in February 1993. This was later modified slightly to become the *Western Shield* monitoring transect for Hills Forest with a section of 55 traps on the northern side of Mundaring Reservoir and another section of 55 traps on the south side of the reservoir. The results of the monitoring are shown in Fig. 7.

Only the northern transect has shown recovery (Fig. 7a). Chuditch and quenda have both recovered remarkably well. Capture rates for chuditch peaked at 14.1% in March 1999 and have remained well above 6%

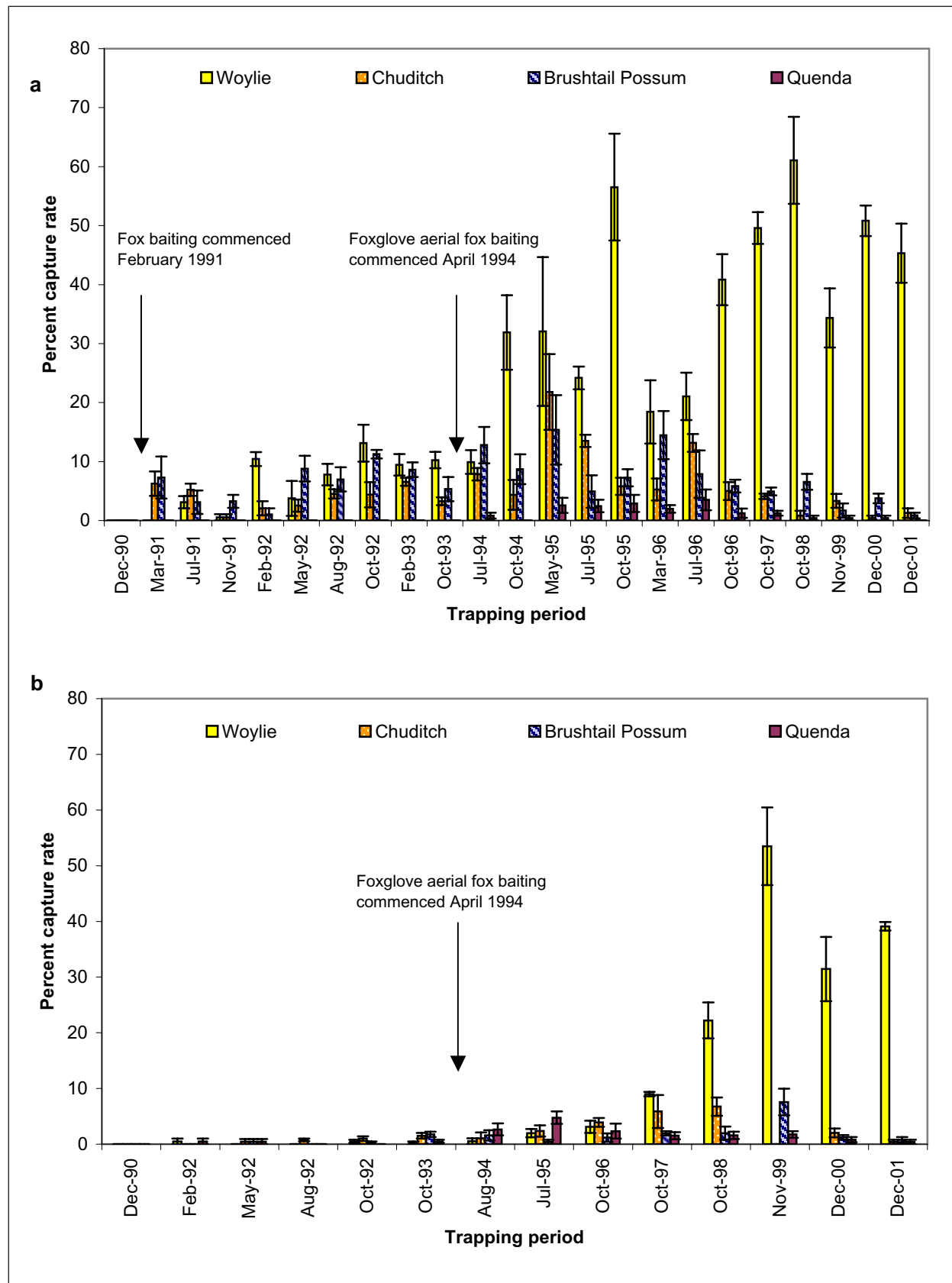


Figure 5. Mean daily percent capture rate (bars denote standard error) for medium-size mammals in Batallong Forest on the woylie monitoring transect (a) east and (b) west of Don Road using small cage traps.

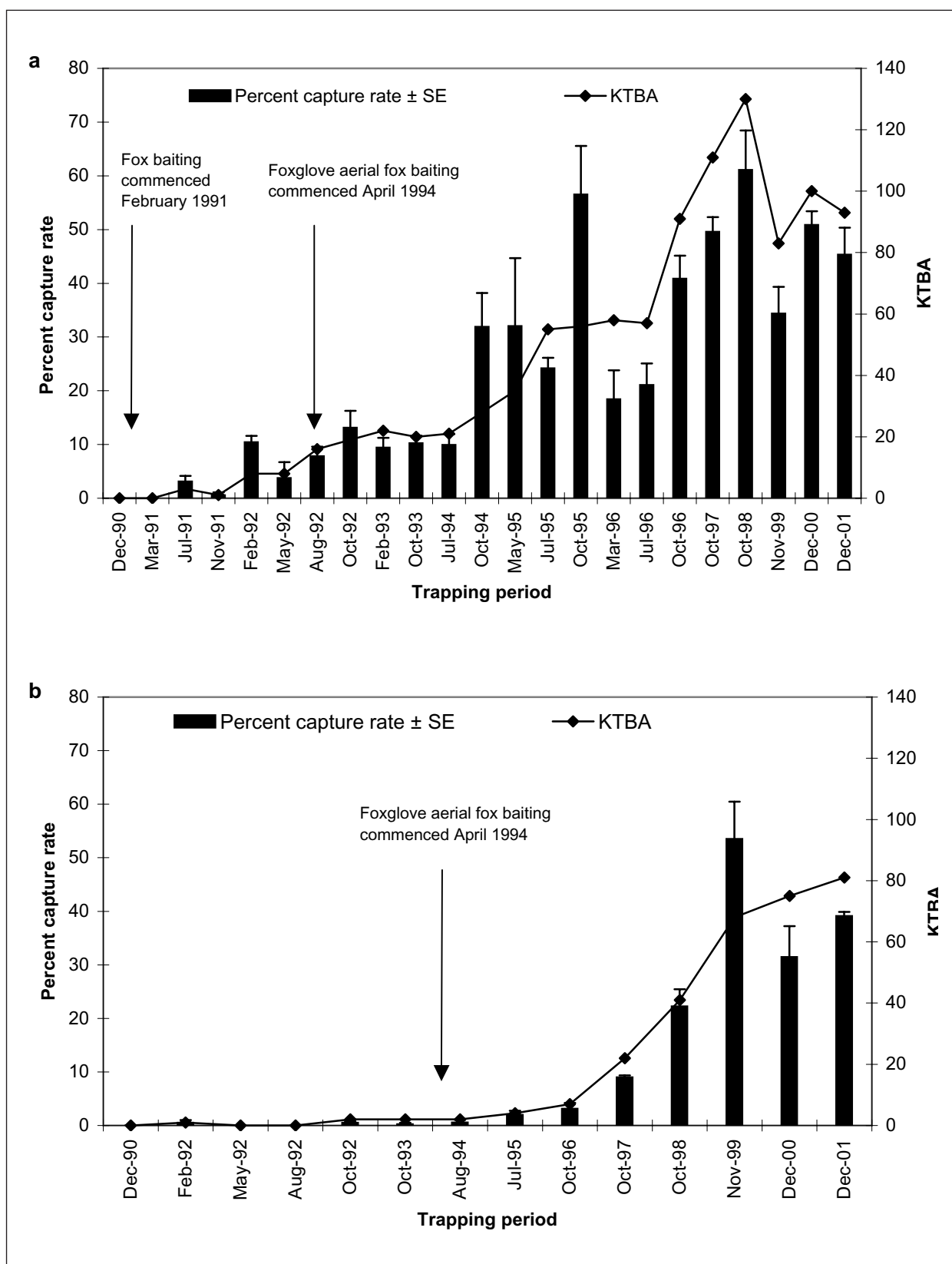


Figure 6. Mean daily percent capture rate (bars denote standard error) and the number of individuals known to be alive (KTBA) for woylies in Batalling Forest on the woylie monitoring transect (a) east and (b) west of Don Road using small cage traps.

since 1998. Quenda capture rates peaked at 6.8% in March 2000 and have remained above 1%.

Brushtail possums, mostly individuals removed from house roofs, have been released into Hills Forest by Perth Hills District staff over many years. The species has been very slow to establish but capture rates over the last three years suggest that establishment may be occurring.

Woylies were reintroduced to Hills Forest with the first release of 20 in 1996 and a second release of 17 in 1998. The population appeared to be establishing but went into decline in 1998 and had collapsed by 2001. There are three factors that may be responsible for this collapse. Firstly there was a small founder size only slightly augmented two years later with a second release. Secondly, the chuditch population was climbing rapidly possibly beyond the carrying capacity of the area at the same time that the woylie population was establishing. Chuditch are known predators on woylies and may have had a significant impact on the population in this situation. Thirdly, rainfall figures for Perth show that winter rainfall has been below average since 2000 (Figs 24 and 25) and this may have reduced the capacity of the area to support woylies.

The southern transect is only 5-11 km from the northern transect and yet capture rates for medium-size mammals have remained below 1.5% and have declined to no captures since March 2000 (Fig. 7b). As there has been no difference in the baiting regime between the two transects, the results suggest that population levels on the southern transect have been too low to sustain recovery without being supplemented by immigration or translocation. The Mundaring Reservoir represents a physical barrier to immediate expansion of the northern population into the area of the southern transect.

Julimar State Forest

This area of state forest is isolated from the main forest belt and has been a proposed Conservation Park since 1994. It was first baited with 1080 fox baits in 1992 in preparation for a translocation of captive-bred chuditch from Perth Zoo (Morris *et al.* 2003). A pre-baiting trapping survey resulted in the capture of one feral cat and many House Mice.

The recovery of native fauna in Julimar has been entirely through translocation. Most releases of zoo-bred chuditch occurred in September 1992 and March 1993 (Morris *et al.* 2003). A translocation of brushtail possums began in May 1993 using derelict and displaced animals from the Perth metropolitan area and surrounding localities. Quenda were first reintroduced in 1994 using displaced animals from development sites and a second release of quenda from a captive colony held at the University of Western Australia occurred in 1998. A reintroduction of wild-caught woylies from Dryandra Woodland occurred in 1995. Brushtail possums, quenda and woylies were all released at more than one release site.

Trapping transects have been set up to monitor the establishment primarily of the chuditch in earlier years

but also of the other reintroduced species. Although trapping has concentrated mostly along the main tracks in the southwestern part of Julimar (the core monitoring area), trapping has extended beyond this area but the trapping effort has not been consistent. There have been varying efforts to monitor the spread of animals in each trapping period. To standardise the monitoring results the trapping data has been trimmed to include only the core monitoring area, which represents transects totalling about 125 traps. Results are presented in Fig. 8.

The establishment of the chuditch population is evident with a peak capture rate of 14.2% in 1998. Capture rates have subsequently dropped and stabilised around 4%, considerably higher than the 1% prescribed in the *Chuditch Recovery Plan*. While chuditch captures were initially concentrated in the core monitoring area, captures are now occurring more frequently beyond this area indicating that chuditch are now not only established but more widespread.

Woylies appeared to be establishing successfully up until 1999 when the capture rate dropped by 65%. No woylies have been trapped since 2000. There is a similarity with the pattern observed in Hills Forest and the same three factors may be responsible for the collapse in the Julimar population. Small founder size (the forty woylies released were split between two release sites separated by about 8 km thereby effectively halving the founder size), abnormally high chuditch predation and drought effects.

While quenda and brushtail possums have persisted they have not shown successful establishment or recovery in that there has been no detectable increase or expansion in the populations. The number of founders may have been insufficient to achieve this within the observed time frame. Habitat may be a factor for quenda as there are limited areas supporting dense cover of low vegetation. Julimar supports open woodland of jarrah and marri as well as wandoo and mature trees with hollows appear to be plentiful. Thus it would appear suitable for possums although they would need to spend time on the ground due to the open nature of the woodland. Competition for tree hollows by feral bees may be a possibility. The area has been regularly used by apiarists and feral bees would be well established.

Western Shield monitoring sites showing recovery of mammal fauna

These monitoring sites have been established subsequent to the implementation of fox control via aerial baiting with 1080 dried meat baits. Except where indicated, the sites have been baited by aircraft four times annually. They are presented by CALM regions.

South West Region

Centaur, Noggerup and Catterick forest blocks

Recovery of at least one species has been observed in Centaur, Noggerup and Catterick forest blocks. Data for Catterick Forest Block are presented in Fig. 9.

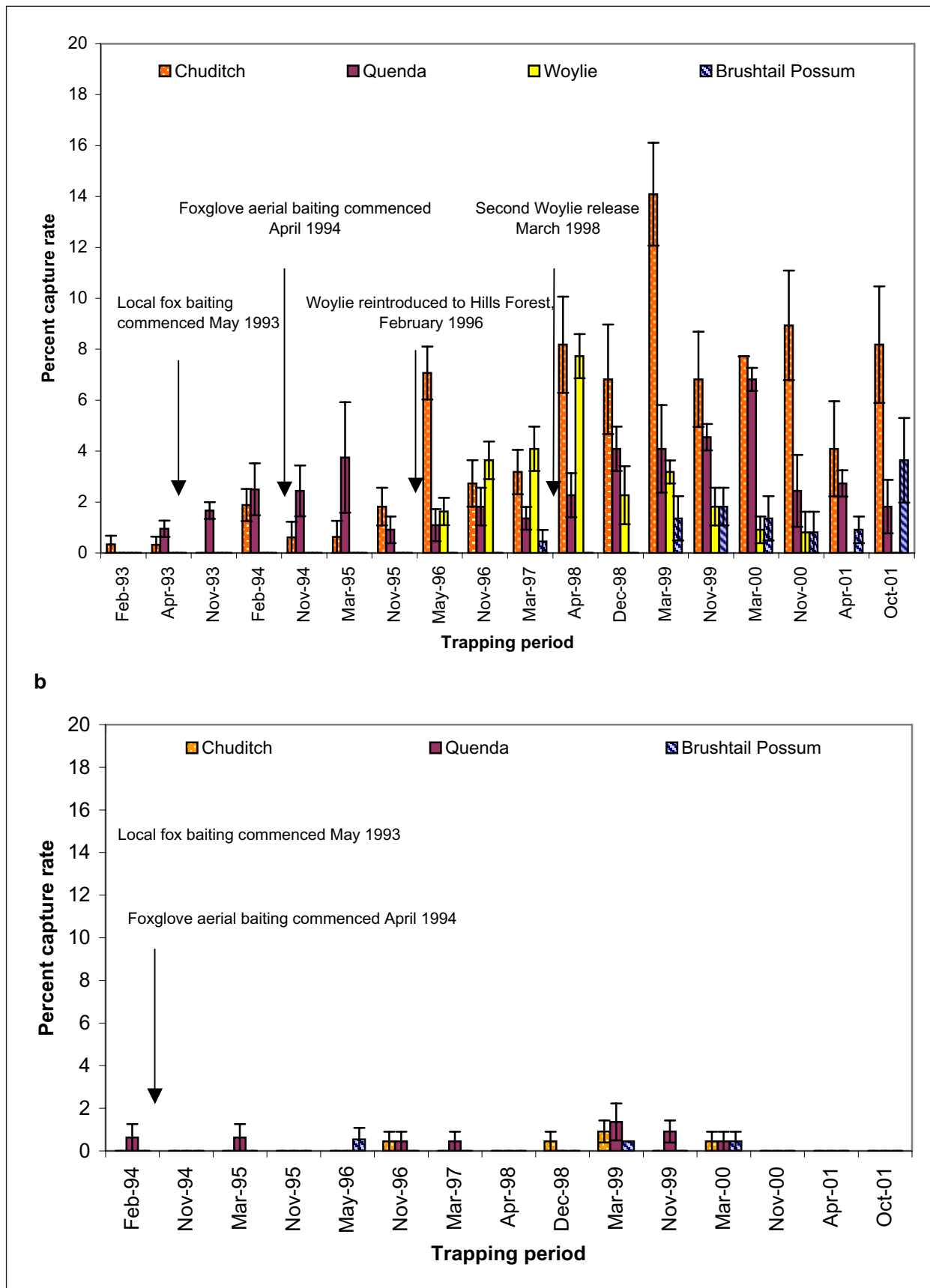


Figure 7. Mean daily percent capture rate (bars denote standard error) for medium-size mammals on (a) the northern transect and (b) the southern transect, Hills Forest, using small cage traps.

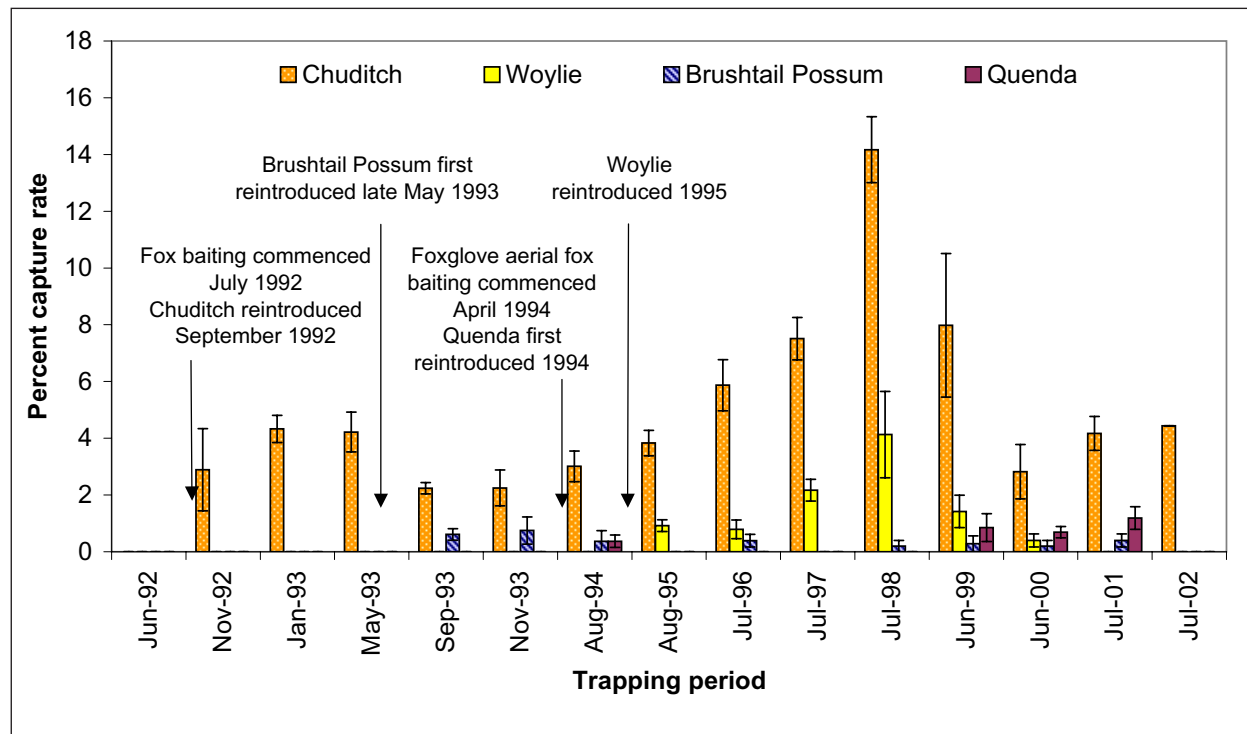


Figure 8. Mean daily percent capture rate (bars denote standard error) for medium-size mammals in the core monitoring area of Julimar State Forest.

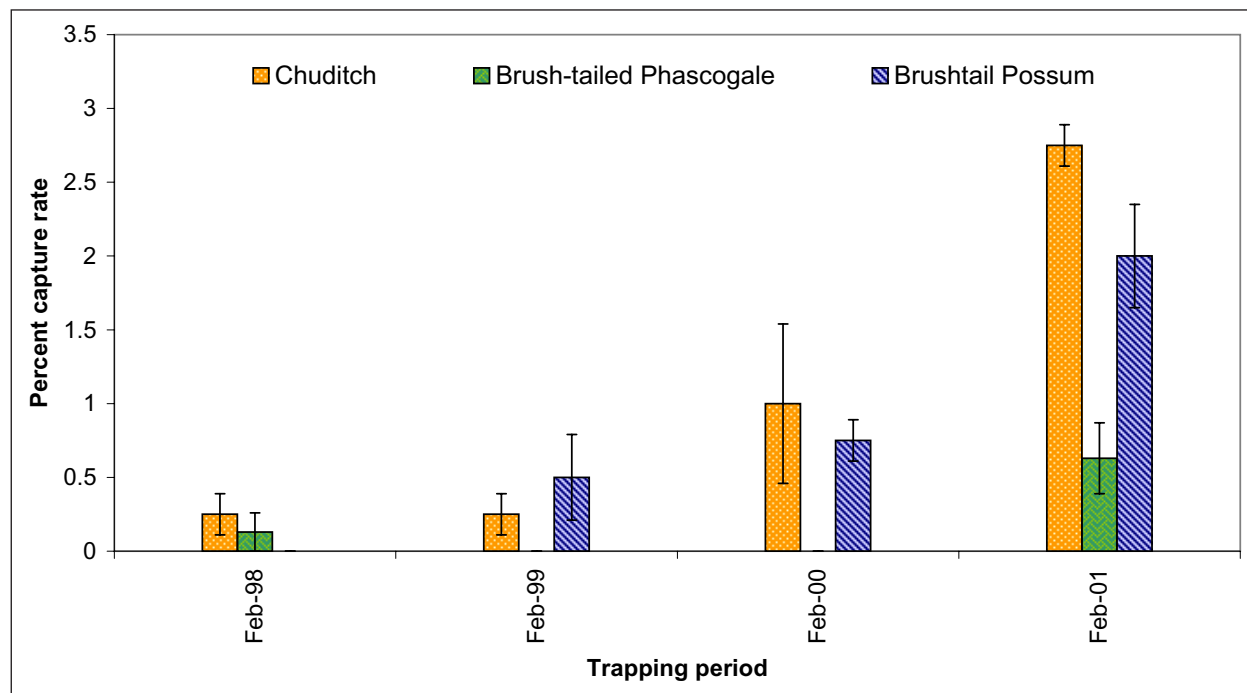


Figure 9. Mean daily percent capture rate (bars denote standard error) for medium-size mammals, including Brush-tailed Phascogale, in Catterick Forest Block using small cage traps.

Chuditch have shown recovery in all three sites with peak capture rates from 2% to 4.2%. Brushtail possums have shown a strong recovery in Centaur and Catterick. Although capture rates have shown no obvious trend in Noggerup, possums have been trapped with increasing regularity.

Woylies were reintroduced to Centaur Forest Block in 1998. Capture rates appear to be on the increase but the latest capture rate of 5.4% is still less than the capture rate of 7.5% prescribed in the Woylie Recovery Plan as a criteria for successful recovery.

St John Forest Block

The monitoring site established in the formerly proposed St John Conservation Park has consisted of a total of 170 small cage traps which has now been reduced to conserve logistics. Monitoring results have been input to the Fauna File database however a substantial portion of this data was lost during a computer upgrade as no backup had been made. This data set has not yet been rectified but earlier extractions of data indicated a strong recovery of brushtail possum though a reintroduction of woylies has failed.

Warren Region

Moopinup and Tone Forest Blocks

Although not baited for fox control until 1996, Moopinup and Tone forest blocks can be regarded as extensions of 'the Perup'. Monitoring results at Moopinup (Figs 10 and 11) have indicated a rapid recovery of the woylie suggesting that this species was well established but at low density. Capture rates are now high enough to significantly exclude captures of other species though chuditch, quenda, brushtail possums and western ringtail possums are all present. KTBA analysis indicates that the woylie population is large enough to sustain removal of animals for translocation (Fig. 11). Chuditch capture rates have been relatively high and have largely remained at or above 1%. Quenda and brushtail possum capture rates are also reasonably high in view of the high capture rates of woylies.

Recovery of brushtail possums has been evident in Tone Forest Block though there has been a decline in the last year. Chuditch persist but are not showing any discernable pattern. Quenda and woylie have been trapped but not for the last three years. Tone Forest Block appears to be only marginally influenced by the recovery patterns in the main Perup area.

Valley of the Giants

Slow recovery of quenda is apparent in the Valley of the Giants with capture rates starting at 0.5% and peaking at 3.3% in April 2001 but remaining above 1% since October 1999 (Fig. 12). Brushtail possum captures have remained below 1% except for an isolated peak of 2.5% in April

2001. Woylies were released in the Valley of the Giants in 1999 from Perup and are persisting and appear to be establishing. Woylies have now been sighted during walking tours by torchlight around the Tree Top Walk (G. Freebury, CALM, Albany, pers. comm.). Capture rates for all three species are still below 3.5% but this may be influenced by the high capture rates of southern bush rat possibly excluding them from traps.

South Coast Region

Stirling Range National Park

The monitoring results for Stirling Range National Park show a recovery in the quenda population though there was an apparent decline in November 2000. Brushtail possums made a late appearance on the transect but are increasing slowly. Interestingly, one individual quokka has been trapped on the transect (in a small Sheffield cage trap) in April 2001 and again in November 2001.

Four species of native small mammal have also been trapped on the transect. One, the western mouse, is currently listed as Priority Four species on the CALM Priority Fauna List. Captures of this species (using cage traps and type A Elliott traps) have been very low. The only species that have been caught in reasonable numbers are the mardo and the southern bush rat. There appears to be a pattern of increasing capture rates of southern bush rat up until 2001 but none of the other species show any discernable patterns. All species declined by 2001.

Porongorup National Park

Quenda and brushtail possums have both shown a strong recovery in Porongorup National Park (Fig. 13) although quenda began to decline in 2000. Capture rates for southern bush rat have been very high up until 2000 (Fig. 14) and may have suppressed capture rates of quenda and brushtail possums but then declined to less than 5%.

Waychinicup National Park

Quenda is the only medium-size mammal trapped on this transect and capture rates and KTBA analysis suggest a recovery and then a subsequent decline in 2001. Rainfall data from Albany (see Figs 26 and 27) show below average winter rainfall for the last six years. However, winter and spring 2000, summer 2000–2001 and autumn 2001 were particularly dry and the following winter (2001) rainfall may have been insufficient to compensate for these drought conditions.

Small mammal captures have consisted of mardo, southern bush rat and house mouse. Southern bush rats have been trapped consistently but show no discernable pattern. The two peaks in capture rates coincide with low capture rates in quenda suggesting that bush rat captures at these times may have excluded potential quenda captures.

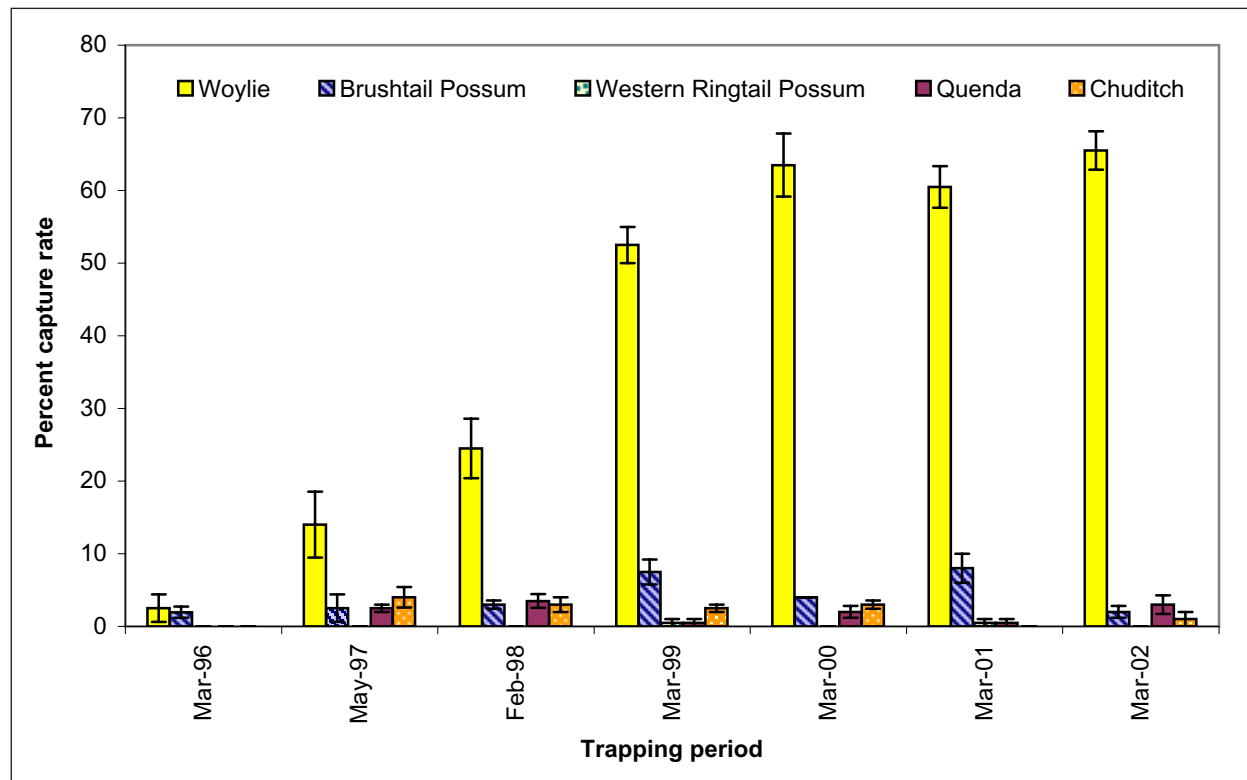


Figure 10. Mean daily percent capture rate (bars denote standard error) for medium-size mammals in Moopinup Forest Block using small cage traps.

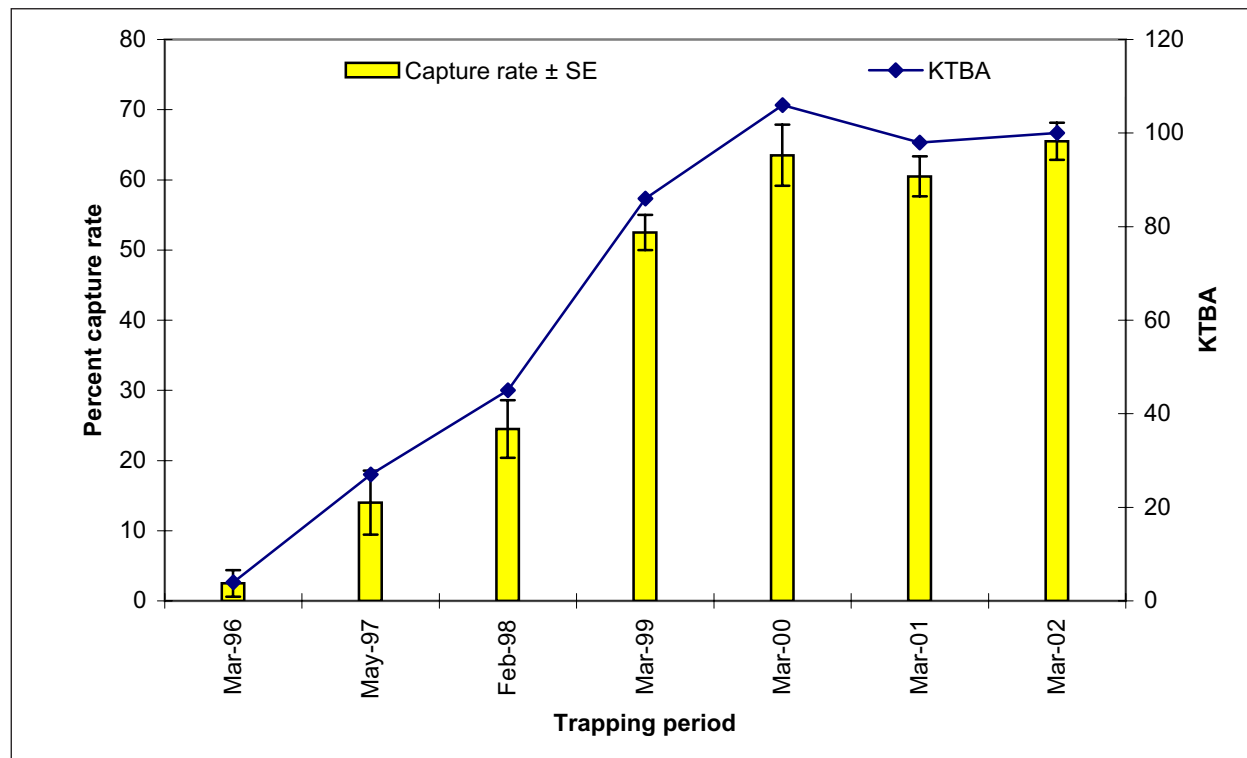


Figure 11. Mean daily percent capture rate (bars denote standard error) and the number of individuals known to be alive (KTBA) for woylies in Moopinup Forest Block using small cage traps.

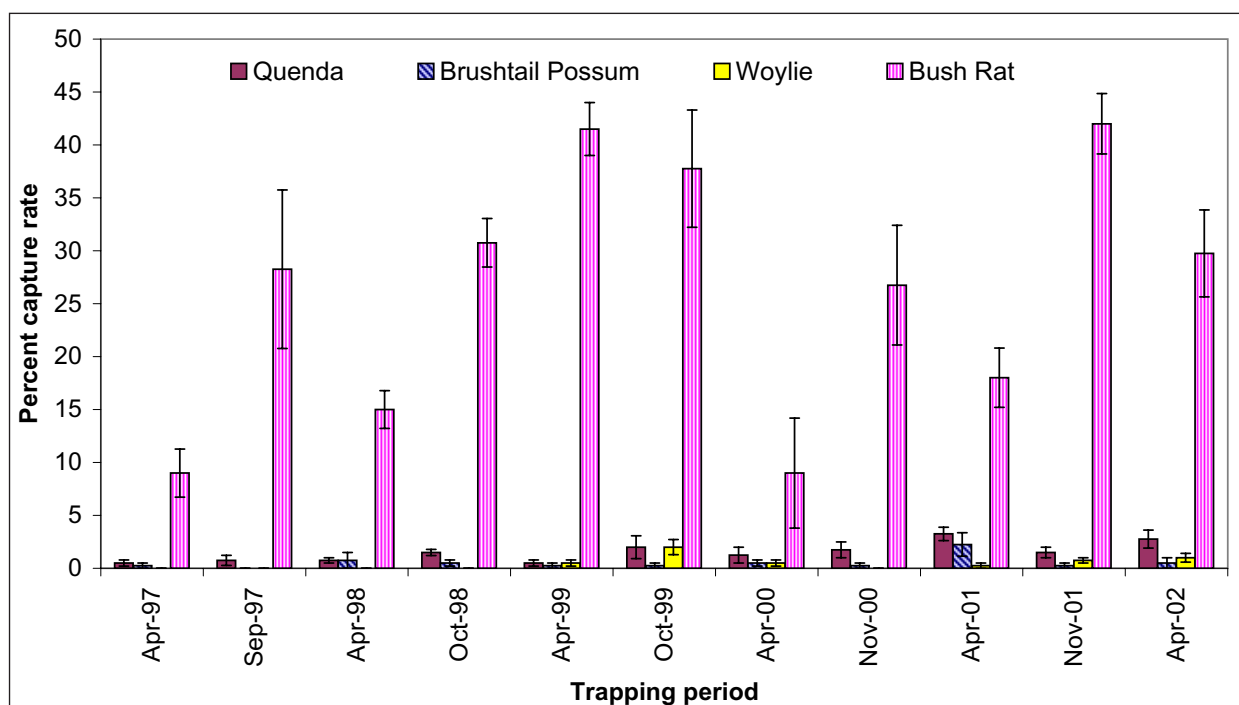


Figure 12. Mean daily percent capture rate (bars denote standard error) for medium-size mammals and southern bush rat in the Valley of the Giants using small cage traps.

Fitzgerald River National Park

Aerial baiting twice yearly for fox control was implemented in the western portion of the park between February 1991 and September 1995 (followed by two supplementary ground baitings) to assess whether fauna recovery could be achieved under this baiting regime (Kinnear *et al.* 2002). Aerial baiting four times yearly under the *Western Shield* program commenced in October 1996.

Two monitoring transects were established in the Fitzgerald River National Park in 1997 by CALM Albany District— one at Twertup in the western end of the park and the other on Moir Track in the eastern end of the park.

With the exception of white-tailed dunnart (*Sminthopsis granulipes*) all other native mammals trapped during a biological survey of the Fitzgerald River National Park in 1987 (Chapman 1995) have been trapped at either one or both of the above monitoring transects. Not recorded in 1987, chuditch have also been trapped on both of the above transects. Chapman (1995) reported observations of woylies near Twertup but trapping efforts failed to confirm their presence. Current trapping efforts have also failed to confirm the presence of this species. Tammar Wallabies were also recorded by Chapman (1995) but appeared to be scarce. Kinnear *et al.* (2002) reported increases in tammar wallaby following baiting twice yearly for fox control.

Recovery of brushtail possums has been evident on both the Twertup and Moir Track transects. The capture rates of brushtail possums at Twertup quickly rose from 14% up to 38% and the decision was made to shift the transect to accommodate captures of other species. Many of the possums caught had ear tags fitted during the earlier study by Kinnear *et al.* (2002) that also demonstrated recovery of possums following fox control. The transect was shifted further along Twertup Track and the results still show a good recovery of brushtail possums but at lower capture rates, though there is a slight decline from 2001. Quenda also appeared to be recovering but capture rates declined from October 2000. Other than House Mice, small mammals also declined from 2000 (Fig. 15). The rainfall figures (January 1997 to October 2002 from Bureau of Meteorology) for Jacup (west) and Ravensthorpe (east) show extended periods of low rainfall from September 2000 to June 2001 and again from January to October 2002 that may have contributed to the observed declines. No patterns in small mammals that may relate to the effects of fox control is evident.

Recovery has been less dramatic and the declines more dramatic on the Moir Track transect. Brushtail possums appeared to be making good recovery and then crashed in 2001. Quenda also appeared to be recovering but crashed earlier in 2000. Declines in the small mammals also occurred in 2001. Again no patterns in small mammals that may relate to fox control are evident.

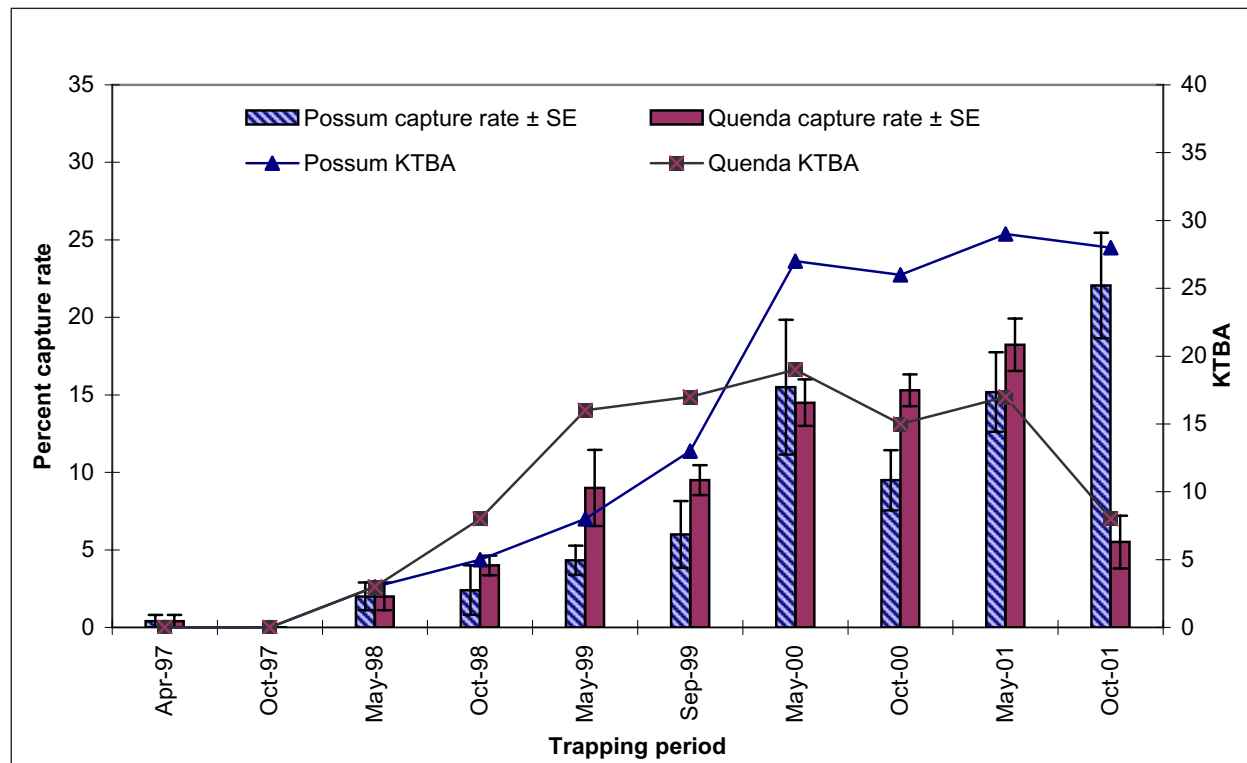


Figure 13. Mean daily percent capture rate (bars denote standard error) and the number of individuals known to be alive (KTBA) for brushtail possum and quenda in Porongorup National Park using small cage traps.

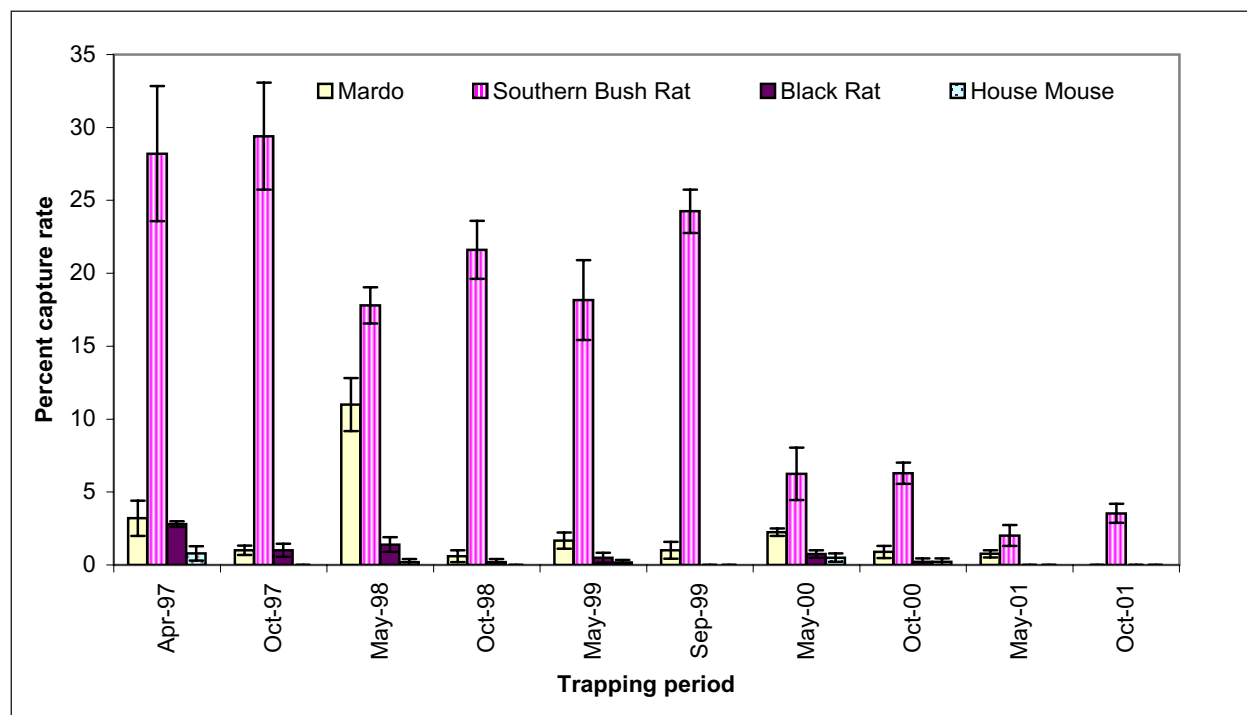


Figure 14. Mean daily percent capture rate (bars denote standard error) for small mammals in Porongorup National Park using small cage traps and type A Elliott traps.

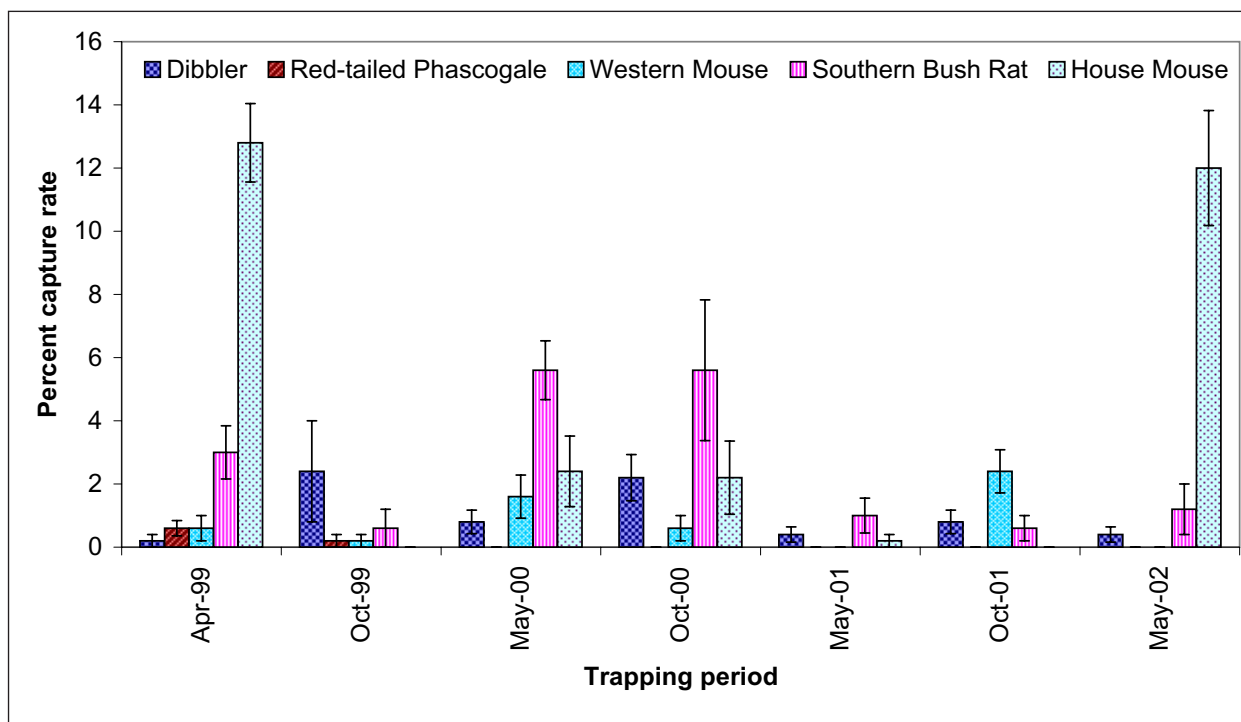


Figure 15. Mean daily percent capture rate (bars denote standard error) for small mammals in Twertup, Fitzgerald River National Park, using small cage traps and type A Elliott traps.

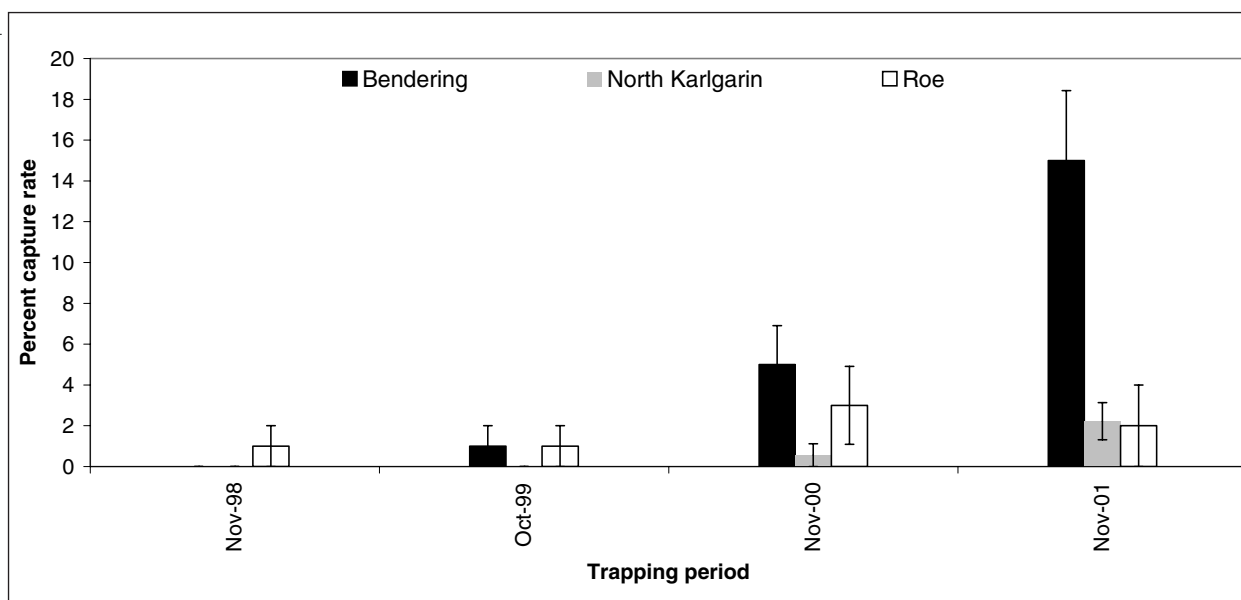


Figure 16. Mean daily percent capture rates (bars denote standard error) of brushtail possums using small cage traps at Bendering, North Karlgarin and Roe nature reserves.

Wheatbelt Region

Dryandra satellite blocks

A transect of 50 small cage traps through Bald Rock and Montague blocks has been monitored since two monthly baiting with 1080 baits for fox control was first implemented in 1996. Capture rates indicate recovery of brushtail possums whereas woylies, though present, have not recovered. The below average winter rainfall since 1999 may be responsible for inhibiting recovery of woylies.

Bendering, North Karlgarin and Roe nature reserves

These three nature reserves are monitored concurrently as they are located close together. Five grids of sixteen pitfall traps were established in North Karlgarin Nature Reserve and have been monitored since October 1993. Fox control in all three reserves by baiting four times a year commenced in 1998. The monitoring was expanded to include Bendering and Roe nature reserves and incorporated the use of Elliott traps and small cage traps to monitor the recovery of medium-size mammals. One transect of 25 small cage traps was established in each of Bendering and Roe nature reserves and nine small cage traps were added to each of the five grids in North Karlgarin Nature Reserve.

Kitchener and Chapman (1977) surveyed the mammal fauna of Bendering (formerly West Bendering) and North Karlgarin (formerly Bendering) nature reserves from 1972 to 1976. Chuditch and red-tailed phascogale were recorded during these surveys but neither species has been recorded since. With the exception of the macropods and bats, all other native mammals recorded by Kitchener and Chapman (1977) have been trapped since monitoring commenced in these reserves in 1993. In addition, western pygmy possum and ash-grey mouse have also been trapped.

The brushtail possum is the only medium-size mammal that has been trapped in these reserves since 1998. Though recorded as present in North Karlgarin Nature Reserve and very common in Bendering Nature Reserve in the 1970s (Kitchener and Chapman 1977) it was initially not detected in either reserve in 1998. It has since shown very good recovery in Bendering Nature Reserve and moderate signs of recovery in North Karlgarin and Roe nature reserves (Fig. 16). Bendering Nature Reserve includes a larger portion of mallee woodland that provides a more favourable habitat for possums (Kitchener and Chapman 1977).

Lake Magenta Nature Reserve

Before fox control was first implemented in 1996 trapping surveys had failed to catch any medium-size mammals (Crook and Burbidge 1982) except for one chuditch in 1994 (Morris *et al.* 2003). Aerial fox baiting four times a year commenced in May 1996 and has been supplemented by six weekly ground baiting around the perimeter and a

few internal firebreaks. A monitoring transect of 200 small cage traps set at 100m intervals was established in 1996 to monitor fauna recovery and the establishment of translocated populations. This transect was reduced to 100 small cage traps set at 200m intervals in 1999 to economise on logistics but still covered the same area.

Captive bred chuditch were first released into the reserve in October 1996 (Fig. 17). Capture rates of chuditch have reached 5.1% and, except for May 1998 and November 2001, have remained at or above 1% up till May 2002 though there has been a noticeable decline since May 2000. No chuditch were captured in November 2002. Woylies were first reintroduced in January 1997 and capture rates have remained low but steady up to November 1999. Capture rates fell and no woylies have been trapped since May 2000 suggesting that the population has failed to establish.

After less than 12 months of baiting foxes, quenda and brushtail possums appeared on the transect (Fig. 17) though neither species had previously been recorded in the reserve. Capture rates indicate a strong recovery of both species, particularly possums, followed by a dramatic crash in quenda captures in 2000 and possum captures in 2001. Rainfall data for Lake Grace show below average winter rainfall over the last three winters with the 2002 winter rainfall being less than half of the average winter rainfall. The drought conditions appear to be the trigger, but may not be solely responsible for the observed population crashes. Other factors such as feral cat activity need to be investigated.

Monitoring data for some of the small mammals have also shown evidence of recovery related to fox control. In addition to the transect of small cage traps, ten lines of ten Elliott traps and six grids of 25 pitfall traps have also been used to survey and monitor smaller ground dwelling fauna. The heath mouse has been trapped more regularly since fox control commenced though capture rates do not reflect an increase in the population (Fig. 18). Interestingly, heath mouse was caught in Dragon Rocks Nature Reserve in 1993 after two years of fox baiting (Morris *et al.* 1993). Capture rates for western pygmy possum in pitfall traps (Fig. 19), though a little inconsistent, appear to reflect an increase in population since fox control commenced followed by a decline in 2000, coinciding with the declines in other species and the drop in rainfall. This pattern in western pygmy possum capture rates has not been recorded at other sites.

Western Shield monitoring sites showing poor recovery or no recovery of mammal fauna

The following sites, established since the implementation of *Western Shield*, have shown poor recovery or no recovery of either extant or translocated fauna. The sites are presented by CALM regions.

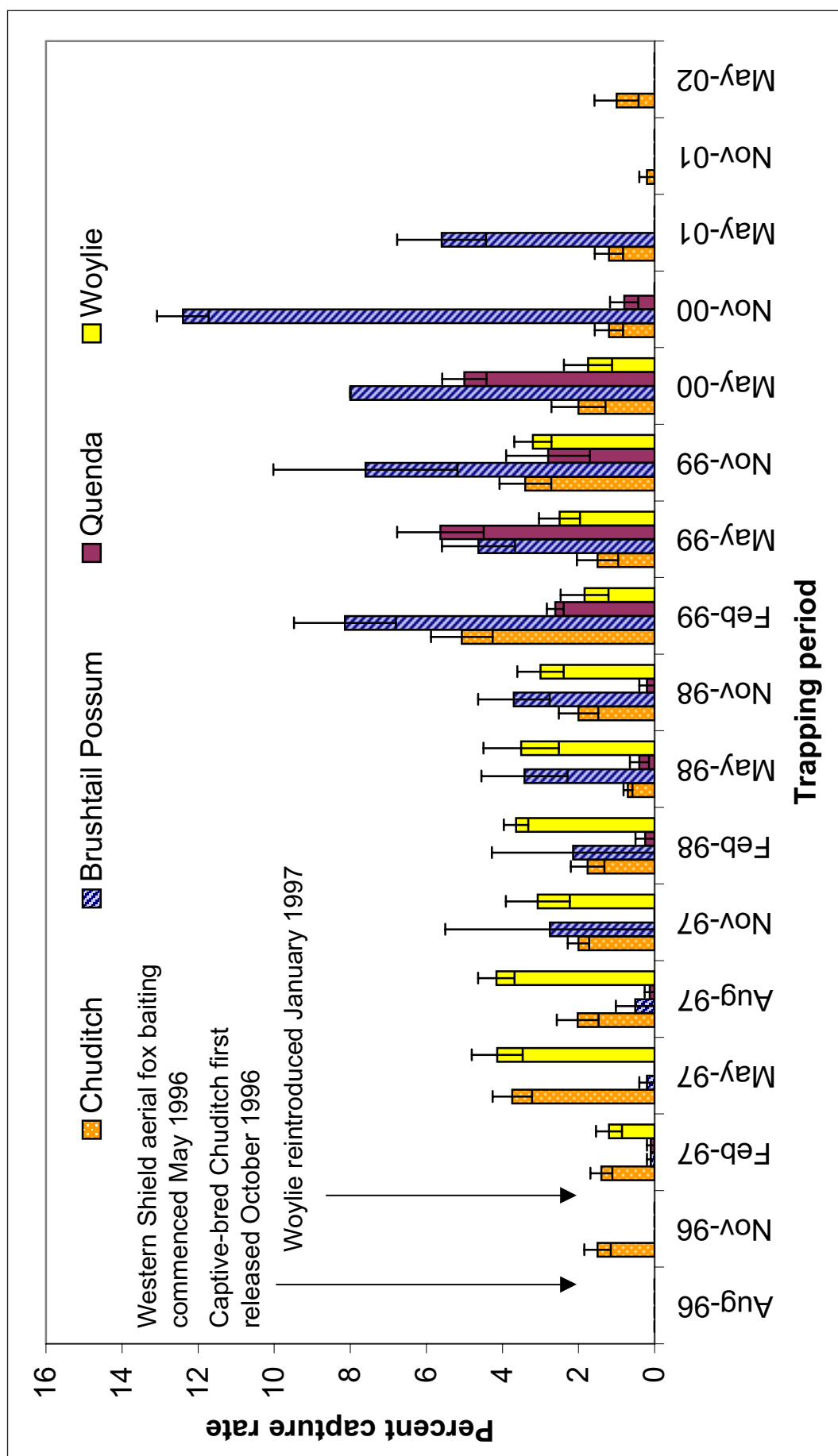


Figure 17. Mean daily percent capture rate (bars denote standard error) for medium-size mammals in Lake Magenta Nature Reserve, using small cage traps.

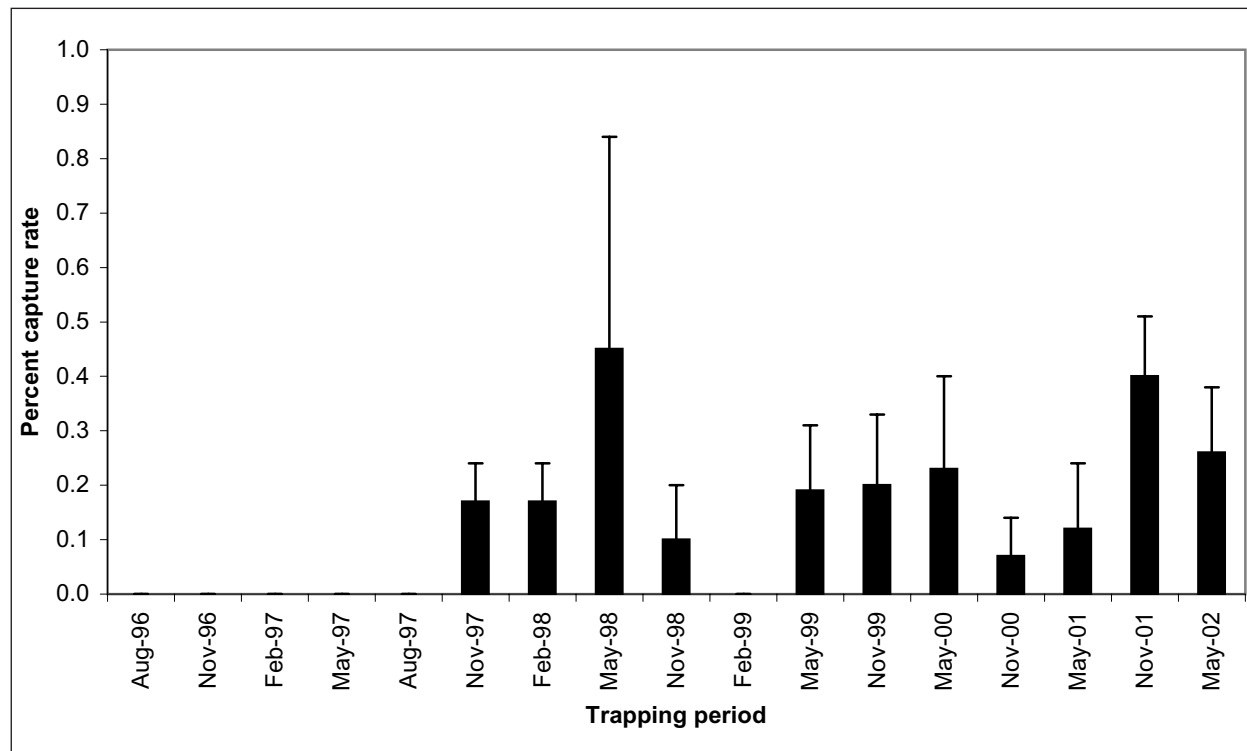


Figure 18. Mean daily percent capture rate (bars denote standard error) for beath mouse in Lake Magenta Nature Reserve, using small cage traps, elliot traps and pitfall traps.

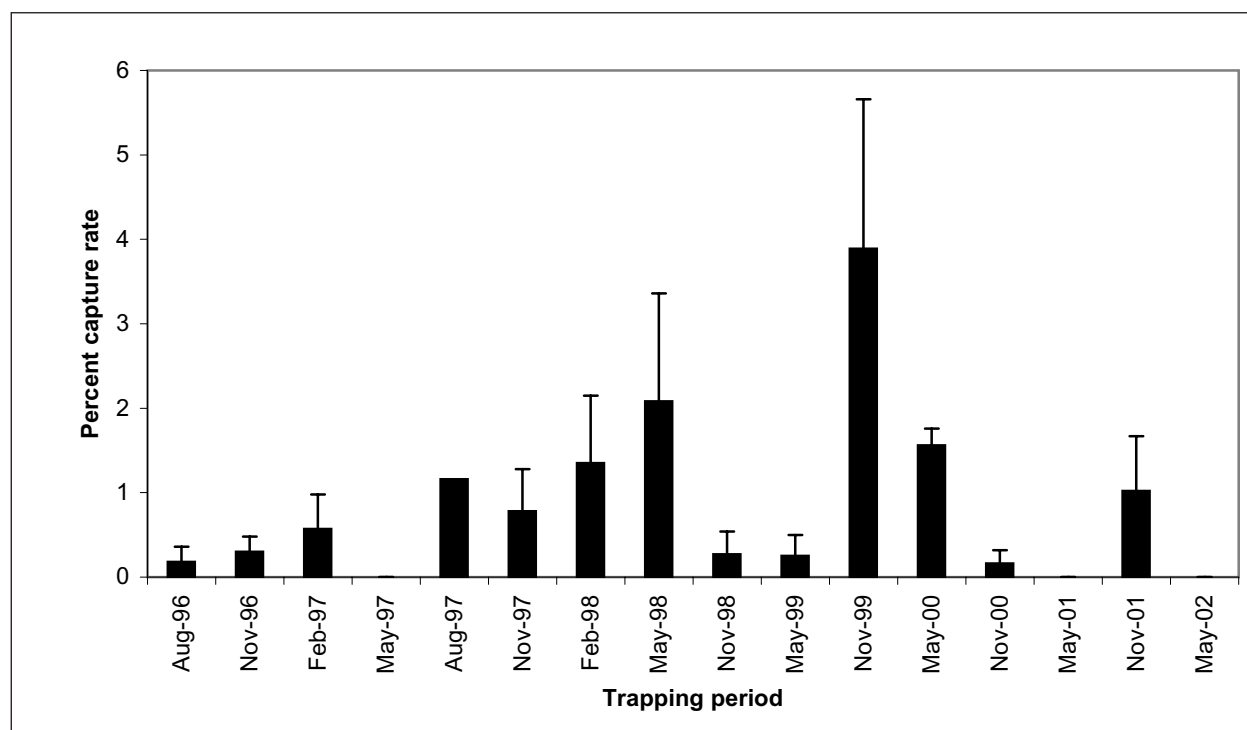


Figure 19. Mean daily percent capture rate (bars denote standard error) for western pygmy possum in Lake Magenta Nature Reserve, using pitfall traps.

South West Region

Milyeannup Forest Block

Chuditch, quenda, and brushtail possums have been caught but at very low capture rates and none show evidence of recovery. Brush-tailed phascogale, mardo and southern bush rat have also been caught, the bush rats being the most abundant species. None of these species exhibit any pattern that may relate to a response to fox control.

Warren Region

Wheatley Forest Block

Karri forest is the dominant vegetation type in this forest block. Brushtail possums, quenda, mardo, southern bush rat and Black Rat have been trapped. With the exception of bush rats in September 1996 capture rates have been very low (0.4% to 2.5%) with no discernable trends.

Gray Forest Block

This is another karri forest site. Southern bush rats are abundant but capture rates of other species have been very low, generally less than 2.5%. Brushtail possums are present apparently at very low density (only two individuals have been caught) but they may be less active on the ground in this habitat and therefore less likely to encounter traps. Woylies were reintroduced to neighbouring Strickland Forest Block in 2000 and have appeared on the transect in 2001 with a capture rate of 3%.

Lake Muir Nature Reserve

The monitoring transect is located in the eastern part of the reserve. Woylies are present in very low numbers and a restocking of woylies in neighbouring Poorginup and Chitelup forest blocks occurred in 1998. Captures of woylies have been sporadic and capture rates have remained low. Chuditch and brushtail possums have made a late appearance on the transect and appear to be showing some indication of recovery, particularly chuditch with a capture rate of 2% in March 2002.

Mt Frankland

Monitoring results show that southern bush rats are the most frequently trapped species and brushtail possums and quenda are the only medium-sized mammals trapped. Capture rates for possums and quenda are less than 1% and insufficient to determine trends.

D'Entrecasteaux National Park, Woolbales site

This monitoring transect has yielded very poor results. Southern bush rats are very abundant but capture rates of the only medium-size mammals trapped, quenda and brushtail possums, have been insignificant.

Walpole-Nornalup National Park, Hilltop site

Slightly better results have been recorded on this transect. Again southern bush rats are very abundant and dominate trap captures. Capture rates of brushtail possums suggest the beginnings of a recovery followed by a decline in 2001. Capture rates for quenda were less than 1% and show no discernable pattern.

Denmark and Denbarker forest blocks (Mt Lindesay)

This area was the site of a woylie reintroduction in 1998 and a chuditch restocking in 1999. A monitoring transect of 100 small cage traps has been established and monitoring results are presented in Fig. 20. Quenda are present but the low capture rates suggest low density along the transect. Woylies appeared to be surviving well until chuditch were released and no further captures were recorded after December 1999. Chuditch appeared to be establishing but declined in 2001 and capture rates have remained below 1%. Southern bush rats were abundant but capture rates were not high enough to significantly impact on the captures of other species.

Wheatbelt Region

Dragon Rocks Nature Reserve

An extensive fauna survey was undertaken in Dragon Rocks Nature Reserve in 1972 (McKenzie *et al.* 1973). The brushtail possum was the only medium-size mammal trapped during the survey with two individuals trapped in 909 trap-nights. One red-tailed phascogale and one western mouse (*Pseudomys occidentalis*) were captured in Elliott traps (1206 trap-nights).

Fox control was undertaken in the southern half of the reserve in 1991 for two years as part of an experiment to investigate the effect of predation by foxes on populations of the western mouse (Morris *et al.* 1993). The results suggested that factors other than fox predation were responsible for regulating abundance in this species. Fox control over the entire reserve under Western Shield began in May 1996.

Fauna monitoring under *Western Shield* using cage traps and Elliott traps commenced in 1999. The intention was to monitor twice a year but limited resources led to a decision to cease monitoring in 2001. Again, the only medium-size mammal trapped was the brushtail possum but there were signs of recovery. One individual was caught in May 2000 and four individuals were caught in May 2001 (mean daily capture rate of 1.25%). Western mouse has also been trapped and the mean daily capture rate, using both cage traps and Elliott traps, in May 2001 (2.38%) was more than double that of May 2000 (0.88%). This is not a sustained increase and it may be due to factors other than fox control. There have been no captures of red-tailed phascogale. Monitoring in Dragon Rocks Nature Reserve will be resumed in 2003 and will be continued on an annual basis.

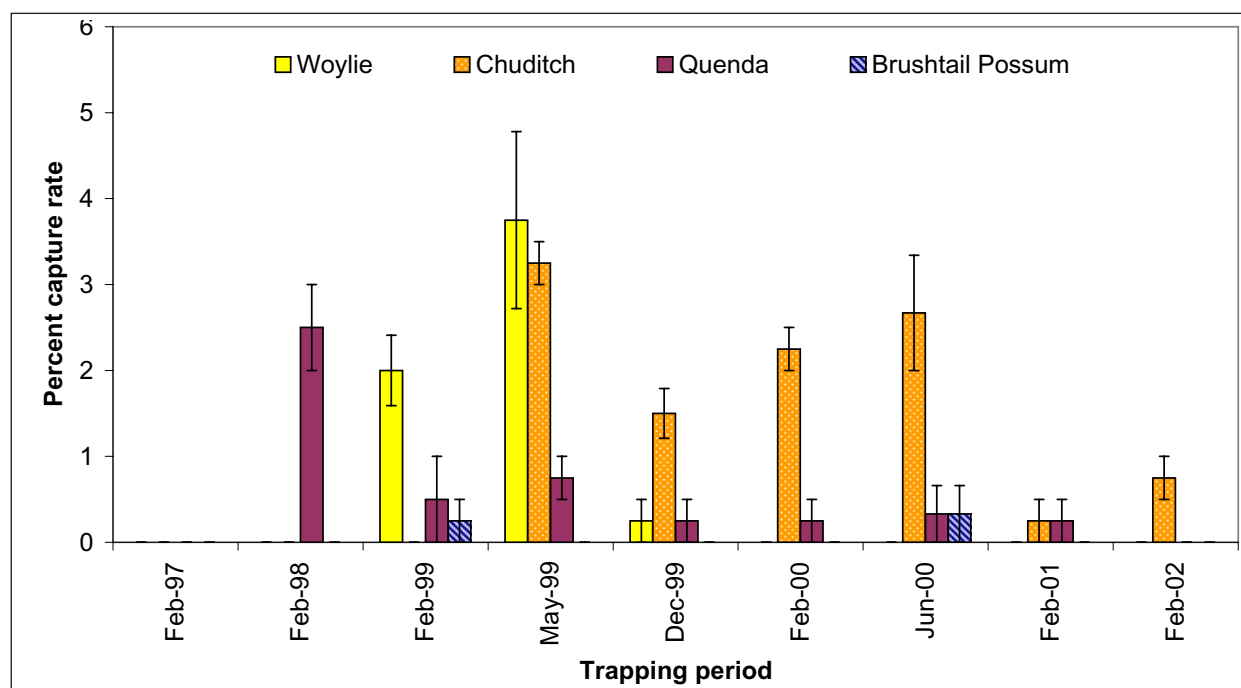


Figure 20. Mean daily percent capture rate (bars denote standard error) for medium-size mammals in Denmark and Denbarker forest blocks using small cage traps.

Spotlighting results

Very few spotlighting transects have been established to monitor fauna recovery due to limited resources for overtime allowances for district staff. Those that have been established show much greater variability in abundance estimates than data from trapping transects and trends in abundance are less evident. The sighting surveys have been done as single events rather than the recommended minimum of two consecutive nights.

Warren Region

Perup forest areas

Spotlighting surveys have been undertaken in Chariup, Moopinup and Kenninup forest blocks. These surveys have recorded brushtail possums, western ringtail possums and small numbers of Western Brush Wallabies.

The data on brushtail possums suggest a decline in Chariup since the sighting rates dropped from 8.4 per 10 km to zero sightings. The monitoring results from trapping in this forest block suggest a stable population during the same period thus the difference in results is probably an indicator of changes in possum activity. The brushtail possum data from Moopinup is consistent with the trapping data from the same period and shows little change in abundance except a temporary drop in March 2000. In Kenninup there appears to have been a general decline though the fluctuation in sightings makes this a subjective interpretation.

Data on western ringtail possums is very scant from trapping data but the spotlighting data suggest an increase in numbers at Moopinup and Kenninup. The spotlighting

data does not reveal much about trends in western brush wallaby numbers since sightings were few and infrequent.

Wheatbelt Region

Dongolocking Nature Reserve

The spotlighting data from this nature reserve shows little change in the abundance of brushtail possums but a large apparent increase in western brush wallaby (Fig. 21a). Rabbits appeared to have increased substantially in 1999 (Fig. 21b) and this may have been due to the above average winter rainfall observed in that year in this area of the wheatbelt (rainfall trends similar to Perth, Figs 24 and 25). The above average winter rainfall may also have assisted the apparent increase in western brush wallaby after 1999. Foxes and feral cats have been observed infrequently indicating low-level presence.

‘Jaloran’ Nature Reserve

Local volunteers under the guidance of CALM staff from Katanning have undertaken the spotlighting surveys in this unnamed nature reserve, formerly known as Jaloran Timber Reserve. The data show a recovery of brushtail possums and western brush wallaby (Fig. 22a). There appears to have been a decline in western grey kangaroos during the same period. Tammar Wallabies are present but are infrequently observed and show no sign of recovery.

Rabbit numbers appear to fluctuate on a three to four year cycle which may be indicative of myxomatosis outbreaks (Fig. 22b). Foxes and feral cats have been observed infrequently indicating low-level presence.

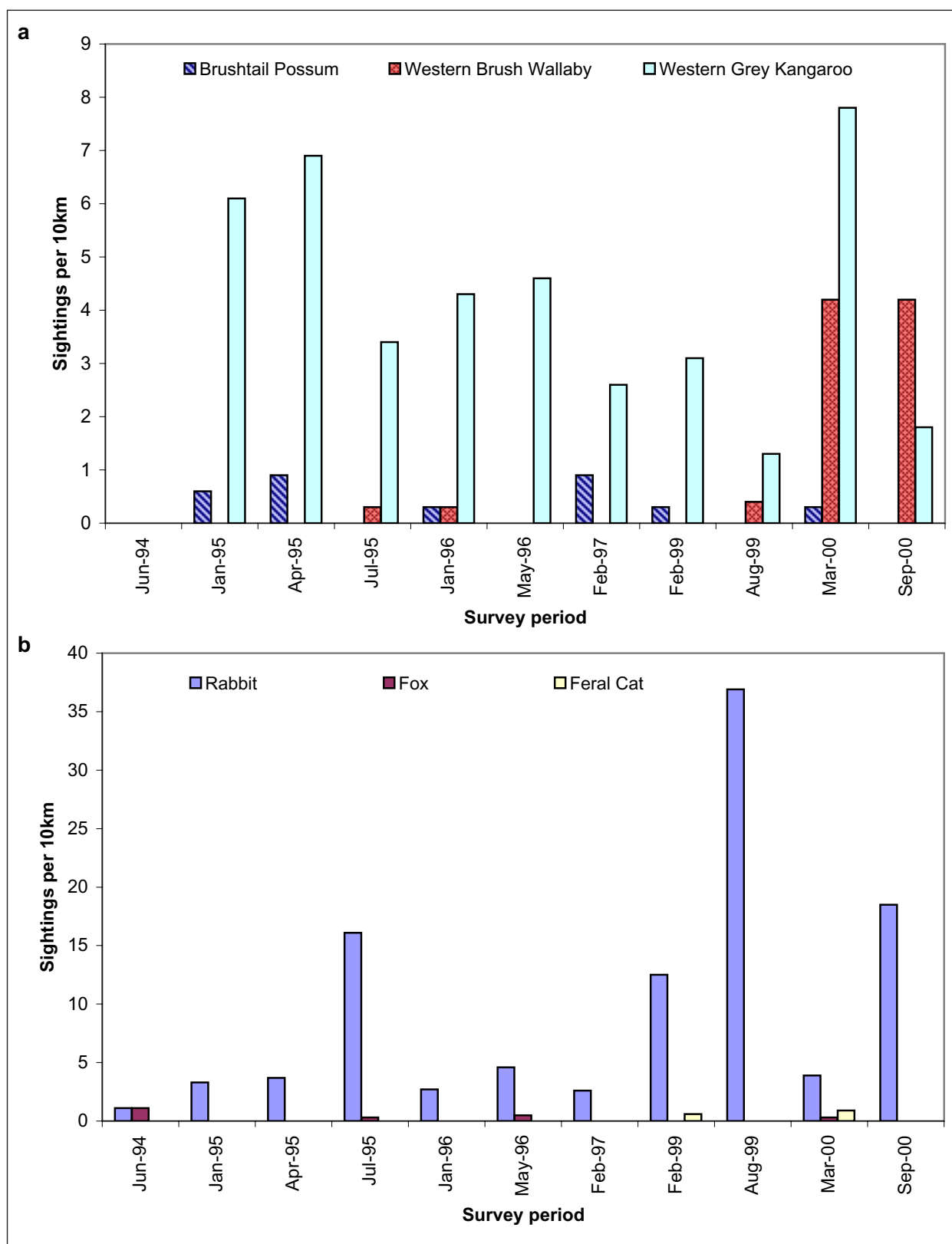


Figure 21. Spotlighting results, presented as the number of sightings per 10km, for (a) native mammals and (b) introduced mammals in Dongolocking Nature Reserve.

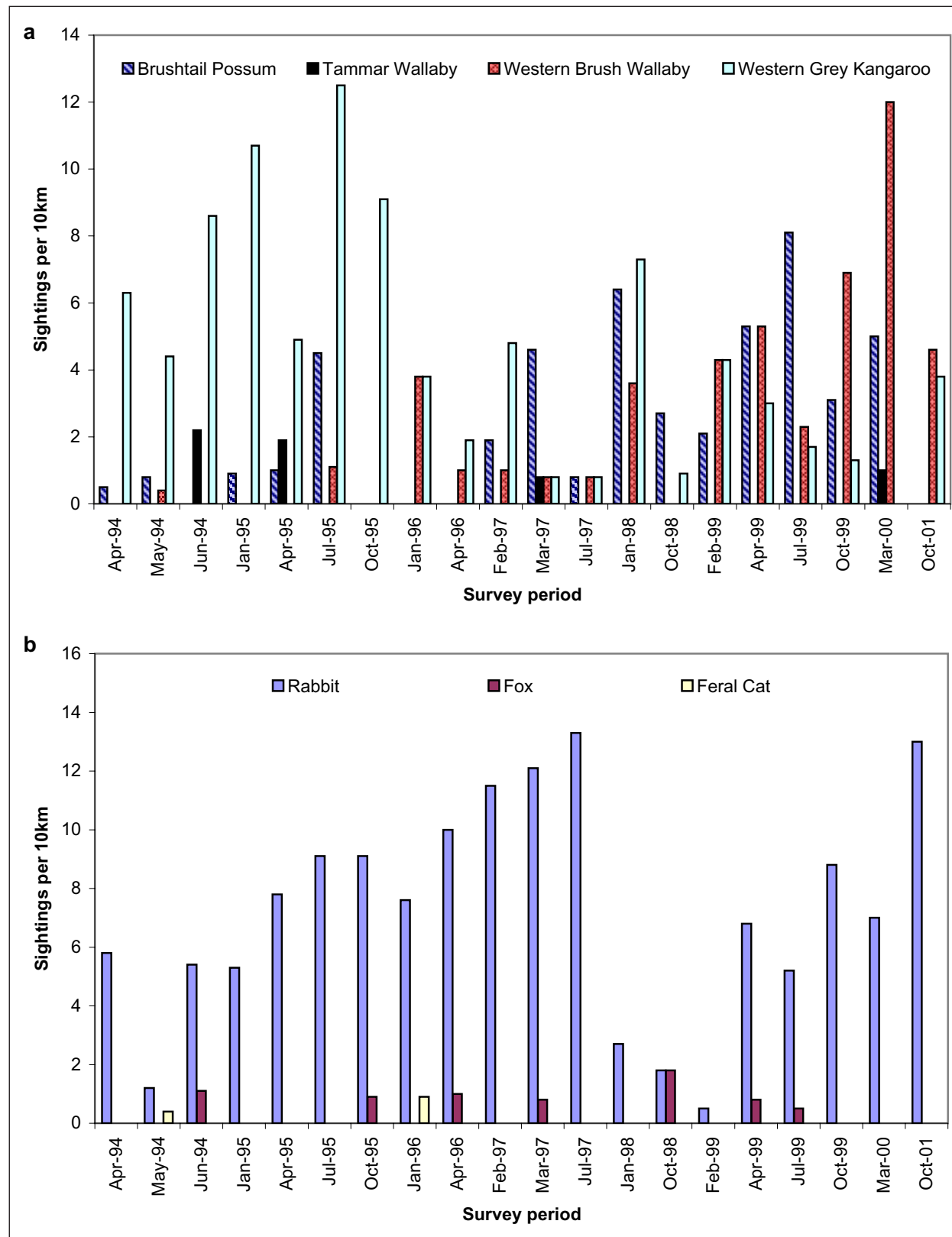


Figure 22. Spotlighting results, presented as the number of sightings per 10km, for (a) native mammals and (b) introduced mammals in 'Jaloran' Nature Reserve.

TABLE 6

Numbers of Rothschild's Rock-wallabies and Euros seen during spotlighting surveys 1992-present (Data from F. Stanley, CALM Karratha). R-w = rock-wallabies; Eu = Euro; - = no survey; and * = species not present.

DATE	BURRUP, VEHICLE		BURRUP, WALKING		DOLPHIN IS		ENDERBY IS	
	R-w	Eu	R-w	Eu	R-w	Eu	R-w	Eu
Jun 92	0	64	-	-	-	-	-	*
Nov/Dec 95	0	26	0	0	21	1	45	*
May 96	0	10	0	2	17	0	9	*
Nov 96	2	17	-	-	-	-	-	*
Sep 97	0	27	-	-	-	-	-	*
Feb 98	-	-	-	-	7	9	41	*
Sep 99	-	-	-	-	19	1	50	*
Nov 00	-	-	-	-	23	6	49	*
Mean	0.4	28.8	0	1	17.4	3.4	38.8	*
($\pm$ SD)	($\pm$ 0.9)	($\pm$ 20.8)		($\pm$ 1)	($\pm$ 6.2)	($\pm$ 3.9)	($\pm$ 17)	

Pilbara Region

Burrup Peninsula, Dolphin and Enderby islands

Fox baiting was implemented on Dolphin Island in the Dampier Archipelago in 1980 to protect and recover the population of Rothschild's Rock-wallaby (*Petrogale rothschildi*). Foxes are able to reach the island from the Burrup Peninsula but another population of rock-wallabies has remained isolated from foxes on Enderby Island. Spotlighting surveys have been undertaken on both Dolphin and Enderby islands since 1979 and results up to 1990 showing clear recovery on Dolphin Island have been published (Kinnear *et al.* 2002). The monitoring of these populations as well as the Burrup Peninsula has been maintained by Pilbara Regional staff and results are provided in Table 6. Results show stable populations on both Dolphin and Enderby islands. The Burrup Peninsula has had a varied baiting history since 1980 with both large temporal and spatial gaps in the distribution of baits. There has been no observable recovery of rock-wallabies on the Burrup Peninsula, although rock-wallabies have persisted at low numbers. Presumably the baiting has not been effective in controlling foxes sufficiently to facilitate recovery.

Monitoring sites showing increases in reptile fauna

The recovery of medium-size mammals has been an expected outcome of broadscale fox control under *Western Shield*. A less expected outcome has been the apparent increase of some reptile populations. Trapping results from at least three monitoring sites show increases of reptile species.

Reptile activity is very temperature dependent and capture rates of reptiles will vary at least partly in response to changes in ambient temperatures. While daily temperatures have not been recorded at monitoring sites, examination of temperature data from the nearest Australian Bureau of Meteorology recording stations show that the observed increases in reptile captures at the sites discussed below have occurred in spite of changes in ambient temperatures (see Fig. 23).

Hills Forest and Fitzgerald River National Park

Increasing capture rates of bobtail skinks (*Tiliqua rugosa*) have been recorded on the Hills Forest northern transect and on the Twertup transect in Fitzgerald River National Park. Activity of bobtails is highest in spring and thus capture rates recorded in spring months are the best indication of population trends.

Waychinnicup National Park

Not only has there been an increase in the capture rates of some species in this national park but there has also been an increase in the number of species that are consistently trapped (Fig. 23). Seven species of reptile have now been recorded on the monitoring transect. Increases appear evident in four of these: *T. rugosa*, *Egernia luctuosa*, *E. napoleonis*, and *E. pulchra*.

Records of feral cats on fauna monitoring transects

Earlier studies have shown that cats replace foxes as a key threat to fauna recovery in arid areas where foxes have been controlled or excluded (Christensen and Burrows 1994; Risbey *et al.* 2000; Morris *et al.* 2004, this issue). It could therefore be expected that the fauna recovery sites in the drier northern and eastern wheatbelt and south coast would be the most likely sites to show increases in feral cat numbers since the commencement of fox control. Feral cats are generally difficult to trap but occasionally they are caught in small cage traps during fauna surveys. Captures of cats have been recorded for all Western Shield fauna monitoring sites (Table 7).

Although capture rates are very low (less than 1%), several sites stand out as having recorded noticeably more cats than most other sites. At Hill Top site in Walpole-Nornalup National Park cats have been trapped during every survey period and the overall capture rate is the highest recorded at 0.63%. Nearby Valley of the Giants has the next highest capture rate at 0.3%. At Porongorup National Park the capture rate is 0.26%.

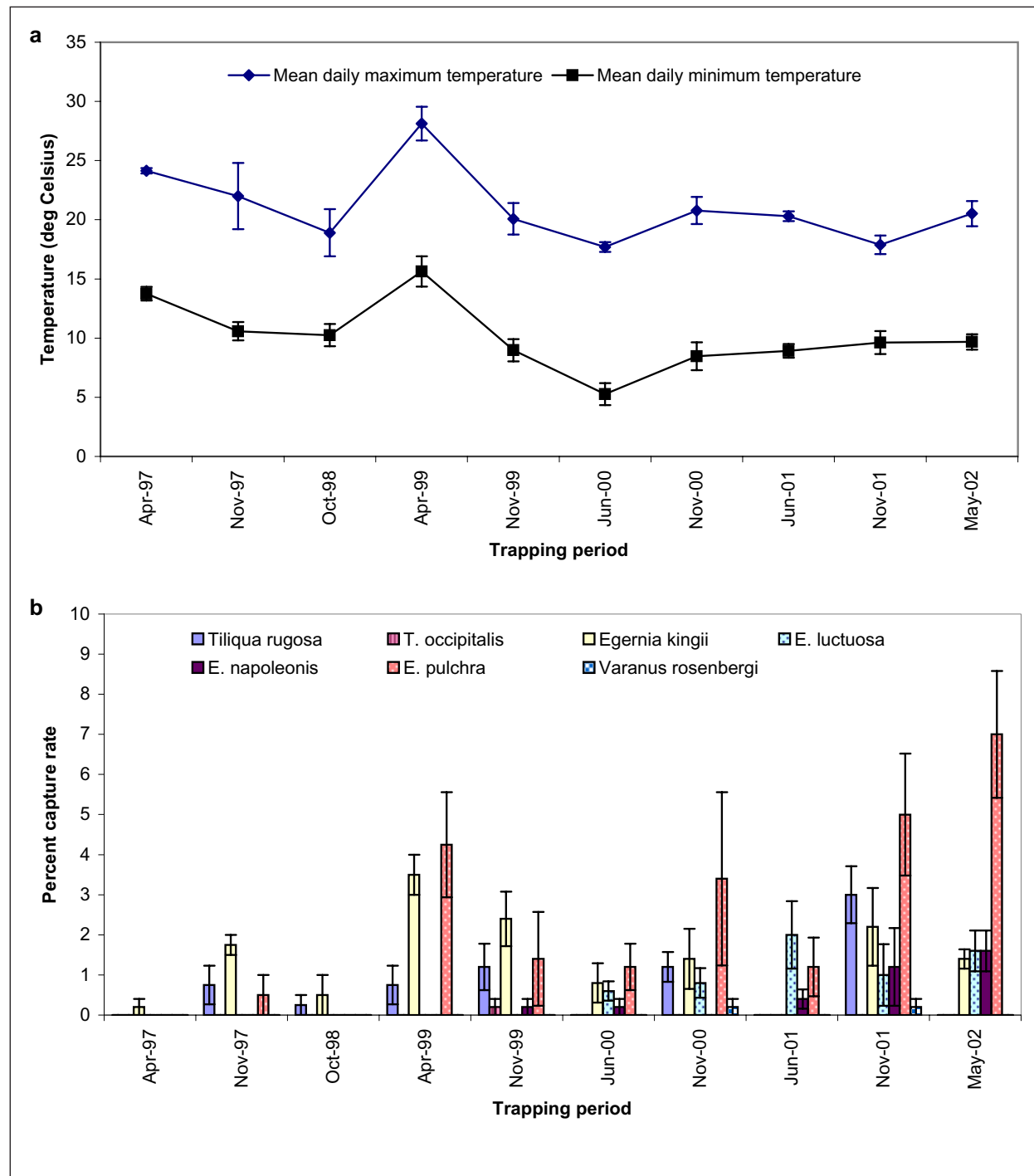


Figure 23. (a) Mean daily temperatures (bars denote standard errors) recorded at Albany Airport during the trapping periods at Waychinicup National Park (data from Australian Bureau of Meteorology).
 (b) Mean daily percent capture rate (bars denote standard errors) for reptiles in Waychinicup National Park, using small cage traps and elliott traps.

TABLE 7

The number of feral cats caught, total number of trapnights, percent capture rate, number of survey periods and the proportion of survey periods during which cats were trapped.

MONITORING SITE	# CATS CAUGHT	TRAPNIGHTS	% CAPTURE RATE	NO SURVEY PERIODS	PROPORTION OF SURVEY PERIODS WHEN CATS WERE CAUGHT (%)
Kalbarri NP	1	2397	0.04	4	25
Badgingarra NP	0	600	0.00	3	0
Nambung NP	1	580	0.17	3	33.3
Julimar CP	5	10 056	0.05	14	28.6
Hills Forest	2	6986	0.03	18	11.1
Batalling	1	12 401	0.01	24	4.2
Centaur	0	1496	0.00	4	0
Catterick	0	4000	0.00	5	0
Milyeannup	1	2120	0.05	5	20
Noggerup	1	5709	0.02	8	12.5
Gray	0	752	0.00	4	0
Wheatley	0	904	0.00	4	0
Tone	0	1392	0.00	8	0
Moopinup	0	1376	0.00	7	0
Chariup	0	1100	0.00	5	0
Boycup	1	800	0.13	4	25
Lake Muir NR	0	1300	0.00	7	0
Hill Top	15	2400	0.63	6	100
Valley of the Giants	13	4400	0.30	11	63.6
Mt Lindesay	2	3500	0.06	9	22.2
Mt Frankland	2	2400	0.08	6	33.3
D'Entrecasteaux NP	3	2500	0.12	6	50
Stirling Range NP	0	2100	0.00	8	0
Porongorup NP	6	2318	0.26	10	40
Waychinnicup NP	0	2350	0.00	10	0
Twertup	1	1750	0.06	7	14.3
Moir Track	0	2150	0.00	10	0
Dryandra Woodland	0	1050	0.00	7	0
Tutanning NR	0	900	0.00	6	0
Boyagin NR	0	1650	0.00	6	0
Bendering NR	0	275	0.00	3	0
North Kalgarin NR	0	531	0.00	3	0
Roe NR	0	300	0.00	3	0
Lake Magenta NR	1	11 461	0.01	17	5.9
Dragon Rocks NR	1	1500	0.07	4	25

These sites are high rainfall sites supporting forests of karri or tingle. Low rainfall sites such as Dragon Rocks and Lake Magenta nature reserves have had very low capture rates of cats. An assessment of cat numbers in Dragon Rocks Nature Reserve in 2000 showed that there was a high number of cats present (Angus and Thomas, 2000). Anecdotal observations from Katanning District staff suggest that cat numbers may be high in Lake Magenta Nature Reserve. Clearly the data from fauna monitoring surveys do not accurately reflect feral cat densities. However, the data from Hill Top, Valley of the Giants and Porongorup suggest that there are unusually high cat numbers and that cats are less trap shy at these sites. Fauna recovery has been poor at Hill Top, very slow at Valley of the Giants but recovery of brushtail possums and quenda has been good at Porongorup.

Rainfall data

Rainfall data from Perth, Bridgetown, Pemberton, Albany, Lake Grace, Narrogin, Pingelly, Jacup and Ravensthorpe

were obtained from the Bureau of Meteorology to examine rainfall patterns in the south west of WA. The figures for Perth (Figs 24 and 25) and Albany (Figs 26 and 27) are shown as representative of the patterns from 1997 to 2002.

The figures indicate below average rainfall for most years except 1999, but particularly for 2000 through to 2002. The low rainfall in the last three years is least pronounced in the extreme south west (Bridgetown, Pemberton) and most pronounced in the eastern wheatbelt and south coast (Albany, Narrogin, Pingelly and Lake Grace).

The south-west of WA has a mediterranean-type climate with most rainfall occurring in the months of winter and early spring. Occasional cyclone events bring high rainfall events into the south west during summer months and this occurred in January 2000. For the purposes of simplifying the rainfall data it is assumed that the winter rainfall is the most important for sustaining the natural growth of the native vegetation. Winter rainfall has been presented as the combined total for the months

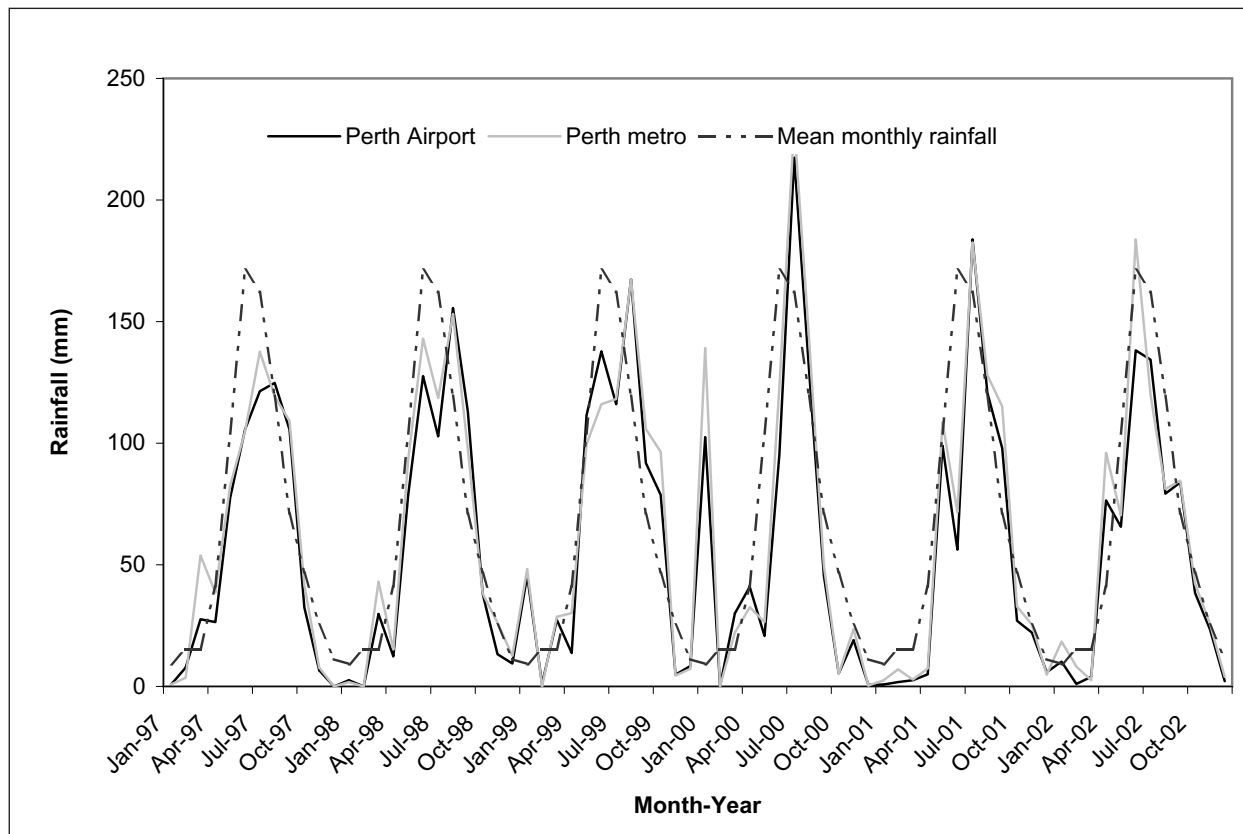


Figure 24. Monthly rainfall for Perth Airport and metropolitan area January 1997–June 2002 compared with the mean monthly rainfall for Perth metropolitan area.

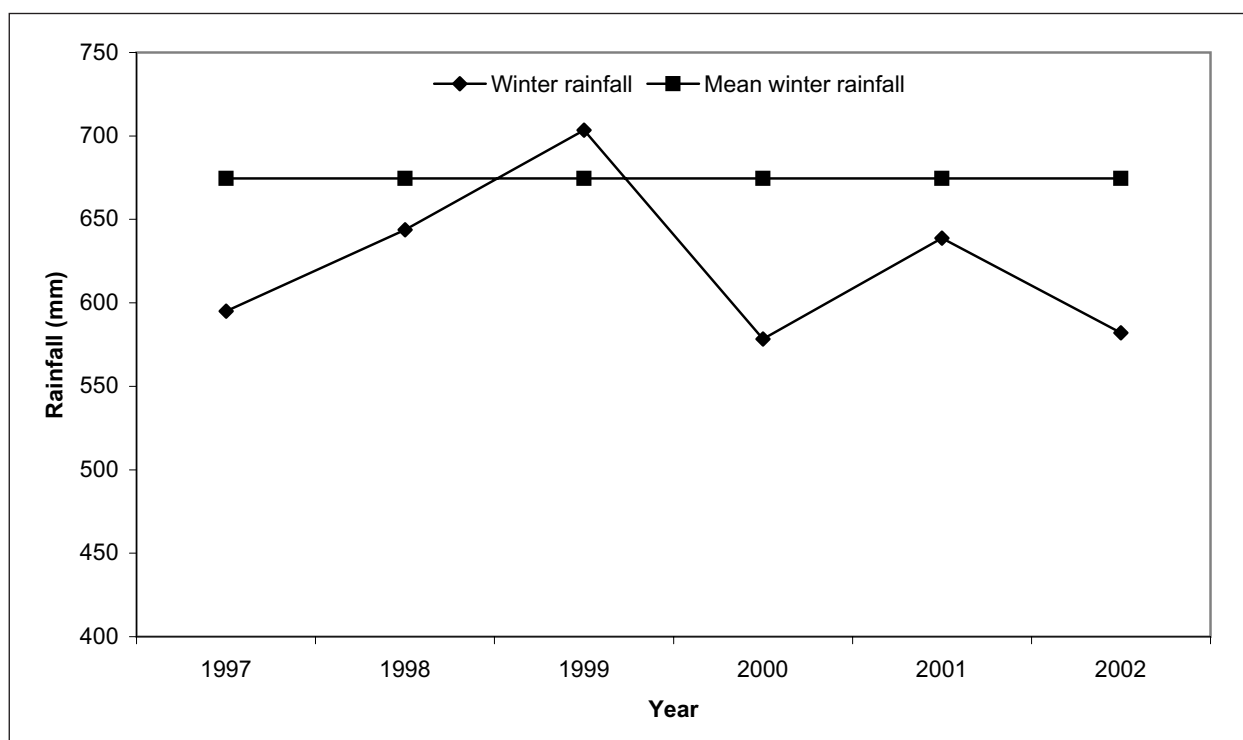


Figure 25. Total winter (May-Oct) rainfall for Perth, 1997–2002, compared with the mean winter rainfall for Perth.

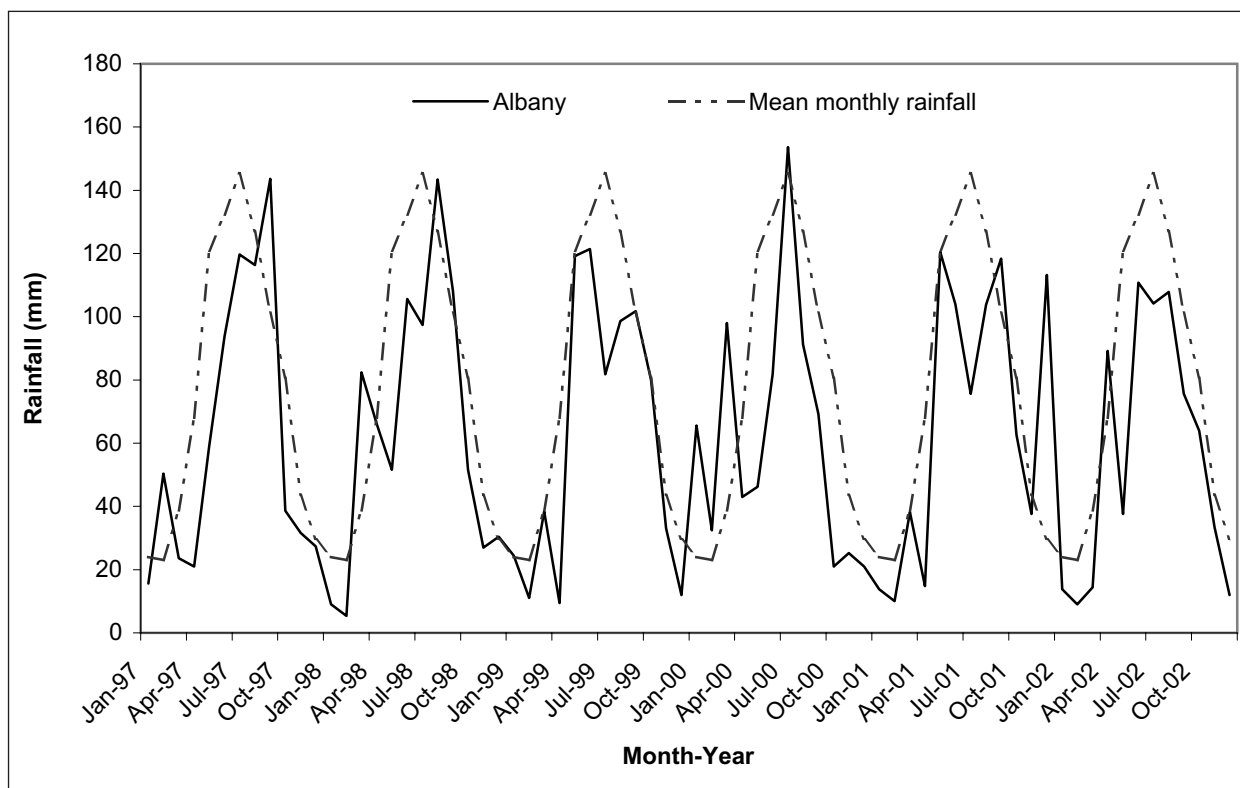


Figure 26. Monthly rainfall for Albany, January 1997–June 2002, compared with the mean monthly rainfall for Albany.

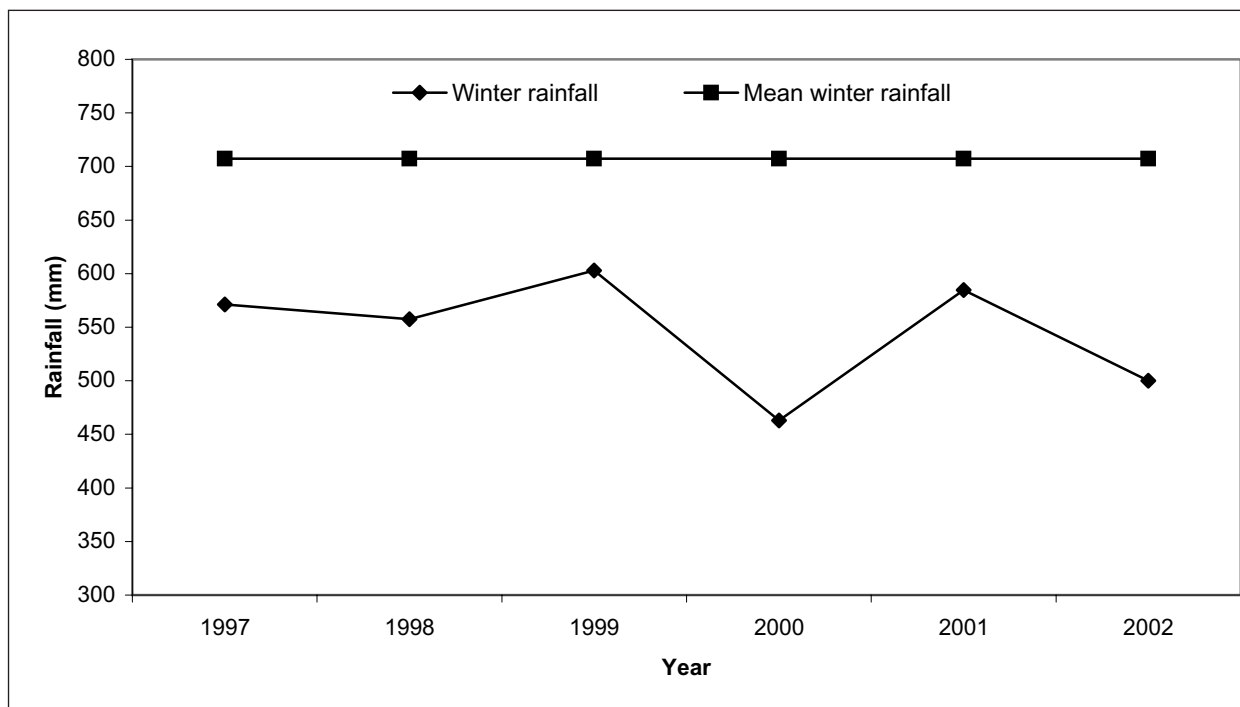


Figure 27. Total winter (May-Oct) rainfall for Albany, 1997–2002, compared with the mean winter rainfall for Albany.

of May through to October (Figs 25 and 27). Albany's winter rainfall has been well below the long term average in all years from 1997 to 2002 (Fig. 27). The impact of the drop in winter rainfall has been most pronounced in the eastern wheatbelt where the winter rainfall in some areas (e.g. Lake Grace) in 2002 was less than half of the long-term average. Clearly, these figures reflect at least mild drought conditions for most of the south-west of WA.

Deficiencies in monitoring

Monitoring of fauna recovery under *Western Shield* has largely focused on the south west of the State from Kalbarri to Fitzgerald River National Park. However, there are some key sites in the Pilbara Region and other remote areas which are currently baited but there is no formal commitment to monitoring the recovery of fauna. Cape Range National Park is baited to protect Black-flanked Rock-wallabies and sea turtles but no resources have been put into monitoring by *Western Shield*. Some monitoring of rock-wallabies in Yardie Creek has been undertaken by tour operators, but this was limited, biased, and is no longer done at all (P. Kendrick, pers comm). The monitoring of the Dampier Archipelago is undertaken using regional resources with no contribution from *Western Shield*. There has been some survey work done in the Esperance District in Cape Arid and Cape Le Grande national parks but there has been no formal establishment of a monitoring program. Some monitoring work was done by CALM Science Division to monitor the establishment of a translocated population of chuditch.

The establishment of monitoring programs for isolated areas is essential to justify the benefits of maintaining fox control and priority needs to be given to identifying monitoring and resource requirements for these areas.

Using monitoring data for adaptive management

Monitoring of fauna under *Western Shield* has been implemented for the purpose of assessing whether fauna recovery is occurring in areas subject to fox control. The results of the monitoring and the manner in which the data are interpreted could have implications for the management of fox control or other fauna and land management practices.

If the data indicate that there has been a sustained increase in fauna abundance it is assumed that fox control is effective and the fauna are recovering. If the data indicate that fauna abundance is high with regular recruitment but has not changed significantly then it is assumed that fox control is effective and fauna abundance reflects the carrying capacity of the site. Other factors may be responsible, or partly responsible, but the desired results have been achieved and no change to the baiting regime is required.

If the data indicate that fauna abundance is very low and not increasing, or it has declined significantly, it may indicate that the level of fox control is not sufficient to

facilitate recovery or perhaps predation by feral cats is significant. It may also indicate that the existing populations are too small to facilitate recovery. Or it may indicate that any number of environmental factors such as rainfall may have made conditions unsuitable for recovery. The response to this scenario may include intensifying the baiting regime, examination of other data relevant to the site or other investigations involving experimental research to identify the cause (e.g. cat predation or increased salinisation reducing habitat suitability).

Formal processes for reviewing baiting regimes and fauna management activities in light of trends in monitoring data have not yet been developed within the *Western Shield* program. Most of the efforts towards this end have been directed at developing and refining the data collection and management system structured around the Fauna File. This process in itself has necessitated the review of data from monitoring sites on a district by district basis. Data from sites showing recovery of one or more species have been used in unpublished reports to corporate sponsors, in media advertisements and in the CALM Annual Report.

With six or more years of data for most sites and a functional data collection and management system in place, development of a formal process for reviewing monitoring data, baiting and fauna management activities is recommended as a priority.

An annual review of monitoring data is suggested with the first stage being the collation of the following information within CALM districts or regions with assistance from the Western Shield Zoologist:

- Survey effort at all sites, indicating whether effort has increased, declined or remained consistent;
- Abundance estimates (percent capture rate, KTBA or other) of individual species and faunal suites (e.g. all medium-size mammals) for all survey periods;
- Data on environmental changes such as rainfall, fire and disease (dieback or zoonoses); and
- Any changes in survey methods, bait types (trapping), or other relevant variables.

The second stage of the review will be the collation of the above information across CALM regions by the Western Shield Zoologist. This will include comparisons of abundance data from all sites by species and by faunal suites, integration of environmental data and identification of any changes to survey methods, bait types, etc.

A draft report of the collated information will form the basis for any recommendations for changes to baiting regimes and other fauna management activities. This report will be circulated to all CALM district and regional Nature Conservation Program Leaders and tabled at Western Shield regional management committees for discussion and recommendations. The revised report will then be submitted to the Western Shield Steering Committee and/or the Western Shield Program Coordinator (if appointed). Final reporting of the review

and recommendations will be made to the CALM Corporate Executive and made available to CALM Strategic Development and Corporate Affairs Division for use in media and educational programs.

EXPENDITURE ON FAUNA MONITORING

Under the CALM accounting system set up for *Western Shield* all expenditure on fauna monitoring activities should be recorded against the 'WSB' tenure code. Table 8 shows all the figures recorded against this code across all CALM regions and districts where *Western Shield* activities have occurred. Amalgamation of forest districts occurred in 2001/02 and this has led to some changes in the management of accounting procedures in the affected districts. Table 8 is based on the new district names with former district names in brackets. It is apparent from Table 8 that some districts have not been using the appropriate *Western Shield* codes and hence expenditure figures cannot be tracked via the 'WSB' tenure code. This has made it difficult to identify total expenditure on Western Shield fauna monitoring activities. This problem became apparent in 2000 when an attempt was made to extract expenditure figures from all CALM districts. A review of the department's accounting system was in progress at the time and it was anticipated that the new system would solve the problem and make it easier for districts and regions to set up appropriate account codes to record expenditure for all *Western Shield* fauna monitoring activities. The new system appears to be working better but not as well as anticipated. The current review of finances associated with the development of service provider agreements should provide an ideal opportunity to bring this matter to the attention of the districts and regions and to achieve consensus on the use of account codes.

Also shown in Table 8 are the estimated costs of fauna monitoring within CALM districts provided by Burbidge *et al* (1995). A comparison of these figures with the expenditure recorded against the 'WSB' tenure code show that the costs of fauna monitoring activities have significantly exceeded the initial estimates. Some of this difference may be due to the monitoring of some sites that were not included in Burbidge *et al* (1995) but were later included in the *Western Shield* strategic plan (CALM 1999).

Wildlife Branch has purchased basic fauna monitoring equipment for the districts and regions (e.g. cage traps, Elliot traps, balances, tagging gear and tags, and bulk supplies of bait material). Four significant items in the form of custom-built trailers have been purchased to facilitate the transport of cage traps within the southwest. The expenditure breakdown for fauna monitoring equipment is shown in Tables 9 and 10. The bulk of the expenditure to date occurred in 1996/1997, with ongoing costs being largely restricted to consumable items such as peanut butter (bait ingredient) and ear tags that

are purchased in bulk to effect discounts for bulk orders.

STAFF TRAINING

History

Prior to 1992 fauna surveys were performed predominantly by research personnel within the Fisheries and Wildlife Service, Forests Department, and subsequently within CALM's Research Division (now Science Division), as well as the Western Australian Museum. It became apparent that more of the responsibilities for the surveying, monitoring and management of threatened fauna needed to be shared with the regions and districts within CALM who were responsible for managing the areas where the fauna occurred. The skills to implement this strategy were generally not available within districts and regions at this time.

Since no commercial courses were available outside of CALM to train staff, an in-house course was developed jointly by Science Division and Central Forest Region in 1992 which was focused entirely on mammals. The *Mammal Conservation Course* was run at the Batalling Field Study Centre up to 1995. In 1996 this course was redeveloped by Science Division and the Pilbara Region to suit the needs of the northern areas and was held in Millstream National Park. It had a broader focus on other fauna groups as well as mammals. Central Forest Region also ran a similar course at Batalling in 1996 and included some other nature conservation issues.

The department's Wildlife Branch became the custodian of the fauna training course in 1997. With the Western Shield Zoologist appointed as course coordinator, the course has been further developed with assistance from Science Division, Nature Conservation Division, districts and regions. The course has been designed so that it is equally applicable to wages and salary staff, and is presented in a format that can be successfully completed by people without tertiary qualifications. The main focus of the course is to ensure that course graduates can design and safely implement fauna monitoring programs and obtain consistent and valid results.

Course participants each receive a course manual with detailed notes that they can refer to at any time in the future. They also have the opportunity to establish important networks with professional biologists from both within CALM and other government agencies such as the WA Museum and the Department of Environmental Protection.

Accreditation

The course has been revised a number of times over the years and has been conducted as an accredited training program. Formal accreditation however requires that the course content be compiled into a formatted presenter's manual. This stage of the accreditation process has not

TABLE 8

Summary of *Western Shield* expenditure (\$) on fauna monitoring (WSB tenure code) from January 1997 to November 2002.

CALM REGION	CALM DISTRICT	EXPENDITURE						ESTIMATED COST P.A. (Burbidge <i>et al</i> 1995)	
		1997	1998	1999	2000	2001	2002		TOTAL
Midwest	Midwest Region (Geraldton)			98	4,932	3,466	4,918	13,414	5,500
	Moora								
	Shark Bay				135,303	124,280	138,929	398,512	7,000
	TOTAL			98	140,235	127,746	143,847	411,926	12,500
Swan	Perth Hills District (Mundaring)	9,550	17,033	21,196	16,554	14,059	11,444	89,835	3,700
	Dwellingup								7,700
	Swan Coastal District (Perth)	326		348	3,040	462		4,176	4,550
	TOTAL	9,876	17,033	21,543	19,594	14,522	11,444	94,011	15,950
South West	Black wood District (Kirup)					17,038		17,038	2,950
	Black wood District (Busselton)	457	5,016	3,391	277		34,775		1,100
	Wellington District (Morningson)	3,003	15,733	33,194	43,281	47,400		142,611	5,300
	TOTAL	3,461	20,749	36,585	43,558	64,438	34,775	203,566	9,350
Warren	Warren Region						475	475	
	Donnelly District (Manjimup)					10,134		10,134	6,050
	Donnelly District (Pemberton)	4,738	7,244	5,032	13,151	29,004		59,169	4,500
	Frankland District (Walpole)	2,577	9,569	13,821	12,251	8,187		46,404	2,050
	TOTAL	7,315	16,812	18,853	25,402	47,324	475	116,182	12,600
South Coast	Esperance	0	4,270	10,318	6,584	2,712	12,656	36,540	12,000
	South Coast Region (Albany)	15,021	26,087	27,892	32,635	31,973	34,312	167,919	14,850
	TOTAL	15,021	30,357	38,210	39,219	34,684	46,968	204,459	26,850
Wheatbelt	Katanning	60,402	46,563	30,585	46,138	37,668	19,495	240,852	8,400
	Merredin								4,000
	Narrogin	22,739	9,302	60,038	68,689	63,071	81,152	304,990	20,450
	TOTAL	83,141	55,865	90,623	114,827	100,739	100,647	545,842	29,250
Pilbara	Exmouth			254				254	1,500
	Karratha								8,850
	TOTAL			254				254	10,350
Goldfields	Kalgoorlie	1,250,184	17,875	16,698	2,111			1,286,868	4,000
	TOTAL	1,250,184	17,875	16,698	2,111			1,286,868	4,000
Nature Conservation	Wildlife Administration	158,439	76,962	25,871	129,064	139,450	91,765	621,551	
	Annual Expenditure Total	1,527,435	235,653	248,735	514,010	528,904	429,921		
	TOTAL EXPENDITURE							3,484,658	124,450

yet been achieved due to other competing priorities. Assistance is required to either address competing priorities or undertake the compilation of the manual and again the creation of a dedicated position to assist the Western Shield Zoologist is recommended.

With accreditation, the course has genuine potential for sale to other State agencies wishing to develop similar training courses as many of the sections are generic to these conservation agencies. The course also has considerable application to university students and ecological management staff from larger mining companies.

Accreditation of the course will only cover accreditation in fauna management and not accreditation for fauna capturing and handling skills. The five-day course

is not long enough to allow most participants time to acquire and develop the skills to a competent standard. This needs to be addressed by a subsequent assessment in the field when candidates have had time and opportunities to practice and develop their skills and feel ready to have their competency assessed. Assessment and accreditation of these skills will ensure that standards and correct procedures are maintained within the Department. The competency standards and protocols for assessment still need to be developed. Issues to be resolved include the selection and appointment of competent assessors and how widely the assessment and accreditation should be imposed within and outside the Department (e.g. should experienced research staff have to be assessed and accredited?).

TABLE 9

Summary of *Western Shield* expenditure (\$) on fauna monitoring equipment by CALM District/Region. (PB=Peanut butter). *4 WS trailers manufactured by Albany Regional Prison for \$2798 each.

COST CENTRE	COST (\$) OF EQUIPMENT SUPPLIED					MISC.	TOTALS
	TRAPS	TAGS	KITS	BAGS	PB		
Perth		73	275				348
Mundaring	325	222	437	220	276	*2,798	4,278
Dwellingup		62	272				334
Central Forest (R)		231					231
Mornington		296	39		184		519
Blackwood		322	489				811
Manjimup	1,136	363	1,339		374	*2,798	6,010
Pemberton		73	275				348
Walpole	4,762	212	924	132	327		6,357
South Coast (R)	8,890	87	718	132			9,827
Albany		145	174		282		601
Esperance	1,626						1,626
Narrogin	3,415	145	35		184	*2,798	6,577
Katanning	5,152	162	68		558	300	6,240
Midwest (R)	1,000	58	359	12		300	1,729
Moora	4,600	300	700	120	70	*3,000	8,790
Gascoyne	2,813	107	616		95	397	4,028
Exmouth	2,473						2,473
Hills Forest Ed.	422						422
Woodvale	1,473	394	156				2,023
Wildlife Admin.	3,018	152	776	744	285	1,890	6,865
Totals	41,105	3,404	7,652	1,360	2,635	14,281	70,437

Table 10

Summary of total expenditure (\$) on fauna monitoring equipment (*Western Shield* budget allocations plus District contributions) 1996-97–1999-00 inclusive.

COST CENTRE	96–97		97–98		98–99		99–00	
	TOTAL	WS	TOTAL	WS	TOTAL	WS	TOTAL	WS
Perth	99		249					
Mundaring	431		448		3,399	2,798		
Dwellingup	89		244					
Central Forest (R)	231							
Mornington					223	223		
Blackwood			634					
Manjimup	1,136	1,136	1,654	80	3,036	2,798	184	
Pemberton	695	695						
Walpole	4,151	4,151			2,207			
South Coast (R)	9,827	9,827						
Albany			424		187			
Esperance					1,626			
Narrogin	180		1,951	1,951	4,261	2,798	184	
Katanning	5,593	5,452	190		184		184	
Midwest (R)	1,729	1,729						
Gascoyne			217		3,810			
Exmouth	2,473	2,473						
Hills Forest Ed.					422			
Woodvale	1,545				477			
Wildlife Admin.	1,348	1,348	305	305	3,618	3,618	1,502	1,502
Totals	29,527	26,811	6,316	2,336	23,450	12,235	2,054	1,502

Course participation

The higher participation rate of women in the course since 1997 (27%) is notable, along with the high retention rate (75.8%) of staff who have completed the course (Table 11). Most Districts in the southwest now have at least four trained staff (Figure 28) though not all of these staff may have responsibilities in fauna monitoring or nature conservation duties. Most of the trained staff are located in the south-west of WA.

Consideration has been given to running a second Fauna Training course in May of each year. A second course would allow CALM to cater for the staff (e.g. Land for Wildlife, Bushcare Facilitators) on the waiting list for fauna training, and to also provide opportunities to full fee paying 'students' from other government agencies, universities (e.g. Ph.D. students) and professionals from mining companies. The profits derived from the full fee paying students could then be used to off set the costs of CALM staff attending the courses each year.

It is envisaged that the course will continue to be refined and amended to reflect the needs of CALM staff.

Costs of the course

The course is run as a five-day live-in course and has been held at several different venues. The cost of running the course includes the cost of accommodation and catering for about 24 to 26 people, stationery, student manuals, field equipment, vehicle running costs and staff time. Costs incurred have varied with the venue. The course held at the Perup Forest Ecology Centre in 2001 cost approximately \$10 900 excluding staff time and student transportation to the course venue compared with an approximate cost of \$9 500 for the course held in 2002 at Rylington Park (about 20 km north of the Perup Forest Ecology Centre). The main difference in cost was due to Rylington Park being a cheaper venue in terms of accommodation.

To date the course has not been run at a cost recovery basis. Attendance fees currently are \$250 per person for CALM staff and volunteers and \$500 per person for non-CALM persons. The logistics of running the course are such that the course can only accommodate 16 participants comfortably and the demand from within the Department has excluded external participation for the last two years. The return from attendance fees therefore equates to \$4000 which is less than half of the cost of running the course. It is anticipated that once the course fully meets national accreditation requirements that the fees will be increased to more closely reflect the actual cost of conducting the course.

Staff commitment and competency in monitoring

Interest in fauna recovery and management has become widespread and CALM district personnel have generally shown enthusiasm and commitment to *Western Shield* fauna monitoring activities. However, the level of commitment and competency within each district has been

partly determined by the skills, abilities and attitudes of the personnel directly involved. The Fauna Management Course has been very important in helping to shape attitudes as well as teaching the basic skills to these personnel to provide the foundation for implementing fauna monitoring programs under *Western Shield*. However, individual competencies need to develop through on-the-job practice and involvement and the extent to which this has been accomplished has varied across districts for several reasons.

As shown in the previous section on fauna monitoring results, the size and density of fauna populations and the extent of recovery has varied greatly across monitoring sites. In those districts where fauna populations have been low or only a few different species are present in trappable numbers, district personnel have had limited opportunities to develop their competency in fauna survey skills. Flexibility in the sharing of personnel and resources across district boundaries would help to provide opportunities to improve and develop competencies as well as promoting enthusiasm. The benefits of this approach has already been recognised at the operational level and needs to be recognised and encouraged by managers.

Traditionally, staff positions that are given the responsibility of coordinating district fauna monitoring programs are also encumbered with other duties, some of which may be seen as more important within the management of the district or may offer better career opportunities.

Staff turnover through movements due to career development or resignations can cause disruptions in any program and necessitate recruitment and training of replacement staff. The development of competencies in fauna management and survey skills that can be retained within the *Western Shield* program is therefore limited by the length of time that individual staff remain involved in the program. Figure 27 shows that many CALM personnel located in south west districts have been through the Fauna Management Course, but it does not show that only a portion of these personnel are currently involved in *Western Shield*. The development of career structures and opportunities within the Nature Conservation Division may be needed to encourage staff to remain or move to positions where their skills in fauna management can be utilised and further developed.

ACKNOWLEDGMENTS

The implementation of the *Western Shield* fauna monitoring program was made possible by the efforts of many dedicated staff throughout CALM's districts and regions and I wish to extend my appreciation to all involved. I particularly wish to thank Alice Reaveley, Gina Broun, Dennis McDonald, Rob Brazell, Robert Turner, Janine Liddelow, Ian Wilson, Greg Freebury, Peter Collins, Alan Rose, Mal Graham, Kris Narducci, and Brian McMahon. Their patience and efforts in managing the collection and input of data into the Fauna File database system, keeping it up-to-date and providing me with

TABLE 11

Breakdown of graduates from the CALM fauna training courses conducted at Batalling Forest, Millstream National Park, Perup Forest Ecology Centre and Rylington Park 1992–2002. The number of female participants in each course is shown in parentheses. [Bat=Batalling Forest, Mls=Millstream NP, Per=Perup, Ryl=Rylington Park, CFR=Central Forest Region, SD=Science Division, PR=Pilbara Region, NCD=Nature Conservation Division, WD=Wellington District, DD=Donnelly District].

YEAR	VENUE	FACILITATION	CURRENT CALM EMPLOYEES	LEFT CALM	EXTERNAL PARTICIPANTS	TOTAL
1992	Bat	CFR,SD,WD	8 (0)	5 (0)	0	13 (0)
1993	Bat	CFR,SD,WD	5 (0)	11 (0)	0	16 (0)
1994	Bat	CFR,SD,WD	8 (0)	3 (0)	2 (1)	13 (1)
1995	Bat	CFR,SD,WD	9 (0)	2 (0)	1 (1)	12 (1)
1996	Bat	CFR,WD	12 (0)	0	1 (0)	13 (0)
1996	Mls	SD,PR	6 (2)	1 (0)	4 (1)	11 (3)
1997	Bat	NCD,SD,WD	12 (4)	4 (0)	0	16 (4)
1998	Bat	NCD,SD,WD	18 (4)	2 (0)	1 (0)	21 (4)
1999	Bat	NCD,SD,WD	12 (7)	3 (0)	1 (0)	16 (7)
2000	Per	NCD,SD,DD	14 (6)	0	1 (0)	15 (6)
2001	Per	NCD,SD,DD	15 (4)	1 (0)	0	16 (4)
2002	Ryl	NCD,SD,DD	16 (2)	0	0 16	(2)
Total			135 (29)	32 (0)	11 (3)	178 (32)

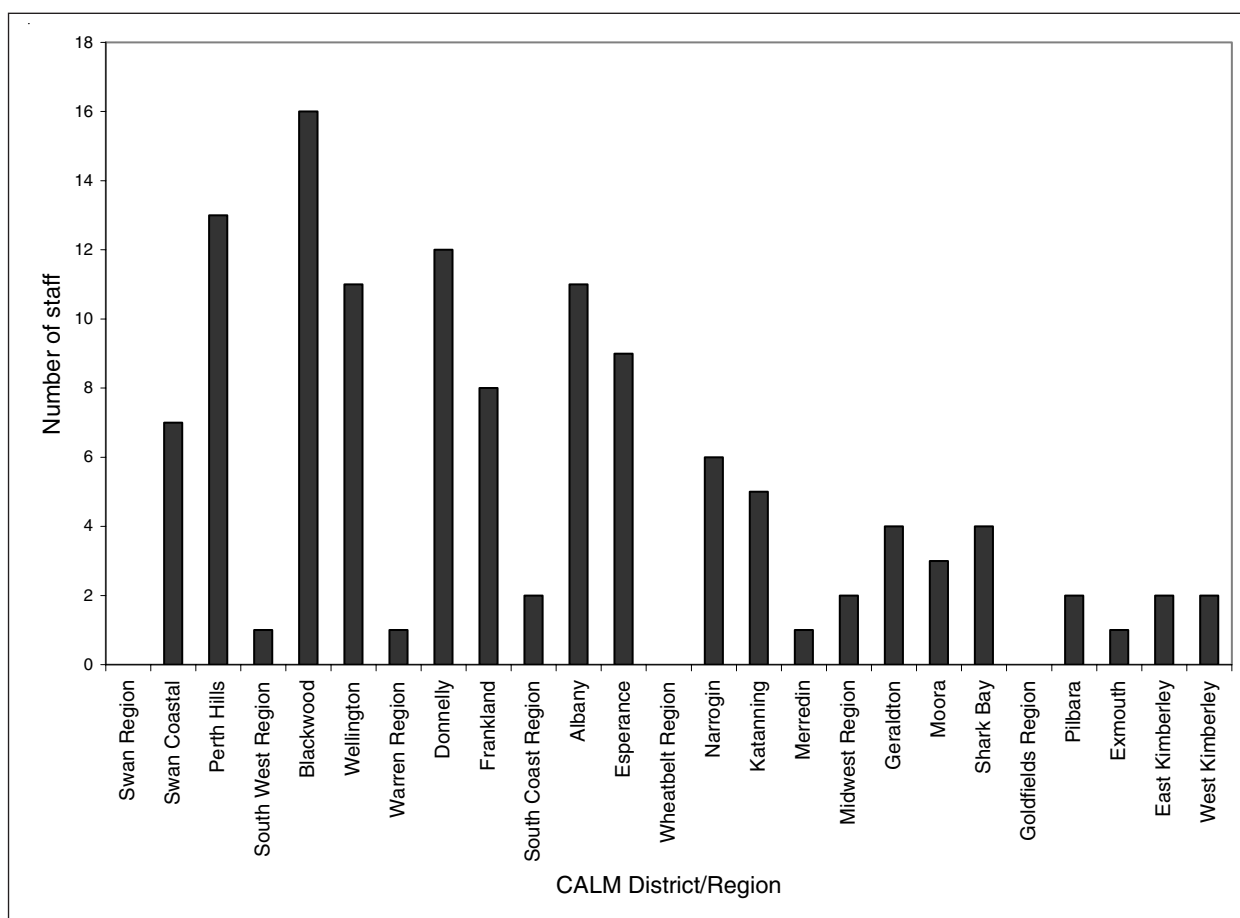


Figure 28. Number of CALM staff, in each region and district, that have attended fauna training courses since 1992.

invaluable feedback for improvements to the system has been instrumental to my collation of the data presented herein. I also wish to thank Peter Kendrick and Fran Stanley for their contribution from the CALM Pilbara Region, including Peter's helpful suggestions on the draft. I am grateful to Peter Mawson for his comments and suggestions on the draft and his active support as supervisor.

REFERENCES

- Angus GJ, Thomas ND (2000) 'An assessment of feral cat (*Felis catus*) abundance at Dragon Rocks Nature Reserve and some implications for fauna conservation.' Department of Conservation and Land Management, Western Australia.
- Burbidge AA, McKenzie NL (1989) Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* **50**, 143-198.
- Burbidge AA, Start AN, Morris KD, Armstrong R (1995) 'Western Shield – bringing back our wildlife.' Department of Conservation and Land Management, Western Australia.
- CALM see Department of Conservation and Land Management.
- Chapman A (1995) A biological survey of the Fitzgerald area, Western Australia. Part 6: Terrestrial mammals. *CALMScience Supplement* **3**: 83-94.
- Christensen P, Burrows N (1994) Project Desert Dreaming: experimental reintroduction of mammals in the Gibson Desert, Western Australia. In *Reintroduction Biology of Australia and New Zealand Fauna* (ed. M Serena), pp. 199-207. Surrey Beatty & Sons, Sydney.
- Crook IJ, Burbidge AA (1982) Lake Magenta Nature Reserve. Western Australian Nature Reserve Management Plan No. 4. Department of Fisheries and Wildlife, Perth.
- Department of Conservation and Land Management (1999) 'Western Shield Fauna Recovery Program – Strategic Plan July 1999 to June 2004.' CALM, Western Australia.
- Friend JA (1990) The numbat *Myrmecobius fasciatus* (Myrmecobiidae): history of decline and potential for recovery. *Proceedings of the Ecological Society of Australia* **16**, 369-77.
- Friend JA (1996) Protecting endangered native fauna from predators. In *Unwanted Aliens - Australia's Introduced Animals* (ed. B Dickman), pp. 127-42. Nature Conservation Council of NSW, Sydney.
- Kitchener DJ, Chapman A (1977) Mammals of Bendering and West Bendering Nature Reserves. In: Biological Survey of the Western Australian Wheatbelt. Part 3. *Records of the Western Australian Museum Supplement* **5**, 17-29.
- Kinnear JE, Bromilow RN, Onus ML, Sokolowski RES (1988) The Bromilow trap: a risk-free soft trap suitable for small to medium-sized macropodids. *Australian Wildlife Research* **15**, 235-7.
- Kinnear JE, Sumner NR, Onus ML (2002) The red fox in Australia – an exotic predator turned biocontrol agent. *Biological Conservation* **108**, 335-359.
- Mawson PR (2004) Translocation and fauna reconstruction sites: *Western Shield* review–2003. *Conservation Science W. Aust.* **5** (2), 108-121. Department of Conservation and Land Management, Western Australia.
- McKenzie NL, Burbidge AA, Marchant NG (1973) Results of a biological survey of a proposed wildlife sanctuary at Dragon Rocks near Hyden, Western Australia. Report No. 12. Department of Fisheries and Fauna, Perth, Western Australia.
- Morris K, Sims C, Himbeck K, Christensen P, Sercombe N, Ward B and Noakes N (2004) *Project Eden*–fauna recovery on Peron Peninsula, Shark Bay: *Western Shield* review–February 2003. *Conservation Science W. Aust.* **5** (2), 202-234. Department of Conservation and Land Management, Western Australia.
- Morris K, Johnson B, Orell P, Gaikhorst G, Wayne A, Moro D (2003) Recovery of the threatened chuditch (*Dasyurus geoffroii* Dasyuridae): a case study. In: *Predators with pouches: the biology of carnivorous marsupials* (eds M Jones, C Dickman, M Archer), pp. 435-451. CSIRO Publishing, Collingwood, Vic.
- Morris K, Whisson L, Burbidge AA, Wallace K (1993) A Recovery Plan for the western mouse (*Pseudomys occidentalis* Tate, 1951). A report submitted to World Wide Fund for Nature (Australia). Department of Conservation and Land Management, Como, Western Australia.
- Orell P, Morris K (1994) Chuditch Recovery Plan, 1992-2001. Department of Conservation and Land Management, Western Australia, Wildlife Management Program 13.
- Rhind S, Nichols (2001) 'A nest box survey for brush-tailed phascogales in the northern Jarrah forest: results and implications.' Alcoa Pty Ltd.
- Risbey DA, Calver MC, Short J, Bradley JS, Wright IW (2000) The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. II. A field experiment. *Wildlife Research* **27**, 223-235.
- Start A, Burbidge A, Armstrong D (1995) Woylie Recovery Plan. Department of Conservation and Land Management, Western Australia, Wildlife Management Program 16.
- Wayne A, Rooney J, Morris KD, Johnson B (in prep). Improved bait and trapping techniques for chuditch (*Dasyurus geoffroii*): overcoming trap saturation by a recovering native fauna.

Communications, community awareness and schools education programs: *Western Shield* review—February 2003

RON KAWALILAK¹, NIGEL HIGGS², ELIZABETH MOORE³

¹Director, Strategic Development and Corporate Affairs Division, Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, Western Australia 6983. ronk@calm.wa.gov.au

²Principal Media Relations Officer, Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, Western Australia 6983. nhigg@calm.wa.gov.au

³Senior EcoEducation Officer, Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, Western Australia 6983. lmoore@calm.wa.gov.au

ABSTRACT

This paper reports on communication of *Western Shield* to the general public and school communities through the Department of Conservation and Land Management's Strategic Development and Corporate Affairs Division (SDCA), Regional and District Offices. A key emphasis has been to integrate *Western Shield* into the Department's three key outputs – Nature Conservation, Parks and Visitor Services and Sustainable Forest Management.

The terms of reference for this paper were:

- Provide an overview of work done to present *Western Shield* and its progress to the general public.
- What mechanisms are in place to ensure educational and interpretive information is accurate and up to date?
- Provide an overview of programs aimed at school pupils and describe how successful they have been.
- Discuss what changes in public perception and attitude have resulted from the community support and education programs carried out.
- What is proposed for the future?

Schools education programs were considered an important avenue through which to raise awareness of *Western Shield* in the general public (Kawalilak *et al.* 1996). Therefore some emphasis in this paper is given to the extent of the program and strategies for influencing teachers and students. There have been three main ways in which this influence has happened: a comprehensive and structured *Western Shield* Schools Program, secondly activities of the CALM Bush Rangers cadets and thirdly activities led by staff of CALM's District and Regional Offices.

The objectives, strategies, numbers of people involved and expenditure of the *Western Shield* Schools Program are outlined in detail. The difficulties, potential economies

and improvements are also given. The activities of the cadets and District and Regional staff are also addressed but in less detail.

The *Western Shield* Schools Program was successful in raising awareness in a large number of teachers and students (>50,000) over the reporting period. An independent evaluation of the impact of the program on students, by Curtin University's National Key Centre for School Science and Mathematics Education, indicated that the program was effective in raising awareness of *Western Shield* and in harnessing student's interest in the conservation of threatened species. No formal evaluation, however, has been carried out on the effectiveness of the cadets or District and Regional Office activities.

There has been no formal evaluation of changes in public acceptance and attitude to *Western Shield* resulting from the school education programs.

INTRODUCTION

The role of the Strategic Development and Corporate Affairs (SDCA) Division is to provide corporate leadership in communications and organisational development, and the expertise, services and communications products to create and maintain the community trust, understanding and the support necessary for the Department to achieve its mission.

In line with its role, the Division has worked with the *Western Shield* Project Team and other Divisions, Regions and Districts to implement the overall communications and schools education activities associated with *Western Shield*. A key emphasis has been to integrate *Western Shield* into the Department's strategic activities, especially as they relate to the Department's three primary outputs, Nature Conservation, Parks and Visitor Services and Sustainable Forest Management. Specifically, the EcoEducation programs involving *Western Shield* have been designed within the context of Western Australia's Department of

Education Curriculum Framework.

Programs and activities to communicate *Western Shield* to schools fall into three categories. Two of these, the *Western Shield* Schools Program and the CALM Bush Rangers activities are directed and managed through the SDCA Division. The third includes activities and talks run in CALM's Regions and Districts, independent of SDCA Division's direct involvement.

Schools education programs can be an important avenue for changing attitudes and influencing the general public particularly if the whole school community (parents, friends and other groups associated with the school) are encouraged to participate in the hands-on activities relating to the programs. This is the case for the SDCA managed programs.

SDCA prepared the initial Strategic Communications Plan for *Western Shield* (Kawalilak *et al.* 1996) primarily based on the plans for *Project Eden* and *Operation Foxglove* (Kawalilak *et al.* 1993).

This plan dovetailed into the Department's (then) Strategic Plan: to increase community awareness, understanding and support for the Department's nature conservation and natural land management programs, services and policies, and to promote wider co-operation in the prevention and solution of conservation and land management problems in Western Australia.

OVERVIEW OF WORK DONE TO PRESENT WESTERN SHIELD AND ITS PROGRESS TO THE GENERAL PUBLIC (Term of Reference 1)

Media relations and strategic communications

Objectives

The objectives of the communications plan (Kawalilak *et al.* 1996) were:

- To create a high level of awareness of, and support for, the operation in the project areas
- To create a high level of awareness in the project areas of the intent or purpose of these projects
- To gain public acceptance of the use of poison, and the aerial distribution of poison baits, to control foxes and cats
- To minimise the possibility of the accidental poisoning of a family pet or working farm dog
- To foster long-term support for, and influence a positive attitude towards the work of the Department.

Achievements

The basis of the communications plan was acknowledged internationally through the International Association of

Business Communicators that awarded the SDCA Division a Gold Quill Merit Award in 1997. This is the Association's second highest award and was for an entry, *Lending a hand to Wildlife* (Kawalilak *et al.* 1997).

Media Statements: Since *Western Shield* was launched in 1996, the Department has issued more than 120 media statements that have referred to *Western Shield*, either as the main topic or as a link to other initiatives. This has resulted in more than 1,400 print, radio and TV media stories concerning *Western Shield*. The number of readers, listeners and viewers of these stories is not easy to calculate, but one two-page feature relating to *Western Shield* that appeared in the Weekend Australian on 19 January 2002, had a potential readership of 315,000.

Staff development: Division staff have presented training sessions in *Working with the Media* and *Taking a Strategic Approach to Communications* (Kawalilak and Higgs 1998) to Departmental officers attending the fauna management course at Batalling. This has resulted in many regional and district staff members involved in *Western Shield* initiating coverage of their activities in their local community news media.

Ministerial Services: SDCA, in collaboration with other Divisions, Branches, Regions and Districts, has organised a range of events involving successive Ministers for the Environment in *Western Shield* related activities, in particular translocations of species. This has assisted in building Ministerial knowledge of, and support for, the program.

Advertising: Advertising largely has been confined to meeting the Department's obligations under the Health Act in relation to the use of toxic baiting programs. Advertisements have been placed in metropolitan, community and regional papers four times a year to inform the public about the baiting programs. Public information bulletins also have been broadcast on ABC Regional radio. No 'branding' or 'image-building' advertising has been undertaken.

Advertisements aimed at teachers also have been placed in specialist media aimed at teachers (further details are provided under Term of Reference 3).

Internet: General information about *Western Shield* is posted on *NatureBase* under the 'Projects' section. In addition, species profiles of many threatened fauna species in the 'Animals and Plants' section tie in with the information on the *Western Shield* initiative.

Media statements issued by the Department or the Minister for the Environment also are posted on *NatureBase*.

LANDSCOPE Expeditions are non-profit, self-supported study and research projects run by the Department in association with UWA Extension, a department of the University of Western Australia. They are an integral part of the Department's community relations activities.

The program gives people interested in nature conservation the chance to work with Department scientists and researchers as paying volunteers in important field-based research projects such as *Western Shield*. Since

1996, 13 *LANDSCOPE* Expeditions have focussed on *Western Shield* and its subsidiary programs including *Project Eden*. These expeditions have included 150 paying volunteers.

The expeditions are designed to improve public understanding of native plant and animals species, ecosystems and natural processes in natural habitats, and to raise funds for research.

The program also is designed to attract major media coverage and, therefore, communicate to the wider community. Earlier this year for example, a two-page feature on a *Project Eden LANDSCOPE* Expedition appeared in the *Weekend Australian* (19 January 2002, circulation 315,000).

Publications, Educational Tools and Miscellaneous Activities: A range of articles, publications and other communications and educational tools on *Western Shield* and its subsidiary activities has been prepared. A list of these is detailed in Appendix 1.

Communications from Districts and Regions: Warning brochures are sent out to dog owners with their dog registration papers (100,000 in 50 shires in 2002). Districts also send out further information regarding baiting successes in their areas through the baiting notification process. In addition, District officers endeavour to have articles in their local press wherever possible.

Performance indicators and evaluation

The Director SDCA commissioned three community awareness surveys (Patterson 1996, 1998 and 2000).

The survey methodology has been consistent. Surveying was on two levels. The neighbours' sample included people who had properties next to forest areas baited under the program. The Department provided the research company with a contact list for neighbouring property owners. The 'affected area' sample was created by the research company. Sampling of areas next to the baited areas was generated from the White Pages (Telstra phone directory). All interviews were conducted by trained market research interviewers engaged by the company.

The initial survey in 1996 was carried out to gauge community awareness of *Operation Foxglove* that was formally launched in November 1993 and was the forerunner to *Western Shield*. This survey involved 137 completed telephone interviews of neighbours and dog-owners in the target area between Mundaring and Collie. This survey found:

- 88 per cent of those surveyed were aware of the baiting program
- 90 per cent of all respondents considered it 'true' that the program was to help protect native species
- 70 per cent of neighbours and 58 per cent of dog-owners in the target area were aware the bait was toxic

to foxes but harmless to native species

- 39 per cent of neighbours and 61 per cent of dog-owners in the target area were aware the Department was responsible for the program (*Operation Foxglove*).

The survey consultants reported that an 88 per cent awareness could be regarded as being at or close to the maximum that is possible to achieve. They stated that 'Very rarely do we find awareness figures in excess of 80 per cent and figures of in excess of 90 per cent are almost never encountered'.

The 1998 survey involved 351 interviews in the Perth Hills, Albany, Pemberton and Manjimup, and Collie areas. The survey results reinforced some findings of the initial survey, most notably:

- 84 per cent of all respondents were aware of the fox baiting program
- 37 per cent of all respondents, however, were unable to express a view as to the effectiveness of the program
- 57 per cent of all respondents (69 per cent of neighbours) were aware the Department was carrying out the program
- 42 per cent of all respondents (72 per cent of neighbours) were aware of the term *Western Shield*.

The 2000 survey canvassed those areas surveyed in 1998. A total of 368 interviews were completed. Major findings were:

- 44 per cent of all respondents had a 'net awareness' of the term '*Western Shield*'
- 88 per cent of all respondents (95 per cent of neighbours) were aware of the fox baiting program
- 90 per cent of all respondents were aware the baiting program was to help protect native animals from foxes
- 51 per cent of all respondents were aware the Department was conducting the program.

Problems and limitations

The limitation of the surveys has been that they have focussed on landowners whose properties are next to baited areas and are more likely to be aware of the program. There have been no general, more widespread, community awareness or attitudinal surveys. This is something that could be addressed as part of the recommendations of the review.

Expenditure

The three awareness surveys cost a total of \$25,290 (\$6,490 in 1996, \$9,000 in 1998, and \$9,800 in 2000) and were funded through the *Western Shield* Project account.

MECHANISMS IN PLACE TO ENSURE EDUCATIONAL AND INTERPRETIVE INFORMATION IS ACCURATE AND UP TO DATE (Term of Reference 2)

SDCA Division maintains a formal approvals process for all media statements, briefing notes, speeches and events prepared and co-ordinate through the Division. This includes obtaining initial clearance of prepared material from the primary contact officer. This is generally a senior officer within Wildlife Branch, Science Division, District or Region who is the nominated officer for a particular aspect of *Western Shield*. Often the Director of Nature Conservation or Director of Science gives the clearance.

The Director SDCA approves communications materials before they are forwarded to the Executive Director for final approval.

The Nature Conservation or Science Divisions approve educational materials and material for *NatureBase* before they are published and disseminated. Further details on the EcoEducation schools programs are provided under Term of Reference 3.

Articles for *LANDSCOPE* magazine are checked for accuracy and approved by the relevant author and by the magazine's Scientific and Technical Advice Panel that comprises representatives of the Nature Conservation Division, Science Division, SDCA Division, and Management Audit Branch. Articles are amended in the light of comments from the Scientific and Technical Advice Panel and in consultation with authors.

Technical aspects of display materials are checked with relevant officers in Nature Conservation and Science Divisions.

Advertisements are checked with the Program Manager.

OVERVIEW OF PROGRAMS AIMED AT SCHOOL STUDENTS AND DESCRIPTION OF HOW SUCCESSFUL THEY HAVE BEEN (Term of Reference 3)

The following overview considers the three avenues through which school students are targeted; *Western Shield* Schools Program (SDCA), CALM Bush Rangers cadet program (SDCA) and activities run by CALM's District and Regional Offices.

Western Shield Schools Program (SDCA)

This program, funded by *Western Shield*, has been documented in unpublished, internal reports to the Department (Moore 1998, 1999, 2000, 2001) and in a paper published in the *Australian Primary and Junior Science Journal* (Moore 2001).

Objectives

The *Western Shield* Schools Program by involving the greater school community aims to contribute to the general community's understanding of the importance of *Western Shield*. Specifically, the objectives are as follows:

- Develop school community awareness of the Department's *Western Shield* strategy: eradication of foxes and feral cats in the areas the Department manages, research and captive breeding of native species and reintroduction of species into their former habitats.
- Promote school community involvement and action for threatened species and communities conservation;
- Provide hands-on opportunities during excursions and camps for students and teachers to participate in *Western Shield*'s research and monitoring methods.
- Provide opportunities during excursions for students to have encounters with captive bred threatened species.
- Give students personal experiences that will bring about changes in attitudes that can prompt changes in habits and lifestyle in relation to their use of resources and impact on threatened species and communities.

Achievements

Table 1 summarises participation in the *Western Shield* Schools Program through use of written resources (e.g. Action Pack), excursion activities and camps. Parents and other adults associated with the school are encouraged to participate as young people are important in influencing older generations' acceptance of conservation behaviours and environmental protection.

This program supports the learning experience in three ways:

- Teacher Inservices including an overnight camp (*Be a Nature Conservation Officer for a Night*)
- Resources for use in schools (an Action Pack, videos, *LANDSCOPE* articles, Internet information, quiz)
- Opportunities for hands-on experiences for students during an excursion or camp (*Back from the Brink* and *Year 11 Biology* excursions, and *Monitoring Marsupials* sessions).

Inservices

Inservice camps for teachers titled *Be a Nature Conservation Officer for a Night*, focusing on *Western Shield* have been offered since 1999. The aims of the Inservices have been:

- To introduce teachers to the *Western Shield* schools program and *Western Shield* project
- To provide teachers with resources about threatened species that they can use in school
- To give teachers a hands-on experience of research monitoring methods and particularly those activities in which students can participate

TABLE 1

Western Shield Schools Program: summary of participation since the program began.

1 YEAR	2 NUMBERS OF ACTION PACKS DISTRIBUTED TO SCHOOLS	3 NUMBERS OF STUDENTS AND TEACHERS USING THE ACTION PACK ¹	4 STUDENT CAMPS <i>WIN A NIGHT OUT WITH THE WOYLIES</i> Student	5 EXCURSIONS <i>BACK FROM THE BRINK</i> Student and Adult numbers ²	6 INSERVICES <i>BE A NATURE CONSERVATIONS OFFICER FOR A NIGHT</i> Teachers and other adult numbers ³	7 OTHER ACTIVITIES <i>MONITORING MARSUPIALS YEAR 11 Biology Student and adult numbers</i>
1996	878 ⁴		61			
1997	300 ⁵	9,300	274			
1998	300	9,300	262	171 ⁶		
1999	250	7,750		1075	80	
2000	400	12,400	35	2281 ⁷	63	
2001	174	5,394		2816	28	155
Total	2,274	44,144	632	6343	171	155

Target audience: primary and secondary school students and their teachers.

Secondary target audience: wider school community

Overall more than 50,000 students, teachers and other adults (sum of columns 2 to 6), have been made aware of *Western Shield* through the Schools Program. This figure does not include an estimate of the numbers of teachers who may have used the Pack when it was first sent to schools in 1996.

This may be a conservative number as some teachers may be using the pack having received it in a previous year. The figure does not include those who have down-loaded the pack from the Internet.

¹ Numbers in this column are based on class size of 30 students plus the teachers using the Pack

² Camps were offered at The Hills Forest (Mundaring), Dryandra Woodland (nr Narrogin), Batalling Forest (nr Collie), Perup Forest Ecology Centre and Wellington Discovery Forest (near Bunbury).

³ Inservices were offered at The Hills Forest (Mundaring), Dryandra Woodland (nr Narrogin) and Wellington Discovery Forest.

⁴ Action Packs were sent out to all primary schools in the State in 1996

⁵ The number of Action Packs requested by teachers from 1997 to 2001 is listed in this column

⁶ Excursions in 1998 and 1999 were offered only at The Hills Forest

⁷ Excursions in 2000 and subsequent years were offered at The Hills Forest and Wellington Discovery Forest

- To give teachers a close encounter with threatened fauna being rehabilitated by animal carers and to find out about threatened species breeding programs
- For teachers to meet and question the Department's Officers working on recovery programs for threatened fauna.

A total of 171 teachers attended the camps over a three-year period to the end of 2001 (Table 1). Feedback from teachers indicated that they planned to use the resources received at the camps with their class of students. Classes have on average 30 students so at least 5,113 students will have been made aware of *Western Shield* as a result of the Inservices. Anecdotal evidence from teachers indicates that teachers after a camp focus on *Western Shield* for more than one year and hence the figure is likely to be conservative.

Resources

The *Western Shield* Action Pack for primary schools was first offered in 1996 for upper primary students and was up-dated in 2000 to fulfil the needs of the Curriculum Framework and the required student outcomes. The pack is now available for down loading from the 'For Schools' site on *NatureBase*.

Teachers of lower secondary students use 'Winning Back Wildlife' module from Manual 2 of the CALM Bush Rangers program. This module outlines the work of *Western Shield*.

Two videos about *Western Shield* are promoted to teachers at Inservices. The video, *Deadly Protectors*, has been made available for loan from the Department's Science Library and three District Education Office Resource Centres in the metropolitan area and from the Department's Katanning and Narrogin District Offices, Kirup and Albany Work Centres and the Wellington District Office for schools in these areas. Feedback from teachers about this video continues to be very good. The video, *Mission Wild*, is also available for loan from the Department's Science Library.

The *LANDSCOPE* reprint, *Bouncing Back*, and *Western Shield – Bringing wildlife back from the brink of extinction*, as well as *Western Shield* newsletters, have been made available to teachers attending the Inservice camps (Appendix 1).

The Biodiversity Quiz, an initiative in 2001, was aimed at raising awareness of *Western Shield*. This quiz competition was sent to all schools State-wide and held in September to help celebrate Biodiversity Month. All answers were available on *NatureBase* so could be

completed by any student throughout the State who had access to the Internet. This was a cost effective way of drawing students' attention to the wealth of information on *NatureBase* about *Western Shield* and threatened species.

Excursions and camp activities for students

An excursion, *Back from the Brink*, has been designed specifically for this program. The aim is to give students some hands-on experience of the science behind *Western Shield* and how species are monitored over time. Students also have a close encounter with captive-bred threatened species or animals that cannot be released back into their natural habitat.

Table 1 indicates the participation and location of these excursions and camps.

The excursions include the following components:

- Short role-play where students act out the sequence of events leading to the decline of native fauna and the role of *Western Shield*
- Introduction to fauna monitoring methods, the field scientist's toolbox and pitfall trap techniques. Students mix bait, set traps, learn how to complete a scientific data sheet, check the traps, find an animal (life-like bandicoot) in their trap, and then record its measurements. Secondary students calculate trap success rate
- Forest walk looking for wildlife habitats and viewing of a demonstration artificial den as well as nesting and bat boxes placed in the forest to encourage wildlife in the local regrowth forest. Students observe ways they can contribute to nature conservation
- Overview of captive breeding programs and animal encounters with captive bred threatened species such as the bilby and rufous hare wallaby
- 'What you can do' game and closing session aimed at giving students ideas on how they can act individually to help save threatened species.

Other initiatives relating to *Western Shield*

Over a period of six years Applecross Primary School has raised \$6500 for the Department's threatened species programs at The Hills Forest Discovery Centre. Currently this money contributes towards the cost of animal encounters provided by Kanyana Wildlife Rehabilitation Centre volunteers during the Exploring The Hills Forest excursions. Students on camp take part in the *Western Shield* monitoring of the area and the data collected from this session is included in the fauna data file for the area.

At the start of the *Western Shield* Schools Program a competition was run for groups to 'Win a night out with the woylies' an overnight camp with all expenses paid. Students were able to participate in monitoring live native animals. These heavily subsidised camps are now offered only to teachers, a more cost-effective strategy. Involvement in monitoring and live trapping, *Monitoring Marsupials* sessions, are now offered to a limited number

of groups of students at The Hills Forest Discovery Centre and Wellington Discovery Forest. The data collected on the camps is included in the Department's fauna data file. These sessions have proved highly successful in building an understanding of *Western Shield* through hands-on activities (Table 1).

Year 11 Biology excursions were offered as an initiative in 2001. This excursion includes hands-on experience and an information session about scientific methods used for *Western Shield* monitoring of small marsupials. Students who have not heard about *Western Shield* in their earlier school years receive an introduction to the program during this excursion.

The *Forest Detective Trail* was developed and trialed in 2001. This excursion is offered to Year 4 and 5 students at The Hills Forest and focuses on scientific investigation and the solving of a mystery. The post-visit work at school introduces the students to *Western Shield* and the impact of fox predation on native fauna. It helps to prepare students for involvement in the *Back from the Brink* excursions for Years 6 and 7 students.

Advertising and promotion

The *Western Shield* Schools Program has been advertised through the following avenues:

- *School Matters*, the Department of Education's bi-monthly news-sheet, which goes to all government schools
- Direct mailing to teachers who have attended programs in previous years
- The Department of Education's mailing list
- Fliers to the Association of Independent Schools and Catholic Education Commission and distributed to all schools
- Contacts at District Education Offices
- The EcoEducation programs involving *Western Shield* have been posted on *NatureBase* under the Internet 'For Schools' site. These pages were most recently updated in 2002. An analysis reveals that these pages regularly attract more than 4,580 'page hits' a year.

Each year workshops and talks are presented to promote CALM's EcoEducation programs including the *Western Shield* Schools Program. The following lists the annual events:

- Catchments, Corridors and Coasts Course workshops
- Murdoch University, workshops for Diploma of Education Science students and Environmental Education and Environmental Science students
- World Environment Day (June 5) activities and *Western Shield* display
- State Science Teachers Conference (Conasta) workshop and display
- Primary Science Teachers conference (PRISSEM)
- Edith Cowan University in Perth and Bunbury workshops for Bachelor and Diploma of Education students

- Average of six inservice days per year at The Hills Forest and Wellington Discovery Forest
- Workshops at District Education offices in the metropolitan area and the south-west.

Other promotional events include

- Conference paper and workshop presented at the Australian Association for Environmental Education Conference in Melbourne January 2001
- Environmental Education Expo presentation for primary teachers at Whiteman Park.

Performance Indicators and Evaluations

Curtin University's National Key Centre for School Science and Mathematics Education carried out an independent evaluation of the pack and student camps (Taylor and Waldrup 1998). This showed that the pack and the camps were particularly successful in raising students' awareness of the nature and extent of the problem of extinction facing native animal species and of the practical measures through *Western Shield* taken by the Department to save them. The camps had a major impact on harnessing students' interest in learning how to conserve threatened species.

Ongoing evaluation through questionnaires completed by students and teachers attending camps, excursions and inservices has provided very positive feedback (See example of collated feedback from one camp). The program is modified in response to the feedback.

Example of Feedback from one camp

Teacher Inservice camp *Be A Nature Conservation Officer for a Night* 2001

18 respondents

Q. Was the Inservice relevant to your school program?

A. Yes 100% (N=18)

Q. Did the activities provide opportunities for your school program?

A. It was great to become more aware of the wildlife/threats and management of the flora/fauna of WA.

It was perfect for what I needed. Made me most keen to keep working in this area.

Gave ideas what excursions would offer to enhance Science programmes including endangered species.

Trapping- great for working scientifically/maths/team work.

Inspired me to learn heaps. I know what programs I can bring them to, and many resources available.

Animal encounter/trapping – getting to know animals - ID - more knowledge I can take back to kids.

Q. Did the Inservice help you to understand the part that the *Western Shield* Project plays in saving threatened species?

A. Yes 100% (N=18)

Q. Did the Inservice help you to understand the part that the *Western Shield* plays in saving threatened species?

A. It was great to become more aware of the wildlife/threats and management of the flora/fauna of WA.

Yes very good. I had no idea beforehand on *Western Shield*. Certainly did - very little knowledge previously about *Western Shield*.

I would like to participate in this. I will look into it when I have a class next year.

Q. Which activity provided the best learning opportunity for you and why?

A. Animal trapping - very informative & helped me to understand exactly how a conservation officer works. Catching and releasing animals and close encounters allowed contact with animals never seen before.

The trapping of animals. Kanyana's talk and demo with animals.

I am very enthused. The activities were excellent. Very stimulating - I am inspired.

I would like to bring my Yr 11 Biology students to do a transect and other activities.

Q. Will the resources provided help you to plan your school program?

A. The resources are fantastic! I have started bits and pieces and it's all here.

The slides and talk were excellent and setting and checking the traps was fantastic.

Definitely - they are great resources. Activities are very relevant.

General Comments

Keep coming up with the great programmes and maybe a few that could be done at school.

Great! Inspirational! I will be back!

Brilliant! Well done. A cheap and effective inservice run by a superb team – well done.

A thoroughly enjoyable inservice – thank you. I feel enthused and refreshed by the environment.

'Thank you to Liz who organized the best Inservice I've ever been on'.

End of Example

There continues to be a demand for the *Western Shield* Schools Program, which is an indication of its relevance and acceptance by teachers and students. To quote one teacher –

'A relevant and practical program for students to learn how to assist threatened species. A must for every Science, and Society & Environment teacher and student. The vision and value behind the program needs to be continually promoted. It is encouraging to see the progress that has been made. Each individual needs to feel included and be part of this vision. Your program certainly helps to do this'.

Table 1 presents an overall summary of the numbers of students and teachers involved since the schools program began.

The main features of the program that contribute to its success are:

- It is curriculum-based and interdisciplinary with an action pack that addresses curriculum outcomes
- It offers incentives for participation. The Department covers most costs for the teacher inservice. By completing the work in the pack, classes have been able to enter a draw to win an excursion to a field centre
- Activities at the field centres are based on small-group work and ensure that all students receive hands-on experience of research methods. The close encounter with rarely seen fauna has a profound impact on attitudes to wildlife
- It provides opportunities for teachers and some selected student groups to participate in real research as well as to meet and question scientists working in the field
- It involves the local community through projects initiated by schools whilst using the packs; and
- It is continuously evaluated and modified according to the feedback.

Expenditure

Tables 3 summarises the expenditure of the *Western Shield* Schools Program over two financial years 2000/01 to 2001/02 with the funding of \$15,000 per year provided by the *Western Shield* budget. Expenditure does not include the cost of the Coordinator's time.

Note that most of the costs associated with the *Back from the Brink* excursions (e.g. equipment, training of staff, changes in the content depending on requirement of the group) are covered by the Exploring The Hills Forest and Wellington Discovery Forest budget and the fees paid by the schools. The *Western Shield* Schools Program budget, however, covers the cost of excursions for the *Back from the Brink* winners of the draw.

Problems and limitations

Whilst the *Western Shield* Schools Program has been meeting its educational objectives, there have been a number of factors that have limited its success.

- With a limited budget, many opportunities for promotion and expansion of the program are missed.
- The current excursion policy of the Department of Education raises issues of duty of care and increased paper work for teachers, which is deterring them from

TABLE 3

Summary *Western Shield* Schools Program (SDCA) expenditure, 2001–01 and 2001–02

ITEM	EXPENDITURE 2000–01	CREDIT 2000–01	EXPENDITURE 2001–02	CREDIT 2001–02
Funding provided by <i>Western Shield</i>		\$15,000.00		\$15,000.00
Student Excursions. (Bus costs & leader costs for winners of draw)	\$986.70		\$615.00	
Trial for secondary Biology excursion	\$655.00			
Trial for Albany excursion			\$1,779.11	
Teacher Inservice (Food, contract leaders, overtime for CALM Officer, vehicle, accommodation)	\$3,669.39		\$3,593.39	
Administration (Contract clerical assistance for collating information, bookings time etc)	\$1,760.00		\$670.00	
Advertising/Promotion. (Adverts in journals, newsletters etc)	\$4,439.00		\$3,365.00	
Biodiversity Quiz. Leaders for Winners			\$273.00	
Video, Deadly Protectors, copies, Bouncing Back <i>LANDSCOPE</i> reprints printed	\$1,800.00			
Printing. (Printing of Action Packs and Certificates)	\$2,342.50		\$3,297.80	
Miscellaneous (Display for National Science Conference and travel)	\$688.00			
Travel Expenses and contractor to work on resources			\$1,500.00	
Income from teacher Inservices		\$900.00		\$1,155.00
Total expenditure	\$16,340.59		\$15,093.30	
Total income from teacher Inservices and budget provided		15,900.00		\$16,155.00
Overall balance	-\$440.59		\$1,061.70	

leaving their school grounds for excursions and camps. Many schools now are fulfilling curriculum outcome requirements of the core value of *Environmental Responsibility* through local projects. Additional time and resources are needed to prepare and promote Emergency Response and Evacuation Plans and to ensure that all leaders have current First Aid certificates to lead at excursion sites.

- Teachers are increasingly reluctant to attend Inservices out of school hours. Inservices are run on Saturdays, as no funds are available for relief teachers during the week. In 2002 Inservices have been cancelled due to lack of support. To continue to raise awareness of *Western Shield* in schools, innovative ways of drawing teachers' attention to the program, inservicing at schools and incursions are required in the future.
- There is no suitable curriculum written resource for secondary students available for pre-excursion preparation and post excursion follow up work. Currently a component of the CALM Bush Rangers' manuals is offered but without supporting resources to complete some of the activities.
- The videos, *Deadly Protectors* and *Mission Wild*, are excellent teaching tools and permission has been given to copy these for educational purposes. Use of these by schools is limited to borrowing from libraries and a few of the Department's District offices. Curriculum-linked activities need to be developed and the video promoted as part of the proposed biodiversity package for secondary schools. Funding is required to develop this package and copy the videos.
- The Biodiversity Quiz for schools in 2001 was not offered in 2002 because of the lack of resources to organise this activity despite the fact that it was an excellent way to promote *Western Shield*.
- Further longer-term evaluation is required to determine changes in behaviour and attitude as students mature and enter adulthood.

CALM Bush Rangers (SDCA)

Achievements

CALM Bush Rangers, which began in 1998, is part of a broad WA Government program known as Cadets WA. Over 1100 young people across WA are participants in nature conservation projects in conjunction with their local communities.

All cadets learn about *Western Shield*. The theory training about *Western Shield* is based on information in the program's manuals; specifically Manual 2 module, *Winning back wildlife*, and Manual 3 module, *The practice of nature conservation*.

Many of the outcomes of the program are achieved through involvement in nature conservation projects and some of these contribute to *Western Shield*. In 2001, Albany SHS, Chisholm Catholic College, Duncraig SHS, Esperance DHS, Gosnells SHS, Kalbarri DHS, Katanning DHS, Kellerberrin DHS, Manjimup DHS, Roleystone SHS, Rossmoyne SHS, John Septimus Roe Anglican Community School, Emmanuel Catholic College, Mt Lawley SHS, Northam DHS, Waroona DHS, Ursula Frayne Catholic College and Wongutha Christian School Units took part in these and related nature conservation projects.

An annual reward scheme for cadets who have shown excellent commitment to their communities includes *Western Shield* monitoring of fauna at Perup Forest Ecology Centre and at Shark Bay on *Project Eden*. The Perup Camp is held in March and October each year and the Shark Bay camp is held in October.

Regional and district activities

Achievements

Table 4 summarises the record keeping and communication of *Western Shield* to schools in Regions around the State. This table excludes activities for the CALM Bush Rangers. The data collected is not comprehensive but is indicative of trends in the Regions. Records of *Western Shield* activities for schools are not generally kept nor are the activities formally evaluated although most officers report positive feedback from participants.

All responding officers indicated that they give talks and run activities about the Department's work which includes aspects of *Western Shield*. These are given in response to requests from schools rather than officers initiating them ie the approach to communicating *Western Shield* is more reactive than pro-active.

Problems and limitations

Although staff around the State involve students in their *Western Shield* monitoring programs the value of these opportunities could be greatly enhanced if there was a co-ordinated approach to ensure that students have relevant information and take part in pre- and post-visit activities at school.

TABLE 4

Summary of record keeping and communication of *Western Shield* to schools through CALM's Regional and District Offices.

SURVEY QUESTIONS	REGIONS								
	SOUTH WEST			WARREN	WHEATBELT		MIDWEST	SWAN *	PILBARA
	Albany	Blackwood	Busselton		Katanning	Narroogin	Moora		Karatha
Formal record kept of talks to schools?	no	no	no	no	yes	yes	no	no	no
Number of talks per year?	3-10	8-12	12-15	15	2	14	?	?	1-2
Record kept of involvement of student groups in Western Shield monitoring/research per year?	no	no	yes	yes	yes	NA	NA	NA	NA
Numbers of students involved per year	6	none	200	185	70	NA	NA	NA	NA
Formal evaluation done on effectiveness of activities	no	no	no	no	no	no	no	no	no
Reactive (R) to requests for activities or pro-active (P)	R	R	R	R	R	R	R	R	R

* Information given for Swan Region excludes activities that are carried out at The Hills Forest. These are covered under SDCA *Western Shield* Schools Program.

CHANGES IN PUBLIC PERCEPTION AND ATTITUDE RESULTING FROM THE COMMUNITY SUPPORT AND EDUCATION PROGRAMS (Term of Reference 4)

The results of the surveys discussed under Term of Reference 1 indicate a consistent high awareness of *Western Shield* in communities adjacent to fox baiting areas since 1998. These surveys focused on awareness rather than changes in attitude.

There has been no formal evaluation of changes in attitudes of school students over time resulting from the *Western Shield* Schools program or other activities. Taylor and Waldrup (1998), however, carried out a formal evaluation of changes in awareness of students before and after using the *Western Shield* Action Pack and before and after attending camps (Term of Reference 3). These were found to be highly successful in raising awareness and encouraging interest in fauna conservation.

A qualitative assessment within school communities indicates that, particularly in country areas, awareness of *Western Shield* and its importance to biodiversity conservation is much greater today than six years ago. Teachers regularly comment favourably on the cross-curricular outcomes and the interest that the subject matter generates in their students.

Overall public acceptance of *Western Shield* implies success of the community support and education programs.

PROPOSED FOR THE FUTURE (Term of Reference 5)

SDCA continually monitors its overall communications activities as they relate to *Western Shield*. In particular, there is a strong emphasis in ensuring *Western Shield* and other biodiversity conservation actions are integrated into the Department's overall communications strategies.

The presentations from all Divisions to this overarching Review will provide opportunities to re-evaluate existing communications and educational activities. In addition, the findings and recommendations of the review will provide a new, and perhaps more focussed, direction which will be included in an updated *Western Shield* communications plan.

The preparation of this submission has identified some areas that will be considered in the immediate future, pending a definitive change in direction for *Western Shield*. These include:

Media relations and strategic communications

- The communications plan will be updated in the light of the presentations to this review as an interim measure. In the longer term, the communications plan will be updated to reflect any changes in the project stemming from recommendations of the review.

- Updating display materials to ensure they reflect the most up-to-date results of the *Western Shield* program and ensuring displays continue to be available to Regions and Districts for use at a range of community events including agricultural and other local shows and other promotional activities.

Schools education program

Ongoing action

- The *Western Shield* Schools program will continue to provide Inservice camps for teachers, resources for use in school and excursions and camps for students.
- Initiatives introduced in 2001 such as *Monitoring Marsupials*, and the *Year 11 Biology* and *Forest Detective Trail* excursions will continue to run at The Hills Forest Discovery Centre and be offered at Wellington Discovery Forest.
- Involvement of the CALM Bush Rangers cadets in nature conservation projects that focus on *Western Shield* will continue.

Proposed action

- Inservicing in schools is viewed as essential to maintain interest in the program and will require additional funding over and above the current funding.
- Inservices, *Be a Nature Conservation Officer for a Night* camp, will be offered in Albany, in 2003. Other areas to be considered for similar camps are Moora, Katanning, Margaret River and Albany.
- *Back from the Brink* excursions may be offered in the Albany area in 2003. A proposal will be prepared for the Albany District Office as resources will be required to support these excursions.
- Planning will begin for an expanded biodiversity conservation secondary schools package. This initiative is still in a very preliminary concept phase. The development of this proposal and a better co-ordinated approach to delivery of opportunities for students in country Districts will involve other Divisions within the Department and a financial commitment through Service Provider Agreements.
- Further independent evaluation is required to ensure that the program continues to be effective and aligned with the Department's required outcomes. Longer-term evaluation of the impact of the program on changes in behaviour is required to determine whether this action is carried through into adulthood.
- The Division will explore opportunities for further partnerships across the Department's Districts and other activities such as *Land for Wildlife* and *Bushcare* to increase awareness of *Western Shield*.

REFERENCES

- Kawalilak R, Thomson C, Higgs N (1993) *Operation Foxglove* communications plan. Department of Conservation and Land Management, Perth.
- Kawalilak R, Thomson C, Higgs N (1996) '*Western Shield* communications plan'. Unpublished, internal document for Department of Conservation and Land Management, Perth.
- Kawalilak R (1997) *Lending a hand to wildlife*. Gold Quill Merit Award entry.
- Kawalilak R, Higgs N (1998) *Working with the media*. Unpublished, internal training guide for Department of Conservation and Land Management, Western Australia.
- Kawalilak R, Higgs N (1998) *Taking a strategic approach to communications*. Unpublished, internal training package for Department of Conservation and Land Management, Western Australia.
- Moore E (1998) *Western Shield* Schools' Program Progress Report. Unpublished, internal report to Department of Conservation and Land Management, Western Australia.
- Moore E (1999) 1998 *Western Shield* Schools' Program Report. Unpublished, internal report to Department of Conservation and Land Management, Western Australia.
- Moore E (2000) 1999 *Western Shield* Schools' Program Report. Proposed budget for 2000. Unpublished, internal report to Department of Conservation and Land Management, Western Australia.
- Moore E (2001) 2000-2001 *Western Shield* Schools' Program Report. Unpublished, internal report to Department of Conservation and Land Management, Western Australia.
- Moore E (2001) Threatened species program. A cross-curricular program that promotes a biodiversity conservation ethic in students. *Investigating Australian primary and Junior Science Journal* 17, 21-25.
- Patterson K Ed (1996, 1998, 2000) *Western Shield* Program Awareness. Unpublished, internal reports to Department of Conservation and Land Management, Western Australia. Patterson Market Research.
- Taylor P, Waldrip B (1998) Evaluation of *Western Shield* Action Pack and Camps. Unpublished, internal report to Department of Conservation and Land Management, Western Australia.

APPENDIX I

Publications

- Bailey C (1996) *Western Shield bringing wildlife back from the brink of extinction*. *LANDSCOPE* 11 (4), 4-48.
- *Western Shield* September 1996 (colour fact sheet and Questions and Answers).
- *Western Shield* Newsletter Aug 1997.
- *Western Shield* Newsletter Nov 1997.
- Morris K (1998) Bouncing back *Western Shield Update*. *LANDSCOPE* 14 (1), 28-35.
- Algar D, Smith R (1998) *Approaching Eden*. *LANDSCOPE* 13 (3), 28-34.
- *Western Shield* Newsletter April 2001.
- Vance M (2002) *Kanyana to the rescue*. *LANDSCOPE* 18 (1), 42-48.

Educational tools

- *Western Shield* Speakers Kit (slides and text).
- *Western Shield* Display (pictures and text) – used extensively by Branches, Regions and Districts at events throughout the target areas including country shows and shopping centres.
- EcoEducation programs that include teacher inservices, resources for use at school and excursion and camp activities and nature conservation projects.
- EcoEducation display (photographs and text about student involvement in *Western Shield*) for teacher conferences and workshops.
- *Western Shield* banner for display purposes.

Miscellaneous activities and products

- Dog Owners brochure for included in dog registration renewals.
- Beta-cam and VHS copies of footage of native fauna helped by *Western Shield* including woylies, bilbies etc. This has been distributed to TV stations.
- *Western Shield* parade in Fremantle Festival.
- Photographic collection of *Western Shield* fauna and baiting operations.
- *Western Shield* Threatened Species Signs for Perth Zoo.
- *Western Shield* component of Gnaragala Park Concept Plan.
- Facilitated and assisted with making international documentaries such as *Return to Eden* (shown on ABC National Television in June 2002 and on international cable networks) as well as articles in international publications such as National Geographic.
- Coordinated the design and production of *Western Shield* logo caps and shirts for staff.
- Inclusion of *Western Shield* themes at Perth Royal Show and various events and displays throughout country areas.
- Production of 350,000 paper tray liners that carried the *Western Shield* message and used in Hungry Jacks restaurants in Western Australia.

Translocations and fauna reconstruction sites: *Western Shield* review—February 2003

PETER R. MAWSON¹

¹Senior Zoologist, Wildlife Branch, Department of Conservation and Land Management,
Locked Bag 104 Bentley Delivery Centre WA 6983. peterm@calm.wa.gov.au

SUMMARY

Objectives

The objectives of *Western Shield* with regard to fauna translocations were to re-introduce a range of native fauna species to a number of sites located primarily in the south-west of Western Australia. At some sites whole suites of fauna needed to be re-introduced, while at others only one or a few species were targeted for re-introduction.

Integration of *Western Shield* activities with recovery actions and co-operative arrangements with community groups, wildlife carers, wildlife sanctuaries, Perth Zoo and educational outcomes were other key objectives.

Achievements

The fauna translocation objectives defined in the founding documents (Burbidge *et al.* 1995) and draft 'Western Shield Strategic Plan' have been largely met, and in some cases exceeded within the first six years of the program in terms of the number of species translocated, the number of translocations attempted and the number of successful translocations. The target sites for the re-introductions were different for some species from those originally proposed, but the variation was made on the basis of better information about species requirements and changes to the baiting strategy (usually a discontinuation of baiting) for some sites neither of which were expected to be immutable.

There has been reasonable integration of *Western Shield* activities with species recovery actions, but there is scope to improve internal communication between Recovery Teams and Western Shield staff.

Cooperative arrangements with community groups, wildlife carers, wildlife sanctuaries and the Perth Zoo have been one of the great successes of the program to date, with a high level of exposure for the program.

Difficulties

Limited human resources in some Department of Conservation and Land Management (CALM) regions and slow production of animals from captive breeding programs have hampered translocation opportunities for some species. More realistic production time lines will

address this problem, but will result in slower progress towards future milestones for some species.

The captive-breeding of western barred bandicoots has also been hampered by disease issues, but this problem is dealt with in more detail elsewhere in this edition (see Morris *et al.* this issue).

There is a clear need to better define criteria that will be used to determine the success or failure of translocation programs, and for those same criteria to be included in Recovery Plans and Interim Recovery Plans.

A small number of the species that are currently the subject of captive-breeding programs and or translocations do not have Recovery Plans or Interim Recovery Plans, contrary to CALM Policy Statement No. 50. In other cases the priorities by which plans are written does not reflect the IUCN rank assigned those species by the Western Australian Threatened Species Scientific Committee.

There is a clear disparity in the effort devoted to *Western Shield* activities between the various regions in the southwest of the State. The reasons for this are not immediately apparent, but this problem could be addressed with a clear directive from the CALM Executive reconfirming the high priority that this program should have in regional activities.

Potential economies

Increased use of student research involvement could help elucidate specific issues relating to fauna translocations for threatened and non-threatened species covered under Western Shield. To maximize this potential it will require a broader commitment from CALM staff to develop project outlines, to co-supervise the students and where possible to assist in identifying and sourcing funds to support student research projects.

Potential improvements

Staff trained to participate in *Western Shield* activities such as fauna monitoring and translocations must be given the opportunity to undertake those duties, and that these activities not be seen as secondary to other activities within CALM (e.g. fire management, tree planting etc.) at critical periods of the year when fauna monitoring or translocations are best carried out.

INTRODUCTION

In the original *Western Shield* proposal (Burbidge *et al.* 1995) the conservation of those elements of the Western Australian native fauna that were declining because of fox predation were to be protected by means of strategic fox baiting. It was expected that a number of extant populations of several species would be able to recover once the impact of foxes was reduced. However, at many sites it was also expected that it would be necessary to re-introduce particular species or entire suites of fauna (predominantly mammals) into some sites in order to reverse the impact of exotic predators. It was proposed that the translocation of up to 13 species to 17 fauna reconstruction sites and 25 species recovery sites would be desirable by the year 2000.

Fauna Reconstruction Sites are defined in the CALM Policy Statement No. 29 (CALM 1995) as 'areas where the Department is proposing to reconstruct, or is reconstructing, the vertebrate fauna as far as possible through predator control, habitat management or translocations'.

Species Recovery Sites are defined in the same Policy Statement as 'areas where management priority is given to the recovery and conservation of one or more nominated threatened species'.

The aims and objectives of the original *Western Shield* proposal were reinforced in the draft '*Western Shield* Strategic Plan 1999-2004' (CALM 1999) mission statement [Note: the draft strategic plan was never ratified by the CALM Corporate Executive.] One of the mission statements relating to fauna translocations was 'To reconstruct the fauna that has become locally extinct because of predation by reducing the density of foxes and feral cats on conservation lands, and encourage their reduction on private lands.' Translocations of native fauna were only to be undertaken in situations where the native fauna species were not present and/or could not colonize areas subject to introduced predator control by natural spread. Species listed as 'threatened' [i.e. listed on Schedule 1 of a Specially Protected Fauna Notice, under the provisions of Section 14(2)(ba) of the *Wildlife Conservation Act 1950*] were to have higher priority for translocation than non-threatened species. Monitoring of translocated threatened species was to continue until the population was established but no definition was provided for 'establishment'.

TRANSLOCATIONS CONDUCTED UNDER WESTERN SHIELD SINCE 1996

The term 'translocation' is defined in Policy Statement 29 (CALM 1995) and in this paper as 'the movement of living organisms from one area with free release in another'. Translocation includes introductions, re-introductions and re-stocking. This definition was based on the IUCN Position Statement on Translocation of Living Organisms (IUCN 1987).

It should be noted that some of the translocations referred to in this review involve the release of animals at more than one location within a baited area at one time or the release of several groups of animals at the one site in successive years. In such cases these releases are incorporated under a single translocation proposal and are presented in this review as single translocations.

Since April 1996 when the *Western Shield* program was officially launched through until 30 September 2002, 88 separate fauna translocations have been carried out. Eighty-three (83) of those translocations were conducted in Western Australia—involving 25 species of native animals (19 mammal taxa, 3 species of bird, 2 species of reptile and one species of amphibian). In addition to the translocations conducted in Western Australia there have been three (3) translocations, involving two (2) species of mammal carried out to South Australia using animals sourced from wild or captive populations in Western Australia. Two (2) translocations, involving one (1) species of mammal, have also been carried out to New South Wales using animals sourced from wild or captive populations in Western Australia.

The specific details of the eighty-eight translocations are set out in Table 1, along with the total number of animals used to found each population and an assessment of the status of each translocation (i.e. success, failure or outcome pending).

CHANGES IN IUCN THREAT STATUS FOR SPECIES TRANSLOCATED SINCE 1996

The Draft Strategic Plan (CALM 1999) stipulated that species listed as threatened were to have a higher priority for translocation than other non-threatened species. Table 2 sets out the conservation status of the various species that have been the subject of translocations and that are referred to in Table 1, at the time of each translocation and as of September 2002.

The conservation status of the majority of the species listed in Table 2 has not changed during the period 1996-2002. The main reason for this lack of change in conservation status is that only a small number of translocations have been conducted for most species and that the outcome of many of the translocations has not yet been confirmed. Even if all of the translocations had been successful the reduction in known previous range of many species has been so great that many more successful translocations would be required before the various species would satisfy the IUCN criteria for down-grading of their threat category.

There are five species listed in Table 2 that now have a lower IUCN threat category than they had in 1996, or at the time translocations first commenced post-1996. Translocations of woylies began in Western Australia as early as 1977, but did not achieve success until after broad-scale fox baiting was introduced in 1992 in programs that were the precursor to *Western Shield*. Woylie translocations became so successful that the species had recovered in

TABLE 1

Translocations of native fauna conducted in Western Australia under the umbrella of *Western Shield* during the period 1996-2002. [RI=re-introduction, RS=re-stocking, IN=introduction. CALM=Department of Conservation and Land Management, AWC=Australian Wildlife Conservancy, CSIRO=Commonwealth Scientific and Industrial Research Organization, SADEH=South Australian Department for Environment and Heritage, NSW NPWS= New South Wales National Parks and Wildlife Service. TNR= Total Number Released. % figures in last column indicate most recent trap success rates reported for the respective translocations. Outcome: P=Pending, N=Failed, Y= Succeeded.

YEAR	TP	SPECIES	LOCATION	SOURCE	PROPONENT	TNR	OUTCOME
1996-8	RI	Quokka	Karakamia Sanctuary (AWC)	Dwellingup	CALM	5	P
2001	RI	Banded H-wallaby	Francois Peron NP	Captive bred (Bernier Is. stock)	CALM	18	N
2001-2	RI	Black-flanked rock-wallaby	Paruna Sanctuary (AWC)	Mt Caroline NR/ Querekin Rock	AWC	22	P
2001-2	RI	Black-flanked rock-wallaby	Avon Valley NP	Mt Caroline NR/ Querekin Rock	CALM	46	P
2002	RI	Black-flanked rock-wallaby	Walyunga NP	Mt Caroline NR/ Querekin Rock	CALM	29	P
1998-9	RI	Tammar wallaby	Warrup Forest	Perup Forest	CALM	63	Y
1998	RI	Tammar wallaby	Karakamia Sanctuary (AWC)	Tutanning NR	CALM / AWC	13	Y
1998-2002	RI	Tammar wallaby	Julimar Forest	Tutanning NR	CALM	57	P
1999-2000	RI	Tammar wallaby	Bennelaking Forest	Tutanning NR	CALM	46	P
2000	RI	Tammar wallaby	Alcoa Huntly Mine	Tutanning NR	CALM / Alcoa Ltd	20	P
2001-2	RI	Tammar wallaby	Paruna Sanctuary (AWC)	Tutanning NR	AWC	44	P
2001-2	RI	Tammar wallaby	Avon Valley NP	Tutanning NR	CALM	100	P
2002	RI	Tammar wallaby	Thames Forest	Perup Forest	CALM	41	P
2002	RI	Tammar wallaby	Boyndaminup Forest	Perup Forest	CALM	40	P
1996	RI	Woylie	Hills Forest	Dryandra Forest	CALM	37	N
1997-8	RI	Woylie	Lake Magenta NR	Dryandra Forest	CALM	35	N
1997-8	RI	Woylie	Francois Peron NP	Dryandra Forest, Batalling Forest	CALM	147	N
1998	RS	Woylie	Poorginup & Chitelup Forest	Perup Forest	CALM	40	P, 0.7%
1998	RI	Woylie	Easter & Barlee SF	Perup Forest	CALM	40	Y
1998-9	RI	Woylie	Genaren Hills, NSW	Dryandra Forest, Karakamia Sanctuary	GHLCG	24	N
1998	RI	Woylie	St Johns Forest	Perup Forest	CALM	40	N
1998	RI	Woylie	Denmark Forest	Perup Forest	CALM	38	N
1998	RI	Woylie	Centaur Forest	Batalling Forest	CALM	39	P, 5.4%
1999	IN	Woylie	Giants Forest	Perup Forest	CALM	40	P, 1.0%
2000	RI	Woylie	Wellington NP	Batalling Forest	CALM	30	P, 6.6%
2000	RI	Woylie	Davis Forest	Batalling Forest	CALM	37	P, 8.1%
2000	RI	Woylie	Kalbarri NP	Dryandra Forest	CALM	32	P
2000-1	RI	Woylie	Paruna Sanctuary (AWC)	Karakamia Sanctuary	AWC	128	P, 5.3%
2000	RI	Woylie	Shannon NP	Perup Forest	CALM	40	P
2000	RI	Woylie	Strickland Forest	Perup Forest	CALM	40	P, 3.0%
2000	RI	Woylie	Watts PP	Batalling Forest	CALM	19	Y, 51.6%
2000	RI	Woylie	Tucker PP	Batalling Forest	CALM	19	P
2000	RI	Woylie	Hadfield Forest	Batalling Forest	CALM	29	P, 8.3%
2001	RI	Woylie	Yathong NR, NSW	Dryandra Forest	NSW NPWS	25	N
2002	RI	Woylie	Thames Forest	Perup Forest	CALM	37	P
2002	RI	Woylie	Flybrook	Perup Forest	CALM	21	P
2002	RI	Woylie	Boyndaminup	Perup Forest	CALM	21	P
1999	RI	Boodie	Roxby Downs, SA	Heirisson Prong, Bernier Is	CSIRO / SA DEH	10	P
2000	RI	Boodie	Roxby Downs, SA	Bernier Island	SADEH	20	P
2002	RI	Boodie	Faure Island (AWC)	Heirisson Prong	AWC	17	P
1998	IN	Mala	Trimouille Is, Montebello Is.	Captive colony, Tanami Desert, NT	PWCNT / CALM	30	Y
2001	RI	Mala	Francois Peron NP	Captive Colony, Peron	CALM	16	N
1998	RS	Euro	Useless Loop	Carrarang Station	CALM	29	Y
1987-96	RI	Numbat	Tutanning NR	Dryandra Forest	CALM	35	Y
1994-9	RI	Numbat	Karakamia Sanctuary (AWC)	Dryandra Forest	CALM	6	P

TABLE 1 (continued)

YEAR	TP	SPECIES	LOCATION	SOURCE	PROPONENT	TNR	OUTCOME
1995-6	RI	Numbat	Dragon Rocks NR	Dryandra Forest	CALM	37	P
1996-8	RI	Numbat	Hills Forest	Dryandra Forest	CALM	62	P
1998-2000	RI	Numbat	Stirling Range NP	Dryandra Forest, Boyagin NR, Perth Zoo	CALM	48	P
1995-6	RI	Quenda	Boyagin NR	Swan Coastal Plain	CALM	26	P, 1.0%
1996	RI	Quenda	Leschenault CP	Big Swamp Wildlife Park	CALM	15-20	P
1994-7	RI	Quenda	Karakamia Sanctuary (AWC)	Various metro sites	CALM	34	Y
1997-8	RI	Quenda	Hills Forest	Jandakot	CALM	18	Y, 1.8%
1997	RS	Quenda	Mt Barker, Albany Hwy	Dongolocking NR	CALM	37	P
2000	RI	Quenda	Paruna Sanctuary (AWC)	Rockingham, Karakamia	AWC	56	P, 1.2%
2000	RI	Quenda	Creery Wetlands	Mandurah transfer station	CALM	22	Y, 27.9%
2000	RI	Quenda	Yalgorup NP	Mandurah transfer station	CALM	9	P
2002	RI	Quenda	Avon Valley NP	Beeliar, Casuarina	CALM	15	P
1995-6	RI	WB bandicoot	Heirisson Prong	Dorre Island	CSIRO / CALM	14	N
2000	RI	WB bandicoot	Roxby Downs, SA	Bernier Island	SA DEH	12	P
2000	RI	Bilby	Dryandra	Captive bred	CALM	36	P
2000-2	RI	Bilby	Francois Peron NP	Captive bred	CALM	55	P
1996-7	RS	Chuditch	Lake Magenta NR	Perth Zoo	CALM	81	Y, 1%
1997-8	RI	Chuditch	Cape Arid NP	Perth Zoo	CALM	46	P
1999	RS	Chuditch	Mt Lindsay NP	Perth Zoo	CALM	48	P, 0.7%
2000	RI	Chuditch	Kalbarri NP	Perth Zoo	CALM	33	P
1998-2000	IN	Dibbler	Escape Island, Jurien	Perth Zoo (Whitlock & Boullanger Islands)	CALM	94	Y, 31.2% F3
2001	RI	Dibbler	Peniup 'NR'	Perth Zoo (FRNP stock)	CALM	41	P
1995-2001	RI	WRt possum	Yalgorup NP	Port Geographe, E Buss PS	CALM	188	P
1991-7	RI	WRt possum	Leschenault CP	Derelicts & Busselton	CALM	106	P
1995-2002	RI	WRt possum	Karakamia Sanctuary (AWC)	Port Geographe	CALM	43	P
1997-9	RI	WRt possum	Lane Poole Reserve	Derelicts, Busselton	CALM	118	N
1999-2001	RI	G stick-nest rat	Heirisson Prong	Salutation Island	CSIRO / CALM	48	P
1993-8	IN	SB mouse	Doole Island NR	Bernier Island, Perth Zoo	CALM	149	P
1999	IN	SB mouse	North West Is. Montebello Is.	Perth Zoo	CALM	26	P
2002	RI	SB mouse	Faure Island (AWC)	Perth Zoo	AWC	88	P
1996	RS	P-mound mouse	Adjacent area, Site 2	Jimblebar Mine	BHP	27	?
1997	RS	P-mound mouse	Adjacent area, Site 3	Jimblebar Mine	BHP	4	?
1997	RS	P-mound mouse	Orebody 25, Newman	Orebody 18, Newman	BHP		?
1997	RS	P-mound mouse	north of HIY	HI Yandi project	Hammersely Iron	101	Y
1996	IN	Thev. Is. mouse	Serrurier Island NR	Thevenard Is. NR	CALM / UWA	65	Y, 205%
1997-8	RS	Malleefowl	Francois Peron NP	Eggs from N wheatbelt	CALM	66	Y, 6 nests
1997-2002	RI	Noisy scrub-bird	Darling Range	Two Peoples Bay NR	CALM	72	P
1999-2000	RI	Western bristlebird	Walpole-Nornalup NP	Two Peoples Bay NR	CALM	15	P
1994-9	RI	Western swamp tortoise	Twin Swamps NR	Perth Zoo	CALM	130	Y
2000-1	IN	Western swamp tortoise	Mogumber	Perth Zoo	UWA / CALM	26	P
2001	RS	Western swamp tortoise	Ellen Brook NR	Perth Zoo		12	Y
2002	IN	Lancelin Island skink	Favourite Island	Perth Zoo	CALM	41	P
2001	IN	Orange-bellied frog	Adelaide Creek	Spearwood Creek	CALM	8-20 Egg masses	P

TABLE 2

Conservation status of translocated species (IUCN rank) at the time that each translocation was conducted and at 30 September 2002. [EW=Extinct in the Wild, CR=Critically Endangered, EN=Endangered, VU=Vulnerable, LR(nt)=Lower Risk (near threatened)].

SPECIES	IUCN CONSERVATION STATUS AT TIME OF TRANSLOCATION	IUCN CONSERVATION STATUS AT 30 SEPTEMBER 2002
Quokka	Nil	VU
Banded hare-wallaby	VU	VU
Black-flanked rock-wallaby	VU	VU
Tammar wallaby	VU, LR(nt)	LR(nt)
Woylie	VU, LR(nt)	LR(nt)
Boodie	VU	VU
Mala	EW	EW
Euro	Nil	Nil
Numbat	VU	VU
Quenda	VU, LR(nt)	LR(nt)
Western-barred bandicoot	EN	EN
Bilby	VU	VU
Chuditch	VU	VU
Dibbler	EN	EN
Western ringtail possum	VU	VU
Greater stick-nest rat	VU	VU
Pebble-mound mouse	VU	LR(nt)
Shark Bay mouse	VU	VU
Thevenard Island mouse	EN	LR(nt)
Mallefowl	VU	VU
Noisy scrub-bird	VU	VU
Western bristle-bird	VU	VU
Western swamp tortoise	CR	CR
Lancelin Island skink	VU	VU
Orange-bellied frog	VU	VU

numbers and range to such an extent that it was de-listed from the IUCN threat categories and down-graded to LR(nt) in 1996. The term 'Conservation Dependent' was previously applied to this species, however in the 2000 review of the IUCN red book the use of this term was discontinued. Conservation dependent provides an apt description of the status of the woylie, since its continued survival in the wild is totally dependent on broad-scale predator baiting programs.

The threat status of the quenda and the tammar wallaby was down-graded in 1998 following an assessment of their conservation status by the Western Australian Threatened Species Scientific Committee using the IUCN criteria of the day. Both species were found not to satisfy the criteria for even the lowest category of threat (Vulnerable), and accordingly were de-listed from Schedule 1 of the Specially Protected Fauna Notice (Government Gazette, 14 July 1998). One of the factors contributing to the decision to de-list the quenda was that it still had a fairly wide distribution and that on the mainland there was evidence of increasing populations in areas baited to control introduced predators. The case for de-listing the tammar wallaby was also bolstered by the fact that there are secure populations in the Abrolhos Islands and on Garden Island.

The Thevenard Island mouse (*Leggadina lakedownensis*) was de-listed on the basis that it was not genetically distinct from the adjacent mainland populations, despite clear morphological differences

(larger size) (Morris 1993). Since populations occur in both the Pilbara and Kimberley regions, there was no justification for maintaining the insular population as endangered. The pebble-mound mouse (*Pseudomys chapmani*) was de-listed following a thorough review (Start *et al.* 2000) that showed this species was still widespread and common in areas with suitable habitat over more than half of its former range. On this basis it did not meet the criteria for the lowest threat category (Vulnerable).

TABLE 3

Criteria used to assess outcome of translocations and the relevant source reference. (IWMG=Interim Wildlife Management Guideline, RP=Recovery Plan, IRP=Interim Recovery Plan)

SPECIES	CRITERIA FOR SUCCESS	SOURCE REFERENCE
Quokka	Not stated	No IRP or RP exists for this species
Banded hare-wallaby	Not stated	Draft Interim Recovery Plan (CALM 2000)
Black-flanked rock-wallaby	F2 breeding, or 50% increase in pop'n within 3 years	Orell, P & Dans, P. (2002)
Tammar wallaby	Breeding of F1 generation	Translocation Proposals
Woylie	Avg. daily trap success of 7.5%	Start <i>et al.</i> (1995)
Boodie	N=265 or more, and population persists for at least 5 yrs	Short & Turner (2000)
Mala	Not stated	Translocation Proposals
Euro	Not stated	No IWMG, Sims (1997)
Banded hare-wallaby	Not stated	IRP, Sims (2001)
Numbat	Sighting rate of 1-5/100km at various sites + at least 9 self-sustaining pop'ns	Friend (1994)
Quenda	Not stated	No IWMG, IRP or RP
Western barred bandicoot	Six criteria defined in translocation proposal	Short (1995), Short and Friend (1995)
Bilby	Not stated	Friend & Orell (2000)
Chuditch	Avg. daily trap success rate of 1%	Orell & Morris (1994)
Dibbler	F1 generation trapped with pouch young	Friend (2001)
Western ringtail possum	Not stated	IRP, Translocation Proposal
Greater stick-nest rat	Establish a mainland pop'n	Morris & Short (1999)
Pebble-mound mouse	Not stated	Translocation Proposals
Shark Bay mouse	'Establish self-sustaining pop'	Morris <i>et al.</i> (2000)
Thevenard Island mouse	Not stated	IWMG, Morris 1993
Mallefowl	Not stated	Morris & Barton (1996), Sims and Barton (1997)
Noisy scrub-bird	Not stated	Danks <i>et al.</i> (1996)
Western bristle-bird	Not stated	Burbidge (1999)
Western swamp tortoise	Not stated	Burbidge <i>et al.</i> (1990)
Lancelin Island skink	Not stated	Pearson & Jones (2000)
Orange-bellied frog	Not stated	Wardell-Johnson <i>et al.</i> (1995)

OUTCOME OF TRANSLOCATIONS CONDUCTED UNDER *WESTERN SHIELD*

A total of 83 translocations have been conducted in Western Australia under the *Western Shield* banner since April 1996. Based on the available criteria for assessing the outcomes of those translocations that have been provided in either the recovery plans and or the translocation proposals, 9 (10.8%) translocations are considered to have failed, 17 (20.5%) to have succeeded, 54 (65.1%) are pending and three (3.6%) can not be determined due to lack of follow-up monitoring.

Of the five translocations made post-1996 from Western Australia the two to New South Wales failed and the three to South Australia are still pending.

Of those translocations that are considered to have failed seven were translocations involving woylies. The two translocations of woylies to New South Wales both failed because of inadequate control of exotic predators. In the case of the Genaren Hills translocation, foxes and possibly cats were the problem, while at Yathong Nature Reserve the failure was solely due to predation by feral cats as foxes had been eliminated from the reserve. Of the five translocations that failed in Western Australia only the translocation to Francois Peron National Park appears to have failed due to feral cat predation. Low founder numbers appear to have contributed to the failure of the translocations to Hills Forest, Lake Magenta Nature Reserve, St. Johns Forest and Denmark Forest. The presence of chuditch as potential predators at Lake Magenta Nature Reserve and Denmark Forest along with the recent severe drought may also have compounded the effect of small founder numbers.

The translocations of banded hare-wallaby and mala (both to Francois Peron National Park) and western barred bandicoots (to Heirisson Prong) have all failed because of feral cat predation of animals released into fox-free environments. The failure of the translocation of western ringtail possums to Lane-Poole Reserve has been attributed to heavy predation by chuditch and health problems of some of the rehabilitated animals sourced from volunteer wildlife carers used in the release.

The remaining 54 translocations for which an outcome is still pending are mostly recent releases (<3 years old, e.g. black-flanked rock-wallaby, quenda, Shark Bay mouse) or involve species that are slow to mature (e.g. western swamp tortoise) or produce only one or a few young each year (e.g. tammar wallaby, chuditch, dibbler). Further monitoring of these translocations in coming years will provide a clearer indication of the fate of these translocations.

LEVEL OF MONITORING OF TRANSLOCATED SPECIES

It is now standard practice within CALM to indicate in the translocation proposal how and when monitoring of translocated populations will be achieved. In many cases

this has been achieved by releasing animals into sites that are already monitored as part of standard *Western Shield* fauna monitoring sites (see Orell this issue). In those cases where the translocations have been to sites that are not part of the current fauna monitoring program, specific provision has been made by the CALM District supporting the translocation to undertake monitoring in accordance with the prescription set out in the proposal.

All of the translocated populations described in Table 1 are, or have been, monitored in some fashion. The intensity of monitoring and the methods used vary across species and for different locations for the same species, according to the availability of resources and the suitability of available techniques in different landscapes. Many populations have been intensively monitored during the first 6-12 months following release. This level of monitoring has been vital in determining the causes of failed translocations (e.g. banded hare-wallaby, mala, western ringtail possum).

Given the available resources (people and funds), the standard and quantity of monitoring has been adequate for most translocations. For those few translocations that are currently monitored at a low level, the human resources and funds required to achieve greater monitoring would be disproportionate to the value of the data that would be forthcoming relative to the goals set out in the draft '*Western Shield* Strategic Plan 1999-2004'. Monitoring of translocated populations in more remote locations is, or will be, limited. This deficiency is primarily a function of available funds.

Are the most appropriate monitoring and analysis techniques employed?

Analytical techniques used to assess the progress of translocated and recovering populations include percentage trap success (i.e. the number of animals trapped per 100 traps set), KTBA ('known to be alive') and, in some cases, population estimates based on mark and recapture data (all translocated animals are individually marked and in most cases unmarked animals captured during monitoring programs are subsequently marked and released) (see Orell this issue). While these techniques may not be the most sophisticated available, they provide sufficient information to address the strategic goals within the available finance and resource structure of the *Western Shield* program. For more specific examples of the analytical techniques used refer to the review paper on fauna monitoring (Orell, this issue).

Have translocations helped achieve *Western Shield* strategic objectives?

The original *Western Shield* proposal and the draft '*Western Shield* Strategic Plan 1999-2004' contained a number of objectives specifically relating to fauna recovery. In determining whether translocations have helped achieve the strategic objectives of the *Western Shield* program it is necessary to assess the performance of the program against the objectives of both documents.

Fauna reconstruction and fauna recovery sites

In the original *Western Shield* proposal (Burbidge *et al.* 1995) one of the stated objectives was to translocate 13 species to 17 fauna reconstruction sites and 25 species recovery sites by 2000. However, in Table 3 of that document only 13 fauna reconstruction sites were listed along with 27 species recovery sites (c.f. 17 fauna reconstruction sites and 25 species recovery sites referred to in the text). Fauna translocations involving 10 species of fauna have now been conducted to 10 of those 13 reconstruction sites, and four species have been translocated to seven (7) of the 27 species recovery sites. A further 12 species of fauna have been translocated to sites other than those identified in the original *Western Shield* proposal, primarily because of the site and habitat specific needs of those species, that were identified after the writing of the *Western Shield* proposal. Two of these species recovery sites have either never been baited or are no longer baited to control foxes and as such have not received any translocations to date.

Only three fauna reconstruction sites listed by Burbidge *et al.* (1995) have not received any fauna translocations during the period 1996-2002 (Batalling Forest, Fitzgerald River National Park and Perup-Denbarker forests), while 20 fauna recovery sites have not received any translocations. Batalling Forest has received woylies on two occasions prior to the establishment of *Western Shield* (i.e. pre 1996) and is now an important source site for woylie translocations. Similarly, Perup-Denbarker forests are significant source areas for woylie and tammar wallaby translocations, and the area is still considered suitable for future translocations of other species (e.g. bilbies). Fitzgerald River National Park is the only anomaly, in that it lacks several of the species that previously inhabited the region, is baited and monitored, but has not been the subject of any translocation proposals. Possible reasons for this will be addressed later in this review.

In the draft 'Western Shield Strategic Plan 1999-2004' the list of fauna recovery sites and species recovery sites were combined in one table but not discretely identified. The list of sites differed from that in the original *Western Shield* proposal and contained 39 sites in total. Fauna translocations involving 12 species have been conducted to 18 of those 39 sites, and fauna have been sourced from five sites to facilitate translocations. A further 13 species have been translocated to sites other than those identified in the draft 'Western Shield Strategic Plan', primarily because of the site and habitat specific needs of those species. Five of the sites identified are currently not baited to control foxes and a further two sites have only been baited for 12 months, and are not considered secure enough to commence translocations yet.

In light of the knowledge CALM now has on the requirements of each species and the apparent suitability of each fauna reconstruction site and species recovery site identified by Burbidge *et al.* (1995) it is recommended

that all of the 13 fauna reconstruction sites listed be retained as such, while the species recovery sites: Karroun Hill Nature Reserve, Noggerup State Forest, Ravensthorpe Range, Saddleback-Quindanning State Forest and Yabberup Forest be deleted or replaced with more suitable sites. With regard to sites listed in the draft 'Western Shield Strategic Plan' it is recommended that Gervase State Forest, Scott River National Park, Karroun Hill Nature Reserve be deleted or replaced with more suitable sites. Wheatley State Forest should be replaced with Easter and Barlee State Forests as these two sites are further to the west and have already received woylies in formal translocations (see Table 1). The decision to delete or replace sites should be based on CALM's ability to bait and monitor those sites effectively, and the range of habitats that these sites can provide for species that are the subject of translocation programs. It is probably also appropriate at this point in time to reassess the list of fauna reconstruction sites and give consideration to adding new sites or replacing some currently listed sites with better alternatives in light of the results of fauna monitoring at those sites and the current and proposed baiting regimes.

Influence of changing climate

The suitability of the current fauna reconstruction sites and species recovery sites in light of recent and predicted climate change requires a considerable amount of subjective assessment. The recent climate changes (over the last 30 years) have been taken into consideration in choosing reconstruction and recovery sites, and for the most part those choices have proven valid. The drought that is affecting most of the southwest of the State (2000-2002) is providing a useful reminder of the natural variation in rainfall and is also providing CALM with a unique opportunity to monitor the natural response of a range of mammal species to drought in the areas where fox predation is controlled or absent. The information available from the Indian Ocean Climate Initiative and modeled by the CSIRO suggests that in the next 30 years rainfall will continue to decrease in the southwest and the number of days above 30°C will increase in summer and the winter minima will also increase. Plant groups such as *Dryandra* will be significantly affected and many species will be lost, and some of the *Acacia* species growing in the high rainfall parts of the southwest will be lost. The flow-on effects of these types of changes, many of which will be even more extreme by 2070 suggest that many of the sites we have identified for fauna translocations in the northern and eastern wheatbelt, particularly those located away from coastal influences will probably become unsuitable for some species of mammal. The native frog species will also be adversely affected, making translocations for this group of fauna difficult if not impossible.

For a number of species that are currently captive-bred and then translocated (e.g. bilby, mala, banded hare-wallaby) we do not know enough of their ecological tolerances to know whether translocations into arid areas

will continue to be possible. Species that are currently limited to mesic areas (e.g. numbat and woylie) but had a much wider distribution including arid areas may not survive in those arid areas in the future. It is also likely that the amount of effort required to successfully establish viable populations will increase (i.e. multiple releases will be required in more than one year). This will place additional calls on financial, staff and captive-breeding resources. For species that currently have fragmented distributions in mesic environments (e.g. quokka on the mainland, tammar wallaby, black-flanked rock-wallaby) it is possible that these species will become extinct in those parts of their current distribution that will be most affected by climate change.

Aside from the actual loss of those populations, the predicted climatic change will also probably result in elevated threat categories for those species placing an increased obligation on CALM to take remedial action (i.e. species currently ranked VU will change to EN or CR in accordance with CALM Policy Statement 50). Added to this is the likelihood that a number of species currently not considered threatened (i.e. Lower Risk (nt)) will actually become threatened (e.g. western mouse, brush-tailed phascogale and water rat) increasing the number of species that will require action to be taken to conserve them. Several species currently restricted to the Kimberley and Pilbara (e.g. long-tailed dunnart, rock ringtail, scaly-tailed possum, monjon, spectacled hare-wallaby, black-footed tree rat and golden-backed tree rat) may also fall into this category meaning we will have to deal with this issue on more than one front. The cost and staff resource implications of such a scenario could not be managed under the current *Western Shield* structure and budget.

There is no evidence to suggest that any of the species that are the subject of translocations or captive breeding programs will benefit from the likely climate changes in the southwest, although there may be some species that are not directly affected.

Integration with species recovery plans

The second objective in the draft 'Western Shield Strategic Plan' incorporated a need to integrate *Western Shield* predator control and fauna monitoring with species recovery plans. Recovery plans have not been written for all of the threatened species (e.g. banded hare-wallaby, western barred-bandicoat and red-tailed phascogale) and some of these species have already been the subject of fauna translocations (e.g. banded hare-wallaby and western barred-bandicoat). Some species do have recovery plans written for them, but the recovery plans are national ones (e.g. mala and bilby) and the meetings are held outside of Western Australia on most occasions making attendance by CALM staff difficult at times. The Western Shield Zoologist attends species recovery team meetings for the numbat, Shark Bay mouse, western ringtail possum and dibbler. The Western Shield Zoologist currently does not attend recovery team meetings for Gilbert's potoroo,

noisy scrub-bird, western bristlebird, western ground parrot or malleefowl although not all of these species currently have translocations as a recovery action. There is scope to improve this situation and to ensure that any decisions made with regard to translocations are done so with access to all relevant information and experience.

Cooperative arrangements

The third objective included a requirement to establish cooperative arrangements with community groups, wildlife carers, wildlife sanctuaries and Perth Zoo to achieve fauna recovery and educational outcomes. The Department has a lengthy history of arrangements with the Perth Zoo for the captive breeding of chuditch, Shark Bay mouse, numbat, dibbler, Lancelin Island skink and western swamp tortoise. The chuditch and Shark Bay mouse programs have now been completed. The Department also has a financial arrangement with the Kanyana Rehabilitation Centre to house, feed and breed bilbies and western barred-bandicoats with the progeny made available to CALM for release at designated sites of its choosing. The details of the productivity of these various programs are covered elsewhere (see Mawson this issue).

Since 1995 CALM has had a formal relationship with what is now the Australian Wildlife Conservancy (AWC), which owns and operates Karakamia and Paruna Sanctuaries and Faure Island, Mount Gibson and Mornington Stations (all pastoral leases). CALM has provided six species of animal for translocation into Karakamia Sanctuary and four species of animal (directly or indirectly) for translocation into Paruna Sanctuary. A further two species of animal have been provided from captive-bred sources external to CALM for translocation to Faure Island, but CALM has had a direct involvement in the development and approval of the translocation proposals for all of these activities in accordance with the department's policy statement (No. 29). In late October 2002 the AWC was able to supply woylies to the CALM to facilitate a translocation of this species into Avon Valley National Park.

Until recently (2000) there had been only limited opportunity for the community to become involved in fauna aspects of *Western Shield*, primarily by accompanying CALM staff on fauna monitoring field trips. Depending on the age and experience of the individuals their participation in the fieldwork varies from observation, to carrying bait buckets, to recording data obtained by CALM staff (e.g. morphometrics, tag identification) to actively assisting in trap clearance. Specific educational opportunities have been developed for school groups and school teachers and are described in detail by Kawalilak *et al.* this issue).

Community groups and school groups have also been invited to participate at the release events for a number of fauna translocations, and several of these events have been reported in local media (print, radio and television), along with delayed accounts in internal CALM communication

media (CALM's Intranet, *Western Shield Newsletter*, *WATSNU* and *Conservation News*). In 2001–2002 a small number of translocations were conducted that benefited from the direct involvement of a small number of community members (registered wildlife carers, Land for Wildlife registrants and volunteers from groups such as the Chittering Landcare Centre, Swan River Trust, Muchea Tree Farm and Bullsbrook Scouts) physically assisting in the transport and release of black-flanked rock-wallabies from access tracks to more remote release sites. These interactions received wide media coverage and were well received by those involved.

WHY TRANSLOCATE SPECIES THAT ARE NOT THREATENED?

During the period 1996–2002 five (5) species of mammal that are currently not listed as threatened species have been translocated to fauna reconstruction sites and fauna recovery sites. Four of those species (woylie, tammar wallaby, quenda and Thevenard Island mouse) were listed as threatened species at the time they were first translocated, but were subsequently de-listed (see section text and Table 2, above). Additional translocations of these species will further secure their conservation status and contribute to the reconstruction of fauna assemblages found at the time of European settlement of Western Australia.

The Thevenard Island mouse was translocated only once (to Serrurier Island) before the taxonomic status of the population was resolved. Since the translocation was successful there was no further requirement to conduct additional translocations for this insular population.

The woylie was de-listed in 1996 on the basis of the success of translocations conducted prior to *Western Shield* commencing, but it was considered appropriate to continue to translocate this species for two reasons. First, the woylie's former distribution was far more extensive than that occupied in 1996 and it was a recorded part of the mammal fauna in nearly all parts of the southwest, hence there was still justification for continuing to translocate this species to baited areas after the species was de-listed. Second, the woylie breeds rapidly and if the habitat is suitable and predators are adequately controlled it is a very useful indicator species. If woylies are unable to survive in fauna reconstruction and species recovery sites with inadequate protection from fox predation then it is almost guaranteed that more susceptible species will also fail. In this respect woylies are used as pioneer species to evaluate the adequacy of fox control. Woylies also provide an ideal species to further develop the animal handling skills acquired during the CALM training course that can then be applied to other species at a later date. Woylies also provide good media and community involvement opportunities during translocations and standard monitoring programs.

Quenda were de-listed in 1998 and are one species where remnant natural populations have shown some

capacity to recover where fox baiting is applied, but the species has little or no dispersal capabilities especially where the suitable habitat is fragmented. Development of remnant vegetation sites in the Perth metropolitan area continues subject to the requirements of the human population. Research has shown that quenda do not respond well to being progressively pushed out of their home ranges into adjacent bush areas, and invariably die of starvation, predation or are killed on roads. Populations that inhabit lands subject to development can be salvaged and translocated to secure conservation estate with costs met by the land developers. All of the quenda translocations listed in Table 1 were the result of animals being salvaged from development / roadwork sites and the costs associated with the capture, relocation and for the most part the monitoring were met by the developers. This type of translocation will continue to arise in the future, and given that quenda were formerly distributed from Kalbarri south and east to Cape Arid there is no reason why this species should not continue to be translocated.

The tammar wallaby was also de-listed in 1998, primarily due to the number of island populations that still exist. However, this species has suffered significant reductions in its range on the mainland, and like the quenda, does not have the capacity to re-colonize suitable habitat without human assistance. All of the tammar wallaby translocations reported in Table 1 have been based on animals sourced from either the Perup Forest or Tutanning Nature Reserve. The tammar wallaby populations at both of these sites have increased dramatically following the establishment of fox control programs and at both sites the tammar wallabies now cause damage to cereal crops grown on private property adjacent to lands managed by CALM. Given that the tammar wallaby is not listed as threatened it is possible to consider issuing damage licences authorizing the destruction of wallabies damaging crops, but it is just as effective and of greater conservation value to capture and translocate animals to new sites where they will not have the opportunity to damage crops. The costs of translocation are borne by CALM, while the costs of destruction would be borne by the landholders, but the political and conservation benefits of translocation mean that the current approach is preferable.

The single translocation of Euros resulted from a need to relocate 29 captive-bred animals from a licensed wildlife park that closed down. Translocation was considered more acceptable than euthanasia of the animals. There is no intention to repeat this process for Euros in the future.

The issue of when a species would no longer be considered for translocation was not specifically addressed by either Burbidge *et al.* (1995) or in the Draft Strategic Plan. However, there is a clear intent in both documents for fauna reconstruction and species recovery sites to receive as many of those species that originally occurred there as possible. The fact that a species' conservation status has improved sufficiently for it to be de-listed from any of the threat categories should not preclude it from

being used in subsequent translocations. If such a narrow view of translocation acceptability had been taken then the total number of translocations that would have taken place would be only 51, which is 32 less than the total of 83 that have actually occurred in Western Australia 1996–2002.

The difficulties involved in breeding and establishing some species that are currently bred as part of the *Western Shield* program means that only a few translocations of threatened species will be possible in some years. While the reasons for this are understandable from a scientific viewpoint there may be less appreciation of this amongst the general public. It would be inadvisable to cease translocations of non-threatened species such as woylies, quenda and tammar wallabies purely because an arbitrary decision had been made to translocate only those species that were listed as threatened at the time of the translocation. To take such a position would be difficult to justify given the lack of certainty that any particular translocation would be successful, and the fact that the very success of those translocations would be a factor contributing to the CALM's ability to de-list a species. Adopting this stance would also place CALM at risk of losing some of the current public support that has been built up largely through the participation of the public in translocations of non-threatened species.

Probably the most important reason for continuing to translocate non-threatened species such as the woylie and quenda are that species such as these have an important role to play in re-invigorating ecosystem function. Work on the woylie (Garkaklis *et al.* 1998; Garkaklis 2001; Garkalis *et al.* 2000) and the quenda (Watson 2002) has shown that the digging carried out by these two species has a significant impact on soil turnover, water penetration, redistribution of surface and subsurface nutrients, dispersal of fungal spores and seeds (e.g. *Santalum* sp.; Murphy 2002; Murphy *et al.* 2002). Our understanding of these processes is currently limited but it would seem intuitive that many of the ills that native vegetation communities are experiencing might be overcome if some of these key ecosystem processes were restored.

TRANSLOCATION OF SPECIES IN RELATION TO CALM POLICY STATEMENT 50

Policy Statement 50 sets out the process by which priorities are established for the conservation of Western Australia's threatened flora and fauna. The policy stipulates that;

- at least every two years threatened taxa are ranked according to the procedures laid down in the Policy Statement
- that all taxa identified as Critical are conserved, through the preparation and implementation of recovery plans or interim wildlife management guidelines / interim recovery plans and that taxa

identified as Endangered and Vulnerable are allocated research and management resources in priority order

- conservation action for taxa identified as Critical commences as soon as possible and always within one year of endorsement of that rank by the Minister.

An examination of the current listing of fauna species that have been translocated, or could be considered for translocation, as part of *Western Shield* activities (see Table 2) indicates that recovery plans have been written and implemented for the two most endangered species [western swamp tortoise (CR) and mala (EW)]. No recovery plans or interim recovery plans have been written for two of the three species ranked as Endangered (western barred-bandicoot and red-tailed phascogale), while an interim recovery plan has been written for the dibbler. Recovery plans have been written for a number of Vulnerable taxa (numbat, chuditch, bilby, greater stick-nest rat, Shark Bay mouse, malleefowl, noisy scrub-bird, Lancelin Island skink and orange-bellied frog) and Interim Recovery Plans have been written for others [banded hare-wallaby (draft only) and western ringtail possum]. A draft recovery plan has also been written for Gilbert's potoroo.

While the current IUCN threat status of some of the species mentioned above has been downgraded since the recovery plans and interim recovery plans were first written, there are still some examples of Endangered species that do not seem to have been dealt with according to the priority setting process outlined in Policy Statement 50. This is despite active research on these species by CALM staff at some time in the recent past (e.g. red-tailed phascogale), and that one species (western barred bandicoot) is currently maintained in captive breeding facilities and has been the subject of translocations to Heirisson Prong in Western Australia and to Roxby Downs in South Australia.

COMPARATIVE EFFORT TOWARDS WESTERN SHIELD AMONGST CALM REGIONS

A range of factors is likely to influence the amount of effort that each CALM region might be able to contribute towards the *Western Shield* program. These factors include the number of trained staff present in each region at any one time, the number of suitable release sites for fauna that have been baited for a sufficient period to achieve an adequate reduction in fox numbers, the number of extant populations of fauna that could be used to provide animals for translocation within and beyond each region, the funding available within each region's nature conservation allocation, and the ability and willingness of regional staff to get involved in the program and to initiate translocations (e.g. author translocation proposals).

Translocations under the *Western Shield* program have been largely restricted to the southwest of the State, Francois Peron National Park, Heirisson Prong and three islands off the Pilbara coast and two islands off the

Midwest coast. A summary of fauna translocations conducted under the *Western Shield* banner 1996–2002 in relation to the CALM regional structure is set out in Table 4.

Some of the fauna recovery sites listed in Burbidge *et al.* (1995) and the Draft Strategic Plan were included primarily, or solely because they were locations supporting significant extant populations of threatened species that were likely to be used as source populations for fauna translocations (e.g. Perup Forest for woylies and tammar wallabies; Mount Caroline Nature Reserve for black-flanked rock-wallaby; Tutanning Nature Reserve for tammar wallabies). A comparison between the number of translocations conducted in each CALM region with the number of translocations involving animals sourced from those same regions produces some interesting results (Table 5).

The Pilbara region has received eight translocations; four (3 species) to islands (Trimouille, Doole, Northwest and Serrurier Islands) and four (1 species) to mainland sites (all sites in the Hamersley Ranges). The island translocations all involved captive-bred stock while the mainland translocations involved wild-caught stock. The Midwest region has received translocations to Francois Peron National Park (5 species), Faure Island (AWC operated, 2 species), Heirisson Prong (3 species), Kalbarri National Park (2 species) and two islands off Jurien (2 species). All of these animals with the exception of woylies to Francois Peron and Kalbarri national parks were derived from captive-bred stocks. No translocations were

conducted using animals sourced directly from the wild in this region.

The Wheatbelt region has received only nine (9) translocations of six species to five sites (Lake Magenta, Tutanning, Dragon Rocks and Boyagin Nature Reserves and Dryandra Forest) while providing founder populations for 25 translocations to other regions, but none to sites within Wheatbelt region. The Swan region has received 44 translocations to 12 sites involving nine species. Two of these sites are managed by the AWC and have received six species between them. The other ten sites are managed by CALM and have received eight species between them. Three species from a number of sites have been sourced from the wild for translocations within the region, and the remaining species have come from captive-bred stocks.

The Southwest region has received only eight translocations (six species) to eight sites. Batalling Forest has provided woylies for eight translocations within and external to the region and western ringtail possums have been sourced from the wild for translocations on two occasions and orange-bellied frogs from one site on one occasion. The Warren region has received 14 translocations (four species) to 12 sites. Perup Forest has provided woylies and tammar wallabies for 13 translocations within and external to the region. The South Coast region has received only four translocations to four sites (4 species) and has provided source populations for two translocations (1 species).

TABLE 4

Numbers of translocations conducted according to location of the release site within various CALM Regions. (Note: Some translocations of fauna approved as a single translocation are counted in each year that animals were released, hence the totals do not match those in Table 1).

CALM REGION	YEAR							TOTAL
	'96	'97	'98	'99	'00	'01	'02	
Midwest	1	2	4	2	5	4	2	20*
Wheatbelt	3	2	2	0	1	1	0	9
Swan	6	6	7	6	7	9	3	44
Southwest	1	0	2	0	5	0	0	8
Warren	0	0	4	5	3	0	5	17
South Coast	0	1	2	1	2	0	0	6
Pilbara	3	3	1	1	0	0	0	8**

* Includes 8 translocations to islands. ** Includes 3 translocations to islands.

Note: No translocations have been conducted in either the Kimberley or Goldfields regions to date.

TABLE 5

Number of translocations conducted according to the location of the source populations of animals within various CALM Regions for the years 1996–2002. (Note: Some translocations of fauna approved as a single translocation are counted in each year that animals were released, hence the totals do not match those in Table 1 above.)

CALM REGION	YEAR							TOTAL
	'96	'97	'98	'99	'00	'01	'02	
Midwest	1	0	1	1	0	1	1	5
Wheatbelt	3	4	4	3	4	4	3	25
Swan	2	1	1	0	4	1	0	9
Southwest	4	5	5	3	7	2	0	26
Warren	0	0	5	3	2	0	5	15
South Coast	0	1	1	2	1	0	0	5
Captive-bred	2	5	7	5	6	7	1	33

TABLE 6

Translocation history according by CALM Region / Division or external institution for the senior author of the translocation proposals for the years 1996–2002. (Note: Some translocations of fauna approved as a single translocation are counted in each year that animals were released, hence the totals do not match those in Table 1 above).

ORIGIN OF AUTHOR BY CALM REGION	NUMBER OF PROPOSALS	ORIGIN OF AUTHOR BY CALM REGION	NUMBER OF PROPOSALS
Midwest	5	South Coast	1
Swan	3	Science Division	25
Wheatbelt	1	Wildlife Branch	10
Southwest	5	Australian Wildlife Conservancy	10
Warren	13	CSIRO, UWA	5

There are now only three Science Division staff members actively engaged in research work on fauna species covered under *Western Shield* (one each on mammals, birds and reptiles). Three other staff are involved in research on cat control techniques. The small number of Science Division staff working on species covered under *Western Shield* relative to the total Division commitment seems at odds with the corporate priority that the program is meant to have. This issue may need to be reviewed.

When the results shown in Tables 4–7 are considered in concert it is clear that that effort being directed to *Western Shield* varies greatly between CALM regions and that in the Wheatbelt and South Coast regions in particular opportunities to advance conservation efforts through translocations are not being taken up with anywhere near the resolve that is being shown elsewhere. It will be important to clarify why there is such disparity in effort between regions and to ensure that there are clear directives from the CALM Executive that *Western Shield* is a corporate conservation program and that it is amongst the department's higher priorities.

COLLABORATIVE EFFORTS WITH ACADEMIC /TERTIARY AND OTHER RESEARCH INSTITUTES

During the seven years that the *Western Shield* program has been running a respectable list of student research projects have been initiated and completed covering a wide range of research fields and focusing on a considerable array of species (threatened and non-threatened).

Topics that have been covered include; biology, physiology, genetics, bioperturbation, reproductive ecology, conservation biology (via translocations) and the impacts of predators and eco-tourism. The various tertiary institutions that have been involved are detailed below along with the species of animals that have been studied by students from those institutions. With time the nature and focus of the research projects have become more refined and there has been a move towards an increase in the number of outcomes that have direct relevance to fauna conservation and management, two issues that will greatly improve the department's capacity to achieve better outcomes through *Western Shield*. Most of these projects

TABLE 7

Translocation history matrix (species x CALM Region) for the years 1996–2002. (Note: Some translocations of fauna approved as a single translocation are counted in each year that animals were released, hence the totals do not match those in Table 1 above).

	MIDWEST	WHEATBELT	SWAN	SOUTHWEST	WARREN	SOUTH COAST	PILBARA
Quokka			1				
Banded hare-wallaby	1						
Black-flanked rock-wallaby			2				
Tammar wallaby			5	1	4		
Woylie	2	1	2	7	10		
Boodie	2						
Mala	1						
Euro	1						
Numbat		2	2	1		1	
Quenda		1	6			1	
Western barred-bandicoot	1						
Bilby	1	1					
Chuditch	1	1			1	1	
Dibbler	1					1	
Western ringtail			3	1			
Greater stick-nest rat	1						
Shark Bay mouse	2						2
Malleefowl	1						
Noisy scrub-bird				1			
Western bristle-bird					1		
Western swamp tortoise			3				

have been conducted with only in-kind contributions provided by CALM, although a small number of the more recent projects have had direct financial input from CALM as well as access to data, field support and student supervision.

Universities

University of Western Australia – quokka, woylie, western swamp tortoise, numbat, chuditch, western barred-bandicoot, heath rat, pebble-mound mouse, dibbler, Gilbert's potoroo, brush-tail possum

Edith Cowan University – chuditch, quenda, woylie, banded hare-wallaby, mala

Murdoch University – brush-tail phascogale, woylie, quokka and western barred bandicoot (via Pest Animal Control CRC and Marsupial CRC), feral cat

Curtin University – western ringtail possum

Notre Dame University – chuditch

Charles Sturt University – woylie

University of New South Wales – quokka, western ringtail

University of Western Sydney – western barred bandicoot

Australian National University – western ringtail possum

Other research facilities

CSIRO – greater stick nest-rat, western barred-bandicoot, boodie, Tunney's rat

Pest Animal Control CRC – quokka, woylie, brush-tail possum

Perth Zoo/Marsupial CRC – dibbler, brush-tail possum, quokka

CONCLUSION

While *Western Shield* has provided many successful translocations, some have failed and it is still to soon to judge many others. There have also been significant departures from the original background document (see Burbidge *et al.* 1995) in relation to both the species used and at the areas covered. While this is basic adaptive management in practice, it is also apparent that there is a need for CALM to renew its commitment to the project and to direct some management and resource attention to regions such as the South Coast and Wheatbelt to ensure a consistent level of commitment within the overall *Western Shield* program.

REFERENCES

- Burbidge AH (1999) Translocation proposal for the western bristle-bird. Department of Conservation and Land Management, Western Australia.
- Burbidge A, Kuchling G, Fuller PJ, Graham G, Miller D (1990) The western swamp tortoise. Wildlife Management Program No. 6. Department of Conservation and Land Management, Western Australia.
- Burbidge AA, Start AN, Morris KD, Armstrong R (1995) '*Western Shield* – Bringing back our wildlife.' Department of Conservation and Land Management, Western Australia.
- CALM see Department of Conservation and Land Management
- Danks A, Burbidge AA, Burbidge AH, Smith GT (1996) Noisy scrub-bird recovery plan. Wildlife Management Program No. 12. Department of Conservation and Land Management, Western Australia.
- Department of Conservation and Land Management (1995) Translocation of Threatened Flora and Fauna. Policy Statement No. 29, July 1995. CALM, Western Australia.
- Department of Conservation and Land Management (1999) 'Draft *Western Shield* Fauna Recovery Program – Strategic Plan (July 1999-June 2004).' CALM, Western Australia.
- Friend JA (1994) Recovery plan for the numbat (*Myrmecobius fasciatus*) 1995-2004. Western Australian Wildlife Management Program No. 18. Department of Conservation and Land Management, Western Australia.
- Friend JA (2001) Translocation proposal for dibbler (*Parantechinus apicalis*) from Perth Zoo to Peniup proposed Nature Reserve. Department of Conservation and Land Management, Western Australia.
- Friend JA, Orell P (2000) Translocation proposal: re-introduction of bilby (*Macrotis lagotis*) to Dryandra woodland from Return To Dryandra breeding colony enclosures and Kanyana Captive breeding colony. Department of Conservation and Land Management, Western Australia.
- Garkaklis MJ (2001) 'Digging by the woylie *Bettongia penicillata* (Marsupialia) and its effects upon soil and landscape characteristics in a Western Australian woodland.' Ph.D. thesis, Murdoch University, Western Australia.
- Garkaklis MJ, Bradley JS, Wooller RD (1998) The effects of woylie foraging on soil water repellency and water infiltration in heavy textured soils in southwestern Australia. *Australian Journal of Ecology* **23**, 492-496.

- Garkaklis MJ, Bradley JS, Wooller RD (2000) Digging by vertebrates as an activity promoting the development of water-repellant patches in sub-surface soil. *Journal of Arid Environments* **45**, 35-42.
- IUCN (1987) The IUCN position statement on translocation of living organisms: introductions, re-introductions and re-stocking. IUCN, Gland, Switzerland.
- Kawalilak R, Higgs N, Moore E (2004) Communications, community awareness and schools education programs: *Western Shield* review–February 2003. *Conservation Science W. Aust.* **5** (2) 96-107. Department of Conservation and Land Management, Western Australia.
- Mawson PR (2004) Captive breeding programs and their contribution to *Western Shield*: *Western Shield* review–February 2003. *Conservation Science W. Aust.* **5** (2) 122-30. Department of Conservation and Land Management, Western Australia.
- Morris KD, (1993) Interim wildlife management guidelines for the Thevenard Island mouse *Leggadina* aff. *lakedownensis*. Department of Conservation and Land Management, Western Australia.
- Morris K, Barton B (1996) Translocation proposal for malleefowl - eggs from nest in the wild to be incubated and subsequent young released into Francois Peron National Park. Department of Conservation and Land Management, Western Australia.
- Morris K, Short J (1999) Translocation proposal for greater stick-nest rat: Salutation Island to Heirisson Prong. Department of Conservation and Land Management, Western Australia.
- Morris K, Sims C, Himbeck K, Christensen P, Sercombe N, Ward B, Noakes N (2004) *Project Eden* - fauna recovery on Peron Peninsula, Shark Bay: *Western Shield* review–February 2003. *Conservation Science W. Aust.* **5** (2), 202-234. Department of Conservation and Land Management, Western Australia.
- Morris K, Speldwinde P, Orell P, (2000) Djoongari (Shark Bay mouse) recovery plan. Wildlife Management Program No. 17. Department of Conservation and Land Management, Western Australia.
- Murphy MT (2002) 'Caching of sandalwood (*Santalum spicatum*) by the woylie (*Bettongia penicillata*) in Dryandra woodland.' B.Sc. (Hons) thesis, Murdoch University, Western Australia.
- Murphy M, Garkaklis MJ, Pronk G, Dell G, Hardy G (2002) The role of caching by woylies (*Bettongia penicillata*) in the development of a sustainable sandalwood industry. Ecological Society of Australia Symposium, Cairns.
- Orell P (2004) *Western Shield* : Fauna monitoring and staff training 1996-2002: *Western Shield* review–February 2003. *Conservation Science W. Aust.* **5** (2) 51-95. Department of Conservation and Land Management, Western Australia..
- Orell P, Dans P (2002) Translocation proposal for black-flanked rock-wallaby (*Petrogale lateralis lateralis*) from Mount Caroline Nature Reserve and Querekin Rock to Walyunga National Park. Department of Conservation and Land Management, Western Australia.
- Orell P, Morris K (1994) Chuditch recovery plan. Wildlife Management Program No. 13. Department of Conservation and Land Management, Western Australia.
- Pearson D, Jones B (2000) Lancelin Island skink recovery plan. Wildlife Management Program No. 20. Department of Conservation and Land Management, Western Australia.
- Short J (1995) Interim recovery plan for the western barred bandicoot (*Perameles bougainville*). CSIRO Division of Wildlife and Ecology, Perth.
- Short J, Friend AJ (1995) Translocation proposal for the western barred bandicoot. CSIRO and Department of Conservation and Land Management, Western Australia.
- Short J, Turner B (2000) Reintroduction of the burrowing bettong *Bettongia lesueur* (Marsupialia: Potoroidea) to mainland Australia. *Biological Conservation* **96**, 185-196.
- Sims C (1997) Methodology for relocation of Euros from Useless Loop to Carrarang Station. Department of Conservation and Land Management, Western Australia.
- Sims C, Barton B (1997) Translocation proposal for malleefowl - eggs from nest in the wild to be incubated and subsequent young released into Francois Peron National Park. Department of Conservation and Land Management, Western Australia.
- Start T, Burbidge A, Armstrong D (1995) Woylie recovery plan. Wildlife Management Program No. 16. Department of Conservation and Land Management, Western Australia.
- Start AN, Anstee SD, Endersby M (2000) A review of the biology and conservation status of the ngadji, *Pseudomys chapmani* Kitchener, 1980 (Rodentia: Muridae). *CALMScience* **3**(2), 125-147.
- Wardell-Johnson G, Roberts JD, Driscoll D, Williams K (1995) Orange-bellied and white-bellied frogs recovery plan. Wildlife Management Program No. 19. Department of Conservation and Land Management, Western Australia.
- Watson KE (2002). An experimental comparison of digging activity and soil displacement by the southern brown bandicoot (*Isodon obesulus*) and the woylie (*Bettongia penicillata*) in southwestern Australia. B. Sc. (Hons) thesis, Murdoch University, Western Australia.

Captive breeding programs and their contribution to *Western Shield: Western Shield* review—February 2003

PETER R. MAWSON¹

¹Senior Zoologist, Wildlife Branch, Department of Conservation and Land Management,
Locked Bag 104 Bentley Delivery Centre WA 6983. peterm@calm.wa.gov.au

SUMMARY

Objectives

The objectives were to establish a number of captive breeding facilities throughout the State of Western Australia to minimize the risk at any one facility and to captive breed up to 11 species of fauna.

Achievements

Three Department of Conservation and Land Management (CALM) captive breeding facilities (Project Eden, Return to Dryandra and Gilbert's potoroo) have been established with financial support provided to a further two breeding programs (Perth Zoo and Kanyana Rehabilitation Centre). A fifth facility has been established by the CSIRO to produce animals for release at Heirisson Prong.

Fourteen threatened species have been, or are being bred to produce animals for release into the wild at suitable locations.

Difficulties

Some species have proven difficult to breed in captivity with little or no net production (e.g. Gilbert's potoroo). For other species there are clear differences in the net production of animals using different husbandry techniques (i.e. intensive versus extensive rearing facilities).

A small number of species have proven relatively easy to breed under one or other husbandry system but there is a shortage of safe translocation sites that these animals can be released into. This has resulted in some species being held in captivity in higher numbers, and for longer periods of time than would be preferable. This problem has been further exacerbated by the extensive impacts of the drought that has affected south-west Western Australia for the last two years.

Release of all of these threatened species invariably requires intensive monitoring for the first and often subsequent translocations. The considerable resources (radio transmitters and staff time) required to adequately monitor the translocated animals to ensure that they survive and to promptly identify any threats also provide a serious impediment to timely releases of animals.

Unforeseen problems, such as those affecting the captive breeding of western barred-bandicoots have led to the suspension of the breeding program for this species pending the resolution of the disease issues encountered in wild and captive stocks. Even when this issue has been resolved consideration should be given to restricting captive breeding of this species to intensive breeding situations, with progeny being transferred direct to the wild.

The extensive pen arrangement used to breed banded hare-wallabies and mala at Dryandra do not appear to suit these species given the problems associated with predation. Consideration should be given to discontinuing the breeding of these species at Dryandra and focusing on those species that do well in extensive pen situations (e.g. bilby and boodie).

The very large in-kind contribution that the Kanyana Rehabilitation Centre provides towards the breeding of bilbies and western barred-bandicoots relative to the current financial contribution provided by the CALM is cause for concern. It is probably unreasonable to expect this level of contribution to continue in the future and efforts should be made to better compensate the Kanyana operation for its contribution.

Potential Economies

The results provided in Table 3 clearly indicate that some species breed better under particular types of husbandry management. Therefore consideration should be given to rationalizing the range of species kept under particular types of husbandry techniques at some of the facilities. Specifically western barred bandicoots should be removed from any captive breeding program until a clear resolution of the disease issues is achieved. The use of volunteer labour should be tempered with a consideration for the need to establish health monitoring procedures to ensure that information recorded on the status of captive animals is of a consistent quality.

Potential Improvements

Conduct a detailed analysis of costs of the Peron and Dryandra facilities to identify where the major cost items are. If staff labour costs are the major item consider outsourcing basic tasks such as feeding animals and cleaning pens. This can help reduce costs while providing an opportunity for greater community involvement.

Discussions should also be held with the Perth Zoo to determine which additional species could be bred at the Zoo and then compare those cost estimates to figures for comparable CALM programs.

Experience with numbats and dibblers suggests that consideration needs to be given to preparing captive bred animals for release with respect to their level of predator awareness, familiarity with more natural food items and an avoidance of providing food at standard times of the day.

INTRODUCTION

The original *Western Shield* document (Burbidge *et al.* 1995) did not make any mention of the possible need to captive-breed native animals to provide founding stock for fauna translocations. Shortly thereafter the need for captive breeding was appreciated and this was reflected by its inclusion in the Priorities section of the draft 'Western Shield Strategic Plan' (CALM 1999).

There were five key points defined in the draft 'Western Shield Strategic Plan' that related to captive breeding.

- Only those species that could not be readily translocated from existing wild populations will be bred in captivity;
- Threatened species will be favoured over non-threatened species for captive breeding;
- Species will only be bred in captivity if release sites within suitable habitat are available;
- Captive breeding facilities will be maintained at several sites to manage the risk of failure or loss; and
- Species will be bred for release in Western Australia unless required by a species recovery plan to be released elsewhere.

These points were combined in Objective 1 of the strategic plan as 'Develop captive breeding facilities where necessary for threatened fauna.' Specific targets were also set with respect to captive breeding with 'Up to eleven species of fauna (mala, boodie, banded hare-wallaby, bilby, western barred-bandicoot, malleefowl, chuditch, numbat, dibbler, djoongari (Shark Bay mouse), Gilbert's potoroo) will be in captive breeding programs at the Peron and/or Dryandra facilities or another appropriate facility such as Perth Zoo.' No performance indicators were specified for the captive breeding component of the draft 'Western Shield Strategic Plan'.

This review will examine the breeding outputs for the various captive breeding facilities that have been established in Western Australia, including those managed by organizations other than CALM. The data presented here are as accurate as possible and are derived from a number of sources both within and external to CALM.

WHERE ARE THE CAPTIVE BREEDING FACILITIES IN WESTERN AUSTRALIA?

There are currently five facilities in Western Australia that are breeding, or have bred species of threatened fauna for

the purpose of providing founding stock for fauna translocations. These are considered in a separate review paper on fauna translocations for Western Shield (Mawson, this issue).

CALM has constructed two purpose-built multi-species captive breeding facilities; one at Francois Peron National Park near Denham and the other at Dryandra Forest near Narrogin. The program at Francois Peron National Park is run under the name 'Project Eden' and an overview of this program is provided in a separate review paper (Morris *et al.*, this issue). The facility at Dryandra is run under the project name 'Return to Dryandra' and an overview of this program is also provided in a separate review paper (Friend and Beecham, this issue). For the purpose of this review paper the outputs of these facilities are presented here along with those of the facilities identified below in order to allow direct comparisons between the different types of facilities and the breeding performance of the various species under different regimes.

CALM also runs a single-species captive breeding facility at Two Peoples Bay Nature Reserve (near Albany) as part of the recovery plan for the critically endangered Gilbert's potoroo (*Potorous gilbertii*).

In addition to those facilities CALM also provides financial support for the captive breeding of two species of threatened fauna at the Kanyana Rehabilitation Centre in Goosberry Hill (an outer suburb of Perth), however the day-to-day management of the Kanyana facility is organized by a voluntary wildlife carers.

The Perth Zoo, the statutory zoo in Western Australia, runs captive breeding facilities for a number of species in collaboration with CALM. The CSIRO and the Useless Loop community (located on the Heirisson Prong on the western edge of Shark Bay), in conjunction with Shark Bay Salt Joint Venture run a captive breeding facility for three species of threatened fauna.

TYPES OF CAPTIVE BREEDING FACILITIES

The captive breeding facility at Francois Peron National Park is an intensive breeding facility that utilizes small mesh-covered pens as well as larger outdoor pens that accommodate breeding pairs or small family groups of animals (Morris *et al.*, this issue). The facility at Dryandra is an extensive breeding facility consisting of two 10ha pens, with animals of several species kept in the pens simultaneously (Friend and Beecham, this issue).

The Gilbert's potoroo captive breeding facility consists of a series of small open-air pens. The captive breeding facilities at Kanyana Rehabilitation Centre are similar to those at Francois Peron National Park and cater for pairs or family groups of animals in open-air, but roofed facilities.

The captive breeding facilities at the Perth Zoo included both outdoor and indoor facilities for different species, with specialized indoor incubation facilities for the western swamp tortoise eggs. Chuditch, numbats and

greater stick-nest rats were maintained in outdoor pens, while Shark Bay mice and dibblers were maintained in indoor facilities.

WHICH SPECIES ARE CAPTIVE BRED AND WHY?

Fourteen species of native animal are being, or have been bred in captivity to provide founding stock for translocations to the wild (Table 1). All 14 species are listed as threatened species under the Western Australian *Wildlife Conservation Act 1950* and are also listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. All of these species are ones that occur in such low numbers or at such low densities in the wild that capture for wild to wild translocations would not be feasible, or they are species that are now restricted to off-shore islands and the costs and logistics associated with visiting those islands to trap and relocate animals are prohibitive. In the case of the mala, this taxon is currently listed as Extinct in the Wild and captive stocks are the only source of animals for translocations. The current IUCN threat categories for these species are shown in Table 1 below. This conforms with the first key point in the draft 'Western Shield Strategic Plan'.

TABLE 1

IUCN threat category for the 14 species of native fauna subject to captive breeding programs in Western Australia (EW=Extinct in the Wild, CR=Critically Endangered, EN=Endangered, VU=Vulnerable).

SPECIES	IUCN THREAT CATEGORY
Chuditch	VU
Dibbler	EN
Numbat	VU
Western barred bandicoot	EN
Bilby	VU
Gilbert's potoroo	CR
Boodie	VU
Mala (mainland taxon)	EW
Banded hare wallaby	VU
Shark Bay mouse	VU
Greater stick-nest rat	VU
Malleefowl	VU
Western swamp tortoise	CR
Lancelin Island skink	VU

Ninety-three percent of species listed in Table 1 have already been the subject of translocation proposals into the wild on islands off the coast or onto the mainland. The outcomes of those translocations are dealt with in more detail in a separate review paper (Mawson, this issue). Gilbert's potoroo is the only exception as it currently occurs in such low numbers in the wild and has proven so difficult to breed in captivity that insufficient animals have been produced to facilitate a translocation. Additional potential release sites for these species have been identified and translocations will be attempted as and when animals

become available and when the significant threats to the species (e.g. feral cats) can be adequately managed.

To date no animals from any of the captive breeding facilities have been provided as founding stock for translocations to other States. All translocations to other States have involved wild-caught stock or the wild progeny of animals bred in captivity.

ANIMAL PRODUCTION FROM CAPTIVE BREEDING FACILITIES

The principal objective of captive breeding facilities is to produce animals that are surplus to the maintenance requirements of the various breeding facilities, and that can be used to found or supplement other facilities and to provide animals for release into the wild as part of approved translocation programs. The specific changes in stock numbers within facilities can be difficult to monitor in larger, open air facilities or in cases where the monitoring process can represent a risk to the pouch young of the species being bred. As a consequence some species are monitored at the individual animal level infrequently or irregularly, and not all births and deaths that occur within the facilities may be recorded. What is of more relevance is the total number of animals produced surplus to the maintenance of breeding stock that can be removed from the facilities for translocation. The data presented in Table 2 show the net output of animals that have been or could be made available for translocations.

Costs of producing captive-bred animals at the various facilities

Calculating the costs associated with producing animals in captive breeding facilities can be difficult and any comparisons between the production costs for the same species at different facilities can be equally difficult. For the purpose of this review paper the costings provided in individual species recovery plans have been used, while known budgets from the Peron and Dryandra facilities have been applied. Kanyana Rehabilitation Centre receives \$6,000 per annum from CALM towards the food costs for the bilbies and western barred bandicoots maintained there. Advice from June Butcher indicates that the volunteer staff at the centre spend 40 hours per week cleaning cages and feeding bilbies and western barred-bandicoots (i.e. 80 hours per week total). This labour is provided by volunteers, but for the purpose of this review that labour has been costed at a conservative \$15 per hour.

Calculating the 'cost per animal' of production at each facility has been achieved by dividing the total expenditure for that species by the net production of animals over the total period that each species has been bred in captivity. In those facilities where more than one species is maintained and bred, and the number of species bred has varied from one year to another the total expenditure has been divided by the number of species and the number

TABLE 2

Net production of the various captive breeding facilities described above. [WBB=western barred bandicoot, BHW=banded hare-wallaby, GSNR=greater stick-nest rat].

Summary of total resident population at the CALM Peron Captive Breeding Centre at May 2002, plus transferred and released animals.

		FOUNDERS	TRANSFERRED IN	TOTAL ANIMALS IN	TRANSFERRED OUT	RELEASED	RESIDENT	TOTAL ANIMALS PRODUCED	NET GAIN	% GAIN
WBB	Female	18	0	18	7	0	19	26		
	Male	12	0	12	4	0	21	25		
	Total			30				51	21	70%
BHW	Female	13	0	13	0	6	13	19		
	Male	12	0	12	0	12	17	29		
	Total			25				48	23	92%
Bilby	Female	6	1	7	1	24	17	42		
	Male	7	4	11	5	20	13	38		
	Total			18				80	62	344%
Mala	Female	18	0	18	0	7	21	28		
	Male	11	0	11	0	9	20	29		
	Total			29				57	28	96%
Malleefowl	Eggs collected	105								
	Chicks hatched	90								
	Birds released	67	Net Gain	% Gain						
			67	64%						

Summary of total resident populations the CALM Return To Dryandra facility at June 2002, plus transferred and released animals.

		FOUNDERS	TRANSFERRED IN	TOTAL ANIMALS IN	TRANSFERRED OUT	RELEASED	RESIDENT	TOTAL ANIMALS PRODUCED	NET GAIN	% GAIN
WBB	Female				0	0	8	8		
	Male				0	0	7	7		
	Sex Unknown	7	20	27	2	0		2		
	Total			27			15	17	-10	0%
BHW	Female	2			0	0	2	2		
	Male	3			0	0	0	0		
	Sex Unknown	13								
	Total			18			2	2	-16	0%
Bilby	Female	6		6						
	Male	7		7						
	Sex Unknown		35	35	1	46	37	84		
	Total			48				84	36	75%
Mala	Female	10	0	10	0	0	10	10		
	Male	9	0	9	0	0	4	4		
	Sex Unknown				4	0		4		
	Total			19				18	-1	0%
Boodie	Female	12	0	12	10	0		10		
	Male	6	0	6	2	0		2		
	Sex Unknown				10		39	49		
	Total			18	22		39	61	43	239%

Summary of total resident population of Kanyana Rehabilitation Center at June 2002, plus transferred and released animals.

		FOUNDERS	TRANSFERRED IN	TOTAL ANIMALS IN	TRANSFERRED OUT	RELEASED	RESIDENT	TOTAL ANIMALS PRODUCED	NET GAIN	% GAIN
WBB	Female	6	6	12	8	0	9	17	5	
	Male	10	5	15	10	0	8	18	3	
	Sex Unknown									
	Total			27				35	8	30%
Bilby	Female	5	11	16	30	23	12	65	49	
	Male	4	9	13	28	23	10	61	48	
	Sex Unknown							126		
	Total			29	58	46	22		97	334%

TABLE 2 (continued)

Summary of total resident population at the CSIRO/SBSJV Heirisson Prong facility at June 2002, plus transferred and released animals.

		FOUNDERS	TRANSFERRED IN	TOTAL ANIMALS IN	TRANSFERRED OUT	RELEASED	RESIDENT	TOTAL ANIMALS PRODUCED	NET GAIN	% GAIN
Boodie	Female	8								
	Male	4								
	Sex Unknown									
	Total	12	10	22	0	114	22	114	92	418%
WBB	Female	9	2			17				
	Male	3				34				
	Sex Unknown									
	Total	12	2	14		51	?	37?	37	264%
GSNR	Female	3	27							
	Male	5	13							
	Sex Unknown									
	Total	8	40	48	*	*		*	?	?

Summary of total resident populations at the Perth Zoo at June 2002, plus transferred and released animals.

		FOUNDERS	TRANSFERRED IN	TOTAL ANIMALS IN	TRANSFERRED OUT	RELEASED	RESIDENT	TOTAL ANIMALS PRODUCED	NET GAIN	% GAIN
Dibbler	Female	4	5	9	1	72	10	83		
	Male	4	9	13	0	57	9	66		
	Sex Unknown									
	Total	8	14	22	1	129	19	149	127	577%
Chuditch	Female	6	26	32	1	155	2	158		
	Male	2	28	30	3	165	2	170		
	Sex Unknown									
	Total	8	54	62	4	320	4	328	266	429%
Shark Bay mice	Female	3	15	18		104	49	153		
	Male	3	21	24		114	55	169		
	Sex Unknown									
	Total			42		218	104	322	280	666%
Numbats	Female	1	25	26	3	43	5	51		
	Male	1	28	29	1	48	6	55		
	Sex Unknown									
	Total	2	53	55	4	91	11	106	51	93%
Western swamp tortoise	Female	3	14	17		14	21	35		
	Male	10	12	22		12	26	38		
	Sex Unknown					218	158	376		
	Total	13	26	39		244	205	449	410	1051%
Lancelin Island skink	Female	9		9	6	21	12	39		
	Male	4		4	4	19	20	43		
	Sex Unknown				22	46	77	145		
	Total	13		13	32	86	109	227	214	1646%

Summary of total resident Gilbert's Potoroo population at the CALM Two Peoples Bay Nature Reserve at September 2002, plus transferred and released animals.

		FOUNDERS	TRANSFERRED IN	TOTAL ANIMALS IN	TRANSFERRED OUT	RELEASED	RESIDENT	TOTAL ANIMALS PRODUCED	NET GAIN	% GAIN
Potoroos	Female	5	0	5	1	0	4	5	-1	
	Male	3	0	3	1	0	2	3	1	
	Total	8	0	8	2	0	6	8	0	0%

years to provide proportional figure per species. This figure has then been divided by the total number of animals produced to generate a cost per animal estimate.

The expenditure figures for the Peron and Dryandra facilities include the capital costs of designing and building pens. Capital costs were not available for Kanyana or the Perth Zoo. This means that the production costs for each animal bred at the Kanyana and Perth Zoo facilities are conservative relative to those for animals bred at Peron and Dryandra. No expenditure figures were available for the Heirisson Prong facility, but the production data for this site are included in Table 3 as a comparison.

The information set out in Tables 2 and 3 clearly indicates that there are differences in the output of captive-bred animals at the various facilities, and that some species perform better under particular husbandry conditions than others.

The production costs per animal for a number of species (chuditch, dibbler, numbat and Shark Bay mouse) were reported by Bradley *et al.* (1999) during the early stages of the captive breeding process for those species at the Perth Zoo (1995–1997 inclusive). The method of calculating the capital costs, labour costs and feeding costs are not described by Bradley *et al.* but it is still useful to

examine the changes in costs per animal from 1997 to the current estimates at 2002. The cost of producing a chuditch fell from \$2,430 to \$1,262 per animal; for dibblers it fell from \$5,439 per animal to \$2,165; for numbats from \$16,318 to \$9,411 per animal and for Shark Bay mice from \$1,483 to \$553 per animal. These results seem logical in that the longer a breeding program is run the better the return on capital investments and the greater opportunity for the staff husbanding the animals to perfect techniques that result in an increased output of animals. For programs that reach their end point and are wound up, such as the chuditch breeding program, there is the added benefit of being able to release the remaining breeding stock into the wild which bolsters the output and reduces the cost per animal.

Carnivorous species such as chuditch and dibbler appear relatively easy to breed in numbers and can be produced at a modest cost relative to the length of time from mating to independence of the progeny. Specialist feeders such as numbats are labour-intensive and relatively costly to breed in captivity, but the production of numbats (as well as the carnivores) is still more cost effective than trapping wild stocks and relocating them given the numbers of animals required to found new populations.

TABLE 3

Net cost of producing animals for fauna translocations in Western Australia. [Notes: 1. The net production of animals includes animals currently held in captive facilities but surplus to maintenance requirements plus those animals already released into the wild under translocations. 2. The period over which animals were captive bred exceeds the period of operation for *Western Shield* for some species. 3. Expenditure data derived from various species Recovery Plans may not accurately reflect the total costs incurred. 4. Total expenditure for *Return to Dryandra* 1996-2002 = \$357,000: equates to \$71,400 for each of the five species maintained at this facility; Total expenditure for *Project Eden* 1996-2002=\$858,000 which equates to \$37,304 per species per annum.]

SPECIES	BREEDING FACILITY	NO. YEARS CAPTIVE BRED	TOTAL EXPENDITURE (\$)	NO. ANIMALS PRODUCED (NET)	COST (\$) PER ANIMAL PRODUCED
Chuditch	Perth Zoo	9	\$335,900	266	\$1,262
Dibbler	Perth Zoo	5	\$275,000	127	\$2,165
Numbat	Perth Zoo	8	\$480,000	51	\$9,411
Western barred bandicoot	Dryandra	4	\$71,400	0	(\$71,400)
	Peron		\$186,521	21	\$8,881
	Kanyana	4	\$148,800	8	\$18,600
	Heirisson Prong	4	?	37+	?
Bilby	Dryandra	4	\$71,400	36	\$1,983
	Peron		\$223,826	62	\$3,610
	Kanyana	4	\$148,800	97	\$1,534
Gilbert's potoroo	Two Peoples Bay	6	\$150,000	0	(\$150,000)
Boodie	Dryandra	3	\$71,400	43	\$1,660
	Heirisson Prong		?	114	?
Mala (mainland taxon)	Dryandra	3	\$71,400	0	(\$71,400)
	Peron	3	\$186,521	28	\$6,661
Banded hare-wallaby	Dryandra	3	\$71,400	0	(\$71,400)
	Peron	3	\$186,521	23	\$8,109
Shark Bay mouse	Perth Zoo	5	\$155,000	280	\$553
Greater stick-nest rat	Heirisson Prong	3	?	0	?
Malleefowl	Peron	2	\$74,608	67	\$1,113
Western swamp tortoise	Perth Zoo	10	\$327,900	410	\$800
Lancelin Island skink	Perth Zoo	3	\$31,000	41	\$756

Intensive breeding facilities appear to be the only feasible option for captive breeding of these species given their biology and the predatory nature of the chuditch and dibblers.

The production of western barred-bandicoots has been significantly and adversely affected by two endemic diseases that have been identified in both captive and wild stocks. These diseases singly or in concert result in mortalities in adult animals and appear to also significantly reduce the production of recruits. Consequently the net production of this species at the three facilities is well below what might have otherwise been expected, and accordingly the cost per animal is high at all three facilities. At this stage it is not possible to determine whether this species is better suited to intensive or extensive breeding facilities, but it appears that the species is density-limited in any facility and that aggression between cage-mates is important and that these factors may influence the process used to provide animals for translocation. In order to maximize production in any pens it may be necessary to remove small numbers of animals regularly and release them rather than wait until larger numbers are available for a single release event.

The production of bilbies at all three facilities has been a feature of the captive breeding programs. Bilbies appear equally suited to both intensive and extensive breeding arrangements. The production cost per animal as shown in Table 3 at the three facilities needs to be considered with caution for two reasons. First, the labour costs for the care and maintenance of bilbies at Kanyana Rehabilitation Centre have only been costed at \$15 per hour which is conservative. Second a significant number of the animals produced at Dryandra had been bred and raised at Kanyana and subsequently transferred to Dryandra for captive breeding or release into the wild. Those animals have effectively been provided at a discount to the Dryandra facility, resulting in the net cost per animal being lower at this facility than the costs for animals produced at Peron. If the labour costs at Kanyana were doubled, the production costs per bilby at Kanyana would almost double (ca.\$3,000 per animal) which would be comparable to those for the Peron facility. On this basis the cost of producing bilbies is probably in the order of \$3,000 per animal regardless of the type of facility.

Boodies appear to be a relatively easy species to produce and the cost per animal also appears low. This species seems ideally suited to extensive style captive breeding relative to the costs of trapping in the wild on Bernier and Dorre Islands and relocation to the mainland.

Mala appear susceptible to significant losses (due to predation) in extensive pen systems and cannot replace themselves, let alone provide recruits for translocation. In intensive pen systems mala appear to do well and can be produced at a higher cost than other species, but there is little or no opportunity to obtain further stocks from the Northern Territory and as such the existing program appears the only option until substantial wild populations can be established.

Banded hare-wallabies are another species that do not appear well suited to extensive pen systems and the only successful production has come from intensive pen programs. The high cost of production per animal is partly a function of the univoltine breeding system of this species and lower number of animals provided as founding stock. The only other alternative is to capture animals from Bernier and Dorre islands and transport them to the mainland, which is expensive and labour intensive (ca. \$10,000 per trip to the islands and a limit of ca. 15-20 animals can be captured and transported per trip).

Shark Bay mice are readily bred in captivity and can be produced in relatively large numbers sufficient for translocations within a short period of time (<1 yr). The low production costs per animal are a significant saving on capture in the wild (Bernier Island) and transfer to the mainland.

Greater stick-nest rats have been bred in the captive facility at Heirisson Prong but the progeny disperse out of the pens making monitoring difficult. The suitability of this species to captive breeding on the mainland remains unknown, but it may benefit from more intensive programs such as those applied to the Shark Bay mouse. The captive colony of Greater stick-nest rats at Perth Zoo suffered from kidney problems believed to be associated with the artificial diet the animals were fed and also from cataracts. Both of these health problems had a significant impact on the productivity of the colony.

Gilbert's potoroo has proven extremely difficult to breed in captivity and it is unlikely that many animals will be available for release into the wild in the near future. Further research is required and has been planned to improve the potential recovery of this species.

Malleefowl are relatively easy to rear (as opposed to breeding) in captivity when fertile eggs are collected in the field, incubated and the chicks raised to 6-8 months of age. The cost per animal was quite low, and the output from this program has led to the successful establishment of this species at the one release site used to date. The alternative of capturing adult birds from the wild has never been attempted and is not a viable one from a practical or financial standpoint.

Western swamp tortoises have been bred in captivity longer than any other species considered in this review paper (more than 10 years) and the current output reflects this extended learning period. The net cost per animal is quite low, largely a reflection of the reptilian ecology of this species and the limited amount of labour required to maintain captive stocks. Given the critical nature of wild stocks at present and the long maturation time (9+ years) for this species captive breeding remains the only viable option for the conservation of this species.

The Lancelin Island skink captive breeding program has performed very well and benefits from the lower labour and capital costs required to maintain and breed this species. Given the small number of wild Lancelin Island skinks (<300 adults) on Lancelin Island, the current program is a very cost effective one relative to other species considered in this review.

COORDINATION BETWEEN CAPTIVE BREEDING PROGRAMS

Two of the species listed above (bilby and mala) are the subject of national recovery plans, and in both cases the recovery actions listed in those plans include captive breeding. Efforts are made to maximize the genetic diversity of captive collections around Australia and a small number of animals are routinely exchanged between facilities each year. The three captive breeding facilities in this State that hold bilbies carry out exchanges of breeding stock without difficulties. Further there are regular transfers of bilbies from the Kanyana facility to the Dryandra facility for release into the breeding pens or direct release into the wild. There is adequate opportunity for similar transfers of bilbies to and from the Peron facility.

With regard to mala, there have not been any exchanges of captive stocks with the Northern Territory since all of the animals held in Western Australia are derived from a single captive colony in the Northern Territory. To date there has not been any need to transfer any mala between the Peron and Dryandra facilities, but there is a ready capacity to do so if required.

Western barred-bandicoots have been transferred variously between Peron, Dryandra and Kanyana in the past. However, since the discovery of the two diseases amongst the captive animals no further transfers have taken place and nor will they until the management of the two diseases is adequately resolved.

Banded hare-wallabies have not been transferred between the Peron and Dryandra facilities that hold them, but there is a ready capacity to do so if required. Given the failure of the colony of banded hare-wallabies at Dryandra such an action would be desirable if the colony at Dryandra was to be re-established.

All of the species bred at the Perth Zoo have not been bred at any other facility and as such there has been no requirement for exchange of animals between facilities, although the Perth Zoo has demonstrated an efficient procedure for the movement of animals into and out of the captive breeding facilities in the past. An efficient system for the preparation (marking, vet checks etc.) of animals that are to be transferred out of the Perth Zoo for release into the wild under approved translocation programs has been developed.

The three species bred at Heirisson Prong have been introduced into that facility with the sole purpose of establishing populations in the wild at that site. There has not been any requirement for the transfer of any animals from Heirisson Prong to any of the other facilities described in this review, but animals established in the wild at Heirisson Prong have been translocated to South Australia and to Faure Island in Western Australia (see Review paper on fauna translocations).

SHOULD CALM BE INVOLVED IN CAPTIVE BREEDING AND IF SO WHICH FACILITIES SHOULD IT RETAIN?

The data presented in Tables 2 and 3 clearly indicate that the CALM currently has the expertise to maintain a range of native species in captivity and breed most of them with varying degrees of success depending on the species. The data also suggest that facilities such as the Perth Zoo may be more economical at such breeding programs, although the species that the Perth Zoo have bred to date have not been kept elsewhere, and the capital costs associated with accommodating those species were invariably not included in the production cost estimates provided in Table 3. The species that the Perth Zoo have bred have also been ones that can be kept at relatively high densities or are species that do not require much space to accommodate (e.g. Shark Bay mice, dibbler, chuditch, western swamp tortoise). In the event that the Perth Zoo was considered a preferred breeding facility there would be a requirement for the CALM and Perth Zoo to be able to ensure a continued supply of funds to run breeding programs, something that has proven more difficult to achieve in recent times.

In order to better assess the merits of CALM continuing any or all of its current facilities it would be prudent to obtain a more detailed breakdown of the production costs at each facility and for each species, with particular attention to the various costs of feed, capital items and staff labour. If the CALM labour costs are found to be the most significant component of the total costs then there may be some merit in outsourcing parts of the program and limiting CALM involvement to program management and animal handling (as opposed to feeding and cleaning of cages).

The involvement of the Kanyana Rehabilitation Centre in the captive breeding of bilbies has been a significant factor in the performance of the CALM Dryandra facility. The results at Kanyana indicate that with appropriate skills non-government groups could breed required animals as readily as any government facility. However, the issue of whether it is appropriate for CALM to continue to rely on the significant volunteer labour contribution in order to produce low cost bilbies (or any other species) does require urgent consideration. The current structure of the Kanyana facility cannot be expected to continue into the future for a number of reasons, foremost of which is the age of its principles.

Once a decision has been made about the merits of volunteer contributions to captive breeding programs consideration could be given to further captive breeding programs involving significant community (i.e. cheap or free) input.

REFERENCES

- Bradley MP, Lambert, C, Power V, Mills H, Gaikhorst, G, Lawrence C (1999) Reproduction and captive breeding as a tool for mammal conservation: the role of modern zoos. *Australian Mammalogy* **21**, 47-54.
- Burbidge A, Kuchling G (1995) The western swamp tortoise. Wildlife Management Program No. 11. Department of Conservation and Land Management, Western Australia.
- Burbidge AA, Start AN, Morris KD, Armstrong R (1995) 'Western Shield – Bringing back our wildlife.' Department of Conservation and Land Management, Western Australia.
- CALM See Department of Conservation and Land Management
- Department of Conservation and Land Management (1999) 'Draft Western Shield Fauna Recovery Program – Strategic Plan (July 1999-June 2004).' CALM, Western Australia.
- Friend JA, Beecham B (2004) *Return to Dryandra: Western Shield* review–February 2003. *Conservation Science W. Aust.* **5** (2), 174-193. Department of Conservation and Land Management, Western Australia.
- Mawson PR, (2004) Translocations and fauna reconstruction sites: *Western Shield* review–February 2003. *Conservation Science W. Aust.* **5** (2), 108-121. Department of Conservation and Land Management, Western Australia.
- Morris K., Sims C, Himbeck K., Christensen P, Sercombe N, Ward B, Noakes N (2004) *Project Eden – fauna recovery on Peron Peninsula, Shark Bay Western Shield* review–February 2003. *Conservation Science W. Aust.* **5** (2), 202-234. Department of Conservation and Land Management, Western Australia.
- Morris K, Speldwinde P, Orell P (2000) Djoongari (Shark Bay mouse) recovery plan. Wildlife Management Program No. 17. Department of Conservation and Land Management, Western Australia.
- Orell P, Morris K (1994) Chuditch recovery plan. Wildlife Management Program No. 13. Department of Conservation and Land Management, Western Australia.
- Pearson D, Jones B (2000) Lancelin Island skink recovery plan. Wildlife Management Program No. 20. Department of Conservation and Land Management, Western Australia.

Feral cat control research: *Western Shield* review— February 2003

D. ALGAR ¹ AND N.D. BURROWS ²

¹ Senior Research Scientist, Department of Conservation and Land Management, Wildlife Research Centre, PO Box 51, Wanneroo, WA 6946. davea@calm.wa.gov.au

² Director, Science Division, Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, WA 6983. neilb@calm.wa.gov.au

SUMMARY

Background

The feral cat (*Felis catus*) is recognised as a significant threat to fauna conservation in Western Australia, particularly in arid and semi arid regions of the State. Not only do feral cats prey on native fauna and have the potential to spread diseases, but they have proven to be an obstacle to fauna reintroduction programs. *Western Shield* fox baiting strategies have been ineffective against feral cats largely because the standard fox/dog baits are not attractive to feral cats. Until the commencement of the research described in this review paper, there was no broad area control technique available for feral cats.

Feral cat control research objectives and broad strategies

The principal objective of the feral cat control research program, commenced by scientists of the Western Australian Department of Conservation and Land Management (CALM) in December 1993, is to design and develop an operationally feasible bait, and baiting regimes to provide effective and cost-efficient broadscale control of feral cats. Essentially, three strategies are being employed to achieve this.

First, a comprehensive and carefully designed series of both cafeteria pen trials with stray cats and subsequent field trials with feral cats were conducted in an endeavour to develop a bait medium that was attractive to feral cats. The medium also had to have operational utility including a capacity to carry a toxin, be relatively simple and inexpensive to manufacture, be easily and safely handled and transported and applicable to aerial deployment over large areas. Initially, a number of bait media, representing a broad range in physical form and type, were examined for acceptability by cats. A variety of flavour enhancers was then added to the most preferred bait medium to assess whether acceptability could be further improved.

Second, field-based research and operational trials focussed on field testing and further development of effective broadscale aerial baiting strategies for feral cats.

This initially involved examination of bait uptake in relation to the time of year (season) to enable baiting programs to be conducted when bait uptake is at its peak and therefore maximise efficiency. A key factor affecting bait uptake is the availability of live prey, the nature and abundance of which varies geographically and temporally. While a number of trials have been undertaken in a range of ecosystems, current and future investigations aim to examine the effects of season, baiting intensity (number of baits laid km⁻²) and baiting frequency (interval between baiting operations) needed to optimise sustained control. These baiting research and development programs are ahead of schedules outlined in the *Western Shield* Proposal and the Western Shield Strategic Plan 1999-2004.

Finally, in addition to optimising the various parameters of baiting strategies, it will be essential that a comprehensive risk assessment of the potential impact of feral cat baiting programs on populations of non-target species be undertaken, and where necessary, methods devised to reduce this risk. This risk assessment is in part required to gain National Registration Authority registration of the new bait as well as assuring the protection of native fauna. While reliable techniques have been developed to assess the relative abundance of feral cats, it is also necessary to further develop techniques to efficiently and reliably census feral cat populations. This, together with an effective baiting strategy, will enable experimental determination of the level of feral cat control necessary to protect either extant fauna or reintroduced fauna across the State's semi-arid and arid bioregions.

Achievements

Investigations thus far have culminated in the development and patenting of a novel feral cat bait that is proving highly effective in experimental and operational baiting programs in arid and semi-arid regions of WA, as described in detail in this review. For example, the most recent large scale aerial baiting trial implemented under dry winter conditions in the Gibson Desert resulted in about a 95% reduction in the relative abundance of feral cats. The feral cat bait, which is also effective against foxes, has been used successfully in the eradication of feral cats from two islands off the Western Australian coast.

Research into the relationships between season, live prey abundance and bait uptake are well advanced in a number of bioregions. Results to hand show temporal (seasonal) variability in live prey abundance and bait consumption. In areas that experience a Mediterranean-type climate and particularly where rabbits are abundant, the optimum baiting period occurs in the drier autumn/early winter months when young, predator-vulnerable prey are not present but before the onset of winter rains. As predator-vulnerable young prey become more abundant, which is a function of long-term weather conditions (season/rainfall), bait uptake is likely to decline. In the arid zone, where rainfall is unreliable, the time and intensity of rainfall events and season determines the overall abundance of prey. Research in the interior arid zone has suggested that the optimum time to conduct baiting programs and maximise their effectiveness is under cool dry conditions in winter. At this time, the abundance and activity of all prey types, in particular small mammals, reptiles and birds, is at its lowest and bait degradation due to ants and to hot, dry weather, is significantly reduced.

The current series of trials is designed to investigate baiting efficacy at differing bait distribution rates (number of baits per unit area) to provide a cost-efficient control strategy. To-date, this series has demonstrated that a baiting density half that used in island eradications is equally efficacious in the control of feral cats in the arid interior. A highly effective toxic baiting of feral cats on the Gibson Desert Nature Reserve and Peron Peninsula this year has supported this evidence. The high level of bio-marking and good control of feral cats during these exercises suggests that further reductions in bait distribution may not reduce baiting efficacy.

Difficulties

There have been no extraordinary difficulties with a research project of this complexity and magnitude. Scientists commenced the project with little or no available background scientific information. There were commercial-in-confidence issues in accessing literature on cat food and the ramifications of patenting various aspects of the research. Other difficulties are associated with the temporal and spatial practical aspects of working on feral cats at an operational or large scale, and in remote areas. However, the main difficulty in such a project, and one which is universal to most research, that is gaining sufficient funding to enable the research to be carried out to a high standard and be completed within an acceptable time frame. To a large extent, this problem has been overcome with sponsorship being provided over a five-year period. The only other significant difficulty has arisen during the course of the collaborative research into the felid-specific toxin where development of the encapsulation system for the toxicant is taking a longer period of time than originally anticipated.

Potential economies

The step-wise approach to developing an optimal broadscale, aerial feral cat control strategy is being pursued to provide for effective and cost-efficient wildlife recovery. The focus is on optimising feral cat predation control through aerial baiting and providing a comprehensive evaluation of any impact on non-target species populations. The program is structured to enable analysis of the cost-benefit of various baiting regimes on both feral cats and non-target species and provide information essential to gaining registration of the feral cat bait.

The development of a readily manufactured sausage-type bait will result in considerable savings in production, handling and delivery of the bait. The cost of feral cat baits is currently about 30¢ per bait at today's level of production. One third of this cost is for materials, and the remainder is associated with labour and production equipment. The future costs of baits will depend on economies of scale (level of production), degree of automation and the cost and depreciation rate of the manufacturing equipment, but it is anticipated that costs can be reduced when manufacture extends to an operational scale.

Potential improvements

Future research will focus on refinements to the bait medium, the development of a felid specific toxin, refinements to bait production and handling and designing bioregionally appropriate baiting regimes with respect to season, intensity and frequency of baiting. Further research on non-target issues is a high priority.

INTRODUCTION

The Department of Conservation and Land Management's (CALM) '*Western Shield*' project has been operational for 6 years and it is timely that the Corporate Executive has initiated a review of the project. The review is in four parts, including the preparation of a series of review papers on various topics relevant to operational and research activities aligned with *Western Shield*. This includes a review of feral cat control research. The terms of reference given to the authors were as follows:

- An overview of the rationale for feral cat control.
- An overview of all research aimed at developing a broadscale control technology for feral cats including results of cat control experiments across various climatic/habitat types.
- Address issues of non-target bait take.
- An overview of what is known of the interaction between feral cats, foxes and dingoes/dingo-dog hybrids.
- Provide an overview of the criteria for determining where and why feral cat control is required.

- Discuss any current obstacles to broadscale implementation and research needs and timelines for overcoming them.
 - Discuss how and when bait registration can be achieved and the likely cost of feral cat baits.
 - Discuss the future of the Felid Specific Toxin including whether non-target issues have been addressed.
- (note: we have re-ordered the original terms of reference in to what we consider to be a more logical sequence)

While a number of papers have been written as internal reports and are now in various stages of preparation for publication or in press, few papers covering the above terms of reference in entirety have been published in scientific journals. To assist the reviewers, we therefore present detail about the objectives, methods and results of feral cat control research.

RATIONALE FOR FERAL CAT CONTROL

The Australian arid zone has experienced a high rate of native mammal decline following European settlement. Since the 1920s, about 33% of all mammals and about 90% of medium size mammals (35–5500 g adult body weight range) have either suffered dramatic range contractions or are extinct (Burbidge and McKenzie 1989). Many of these species are now restricted to several offshore islands and due to small population sizes and restricted geographic ranges, are vulnerable to total extinction. Large tracts of the arid interior of Western Australia are relatively pristine and have not experienced disturbances usually associated with European settlement such as pastoralism and clearing for agriculture and urbanisation. A number of causes have been proposed to explain this decline. These include changed fire regimes, competition from introduced herbivores, disease, extreme variability in weather and site fertility and predation by introduced predators, specifically the fox (*Vulpes vulpes*) and the feral cat (*Felis catus*) (Burbidge and McKenzie 1989; Johnson *et al.* 1989; Morton 1990; Dickman 1996; Environment Australia 1999; Abbott 2002). Predation by feral cats also threatens the continued survival of many other native species persisting at low population densities (e.g. Smith and Quin 1996; Risbey *et al.* 2000) and has been identified as one of the major obstacles to the reconstruction of faunal communities as it has prevented the successful re-introduction of species to parts of their former range (Christensen and Burrows 1995; Gibson *et al.* 1995; Dickman 1996; Environment Australia 1999).

Management of introduced predators is now generally viewed as a critical component of successful reintroduction, recovery or maintenance of small to medium-sized native fauna populations (Christensen and Burrows 1995; Fischer and Lindenmayer 2000). It has also been suggested that competition by feral cats with native carnivorous species (eg. some dasyurids, predatory birds and larger reptiles) may reduce their population

viability (Cross 1990). However, compelling evidence for competition has not been obtained (Dickman 1996). Cats are also the hosts and reservoirs for a number of diseases such as *Toxoplasmosis* that can affect wildlife (Cross 1990; Dickman 1996; Environment Australia 1999).

As a consequence of these impacts, control of feral cats is recognised as one of the most important fauna conservation issues in Australia today. The impact of feral cats on native fauna is acknowledged by Commonwealth legislation, as outlined in Schedule 3 of the *Environment Protection and Biodiversity Conservation Act 1999*. The national *Threat Abatement Plan for Predation by Feral Cats* (Environment Australia 1999) lists 38 species on Schedule 1 of the above Act for which there is a known or inferred threat from feral cat populations. That is, 38 endangered species have been identified as potentially benefiting from effective feral cat control, as part of their management/recovery programs.

OVERVIEW OF RESEARCH AND SUMMARY OF KEY RESULTS

Historically, a range of techniques has been used in attempts to control feral cats, including shooting, trapping, poison baiting, biological control, hunting and exclusion fencing. The *Threat Abatement Plan for Predation by Feral Cats* (TAP) identifies these control techniques at the time as generally expensive, labour intensive and requiring continual application to be effective at controlling feral cats even over small areas (Environment Australia 1999). These existing methods, in their current form, are not suitable for broadscale control of feral cats over most of Australia.

Outlined in the TAP are a number of potential techniques which might offer effective feral cat control including various means of reducing reproductive success, biological control and development of new bait types with improved target-specificity. Reducing reproductive success through development of an immunocontraceptive agent was dismissed as a viable control option because the concept has not been successfully applied to a free ranging population of any species (Environment Australia 1999). The use of chemical sterilants was considered inappropriate, as there are no effective compounds that produce permanent sterility in cats (Moodie 1995, cited in Environment Australia 1999). In addition, fertility control does not address the immediate problem of predation by feral cats being at levels that are detrimental to the continued survival of a threatened species population. No benefit was expected from the release of endemic pathogens as lethal, self-disseminating biological agents (Moodie 1995, cited in Environment Australia 1999). The possibility of creating a new felid pathogen is likely to be unacceptable because of issues of target specificity in relation to domestic cats, and possibly to *Felidae* outside Australia (Fisher *et al.* 2001).

Development of an effective broadscale baiting technique, and the incorporation of a suitable toxin for

feral cats, was cited as a high priority in the TAP as it was most likely to yield an operational and cost-effective method to control feral cat numbers in strategic areas (Environment Australia 1999). Under the Threat Abatement objectives and actions, 'Objective 4: Improve the effectiveness of feral cat control methods: delivery systems', the actions required were listed as:

- Identify the most attractive bait materials for use with feral cats and the conditions under which different baits will be most effective by reviewing the results of previous studies on a range of potential baits.
- Assess existing delivery systems for their effectiveness in delivering control substances to feral cats and minimising the risk of non-target impacts.
- Identify and develop the most attractive bait(s) for use in combination with the cat-specific toxin to provide a feral cat control system suitable for broadscale use.

Bait development

Commencing in December 1993 CALM scientists conducted a comprehensive and carefully designed series of cafeteria pen trials with stray cats and subsequent field trials with feral cats in an endeavour to develop a bait medium that was attractive to feral cats, capable of carrying a toxin, relatively easily and cheaply manufactured and could be deployed aerially over broadscale areas (Friend and Algar 1993; 1994a and b; 1995; Algar and Sinagra 1995; 1996 a, b and c). Initially, a number of bait media, representing a broad choice in physical form and type, were examined for acceptability. A range of flavour enhancers was then added to the most preferred bait medium to assess whether acceptability could be further improved. These initial trials indicated the suitability of kangaroo meat as a bait medium and early trials conducted in the Gibson Desert (see Section 'Baiting trials') using a prototype bait consisting of a 30-40 g, fresh kangaroo meat chunk confirmed bait acceptance by feral cats. Using kangaroo meat chunks as baits however presented a number of problems in bait manufacture and field application:

- a) Provision of standard sized kangaroo meat chunks precluded automation of bait production as the baits could only be cut manually.
- b) Manual production of baits was labour intensive and resulted in considerable wastage of meat.
- c) Dosing the baits with the toxin had to be performed manually.
- d) It was difficult to provide a uniform coating of the surface of baits with flavour enhancers and in the presence of rain the coating would wash off.
- e) The coating made it extremely difficult to avoid baits clumping together when deploying them in the field.
- f) Finally, the lean kangaroo meat would dry quickly in the sun, even during the cooler months, and become too hard within a short time to be acceptable to feral cats.

To overcome these problems, the use of a kangaroo meat sausage was assessed as a suitable alternative to the kangaroo meat chunk. These investigations have recently culminated in the development and patenting of a novel feral cat bait that is proving highly effective in experimental and operational baiting programs (see below, results of feral cat control experiments across various climatic/habitat types) to control feral cats. Paralleling this has been the development of an automated bait manufacturing process including the incorporation of a toxin (1080) (Armstrong, 2004). These baits are now routinely manufactured at the CALM Bait Factory in Harvey. The bait, hereafter referred to as the feral cat bait, is similar to a chipolata sausage in appearance, approximately 20 g wet-weight, dried to 15 g, blanched (that is, placed in boiling water for one minute) and then frozen. This bait is composed of 70% kangaroo meat mince, 20% chicken fat and 10% digest and flavour enhancers (Patent No. AU13682/01). Toxic feral cat baits are dosed at 4.5 mg of sodium monofluoroacetate (compound 1080) per bait. Prior to laying, feral cat baits are generally thawed and placed in direct sunlight. This process, termed 'sweating', causes the oils and lipid-soluble digest material to exude from the surface of the bait. All feral cat baits are sprayed, during the sweating process, with an ant deterrent compound (Coopex®) at a concentration of 12.5 g l⁻¹ Coopex as per the manufacturer's instructions. This process is aimed at preventing bait degradation by ant attack and the deterrent to bait acceptance from the physical presence of ants on and around the bait medium.

Feral cat bait design and development was essentially completed in 1999; certain refinements to the manufacturing process have occurred since this time to enable streamlining of bait production to produce a product of consistent standard and quality. These refinements have not affected feral cat bait acceptability (Algar and Brazell unpublished data). There are several factors in the bait production process and storage yet to be resolved, these include:

- Incorporation of the ant deterrent compound in the bait, rather than surface spraying
- Longevity of baits in storage.

Bait uptake in relation to time of year

Following development of the feral cat bait, a number of trials has been conducted examining bait uptake of this bait by feral cats in relation to the time of year. Examination of whether bait uptake is influenced by the time of year and if so, when bait uptake is at its peak, will determine the optimum period or periods to conduct control programs to maximise efficiency. To date, this research has been focused in semi-arid and arid areas.

The bait uptake trials were conducted by placing baits by hand along roads and tracks at dusk and measuring bait removal the following morning. We have observed that the uptake of baits recorded using this methodology is often significantly lower than that observed by the broadscale application of biomarked baits and therefore

likely to be an underestimate of bait acceptance (Algar *et al.* in press, a).

Research into bait uptake by feral cats has indicated a temporal variability in bait consumption in areas influenced by Mediterranean climatic regimes (Algar and Angus 2000a; Algar *et al.* in press, a). This variability is correlated with the availability of prey (particularly where rabbits are the primary prey), which is a function of season/rainfall. In these areas, the optimum baiting period occurs in the drier autumn/early winter before the onset of winter rains when young, predator-vulnerable prey are not present. As predator-vulnerable young prey become more abundant, which is a function of long-term weather conditions (season/rainfall), bait uptake is likely to decline.

In the arid zone, where rainfall is unreliable, it has been observed that the time and intensity of rainfall events determines the abundance of many prey species, particularly mammals and birds (e.g., see Morton 1990). Research conducted in the arid zone has suggested that the optimum time to conduct baiting programs and maximise their effectiveness is under cool, dry conditions in late autumn/winter (Algar *et al.* 2002a). At this time rainfall, which will cause degradation of feral cat baits is less likely to occur than during the summer months, and the abundance and activity of all prey types, in particular predator-vulnerable young mammalian prey and reptiles, is at its lowest and bait degradation due to rainfall, ants and to hot, dry weather, is significantly reduced.

Baiting trials

Since completing development of the feral cat bait, a number of broadscale experimental and operational baiting programs have been conducted across various climatic/habitat types (Table 1). These baiting programs have commenced ahead of schedules outlined in the Western Shield Proposal (Burbidge *et al.* 1996) and the

Western Shield Strategic Plan 1999–2004 (CALM 1999). The baiting campaigns conducted as part of the research program involved the examination of the level of control achieved under different baiting intensities (number of baits laid km⁻²). These programs commenced following research examining bait uptake in relation to the time of year to enable baiting programs to be conducted when bait uptake is at its peak and therefore maximise efficiency. Other baiting campaigns have been conducted in the Gibson Desert Nature Reserve, initially with the prototype bait, and more recently using the feral cat bait. We present the key results of the various field trials relevant to feral cat control research carried out by CALM. These results are summarised in Table 1 and then the trials are documented in some detail by Bioregion (after Thackway and Cresswell 1995) apart from those on the Cocos (Keeling) Islands, which is an external territory and not described by Bioregion.

The Gibson Desert Bioregion – Gibson Desert Nature Reserve

The 18 900 km² Gibson Desert Nature Reserve (GDNR) is located in the interior of Western Australia, some 900 km from the west coast, at about 24.5° S to 25.5° S, 124.7° E to 126.3° E. The region has an arid climate (Beard 1969) with an annual average rainfall of about 217 mm. Typical of the arid zone, rainfall is erratic and undependable. Summers are hot with daily maximum temperatures often exceeding 45° C and winters are cool with overnight temperatures often falling below zero. The bioregion is characterised by gently undulating laterite plains, sand dunes, sand plains, stony mesaform hills and relict drainages. Various spinifex (*Triodia*) species form the dominant vegetation cover in association with scattered low shrubs and trees (see Thackway and Cresswell 1995). Introduced vertebrate fauna in the region include

TABLE 1

Summary of recent broadscale feral cat baiting programs. Baiting efficacy is the per cent reduction in the relative abundance of the feral cat population following the baiting operation, or where non-toxic biomarker baits were used, the per cent of trapped feral cats that had taken a feral cat bait.

DATE	LOCATION & BIOREGION		BAITING INTENSITY (BAITS KM ⁻²)	BAITING EFFICACY (%)
June 1999	Hermite Is., Montebellos, Pilbara Bioregion	Toxic operational baiting	100	80
March 2001	Faure Is., Carnarvon Bioregion	Toxic operational baiting	100	>90
July 2001	Gibson Desert Nature Reserve, Gibson Desert Bioregion	Biomarked non-toxic baits - cats trapped	100 50	82 100
March 2002	Pimbee Station, Carnarvon Bioregion	Biomarked non-toxic baits - cats trapped	50	100
March 2002	Peron Peninsula, Carnarvon Bioregion	Biomarked non-toxic baits - cats trapped	50	50
April 2002	Peron Peninsula, Carnarvon Bioregion	Toxic operational baiting	50	80
May 2002	Wanjarri Nature Reserve, Murchison Bioregion	Biomarked non-toxic baits - cats trapped	50 25	83 78
June 2002	Gibson Desert Nature Reserve, Gibson Desert Bioregion	Toxic operational baiting	50	96
August 2002	West Is., Cocos (Keeling) Islands	Toxic on-track baiting (baits suspended)	Baits at 100 m intervals	89

dingoes (*Canis lupus dingo*), foxes, feral cats, house mouse (*Mus domesticus*) and camels (*Camelus dromedarius*), which are widespread, and rabbits (*Oryctolagus cuniculus*) which are largely restricted to fossil drainage lines and are only relatively abundant after good rains.

The Gibson Desert project comprises a series of trials that commenced in 1989 (Christensen and Burrows 1995), is a BACI design (Before, After Control, Impact; Stewart-Oaten *et al.* 1986) with a baited (Impact) area and an unbaited reference (Control) area (see below). Surveys (described below) have been undertaken at regular intervals over the period 1989–2002 (Figure 1a–c) to determine the impact of various toxic baiting trials on the relative abundance of foxes, dingoes and feral cats.

There is no known efficient technique for reliably estimating the actual population of dingoes, foxes and feral cats in this environment (Jones 1977, Mahood 1980). The animals are difficult to capture and spotlighting was attempted but was unsuccessful due to the combined effects of relatively low animal density, thick spinifex cover and the cautious behaviour of the animals. Initially, introduced predator abundance surveys were carried out using two techniques; cyanide transects (Algar and Kinnear 1992) and track (paw print) count transects described below. The cyanide technique enables the calculation of the 'catch per unit effort index' (CPUEI) for each predator species (Algar and Kinnear 1992) but is very labour intensive, time consuming and potentially dangerous. Also, the cyanide technique was not reliable for estimating feral cat abundance because the uptake of cyanide baits by feral cats varied considerably from season to season depending on the availability of live prey. After initial trials, the cyanide technique was abandoned in favour of the track count transect technique.

Wilson and Delahay (2001) provide a summary of the strengths and weaknesses of using track counts along transects in their review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. They cite work by Stander (1998) who was able to validate track counts against populations of lion (*Panthera leo*), leopard (*Panthera pardus*) and hunting dog (*Lycaon pictus*) of known size. They also cited work by Servin *et al.* (1987) and O'Donoghue *et al.* (1997) who demonstrated a relationship between track counts and actual abundance for fox and coyote (*Canis latrans*) respectively. Edwards *et al.* (2000) evaluated the efficacy of spotlight surveys and track surveys for assessing relative abundance of feral cats and dingoes in semi-arid rangelands in central Australia and reported that the track count method was more efficient and precise than spotlight surveys. On the other hand Stephenson and Karczmarczyk (1989) reported a poor correlation between snow-track count index and actual numbers of lynx but this involved a small number of surveys (Wilson and Delahay 2001). In an operational trial in Shark Bay, a semi-arid region of Western Australia, the mortality rate of radio collared feral cats following toxic baiting was closely correlated with the reduction in the track count index which was measured before and after baiting (K. Morris, CALM, pers. comm.).

The track count transect technique adopted in this and other trials involved scraping roads each day using 2 m long sections of steel railway line dragged behind a 4WD vehicle and then inspecting the roads just after sunrise each morning for fox, feral cat and dingo paw prints (tracks), which were readily discernible in the red sandy loam soils. Each survey involved inspecting 30–60 km of transect (along roads) each night over 3–4 nights. Experienced observers were securely positioned on a seat mounted on the front of a 4WD vehicle, which was driven along the road at 15–20 kmh⁻¹. The observers were skilled at track identification and were able to recognise (and record) the paw prints of foxes, feral cats and dingoes and of individual animals based on the size, shape and location of the prints along the transects. While animals usually followed the scraped roads for some distance, some individuals would meander on and off the roads. To reduce the possibility of double counting, individual sets of tracks that were physically indistinguishable (same species, same size, same shape, travelling in the same direction) but were less than 2 km apart on the transect, were assumed to be the same animal. Using this rule, and the same skilled observers, this technique provided a reliable and repeatable estimate of relative abundance with the standard error of the mean count over 3–4 nights being in the range 5–11% of the mean. As the transect distances were variable over the 13 years of the trial, the track counts were standardised to the number of tracks per 100 km and the resulting figure termed the track density index (TDI). Two and sometimes three introduced predator surveys were carried out each year in the impact area (treatment) and in the reference area (control) over the period 1989–2002 (Figure 1a–c).

Fundamentally, the Gibson Desert project aimed to determine whether applying toxic baits (the impact) significantly altered (decreased) the abundance of foxes, feral cats and dingoes in the impact area. In addition to tabulating and graphing the results of the individual trials described below, the overall impact of toxic baiting over the period of the project (1989–2002) was assessed by comparing the relative abundance of introduced predators at the site before and after baiting commenced, even though baiting was carried out irregularly (Table 2). As described above, the project was conducted over a relatively long period and at a large scale consistent with the natural density and activity patterns of these predators in this environment. Optimal experimental design that incorporates random assignment of treatments and controls appropriately replicated in space was not practical. First, reasonable spatial replication that assumes coverage of natural variation was not possible at the scale of this project. Second, the remoteness of the site, the limited access and resource limitations, made spatial replication unfeasible. Instead, the design is one that is spatially unreplicated (single-site) that requires a number of samples to be taken over time from two reasonably well defined populations in a treatment (impact) area and reference (control) area.

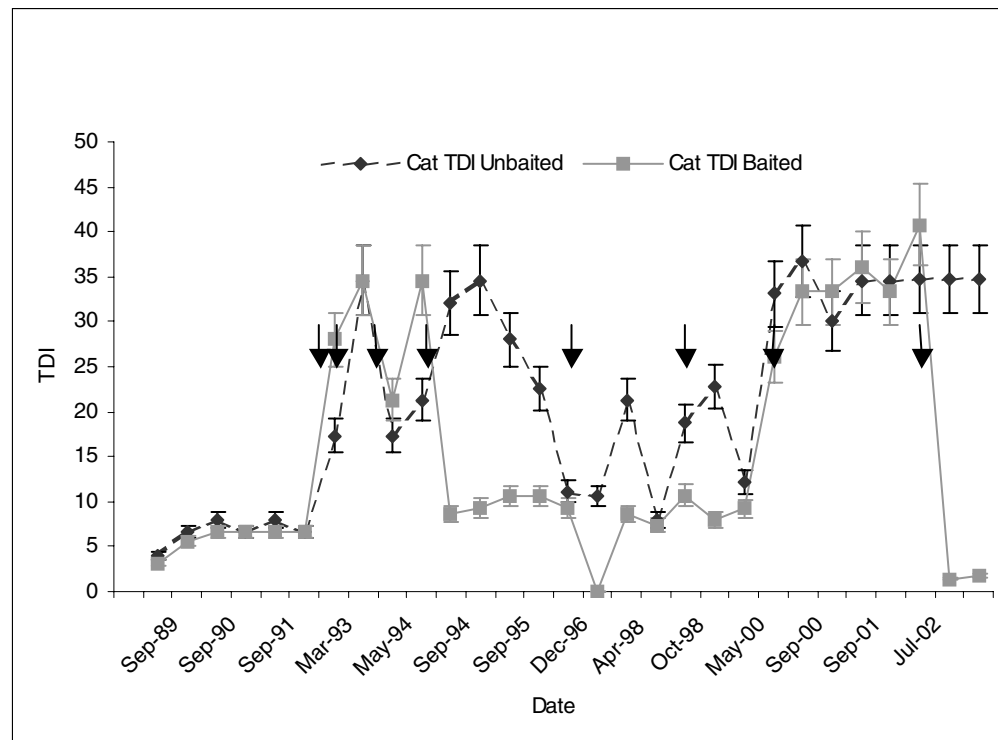


Figure 1a. Relative abundance of feral cats in the Gibson Desert study sites estimated using the track density index (TDI). Toxic baiting is shown by the arrows. Various cat baits were used in May 1994, Sep. 1996, Sep. 1998 and Jun. 2002 (see Table 2).

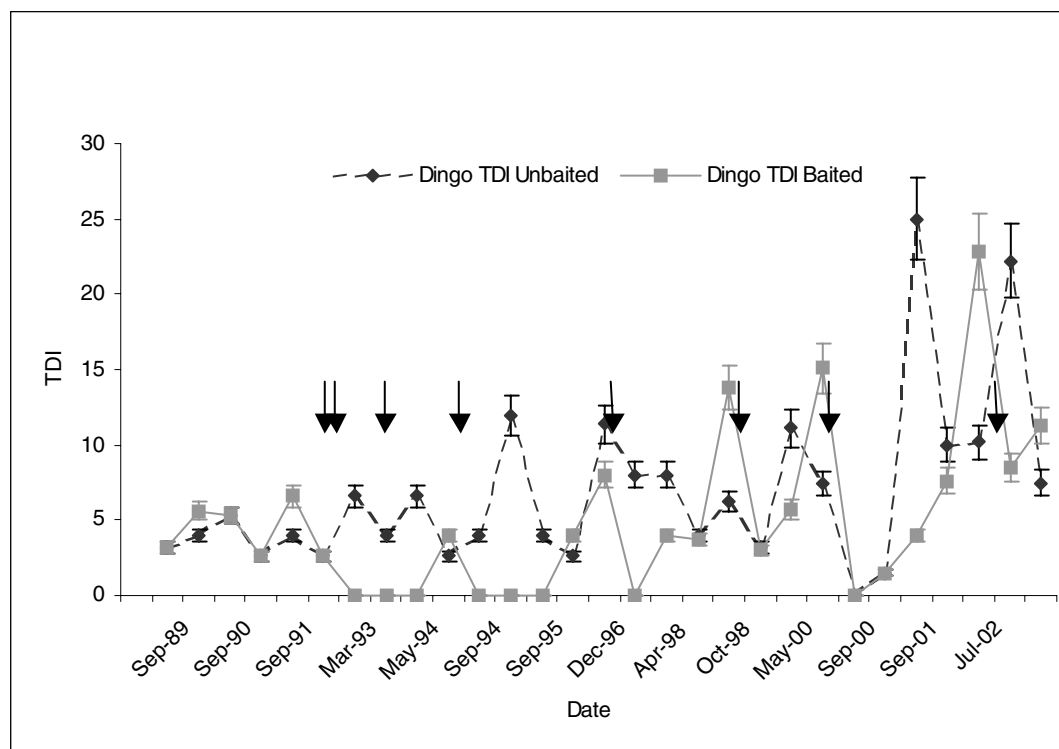


Figure 1b. Relative abundance of dingoes in the Gibson Desert study site estimated using the track density index (TDI). Toxic baiting is shown by arrows; Apr. 1992, Aug. 1992, Mar. 1993, May 1994, Sep. 1996, Sep. 1998, May 2000, Jun. 2002.

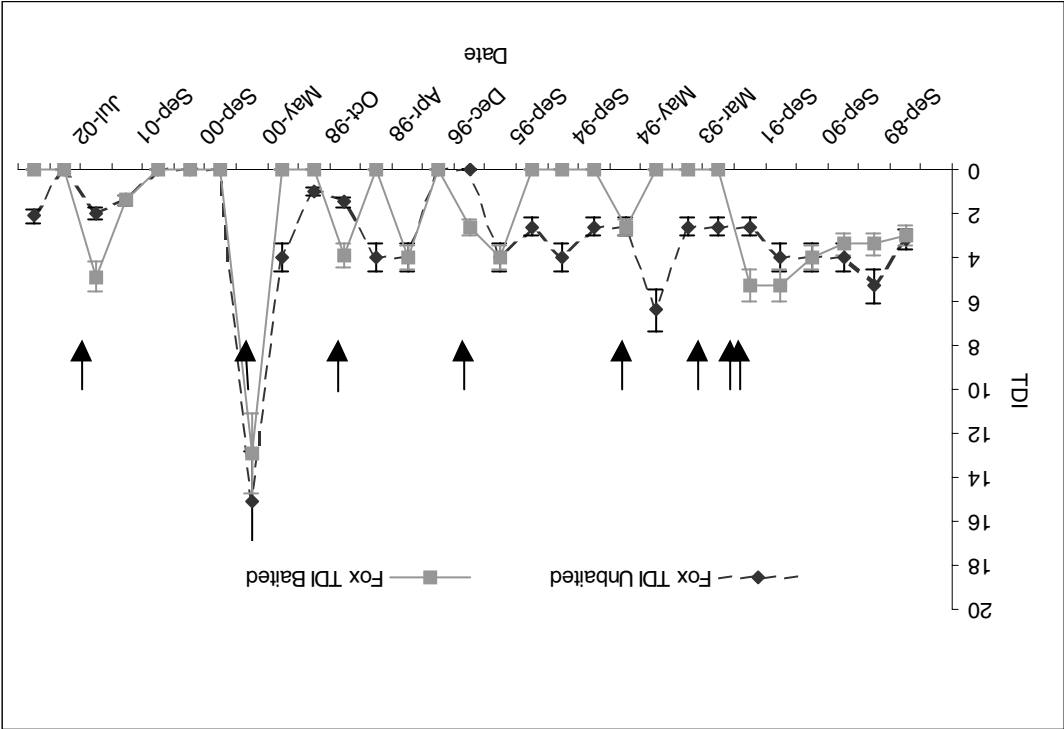


Figure 1c. Relative abundance of foxes in the Gibson Desert study sites estimated using the track density index (TDI). Toxic baiting is shown by the arrows; Apr. 1992, Aug. 1992, Mar. 1993, May 1994, Sep. 1996, Sep. 1998, May 2000, Jun. 2002.

Eberhardt (1976), in supporting the case for a role for non-traditional experimental designs in field ecology argues that two areas not widely separated in space, that are subject to the same climatic factors, are similar in landform, geology, soils and vegetation, have populations of (subject) animals with a similar make-up, would be expected to follow much the same population abundance trend over time, in the absence of human intervention. Stewart-Oaten *et al.* (1986) developed the BACI (Before, After, Control, Impact) sample design to deal with single-site environmental problems such as assessing the impacts of the discharge of effluents into aquatic ecosystems at a single point, where replicated experimental design is not possible. Because of the scale of this project, it was appropriate to adopt the BACI sample design of Stewart-Oaten *et al.* (1986). An impact (baited) and a control (unbaited reference) area were established and the relative abundance of introduced predators was sampled simultaneously at both places at various times before and after baiting with the objective of determining whether the differences between the impact and the control abundances had changed as a result of the baiting. Sampling times were used as 'replicates' and observations taken at the same time were averaged with one observation (the mean) used to represent the sample at each of the various time periods (Stewart-Oaten *et al.* 1986). The before and after mean differences in abundance (control and impact sites) were compared by a 't' test ($\alpha = 0.05$). The 't' test assumes that the observed differences, calculated at different times, are independent and that any differences are due to the impact (baiting in this case) (Stewart-Oaten *et al.* 1986). Similarly, we calculated and compared (using a 't' test) the mean ratios of introduced predator abundance; the Control-to-Impact abundance ratio for sample periods before and after baiting.

The results of the Gibson Desert Biorregion trials are presented at two levels. Firstly, we summarise the overall impacts of baiting on introduced predators and discuss long term trends in relative abundance in the Impact (baited) and Control (unbaited reference) areas, before and after baiting commenced in the study area, and then we summarise the results of the individual baiting trials shown in Table 2.

Over the thirteen year duration of the project, there has been a significant change in the difference in relative abundance (TDI) of introduced predators between the Impact (baited) area and the Control (unbaited reference) areas after baiting commenced, even though baiting over this period has been irregular (Table 3). The data presented below for individual trials using initially a prototype version and more recently the manufactured feral cat bait for feral cats over the period 1994–2002, show that the results of baiting operations were variable, as was the bait density and the time (season) of bait delivery. Notwithstanding this, the mean difference in relative abundance of feral cats between the Impact and the Control areas in the period prior to the commencement of baiting was 2.18 compared with a mean difference during the period after baiting commenced of 11.8 (Table 3). Similarly, there is a

TABLE 2

Summary of broadscale baiting operations associated with various research trials to develop techniques for controlling introduced predators in the Gibson Desert, Western Australia. Fox baits were 40–50 g dried meat. The bait type used for feral cats was initially the prototype version (fresh, small kangaroo meat chunks) and later the finalised manufactured (sausage product) feral cat bait. Baits were delivered at various densities by aircraft. Rainfall is from Carnegie Station.

DATE	RAINFALL 3 MONTHS PRIOR TO BAITING (MM)	BAITING TRIAL	AREA BAITED (KM ²)	BAIT TYPE	MEAN BAIT DENSITY (BAITS KM ²)
Apr. 1992	170	# 1	1 600	Fox bait toxic	6
Aug. 1992	90	# 1	1 600	Fox bait toxic	5
Mar. 1993	70	# 1	1 600	Fox bait toxic	5
May 1994	2	# 2	400	Prototype cat bait toxic	10
Sep. 1996	78	# 3	400	Prototype cat bait toxic	22
Sep. 1998	130	# 3	400	Prototype cat bait toxic	11
May 2000	214	# 4	1 600	Fox bait toxic	5
Jul. 2001	21	# 5	700	Feral cat bait non-toxic biomarker	50 and 100
Jun. 2002	10	# 6	625	Feral cat bait – toxic	50

TABLE 3

Changes in a) the mean difference in introduced predator relative abundance (TDI) between the Impact (baited) area and the Control (unbaited reference) area and b) in the mean ratio of introduced predator abundance; the Impact:Control ratio, before and after the commencement of baiting. Significant differences are shown as (**) $\alpha=0.05$ and using a two-tailed t test.

VARIABLE	TIME PERIOD	MEAN (S.E.)		
		FERAL CAT	FOX	DINGO
a) Difference in relative abundance	Pre-baiting	2.18 (1.54)	0.00 (0.46)	0.47 (0.19)
	Post-baiting <i>d.f.=24, t=3.28**</i>	11.81 (2.49) <i>d.f.=21, t=2.30**</i>	2.74 (0.93) <i>d.f.=21, t=4.71**</i>	5.34 (1.00)
b) Relative abundance ratio	Pre-baiting	1.12 (0.26)	1.21 (0.11)	0.88 (0.45)
	Post-baiting <i>d.f.=24, t=5.49**</i>	0.49 (0.30) <i>d.f.=21, t=4.07**</i>	0.37 (0.17) <i>d.f.=21, t=1.92</i>	0.54 (0.17)

statistically significant difference ($\alpha=0.05$) between the mean relative abundance ratios for the Impact and Control areas before and after baiting commenced, with the mean before Impact:Control TDI ratio being 1.12 and the mean after Impact : Control TDI ratio being 0.49 (Table 3). Together with the individual trial data below, this suggests that the (significant) difference is due to baiting. Similar results apply to fox and dingo relative abundance, although the before and after abundance ratios for dingoes were not significantly different. This is probably due to the scale and frequency of baiting and the relatively rapid re-invasion by dingoes, especially in the smaller scale baiting operations.

A linear regression procedure PROC REG (SAS Corporation 1995) was used to develop a model to predict baiting effectiveness (per cent reduction in relative abundance of feral cats following baiting) using a linear combination of a number variables including baiting density, 12 months precedent rainfall, 3 months precedent rainfall, minimum temperature and maximum temperature. With only 5 degrees of freedom, the power of the regression analysis is low, but the procedure helped to statistically determine which variables acting alone or in combination explained most variation in baiting effectiveness. Based on a small number of feral cat baiting operations in the Gibson Desert (Table 2), bait density,

precedent 3 months rainfall and minimum temperature during the baiting operation explained most of the variation in baiting effectiveness, with the first two variables accounting for most variation in the model;

$$BE = BD(0.41) - RN3(0.35) - MINT(0.25) + 83.4 \dots \dots \dots (R^2 \text{ adjusted} = 0.46, P > F = 0.305)$$

where:

BE = baiting effectiveness (% reduction in TDI)

BD = baiting intensity (baits km⁻²)

RN3 = total rainfall in the previous 3 months (mm)

MINT = minimum temperature (°C)

Because of the small number of samples upon which the model is based, and as reflected in the high intercept value, the model has limited application. However, it further supports the suggestion that baiting effectiveness is directly related to baiting intensity and inversely related to both rainfall prior to baiting and minimum daily temperature. Increasing baiting intensity, to a point, increases the chances of feral cats finding and consuming a bait. Prey availability is probably lower under cool, dry conditions, further enhancing the likelihood of hungry feral cats consuming a bait. This is discussed further below.

The track density index (TDI) survey data for the period 1989–2002 are presented in Figures 1a–c. These

show that in the absence of control measures (baiting) canid abundance was variable but relatively low with the TDIs mostly less than 5 for foxes and 10 for dingoes. The highest canid densities were recorded during the year 2000 when the TDI reached 15.1 for both species. Fox abundance over the monitoring period was lower than what has been reported for other more productive natural environments in Western Australia. For example, over the period 1989 to 1991 when the CPUEI was measured together with TDI (prior to baiting), the CPUEI varied from 0.9 to 2.0 compared with CPUE indices of about 11 for *Banksia* woodlands (Algar and Kinnear 1992) and 17 for *Acacia* shrublands (Algar and Smith 1998) in near-coastal environments further to the south and west. In the unbaited areas of the Gibson Desert, the fox TDI varied from 0.0 to 15.1 but was commonly less than 5 (Figure 1b). By comparison, the fox TDI for the Peron Peninsula (mid-west coast of Western Australia) prior to control measures was in the vicinity of 85 (Neil Burrows, unpublished data). Following fox control on the Peron Peninsula, and in the absence of effective feral cat control, the cat TDI increased to about 60, which is almost double the highest level recorded in the Gibson Desert. In environments of high fox or feral cat abundance, such as parts of the mid-west coast of Western Australia, rabbits are usually also abundant and are an important dietary item (e.g. Jones 1977, Catling 1988, Short *et al.* 1997, Molsher *et al.* 1999). In the Gibson Desert where rabbits are normally scarce, none of the sampled fox scats or stomachs contained rabbit (Burrows *et al.* 2003).

In the absence of control measures, the feral cat TDIs were usually two to three times higher than that of the canids. As with the canids, the feral cat TDI was lowest during the late 1980s and peaked at about 35 during the early 1990s and again in the early 2000s. The feral cat TDI varied across a larger range than the canid TDI suggesting that feral cats may be more responsive to changing seasonal conditions than the canids; they showed a greater capacity to increase in abundance following seasons of average or above average rainfall. Feral cats are

able to breed two to three times a year if conditions are suitable (Jones and Coman 1982), whereas the canids only breed once each year (Coman 1995, Corbett 1995). The impact of baiting events on the relative abundance of canids is clearly evident in Figures 1a–c. Baiting is followed by a significant reduction in the TDI. A similar pattern is evident for feral cats, but only following baiting with a feral cat bait type, either the prototype version (fresh, small kangaroo meat chunk) or the finalised manufactured (sausage product) feral cat bait. The magnitude of the reduction in feral cat relative abundance following baiting is quite variable and appears to be related to the density of baits, the season of baiting and the precedent rainfall.

Trends in the relative abundance (TDI) of feral cats in the unbaited reference area were associated with variation in the amount of rainfall (Figure 2), which in turn affects resource availability in these arid ecosystems (Morton 1990). The long term average annual rainfall for the region is about 217 mm. Rainfall records for the region (Figure 3), based on the mean rainfall for Carnegie, Glen Ayle and Warburton, meteorological stations within 250 km radius of the study site, show a period of below average rainfall during the 1980s, when the mean annual rainfall over the period 1981–1991 was 152 mm, followed by a period of well above average rainfall during the 1990s when the average annual rainfall over the period 1991–2001 was about 340 mm. This coincides with periods of low and high introduced predator densities (especially cat and dingo) respectively (Figure 1a–c).

GDNR Baiting Trial 1 (1989–93)

Aim

To control the abundance of introduced predators, especially the fox, by broad area aerial baiting so that founder populations of reintroduced mammals could establish. Research in the south-west of WA had shown that foxes were a serious threat to medium size mammals so baiting was largely aimed at controlling foxes. Because

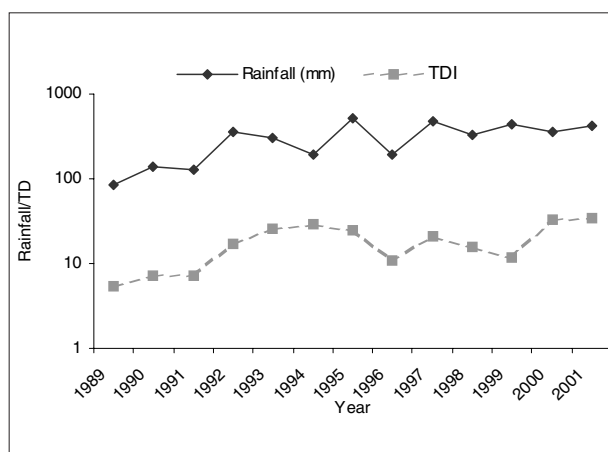


Figure 2. Mean annual rainfall (Carnegie Stn.) with mean track density index (TDI) for feral cats in an unbaited reference area in the Gibson Desert. Y axis is logarithmic.

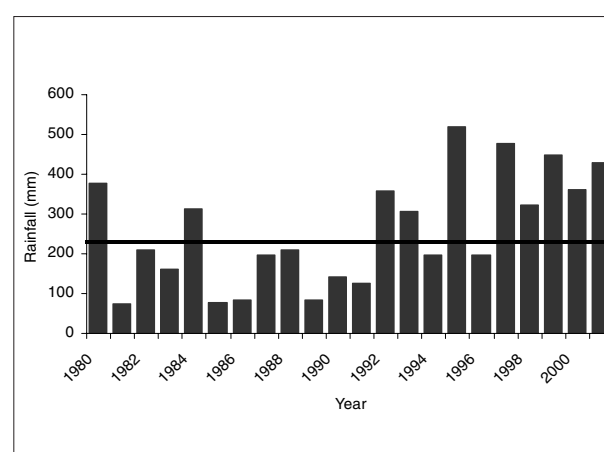


Figure 3. Average annual rainfall from three locations in the vicinity of the Gibson Desert Study area. The dark line is the long term average.

of their low density (at the commencement of this trial), smaller size and lack of evidence to the contrary, feral cats were thought not to be a serious threat.

Methods

Surveys to determine the relative abundance of foxes, feral cats and dingoes commenced in the area in May 1989 (Figure 1a–c), several years prior to the first (fox) baiting operation, which occurred in April 1992 (Table 2). At this time, and prior to mammal reintroductions, an area of approximately 1 600 km² (40 km x 40 km) was baited to provide protection for the reintroduced animals, which were released virtually in the centre of the baited area (Christensen and Burrows 1995). Heavy rain fell soon after baiting so the planned reintroduction was delayed and the area re-baited in August 1992. An aircraft was used to deliver standard 'fox' baits, which are 40–50 g dried meat injected with the 4.5 mg of the poison sodium monofluoroacetate (1080) (Table 2). This bait is routinely used to control foxes in the south-west of WA because of the known high resistance of native fauna to 1080 (King 1990). In August 1992, a total of 7800 fox baits was delivered at an average density of about 5 baits km⁻². Prior to and about one month after baiting, both an unbaited reference (control) area and the baited area were re-surveyed using the track count transect method described above to assess introduced predator densities. The 1600 km² area was baited again in March 1993 (Table 2) using standard fox baits and surveys of introduced predator densities were carried out before and about five months after baiting in both the baited and the unbaited areas.

Results and discussion

Aerial baiting using the standard fox bait (Table 2) was highly effective at reducing the abundance of canids as measured by the TDI (Table 4 and Figures 1b and c). Fox and dingo TDIs in the baited and unbaited reference areas were low prior to baiting, but fell to zero in the baited area three months after baiting and remained at zero for at least 12 months, suggesting local eradication or near eradication over this time (Burrows *et al.* 2003). Precisely when foxes and dingoes re-established following baiting is unknown because of the interval between post-

baiting surveys. Figures 1b–c show that foxes and dingoes were not detected until May 1994 following baiting operations in August 1992 and March 1993. Even then, the TDIs were low at 2.6 and 4.0 for foxes and dingoes respectively. These data suggest that dingoes re-established more rapidly than foxes, which is to be expected. Dingoes occupy large home ranges and young animals are capable of dispersing over long distances. Home ranges of up to 77 km² and dispersal distances of 250 km have been recorded for parts of arid Australia (Corbett 1995).

Foxes in the semi-arid and arid zones of Western Australia appear to be highly susceptible to 1080 baiting. Virtual eradication of foxes was achieved following a single baiting on Peron Peninsula in the Shark Bay Region (Algar and Smith 1998) and in the Gascoyne region (Thomson *et al.* 2000). It is highly likely that in the arid environment of the Gibson Desert, the dried meat fox baits remain toxic in the field for some considerable time after delivery. This, combined with the low natural abundance of foxes and dingoes in this environment, especially during drought periods, probably explains the relatively long interval before re-invasion of the site.

The 1992 fox baiting operation appears to have had a positive impact on the feral cat population (Figure 1a and Table 4). Feral cat TDI in the baited area increased from 6.6 to 28.0 and in the unbaited area, from 6.6 to 17.3 (Table 4), suggesting that there was little if any ingestion of the fox baits by feral cats. The 10.7 units of increase in the feral cat TDI in the unbaited reference area is probably due to the above average rainfall (therefore higher prey availability and favourable breeding conditions) over the period (Burrows *et al.* 2003). This could also explain 10.7 of the 21.4 units of increase in the baited area. Dingoes have been shown to influence the abundance of feral cats in other ecosystems (Williams *et al.* 1995; Pettigrew 1993), so the removal of canids from the baited area may explain the balance of the feral cat TDI increase in the baited area (a further 10.7 units). However, with the removal of foxes and dingoes, it might be expected that feral cat activity on the roads and tracks would increase, giving the appearance that feral cat abundance had increased. A rapid and significant increase in feral cat abundance following removal of foxes was also observed in the Shark Bay area of Western Australia (Algar and Smith 1998).

TABLE 4

Baiting trial 1: Mean relative abundance of introduced predators (foxes, dingoes and feral cats) as determined by the track density index (TDI) before and after baiting using standard fox baits at a density of about 5 baits km⁻². TDI standard errors are in parentheses. Post-bait surveys were carried out 1–3 months after baiting.

DATE BAITED	FOX TDI				DINGO TDI				FERAL CAT TDI			
	BAITED		NOT BAITED		BAITED		NOT BAITED		BAITED		NOT BAITED	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
August 1992	5.3	0.0	2.6	2.6	2.6	0.0	4.0	6.6	6.6	28.0	6.6	17.3
	(0.3)		(0.2)	(0.2)	(0.2)		(0.3)	(0.4)	(0.4)	(2.1)	(0.5)	(1.3)
March 1993	0.0	0.0	2.6	6.6	0.0	0.0	4.0	6.6	34.6	21.3	34.6	17.3
			(0.2)	(0.5)			(0.3)	(0.4)	(2.8)	(1.7)	(2.4)	(1.4)

While the March 1993 baiting maintained the canid TDI at zero until at least September 1993, the feral cat TDI in both the baited and unbaited areas inexplicably fell by 39% and 50% respectively (Figure 1a and Table 4).

GDNR Baiting Trial 2 (1994–98)

Aim

To develop effective and efficient operational baiting techniques to control introduced predators, particularly the feral cat (Burrows *et al.* 2003). Baiting trial 1 (above) showed that standard fox baits had no direct impact on the feral cat population.

Methods

With the loss of the reintroduced mammals to predation by feral cats (see Christensen and Burrows 1995) the bait trial area was reduced to about 400 km² (20 km x 20 km) within the initial 1 600 km² impact area described above. The unbaited (control) area was also reduced in size (to 400 km²) and located closer to the baited area (within 5 km). The same transects were used in the baited area to assess the relative abundance of introduced predators. Aerial baiting was carried out in May 1994, September 1996 and September 1998 using a prototype of the feral cat bait (Algar and Smith 1998) dispensed at different densities for each trial (Table 2). The prototype bait used in these trials was a small (30–40 g), fresh (rather than dried) kangaroo meat bait coated in digest, and dosed at 4.5 mg of 1080 per bait. The bait is also ingested by, and is lethal to, foxes and dingoes. Introduced predator track count surveys (as described above) were carried out over 3–4 consecutive nights in the baited and unbaited areas using about 30 km transects in each area before and after each baiting operation.

Results and discussion

The smaller scale baiting trial (400 km²) conducted in May 1994 at a density of 10 baits km⁻² using the prototype

feral cat bait (Table 2) virtually eradicated canids from the baited area for at least 12 months after baiting with the TDI for foxes and dingoes falling to 0.0 (Table 5 and Figures 1b and c). Following the baiting, foxes and dingoes were first recorded in the baited area in September 1995. The feral cat TDI in the baited area fell from 34.6 measured just prior to baiting, to 8.6 measured about 3 months after baiting, representing a reduction in cat abundance of about 75%. Over the same period, feral cat TDI in the unbaited reference area increased from 21.3 to 34.6 (Table 5), representing a 62% increase in abundance (Burrows *et al.* 2003). In the absence of further baiting, feral cat TDI in the baited area increased slightly over the two years following the 1994 baiting, but declined in the unbaited area after an initial increase (Figure 1a). This may have been in response to an increase in dingo abundance over this period (Figure 1c) causing a real or apparent reduction in feral cat density.

The second small scale baiting conducted in September 1996 at a density of 22 baits km⁻² also virtually eradicated canids (TDI = 0.0) when their abundance was assessed some three months after baiting (Table 5). There was also a 30% reduction in dingo abundance in the unbaited reference area suggesting that they may have been affected by the baiting. Dingoes are capable of travelling long distances and some animals may have ventured into the baited area, about 5 km from the unbaited area. The baiting did not appear to impact on feral cats or foxes in the unbaited reference area, suggesting that the buffer (distance) between the two areas was adequate for these species at least. In the baited area, feral cat TDI fell from 9.3 to 0.0 (measured 3 months after baiting), but remained about the same in the unbaited reference area (Table 5). This represents a 100% reduction in abundance based on the TDI survey technique. It is unlikely that eradication was achieved, but feral cat abundance was reduced to an undetectable level using the track count technique. Feral cat abundance was very low prior to baiting (TDI = 9.3), so these results need to be interpreted cautiously. The next survey was conducted in September 1997, some 12 months after the baiting operation. The

TABLE 5

Baiting trial 2: Mean relative abundance of introduced predators (foxes, dingoes and feral cats) as determined by the track density index (TDI) before and after baiting using the prototype feral cat bait at a density of a) 10 baits km⁻² (1994), b) 22 baits km⁻² (1996) and c) 11 baits km⁻² (1998). TDI standard errors are shown in parentheses. Post-bait surveys carried out 1–3 months after baiting.

DATE BAITED	FOX TDI				DINGO TDI				FERAL CAT TDI			
	BAITED		NOT BAITED		BAITED		NOT BAITED		BAITED		NOT BAITED	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
May 1994	2.6 (0.2)	0.0	2.6 (0.2)	2.6 (0.2)	4.0 (0.3)	0.0	2.6 (0.2)	12.0 (0.9)	34.6 (2.9)	8.6 (0.6)	21.3 (1.8)	4.6 (2.6)
September 1996	2.6 (0.2)	0.0	0.0 (0.0)	0.0 (0.0)	8.0 (0.6)	0.0	11.4 (0.8)	8.4 (0.6)	9.3 (0.6)	0.0	11.1 (0.7)	10.6 (0.8)
September 1998	3.9 (0.3)	0.0	1.5 (0.1)	1.0 (0.1)	13.8 (1.2)	0.0	6.2 (0.5)	1.0 (0.1)	10.7 (1.0)	8.0 (0.6)	18.7 (1.7)	22.8 (2.1)

feral cat TDI in the baited area had increased from 0.0 to 8.6, but it was significantly lower than the TDI in the unbaited area, which was 21.3 (Figure 1a). The virtual eradication of feral cats during this second feral cat baiting trial is ascribed to the higher density of baits delivered on the ground and to the below average rainfall during 1996, which probably resulted in a reduction in prey available to feral cats making them more inclined to consume the baits (Burrows *et al.* 2003).

The third baiting trial conducted in September 1998 at a density of 11 baits km⁻² and following above average rainfall in 1997 and 1998 (Burrows *et al.* 2003) also reduced canid abundance dramatically, with the TDI falling from 3.9 to 0.0 for foxes and from 13.8 to 3.0 for dingoes (Table 5). When measured in May 1999, six months after baiting, fox TDI was 0.0 and the dingo TDI had increased to 5.7 (Figures 1b and c). The relatively rapid recovery of dingoes was probably a function of the small area baited and the large home range and dispersal capacity of dingoes. Following baiting, the feral cat TDI fell from 10.7 to 8.0, representing a 25% reduction in abundance (Table 5). However, feral cat density in the unbaited control area over the same period increased from 18.7 to 22.8 (Figure 1a), representing a 22% increase. The difference in feral cat density between the baited and the unbaited control prior to baiting may have been due to the higher density of dingoes in the baited area (Figure 1c), or to the previous feral cat control measures, or to both factors. It appears that the September 1998 feral cat baiting operation was less effective in reducing feral cat density than the previous operation in September 1996. As with foxes and dingoes, the capacity of feral cat populations to recover after successful baiting operations is probably a function of the effectiveness of the initial baiting in reducing the original population, the size of the area baited and precedent and antecedent rainfall.

The relatively poor feral cat baiting result in September 1998 (25% reduction in TDI) is attributed to above average rainfall during 1997 and 1998 (Figure 3) and the probable subsequent increase in abundance of prey species, and to the low density of baits (Burrows *et al.* 2003). Feral cats are not as adept at finding baits as canids (David Algar personal observation), so increasing the density of baits increases the likelihood of feral cats finding a bait before they have killed and eaten live prey. The above average rainfall was reflected in the condition of the vegetation, which was lush and green, and in the abundance of potential prey species particularly birds, small native mammals and the introduced house mouse. Working in a semi-arid environment on the Western Australian coast, Short *et al.* (1997) and Algar *et al.* (in press, a) found that bait uptake by feral cats was inversely proportional to rabbit density, the inference being that when prey (rabbits) were abundant, feral cats were less likely to consume a bait. In the Gibson Desert study area rabbits are present but at very low densities along fossil drainage lines (Burrows *et al.* 2003, Liddelow *et al.* 2002).

GDNR Baiting Trial 3 (2000)

Aim

Meso-predator release amongst sympatric populations of predators has been reported in North America (Lindstrom *et al.* 1995). The aim of this trial was to investigate the response of feral cat populations following the selective removal of foxes and dingoes. Earlier baiting (Trials 1 and 2 above) using standard fox baits demonstrated the effectiveness of this technique in reducing the abundance of canids, but feral cat abundance appeared to increase in some instances (see Figure 1a and Christensen and Burrows 1995). The hypothesis under test in this trial was that feral cat abundance is influenced by the abundance of canids such that felid abundance decreases with increasing abundance of canids. The importance of this is firstly knowing whether there is interspecific or intraspecific competition amongst the predators and secondly, managing dingo populations could be an important technique for managing feral cat populations, especially in areas where dingoes are important or have significance, such as on some Aboriginal land. There are also measures in some States (eg. NSW) to list the dingo as a threatened species; there is debate amongst scientists as to whether the dingo is in fact a native species.

Methods

To test this the original 40 km x 40 km (1 600 km²) area that was baited in Trial 1 above, was again baited in May 2000 using standard fox baits. From previous trials (above) these baits are not attractive to feral cats so have little or no direct impact on feral cat abundance. This has been further substantiated by bait uptake trials where fox baits that have been carefully laid along transects have been consistently by-passed by feral cats (Neil Burrows personal observation). Surveys of the relative abundance of introduced predators (using the track count method) were carried out in the baited and unbaited (reference) area before, 1 week after, 8 weeks after and 16 weeks after baiting. If feral cat abundance increased rapidly following the removal of canids and before any effects of breeding, dispersal or migration, then it was likely that the feral cats had changed their activity behaviour in response to the removal of canids, rather than increased in abundance. On the other hand, if feral cat abundance steadily increased in the baited area (canids absent), but not in the control area (canids present), then we could assume a direct response between canids and feral cats, mediated by numerical changes.

Results and discussion

Canid TDI fell by about 90% within 1 week of baiting and by 8 weeks, no canid tracks were recorded in the baited area, whereas in the unbaited area their abundance remained constant, notwithstanding the lack of data at weeks 1 and 8 post-baiting (Table 6). There was a slight but insignificant increase in feral cat TDI in the baited

TABLE 6

Baiting trial 3: Mean relative abundance of introduced predators (foxes, dingoes and feral cats) as determined by the track density index (TDI) before and after baiting using standard fox baits in a 1 600 km² baited area and an unbaited control area. TDI standard errors shown in parentheses. Baiting was conducted in May 2000 and post-bait surveys carried out 1 week, 8 weeks and 16 weeks after baiting (nd = no data).

TDI	BAITED AREA				UNBAITED AREA			
	PRE-BAIT	1 WEEK AFTER	8 WEEKS AFTER	6 WEEKS AFTER	PRE-BAIT	1 WEEK AFTER	8 WEEKS AFTER	16 WEEKS AFTER
Fox	13.9 (1.3)	1.0 (0.1)	0.0	0.0	13.3 (1.3)	nd	nd	13.3 (1.3)
Dingo	11.2(1.2)	1.5 (0.1)	0.0	1.5 (0.1)	13.3 (1.2)	nd	nd	11.2 (0.9)
Feral cat	26.1(2.3)	28.6 (2.4)	36.7 (3.2)	33.3 (3.2)	23.3 (2.1)	nd	nd	30.0 (2.8)

area one week after baiting, but by 8 weeks, the TDI had increased from 26.1 to 35.0, representing a 34% increase in abundance. By 16 weeks after baiting, feral cat density had decreased slightly to 33.3 and dingoes had re-invaded the baited area, albeit at a very low density (TDI = 1.5). There was no evidence of re-invasion by foxes (Table 6). The relatively rapid increase in feral cat TDI following baiting of canids suggests that feral cats changed their activity patterns in response to the removal of canids. That is, it is most likely that actual feral cat density did not increase in the 8-week period post-baiting, but, in the absence of canids, used the roads more frequently. This trial suggests that feral cats change their behaviour following the removal of canids, giving the appearance of increased abundance, rather than actually increasing in abundance. Molsher *et al.* (1997) reported little change in feral cat abundance following the removal of foxes in eucalypt forests in south-east Australia and Edwards *et al.* (2001) suggested that the presence of dingoes could assist the survival of feral cats by providing a source of carrion. The findings reported here are inconclusive with respect to the longer-term response of feral cat populations following the removal of canids. If there is strong competition between feral cats and canids, then control measures that eradicate canids only could result in compensatory predation by increased feral cat abundance. This requires investigation, especially in the south-west where foxes are selectively removed using fox baits, but feral cats appear unaffected by the baiting.

GDNR Baiting Trial 4 (2001)

Aim

This trial, using the feral cat baits, aimed to a) determine bait uptake by feral cats under cool, dry winter conditions, b) compare the effect of different baiting intensities on bait uptake by feral cats and c) investigate bait uptake by non-target animals (Angus *et al.* 2002a). The hypotheses under test were a) the abundance of prey species (reptiles, small mammals and birds) is low over the cold, dry winter months, so feral cats are more likely to take baits, b) increasing the density of baits increases the chances of a feral cat finding and consuming a bait and c) native mammals and reptiles do not consume the baits.

Methods

Two non-toxic baiting densities were compared for both target and non-target (native) reptiles and mammals uptake over the cool, dry winter season (July 2001).

Non-toxic feral cat baits containing the biomarker Rhodamine B (RB) were used as this is an efficient systemic marker for determining bait consumption by feral cats and a wide range of non-target species (Fisher *et al.* 1999; Fisher 1998). When Rhodamine B is consumed, the compound causes short-term staining of body tissues, digestive and faecal material with which it comes in contact. Certain metabolites of RB are absorbed by the body and are incorporated into the structure of growing hair. This technique has advantages over other bait markers in being relatively non-invasive, simple and inexpensive. Analysis for the presence of Rhodamine in the mystacial vibrissae is described in Fisher *et al.* (1999). Trapping programs are employed to capture feral cats and non-target species to allow identification of those animals containing the biomarker and thus determination of the percentage of the population that consumed a bait (i.e. baiting efficiency).

This trial enabled the concurrent assessment of possible efficacy in feral cat control and risk to non-target species, in the absence of a toxin. Two densities of non-toxic bait distribution, 100 baits km⁻² and 50 baits km⁻², were trialed with each treatment being approximately 350 km² in area and in similar habitats. These baiting intensities were selected following the success of feral cat baiting programs on Hermite and Faure Islands (see Sections 3.3.2 and 3.3.3) using high baiting levels compared with the variable responses achieved in the earlier trials in the GDNR at lower baiting intensities. The baiting operation was carried out under cool, dry conditions in July when daily air temperatures ranged from overnight minima of 0–4° C to maxima of 22–25° C. Baits were distributed from an aircraft with special navigation and bait delivery system to ensure accuracy in the location and density of baits delivered (Angus *et al.* 2002a). Ten days after baiting, introduced predators (foxes, feral cats and dingoes) were trapped using Victor Softcatch leghold traps. Traps were placed at 500 m intervals along transects within each treatment area with a total of 502 trap nights in the 100 baits km⁻² treatment and a total of 773 in the 50 baits km⁻²

treatment (see Angus *et al.* 2002a). Captured predators were destroyed and their vibrissae and stomachs were removed for later examination.

Bait uptake by non-target vertebrate fauna was examined by sampling the fauna using grids of pitfall and medium Elliott box traps at two sites in each treatment (Angus *et al.* 2002a). Baits were deliberately delivered close (<130 m) to the non-target trap sites. All trapped animals, including reptiles and small mammals, were examined for signs of staining by RB.

Results and discussion

Based on the trap data (Table 7), bait uptake by feral cats was high at 100% and 82% for the 50 baits km⁻² and 100 baits km⁻² treatments respectively, or about 89% overall. There was no statistically significant difference ($z=1.63$, $P>0.05$) in bait uptake between the two bait intensity treatments (Angus *et al.* 2002a). The greater percentage of marking from the 50 baits km⁻² treatment suggests that this baiting intensity would be at least as efficacious as the 100 baits km⁻² for the control of feral cats.

A summary of non-target fauna captures is presented in Table 8. Skinks were the most numerous captures, with a strong representation by *Ctenotus pantherinus ocellifer*. The only taxon represented at all sites was *Ningauai ridei*, with most taxa represented at two or three sites.

None of the non-target mammals or reptiles sampled during this trial was marked by RB. If any individual did consume bait material, the amount consumed was

insufficient to produce a detectable marking by RB. The distance between the mid-point of the nearest bait drop and the edge of the fauna sampling grids varied. This distance may have been greater than that normally traversed by some individuals sampled, however no bait drop was more than 130 m distant from the nearest sampling grid and baits were delivered directly overhead at two of the sites. Based on published home range data (e.g. Strahan 1995; see Moro and Morris, 2000) many of the individuals sampled would have potentially encountered baits. Not all species known to occur in the same broad location were represented in the sample. For these reasons, the assessment of risk to non-target fauna requires further investigation. It is significant however, that three small mammal species were sampled from sites that had directly received a high concentration of baits and that none showed any sign of having consumed bait material. Future work, specifically aimed at assessing non-target risk, will require a maximisation of the quantity and diversity of non-target animals that are likely to come into contact with a field application of baits.

GDNR Baiting Trial 5 (2002)

Aim

To investigate the effectiveness of baiting using toxic feral cat baits delivered at a density of 50 baits km⁻² under cool, dry conditions in June/July 2002. The hypothesis under test was that baiting feral cats would be most effective

TABLE 7

Summary of predator vibrissae marking with RB, as determined by examination under low intensity UV light source of fluorescence microscope.

	50 BAITS KM ⁻²			100 BAITS KM ⁻²		
	FERAL CAT	DINGO	FOX	FERAL CAT	DINGO	FOX
Marked animals (Total)	13 (13)	2 (3)	2 (2)	18 (22)	4 (7)	2 (2)
% Marked	100	66.7	100	81.9	57.1	100

TABLE 8

Non-target fauna captures (source Angus *et al.* 2002a).

TAXON	BAITING INTENSITY	
	50 BAITS KM ⁻²	100 BAITS KM ⁻²
<i>Ctenophorus isolepis gularis</i>	4	1
<i>Pogona minor minor</i>	1	-
<i>Delma haroldi</i>	3	2
<i>Delma nasuta</i>	5	-
<i>Delma tineta</i>	-	2
<i>Ctenotus calurus</i>	2	1
<i>Ctenotus helenae</i>	-	1
<i>Ctenotus pantherinus ocellifer</i>	10	4
<i>Cyclodomorphus branchialis</i>	1	-
<i>Neobatrachus sutor</i>	2	-
<i>Ningauai ridei</i>	8	3
<i>Sminthopsis youngsoni</i>	-	1
<i>Notomys alexis</i>	3	-
<i>Pseudomys desertor</i>	-	2
<i>Pseudomys hermannsburgensis</i>	3	-
Total	42	17

during cool, dry winter months when prey availability is at its lowest, and by baiting at a high density to increase the likelihood of feral cats finding a bait (see Liddelow *et al.* 2002).

Methods

The bait used during this trial was the same as that used in the RB trial described above, except that one flavour enhancing ingredient (no longer commercially available) was omitted and each bait was injected with 4.5 mg of the toxin 1080 instead of RB. The area baited was 625 km² and baits were aerially distributed at a density of 50 baits km⁻². Two track density transects (see method described above) were employed to assess predator activity, one within the area to be baited, the other within the non-baited reference (control) area. Assessment was carried out simultaneously on the two transects by two separate teams. Transects were assessed on the three days before baiting was carried out and for three consecutive days, commencing nine days after baiting. The unbaited control transect traversed 32.7 km of this treatment. The baited treatment transect traversed both the core (23.3 km) and nominal buffer zones (5 km). Following baiting, an additional 11.1 km transect was established within the core baited area. This transect was assessed post-baiting only.

Results and discussion

The baiting operation was highly successful with about a 96% decrease in the mean track density index (TDI), within the core baited area (Figure 1a and Table 9). Only one individual cat paw print was detected within the core-baited area following baiting. There was no detectable change in the cat density (TDI) in the unbaited reference area. The efficacy of this trial confirmed previous findings from this site that baiting for feral cats in the autumn-winter months, when prey availability and non-target risk are low, can achieve a substantial reduction in relative abundance measured soon after baiting.

The Pilbara Bioregion – Montebello Islands

Aim

The importance of islands to the conservation of Australian mammal species has been well documented (Burbidge and McKenzie 1989; Abbott and Burbidge 1995; Burbidge *et al.* 1997). One of the key factors in the historic importance of islands has been that most have remained free of introduced predators. Burbidge (1999) highlighted the current and future importance of islands to nature conservation and stated that ‘*Australian nature conservation agencies need to pay more attention to the eradication of exotic animals from islands.*’ Burbidge and Manly (2002) analysed the relationship between disturbances and native mammal extinctions on Australian islands and implicated feral cats in the extinction of these species on arid islands. They concluded that high estimated extinction probabilities are associated with ground dwelling, herbivorous, ‘critical weight range’ mammals of high body weight on islands of low rainfall, low to moderate presence of rockpiles and the presence of feral cats, foxes and rats.

Feral cats and black rats (*Rattus rattus*) became established on the Montebello Islands during the late nineteenth century and were probably introduced from pearling vessels. Feral cats occurred on several islands at various times, but by 1995 were naturally restricted to Hermite (Burbidge *et al.* 2000). Montague (1914) attributed the recent extinction of the Golden Bandicoot (*Isodon auratus*) to predation by feral cats and predicted that the Spectacled Hare-wallaby (*Lagorchestes conspicillatus*) would suffer the same fate. Later surveys by Sheard (1950) and Serventy and Marshall (1964) found that the above two species had become extinct on the islands, confirming Montague’s prediction.

Montebello Renewal (part of ‘*Western Shield*’) aims to eradicate feral cats and black rats from the Montebello Islands to allow the successful re-introduction of locally extinct species (Burbidge 1997, Burbidge in this issue).

TABLE 9

Relative abundance (TDI) of feral cats along transects assessed for three nights before and after toxic baiting at a density of 50 baits km⁻² in winter (June/July) 2002.

	DATE	MEAN RELATIVE ABUNDANCE (TDI) UNBAITED REFERENCE AREA	MEAN RELATIVE ABUNDANCE (TDI) BAITED AREA
BEFORE BAITING			
	21/06/02	39.8	42.9
	22/06/02	33.6	34.4
	23/06/02	30.6	60.1
Mean TDI		34.7	45.8
AFTER BAITING			
	03/07/02	24.5	0.0
	04/07/02	42.8	0.0
	05/07/02	36.7	4.3
Mean TDI		34.7	1.4

This project provided our first opportunity to assess the effectiveness of the feral cat bait and trapping techniques that Department researchers had developed in the eradication of feral cats from an island.

Methods

The Montebello Islands comprise a group of over 100 islands, islets and rocks off the Pilbara coast of WA. The islands are located between 20°21' and 20°32' S and between 115°3' and 115°36' E, approximately 100 km off the WA coast. The total area of the islands is approximately 2300 ha with Hermite Island being the largest at 1020 ha. The archipelago has a tropical, arid climate. The nearest weather station is on Barrow Island, 30 km to the south, which has a median rainfall of 285 mm, and mean daily maximum and minimum temperatures of 30.3° C and 21.4° C respectively.

Hermite Island is a difficult location on which to conduct a feral cat eradication campaign because of its isolation, rugged terrain and absence of vehicle access. The shape of the island is elongated and highly convoluted, with a number of sandy beaches, areas of mangroves, cliffs and limestone ridges and peninsulas. Its interior is low, undulating and is vegetated with a dense mat of Spinifex (*Triodia* sp.) with occasional *Acacia coriacea* thickets on deep sand.

The program to eradicate feral cats on Hermite Island involved aerial baiting to remove the majority of the feral cats, followed by intensive trapping to remove the remaining individuals. A reconnaissance of Hermite Island was conducted prior to the baiting program to assess feral cat abundance. Searches for evidence of fresh feral cat activity were conducted around most mangrove stands and sandy areas on the island. These were examined daily over a five day period. The location of fresh feral cat activity on swept areas, its extent and the distances between sites suggested that at least 20 feral cats were present prior to baiting.

About 1 100 feral cat baits were dropped by hand from a helicopter on the 3 July 1999. Hermite Island has two main soil types—deep sand and skeletal sands on limestone. Aerial baiting primarily targeted sandy soils with the flight path essentially following the 140 km coastline and then through the centre of the island to maximise bait availability and the area covered. Monitoring feral cat activity along a number of the beaches post-baiting indicated that several feral cats were still present. A trapping program was implemented to remove the remaining feral cats. The trapping program, techniques and assessment of feral cat activity are discussed in detail in Algar and Burbidge 2000 and Algar *et al.* 2002b.

Results and discussion

The intensive searches showed that feral cats, prior to baiting, had been active across much of the island, mostly along the sandy beaches, mangroves and *Acacia* thickets where 'highways' of tracks and numerous scat piles were observed. Some evidence of feral cat activity was observed

along the limestone ridges and in the Spinifex plains, but these areas were understandably less favoured habitat and were used as pathways to the more preferred sites.

Four feral cats were captured during the trapping program. No evidence of fresh feral cat activity was observed across the island once the four feral cats had been trapped and it was concluded that eradication had been successfully completed. This was confirmed by searches for feral cat activity in August 2000. The fact that only four feral cats remained after baiting indicates that it was responsible for removing at least 80% of the feral cats from the island.

Feral cat eradication programs on islands are usually conducted using a combination of baiting, trapping and hunting (Veitch 1985; Rauzon 1985; Bloomer and Bester 1992; Bester *et al.* 2000). These eradication programs have met with varied success, their success and time to completion, often taking months or years, or are still ongoing, having been limited in part by lack of effective bait and trap lures. Bait acceptance by feral cats is in part related to the abundance of prey species (Algar *et al.* in press, a). The major prey items available to feral cats on the Island would have been rats, birds, reptiles and insects. The baiting campaign on Hermite Island was conducted when rat numbers were very low after a rat eradication attempt (see Burbidge, this issue) and when the availability of natural prey items, particularly reptiles and insects, was likely to be at its lowest (mid-to late-winter). The feral cat eradication program on Hermite Island was achieved in a matter of weeks and could have been completed sooner using the modification to the trap set (Algar *et al.* 2002b).

The advances in feral cat control strategies developed by CALM and the successful eradication program on Hermite Island led to the planning of feral cat eradication programs for a number of additional islands off the Western Australian coast, as per the Western Shield Strategic Plan 1999-2004 (CALM 1999).

The Carnarvon Bioregion - Faure Island, Pimbee Station and Peron Peninsula

Faure Island

Aim

Feral cats became established on Faure Island, off the Gascoyne coast of Western Australia, during the late nineteenth century and were probably introduced from pearling vessels or by early pastoralists. Australian Wildlife Conservancy (AWC), lease holders of the Faure Island pastoral lease, is planning to establish the area as a site for the conservation of threatened mammals and ecotourism. No native mammals now occur on the island; however there is evidence from sub-fossil deposits that at least four species once occurred on the island. AWC propose to translocate five native mammal species to the island: the western barred bandicoot (*Perameles bougainville*), boodie (*Bettongia lesueur*), greater stick nest rat (*Leporillus conditor*), Shark Bay mouse (*Pseudomys fieldi*) and banded

hare-wallaby (*Lagostrophus fasciatus*). To enable the successful recolonization of the island by these species it was necessary to implement a feral cat eradication program.

Following the success of the feral cat eradication program on Hermite Island, Montebellos (Algar and Burbidge 2000; Algar *et al.* 2002b; see above), a request was made to CALM to conduct the eradication program.

Methods

Faure Island is located between 25°48' S and 25°54' S and between 113°51' E and 113°56' E. The island, an area of 58 km², lies within the eastern gulf of Shark Bay at the head of the Hamelin Pool embayment, approximately 18 km east of Monkey Mia. The land systems on Faure are described by Payne, Curry and Spencer (1987). Climatic data for the general Bioregion, which includes Pimbee Station and Peron Peninsula (see below), is described as 'semi-desert Mediterranean' (Beard 1976). Payne *et al.* (1980) provide climatic data for a number of nearby centres. Mean maximum daily temperatures, for nearby reporting centres, are as high as 38°C for summer months and as low as 21°C for winter months. January and February are the hottest months while June and July are the coolest months. Annual average rainfall for the general area is in the vicinity of 220 mm. The area receives reliable winter rainfall with June being the wettest month at approximately 50 mm on average. Rainfall is extremely unreliable and often absent, outside the winter months. However mean annual rainfall may be exceeded during a single cyclonic event.

A preliminary study to assess the feasibility of feral cat eradication on the island was conducted in September 2000 (Algar and Angus 2000b). During this preliminary study a small-scale trapping program, feral cat bait acceptance trial and intensive searches for evidence of feral cat activity were conducted. These surveys of feral cat activity indicated a population of approximately 40 adult feral cats on the island at that time.

During this preliminary study, feral cats readily consumed non-toxic baits. On-track bait acceptance trials indicated that 67% of the sample population consumed at least one bait. During this period, the principal dietary item was reptiles in particular young *Varanus gouldii* which hatch in late winter/early spring depending on seasonal conditions. Activity of varanids and their relative size in September provided a reasonable prey source. Bait acceptance by feral cats is in part related to the abundance of prey species and bait consumption generally increases as prey availability declines (Algar *et al.* in press, a). On Faure Island, growth of hatchling varanids, through summer and into autumn, was likely to reduce their vulnerability to predation. Bait consumption by feral cats in autumn was therefore expected to increase from that recorded in September.

The feral cat eradication campaign was conducted during late February/March 2001 when bait acceptance was predicted to be high and the campaign was unlikely

to be affected by rainfall. An aerial baiting campaign was adopted as the primary control technique. Following the baiting campaign a selective site ground-baiting, trapping and monitoring program was employed to remove any feral cats that remained.

In an attempt to maximize the availability of baits, a baiting intensity of 100 baits km⁻² was used. This baiting intensity was aimed at maximizing the likelihood of feral cats encountering a bait when hungry. Feral cat baits were deployed from a Beechcraft Baron aircraft at an altitude of 150 m. One flight line followed the coast; another deployed baits in the interdunal swales and the remaining flight transects were at 1 km intervals across the island. A total of 10 000 baits was deployed on the 28 February 2001.

An intensive trapping and feral cat activity monitoring program across the island, commenced ten days following baiting. The trapping and monitoring exercise was conducted over 20 days in total and is discussed in detail (Algar *et al.* 2001).

The standard trapping technique is described by Algar *et al.* (2002b). Traps were positioned along all vehicle access and along the coastal/dune areas not readily accessible by vehicle. Traps using the Felid Attracting Phonic (FAP)/Pongo lure combination were located at 1 km intervals and those employing the pongo lure alone were positioned at the intervening 500 m intervals. Traps were set in position for a period of at least 11 days before retrieval. In total, 123 trap sets were placed over the island during the trapping period. Ninety-four of these were in place for more than 14 days to achieve a total of 1819 trap nights.

Four methods were used to monitor feral cat activity on the island: observation from the vehicle undertaking the on-track trapping program, cross-country transects conducted both by foot and by motor cycle and intensive on-foot searches along the beaches, interdunal swales and mangroves.

Vehicle access on Faure provided 59 km of transect. Evidence of feral cat activity along the tracks was assessed daily from a 4WD vehicle. On-foot searches were conducted on the southern part of the east coast, the entire south coast and much of the west coast, providing 22 km of walking transect. The beach areas on the eastern and northern coasts was inter-tidal and comprehensively covered by the vehicle transect. On-foot transects were completed every second day with all evidence of feral cat activity cleared on inspection. Further to the regular inspection of transects; intensive, random searches were made of dune and mangrove areas, not otherwise readily accessible. Any evidence of past feral cat activity was cleared from these areas which were re-examined routinely every two days. Motor cycle transects were established such that they bisected each block of inaccessible land, along the longest axis. FAP attractant stations were placed at nominal intervals of 1 km, along each transect. Each station consisted of a FAP hidden within the foliage of a shrub with a cleared sand pad at least 2 m wide. All transects were traversed prior to FAP station placement and all sign

of feral cat activity removed from approximately 10 m either side of the alignment. Following FAP station placement, transects were traversed every second day, for at least 9 days. A total of 21 stations were placed along 28 km of transect.

A ground baiting program, using the feral cat bait, was implemented in areas where evidence of fresh feral cat activity was observed (see Results and discussion). Bait was deployed at approximately 20 m intervals along tracks or cross-country.

Results and discussion

Evidence of fresh feral cat activity, particularly kittens, was observed around the water points, homestead and Landing by the caretaker manager on a visit to the island in mid February (D. Hoult, pers. comm.). Following the aerial baiting program, evidence of fresh feral cat activity was noted on both foot and motor cycle transects that traversed an area of approximately 2 km² along the south coast. The intensive foot searches identified a core of activity immediately inland of the coastal dunes and indicated that 2–3 feral cats had survived the aerial baiting program. This activity was noted on the first day of monitoring and ground baiting was conducted in the area, that day and the following. Subsequent assessment of feral cat tracks and activity in the ground baited area over the next two days indicated that at least five baits were taken by feral cats. No fresh feral cat activity was found over the following 16-day monitoring period. Intensive searches in this area failed to locate any baits. Elsewhere on the island, baits were regularly found during such searches. It is believed that no baits were aurally deployed in the area where the 2–3 cats were located. The aerial baiting campaign was responsible for the removal of at least 90% of the feral cats on the island. Given that the remaining feral cats readily took baits, complete coverage of the island, with the prescribed baiting density, may have resulted in total eradication. No evidence of fresh feral cat activity was recorded at any other location during the 20-day monitoring period. An intensive survey for evidence of feral cat activity conducted in June 2001 by an independent team confirmed that eradication of feral cats on the island had been successful (Thomas and Whisson 2001).

Faure Island may be the second largest island in the world where feral cats have successfully been eradicated. The feral cat eradication campaign and monitoring program on Faure was achieved in a matter of weeks. Elsewhere in the world, feral cat eradication projects on islands have often taken months or years, or are still ongoing. The baiting intensity employed here was close to the maximum possible application given the current configuration of baiting aircraft in Western Australia and was conducted in the absence of any information on the impact of aerial baiting density on efficacy. Since the baiting program on Faure Island, research aimed at clarifying the optimum baiting density for feral cats has been conducted.

Pimbee Station and Peron Peninsula

Aim

A series of field experiments is being conducted aimed at maximising the efficiency of aerial baiting for feral cats. The relative efficacy of various baiting regimes is being compared by the aerial deployment of non-toxic baits containing the biomarker RB. Subsequent trapping and examination of feral cats is then conducted to determine the proportion of these populations that have consumed bait material. The first study in this series was conducted at the Gibson Desert Nature Reserve and compared the relative efficacy of 50 and 100 baits km⁻² (Angus *et al.* 2002a; this review). The efficacy and efficiency of the baiting regimes examined was comparable to that achieved previously with this bait medium. The 50 baits km⁻² regime was found to be as equally efficacious as the 100 baits km⁻² regime, for the control of feral cats.

The trial, described here, was conducted to clarify the importance of prey abundance (particularly rabbits) to bait acceptance, under the above baiting regime, by feral cats. A single aerial baiting regime of 50 baits km⁻² was conducted in an area (Pimbee Station) where prey abundance was low and the results compared to the same bait application in an area where prey availability was high (Peron Peninsula).

Methods

Pimbee Station is located at approximately 120 km ENE of Peron Peninsula at 25°30' S and 114°50' E. The lease was purchased by CALM in 2001 through funding by the National Reserve System Program of the Natural Heritage Trust. The lease is to be managed for the purposes of conservation (see McNamara *et al.* 2000). The study site is dissected by linear and convoluted sand dunes, 10–20 m in height, with broad swales and interdunal plains. Dunes are of red-orange Quaternary aeolian sand (Hocking *et al.* 1987). Dune crests are vegetated by low woodlands of *Acacia anastema* with a sparse mid-storey of *A. scelosperma* and *A. ramulosa* over wanderie grasses (generally *Eriachne* spp and *Eragrostis* sp.). Swales are vegetated by dense to moderately dense tall shrublands dominated by *A. ramulosa*. Scattered emergents include *A. pruinocarpa* and *A. aneura*, associated shrubs include *Ptilotus obovatus*, *Senna helmsii* and *Eremophila* sp. over wanderie grasses.

Peron Peninsula was formerly a pastoral station. The peninsula was purchased by the Western Australian State Government in 1990 to establish Francois Peron National Park on the northern end of the peninsula. The peninsula, an area of 1 050 km², lies between 25°30'–26°15' S and 113°20'–113°45' E, within the Shark Bay World Heritage Area and is joined to the mainland by a narrow neck (the 3.4 km Taillefer Isthmus). This area is now the site of 'Project Eden', part of the broader *Western Shield* program (see this review). Beard (1976) and Payne *et al.* (1980) describe the vegetation of the peninsula. Five broad vegetation units occur across the peninsula, described in

more detail in Algar *et al.* (in press, a) - *Acacia ramulosa* scrub, *Acacia* thicket, *Acacia ligulata*/*Triodia plurinervata* shrub steppe, *Acacia/Lamarchea* thicket and the succulent steppe of the birridas. A minor association occurs in small, near-coastal strips. This is variously a *Spinifex longifolius* grassland or myrtaceous heath on coarse, pale sand or coquina deposits.

Non-toxic feral cat baits containing the biomarker RB were aerially deployed from a Beechcraft Baron aircraft at single rate of 50 baits km⁻² on 7 March 2002 (Pimbee Station) and 6-7 March 2002 (Peron Peninsula). Baiting was conducted on the northern and western portions of Pimbee Station, an area of 400 km² and in Zone 4 (250 km²) and approximately half (100 km²) of zone 2 on Peron Peninsula (see Algar *et al.* in press, a; for zone locations).

The program on Pimbee Station is described in detail in Angus *et al.* (2002b). Trapping for predators on Pimbee Station was conducted between 17-26 March 2002. Trapping methodology follows that of Angus *et al.* (2002a). Traps were placed at 500 m intervals, along linear transects separated by a distance of approximately 2 km. The two lure systems, FAP + Pongo and Pongo only, were employed at alternate 500 m intervals along each transect. As existing vehicle access was insufficient to allow transects at 2 km intervals, Suzuki 300 cc ATVs were used to access transects where no conventional vehicle access was available. A total of 1 381 trap nights was conducted. Project Eden staff conducted feral cat trapping on Peron Peninsula over two periods 17-20 March and 21 March - 3 April. The trapping methodology on Peron differed slightly from that used at Pimbee in that, only existing vehicle access is used to locate traps. Stomachs of captured feral cats at both sites were collected for diet analysis, to provide information of the importance of rabbits in the diet of feral cats from the two sites.

A single transect 6.5 km in length, was established to assess rabbit activity on Pimbee Station. The transect was over existing vehicle access that was clear of vegetation and had a soft, sandy substrate. Previous animal activity was removed from the transect by towing two truck tyres behind a vehicle. The following morning, the transect was examined for rabbit tracks. Tracks were counted on a 10 m section of transect, every 100 m. The number of tracks at each 10 m sample station was recorded as one, two or three or more. The transect was traversed on three consecutive mornings between 23-25 March 2002. Further to the track count transect, a spotlighting transect was traversed on the nights of the 22 and 25 March 2002. A single 1.06 million Cd, variable beam spotlight was operated from a vehicle, driven at a speed of less than 15 kmh⁻¹ and the location of all rabbits observed was noted. Rabbit activity on Peron Peninsula is monitored at fortnightly intervals during the Comprehensive Track Count (CTC) program (see 'Project Eden' protocols). Presence/absence of rabbit activity is recorded at 60 locations, over 10 m of track, along the CTC transect, and the presence data are then expressed as a percentage of the total.

Results and discussion

A total of 11 feral cats and 14 foxes was captured during the trapping exercise on Pimbee Station. In addition to these captures, a single feral cat was shot, at the homestead. All feral cats in the sample population were marked by RB as were all the foxes. The program on Peron Peninsula resulted in the capture of 38 feral cats between 17-20 March 2002 with 16 (42%) of the animals being marked by RB and a further 16 feral cats being trapped between 21 March - 3 April with 11 (69%) being marked by RB. The pooled sample on Peron Peninsula resulted in 50% of the population being marked by RB. There was a highly significant difference between the two sites in the percentage of individuals marked by RB ($z=3.19$, $P<0.001$).

No rabbit activity was recorded on the track count transect, during the three traverses on Pimbee Station. The only rabbits sighted at this site during spotlight transects were within a 100 m radius of the homestead complex. Rabbits were absent or extremely sparse over the remainder of the study site. In contrast, rabbit activity was recorded on 32%, 22% and 32% of the recording stations on Peron Peninsula for 26 February, 3 April and 17 April 2002 respectively.

Rabbit was not found in the stomach contents, dominated by reptiles and to a lesser extent invertebrates, of any of the feral cats collected on Pimbee Station. In contrast, rabbit was the most common dietary item of feral cats on Peron Peninsula, occurring in 70% of the animals containing stomach material.

This trial further confirmed the importance of rabbit abundance in influencing bait acceptance by feral cats. Rabbits were present over a very small percentage of the study site on Pimbee Station and were not important to the diet of feral cats or foxes at the time of sampling. In comparison, rabbit activity was relatively common on Peron Peninsula and rabbits were an important dietary item. Availability of prey influences the probability that bait material is accepted upon encounter (Short *et al.* 1997; Algar *et al.* in press, a). When prey is in abundance, the probability that an individual feral cat is hungry at any given time is lower than when prey is scarce. Several authors have suggested that baiting for feral cats is only efficacious when prey availability is low (Short *et al.* 1997; Burrows *et al.* 2003; Algar *et al.* in press, a). Short *et al.* (1997) predicted that bait acceptance by feral cats is likely to be poor when rabbit abundance is greater than 1.2 km⁻¹, measured via spotlight transects. It is therefore possible that a greater density of bait distribution may increase the probability of bait encounter at a time when an individual feral cat is hungry and efficacy may be improved by greater baiting density, during periods of high prey availability.

This exercise confirms the efficacy of 50 feral cat baits km⁻² where rabbits are not abundant, for the control of feral cats. The level of feral cat control predicted by this baiting regime is equivalent to that achieved previously at the Gibson Desert (this review). The high level of marking of the sample populations from Pimbee Station

and the Gibson Desert at this baiting intensity indicates that this density of baits was not close to the lower limit required for effective control of feral cats. Further significant improvement in the efficiency of aerial baiting for feral cats could be expected from investigating lower densities of bait distribution.

Following this research, a toxic aerial baiting program was conducted as part of *Project Eden* on 11–12 April 2002 and resulted in an 80% reduction of feral cat numbers on Peron Peninsula (see review paper by Morris *et al.* *Project Eden*, this issue).

The Murchison Bioregion – Wanjarri Nature Reserve

Aim

This is the second exercise in a series aimed at improving the efficiency of aerial baiting programs for feral cat control in WA by investigating whether or not high levels of efficacy can be achieved at low densities of bait distribution.

This study compared the relative efficacy of bait distributions of 50 and 25 baits km⁻² in the north-eastern goldfields region of WA. A concurrent assessment of potential risk to non-target species was also conducted.

Methods

This study was conducted at Mt Keith (27°10' S, 120°45' E) and Yakabindie Stations (27°39' S, 120°44' E), to the north and south of Wanjarri Nature Reserve respectively. The two pastoral leases are owned and managed by WMC Resources Ltd for the grazing of sheep and more recently of cattle. The site is approximately 97 km south-east of the Wiluna township and 60 km north of the Leinster township, in the north-eastern goldfields region. Landform of the two areas is described by Pringle and van Vreeswyk (1994) as the Sand Sheet Landform of the Bullimore Land System. This Land System is of poor pastoral value and is therefore very occasionally grazed. The landform consists of broad, gently undulating plains of red-orange sand with occasional, scattered granitic outcrops. Vegetation is *Triodia basedowii* hummock grassland with sparse emergent shrubs of *Acacia coolgardiensis*, *A. colletoides*, *Senna* sp., *Eremophila* sp., *Grevillea* sp. and *Hakea* sp. Emergent trees include scattered mallees (*Eucalyptus* sp.), *A. pruinocarpa* and *A. aneura*, the latter forming close groves, up to tens of hectares in extent. Much of the Mt Keith treatment site was burnt in 1998 and again in January 2001. Therefore much of the site is vegetated by young spinifex and fire successors that include *Ptilotus* sp., *Swainsona* sp. and *Leptosema chambersii*. Areas of vegetation not burnt in the past 5 years were generally less than 1 ha in extent.

Climate of the area is desert, summer and winter rainfall (Gilligan 1994). Rainfall is erratic and generally low. Yeelirrie, the closest reporting centre, records a mean annual rainfall of 223 mm over 39 rain days. Significant

summer rainfall can occur locally with the formation of thunderstorm cells and the passage of tropical depressions from the north-west. Autumn and early winter rainfall is generally lighter but more regular with the passage of rain-bearing cold fronts across the south-west corner of the State. The mean daily maximum temperature recorded at Yeelirrie in January is 37.9° C and the mean daily minimum in July is 3.9° C.

Non-toxic feral cat baits containing the biomarker RB, were deployed from a Beechcraft Baron aircraft using the AGNAV navigation system described previously (Angus *et al.* 2002a). A nominal 50 baits km⁻² was deployed over the Mt Keith treatment area and 25 baits km⁻² deployed over the Yakabindie treatment area. Although the dimensions of the two treatment sites varied, each was approximately 400 km² in extent. Baits were distributed at the Yakabindie treatment site on 8 May 2002 and the Mt Keith treatment site on 8–9 May 2002.

The trapping program employed in this study was as described by Angus *et al.* (2002a). A 2 km transect spacing was employed, with off-road access by Suzuki 300 cc ATVs. Insufficient traps were available for a 500 m trap spacing along transects, therefore traps were placed at 1 km intervals. The lure type used was alternated between trap sets along each transect, as described previously. A total of 593 trap nights was conducted at the Yakabindie site between the 24–31 May 2002. A total of 672 trap nights was conducted at the Mt Keith site between the 24 June–2 July 2002.

Bait uptake by non-target vertebrate fauna was examined by sampling the fauna using grids of pitfall and medium Elliott box traps at 16 sites in a 50 bait km⁻² baiting intensity on Mt. Keith. All trapped animals, including reptiles and small mammals, were examined for signs of staining by RB.

Results and discussion

Eighteen feral cats were trapped at the Mt Keith site and 23 at the Yakabindie site. Within the sample of feral cats from the Mt Keith treatment (50 baits km⁻²), 83% of feral cats were marked by RB. Within the sample of feral cats from the Yakabindie treatment (25 baits km⁻²), 78% of feral cats were marked by RB. Although a greater proportion of marking occurred in the higher baiting density treatment, this was not significantly different ($z=0.41$, $P>0.05$) from the lower baiting density. From the overall sample population, 80% of feral cats were marked by RB.

A summary of non-target fauna captures is presented in Table 10. None of the non-target mammals or reptiles sampled during this trial was marked by RB.

This study confirms the high bait acceptance achieved previously by distributing 50 feral cat baits km⁻² (Angus *et al.* 2002a; Liddelow *et al.* 2002; this review) and indicates that half this rate of distribution is likely to be equally efficacious under similar environmental conditions. The proportion of marking in the sample population from the 25 baits km⁻² treatment was significantly lower than

marking by the 50 baits km⁻² distribution at the Gibson Desert ($z=1.81$, $P<0.05$; see Angus *et al.* 2002a) and that at Pimbee Station ($z=1.74$, $P<0.05$; Angus *et al.* 2002b; this review). However the distribution of 25 baits km⁻² during this study was not significantly different from the proportion of marking from the simultaneously sampled 50 baits km⁻² treatment at Mt Keith; nor the 100 baits km⁻² distribution at the Gibson Desert ($z=0.30$, $P=0.62$) (see Angus *et al.* 2002a). This level of marking was also not significantly different from the proportion of individuals removed by toxic baiting at 50 baits km⁻² at the Gibson Desert ($z=1.58$, $P=0.06$; see Liddelow *et al.* 2002). The high level of marking reported here suggests that this distribution is not near to the lower limit necessary for feral cat control, under these conditions. Similar results may be achieved at significantly lower baiting densities than those examined to-date.

TABLE 10
Non-target fauna captures.

TAXON	NO. INDIVIDUALS
Ctenophorus isolepis isolepis	2
<i>Ctenotus helenae</i>	1
<i>C. quattuordecimlineatus</i>	3
<i>Diplodactylus elderi</i>	1
<i>D. strophurus</i>	1
<i>Menetia greyii</i>	1
<i>Rhynchoedura ornate</i>	1
<i>Mus musculus</i>	2
<i>Ningauai ridei</i>	16
<i>Notomys alexis</i>	3
<i>Pseudomys hermannsburgensis</i>	5
<i>Sminthopsis hirtipes</i>	1

Although rabbit density assessment was conducted during this exercise, the area is known to support few rabbits. Algar *et al.* (2002a) reported a mean ($\pm$ s.e.) rabbit presence of 0.98% (± 0.38) on transects assessed at Wanjarri Nature Reserve between January 2001 and January 2002. Rabbit presence during May and June 2001 was 0% and 0.46% respectively. This is in contrast to Peron Peninsula, for example, where Algar *et al.* (in press, a) recorded a mean ($\pm$ s.e.) rabbit presence between November 1999 and March 2000 of 49.43% (± 3.49), employing the same sampling technique. Mean ($\pm$ s.e.) monthly rabbit abundance at Peron Peninsula for the months of May and June, for the period 1996-2000, was 50.87% (± 4.57 ; $n=15$; range=30-85%) and 51.75% (± 8.98 ; $n=4$; range=27-65%) respectively (Project Eden, unpublished data – note that these figures were obtained from 1 km sample stations and varying transect distances). This study as with the other baiting intensity trials, under conditions of relatively low prey abundance, particularly that of rabbits have all resulted in relatively strong bait acceptance by feral cats. This is in contrast to the seasonally poor results achieved in the Shark Bay area with this bait (Algar *et al.* this issue) and others (Risbey *et al.* 1997; Short *et al.* 1997), where prey species (rabbits) are in relative abundance. Sufficient evidence exists to suggest that prey availability (particularly that of rabbits) and seasonal factors

influencing their abundance and breeding success are an important influence in seasonal/temporal/spatial variations in bait acceptance by feral cats (see also Burrows *et al.* 2003).

West Island, Cocos (Keeling) Islands

Aim

The early settlers first introduced cats to the southern atoll of the Cocos (Keeling) Islands in the late 1820s and throughout the island's history cats have arrived as domestic pets. Over the last two decades, the number of stray/feral cats present has concerned the community and a number of short-term control programs have been implemented (Garnett 1992; Reid 2000). These control campaigns have only reduced feral cat numbers over a limited period and the problem has persisted. A recent policy adopted by the Shire Council has restricted the importation of cats to sterilized animals only. The presence of feral/stray cats potentially poses health problems to the human population as cats are hosts and reservoirs for a number of diseases and parasites. The presence of feral/stray cats in residential areas has also presented a significant nuisance problem with cats calling and fighting through the night and urinating and defecating around the houses. The Cocos-Malay people were also concerned that feral cats were predators of their domestic chickens around the kampong and pondoks where chickens are allowed to range free.

Successful control of stray and feral cats would also benefit the proposed reintroduction of the endangered buff-banded rail (*Rallus philippensis andrewsi*) to several islands within the group (Garnett 1993; Parks Australia 1999; Garnett and Crowley 2000; Reid 2000). This taxon was once widespread on all the Cocos (Keeling) Islands but is now restricted to the cat-free North Keeling Island. The last record for this species, other than on North Keeling Island, was an individual killed by a feral cat on West Island in 1991 (Garnett 1993).

Members of the Shire Council on behalf of the Island Community made an approach to CALM to provide a long-term solution to the cat problem on the islands. The program on the Cocos (Keeling) Islands offered the opportunity to expand the range of environmental conditions under which the current control techniques have been assessed. Two broad climatic regimes under which the techniques have not been tested are the wetter temperate and tropical climates. The Cocos (Keeling) Islands offered the opportunity to assess current procedures on a closed population in a wet tropical climate with rats and chickens as the principal prey species.

Methods

The Cocos (Keeling) Islands are a remote Australian External Territory located in the Indian Ocean. They lie 2768 km north-west of Perth, 3658 km almost due west of Darwin, 900 km west of Christmas Island and 1000 km south-west of Java Head. The islands are two coral atolls

only several meters above sea level which have developed on top of old volcanic seamounts. The inhabited southern atoll is 14 km long and 10 km across and comprises 26 islands. Some islands are linked together (or separated by very shallow water) at low tide, while others are in deeper water and are accessible only by boat. The islands of the southern atoll are located at latitude 12° 12' S and longitude 96° 54' E. The uninhabited northern atoll 26 km to the north comprises a single island, North Keeling Island, an area of 1.3 km² that is a seabird rookery of world-wide significance.

Climate is oceanic-equatorial and humid with a mean annual rainfall of approximately 2000 mm, high humidity (65–84%), and uniform temperatures year round (mean daily temperature: 25.8–27.5° C) (Falkland 1994). The southeast trade winds dominate for most of the year but with periods of doldrums during the tropical cyclone season (November–April).

The total land area of all the islands of the southern atoll is 14 km². The reef islands of the Cocos (Keeling) Islands are described in detail by Woodroffe and McLean (1994) and summarized below. The smaller islands are less than a hundred meters wide, some are virtually vegetated sandbanks, and all are made up of coral clinker and sand thrown up from the surrounding reef. All the islands are flat, their highest points being sand hills on the ocean side. The majority of islands in the atoll have a conglomerate platform on the ocean side, although there are extensive sandy/shingle areas on South and Horsburgh Islands. The ocean side of West Island is predominantly sand. The lagoon side of the islands is either sandy beaches or intertidal sands with variable areas of coral shingle. On a number of islands sandy spits extend into the lagoon.

The vegetation on the southern atoll is dominated by groves of coconut palms. This coconut woodland has ceased to be cleared and has become largely overgrown and difficult to penetrate. The understorey is mostly coconut seedlings with some shrubs, grasses or other perennials or a dense mat of decaying palm fronds and coconuts. These woodlands are fringed on the lagoon shore by shrub land of *Pemphis acidula* and on the ocean shores by cabbage bush (*Scaevola taccada*) and clumps of octopus bush (*Argusia argentea*) (Williams 1994; Woodroffe and McLean 1994). There are no native mammal species on the atoll; however, a number of species have been introduced. Two species of introduced rats, the brown rat (*Rattus norvegicus*) and black rat (*R. rattus*), are present on the islands (Wood Jones 1909). Two bird species have also been introduced and become established on the southern atoll (Carter 1994). 'Feral chicken', domestic chicken that have become semi-wild, occur on most if not all islands in the southern group. The green junglefowl (*Gallus varius*) of Java was also introduced to West Island.

A control program was implemented in November 2000 (see Algar *et al.* in press, b). During this exercise trials were also conducted to determine the value of baiting as a possible control option on this and other similar

islands. Preliminary trials with non-toxic feral cat baits placed on the ground resulted in all baits being removed overnight by non-target species. Land crabs (*Cardisoma carnifex*) which dominate the forest floor, hermit crabs (*Coenobita perlata*) along the coastal areas and chickens were responsible for removing the baits. A subsequent trial using 30-cm wooden skewers to elevate the baits above the ground prevented land crabs from taking baits but over three-quarters of the baits were still taken by hermit crabs and chickens. Further trials examining bait placement and non-target interactions indicated that suspending the baits on a string from a stake angled into the ground overcame the problem. Baits suspended approximately 30 cm above the ground prevented non-target animals from removing the baits while maintaining their attractiveness to feral cats. This new approach to baiting provided a relatively simple means to control feral cats where non-target species posed a problem.

A second visit to the islands provided the opportunity to test this baiting technique as a control strategy for feral cats. A trial of the baiting technique was conducted on West Island, an area of 6.23 km². Bait stations were located at 100 m intervals along all unrestricted road and track access. Each bait station comprised a fence dropper angled into the ground from which a non-toxic feral cat bait was suspended, approximately 30 cm above the ground, using saddler's twine. The roads and tracks were not comprised of a sandy substrate that would permit identification of feral cat tracks along their length so a sand pad 40 x 40 cm, cleared of track activity was located beneath each bait. A total of 202 bait stations were located across the island. Each bait station was examined daily, over a 20-day period, for bait removal and activity on the sand pads was noted. Bait removal was assigned to a particular species; this was possible on most occasions except when rainfall had resulted in track activity being washed away. The original intention was to replace any bait removed by feral cats with a toxic feral cat bait that night at that bait station and those stations either side however, a cat or cats often removed a series of baits along a given road. As such, in many instances toxic baits were strung at a number of bait stations central to the location of feral cat activity.

It was assumed that continuous feral cat activity along a segment of a road or track as observed on the sand pads, was the same individual as it was impossible to differentiate between animals. If toxic baits had been consumed and further activity was observed at the same location at a later date, this activity was ascribed to a different individual. The number of feral cats present and those removed as a result of this baiting technique was therefore calculated upon feral cat activity at bait stations, removal of toxic baits from bait stations, their location across the island and subsequent disappearance of feral cat activity over time.

Results and discussion

An estimated total of 33 feral cats was removed as a result of this baiting technique (Brazell and Algar unpub. data).

The total number of feral cats on West Island was calculated to be 37 animals, the technique therefore resulted in an 89% baiting efficiency.

The technique did not exclude all non-target species from removing baits, as rats and hermit crabs were still able to climb up the dropper post and remove the baits. Bait removal by these species tended to be localised to several coastal areas where cabbage bush was present. Suspending the baits stopped land crabs accessing the baits and in all but one instance prevented chicken from removing baits. Utilising a different post, smooth and of thinner diameter, from which the baits are suspended should prevent rats, hermit crabs and other species capable of climbing from removing the baits.

This new approach to baiting small-scale areas provided a relatively simple means to control feral cats where non-target species posed a problem. The technique may have potential application at specific sites on the mainland (e.g. Two People's Bay Nature Reserve) where aerial or on-track deployment of feral cat baits may pose an unacceptable risk to non-target species.

NON-TARGET BAIT TAKE ISSUES

As discussed above, some work has been done on the uptake of feral cat baits by non-target animals and the indications at this stage are very encouraging, with no non-target species taking baits however, this work is incomplete. It is essential that a comprehensive assessment of risk to non-target species from the new bait medium be undertaken. This risk assessment is in part required to gain National Registration Authority registration of the bait and also to ensure the protection of native fauna. Further assessment of bait uptake by a range of non-target species likely to be at risk is to be conducted in the near future and a number of methods to reduce exposure to the toxin are also being investigated. Assessment of bait uptake by non-target species is presented in detail in the section discussing research needs (see pp. 156–157).

INTERACTION BETWEEN FERAL CATS, FOXES AND DINGOES/DINGO-DOG HYBRIDS

The extent of any interaction between feral cats and canids is not clear (Dickman 1996). Dingoes have been reported to predate feral cats (Corbett 1995), as have foxes (Coman 1973) however, the frequency appears extremely low. Both canid species also probably compete for food with feral cats, especially when food resources are limited. Molsher (1999) studied the ecology of feral cats at a site in NSW and their interaction with prey and foxes, finding that foxes potentially limited feral cats through competition for food resources and by excluding them from some habitats.

The abundance of feral cats at another site in NSW has been shown to be negatively correlated with both

foxes and dingoes (Catling and Burt 1994, see Dickman 1996). Reduction in fox numbers following baiting programs has resulted in dramatic increases in feral cat abundance (Christensen and Burrows 1995; Algar and Smith 1999). Feral cat numbers have also increased following local declines in dingo abundance (Pettigrew 1993). However, there is no technique currently available for reliably measuring the abundance of dingoes, foxes or feral cats. The observed increases in feral cat numbers following the removal of canids may in part be an artefact of track based census methods. It is likely that tracks/roadways are preferred habitat by feral cats, particularly when foxes and dogs are absent, therefore feral cats may preferentially range toward road transects following reductions in fox and dog populations potentially giving higher index values unrelated to population size. The results of an experimental trial to examine the relationship between feral cat and canid abundance in the Gibson Desert (this review) suggested this was likely to be the case.

In the south-west of Western Australia where foxes are controlled using the fox bait, described earlier, there is the issue of how feral cat populations will respond long-term to a reduction in fox density, and what impacts this will have on native fauna. This requires careful monitoring and possible research action if the monitoring reveals a problem.

CRITERIA FOR DETERMINING WHERE AND WHY FERAL CAT CONTROL IS REQUIRED

Current knowledge suggests that feral cat control is required in semi-arid, arid, wet-dry tropical bioregions and offshore islands (essentially anywhere outside the south-west botanical province) where native fauna reconstruction/reintroduction programs are planned or where it can be demonstrated that feral cat predation is threatening extant populations of native fauna. As resources are limited, it is reasonable to assume that feral cat control will focus on strategic areas. At this stage these areas are in the semi-arid and arid regions. We suggest that management resources and research effort should focus on several potential fauna reconstruction sites in the arid and semi-arid zone where the objective would be to protect extant fauna and to reconstruct the original fauna through the amelioration of threatening processes (including controlling introduced predators) and reintroductions. Such an ecosystems focus will be more cost-effective than attempting to reintroduce individual, disconnected species across the State with discrete baiting programs. Nevertheless baiting programs may be warranted where individual species such as the Gilbert's Potoroo (*Potorous gilbertii*) at Two People's Bay Nature Reserve are threatened with extinction.

We suggest the advancement of *Western Shield* into the semi-arid and arid zones by the identification of three sites/reserves where operational scale research trials should

progress with the objectives of a) refining baiting strategies b) demonstrating that feral cat control can be sustained (i.e., replicating the results reported above) and c) reintroducing fauna (reconstructing the original fauna). Candidates for focussed fauna reconstruction sites in the semi-arid and arid zones include one of the resumed pastoral leases in the Murchison-Gascoyne region, Wanjarri Nature Reserve in the northern Goldfields, and the Gibson Desert Nature Reserve in the Gibson Desert. A set of biological, climatic, information and management criteria would need to be established before selecting sites. The high priority research activities outlined below could focus on these sites.

While there exists variability in the vulnerability of species to predation by feral cats, our knowledge and understanding of predator-resilience for various species is inadequate. In the interim, we recommend that the precautionary approach is to assume all potential candidates for re-introduction are likely to be vulnerable to feral cat predation until it can be demonstrated otherwise or unless feral cats can be controlled. Apart from eradication, the appropriate level of feral cat control for each native species is largely unknown.

CURRENT OBSTACLES TO BROADSCALE IMPLEMENTATION, RESEARCH NEEDS AND TIMELINES FOR OVERCOMING THEM

While there are a number of outstanding research issues that need to be addressed to improve the effectiveness and reliability of baiting to control feral cats in a number of bioregions, the current operational obstacles to broadscale feral cat control are a) the need to register the feral cat bait for operational use and b) the provision of adequate resources to implement control strategies. There are a number of key factors (not necessarily obstacles) that need to be researched if an effective broadscale aerial baiting strategy for feral cats is to be developed. Optimizing the various parameters of baiting programs need to be examined in sequence if the control strategy is to be effective and cost-efficient. In addition to the baiting parameters it will be necessary to assess the potential impact of baiting programs on non-target species populations and to validate the reliability and accuracy of the census technique used to estimate feral cat abundance.

These research areas are discussed below and the timeframe of activities is outlined in Table 11.

Examination of baiting intensity (number of baits laid km⁻²) in relation to baiting efficiency to optimise control

Having defined the optimum time period to conduct baiting programs (see pages 134–135 ‘Bait uptake...’), the second stage in developing an effective broadscale aerial baiting strategy for feral cats is to examine baiting intensity (number of baits laid km⁻²) to maximise baiting efficiency. For feral cat baiting programs to be efficient and cost-effective, baits must be delivered at a level that maximises their uptake by feral cats but minimises the number of baits required which will also minimise the potential risk posed to non-target species. A series of trials is currently being conducted with the objective of determining an optimum delivery of baits, from an aircraft, for the control of feral cats. Successful control has previously been achieved by deploying a nominal 100 baits km⁻² in strategic areas (Algar and Burbidge 2000; Algar *et al.* 2001; Algar *et al.* 2002b; this review). This nominal distribution of baits was used as a benchmark, against which to assess the efficacy of lower baiting densities.

Assessing the efficacy of differing baiting intensities is being conducted in a series of trials using non-toxic Rhodamine B biomarked baits followed by trapping exercises to determine the extent of labelled animals in the trapped population. The use of this biomarker technique also enables concurrent study of bait consumption by non-target species and assessment of the potential risk to these species populations at various toxic baiting intensities (see page 156 ‘Assessment of the potential...’). To date, this series of trials has demonstrated that a baiting density of 50 baits km⁻² is equally efficacious in the control of feral cats. This evidence has been supported by a highly efficacious toxic baiting for feral cats at the Gibson Desert Nature Reserve (this review). The high level of marking and good control of feral cats during these exercises suggests that further reductions in bait distribution, under similar environmental conditions, will not reduce baiting efficacy.

Further baiting intensity trials are to be conducted (as discussed in the section ‘Baiting trials’, p. 135), to refine the optimal baiting intensity. The encouraging results reported to date are to be replicated to be confident that baiting outcomes can be predicted within limits.

TABLE 11
Timeframe of activities.

ACTIVITY	YEAR				
	2001	2002	2003	2004	2005
Optimising timing of baiting					
Baiting intensity trials					
Non-target uptake assessment					
Census techniques					
Toxic baiting and baiting frequency					

Examination of baiting frequency (number of times/year or yearly intervals) required to provide sustained effective control.

Once the optimal baiting intensity has been defined, both in terms of effective feral cat control and risk to non-target populations, it will be possible to conduct toxic baiting programs to assess the required baiting frequency to provide cost-effective control over time. Re-introduction of native species to strategic areas can only occur if sustained feral cat control can be shown over time. However, it is important to recognise that the level of feral cat control required to allow re-introduced species to maintain viable populations is unknown, but may vary according to individual species, suite of species and site.

The level of control achieved over time with baiting will in part be dependent on the frequency of baiting (the time interval between baiting programs). Feral cat density post-baiting will be dependent on the number of resident individuals not removed during the baiting campaign and the rate of dispersal into the baited area over time. Natal recruitment from these two populations will also influence feral cat density over time. The relative abundance of non-baited resident animals and their potential recruitment can be determined. The density of feral cats immediately outside and distant from a baited site will determine the rate of reinvasion. This value would be unknown and highly variable, both temporally and spatially.

To provide a practical solution to optimising the frequency of baiting a theoretical framework is proposed where baiting frequency is examined in terms of the size of the baited area, potential buffer zones and the extent and timing of recruitment into a core area. Conservation sites where feral cat baiting is likely to be warranted differ according to size and the option of utilising a baited buffer and these factors tend to be related to geographic zone. It is proposed that three sites be selected where feral cat control is needed. These sites will differ in size and the degree to which a buffer zone can be included to protect a core area. Following standardised baiting programs at each site, regular, routine monitoring of relative feral cat abundance will be conducted at each site. This monitoring program will provide the first set of data on the time and extent of reinvasion and therefore a benchmark of baiting frequency for the different site types. Optimising baiting frequency will require a long-term commitment and is beyond the scope of the current program. It is suggested that in the long-term, as other areas are baited and Operation staff become involved, additional monitoring programs can be conducted and the information added to the database. Optimising baiting frequency in the long-term can therefore be responsive to the level of control achieved over time for a generalised site type.

Assessment of the potential impact of baiting programs on non-target species populations and development of methods to reduce the potential risk where possible

It is essential that a comprehensive assessment of risk to non-target species from the feral cat bait be undertaken. This risk assessment is in part required to gain National Registration Authority registration of the bait. Assessment of bait uptake by a range of non-target species likely to be at risk is to be conducted. A number of methods to reduce exposure to the toxin is also being investigated.

A desktop evaluation has been conducted to assess the likely risk to non-target species. This investigation has broadly defined a range of species potentially at risk from operational baiting campaigns. Assessment of risk to these species will be undertaken in both field and complementary laboratory trials. Assessment of bait consumption by non-target species in the field under natural conditions of climate and alternative food resources is being conducted concurrently with the non-toxic biomarker baiting intensity trials (see sections 'Baiting trials' and previous section). Maximum bait consumption by non-target species is expected to occur when their other food resources are lowest and therefore when prey abundance for feral cats is also at a minimum. As such, assessing bait uptake by non-target species when the baiting intensity trials are being conducted is appropriate. These trials will provide information on bait consumption by individuals in the field and thus the possible impact of an operational baiting program on species populations at the various baiting intensities.

The study areas selected are unlikely to contain the entire suite of native species across all the broad range of sites where operational feral cat baiting programs will eventually be conducted. It is anticipated that additional field studies, researching bait uptake by certain species with restricted ranges may also be required. The distribution pattern of baits deployed from a plane is being mapped to enable simulation by hand placement of baits on the ground. It will therefore be possible to mimic bait distribution of an aerial baiting program over a specific fauna-trapping site. This will permit non-target bait uptake studies to be conducted as part of other fauna programs to allow maximisation of species and individuals assessed at minimum cost.

To complement the field trials, a more rigorous assessment of the amount of bait consumed by a number of non-target species will be examined in penned laboratory trials. In addition, laboratory trials will be used to evaluate bait consumption by species not readily available in the field. Feral cats will consume the entire bait; however most non-target species have a much lower body weight and may be unable to eat the entire bait. The biomarking of individual animals in the field indicates potential risk to baiting programs, as its presence is qualitative rather than quantitative. The presence of the biomarker does not indicate the quantity of the bait

consumed and therefore whether a lethal dose would have been acquired if the bait was toxic. Laboratory examination of bait consumption will provide information on actual risk from baiting for individual species.

The baiting intensity trials, described previously, are designed to reduce the number of baits deployed to a level that maximises effectiveness and cost efficacy. Any reduction in baiting intensity will also reduce the potential risk posed to non-target species. Currently, toxic feral cat baits are dosed at 4.5 mg of 1080 per bait. There is potential scope to reduce the dose per bait to 3.0 mg 1080 and thereby reduce the risk to non-target species from baiting programs. An oral LD_{50} value of 0.40 mg 1080 kg^{-1} was determined for immature feral cats after gastric intubation McIlroy (1981). More recent studies (Eason and Frampton 1991; Eason *et al.* 1992), using baits coated with 1080, on a mixed-age feral cat population determined an oral LD_{50} of 0.28 mg 1080 kg^{-1} and LD_{90} of 0.35 mg 1080 kg^{-1} . A series of pen trials, using 1080 injected baits, will be conducted to determine whether baits are lethal to feral cats at the reduced dose rate.

The majority of potential bait consuming, non-target mammal species are significantly smaller than feral cats and have different dentition. The carnassial teeth in cats are highly specialised and adapted to cutting and shearing. The loss of grinding pre-molars and reduced chewing efficiency leads to their propensity to swallow relatively larger portions of food and inert material such as bone. The potential of cats to ingest larger particles (eg. tablets or capsules containing toxin) relative to most non-target species has the potential to reduce exposure of many non-target mammals to bait toxicants and thereby decrease the risk of baiting to non-target species. The inclusion of toxic tablets in baits could be a practical vehicle for toxins that would be ingested by feral cats yet rejected by smaller mammals. Colleagues at the Victorian Institute of Animal Science, Department of Natural Resources and Environment (DNRE) are investigating the use of toxic tablets for the inclusion in feral cat baits. This investigation is part of their contribution to the collaborative research program between CALM, DNRE and Environment Australia for the development of a felid-specific toxin and delivery system.

Provide scientific validation of the Track Density Index (TDI) as a reliable estimate of relative feral cat abundance.

A technique that provides the capacity to efficiently and reliably estimate feral cat relative abundance is an essential prerequisite for the planning and implementation of clearly defined prescriptions for feral cat control, in particular the determination of optimum frequency of baiting operations. Also, it will provide an objective assessment of the effectiveness of operational control measures in reducing feral cat density. Any technique that is considered for use as an index of abundance must also be relatively inexpensive and simple to conduct as it will be used by researchers, wildlife managers and others alike.

Department researchers have employed a track count index (TDI) (Burrows *et al.* 2003; this review 'Project Eden' and Gibson Desert) to assess relative changes in feral cat abundance. Trials are required to scientifically validate the accuracy of this technique to measure relative feral cat abundance. Results from baiting intensity trials will provide information on the extent of feral cat removal following specific baiting regimes. These results will be used to establish a series of toxic baiting programs where feral cat numbers will be manipulated to approximate relative abundances. At each site, a number of feral cats will be trapped and radio-collared with mortality transmitters. Indices of relative feral cat abundance will be determined pre-baiting and ten days post-baiting. The difference between the pre- and post-baiting indices will then be compared to the reduction in the population size determined by the mortality transmitter returns. Five baiting programs will be conducted at different baiting intensities to provide different levels of population reduction. This will allow regression analysis of the data (change in population level as determined by mortality transmitters versus change in index pre- and post baiting) for assessing the accuracy of the index as a measure relative abundance.

Discuss how and when bait registration can be achieved and the likely cost of feral cat baits.

An experimental permit was recently obtained from the Australian Pesticides and Veterinary Medicines Authority (APVMA) (formerly the National Registration Authority) to allow completion of the research required to permit submission for full registration of the feral cat bait. An additional permit was issued for the ongoing feral cat baiting program on Peron Peninsula *Project Eden*. The experimental permits; Permit No. PER5356 is for the sites listed in Table 12 and Permit No. PER5112 is for Peron Peninsula. The permits are valid till the end of 2006 and 2005 respectively. The permits apply to an experimental 1080 bait used for feral cat control as described below:

Type:	Trial	Category:	Field
Reg. Category:	47	Section:	Ag
Permit Record No.	1213		

A number of sites were selected within Western Australia where research is proposed. Several sites were listed for baiting where an existing commitment to feral cat control is in place. Other sites were also nominated for potential feral cat baiting campaigns because of evidence that feral cats were threatening the continued survival of endangered species in the area. Toxic baiting will only be permitted at any of these sites following approval being granted under the 'Risk Assessment' guidelines of the State and Federal statutory regulations for the 'Code of Practice on the Use and Management of 1080.'

TABLE 12
Sites listed under the experimental permit.

SITE	AREA (KM ²)	LOCATION (CENTROID)	TIMING OF BAITING PROGRAMS
FERAL CAT CONTROL RESEARCH SITES			
Gibson Desert Nature Reserve	2500	24°45'31"S 124°41'53"E	2002–2006
Wanjarri Nature Reserve	2000	27°22'32"S 120°43'12"E	2003–2006
Mt. Augustus	2000	24°20'09"S 116°50'46"E	2003–2006
Purnululu National Park	1000	17°27' S 128°34' E	2003–2006
ONGOING BAITING PROGRAMS			
Peron Peninsula Permit (PER5112)	1500	25°41'58"S 113°33'06"E	12/2001–2005
Cocos Island	14	12°12' S 96°54' E	2002
Garden Island	11	32°12'07"S 115°40'40"E	2002
POTENTIAL FERAL CAT BAITING PROGRAMS TO PROTECT ENDANGERED SPECIES			
Lake Magenta Nature Reserve	1078	33°29'31"S 119°07'38"E	Potentially if required
Dragon Rocks Nature Reserve	322	32°44'53"S 119°02'06"E	As above
Cape Arid National Park	2781	33°42'09"S 123°22'16"E	As above
Stirling Range National Park	1157	34°21'46"S 117°59'25"E	As above
Dryandra State Forest	240	32°48'26"S 116°59'42"E	As above

The sites listed under the experimental permit to be granted are tabled by purpose, and described by size, location and timing of baiting in Table 12. It is anticipated that additional sites, both research and areas to protect endangered species, will be submitted to APVMA later this year for inclusion on this list.

It is anticipated that the research required to provide the information for full registration of the feral cat bait will be completed by the end of 2005 and that submission will occur the following year. Discussions with APVMA, the State Coordinator for APVMA and State and Federal reviewers have indicated that the research outlined in this review is that necessary for registration. These authorities have indicated that the key determinants to achieve registration will be baiting efficacy and non-target considerations.

The cost of feral cat baits is currently 30¢ per bait at today's level of production, one third of this cost is for materials, and the remainder is associated with labour and production equipment. The future costs of baits will depend on economies of scale (level of production), degree of automation and the cost and depreciation rate of the manufacturing equipment. It is also important to realise that the price of baits is not the total cost of baiting as there are additional costs associated with ground transport of the baits and aerial deployment.

WHAT IS THE FUTURE OF THE FELID SPECIFIC TOXIN AND HAVE NON-TARGET RISKS BEEN ASSESSED?

A toxicant compound, Felid Specific Toxin (FST), that exploits some unique physiological characteristics of cats, is being developed by the Victorian Institute of Animal Science, Department of Natural Resources and Environment (DNRE) as a selective lethal agent for bait delivery. The identification of this highly specific cat toxin creates the potential for significant improvement in the ability to control feral cats where the use of 1080 may pose a problem. A collaborative research program between CALM, DNRE, Environment Australia and now Landcare Research (New Zealand) is developing the toxin/bait combination.

The bait, toxin, target specificity (ie. particle size) and liquid delivery have been considered. The focus of current research is to bring these concepts together in a purpose designed delivery vehicle that contains an improved, high penetrating liquid solvent. This research is likely to be pursued by external groups that specialise in this work. A prototype delivery vehicle is to be used this year in a small-scale field demonstration.

Two approaches are being used to assess non-target risks; the inclusion of toxic pellets in baits as a practical vehicle for toxins that would be ingested by feral cats yet rejected by smaller mammals and direct non-target dose response testing. A number of non-target species, plains rats (*Pseudomys australis*), northern quolls (*Dasyurus hallucatus*), eastern barred-bandicoots (*Perameles gunnii*) and fat-tailed dunnarts (*Sminthopsis crassicaudata*) are being tested by DNRE in the laboratory for the ability to ingest pellets. Field assessment of pellet ingestion is also being conducted on populations of bush rats (*Rattus fuscipes*) and swamp rats (*R. lutreolus*). Non-target dose response testing has been conducted on tammar wallabies (*Macropus eugenii*), common brushtail possums (*Trichosurus vulpecula*), mallard ducks (*Anas platyrhynchos*), ferrets (*Mustela furo*) and stoats (*M. erminea*). The 'Memorandum of Understanding' with Landcare Research was recently completed but as yet the dose response data is confidential.

CONCLUSIONS AND RECOMMENDATIONS

If further fauna declines are to be averted and re-introductions are to succeed, integrated management programs, which address threats must be implemented. Effective control strategies for feral cats must be an integral component of these management programs. CALM researchers are leading the way, both nationally and internationally, in the development of feral cat control techniques and strategies that address these concerns. A step-wise approach is being pursued in the development of an effective and cost-efficient broadscale feral cat control strategy to provide wildlife recovery. The focus is on optimising feral cat control through aerial baiting campaigns and providing a comprehensive evaluation of any impact on non-target species populations. The program is structured to enable analysis of the cost-benefit of various baiting regimes on both feral cats and non-target species and provide information essential to gaining registration of the feral cat bait. Once registration is achieved, the baiting protocols developed will extend predator control and wildlife re-introductions to the arid and semi-arid interior of Western Australia under the umbrella program 'Western Shield'. Results of this program will also be of considerable value to other States and Territories involved in feral cat control and re-introduction projects.

ACKNOWLEDGMENTS

A number of people have contributed to various aspects of the research outlined in this review paper. To these people, listed in alphabetical order, we offer our thanks: John Angus, Per Christensen, Phil Fuller, Neil Hamilton, Tom Leftwich, Graeme Liddelow, Mike Onus, Alex Robinson, Joe-Ann Sinagra, Ray Smith, Bruce Ward and Colin Ward. We also acknowledge assistance provided by CALM staff from the Goldfields Region.

REFERENCES

- Abbott I (2002) Origin and spread of the cat, *Felis catus*, on mainland Australia, with discussion of the magnitude of its early impact on native fauna. *Wildlife Research* **29**(1), 51-74.
- Abbott I, Burbidge AA (1995) The occurrence of mammal species on the islands of Australia: A summary of existing knowledge. *CALMScience* **1**, 259-324.
- Algar D, Kinnear J (1992) Cyanide baiting to sample fox populations and measure changes in relative abundance. In: P O'Brien and G Berry (Eds.) *Wildlife Rabies Contingency Planning in Australia*. Bureau of Rural Research, Proceedings No. 11, 135-138
- Algar D, Sinagra JA (1995) Broadscale control of feral cats in Western Australia: Year 1 progress report to Australian Nature Conservation Agency. Department of Conservation and Land Management, Western Australia.
- Algar D, Sinagra JA (1996a) Methods of broadscale control of feral cats in W.A.: Annual report, January 1996: Feral Pests Program, project 11. Department of Conservation and Land Management, Western Australia, pp. 1-32.
- Algar D, Sinagra JA (1996b) Methods of broadscale control of feral cats in W.A. Progress report, April 1996: Feral Pests Program, project 11. Department of Conservation and Land Management, Western Australia, pp. 1-8.
- Algar D, Sinagra JA (1996c) Broadscale control of feral cats in Western Australia: Final report to Australian Nature Conservation Agency. Department of Conservation and Land Management, Western Australia.
- Algar D, Smith R (1998) Approaching Eden. *Landscape* **13**, 28-34.
- Algar D, Angus GJ (2000a) Recommendations on a control strategy for feral cats at Peron Peninsula, Western Australia. Report to Project Eden Management Committee. Department of Conservation and Land Management, Western Australia.
- Algar D, Angus GJ, (2000b) 'Felines of Faure.' Department of Conservation and Land Management, Western Australia.
- Algar D, Burbidge AA (2000) Isle of cats: the scourging of Hermite Island. *Landscape* **15**, 18-22.
- Algar D, Angus GJ, Sinagra JA (1999) Preliminary assessment of a trapping technique to measure feral cat abundance. Project ISP#11, Report to Environment Australia. Department of Conservation and Land Management, Western Australia.
- Algar D, Angus GJ, Brazell RI, Gilbert C, Withnell GB (2001) Farewell Felines of Faure. Report to Australian Wildlife Conservancy. Department of Conservation and Land Management, Western Australia.

- Algar D, Angus GJ, Fuller PJ, Onus ML (2002a) Operation Wanjarri: optimising feral cat baiting strategies in the arid zone. Report to Environment Australia. Department of Conservation and Land Management, Western Australia.
- Algar D, Burbidge AA, Angus GJ (2002b) Cat eradication on the Montebello Islands. In *Turning the tide: the eradication of invasive species* (eds. C.R. Veitch and M.N. Clout), pp. 14-18. Invasive Species Specialist Group of the World Conservation Union (IUCN). Auckland.
- Algar D, Angus GJ, Williams MR, Mellican AE (in press, a) An investigation of bait uptake by feral cats on Peron Peninsula. *Conservation Science Western Australia*
- Algar D, Angus GJ, Brazell RI, Gilbert C, Tonkin DJ (in press, b) Feral cats in paradise: focus on Cocos. *Atoll Research Bulletin*.
- Agus GJ, Onus M, Fuller PJ, Liddelow G, Ward B (2002a) Comparison of two aerial baiting regimes with respect to bait acceptance by introduced predators and non-target native fauna, at the Gibson Desert Nature Reserve, Western Australia. Report to the Wind Over Water Foundation. Department of Conservation and Land Management, Western Australia.
- Angus GJ, Onus ML, Hamilton N, Withnell GB (2002b) Assessment of bait acceptance by introduced predators from a single aerial deployment of bio-marked baits in the Gascoyne Region, Western Australia. Report to the Wind Over Water Foundation. Department of Conservation and Land Management, Western Australia.
- Angus GJ, Martin KR, Onus ML., Hamilton N, Brazell RI, Withnell GB (2002c) Assessment of the comparative efficacy of two aerial baiting regimes through acceptance of non-toxic baits by feral cats in the north-eastern Goldfields, Western Australia. Report to the Wind Over Water Foundation. Department of Conservation and Land Management, Western Australia.
- Armstrong R (2004) Baiting operations: *Western Shield* review–February 2003. *Conservation Science W. Aust.* 5 (2), 31-50. Department of Conservation and Land Management, Western Australia.
- Beard JS (1969) The natural regions of the deserts of Western Australia. *Journal of Ecology* 5 677-711.
- Bester MN, Bloomer JP, Bartlett PA, Muller DD, van Rooyen M, Buchner H (2000) Final eradication of feral cats from sub-Antarctic Marion Island, southern Indian Ocean. *South African Journal of Wildlife Research* 30, 53-57.
- Bloomer JP, Bester MN (1992) Control of feral cats on sub-Antarctic Marion Island, Indian Ocean. *Biological Conservation* 60, 211-219.
- Burbidge AA (1997) Montebello Renewal. *Landscape* 12, 47-52.
- Burbidge AA (1999) Conservation values and management of Australian islands for non-volant mammal conservation. *Australian Mammalogy* 2, 67-74.
- Burbidge AA (2004) *Montebello Renewal: Western Shield* review–February 2003. *Conservation Science W. Aust.* 5 (2), 194-201. Department of Conservation and Land Management, Western Australia.
- Burbidge AA, McKenzie NL (1989) Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* 50, 143-198.
- Burbidge AA, Start, AN, Armstrong R, Morris KD (1996) 'Western Shield proposal.' Department of Conservation and Land Management, Western Australia.
- Burbidge AA, Williams MR, Abbott I (1997) Mammals of Australian islands: factors influencing species richness. *Journal of Biogeography* 2, 703-715.
- Burbidge AA, Blyth JD, Fuller PJ, Kendrick PG, Stanley FJ, Smith LE (2000) The terrestrial vertebrate fauna of the Montebello Islands, Western Australia. *CALMScience* 3, 95-107.
- Burbidge AA, Manly BJF (2002) Mammal extinctions on Australian islands: causes and conservation implications. *Journal of Biogeography* 29, 465-473.
- Burrows ND, Algar D, Robinson AD, Sinagra JA, Ward B, Liddelow G (2003) Controlling introduced predators in the Gibson Desert of Western Australia. *Journal of Arid Environments* 55, 691-713.
- CALM – see Department of Conservation and Land Management
- Carter M (1994) Birds of Cocos-Keeling Islands. *Wingspan* September 1994, 14-18.
- Catling PC (1988) Similarities and contrasts in the diets of foxes, *Vulpes vulpes*, and cats, *Felis catus*, relative to fluctuating prey populations and drought. *Australian Wildlife Research* 15, 307-317.
- Catling PC, Burt RJ (1994) Studies of the ground-dwelling mammals of eucalypt forests in south-eastern New South Wales: the species, their abundance and distribution. *Wildlife Research* 21, 219-239.
- Christensen PES, Burrows ND (1995) Project Desert Dreaming: the reintroduction of mammals to the Gibson Desert. In: M Serena (Ed.) *Reintroduction Biology of Australian and New Zealand fauna*. Surrey Beatty and Sons, Chipping Norton. pp. 199-208.
- Coman BJ (1973) The diet of red foxes, *Vulpes vulpes* L., in Victoria. *Australian Journal of Zoology* 21, 391-401.
- Coman BJ (1995) Fox *Vulpes vulpes*. In *The Mammals of Australia* (ed. R Strahan), Australian Museum/Reed Books. pp. 698-699.

- Corbett L (1995) *The Dingo in Australia and Asia*. University of NSW Press.
- Cross J (1990) The feral cat – justification for its control. Report, Charles Sturt University, Wagga Wagga, New South Wales.
- Department of Conservation and Land Management (1999) 'Western Shield Strategic Plan, July 1999 to June 2002.' CALM, Western Australia.
- Dickman CR (1996) Overview of the impact of feral cats on Australian native fauna. Report to Australian Nature Conservation Agency.
- Eason CT, Frampton CM (1991) Acute toxicity of sodium monofluoroacetate (1080) baits to feral cats. *Wildlife Research* **18**, 445-449.
- Eason CT, Morgan DR, Clapperton BK (1992) Toxic bait and baiting strategies for feral cats. In *Proceedings of the Fifteenth Vertebrate Pest Conference* (eds. JE Borrecco and RE Marsh), pp. 371-376. University of California: Davis.
- Eberhardt LL (1976) Quantitative ecology and impact assessment. *Journal of Environmental Management* **4**, 27-70.
- Edwards GP, de Prue ND, Shakeshaft BJ, Crealy IV (2000) An evaluation of two methods of assessing feral cat and dingo abundance in central Australia. *Wildlife Research* **27**, 143-149.
- Environment Australia (1999) *Threat Abatement Plan for Predation by Feral Cats*. Environment Australia, Biodiversity Group, Canberra.
- Falkland AC (1994) Climate, hydrology and water resources of the Cocos (Keeling) Islands. *Atoll Research Bulletin* **400**, 1-52.
- Fischer J, Lindenmayer DB (2000) An assessment of the published results of animal relocations. *Biological Conservation* **96**, 1-11.
- Fisher P (1998) Rhodamine B as a marker for the assessment of non-toxic bait uptake by animals. Technical Series No. 4. Vertebrate Pest Research Unit, Department of Natural Resources and Environment.
- Fisher P, Algar D, Sinagra JA (1999) Use of Rhodamine B as a systemic bait marker for feral cats (*Felis catus*). *Wildlife Research* **26**, 281-285.
- Fisher P, Algar D, Johnston M (2001) Current and future feral cat control management for conservation outcomes. In *Proceedings of Veterinary Conservation Biology Wildlife Health and Management in Australasia. July 2001*. (eds. L. Vogelnest and A. Martin) Taronga Zoo, Sydney.
- Friend JA, Algar D (1993) Methods of broadscale cat control and fox control at a numbat re-introduction site. Year 1, final report. Feral Pests Programme, project 11. Department of Conservation and Land Management, Western Australia.
- Friend JA, Algar D (1994a) Methods of broadscale cat control and fox control at a numbat re-introduction site. Year 1, final report, December 1993: with appendix, February 1994: Feral Pests Programme, project 11. Department of Conservation and Land Management, Western Australia.
- Friend JA, Algar D (1994b) Methods of broadscale control of feral cats and fox control at a numbat re-introduction site. Year 2, progress report, June 1994: Feral Pests Program, Project 11. Department of Conservation and Land Management, Western Australia.
- Friend JA, Algar D (1995) Methods of broadscale cat control and fox control at a numbat re-introduction site: Year 2, final report to Australian Nature conservation Agency. Department of Conservation and Land Management, Western Australia.
- Garnett S (1992) *The Action Plan for Australian Birds*. Australian National Parks and Wildlife Service, Canberra.
- Garnett S (1993) Threatened and Extinct Birds of Australia, RAOU Report No. 82. Royal Australasian Ornithologists Union and Australian National Parks and Wildlife Service, Melbourne.
- Garnett ST, Crowley GM (2000) *The action plan for Australian birds 2000*. Environment Australia, Canberra.
- Gibson DF, Johnson KA, Langford DG, Cole JR, Clarke DE, Willowra Community (1995) The Rufous Hare-wallaby *Lagorchestes hirsutus*: a history of experimental reintroduction in the Tanami Desert, Northern Territory. In *Reintroduction Biology of Australian and New Zealand Fauna* (ed. M. Serena), pp. 171-176. Surrey Beatty and Sons, Chipping Norton.
- Gilligan SA (1994) Climate. In: H.J.R. Pringle, A.M.E. van Vreeswyk and S.A. Gilligan (Eds.). *An inventory and condition survey of rangelands in the north-eastern goldfields, Western Australia*: Technical Bulletin 87. Western Australian Department of Agriculture, South Perth.
- Hocking RM, Moors HT, Van de Greaff WJE (1987) Geology of the Carnarvon Basin, Western Australia. *Geological survey of Western Australia, Bulletin* 133. Western Australian Department of Mines, Perth.
- Johnson KA, Burbidge AA, McKenzie NL (1989) Australian Macropodoidea: status, causes of decline and future research and management. In *Kangaroos, Wallabies and Rat Kangaroos* (eds. G. Grigg, P. Jarman and I. Hume) Surrey Beatty and Sons, Chipping Norton.
- Jones E (1977) Ecology of the feral cat, *Felis catus* (L.), (Carnivora : Felidae) on Macquarie Island. *Australian Wildlife Research* **4**, 537-547.
- Jones E, Coman BJ (1982) Ecology of the Feral Cat, *Felis catus* (L.), in south-eastern Australia III. Home ranges and population ecology in semiarid north-west Victoria. *Australian Wildlife Research* **9**, 409-420.

- King DR (1990) *1080 and Australian Fauna*. Western Australian Agricultural Protection Board, Perth.
- Liddelow GL, Ward BG, Angus GJ, Hamilton N (2002) 'An assessment of an aerial baiting program for the control of feral cats at the Gibson Desert Nature Reserve, Western Australia.' Department of Conservation and Land Management, Western Australia.
- Lindstrom ER, Brainerd SM, Helldin JO, Overskaug K (1995) Pine-marten – red fox interactions: a case of intraguild predation? *Annals of Zoology Fennici* **32**, 123-130.
- Mahood IT (1980) The feral cat. University of Sydney Refresher Course for Veterinarians. *Proceedings* No. **53**, 447-455.
- McIlroy JC (1981) The sensitivity of Australian animals to 1080 poison. II. Marsupial and eutherian carnivores. *Australian Wildlife Research* **8**, 385-399.
- McNamara K, Brandis T, Hopkins A (2000) Filling in the gaps: building a reserve system in the Gascoyne & Murchison region. *Landscape* **16**, 43-48.
- Molsher RL (1999) 'The ecology of feral cats, *Felis catus*, in open forest in New South Wales: interactions with food resources and foxes.' PhD thesis, School of Biological Sciences, University of Sydney, Australia.
- Molsher R, Newsome A, Dickman C (1999) Feeding ecology and population dynamics of the feral cat (*Felis catus*) in relation to the availability of prey in central-eastern New South Wales. *Wildlife Research* **26**, 593-607.
- Moodie E (1995) 'The potential for biological control of feral cats in Australia.' Unpublished report to Australian Nature Conservation Agency, Canberra.
- Montague PD (1914) A report on the fauna of the Monte Bello Islands. *Proceedings of the Zoological Society of London 1914*, 625-652.
- Moro D, Morris KD (2000) Movements and refugia of Lakeland Downs short-tailed mice, *Leggadina lakedownensis*, and house mice, *Mus domesticus*, on Thevenard Island, Western Australia. *Wildlife Research* **27**, 11-20.
- Morris K., Sims C, Himbeck K., Christensen P, Sercombe N, Ward B, Noakes N (2004) *Project Eden – fauna recovery on Peron Peninsula, Shark Bay Western Shield* review–February 2003. *Conservation Science W. Aust.* **5** (2), 202-234. Department of Conservation and Land Management, Western Australia.
- Morton SR (1990) The impact of European settlement on the vertebrate animals of arid Australia: a conceptual model. *Proceedings of the Ecological Society of Australia* **16**, 201-213.
- O'Donoghue M, Boutin S, Krebs CJ, Hofer EJ (1997) Numerical responses of coyotes and lynx to the snowshoe hare cycle. *Oikos* **80**, 150-162.
- Parks Australia (1999) *Pulu Keeling National Park Plan of Management*. Parks Australia North, Darwin.
- Payne AL, Curry PJ, Spencer GF (1987) An inventory and condition survey of rangelands in the Carnarvon Basin, Western Australia. Technical Bulletin No. 73. Western Australian Department of Agriculture, Perth..
- Pettigrew JD (1993) A burst of feral cats in the Diamantina – a lesson for the management of pest species? In *Cat Management Workshop* (eds. G Siepen and C Owens) Queensland Department of Environment and Heritage, Brisbane.
- Pringle HJR, van Vreeswyk AME (1994) Land systems. In HJR Pringle, AME van Vreeswyk and SA Gilligan (Eds). *An inventory and condition survey of rangelands in the north-eastern goldfields, Western Australia*: Technical Bulletin 87. Western Australian Department of Agriculture, South Perth.
- Rauzon MJ (1985) Feral cats on Jarvis Island: their effects and their eradication. *Atoll Research Bulletin* **282**, 1-30.
- Reid JRW (2000) Survey of the Buff-banded Rail (*Rallus philippensis andrewsi*) in Pulu Keeling National Park, Cocos Islands, Indian Ocean. Report to Parks Australia, North.
- Risbey DA, Calver M, Short J (1997) Control of feral cats for nature conservation I. Field tests of four baiting methods. *Wildlife Research* **24**, 319-326.
- Risbey DA, Calver MC, Short J, Bradley JS, Wright IW (2000) The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. II. A field experiment. *Wildlife Research* **27**, 223-235.
- Serventy DL, Marshall AJ (1964) A natural history reconnaissance of Barrow and Montebello Islands, 1958. Technical Paper No. 6. CSIRO Division of Wildlife Research.
- Servin J, Rau JR, Delibes M (1987) Use of radio tracking to improve the estimation by track counts of the relative abundance of red fox. *Acta Theriologica* **32**, 489-492.
- Sheard K (1950) A visit to the Monte Bello Islands. *Western Australian Naturalist* **2**, 150-151.
- Short J, Turner B, Risbey DA, Camamah, R (1997) Control of feral cats for nature conservation. II. Population reduction by poisoning. *Wildlife Research* **24**, 703-714.
- Smith AP, Quin DG (1996) Patterns and causes of extinction and decline in Australian conilurine rodents. *Biological Conservation* **77**, 243-267.
- Stander PE (1998) Spoor counts as indices of large carnivore populations: the relationship between spoor frequency, sampling effort and true density. *Journal of Applied Ecology* **35**, 378-385.

- Stephenson RO, Karczmarczyk P (1989) Development of techniques for evaluating lynx population status in Alaska. Alaska Department of Fish and Game Research, Final Report, Project W-23-1.
- Strahan R (1995) (Ed.) *The Mammals of Australia*. Reed Books, Chatswood.
- Stewart-Oaten A, Murdoch WW, Parker K (1986) Environmental assessment: pseudoreplication in time? *Ecology* **67**, 929-940.
- Thackway R, Creswell ID (1995) *An interim bioregionalisation for Australia*. Australian Nature Conservation Agency, Canberra.
- Thomas ND, Whisson L, (2001) 'Farewell felines of Faure – follow-up survey of feral cats on Faure Island.' Department of Conservation and Land Management Western Australia.
- Thomson PC, Marlow NJ, Rose K, Kok NE (2000) The effectiveness of a large-scale baiting campaign and an evaluation of a buffer zone strategy for fox control. *Wildlife Research* **27**, 465-472.
- Williams DG (1994) Vegetation and flora of the Cocos (Keeling) Islands. *Atoll Research Bulletin* **404**, 1-29.
- Williams KI, Parer I, Coman B, Burley J, Braysher M (1995) *Managing vertebrate pests: Rabbits*. Bureau of Resource Sciences, Australian Government Publishing Service, Canberra.
- Wilson GJ, Delahay RJ (2001) A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. *Wildlife Research* **28**, 151-164.
- Wood Jones F (1909) Fauna of the Cocos-Keeling Atoll. *Proceedings of the Zoological Society of London* 1909, 132-159.
- Woodroffe CD, Berry PF (1994) Scientific studies in the Cocos (Keeling) Islands: an introduction. *Atoll Research Bulletin* **399**, 1-16.
- Woodroffe CD, McLean RF (1994) Reef islands of the Cocos (Keeling) Islands. *Atoll Research Bulletin* **403**, 1-36.
- Veitch CR (1985) Methods of eradicating feral cats from offshore islands in New Zealand. In *Conservation of Island Birds* (ed. PJ Moors), pp. 125-141. ICBP Technical Publication No. 3.

Threatened fauna issues not covered under *Western Shield*: *Western Shield* review—February 2003

JOHN BLYTH¹ AND ANDREW A. BURBIDGE²

¹ Department of Conservation and Land Management, Wildlife Research Centre,
PO Box 51, Wanneroo, WA 6946. johnbl@calm.wa.gov.au

² Department of Conservation and Land Management, Wildlife Research Centre,
PO Box 51, Wanneroo, WA 6946. andrewb@calm.wa.gov.au

This review paper addresses the following terms of reference:

- Provide an overview of threatened fauna recovery projects not included under the *Western Shield* umbrella.
- List critically endangered and endangered fauna species for which there are no or limited recovery programs and provide a brief overview of what needs doing for each of them.
- Discuss the pros and cons of including additional or all fauna recovery projects under *Western Shield*.
- Discuss links between recovery plans and *Western Shield* activities.

INTRODUCTION

The *Western Shield* Fauna Recovery Program provides for the recovery of terrestrial vertebrate animals, especially ‘critical weight range’ (CWR) mammals (Burbidge and McKenzie 1989), threatened by predation by introduced animals. Current concentration is in the south-west region, and expansion to the rangelands awaits an operational technique for controlling feral cats as well as foxes. *Western Shield* is based upon a program for the abatement of a single Threatening Process and enhancement, largely by translocation, of the status of target native species.

Western Shield’s current objectives (CALM, 1999) are to:

- Maximise the recovery of sustainable populations of vulnerable native fauna by reducing the impact of predation by foxes and feral cats.
- Develop cost efficient and effective control techniques for foxes and feral cats.
- Through education and public relations programs increase the awareness of the effect of fox and feral cat predation on native fauna and what can be done to mitigate this effect (best practice).

- Link predator control and fauna recovery to complementary research projects.
- Develop and maintain partnerships with groups and organisations that maximise the efficiency and effectiveness of fauna recovery across Western Australia.

Thus, *Western Shield* is not, in its present form, a broad fauna recovery program for all Western Australian threatened fauna. In addressing the terms of reference we have kept in mind three broad questions:

1. To what extent should *Western Shield* operate as the department’s umbrella program for all recovery work on threatened fauna and threatened faunal communities?
2. To what extent should the total money available from departmental resources for the recovery of threatened species and ecological communities be distributed in accordance with levels of threat as allocated by the Threatened Species Scientific Committee and Threatened Ecological Communities Scientific Committee?
3. If strict allocation according to threat status is not practicable what alternative mechanism should be established to ensure that all of the State’s threatened species and communities are provided sufficient resources for reasonable confidence of recovery? In particular, what coordination or change is needed to ensure that the highest priority threatened species and communities receive resources, and that *Western Shield* does not warp departmental priorities?

The questions above are critical ones for the Department, particularly with the increasing uncertainty that Commonwealth funds (now mainly from the Natural Heritage Trust (NHT)) will continue to be available for the State’s highest priority recovery programs.

THE THREATENED FAUNA OF WESTERN AUSTRALIA

The list of threatened fauna¹ (excluding most marine species²) gazetted under the Western Australian Wildlife Conservation Act on 9 April 2002 includes 17 Critically Endangered (CR) species, 26 Endangered (EN) species and 91 Vulnerable (VU) species (Tables 1 and 2).

It is apparent from Table 2 that only six of the 43 fauna taxa currently listed as CR or EN in Western Australia are benefiting or likely to benefit directly or significantly from funding via the current *Western Shield* program. Of these six, Gilbert's potoroo, dibbler, western barred bandicoot and western ground parrot are the subject of significant other recovery actions that are not covered under *Western Shield*. For Gilbert's potoroo, dibbler and western ground parrot these additional actions are critical to the species' recovery. There are also other taxa such as western swamp tortoise that, while it potentially benefits from *Western Shield*, is currently entirely funded from other programs for actions to ensure the species' survival.

Thus, there are 40 CR and EN animal species not adequately funded under *Western Shield* (Table 2). Of these, 24 are currently the subject of greater or lesser recovery actions funded from a variety of sources (Tables 2 and 4), and 16 have no recovery actions in train in Western Australia (although four species of arachnids are under the general supervision of the North West Cape Karst Management Advisory Committee).

As noted above, 24 taxa of Kimberley camaenid land snails are to be listed as CR or EN. Most (23) occur in the Ningbing Range area and their recovery can be dealt with through a single plan dealing with the whole range. This plan would need to be written in consultation with other stakeholders. A millipede from the south coast forests is to be listed as EN and will need separate recovery actions. This species is now the subject of recovery planning under the supervision of the recently established South Coast Threatened Invertebrate Group. This group is also dealing with other relict species of invertebrates occurring in humid areas, historically with long periods

between fires, along the south coast of Western Australia.

To ensure this review is comprehensive, fauna-based Threatened Ecological Communities (TECs) need to be considered as well as species. There are currently eight CR and four EN faunal TECs listed on the department's TEC Database (Table 3).

None of the twelve CR and EN TECs listed in Table 3 benefits from *Western Shield*. Thus, only six of 55 CR and EN faunal species and TECs are benefiting directly or significantly from *Western Shield*.

On the other hand, two species of mammals currently listed as Vulnerable (not shown in Table 2) are now listed under this lower threat category because of actions under *Western Shield*. These are chuditch (*Dasyurus geoffroyi*), and numbat (*Myrmecobius fasciatus*). Complete cessation of fox baiting within the range of these species would almost certainly result in them quickly needing to be reclassified into one of the higher threat categories. Other Vulnerable species are benefiting from *Western Shield*, eg, bilby (*Macrotis lagotis*), western ringtail possum (*Pseudocheirus occidentalis*), boodie (*Bettongia lesueur*), black-flanked rock-wallaby (*Petrogale lateralis*), quokka (*Setonix brachyurus*), and probably the dayang (heath rat) (*Pseudomys shortridgei*). Three mammals, now in the 'Conservation Dependent' category, have recovered sufficiently due to *Western Shield* that they could be delisted: woylie (*Bettongia penicillata*) (Start *et al.* 1998), tammar wallaby (*Macropus eugenii*) and quenda (*Isodon obesulus*). In addition, it is clear that a number of other species of mammals not currently listed as threatened, have recovered in *Western Shield* areas. These species, including the common brushtail possum (*Trichosurus vulpecula*) and western brush wallaby (*Macropus irma*) (not strictly a CWR species, but appears to benefit from fox control), could be expected to continue declining within the distribution of foxes if fox baiting was significantly reduced. Some larger ground-nesting birds, including the Vulnerable malleefowl (*Leipoa ocellata*) and the Near Threatened bush stone-curlew (*Burhinus grallarius*), probably also benefit from fox baiting, as do larger reptiles, such as carpet pythons (*Morelia spilota*), *Varanus* spp. and *Egernia* spp.

TABLE 1

Threat categories and taxonomic groups of threatened animals in WA¹ (excluding whales, albatrosses and petrels)²

CATEGORY	MAMMALS	BIRDS	REPTILES	FROGS	FISH	INVERTEBRATES	TOTAL
CR	3*	1	1	1	0	11	17
EN	7	5	2	0	0	12	26
VU	27	21	14	2	4	23	91
Total	37	27	17	3	4	46	134

* includes one taxon (*Lagorchestes hirsutus* ssp. (NTM U2430), Mala, Rufous Hare-wallaby) listed as Extinct in the Wild

¹ At its March 2002 meeting, TSSC recommended that 20 taxa of Camaenid snails be listed as CR, four as EN and two as VU. A millipede was also recommended as EN. This will increase by 50% the number of CR+EN fauna taxa in WA.

² We have not included whales, albatrosses and petrels in this review, because as oceanic species they are dealt with by National Recovery Plans overseen by the Commonwealth government. No albatrosses or listed petrels breed in WA.

Table 2

Recovery programs in WA for CR and EN fauna listed under the *Wildlife Conservation Act 1950*.

SPECIES	THREAT CATEGORY	WESTERN SHIELD FUNDING	OTHER CALM AND/OR EXTERNAL FUNDING
MAMMALS			
<i>Potorous gilbertii</i> , Gilbert's potoroo	CR	Partly	Yes
<i>Zyzomys pedunculatus</i> , antina, central rock-rat	CR	No	Yes
<i>Dasyercus hillieri</i> , amputa	EN	No	No
<i>Parantechinus apicalis</i> , dibbler	EN	Partly	Yes
<i>Phascogale calura</i> , kenngoor, red-tailed phascogale	EN	Partly	No
<i>Sminthopsis psammophila</i> , sandhill dunnart	EN	No	No
<i>Notoryctes caurinus</i> , kakarratul, northern marsupial-mole	EN	No	No
<i>Notoryctes typhlops</i> , Itjaritjari, southern marsupial-mole	EN	No	No
<i>Perameles bougainville bougainville</i> , marl, western barred bandicoot	EN	Partly	No
<i>Lagorchestes hirsutus</i> ssp. (NTM U2430), mala, rufous hare-wallaby	EW	Fully	No
BIRDS			
<i>Pezoporus occidentalis</i> , night parrot	CR	No	Yes
<i>Calyptorhynchus latirostris</i> , Carnaby's black-cockatoo	EN	No	Yes
<i>Cacatua pastinator pastinator</i> , Muir's corella	EN	No	Yes
<i>Pezoporus wallicus flaviventris</i> , western ground parrot	EN	Partly	Yes
<i>Falcunculus frontatus whitei</i> , crested shrike-tit (northern)	EN	No	No
<i>Erythrura gouldiae</i> , Gouldian finch	EN	No	Yes
REPTILES			
<i>Pseudemydura umbrina</i> , western swamp tortoise	CR	No	Yes
<i>Caretta caretta</i> , loggerhead Turtle	EN	No	Yes
<i>Lepidochelys olivacea</i> , Olive Ridley Turtle	EN	No	No
FROGS			
<i>Geocrinia alba</i> , white-bellied Frog	CR	No	Yes
POLYCHAETE WORMS			
<i>Prionospia thalangi</i> (Bundera Sinkhole)	CR	No	Yes
MOLLUSCS			
Undescribed Rhytidid sp. (WAM#2295-69), Stirling Range Rhytidid snail	EN	No	No
MILLIPEDES			
<i>Stygiochiropus peculiaris</i> , Camerons Cave millipede	CR	No	Yes
ARACHNIDS			
<i>Hyella</i> sp. (BES#1154, 2525, 2546), Camerons Cave pseudoscorpion	CR	No	Yes
<i>Kwonkan eboracum</i> , Yorkrakine trapdoor spider	CR	No	Limited
<i>Teyl</i> sp. (B.Y. Main 1953/2683, 1984/13), Minnivale trapdoor spider	CR	No	Limited
<i>Aganippe castellum</i> , tree-stem trapdoor spider	EN	No	No
<i>Draculoides brooksi</i> , Northern Cape Range Draculoides	EN	No	No
<i>Draculoides julianneae</i> , Western Cape Range Draculoides	EN	No	No
<i>Bamazomus subsolanus</i> ms (WAM#98/1540), Eastern Cape Range Bamazomus	EN	No	No
<i>Bamazomus vespertinus</i> ms (WAM#95/748), Western Cape Range Bamazomus	EN	No	No
<i>Moggridgea</i> sp. (B.Y. Main 1990/24, 25), Stirling Range Moggridgea spider	EN	No	Limited
<i>Moggridgea tingle</i> , Tingle trapdoor spider	EN	No	No
CRUSTACEANS			
<i>Bunderia misophaga</i> (Bundera Sinkhole)	CR	No	Yes
<i>Danieolpolina kornickeri</i> (Bundera Sinkhole)	CR	No	Yes
<i>Hurleya</i> sp. (WAM#642-97), Crystal Cave crangonyctoid	CR	No	Yes
<i>Lasionectes exleyi</i> , Cape Range remipede	CR	No	Yes
<i>Speleophria bunderae</i> (Bundera Sinkhole)	CR	No	Yes
<i>Stygocyclopia australis</i> (Bundera Sinkhole)	CR	No	Yes
<i>Liagoceradocus branchialis</i> , Cape Range Liagoceradocus amphipod	EN	No	Yes
NATIVE BEES			
<i>Leioproctus douglasiellus</i>	EN	No	No
<i>Neopasiphae simplicior</i>	EN	No	No
MOTHS			
<i>Synemon gratiosa</i> , graceful sunmoth	EN	No	No

TABLE 3

Recovery programs for CR and EN fauna-based Threatened Ecological Communities in WA.

THREATENED ECOLOGICAL COMMUNITY (FAUNA-BASED)	THREAT CATEGORY	WESTERN SHIELD	OTHER FUNDING
Cape Range remipede community (Bundera Sinkhole)	CR	No	Yes
Camerons Cave troglobitic community	CR	No	Yes
Aquatic root mat community of caves of the Swan Coastal Plain	CR	No	Yes
Aquatic root mat community Number 1 of caves of the Leeuwin-Naturaliste Ridge	CR	No	Limited
Aquatic root mat community Number 2 of caves of the Leeuwin-Naturaliste Ridge	CR	No	Limited
Aquatic root mat community Number 3 of caves of the Leeuwin-Naturaliste Ridge	CR	No	Limited
Aquatic root mat community Number 4 of caves of the Leeuwin-Naturaliste Ridge	CR	No	Limited
Tumulus springs community (organic mound springs) of the Swan Coastal Plain	CR	No	Limited
Organic mound springs community of the Three Springs area	EN	No	No
Mandora Marsh organic mound springs community	EN	No	No
Black Spring organic mound spring community	EN	No	No
Ethel Gorge aquifer stygobiont community	EN	No	No

DISCUSSION OF SPECIFIC TERMS OF REFERENCE

Term of Reference 1. An overview of threatened fauna recovery projects not included under the *Western Shield* umbrella

The 24 taxa referred to in Table 2 as receiving or having received funding from sources other than *Western Shield* consist of three mammals, five birds, one tortoise and one turtle, one frog and 13 invertebrates (Table 4). None of the twelve CR and EN faunal TECs (Table 3) receives any funding from *Western Shield*, and the eight CR TECs for which some recovery actions are occurring are also listed in Table 4.

Twenty of the 24 taxa in Table 4 are covered by Western Australian Recovery Plans (RPs) or Interim Recovery Plans (IRPs), for all of which significant implementation has begun. The Gouldian finch and loggerhead turtle have national RPs, of which limited implementation occurs in Western Australia. The two species with no IRPs are trapdoor spiders. Of these, the Stirling Range Moggridgea is under the care of the South Coast Threatened Invertebrates Group, and survey work by the WA Museum and Dr Barbara York Main, contracted by the Department, has rediscovered one population of the Yorkrakine trapdoor spider, for which recovery work is urgently needed. All eight CR TECs have IRPs and implementation has commenced for them, (Table 4) while IRPs are not written for the four EN TECs, although some very limited recovery actions have been implemented.

Even for those species and communities with completed Western Australian RPs or IRPs, there are varying degrees of adequacy of funding. Most of the CR and EN vertebrates are covered by full RPs and substantial funding has been available for their implementation. However, significant spending has yet to occur under the Muir's corella RP, which is in late draft, and there is insufficient information to prepare full RPs for the central rock rat and the night parrot, neither of which are positively known to still occur in WA. The central rock rat occurs in other jurisdictions and the night parrot is

likely to do the same. Until recently, there has also been inadequate information for the western ground parrot.

The situation is very different for invertebrate fauna and faunal communities, none of which have full Recovery Plans. The two trapdoor spiders referred to above do not have IRPs either, and the amounts of money available and/or spent per species are vastly smaller for invertebrates than for vertebrates. For most of the TECs listed in Table 4, and the individual threatened species they contain, the sums of money identified in the IRPs are all understated because further research is needed, is difficult to cost, and may point to new or altered actions being required. Nevertheless, for some of these TECs containing gazetted threatened species, there is only one occurrence, the area of each one is very small, and the threatening processes are manageable. In these cases, such as Cameron's Cave and Bundera Sinkhole, the cost will be relatively low, even at the whole ecosystem level. Per threatened species it will be at least an order of magnitude less than many single species recovery programs.

For other TECs, especially the Yanchep Caves and the Swan Coastal Plain organic mound springs community, protecting the TECs will also provide relatively cheap protection of all threatened species within them. However, total costs could be very significant because of the need for detailed research and the possible need to provide quite large volumes of water to maintain these groundwater systems into the foreseeable future. Although all spending on these two Swan Coastal Plain communities has, until very recently, been by the Department and the Water and Rivers Commission, a trial artificial recharge of groundwater for Yanchep caves was underway at the end of 2002 and was largely funded by the Water Corporation. In addition, negotiations for longer term funding are currently in train with the Water Corporation and the Forest Products Commission. These negotiations are aimed at designing and funding more robust and generous artificial watering systems as an emergency measure to conserve the TECs and species within them, and to design and implement long term management strategies that will return groundwater aquifers of the Gnangara Mound to sustainability.

For many species and TECs, the sums required in the future under RPs or IRPs are much greater than has so far been committed (Table 4). With the scaling down of Commonwealth funding, there is no obvious source for most of this money, including for species that have been relatively well funded to date. For example, the western swamp tortoise (CR) has been funded significantly by the Commonwealth during the past 10 years, but there is no assurance of any future funding. If Commonwealth funding does not eventuate, this recovery program could

be seriously impacted, eg, by the lack of funds to employ the chief investigator Dr Gerald Kuchling. Captive breeding at Perth Zoo, the source of all translocated tortoises, would also be greatly impacted. Recovery programs for other taxa, including Gilbert's potoroo, Australia's most endangered mammal, are similarly at risk.

Thirteen taxa and TECs in Table 4, discussed above, for which funding is deficient are also listed in Table 5, with indicative amounts of funding needed to conduct appropriate recovery programs in the future.

TABLE 4

Recovery actions for CR and EN taxa and ecological communities not adequately funded under *Western Shield*

TAXON/TEC	THREAT CATEG-ORY	PAST & CURRENT ACTIONS	TOTAL COST OF RP	SPENT TO DATE	FUNDING SOURCE ¹
Gilbert's potoroo	CR	Recovery Plan (RP), Recovery Team (RT)	\$759 750 first 3 years	\$945 300 1997-01	NHT (Natural Heritage Trust), Department
Dibbler	EN	Draft RP, RT	RP still in draft. Cost/year about same as to date	\$1.328m 1997-01	NHT, Department
Central rock-rat	CR	Interim Recovery Plan (IRP), Searching in WA (unsuccessful); more proposed by Pilbara Region Biological Survey	\$13 605 for two field trips	\$28 650 over last 5 years	NHT, Department (proposed)
Night parrot	CR	IRP, Publicity, searching (unsuccessful)	\$18 500 for searching	~\$30 000 (publicity and searching)	NHT, Department, Australian Museum, volunteers
Muir's corella	EN	Draft Recovery Plan (RP) and Recovery Team (RT), research, monitoring, liaison	\$59 100 (Year 1)	\$4 000	Department, Dept of Ag, WAM
Carnaby's black cockatoo	EN	RP, RT	\$2 253 000 over next five years	\$50 000	Department, NHT, Gordon Reid Foundation, Birds Australia, landowners, community groups
Western ground parrot	EN	RP, RT, research, public liaison	\$108 855 over 3 years	\$120 000 over last 5 yrs	Department, NHT Birds Australia,
Gouldian finch	EN	National RP & RT, extensive research, liaison. Survey in WA	\$1 046 200 Five- year national plan to February 03	~\$5 000 over last 5 years in WA	NHT, mining companies, Department
Western swamp tortoise	CR	RP, RT	\$1 323 900 over the next five years	Work at similar level since 1992	NHT, Department, Perth Zoo, UWA
Loggerhead turtle	EN	National RP, limited WA actions	\$ 5 620 000 for all species	\$60 000 since 1996	Department, NHT, Landscape Expd
White-bellied frog	CR	RP, RT	\$301100 over 3 years	~\$170 000 over last 5 years	NHT, Department (about equal contributions)
Bundera Sinkhole polychaete	CR	IRP, RT	>\$99 750 total over 3 years ³	Department, NHT, ~ \$45 000 over ¹ last 3 years ³	Dept. of Defence, Department, NHT
Camerons Cave millipede	CR	IRP, RT, survey, revesting and monitoring of Cameron's Cave under TEC RP	\$58 750 over 3 years ²	>\$15 000 over last 3 years ²	

TABLE 4 (continued)

TAXON/TEC	THREAT CATEG-ORY	PAST & CURRENT ACTIONS	TOTAL COST OF RP	SPENT TO DATE	FUNDING SOURCE ¹
Camerons Cave pseudoscorpion	CR	IRP, RT, survey, retesting and monitoring of Cameron's Cave under TEC RP	\$58 750 over 3 years ²	>\$15 000 over last 3 years ²	Department, NHT
Yorkrakine trapdoor spider	CR	Survey, status report, monitoring by WA Museum under contract	NA	\$14 000 over three years	NHT, Department
Minnivale trapdoor spider	CR	IRP, Searching by WA Museum under contract	\$24 155 over three years	\$6 000 over three years	NHT, Department
Stirling Range Moggridgea spider	EN	RT, some searching	NA	\$9 700	Department, NHT
<i>Bunderia misophaga</i> (Bundera Sinkhole)	CR	IRP, RT, fencing, traffic management, research and monitoring under TEC RP	>\$99 750 total over three years ³	~ \$45 000 over last 3 years ³	Department, NHT, Dept. of Defence
<i>Danieolpolina kornickeri</i> (Bundera Sinkhole)	CR	IRP, RT, fencing, traffic management, research and monitoring under TEC RP	>\$99 750 total over three years ³	~ \$45 000 over last 3 years ³	Department, NHT, Dept. of Defence
Crystal Cave crangonyctoid	CR	IRP, RT, emergency provision of water, negotiations for long term strategy	\$333 350 over next 5 years ⁴	\$120 000 over last 5 years	Department, DoE
Cape Range remipede	CR	IRP, RT, fencing, traffic management, research and monitoring in TEC RP	>\$99 750 total over three years ³	~ \$45 000 over last 3 years ³	Department, NHT, Dept. of Defence
<i>Speleophria bunderae</i> (Bundera Sinkhole)	CR	IRP, RT, fencing, traffic management, research and monitoring under TEC RP	>\$99 750 total over three years ³	~ \$45 000 over last 3 years ³	Department, NHT, Dept. of Defence
<i>Stygocyclopia australis</i> (Bundera Sinkhole)	CR	IRP, RT, fencing, traffic management, research and monitoring under TEC RP	>\$99 750 total over three years ³	~ \$45 000 over last 3 years ³	Department, NHT, Dept. of Defence
Cape Range Liagoceradocus amphipod	EN	IRP, RT, fencing, traffic management, research and monitoring under TEC RP	>\$99 750 total over three years ³	~ \$45 000 over last 3 years ³	Department, NHT, Dept. of Defence
Cape Range remipede community	CR	IRP, RT, fencing, traffic management, research and monitoring under TEC RP	>\$99 750 total over three years ³	~ \$45 000 over last 3 years ³	Department, NHT, Dept. of Defence
Camerons Cave troglobitic community	CR	IRP, RT, survey, retesting and monitoring of Cameron's Cave under TEC RP	\$58 750 over 3 years ²	~\$15 000 over last 3 years ²	Department, NHT
Root mat community of Yanchep caves	CR	IRP, RT, emergency provision of water, negotiations for long term strategy	>\$333 350 over next 5 years ⁴	~\$140 000 over last 5 years ⁴	Department, DoE Water Corporation, Forest Products Commission
Leeuwin-Naturaliste cave community No 1	CR	IRP, RT,	\$87 900 over 3 years ⁵	~\$25 000 over last 3 years ⁵	Department
Leeuwin-Naturaliste cave community No 2	CR	IRP, RT,	\$87 900 over 3 years ⁵	~\$25 000 over last 3 years ⁵	Department
Leeuwin-Naturaliste cave community No 3	CR	IRP, RT,	\$87 900 over 3 years ⁵	~\$25 000 over last 3 years ⁵	Department
Leeuwin-Naturaliste cave community No 4	CR	IRP, RT,	\$87 900 over 3 years ⁵	~\$25 000 over last 3 years ⁵	Department
Organic mound springs of Swan CP	CR	IRP, Acquisition of two occurrences, fencing, weed control.	> \$93 650 over 3 years (excl purchase)	~\$230 000 over last five years ⁶	NHT, Department

¹ In order of magnitude of contribution.² Total figure for the Camerons Cave troglobitic community and all threatened species within it.³ Total figure for the Cape Range remipede community (Bundera Sinkhole) and all threatened species within it.⁴ Total figure for the Yanchep Cave root mat community and the Crystal Cave crangonyctoid.⁵ Cost of planned recovery actions for all four Leeuwin Naturaliste cave communities excluding possible maintenance of stream levels, water quality investigations, and possible regeneration program for trees above caves.⁶ Includes acquisition of two occurrences at total cost of \$190 000.

Term of Reference 2. CR and EN fauna for which there are inadequate recovery programs

Listing taxa and TECs for which there are inadequate recovery programs is difficult, as funding levels and guidelines vary from year to year. Apportioning funding is particularly difficult in relation to external funding from the NHT, as this program seems to be in a hiatus with relation to funding to the State.

However, the 16 EN species and four EN TECs listed in Tables 2 and 3 with no funding in WA clearly fall under this term of reference (Table 5). In addition, Table 5 lists 13 CR and EN taxa and TECs from Table 4 for which current actions are limited and funding in WA is

inadequate. Most of the unfunded taxa require clarification of their distribution, and ecological and biological characteristics. The four Cape Range invertebrates are under the general supervision of the North West Cape Karst Management Advisory Committee. Table 5 includes four vertebrate species (sandhill dunnart, loggerhead and Olive Ridley turtles and Gouldian finch) for which national Recovery Plans exist but for which little or no implementation is currently being conducted in Western Australia.

If VU taxa and TECs were included, the table would be much larger. Attention especially needs to be paid to identifying those VU taxa and TECs whose conservation status is declining.

TABLE 5

Some urgent actions needed for neglected and under-funded CR and EN fauna and TECs³

TAXON / TEC	CAT	ACTIONS REQUIRED	APPROX COST
Ampurta	EN	Searching in WA	\$15 000 per year for 3 years
Sandhill dunnart	EN	Survey in WA as in recent national RT, research into fire and predators	\$20 000 per year for 3 years
Northern marsupial mole	EN	Survey and ecological work as in SA, NT	\$100 000 per year for 3 years
Southern marsupial mole	EN	Survey and ecological work as in SA, NT	Included in above
Antina	CR	Searching in WA	(Pilbara Survey)
Night parrot	CR	Following up reported sightings	\$5000 per year
Crested shrike-tit (northern)	EN	Survey and ecological studies in WA	\$20 000 per year for 5 years
Gouldian finch	EN	Survey and conservation actions in WA	\$20 000 per year for 5 years
Loggerhead turtle	EN	Establish RT, implement RP in WA	\$ 15 000 per year for 5 years
Olive Ridley turtle	EN	Not known to breed in WA. Survey of Kimberley Islands and mainland required.	\$ 7 000
Stirling Range rhytidid <i>Kwonkan eboracum</i> ,	EN	Survey and conservation actions within SRNP	\$20 000 per year for 5 years
Yorakine trapdoor spider	CR	Single very threatened population known	\$25 000 per year for 5 years
<i>Teyl</i> sp. Minnivale trapdoor spider	CR	No extant animals known	Calculate if and when population found
<i>Moggridgea</i> sp., Stirling Range <i>Moggridgea</i> spider	EN	South Coast Invertebrates Recovery Team	Included in rhytidid
Tingle trapdoor spider	EN	South Coast Invertebrates Recovery Team	\$20 000 per year for 3 years
Tree-stem trapdoor spider	EN	Survey, biological and ecological research	\$25 000 per year, 3 yrs
Eastern Cape Range Bamazomus	EN	Survey, preparation of IRP	\$60 000 over 2 years
Western Cape Range Bamazomus	EN	Survey, preparation of IRP	Included in above
Northern Cape Range Draculoides	EN	Survey, preparation of IRP	Included in Eastern Cape Range Bamazomus
Western Cape Range Draculoides	EN	Survey, preparation of IRP	Included in Eastern Cape Range Bamazomus

³ Some broad indications only; not a comprehensive compilation

TABLE 5 (continued)

TAXON / TEC	CAT	ACTIONS REQUIRED	APPROX COST
<i>Leioproctus</i> Native bee	EN	Survey	\$25 000 per year for 3 years
<i>Neopasiphae</i> Native bee	EN	Survey	Included in <i>Leioproctus</i>
Graceful sun moth	EN	Survey proposed by WA Insect Study Society; funding to be sought from Gordon Reid Foundation or TSN	\$90 000 one off, follow up funds as indicated by survey
Aquatic root mat community of caves of the Swan Coastal Plain	CR	Implementing IRP, emergency water supply; funding proposed from other agencies with responsibilities for groundwater management	\$500 000 over 5 years
Aquatic root mat community Number 1 of caves of the Leeuwin-Naturaliste Ridge	CR	Implementation of IRP for all four Leeuwin-Naturaliste cave communities	\$200 000 over 5 years
Aquatic root mat community Number 2 of caves of the Leeuwin-Naturaliste Ridge	CR	Implementation of IRP	Included in No. 1
Aquatic root mat community Number 3 of caves of the Leeuwin-Naturaliste Ridge	CR	Implementation of IRP	Included in No. 1
Aquatic root mat community Number 4 of caves of the Leeuwin-Naturaliste Ridge	CR	Implementation of IRP	Included in No. 1
Tumulus springs community (organic mound springs) of the Swan Coastal Plain	CR	Implementation of IRP, Hydrological research and emergency water supply if necessary	~\$200 000 over 5 years
Organic mound springs community of the Three Springs area	EN	Further faunal survey and hydrological research, writing and implementing IRP	>\$100 000 over 5 years
Mandora Marsh organic mound springs community	EN	Further faunal survey and hydrological research, writing and implementing IRP	>\$120 000 over 5 years
Black Spring organic mound spring community	EN	Further faunal survey and hydrological research, writing and implementing IRP	>\$120 000 over 5 years
Ethel Gorge aquifer stygobiont community	EN	Writing and implementing IRP	>\$50 000 over 5 years

Term of Reference 3. Pros and cons of including additional or all fauna recovery projects under *Western Shield*

In considering this term of reference we wish to address the wider question of how best to organise, coordinate and fund all recovery work on threatened species and ecological communities in this State. The approach taken should be consistent with the department's redrafted Policy Statement No. 9 'Conserving Threatened Species and Ecological Communities' currently in the public review stage. One of its primary objectives is that:

Recovery plans for threatened species and ecological communities will be prepared, published and implemented on a priority basis according to priorities recommended by the WA Threatened Species Scientific Committee and the WA Threatened Ecological Communities Scientific Committee and endorsed by the Minister, with the most threatened species and ecological communities being treated first.

One logical structure to achieve the above objective would be to have two overarching programs, *Western Shield* and Western Everlasting, driving all work on recovering threatened species and ecological communities. *Western Shield* would deal with threatened fauna and ecological communities based on animals, and Western Everlasting would deal with threatened flora and ecological communities based on plants and micro-organisms. The department's total State budget available for recovery work could then be divided between the two programs according to the number of CR and EN taxa and communities (and to a lesser extent VU taxa and communities) being dealt with by each and the relative cost of recovery work (recovery of animals tends to be more expensive than for plants).

The major advantage of putting all threatened fauna and threatened faunal community recovery under *Western Shield* is to ensure that departmental resources available for such work are assigned to the highest priority taxa and threatening processes. It would also give the recovery

of other fauna and faunal communities more status and public recognition by being dealt with under the department's flagship fauna program. A new management structure and decision making process will be required for *Western Shield* and Western Everlasting if this happens.

The major risk in such an amalgamation is the danger of losing the gains made in the recovery of taxa threatened mainly by exotic predators. This can be, at least in part, addressed by reducing the resources being spent on species that are now more secure. In the recent past, considerable resources from *Western Shield* have been directed towards vulnerable taxa such as black-flanked rock-wallaby (*Petrogale lateralis lateralis*), bilby (*Macrotis lagotis*) and Shark Bay rufous hare-wallaby (*Lagorchestes hirsutus bernieri* and *L. h. dorrae*), and even non-listed taxa such as the tammar wallaby (*Macropus eugenii*) and woylie (*Bettongia penicillata*).

We acknowledge that some species referred to above are conservation dependent and fox-baiting throughout much of their range is still necessary. However, the following steps could significantly reduce the costs of continued management of these less threatened species:

- translocations to be restricted to CR and EN species in all but exceptional circumstances
- a more strategic approach to widespread baiting programs with consideration being given to stopping baiting in areas where it has proved to be of little or no benefit
- a clear decision-making process to ensure the greatest benefit, especially for CR and EN species (see discussion of decision making process under Term of Reference 4 below)
- continued development of improved, cost-effective baits and more targeted baiting methods.

A major issue is that many Western Australian threatened fauna programs have depended for some time on Commonwealth funding, initially via the Australian Nature Conservation Agency's Endangered Species Program and later via the Natural Heritage Trust. This has meant that some high priority species recovery work that should be departmental core business has depended almost entirely on external funding, while some low priority species have been well funded from *Western Shield*. Even a relatively minor reduction in Commonwealth funding has had significant ramifications; eg, a \$40,000 reduction in NHT funds for Gilbert's potoroo caused significant problems in implementing recovery work for the most endangered mammal in Australia. In our view, this situation should never have arisen—the highest priority species should be funded as part of the department's core funding, while external funds should be used as 'top up/matching funds' for lower priority segments of recovery plans or to initiate new projects on lower priority species or threats.

For those species and ecological communities without obvious sources of funding the situation is even more parlous. For example, last year's faunal monitoring of the Yanchep cave root mat community indicated a sudden decline in condition of the root mat and the absence of many species, despite a limited artificial watering system that had apparently been adequate in previous years. The several to many undescribed species of invertebrates known only from this community appear to be threatened with imminent extinction unless a major emergency watering system is established quickly (all of these species qualify for listing as CR). The Department has allocated an additional \$40,000 to assist with this task, but much more will be needed. Negotiations with Water and Rivers Commission, Water Corporation and Forest Products Commission are in train to gain assistance, but this Department will need to contribute to a multi-agency recovery effort.

Dividing resources more evenly and logically between all of the most threatened elements of biological diversity in the State would require *Western Shield* and Western Everlasting to use available State money to meet their core needs and to seek alternative sources of money for other tasks. Because of the 'flagship' nature of many of the taxa currently being dealt with under *Western Shield*, that program is well positioned to attract significant resources from outside the Department.

Term of Reference 4. Links between recovery plans and *Western Shield* activities

There is currently no formal linkage, and limited informal linkage, between the implementation of recovery plans by recovery teams and the operation of *Western Shield*, even for those species for which *Western Shield* is seen to be delivering the most essential recovery actions. For example, a decision to stop *Western Shield* fox-baiting in an area significant to the recovery of the dibbler was recently taken without reference to the Dibbler Recovery Team. *Western Shield* has no input to the recovery team for the western swamp tortoise, for which fox-baiting is essential and organised by the recovery team without assistance from *Western Shield*. For Gilbert's potoroo the baiting of Two Peoples Bay Nature Reserve is funded and executed by *Western Shield*, but the monitoring is otherwise funded. There are numerous other examples. For the 37 species and twelve faunal communities to which *Western Shield* does not contribute, there is no link between the recovery plans and *Western Shield*.

Whatever the role and form of *Western Shield* following the departmental review, some formal linkage is needed between the program and recovery teams for all threatened fauna and faunal communities that *Western Shield* has the potential to benefit. For example, a simple but regular (say monthly) email report on *Western Shield* activities could be distributed to the Chairpersons of all relevant

recovery teams. Such reports should list significant issues needing input or decision, including funding matters, the results of decisions, and any significant activities conducted or planned. It would also be appropriate to hold an annual workshop between the *Western Shield* program team and relevant Recovery Team Chairpersons and senior Region and District staff.

Perhaps more importantly, a clear decision-making process is needed so that the interests of Regions, Districts and Recovery Teams are automatically included in each decision about matters that might affect them. Such decisions in *Western Shield*'s current form include how, when and where to bait, what animals should be translocated and where, how and by whom monitoring will be conducted. The decision-making process should include clear criteria for determining when a translocation, either of a particular species or to a particular place, should be discontinued.

An improved decision-making process of the kind suggested above would also contribute to ensuring that resources are divided more evenly and logically between all of the most threatened elements of biological diversity in the State.

CONCLUSIONS

It is our view that:

- *Western Shield* is very limited in terms of the number of species of threatened fauna addressed.
- The great majority of CR and EN taxa and faunal TECs are not addressed by *Western Shield* and some of these not addressed at all by the Department.
- Commonwealth (including NHT) funding has supported the recovery of many taxa and communities in the past. If this funding is not continued, additional resources from the State will be urgently required; otherwise the recovery of these taxa and communities will be compromised.
- *Western Shield* continues to spend significant resources on low priority (Vulnerable and Conservation Dependent) taxa, including those delisted some time ago (woylie, tammar wallaby, quenda), for which savings can be made in a variety of ways.
- Communication between *Western Shield* management and recovery teams is poor, even for those six species significantly aided by *Western Shield*, unless a member of the recovery team is 'in the know', and regular liaison should be formalised.
- The decision-making process for *Western Shield*, whatever the program's eventual form, needs to be clarified and formalised with input from all interested or affected groups within the Department.

THE FUTURE

It is our view that the review of *Western Shield* should recommend either:

1. That *Western Shield* be broadened to include all threatened WA fauna species and all threatened faunal ecological communities and funds (including staff salaries) currently allocated to *Western Shield* be reallocated on a degree of threat basis.
Or
2. That the Department retain *Western Shield* as a program that deals primarily with exotic predators and the recovery of species threatened by them, but move towards a more over-riding, priority-driven method of funding recovery of threatened species and threatened ecological communities State-wide. The method should be based on priorities recommended by the Threatened Species Scientific Committee and the Threatened Ecological Communities Scientific Committee.

We also recommend that whichever option is adopted, additional State funding be found to better recover all CR and EN fauna taxa and communities. If most *Western Shield* funds currently allocated to low priority taxa are diverted to high priority taxa and communities, a lesser amount of new money will be required.

REFERENCES

- Burbidge AA, McKenzie NL (1989) Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* **50**, 143-198.
- CALM see Department of Conservation and Land Management
- Department of Conservation and Land Management (1999) 'Draft *Western Shield* Fauna Recovery Program – Strategic Plan (July 1999-June 2004).' CALM, Western Australia.
- Start AN, Burbidge AA, Armstrong D (1998) A review of the conservation status of the woylie, *Bettongia penicillata ogilbyi* (Marsupialia: Potoroidae) using IUCN criteria. *CALMScience* **2**(4), 277-289.

Return to Dryandra: Western Shield review—February 2003

TONY FRIEND¹ AND BRETT BEECHAM²

¹ Principal Research Scientist, Department of Conservation and Land Management,
120 Albany Highway, Albany, WA 6330. tonyf@calm.wa.gov.au

² Ecologist, Department of Conservation and Land Management,
PO Box 100, Narrogin, WA 6312. brettb@calm.wa.gov.au

SUMMARY

The *Return to Dryandra* project was established in order to reintroduce five threatened marsupials, extinct in the south-west of Western Australia, to Dryandra Woodland. The target species are the bilby (*Macrotis lagotis*), western barred bandicoot (*Perameles bougainville*), boodie (*Bettongia lesueur*), mala (*Lagorchestes hirsutus*) and banded hare-wallaby (*Lagostrophus fasciatus*). Dryandra was seen as a suitable site from which to spearhead the reintroduction of these species into the southwest because:

1. It is a large area where fox control has been shown to cause mammal recovery.
2. It is within the former range of the five selected species.
3. Suitable habitat is present, in good condition.
4. It is close to a District office of the Department of Conservation and Land Management (CALM), so District staff can provide necessary support.
5. It is relatively close to Perth and has high ecotourism potential that would be enhanced by the presence of rare mammals.

The concept was to establish populations of these five species in a 20-hectare predator-proof enclosure within Dryandra, provided with supplementary food and water, so that mammal densities could rise well above those found in the wild. Thus high numbers of site-adapted animals could be generated in order to provide translocation stock for release into Dryandra. The original concept allowed for spotlight walks through the breeding enclosure as a low-level eco-tourism activity, to provide educational opportunities and to involve the community. The *Return to Dryandra* project was to be run jointly by CALM's Narrogin District and Science Division staff.

Subsequently, the aims of the project were enlarged in two directions:

1. to include the construction of a separate viewing enclosure and visitor centre, to be built in partnership with a corporate sponsor
2. as well as providing animals for reintroduction to Dryandra Woodland, the breeding enclosure would also supply stock for translocations to other reserves in the south-west under the *Western Shield* program.

The breeding enclosure was built during 1997 and founder groups of the five species were introduced in 1998. Feeding, monitoring and other routine procedures were established. Predation by diurnal raptors and owls caused some early losses, but breeding commenced and the populations, with the exception of the banded hare-wallabies, which were heavily preyed on by raptors, began to grow.

Plans for a visitor centre/viewing enclosure were developed in 1997 and CALM's Executive Director presented a sponsorship proposal to a potential corporate sponsor. This proposal was kept alive for over a year but eventually failed. A funding application for the centre to the Commonwealth Regional Tourism Program was prepared and submitted in 1999 and \$85 000 was granted on a dollar-for-dollar basis. During this process the management and planning of the visitor centre concept was separated from the *Return to Dryandra* project. The visitor centre/viewing enclosure, known as Barna Mia, was opened by the Minister for the Environment on 14 December 2002.

This review will deal with the *Return to Dryandra* project, touching on Barna Mia only where issues of supply and exchange of animals arise. It was prepared for the *Western Shield* review and information contained within was accurate as at February 2003.

Objectives

The objectives of the *Return to Dryandra* project as originally stated, are as follows:

1. Reintroduction of five species of locally extinct mammals to Dryandra, via a large enclosure to breed animals on site for release. These species are:

<i>Macrotis lagotis</i>	Bilby (dalgyte)
<i>Perameles bougainville</i>	Western barred bandicoot (marl)
<i>Bettongia lesueur</i>	Boodie (burrowing bettong)
<i>Lagorchestes hirsutus</i>	Mala (rufous hare-wallaby)
<i>Lagostrophus fasciatus</i>	Banded hare-wallaby (merrnine)

2. Use of reintroductions to Dryandra to test alternative reintroduction methodologies.
3. Involvement of the local community, through a Friends of Dryandra group and volunteers from other places, through Landscape Expeditions and possibly Earthwatch.

Later, the public involvement aspect was expanded by including the development of an interpretive centre with an animal viewing area within Dryandra.

Achievements

- Design and construction of the breeding enclosure.
- No entry by cats or foxes into the breeding enclosure in five years.
- Establishment of intensive captive breeding colonies of western barred bandicoots and bilbies at Kanyana Wildlife Rehabilitation Centre as part of *Return to Dryandra*.
- Genetic variation in Kanyana bilby colony maintained by exchanges of bilbies with other breeding colonies at Monarto Zoo and Yookamurra Sanctuary, SA; the Territory Wildlife Park and the Alice Springs Desert Park/Arid Zone Research Institute, NT; and the Peron Captive Breeding Centre.
- Establishment of breeding populations of all five species within the Dryandra breeding enclosure.
- Establishment of suitable feeding regimes within the breeding enclosure.
- Establishment of an effective monitoring regime within the breeding enclosure.
- Bilby health monitoring program established through collaboration with Murdoch University.
- Production of sufficient surplus animals for releases of bilbies, western barred bandicoots and the proposed release of boodies.
- Reintroduction of bilbies from the breeding enclosure into Dryandra Woodland.
- Comparison of success of 'soft' and 'hard' release techniques for bilbies completed.
- Elimination of the use of collars for attaching radio-tags to bilbies, in favour of tail mounts, a practice then followed by *Project Eden*.
- Participation in disease investigations on chlamydiosis and a wart-like syndrome found in western barred bandicoots.
- No re-appearance of the wart-like syndrome in the western barred bandicoot population within Dryandra breeding enclosure since 2000.
- Provision of animals for the public viewing enclosure at the Barna Mia interpretive centre.
- Development of strong partnerships with Kanyana Wildlife Rehabilitation Centre and Pingelly Marsupial Retreat.

Difficulties

- Predation of enclosure animals, particularly hare-wallabies, by diurnal and nocturnal birds of prey.
- Difficulty in planning releases due to uncertainty about the numbers of animals that could be produced.
- Limits to the numbers of animals of each species that can be held in the breeding enclosure.
- Occurrence in western barred bandicoots in the enclosure of a wart-like syndrome, also found in other captive and wild populations.
- Significant mortality of released bilbies caused by radio-collars
- Bilbies proved difficult to monitor by alternative means (e.g. trapping, searches for burrows and sign) once tail-mounted transmitters failed or fell off.

Potential economies

This project has been run extremely efficiently and has been heavily subsidised from Narrogin District and Science Division resources (see 'Return to Dryandra Draft Strategic Plan') to the extent that it is clear that the base funding of the project is far from adequate. Two ways in which costs to CALM could be reduced are:

- Greater use of volunteers in monitoring enclosure populations and animals released outside. This would need to be carefully managed to retain a sense of ownership of the project by CALM staff. On the other hand it would generate more public awareness and community support. However this would only reduce costs marginally as vehicle running has been the greatest cost associated with the monitoring of animal populations, particularly when animals are released from the enclosure into Dryandra Woodland proper.
- Reduced frequency of monitoring, recognising that this will reduce the ability to predict numbers available for translocation.

However, in order to carry out reintroductions into Dryandra and continue the research to develop better reintroduction techniques that have already benefited other programs such as *Project Eden*, greater personnel input is required. Similar work is being undertaken as in *Project Eden*, but with only 0.5 FTE dedicated to captive breeding and monitoring released animals, compared with at least 2.0 FTE at Denham. The operating (non-salary) budget available for *Return to Dryandra* can support the operation and monitoring of the breeding enclosure, but cannot support the implementation and monitoring of translocations.

Potential improvements

The requirements of the project have not been recognised in its level of funding, and the project has been heavily subsidised from District and Science Division resources.

More resources are required, particularly for monitoring released animals. The many aspects of the project require more than half of one person's time in the District, as well as the input from Science Division. The budget for the project should allow the allocation of at least one FTE, and it would be most efficient if this were a single person.

A substantial increase in the operational budget is also required, as the project should not continue to divert resources from other areas.

INTRODUCTION

Background to the project

The 1996 *Western Shield* plan (Burbidge *et al.* 1996) proposed the reintroduction of 13 native mammal species to 40 areas of the south-west of Western Australia over approximately five years. Translocations of some of these 13 species (e.g. numbat *Myrmecobius fasciatus*, chuditch *Dasyurus geoffroii*, woylie *Bettongia penicillata* and quenda *Isodon obesulus*) using direct release had already been performed with success. Other species, however, such as those that only survive on offshore islands, were likely to be much more difficult to reintroduce due to behavioural differences and the high cost of obtaining sufficient numbers from the wild.

Seven species, all in this 'difficult' category, were listed in Burbidge *et al.* (1996) as extinct in the southwest and requiring reintroduction from other areas. Reintroduction of five such species in various combinations, *Bettongia lesueur*, *Lagorchestes hirsutus*, *Lagostrophus fasciatus*, *Macrotis lagotis* and *Perameles bougainville*, was proposed to five fauna reconstruction sites in the south west (Dryandra Woodland, Dragon Rocks Nature Reserve, Fitzgerald River National Park, Kalbarri National Park and Lake Magenta Nature Reserve). The document did not specify how these reintroductions should be performed.

The *Return to Dryandra* proposal presented a method of implementing the reintroduction of these species to the south-west, utilising closely monitored, staged releases from a large breeding compound situated at a south-west release site. This approach is desirable for these five species because the following:

- The western barred bandicoot, banded hare-wallaby and boodie have only survived on islands that are free of mammalian predators. Consequently, it is logistically difficult to obtain sufficient numbers for translocations and the animals themselves are likely to be predator-naïve. Wild-wild translocation may result in high initial mortality, even if lack of acclimatisation to the translocation site causes no problems.
- Bilbies are still found over wide areas in the Pilbara and Kimberley, particularly around the fringes of the Great Sandy Desert. They live in small, widely dispersed colonies, however, and the location and capture of even a few individuals is a costly exercise.
- *Lagorchestes hirsutus* is found on Bernier and Dorre Islands in Shark Bay, but captive colonies of the central

Australian form (mala), which is extinct in the wild, exist in Alice Springs and, until 2001, in a 1 km² enclosure on the Lander River in the Tanami Desert, NT. As the south-western subspecies, *Lagorchestes hirsutus hirsutus*, is extinct, it was considered that the central Australian subspecies, having been more recently exposed to a range of predators than the island populations, would be the best choice for reintroduction at Dryandra. More recently, genetic work has indicated that the island populations, despite being more numerous, exhibit less variation but fall within the range of variation of the mainland animals (Eldridge *et al.* 2003). Although these animals are quite readily available, the wide climatic differences between the Tanami and Dryandra suggests that reintroduction into the south-west should allow acclimatisation, and preferably on-site breeding of animals for release.

Dryandra Woodland was proposed as an ideal choice of site because:

1. It is a large area where fox control has been shown to cause mammal recovery.
2. It is in the former range of the selected species.
3. It is close to a CALM District office, and there is an onsite CALM staff presence, so District staff can provide necessary support.
4. It is relatively close to Perth and has high ecotourism potential that would be enhanced by the presence of rare mammals, sensitively displayed on spotlight walks through an enclosure.

Project management

The project *Return to Dryandra* was born on 14 October 1996, when CALM Corporate Executive approved initial funding for the original proposal. The *Return to Dryandra* Steering Group (Committee) was formed in March 1997. The original committee comprised the District Manager, Narrogin (chair), Manager, Wildlife Branch, a research scientist from Science and Information Division, and Parks, Planning, Recreation and Tourism officers from Wheatbelt Region and State Operational Headquarters. The role of the steering group was outlined in the minutes of the first meeting as follows:

- To establish a planning/managing role to keep the operation 'on track'.
- To keep appropriate directors and others informed.
- To liaise and plan with appropriate personnel, both within and outside CALM.

It was also agreed that the Narrogin District Manager (DM) would chair the group.

This committee met five times in 1997 in Perth during the planning phase and during the construction of the breeding enclosure. The breeding enclosure construction was implemented through the District Manager, Narrogin. Planning and negotiation for the acquisition of animals and the development of the monitoring protocol was the

responsibility of Science Division. Animal husbandry procedures were developed jointly.

The 'Return to Dryandra: A *Western Shield* Project - Project Brief' of late 1997 included a section dealing with the approvals process, and stated that the steering committee would answer to the Director, Nature Conservation via the Regional Manager, Wheatbelt. It also recognised that the project spanned several departmental programs, and that every endeavour would be made to keep relevant directors informed.

In June 1997 the Return to Dryandra plan was presented to the National Parks and Nature Conservation Authority (NPNCA). The NPNCA passed a motion to note the nature conservation elements of the program and to endorse the tourism component.

Subsequent meetings of the Steering Committee were held in Narrogin in February 1998 and March 1998, chaired by Acting DM Narrogin.

The Return to Dryandra Steering Committee was not recognised in the management structure provided in the '*Western Shield* Strategic Plan' (July 1999), although the analogous *Project Eden* Management Committee appeared in the plan of responsibilities.

The Return to Dryandra Steering Committee did not meet again until 2001. During this period, the viewing enclosure project (Barna Mia) was developed under the auspices of Narrogin District with input from the Wheatbelt Region and Parks and Visitor Services Division. The then Dryandra Woodland Focus Group, a body incorporating local government representatives from seven shires from the vicinity of Dryandra, local businesses, Chamber of Commerce, Heartlands and Central Southern Tourist Associations and the Wheatbelt Development Commission, was also important in developing the Barna Mia marketing position.

The next meeting of the Return to Dryandra Steering Committee was held in August 2001. The committee was chaired by the Acting DM Narrogin, with representation from Narrogin District, Science Division and Wildlife Branch. This meeting included a review of the membership, roles and responsibilities of the steering committee.

In October 2001, the *Western Shield* South West Management Committee (WSSMC) reviewed the structure and reporting arrangement for the Return to Dryandra program. The initial proposal from the WSSMC was that the Return to Dryandra Steering Committee be reconstituted with the following membership:

- Chair - District Manager, Narrogin
- Regional Leader Nature Conservation, Wheatbelt
- Technical Advisor, Science Division
- *Western Shield* Project Manager
- *Western Shield* Zoologist.

This proposal was subsequently modified on the grounds that three of the five members of this proposed Return to Dryandra Steering Committee were also part of the WSSMC. It was therefore recommended that the

Return to Dryandra Steering Committee be subsumed into the WSSMC, and that the DM, Narrogin be responsible for the day-to-day management of the project. The *Western Shield* Strategic Committee (WSSC) endorsed this recommendation.

The draft 'Return to Dryandra Strategic Plan 2002-2005' (May 2002) provides a clear statement of the current project management roles and responsibilities within this structure. Current arrangements between Narrogin District and Science Division officers promote close liaison in the management of the Return to Dryandra program.

Plans and changes

Planning instruments relating to the *Return to Dryandra* project are as follows:

1. '*Return to Dryandra* - a *Western Shield* Project' (Friend T, Bowra T, 11 August 1996), the original proposal presented on 14 October 1996 to Corporate Executive and approved for funding under the 'New Initiatives' funding scheme.

Aims:

- Reintroduction of five species of locally extinct mammals to Dryandra, via a large enclosure to breed animals on site for release.
- Use of reintroductions to Dryandra to test alternative reintroduction methodologies
- Involvement of the local community, through a Friends of Dryandra group and volunteers from other places, through Landscape Expeditions and possibly Earthwatch.

2. '*Return to Dryandra* - Project Brief' (Moncreiff D, 11 November 1997). The original proposal was expanded to incorporate the establishment of a visitor centre. Community involvement through recruitment of volunteers and fee-paying eco-expeditioners was dropped from the aims.

Aims:

- Reintroduction of five species of locally extinct mammals to Dryandra, via a large enclosure to breed animals on site for release.
- Use of reintroductions to Dryandra to test alternative reintroduction methodologies
- To provide controlled access to visitors to allow them an intimate nature based experience
- To run the facility in a cost neutral manner by collecting tourist revenue.

This updated plan contained a detailed proposal for a separate viewing enclosure and visitor centre, integrating the reintroduction and science themes with a public awareness and cost recovery theme.

3. '*Return to Dryandra*. Phase I: Breeding Enclosure. Operations/Procedures Manual' (Anthony C, Friend T, 1999). The aims of the *Return to Dryandra* project were stated as follows:

- To re-establish self-sustaining populations of at least five medium-sized mammal species (now extinct in the Wheatbelt) in Dryandra Woodland.
- To compare the success of different reintroduction methodologies for each species to develop optimal release strategies.
- To provide stock for other *Western Shield* reconstruction sites.
- To involve the community in order to increase public awareness and to provide educational opportunities.

The concept of using the Dryandra breeding enclosure to provide animals for reintroductions in other reserves in the south-west arose soon after the project was approved, and the *Western Shield* translocation overview tables reflected this from at least as early as November 1997. This was not acknowledged in the aims for the project prior to this document.

4. 'Return to Dryandra: Strategic Plan 2002-2005' (Durell G, Friend T, 2002), the draft plan for the next three years.

This plan restates the aims of the 1996 proposal. The *Western Shield* Project Manager required that the plan should not include the viewing enclosure project (Barna Mia), although there is reference to the need to supply animals from the breeding enclosure to the viewing enclosure and further exchange of animals to reduce the chance of inbreeding within the Barna Mia enclosure.

The objectives of the plan relate mainly to consolidation of the breeding program, the supply of animals for translocation into Dryandra Woodland and the implementation of those translocations.

The objectives for the breeding enclosure for the next three years are to:

- provide sufficient numbers in 2002/03 and 2003/04 to translocate and establish wild populations of bilbies and boodies whilst maintaining sufficient numbers within the breeding enclosure as a breeding colony; and
- re-establish and undertake a breeding research program to provide sufficient numbers of banded hare-wallabies, rufous hare-wallabies and western barred bandicoots within the breeding enclosure for release into the wild in 2004/05 and 2005/06.

Return to Dryandra in relation to Western Shield

The 1996 *Western Shield* proposal (Burbidge *et al.* 1996) focussed on extending fox control, developing cat control methods and establishing a fauna monitoring system covering fauna recovery sites and fauna reconstruction sites. Although fauna reconstruction sites require translocations, these were not described or costed in the proposal. While it was clear from current knowledge that

many species could be transferred through wild-wild translocation from recovery sites to reconstruction sites, this strategy would not be appropriate or possible for another group of species. Seven species were listed in Table 1A of Burbidge *et al.* (1996) as 'Extinct in the south-west, require re-introduction from islands or areas outside the south-west'. The practical difficulties in obtaining these species in sufficient numbers for reintroduction, and the issue of acclimatisation suggested a field breeding system involving large pens in natural habitat. By 1996, field breeding was already being used successfully by CSIRO and the Useless Loop community at Heirisson Prong to provide boodies for release to the wild (Short *et al.* 1994). Thus the *Return to Dryandra* project filled an obvious gap in the 1996 *Western Shield* proposal.

When translocation plans were later developed for the *Western Shield* project, they incorporated the expectation that individuals of the five *Return to Dryandra* species would be available from the Dryandra breeding enclosure for release in Dryandra and other areas

The *Return to Dryandra* project is also closely aligned with the strategic plan for the *Western Shield* Fauna Recovery Program. Its activities encompass many of the strategies supporting the objectives of *Western Shield* established in the strategic plan, including:

- Undertake translocations to fauna reconstruction sites (Objective 1).
- Develop captive breeding facilities where necessary for threatened fauna (Objective 1).
- Develop and implement a protocol for monitoring native fauna populations that allows meaningful measurement of population trends in introduced predator controlled areas (Objective 1).
- Integrate *Western Shield* predator control and fauna monitoring operations with species recovery plans (Objective 4).
- Wherever possible utilise *Western Shield* predator control and fauna monitoring operations to add value to compatible research projects (Objective 4).
- Establish cooperative arrangements with community groups, wildlife carers, wildlife sanctuaries and Perth Zoo to achieve fauna recovery and educational outcomes (Objective 5).

Links between Return to Dryandra and recovery plans

National Recovery Plans

The *Return to Dryandra* project has links with the national Recovery Plan for the Bilby (Southgate 1994, 1995; Paltridge 2000), which proposes Dryandra as a reintroduction site for the species.

The national *Mala Recovery Plan* (Langford 1999) lists Dryandra, Peron and the Monte Bello Islands as proposed translocation sites for mainland mala (i.e. the undescribed subspecies of *Lagorchestes hirsutus* from the

Tanami Desert, NT, a highly threatened taxon now listed as Extinct in the Wild). The plan envisages the ongoing management of the captive breeding program at the Dryandra compound, and the translocation of mala into Dryandra Woodland, Dragon Rocks Nature Reserve and Lake Magenta Nature Reserve.

Return to Dryandra project personnel from Science Division have represented CALM on the national Bilby and Mala Recovery Teams. This has allowed the project to develop strong links with recovery work on these species in other States. There is a need, however, for better dissemination of information from these forums to reach a broader audience within CALM, particularly at a management and operational level. In addition, no published recovery plan is available for the bilby.

It is also essential that operational staff establish and maintain links with other state-based programs supporting the national recovery of threatened species.

State and other recovery plans

The remaining three species, western barred bandicoot, boodie and banded hare-wallaby do not have recovery plans or recovery teams guiding their management. However all three do have published recovery outlines (Maxwell *et al.* 1996). It is essential that recovery objectives and actions be set for these species to provide clear direction for the role of *Return to Dryandra* in their management.

Although a draft report 'Translocation Priorities for *Western Shield* 2001-2003 Wheatbelt Region' (Orell 2001) provides a framework for planning translocations under *Western Shield*, it is necessary that prior to the development of translocation proposals, interim recovery plans at the very least should be developed for species without a plan.

The workshop on disease in western barred bandicoot populations held on 16 July 2002 also recommended that the Department's endorsement be sought for the formation of a western barred bandicoot recovery team and writing of a recovery plan.

Resourcing the *Return to Dryandra* program

Initial funding provided by CALM's Executive Director to start the *Return to Dryandra* project comprised \$40 000 in 1996-97 and \$15 000 per year for three years thereafter. These figures were based on a preliminary budget request that contained no salary component. A

revised budget was formulated for the next four years (1997/98 to 2000/01). This budget included 0.5 FTE salary in Narrogin District to carry out enclosure maintenance and monitoring but did not include other wages/salary support provided by the District or Science Division. Another 0.5 FTE was granted by the Director, Parks and Visitor Services to carry out interpretive work within Dryandra Woodland not related to *Return to Dryandra*. This allowed the employment of a CALM Graduate Recruit, Clare Anthony, to carry out both of these roles.

The *Return to Dryandra* program was not able to function without budgetary input from both Narrogin District and Science Division. When District costs increased due to the extra monitoring required for the bilby releases in 1999/2000, 2000/01 and 2001/02, the extra expenditure was borne by the District. For example, the District allocated \$18 300 in 2000/01 for salaries/wages and plant to the program, and \$20 500 (including \$5600 materials) in 2001/02.

Science Division budgetary input also increased. This was buffered to some degree by the availability of Coles Supermarkets 'Save the Bilby' funds through the national Bilby Recovery Team (\$11 500 in 1999/2000 and \$11 450 in 2000/01, \$0 in 2001/02), although this also funded bilby monitoring trips to the Pilbara. In 2001/02, no funds were allocated from *Western Shield* for the Science Division input to *Return to Dryandra*, but to compensate, \$15 000 was allocated from Science Division budgets.

The role of Kanyana Wildlife Rehabilitation Centre

Kanyana Wildlife Rehabilitation Centre is a privately owned (incorporated, not-for-profit) wildlife rescue facility at Gooseberry Hill, near Perth. It is owned and run by June and Lloyd Butcher with the help of over 90 volunteers. While the main emphasis is on saving injured and orphaned wildlife and releasing them back into the wild, captive breeding colonies of western barred bandicoots and bilbies have been established there and function as an integral part of the *Return to Dryandra* program.

The western barred bandicoot breeding colony was established in 1994 as part of the CALM Science Project 'Genetics and ecology of the Western Barred Bandicoot', run by Tony Friend. The purpose of the breeding colony was to carry out an inter-island hybridisation experiment, measuring the success of crossing bandicoots from Bernier

TABLE 1

Return to Dryandra allocated budget (enclosure costs). WS = *Western Shield*, ED = Executive Director

SOURCE	COST CENTRE	1996-97	1997-98	1998-99	1999-2000	2000-01	2001-02
WS	Narrogin		42 000	30 000	30 000	30 000	30 000
WS	Woodvale	40 000		11 000	11 000	11 000	
ED	Woodvale		15 000	15 000	15 000		
Science	Woodvale						15 000
Totals		40 000	57 000	56 000	56 000	41 000	45 000

and Dorre Islands. This experiment was finished by late 1997, and the colony, which was producing young reliably, provided an opportunity to breed animals for the Return to Dryandra project.

The bilby breeding colony at Kanyana was established specifically to provide animals for the Return to Dryandra program. The first bilby was an orphaned young female rescued at Jigalong and forwarded to Kanyana in a poor state of health. Other founder animals were acquired through the disbanding of a breeding colony at the CALM Broome office, from the wild at Shay Gap in the Pilbara, and from the captive breeding colony at the Arid Zone Research Institute in Alice Springs. All of the bilbies used in the *Western Shield* project originate from wild populations in Western Australia and the Northern Territory, as the national Bilby Recovery Team has decided that bilbies from the genetically distinct Queensland populations will be managed separately.

The two breeding colonies at Kanyana have been funded from a variety of sources, including *Return to Dryandra* funding. Since the inception of *Return to Dryandra*, the project has funded the Kanyana bilby and western barred bandicoot breeding colonies at the rate of \$2.00 per animal per week. This comprises about \$6000 per year, a substantial contribution towards food items that need to be bought (mealworms, minced meat, cheese etc) rather than donated by local supermarkets. Other running costs have been provided from Kanyana's income from appeals and donations, and the Coles Supermarkets 'Save the Bilby Fund' through CALM. Cages have been funded from a variety of sources, including CALM and a WWF Threatened Species Network Grant (western barred bandicoot cages), BBC TV Natural History Unit, Tony Bomford Productions, Magellan GPS, and the Environment Minister's Community Conservation Grants (bilby cages). Volunteers provide a great deal of time, as the bilby maintenance regime, including daily feeding, is labour-intensive. The bilbies are kept on a deep bed of coarse river sand and daily removal of faeces from the surface and weekly sifting of the entire substrate to remove faeces is required.

As of February 2003, the Kanyana breeding colonies had supplied 45 bilbies (including 6 bred elsewhere or wild-caught) and 18 western barred bandicoots to the Return to Dryandra enclosure.

The role of Pingelly Animal Refuge

The Pingelly Animal Refuge is owned and run by Howard and Bev Robinson, who rehabilitate injured and orphaned wildlife, specialising in kangaroos. Howard is a CALM employee in Narrogin District. He was part of the team building the enclosure and other infrastructure and is often involved with monitoring program within the enclosure. Howard and Bev often take pouch young, thrown during monitoring sessions, for hand-rearing to weaning and

eventual release back into the enclosure. Up to February 2003, Pingelly Animal Refuge had cared for six boodies, four mala, one banded hare-wallaby, one western barred bandicoot and five bilbies from the Dryandra breeding enclosure.

Collaboration with Murdoch Vet School bilby health monitoring project

After the release of bilbies from Kanyana into the Dryandra breeding enclosure, CALM was approached to collaborate in an ARC SPIRT grant application. The application involved Dr Kris Warren and Prof Ralph Swan (Murdoch School of Veterinary Sciences), Dr Tony Friend (CALM) and Mrs June Butcher (Kanyana), with industry funding from BHP and CALM. The project involved monitoring disease conditions and other health parameters in bilbies at Kanyana, in the Dryandra enclosure, after release in Dryandra, and in wild populations in the Pilbara. Bilbies were examined under anaesthetic on site and blood, urine and faecal samples were taken so that a range of health parameters (haematology, blood biochemistry, parasite loads etc) could be recorded.

The collaboration was extremely valuable, not only in providing very detailed knowledge of the progression of disease states in bilbies through the captive breeding and reintroduction process, but through having strong input from specialist wildlife veterinarians into all aspects of the *Return to Dryandra* program. Perhaps the most valuable contribution made by Kris and Ralph has been into the disease issues confronting western barred bandicoot conservation (see below). Kris and Ralph took the lead in investigating the occurrence and treatment in the bandicoots of chlamydiosis and the wart-like syndrome, respectively, through collaboration with other vets, pathologists and disease specialists in Australia and abroad. Their work has provided sufficient understanding of the disease issues to allow informed management decisions to be made regarding the captive colonies and translocations of the western barred bandicoot.

The Murdoch work has not revealed any such serious problems for the conservation of the bilby or the management of bilby translocations. One issue, however, was the occurrence in some Kanyana bilbies of *Cryptosporidium muris*, an enteric parasite that can cause death, and which was most likely transmitted to the bilbies by mice in the Kanyana enclosures. This infection was successfully treated with dimetridazole in the bilbies at Kanyana and they were released at Dryandra, where there has been no subsequent occurrence of the disease (Warren *et al.*, in press).

The collaboration has also assisted in the management of the enclosure, as the pelletised food provided for the animals was designed by Warren Potts of Glen Forrest Stockfeeds in consultation with Kris Warren and Tony Friend.

OVERVIEW OF THE PROGRAM AGAINST ORIGINAL TARGETS

Reintroduction of five species of locally extinct mammals to Dryandra, via a large enclosure to breed animals on site for release

The *Return to Dryandra* proposal was for a five-year project, during which time the breeding populations would be established in the 20 ha enclosure and release groups of each species produced. At that stage, it was not possible to predict accurately the numbers of animals that the breeding enclosure could produce. The original plan anticipated that production of young within the breeding enclosure would generate release groups of 20 animals of each species within 2-4 years. While the species were capable of producing young at that rate, survival of young within the large enclosures was not guaranteed.

Design, location and construction of the enclosure

The enclosure was designed to be fox and cat-proof. No breach of the fence was considered acceptable due to the potential damage that might occur to breeding populations before the predator was removed. The enclosure covers 20 hectares, and an internal fence divides it into two 10 ha areas. The 1.8 km fence around the enclosure is 2.4 m in height, with a 900 mm overhang towards the outside, with two electrified and one earth wire near the outer edge. The internal dividing fence is also 2.4 m high, but is not electrified and does not have an overhang. The fence is constructed of rabbit netting attached to posts 4 m apart. At the base of the fence the netting is spread as an apron extending horizontally to about 500 mm from the base, both inside and outside the enclosure. Bird netting is attached over the lower 500 mm of rabbit netting to prevent the escape of small bandicoots through the rabbit netting. This design was the result of discussions between CALM staff of Narrogin District and Science Division and June Butcher of Kanyana, with final plans being ratified by the Return to Dryandra Steering Committee. Plans were drawn up by a design draftsman who also recommended some changes that were implemented.

Access to the enclosures is via a gate at the north-eastern end and another gate in the dividing fence provides access between the 10-hectare sections. A shed, used for storage of feed and other materials and equipment required for maintenance and monitoring of the animals, is situated outside the enclosure, at the north-eastern corner. Feed hoppers set up in each section of the enclosure and water drippers fed from a rainwater tank at the shed provide supplementary food and water for the animals.

The construction of the fence was completed in February 1998. The cost in materials was \$55 000 and the labour component, provided by Narrogin District personnel, was approximately the same.

Once the fence was completed and electrified, brushtail possums (*Trichosurus vulpecula*) and woylies within the fence were trapped and removed. The internal perimeter sand track was brushed regularly and used to detect remaining medium-sized mammals. Reptiles were not removed, with the exception of a carpet python (*Morethia spilotes*).

Disease considerations

One of the concerns with the translocation of animals is that disease could be transmitted into the resident populations. Discussions were held in 1997 with wildlife veterinarians Dr Graham Phelps and Dr Andy Keefe regarding possible measures to be taken prior to any translocations into Dryandra. The consensus was that the screening of the individuals to be translocated prior to movement was impractical, given that the number of potential disease agents that might be screened for was unmanageable. Dr Phelps recommended that serum be collected, prior to any movement of fauna, from as many resident animals as possible, to allow before-and-after comparison if any disease agent were subsequently found. This strategy was not preventative, but would help in understanding the disease process and in avoiding further dissemination.

To this end, veterinarian Dr Ian Hutchinson spent two days at Dryandra with Narrogin District staff during a *Western Shield* monitoring in March 1998. Blood was collected from 24 woylies and 5 brushtail possums, and the serum is now in storage.

Establishment of breeding populations in the enclosure

Animals were sourced from a variety of locations including Bernier and Dorre Island, in Shark Bay, wild populations on the mainland and captive populations on the mainland. The transfer of animals from the island nature reserves to the breeding enclosure was approved by the Director, Nature Conservation and ratified by the National Parks and Nature Conservation Authority. Transfers of mala from the Tanami Desert enclosure and bilbies from the Great Sandy Desert were also approved by the Director, Nature Conservation.

Boodie

The boodies were captured and flown from Dorre Island. Twenty animals from Dorre Island were released into the northern enclosure on the 30 April and 1 May 1998.

Banded hare-wallaby (merrnine)

The banded hare-wallabies were also captured and flown from Dorre Island. A total of 18 animals were released into the southern enclosure over an 18-month period. Five animals were added in April/May 1998 and 13 animals were added in September 1999.

Mala (rufous hare-wallaby)

Nineteen mala were released into the breeding enclosure in March 1998. These animals came from a captive population located on the Lander River in the Tanami Desert, managed by the Northern Territory Parks and Wildlife Commission.

Western barred bandicoot (marl)

Western barred bandicoots were sourced from wild populations on Dorre Island and Bernier Island and captive populations at Kanyana Wildlife Rehabilitation Centre and Heirisson Prong, providing 27 founder animals. Seven Dorre Island animals were introduced into the breeding enclosure on 30 April 1998, together with 11 animals from the Kanyana Wildlife Rehabilitation Centre. Two Bernier Island animals from the *Project Eden* captive colony near Denham were added on 5 May 1998, followed by seven animals from Kanyana on 9 December 1998. Western barred bandicoots transferred from Kanyana were the result of crossing Dorre and Bernier stock.

Bilby (Dalgite)

A total of 45 bilbies were introduced to the breeding enclosure between November 1998 and April 2002. All were transferred from the captive-breeding program at Kanyana Wildlife Rehabilitation Centre, including two individuals originally taken from wild populations in the Pilbara.

Maintenance of the enclosure and animal husbandry procedures

Procedures for the routine maintenance and monitoring of the animals, including radio-tracking of a proportion of newly introduced animals, are described in detail in Anthony and Friend (1999). The day-to-day maintenance tasks are carried out by the Return to Dryandra field officer (Narrogin District) and involve replenishing the supplementary food supplies after recording consumption, and checking the integrity and operation of the fences and the water system. Monitoring the animal populations is carried out jointly by Science Division and Narrogin staff and involves trapping (using cage and Elliott traps) at three-month intervals in the northern and southern sections of the breeding enclosure. This procedure monitors boodies, western barred bandicoots, bilbies and banded hare-wallabies efficiently. Mala can only be reliably captured by luring them into soft traps baited with fresh lucerne at the end of summer, when green pick is virtually absent from the enclosure. Monitoring of animals radio-tagged for the initial period after release is primarily carried out by the Return to Dryandra field officer, supported by other trained Narrogin District staff.

Dynamics of enclosure populations

The populations in the breeding enclosure have now been monitored regularly for four years, providing information about population dynamics as summarised in Figures 1–5.

Bilby

Bilbies were first released, in November 1998, into the northern section of the enclosure only. In August 1999, three bilbies from Kanyana were released into the southern section to avoid breeding with closely related animals in the northern section. Subsequently both sections were used for bilby releases.

Survival of bilbies released into the enclosure has been good, with only three radio-collared bilbies found dead. This may underestimate mortality, because burrows are not dug up in the enclosure to retrieve transmitters because of their importance as refuges for bilbies.

The population grew slowly at first, then between December 1999 and March 2000 the total number of bilbies in the enclosure doubled. During the first release of bilbies into Dryandra Woodland, 18 bilbies were removed from the enclosure in April/May 2000, followed by another 8 in July and 10 more in October. There was a further drop in bilby numbers after this as some of the older females became infertile. However numbers increased again and have been quite stable since at 30–40, even though another 10 animals were released in October 2001. Throughout this time, small groups of 4–6 Kanyana-bred bilbies were released into the enclosure every few months.

Bilbies are doing well under the conditions provided in the breeding enclosure. They are protected from diurnal raptors by being underground during the day, and they are too big for most owls to tackle.

Western barred bandicoot

All bandicoots were radio-collared before release and 7 were found dead during the tracking period. Birds of prey were responsible for three mortalities, although two were of animals newly released from Kanyana during a period when eight captive bandicoots died from toxoplasmosis resulting from a batch of infected minced meat. If the newly-introduced bandicoots contracted the disease prior to release, its effects may have made them easier targets for birds. One bandicoot was eaten by a carpet python inside the enclosure.

All bandicoots were initially introduced into the northern section of the enclosure, but a male was recorded on the southern side of the dividing fence in March 2000. Subsequently other animals crossed the barrier, probably by squeezing under the gate, and a breeding population eventually became established there. This has probably been of benefit to the breeding program, because individuals of both sexes are aggressive towards each other and this probably limits the number of bandicoots that can coexist in a confined area.

Seven animals were removed in 2000, comprising five transferred to a soft release enclosure and two found with wart-like symptoms and taken to Kanyana. Twice numbers have dropped to low levels for no apparent reason. Predation by owls may be heavy at times and could account for dips in population numbers.

The western barred bandicoot population is low, but this may be due to social factors. New animals are recorded at most monitoring sessions, and pouch young are usually

present as well. Monitoring radio-collared animals in the enclosure will reveal causes of mortality and this may suggest changes in management. The graphs show decline in numbers over summer. It has been suggested that the water-drippers may be too high for bandicoots, and so they may be suffering from a lack of water, which they will need when eating the high protein omnivore pellets. This possibility was addressed during summer 2002/3 by providing water in bowls on the ground.

Boodie

The boodie population has grown steadily throughout the period. On two occasions groups of animals were removed. Eight boodies were transferred to Yookamurra in March 2000 in exchange for eight numbats (for the Stirling Range NP reintroduction). In November 2001 and January 2003 14 boodies were sent to Adelaide to be part of an investigation into the suitability of several potential surrogate species for cross-fostering Gilbert's potoroo. Each time the boodie population recovered quickly to its previous level and continued to increase. The proportion of females with pouch young fluctuates, but new animals are found at almost every monitoring session.

The boodie population appears strong enough to support a reintroduction soon and one is planned for spring 2003.

Mala

These animals are very flighty and can damage themselves in cage traps. They are also not strongly attracted by peanut butter-based bait. Consequently Bromilow 'soft' traps baited with fresh lucerne are used to trap mala. This is done only once a year, in February, when green pick is

scarce and the lucerne is very attractive to browsing mammals.

Mala numbers appear to be declining slowly. Young animals are regularly recorded, but they may not be reaching adulthood and the old founders are now disappearing. Four of the eleven collared animals died, three due to raptor predation. Mala nest in scrapes underneath bushes and appear to be vulnerable to predation by wedge-tailed eagles. The remains of one mala were found outside the enclosure, presumably dropped by a large raptor. More precise information on causes of mortality can be gained through radio-tracking individuals. Such studies, particularly on young animals, are required so that an informed decision may be made on the future of the rufous hare-wallaby colony.

Banded hare-wallaby

All 18 banded hare-wallabies were radio-collared before release, and seven died within the six-month life of the radio-collars. Raptors definitely accounted for three of these deaths, and one at least was a wedge-tailed eagle, as the carcase was found 500 metres outside the enclosure. Banded hare-wallabies rest above ground, sitting under bushes during the day. Damaged collars belonging to two other banded hare-wallabies were found, indicating predation, presumably by raptors.

Two deaths were due to injuries sustained during the capture on the islands, probably due to damage by landing nets.

Banded hare-wallabies are slow breeders and this, combined with their tendency to sit in semi-exposed situations during the day and hence sustain a high level of predation may make it very difficult to run a strong breeding colony.

TABLE 2

Summary of animals released into the enclosure, new animals recorded and current numbers, Dryandra breeding enclosure 1998–2002.

SPECIES	NUMBER RELEASED	RELEASE DATE	NEW ANIMALS RECORDED TO DECEMBER 2002	NUMBERS KNOWN TO BE ALIVE (KTBA) DECEMBER 2002
Bilby	45	1998–2001	85	43
Western barred bandicoot	27	1998	60	19
Boodie	20	1998	75	50
Mala	19	1998	44	14
Banded hare-wallaby	18	1998–99	6	0

TABLE 3

Fate of radio-collared animals released into the *Return to Dryandra* breeding enclosure.

SPECIES	NO. RADIO-TAGGED AT RELEASE	DEATHS OF RADIO-TAGGED ANIMALS	CAUSE OF DEATH
Bilby	25	3	U, UP
Western barred bandicoot	27	8	RA, U, UP, CP
Boodie	12	0	
Mala	13	4	RA, U
Banded hare-wallaby	18	7	RA, CA, U
U Unknown cause of death	UP Unidentified predator		RA Raptor
CA Capture injury	CP Carpet python		HA Handling death

Reintroductions into Dryandra Woodland

Prior to the introduction of animals into the enclosure, a schedule of releases was drawn up for planning purposes. This schedule was optimistically based on the highest projections of animal production (Table 4).

Timetable for introductions into Dryandra enclosure (*italics in Table 4*)

26 March 1998	20 mala from Tanami Desert
Early April 1998	10 western barred bandicoots from Kanyana
30 April 1998	30 boodies, 2 pairs of banded hare-wallabies and 10 western barred bandicoots from Dorre Island
September 1998	12 bilbies from Kanyana/Pilbara or Kimberley
March 1999	16 banded hare-wallabies from Dorre Island

Timetable for releases into Dryandra Woodland (**bold in Table 4**)

March 1999	20 western barred bandicoots
April 1999	30 boodies
September 1999	20 mala
March 2000	20 banded hare-wallabies
March 2002	20 bilbies

Figures 1–5 show that these breeding projections were not achieved in this time scale. In fact no species was sufficiently numerous for a translocation group to be removed until March 2000, when the bilby population in the enclosure surpassed 40 animals. This translocation commenced in April 2000 and is summarised below (Bilby reintroduction).

Bilby reintroduction

A Translocation Proposal for bilbies into Dryandra Woodland was prepared (Friend and Orell 2000b) and approved by the Director, Nature Conservation. A summary of events, reported more fully in Friend (2000a, b) follows.

First release

The first releases of bilbies from the enclosure into Dryandra proper were set up as an experiment to compare the average dispersal distance and survival of animals released in two different ways. One group would be placed in a one-hectare 'soft release' enclosure with artificial burrows, food and water for two weeks before release by opening gates. The other group would undergo 'hard release', being placed into artificial burrows with no enclosure, although with food and water provided. All bilbies would be fitted with radio-collars (see Discussion). In April 2000, eight bilbies were moved from the breeding enclosure into the soft-release enclosure. One was later removed for treatment, however, as its foot had become caught under its collar. On 3 May 2000, the release gates were opened. On the same day another group of nine bilbies was released into hard-release burrows in another part of Dryandra Woodland, followed by two more the next day.

Six of the bilbies moved quickly out of the main block of Dryandra into the surrounding farming area. Five were captured and brought back but a fox took one before he could be found. Many bilbies settled at first in old rabbit warrens around the perimeter of Dryandra, while some settled in burrows in farmland near the Woodland boundary. By June, most bilbies were surviving, so another release was carried out.

Second release

Eight bilbies were released into burrows previously dug by bilbies, four unfenced and four within the release enclosure but with the gates open. Food and water were provided at all sites. Less dispersal occurred this time, and bilbies tended to stay within the Woodland, settling near other bilbies.

From early July 2000 until late August, however, a total of 9 deaths were caused by foot entrapment in collars following weight loss. Remaining bilbies were trapped, their collars were tightened and supplementary food provided. It seems that at the time of the release in autumn, grasshoppers were abundant in the farmland.

TABLE 4

Schedule for translocations to and from Dryandra breeding enclosure (dated 4 February 1998).

SPECIES	1998	1999	2000	2001	2002	2003
Boodie	<i>Dryandra enclosure</i>	Dryandra 30	Lake Magenta 40, Dragon Rocks 40			
Bilby (dalgyte)	<i>Dryandra enclosure</i>	Lake Magenta 20	Fitzgerald River 20	Dragon Rocks 20	Dryandra 20	
Mala	<i>Dryandra enclosure</i>	Dryandra 20	Dragon Rocks 20	Lake Magenta 40		
Western barred bandicoot (marl)	<i>Dryandra enclosure</i>	Dryandra 20	Dragon Rocks 20	Cape Le Grand 20 Fitzgerald River 20	Cape Arid 20	
Banded hare-wallaby (Merrine)	<i>2 pair into Dryandra enclosure</i>	<i>Dryandra enclosure</i>	Dryandra 20	Dragon Rocks 20	Lake Magenta 40	Fitzgerald River 20

With onset of cold weather, food became scarce and weight loss occurred.

Nevertheless, four females were recorded with pouch young. The end result of the two releases was that four colonies were established (Figure 6), although two were of only two animals.

Third release

The strategy for a third release, designed to lessen the risk of foot entrapment, was to place high-powered collars on the bilbies for the first week to trace dispersal, after which the animals would be recaptured, collars removed and tail transmitters attached instead.

Ten bilbies were fitted with collars and tail tags. Five were released in burrows in the release enclosure with food and water provided, while five were released in burrows dug and recently used by other bilbies. Six of the bilbies dispersed long distances, two outside Dryandra, while four didn't move far and none stayed in the release enclosure.

The main cause of mortality in spring was predation by carpet pythons. Two residual colonies existed by spring 2001. Another release followed in October 2001, using powerful tail transmitters of a new design. However, the transmitters failed early and contact with the bilbies was lost. Some were located by trapping at burrows, so burrow searches were instigated, trapping when an active burrow was found. This method was very labour-intensive, with little result. It was found that brushtail possums were also using the burrows, so signs of activity at a bilby burrow do not always provide evidence of bilby presence.

Discussion

The bilby releases in 2000–2001 encountered several problems, in particular, foot entrapment in radio-collars after weight loss, predation by carpet pythons, and premature failure of tail transmitters.

Thorough research into transmitter attachment was carried out before tags were ordered for the Dryandra Woodland release. In their reintroduction manual for bilbies, Southgate *et al.* (1994) recommended two attachment types, a soft collar and a hard collar. Southgate had used collars in all his releases of captive-bred bilbies in the Northern Territory, without problems. Peter McRae used radio-collars extensively on bilbies in the south-western Queensland population during 1995–97 without problems. Both collar types recommended by Southgate *et al.* (1994) were used extensively in the *Return to Dryandra* breeding enclosure during releases of bilbies from Kanyana in 1998 and 1999 (Table 8), without any problem apart from chafing in a few animals that put on weight.

In 1997, during a release of four bilbies into coastal sand-dune habitat on Thistle Island, SA, three bilbies died or suffered injury through foot entrapment. The South Australian workers then began using tail-mounted transmitters, but these had limited range and fell off after 1–2 months (J. van Weenen, DoE & Heritage, Adelaide, pers. comm.). The decision to use collars initially at

Dryandra was made on the basis of experience and the greater practicality of the collar attachment. Collars were also purchased for the Peron bilby release in 2000, but tail tags were used for that release after the events at Dryandra were reported (C. Sims, CALM, pers. comm.).

Subsequent development of tail transmitters through the Return to Dryandra project has resulted in a model that will be used first in a release in 2003. These powerful, six-month, activity-sensing tail tags will optimise the tail mode of attachment and provide safety for the animals.

Predation by carpet pythons has been a feature of the late spring, as these reptiles attain maximum activity during and after the mating season. It is unlikely that there is any solution to this problem, apart from carrying out releases in areas where fewer carpet pythons are encountered.

The task of monitoring bilbies after the loss of their tail-transmitters will add challenge to the reintroduction of this species to unfenced areas. Indirect methods, like burrow searches followed up with hair tubes may be the only choice, rather the more traditional trapping and radio-tracking techniques.

Western barred bandicoot reintroduction

A Translocation Proposal for western barred bandicoots into Dryandra Woodland using stock from the Dryandra breeding enclosure, the Peron Captive Breeding Centre and Kanyana was prepared (Friend and Orell 2000a) and approved by the Director, Nature Conservation.

The translocation was planned as a comparison of soft versus hard release methods. Another release enclosure, approximately 1 ha in area, was built, in an area of sandplain heath providing the dense cover preferred by western barred bandicoots. The release enclosure was surrounded by a rabbit mesh fence, 1080 mm high with a 500 mm skirt under the soil, running each way from the fence to prevent animals from digging in or out.

Five bandicoots were captured from the breeding enclosure, fitted with radio-collars and released into the small enclosure. Omnivore pellets and water were provided. The bandicoots were to be left in the enclosure for three weeks to allow them to build nests and establish home ranges before the gates were opened. Another group were to be released at the same time at an unenclosed site.

Within a week of the transfer to the small enclosure, the wart-like syndrome was discovered in western barred bandicoots at Kanyana. The bandicoots were left in the small enclosure for several months, in case the disease situation could be resolved quickly. They were recaptured, inspected and found to be free of the symptoms. However, the release was cancelled when it became clear that there was not going to be a quick resolution of important questions about the disease that would affect the release of possibly infected animals into Dryandra.

The discovery of the disease in western barred bandicoots raised many serious questions about the Department's consideration of disease management both within the *Return to Dryandra* program and more broadly across *Western Shield* and threatened fauna recovery

programs. Discussions with the veterinary staff assisting the *Return to Dryandra* program revealed many unresolved questions, including:

- The identity of the disease causing the wart-like symptoms
- Our inability to screen animals before symptoms appear
- The vector(s) by which the disease is spread (including staff)
- Identifying if any other species may be at risk.

A workshop on disease in western barred bandicoot populations was subsequently held on 16 July 2002 (Friend 2002). It was resolved that there is an urgent need to develop clear protocols for dealing with existing and potential disease threats at a Department level, as the implications of poor and uncoordinated disease risk management are significant for *Western Shield* and threatened fauna recovery. The development of these protocols was proposed as one of the outcomes of the disease workshop.

Use of reintroductions to Dryandra to test alternative reintroduction methodologies

As Dryandra was to be the first translocation site in the south-west for these species, it was appropriate to compare different release methods at each release. This way, the most successful release methods could be used in subsequent releases.

The first bilby release was set up as a comparison of hard and soft release methods. The eight soft release animals were moved from the breeding enclosure, fitted with transmitters, and placed in a release enclosure provided with artificial burrows, food and water. These eight animals remained in the enclosure for three weeks, and were trapped after two weeks to examine their condition. One had its foot caught in its collar and it was moved back to the breeding enclosure. After three weeks the gates were opened and all animals left on the first night. Only one stayed close by. She was an adult female and the only female with pouch young. On the same evening, nine radio-collared bilbies were released into artificial burrows in another part of the Woodland. The following night two more were released into the same burrows.

The distances of dispersal after two nights of the two groups of bilbies did not differ from each other (hard release, $n=10$, distance= 4.3 ± 4.3 km, soft release $n=7$, distance= 6.3 ± 4.7 km).

As the western barred bandicoot release did not proceed, no result was obtained for a planned comparison of soft and hard releases.

Involvement of the local community, through a Friends of Dryandra group and volunteers from other places, through Landscape Expeditions and possibly Earthwatch

The use of volunteers in the Return to Dryandra project has not been as extensive as originally envisaged. This is partly due to the readiness of Narrogin District personnel to be involved, particularly in the monitoring within the breeding enclosure. There is no Friends of Dryandra group, partly due to a lack of staff time available to actively encourage and support the formation of such a group. Involvement of the community in the implementation of the project has been predominantly through the input of Kanyana Wildlife Rehabilitation Centre (intensive breeding programs for bilbies and western barred bandicoots, hand-rearing of thrown pouch young and rehabilitation of injured and sick animals) and the Pingelly Animal Refuge (hand-rearing of thrown pouch young and rehabilitation of injured and sick animals). Kanyana has 90 enrolled volunteers and at times this resource has been utilised at Dryandra when help is needed. Volunteers are recruited for enclosure monitoring when a full team is not available from Science Division or Narrogin District. All volunteers are registered through the CALM Community Involvement Program.

OVERVIEW OF THE CAPTIVE BREEDING PROGRAM

Establishment of the breeding program at Dryandra

The rationale behind the captive breeding program was to establish breeding groups of locally extinct species within a protected section of Dryandra, in order to produce groups of wild, acclimatised animals for reintroduction. This was done by fencing off a suitable area of Dryandra Woodland, providing food and water *ad hoc*. and monitoring the resulting populations.

This strategy has cost advantages over intensive captive breeding in small cages, as well as the more important benefit of producing animals that are more site-adapted and wild-adapted. However, the two methods cannot be compared on equal terms. Despite the provision of unlimited food, space is limited and this has had an undeniable effect on population growth, particularly amongst boodies. This method has not been used widely before, so there are few data to allow reasonable predictions about population dynamics. However, there are some data from Dryandra (see below) and the experience at Heirisson Prong, where the enclosure-breeding method was used extensively for the first time in Western Australia (Short *et al.* 1994). For instance,

the western barred bandicoot breeding colony at Heirisson Prong did not grow beyond 20 animals, but over 120 animals were produced over 3 years for release into the surrounding protected area. This was achieved by releasing animals in a steady stream rather than in large groups (J. Richards and J. Short, CSIRO, Perth, pers. comm.) Groups of boodies were removed from the Return to Dryandra enclosure on two occasions and numbers returned to pre-removal levels within 3–6 months (Figure 3).

However, there must be some examination of the appropriateness of using a large enclosure, such as at Dryandra, for captive breeding. There would appear to be several questions about the reasons for apparent lack of breeding success of several of the species, which can only be resolved by intensive monitoring of the fate of individual animals. In practice, however, the size of the enclosure makes this difficult or impossible. Similar problems were encountered with much smaller (0.5 ha) captive breeding enclosures for the eastern barred bandicoot at Gellibrand Hill in Victoria (Backhouse *et al.* 1994). Management of the apparent impact of raptor and owl predation on population numbers is also likely to be difficult in a large open enclosure, whereas netting may be viable for smaller enclosures.

Founder numbers, breeding success and death rates within the colonies, and costs per animal produced

These parameters have been developed for comparisons between intensive breeding systems, in which births and deaths are always recorded. Although the monitoring procedures used in the Dryandra breeding enclosures allow individuals to be traced, deaths are rarely recorded and breeding success can only be measured in terms of the numbers of pouch young and new independent individuals recorded.

It should also be remembered that due to space limitations, the maximum potential output of the breeding enclosure can only be realised if animals are being removed constantly. As to date only bilbies, and to a lesser extent, boodies, have been removed, the potential output of the other species cannot be assessed. This is most likely an issue with western barred bandicoots, which are aggressive towards each other and display self-limitation to a

significant degree (J. Richards and J. Short, CSIRO, Perth, pers. comm.). It is unlikely to be an issue with banded hare-wallabies, which have been removed by birds of prey but have not been able to breed quickly enough to replace the losses.

Degree of coordination between Dryandra captive colonies and those at Shark Bay and Kanyana

The Dryandra breeding enclosure populations were established from animals from different sources. The degree of coordination in the management of the various breeding colonies has differed depending on the species concerned.

The Kanyana breeding colonies of bilbies and western barred bandicoots were established with financial support from the *Return to Dryandra* project (amongst other sources) specifically to provide animals for release in the Return to Dryandra enclosure.

Exchanges of bilbies have occurred between Kanyana, Peron Captive Breeding Centre, and a number of zoos (Monarto, Alice Springs Desert Park and the Territory Wildlife Park) as well as enclosed populations, such as Yookamurra Sanctuary in South Australia. Perth Zoo does not hold breeding colonies of any of the Return to Dryandra species.

Bilby

The Kanyana and Dryandra breeding enclosure bilby colonies have been managed in very close coordination. From the outset, Dryandra acted as a half-way house for the bilbies produced at Kanyana. Kanyana animals were released into the enclosure, where they bred. The bilby is the only species released into Dryandra so far, and almost all of the release animals have been enclosure-bred. Exchanges of animals with the PCBC breeding colony have occurred, to promote gene flow between the breeding populations.

Coordination between staff, *Return to Dryandra* and *Project Eden*, at Peron has been fairly limited. However there is the potential for much greater coordination and communication to occur, particularly amongst field staff. Better coordination may mean that operational problems are overcome more rapidly and ideas shared.

TABLE 5

Summary of production and costs, *Return to Dryandra* breeding enclosure, 1998–2002.

SPECIES	TOTAL INTRODUCED	NUMBER REMOVED	CURRENT RESIDENTS	NUMBER PRODUCED	TOTAL COST*	COST PER ANIMAL
Bilby	35	46	43	54		
Western barred bandicoot	27	7	19	-1		
Boodie	20	22	50	52		
Mala	19	4	14	-1		
Banded hare-wallaby	18	1	1	-16		
Totals	119	81	126	88	\$395 000	\$4489

*Total cost is calculated as the initial cost of the infrastructure (\$100 000), plus the total allocated budget 1997/98 to 2001/02 (Table 1).

TABLE 6

Summary of coordination between captive breeding programs.

DEGREE OF COORDINATION BETWEEN RETURN TO DRYANDRA BREEDING ENCLOSURE AND BREEDING COLONIES AT:		
	Kanyana	Peron Captive Breeding Centre (PCBC), Shark Bay
Bilby	Close coordination, as Kanyana breeds bilbies to stock the <i>Return to Dryandra</i> Enclosure	Exchange of individuals between Kanyana and Return to Dryandra breeding enclosure to enlarge gene pool and even up sex ratios
Western barred bandicoot	Close coordination, as Kanyana breeds western barred bandicoots to stock the <i>Return to Dryandra</i> Enclosure	Prior to discovery of diseases, exchange of individuals between PCBC and Kanyana to enlarge gene pool and even up sex ratios. Several animals introduced to Kanyana from Heirisson Prong. TP includes release of PCBC western barred bandicoots at Dryandra.
Boodie	No breeding colony at Kanyana	No breeding colony at PCBC
Mala	No breeding colony at Kanyana	No exchanges carried out
Banded hare-wallaby	No breeding colony at Kanyana	Proposed restocking from PCBC

Western barred bandicoot

Western barred bandicoots have been bred at Kanyana since the commencement of an experiment in collaboration with CALM Research Scientist Dr Tony Friend in 1994 to examine the potential for breeding between Bernier and Dorre Island animals. Due to Kanyana's success in breeding western barred bandicoots, the output of the colony was then directed towards providing animals for release at Dryandra.

including within the breeding enclosure. Sandy loams occur in Dryandra from the upper valley slopes to the valley floors.

Disadvantages:

- The presence of a rich and varied fauna in Dryandra may result in higher predation by native fauna than may occur in more depauperate areas.
- Potential risks of introducing diseases into wild populations of other fauna, including threatened species such as the numbat and woylie.

CRITICAL ANALYSIS OF THE VIABILITY OF THE DRYANDRA SITE FOR THE PROJECT

1. Viability of the Dryandra site for the breeding enclosure

Advantages:

- Area of natural habitat in good condition available for enclosure.
- Area under intensive fox control provides an extra defence against fox incursion into the breeding enclosure.
- Proximity to Narrogin and other district activities in Dryandra facilitate frequent servicing of the enclosure. This has proved important.
- Developing nature-based tourism in Dryandra, which will generate additional support for feral predator control and for the aims and objectives of the program.
- Suitable habitat for releases is available within Dryandra. This is especially true for bilbies and boodies, both of which require the open woodland and loamy soils that are widespread within Dryandra,

2. Viability of Dryandra as a fauna reconstruction site

Advantages:

- Proximity to Narrogin and other District activities in Dryandra facilitates frequent monitoring visits for radio-tracking released animals.
- Development of nature-based tourism in Dryandra, which will generate additional community support for feral predator control and for the aims and objectives of the program.
- Suitable habitat for releases is available within Dryandra. This is especially true for bilbies and boodies, both of which require the open woodland and loamy soils that are widespread within Dryandra. Sandy loams occur in Dryandra from the upper valley slopes to the valley floors.

Disadvantages

- Management of Dryandra is complex, due to its convoluted shape and the multiplicity of land uses within and surrounding the Woodland.

MANAGEMENT OF THE PROJECT IN RELATION TO INVOLVEMENT OF STAFF FROM DIFFERENT DEPARTMENTAL DIVISIONS

The *Return to Dryandra* project was conceived as a joint project between Narrogin District (Regional Services Division) staff and Science (previously Science and Information) Division staff based at Woodvale. The emergence of the viewing enclosure as an adjunct project invited the participation, at an early stage, of Parks and Visitor Services (previously Parks, Planning, Recreation and Tourism) Division staff. Nature Conservation Division staff were also involved in the Return to Dryandra Steering Committee. The everyday running of the breeding enclosure project is the responsibility of Narrogin District staff. The overview of the animal management and monitoring is the responsibility of Science Division staff. The project thus requires project staff to communicate outside their normal lines of responsibility and between geographically separated offices. This is not unusual within CALM, and Science Division staff frequently work closely with Regional Services staff. The best communication happens in the field, on the job, and the monitoring sessions are a great forum for communication between the operators. There is a need also, however, for discussion at a high level within the project and for communication between managers to occur. The Return to Dryandra Steering Committee was a very useful forum in the early stages and its existence expedited the development of the project. The reasons for the hiatus in its operation are not clear. The revival of the committee in 2001 was a very positive move towards restoring the momentum of the project, which had stalled somewhat over the difficulties encountered, particularly the western barred bandicoot disease issues and the high mortality of released bilbies.

The subsequent incorporation of the Return to Dryandra Steering Committee into the WSSMC was primarily aimed at providing a better forum for coordinating the role of the breeding facility in meeting the objectives of *Western Shield* and associated fauna recovery programs. The management of the breeding facility remains with the District Manager, Narrogin, and an informal committee has been established to support the project.

There still appears to be a need to clarify the role of *Return to Dryandra* beyond reintroductions into Dryandra Woodland. The WSSMC has an expectation that the breeding facilities will continue to be managed to provide animals for translocations to other sites as well as Dryandra. However the 'Return to Dryandra Strategic Plan 2002-2005' is not clear on the role of the project beyond research into the capacity of the breeding facility to produce more banded hare-wallabies, mala and western barred bandicoots and translocations of bilbies and boodies into Dryandra Woodland.

The problems encountered in the management of the *Return to Dryandra* program, particularly its place within the *Western Shield* program, are symptomatic of the overlapping and unclear roles of the various programs, branches and divisions within the Department that are involved in fauna management and threatened species recovery.

OVERVIEW OF FUTURE PLANS (STRATEGIC PLAN)

The *Return to Dryandra* project has not met the rather ambitious goals set at the outset, due to unpredicted factors reducing population growth within the enclosure, particularly bird predation, but possibly also intraspecific aggression. In the next three years it is proposed to build on the success of the bilby and boodie breeding colonies and produce sufficient animals for further translocations in Dryandra.

The objectives for the breeding enclosure for the next three years, as stated in the draft strategic plan, are to:

- Provide sufficient numbers in 2002/03 and 2003/04 to translocate and establish wild populations of bilbies and boodies whilst maintaining sufficient numbers within the breeding enclosure as a breeding colony.
- Re-establish and undertake a breeding research program to provide sufficient numbers of banded hare-wallabies, mala and western barred bandicoots within the breeding enclosure for release into the wild in 2004/05 and 2005/06.

Releases into Dryandra Woodland are planned for bilbies in autumn 2003 and boodies in spring 2003, in order to capitalise on the high numbers present in the enclosure.

Mala and western barred bandicoots in the breeding enclosure will be fitted with radio-collars and monitored closely to determine causes of mortality. An investigation will be carried out into the possibility that western barred bandicoots have been suffering from a lack of water in summer because the drippers are too high for them to reach.

Continuation of the banded hare-wallaby breeding program will require the introduction of new stock. Animals could either be brought from the islands or transferred from the PCBC. Additional shelter will be provided in the enclosure and close monitoring will be carried out to determine whether the new shelters are effective in reducing predation.

However, in order to carry out reintroductions into Dryandra and continue the research into reintroduction techniques that has already benefited other programs such as *Project Eden*, greater personnel input is required. Similar

work is being undertaken as in *Project Eden*, but with only 0.5 FTE dedicated to captive breeding and monitoring released animals, compared with at least 2.0 FTE at Denham. The provision of 0.5 FTE is sufficient for the maintenance of the breeding enclosure and provides valuable input to monitoring both in the enclosure and during releases. While it has been possible to redirect staff resources from Narrogin District and Science Division for specific short-term projects, more consistent staff input is required. Increase of the Narrogin staff component to 1.0 FTE would provide continuity, consistency, thoroughness and momentum and will allow the kind of comprehensive investigation that the project needs.

Consideration needs to be given as to whether the facilities at Dryandra are appropriate for the captive breeding of all five species involved to date. Whilst the bilby and boodie appear to be relatively successful, there are some questions about the viability of the western barred bandicoot and mala, and serious concerns about the banded hare-wallaby.

ACKNOWLEDGMENTS

We would like to thank all those who have contributed to the *Return to Dryandra* Project. Many volunteers have given their time, not only in the captive breeding and wildlife rehabilitation centres, but also in the field, putting in long hours in the sun, wind or rain. Narrogin District staff, in particular, Brian Macmahon, Howard Robinson and Martin Clarke, have done a fantastic job in building and maintenance of the enclosure and care of the animals and participating enthusiastically in the monitoring. Clare Anthony has worked tirelessly in maintaining the enclosure and feeding the animals, as well as doing the lion's share of the radio-tracking after releases. Neil Thomas of Science Division has been the backbone of the enclosure monitoring and has faithfully maintained the databases since the commencement of the project. June and Lloyd Butcher have given great support to the project by running the bilby and western barred bandicoot captive colonies. Kristen Warren and Ralph Swan have made a major contribution through the health monitoring project. We would also like to acknowledge gratefully the support of Syd Shea, Gordon Wyre and Keiran McNamara. Comments on this review were received from Clare Anthony, Howard Robinson and Kate McGregor. Constructive comments by the two external referees were very helpful.

REFERENCES

- Anthony C, Friend T (1999) 'Return to Dryandra. Phase I: Breeding Enclosure. Operations/Procedures Manual.' Unpublished report, Department of Conservation and Land Management, Western Australia.
- Backhouse GN, Clark TW, Reading RP (1994) The Australian Eastern Barred Bandicoot - Evaluation and Reorganization. In *Endangered Species Recovery: Finding the Lessons, Improving the Process* (eds. TW Clark, RP Reading, AL Clarke), pp. 251-271. Island Press, Washington.
- Burbidge AA, Start AN, Morris KDM, Armstrong R (1996) 'Western Shield - Recovering our native fauna.' Unpublished report, Department of Conservation and Land Management, Western Australia.
- Durell, G. and Friend T (2002) 'Return to Dryandra: Strategic Plan 2002-2005.' Unpublished report, Department of Conservation and Land Management, Western Australia.
- Eldridge M, Spencer PBS (in press). Insular populations of rare species: are offshore islands arks or tombs? *Conservation Genetics*
- Friend JA (2000a) 'Reintroduction of the bilby to Dryandra.' Progress report 28 August 2000. Unpublished report, Department of Conservation and Management, Kensington.
- Friend JA (2000b) 'Dryandra Bilby reintroduction - Update: 22 September 2000.' Unpublished report, Department of Conservation and Land Management, Western Australia.
- Friend JA (2002) 'Workshop on disease in western barred bandicoot populations, held at WA Wildlife Research Centre, Tuesday July 16th, 2002.' Unpublished report, Department of Conservation and Land Management, Western Australia.
- Friend JA, Bowra T (1996) 'Return to Dryandra - a Western Shield Project.' Unpublished report, Department of Conservation and Land Management, Western Australia.
- Friend JA and Orell P (2000a) 'Re-introduction of bilby (*Macrotis lagotis*) to Dryandra Woodland from Return to Dryandra breeding enclosures and Kanyana captive breeding colony.' Unpublished report, Department of Conservation and Land Management, Western Australia.
- Friend JA and Orell P (2000b) 'Reintroduction of western barred bandicoot (*Perameles bougainville bougainville*) to Dryandra Woodland from captive breeding and field breeding centres in Western Australia.' Unpublished report, Department of Conservation and Land Management, Western Australia.
- Langford D (1999) *The Mala* (*Lagorchestes hirsutus*) *Recovery Plan*. Environment Australia, Canberra.
- Maxwell S, Burbidge AA, Morris KD (1996) *The 1996 Action Plan for Australian Marsupials and Monotremes*. Environment Australia, Canberra.
- Paltridge R (2000) Draft Recovery Plan for the Greater Bilby *Macrotis lagotis*. Unpublished report, Parks and Wildlife Commission of the Northern Territory.

Short J, Turner B, Parker S, Twiss J (1994) Reintroduction of endangered mammals to mainland Shark Bay: a progress report. In *Reintroduction biology of Australian and New Zealand fauna*. (ed. M Serena), pp. 183-88. Surrey Beatty & Sons, Chipping Norton.

Southgate R, Bellchambers K, Romanow K, Whitfield S (1994) Reintroduction of the Greater Bilby. Volume 1. A field guide. Project 95. Final Report to World Wide Fund for Nature (Australia). Conservation Commission of the Northern Territory.

Southgate R, (1995) 'Recovery Plan for the Greater Bilby *Macrotis lagotis*.' Unpublished report, Parks and Wildlife Commission of the Northern Territory.

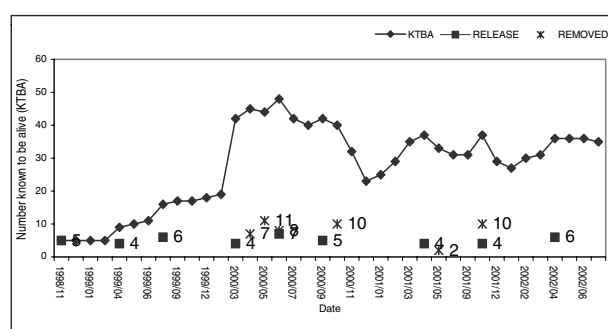
Warren KS, Swan RA, Morgan-Ryan UM, Friend JA, Elliot A (in press). *Cryptosporidium muris* infection in bilbies (*Macrotis lagotis*). *Journal of Zoo and Wildlife Medicine*.

APPENDIX

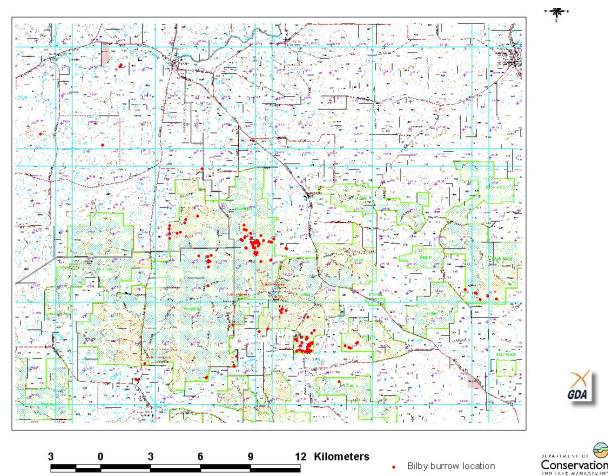
Graphic and tabular data not contained in the body of the paper that, nevertheless, provides useful benchmark information. The graphs show population sizes for each of the five species of marsupial introduced into the *Return to Dryandra* breeding enclosure. Population size is expressed as numbers Known To Be Alive (KTBA). If an animal is caught before and after a trapping session at which it is not caught, it is added to the total for the session at which it was not caught. Totals for the most recent trapping session are not shown, although animals caught in that session are taken into account in the last total shown.

The results of monitoring radio-collared animals after initial release into the breeding enclosure are also shown.

Bilby (*Dalgyte*)



Appendix figure 1b: Bilby burrow locations – Dryandra.



Appendix figure 1a: Bilby numbers known to be alive within the breeding enclosure

APPENDIX TABLE 1a: Bilby releases into enclosure.

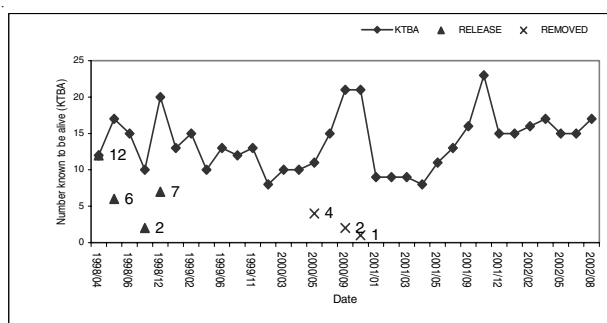
DATE	NUMBER	SOURCE
20/11/1998	5	Kanyana, AZRI, Shay Gap
27/4/1999	4	Kanyana, Rudall River
9/8/2000	6	Kanyana
17/3/2000	4	Kanyana
8/6/2000	7	Kanyana
29/9/2000	5	Kanyana
19/4/2001	4	Kanyana
2/10/2001	4	Kanyana
29/4/2002	6	Kanyana
Total	45	
New animals recorded to 13/12/2002	85	

APPENDIX TABLE 1b: Bilby removals from enclosure.

DATE	NUMBER	DESTINATION
12-13 April 2000	7	Releases outside enclosure
3-4 May 2000	11	Releases outside enclosure
28-29 June 2000	8	Releases outside enclosure
25-26 October 2000	10	Releases outside enclosure
23-24 October 2001	10	Releases outside enclosure
23 May 2001	2	Returned to Kanyana
Total removals	46	

APPENDIX TABLE 1c: Deaths of radio-collared bilbies in the breeding enclosure (25 animals collared).

DATE FOUND	ID #	CAUSE
31/07/1999	Wilga	Unknown
10/11/1999	Meriki	Unknown
26/11/1999	Niribi	Unidentified predator
Total	3	

Western barred bandicoot (Marl)

Appendix figure 2: Western barred bandicoot numbers known to be alive within the breeding enclosure.

APPENDIX TABLE 2a: Western barred bandicoot releases into enclosure:

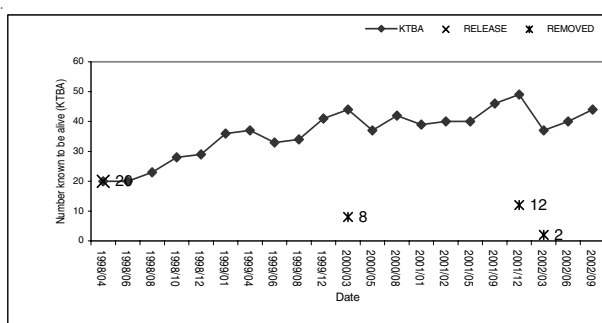
DATE	NUMBER	SOURCE
30/4/1998	11	Kanyana
30/4/1998	1	Dorre Island
1/5/1998	6	Dorre Island
5/05/1998	2	Peron CBC
9/12/1998	7	Kanyana
Total	27	
New animals recorded to 13/12/2002	60	

APPENDIX TABLE 2b: Western barred bandicoot removals from enclosure:

DATE	NUMBER	DESTINATION
4-5/9/2000	5	to soft release enclosure
27/9/2000 & 25/10/2000	2	to Kanyana with warts

APPENDIX TABLE 2c: Deaths of radio-collared western barred bandicoots (27 animals collared):

DATE FOUND	ID #	CAUSE
9/6/1998	0013	Died during handling
11/6/1998	0008	Found dead in nest
11/6/1998	K040	Found remains on ground
14/12/1998	K017	Raptor/toxo?
14/12/1998	K053	Raptor/toxo?
30/12/1998	K038	Carpet python
18/1/1999	K049	Raptor?
Total	7	

Boodie (Burrowing Bettong)

Appendix figure 3: Boodie numbers known to be alive within the breeding enclosure.

APPENDIX TABLE 3a: Boodie releases into enclosure.

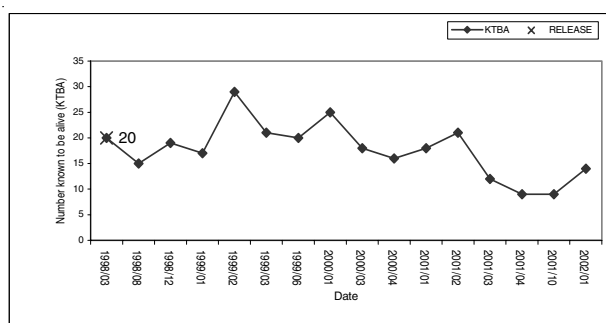
DATE	NUMBER	SOURCE
30/4/1998	20	Dorre Island
New animals recorded to 13/12/2002	75	

APPENDIX TABLE 3b: Boodie removals from enclosure.

DATE	NUMBER	DESTINATION
13/3/2000	8	sent to South Australia

APPENDIX TABLE 3c: Boodie deaths (no deaths amongst 13 radio-collared animals):

DATE FOUND	ID #	CAUSE
13/1/1999	?	Died in trap
Total	1	

Mala (Rufous hare-wallaby)

Appendix figure 4: Mala numbers known to be alive within the breeding enclosure.

APPENDIX TABLE 4a: Mala releases into enclosure:

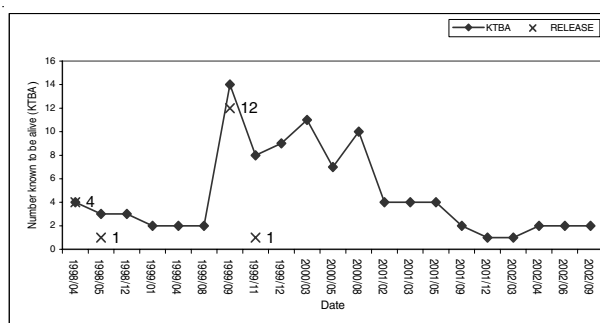
DATE	NUMBER	SOURCE
26/3/1998	19	Tanami Mala
Paddock		
New animals recorded to 13/11/2002	44	

APPENDIX TABLE 4b: Mala removals from enclosure.

DATE	NUMBER	DESTINATION
Various	4	to carers

APPENDIX TABLE 4c: Deaths of radio-collared mala (11 collared at release):

DATE FOUND	ID	CAUSE
16/7/1998	N/A	Raptor predation
16/7/1998	N/A	Raptor predation
24/2/1999	N/A	Raptor predation
20/2/2000	N/A	Found mummified
Total	4	

Banded hare-wallaby (Merrnine)

Appendix figure 5: Banded hare-wallaby numbers known to be alive within the breeding enclosure.

APPENDIX TABLE 5a: Banded hare-wallaby releases into enclosure:

DATE	NUMBER	SOURCE
30/4/1998	4	Dorre Island
1/5/1998	1	Dorre Island
8/9/1999	10	Dorre Island
9/9/1999	3	Dorre Island
Total	18	
New animals recorded to 26/6/2002	6	

APPENDIX TABLE 5b: Deaths of radio-collared banded hare-wallaby (18 collared at release):

DATE FOUND	ID #	CAUSE
2/5/1998	M13	Capture injury
9/11/1998	F22	Raptor
14/9/1999	M17	Capture injury
16/10/1999	M14	Unknown predator (raptor?)
16/10/1999	M10	Unknown predator (raptor?)
11/2/2000	M15	Raptor
?	M11	Raptor
Total	7	

Montebello Renewal: Western Shield review—February 2003

ANDREW A BURBIDGE¹

¹WA Threatened Species and Communities Unit, Department of Conservation and Land Management, PO Box 51, Wanneroo, WA 6946, Australia. Current address: Research Fellow, Science Division, Department of Conservation and Land Management, WA Wildlife Research Centre, PO Box 51, Wanneroo, WA 6946, Australia. andrewb@calm.wa.gov.au

SUMMARY

Objectives

1. To rid the Montebello Islands Conservation Park of exotic black rats and feral cats.
2. To reintroduce locally extinct animals and, where justified, introduce mammals threatened on the mainland by predation by exotic carnivores.

Achievements (against targets)

1. Feral cats eradicated. Black rats possibly eradicated (requires at least another two years of monitoring).
2. Hermite Island targeted for reintroductions; eradication of black rats not yet confirmed. Reintroductions delayed.
3. Mala introduced successfully to Trimouille Island and djoongari introduced successfully to North West Island. Other introductions possible, eg, of critically endangered antina (Central rock-rat) to Alpha Island if black rat eradication confirmed.

Difficulties

1. Black rat eradication not achieved in planned timeframe or by using initial methodology (bait stations laid and serviced on foot). New eradication method (aerial baiting from helicopter-borne spreader bucket) trialed successfully.
2. Introductions were commenced before rat eradication achieved archipelago-wide (this was not known at the time). No evidence that rats have spread to either island used for introductions.

Potential economies

1. Aerial baiting is more cost-effective and much quicker than hand baiting with bait stations. This technology can potentially be used for introduced rats and mice on any island in WA where there are no non-target populations that may be affected by the bait type.

Potential improvements

1. No further improvements are considered necessary at this time.

Future Plans

1. Continue to monitor for rats; the islands should not be considered rat-free until rats have not been detected for at least three years.
2. Continue to monitor the mala and djoongari populations. In 2003, mala will have been established on Trimouille Island for five years and a review of the subspecies IUCN Red List status should be undertaken. Downgrading of the mala from 'Extinct in the Wild' to 'Endangered' may be warranted.
3. Once the Montebellos are considered rat- and cat-free, reintroduce spectacled hare-wallabies, golden bandicoots, rakali (water-rat) and spinifexbirds from Barrow Island and also establish the Barrow Island black-and-white fairy-wren.

INTRODUCTION

This review addresses the following terms of reference:

- Provide an overview of the project against original targets.
- Discuss feral animal eradication methods and results, with justification for any new methods introduced.
- Discuss translocations, and why they took place before eradication of introduced animals had been achieved within the whole archipelago.
- Present an overview of future plans.

The Montebello Islands are situated off the Pilbara coast, to the north of Barrow Island (Fig. 1). They comprise about 180 islands, islets and rocks with a total area of more than 2100 ha. The largest islands are Hermite (1020 ha), Trimouille (520 ha), North West (135 ha), Alpha (120 ha) and Bluebell (65 ha).

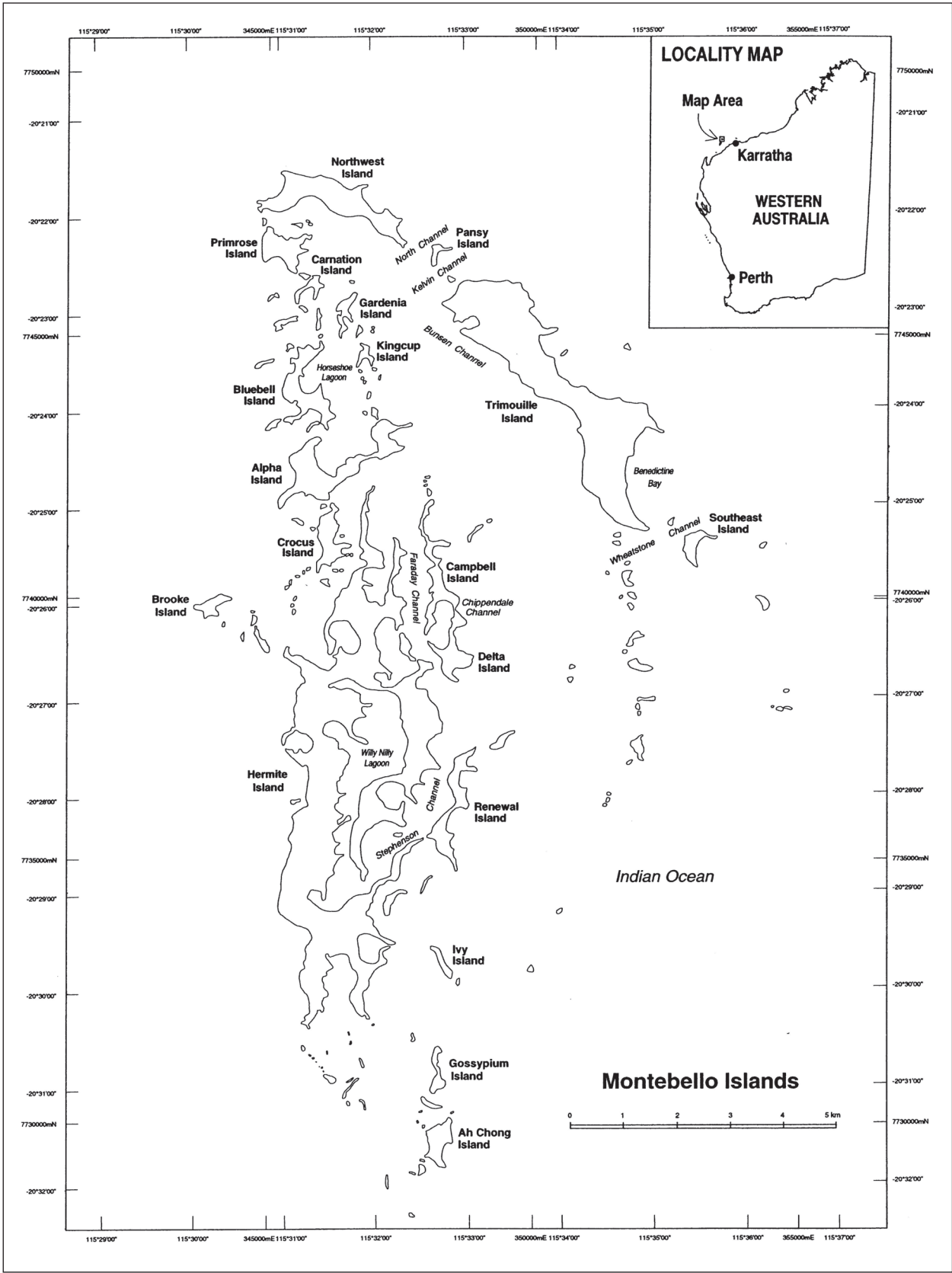


Figure 1. Montebello Islands.

In 1952 and 1956, three nuclear weapons tests were conducted in the Montebellos; one in a ship adjacent to Trimouille Island, one on a tower at the northern end of Trimouille and one on a tower on Alpha Island. In 1952, the islands and surrounding seas were placed under Commonwealth control and declared a prohibited area. In 1992, the Montebellos reverted to State control and were declared a Conservation Park. As part of an agreement between the Commonwealth and the State, Western Australia agreed to eradicate feral mammals from the archipelago and, to the extent possible, restore the native fauna. Some funds were provided by the Commonwealth to support this project and to contribute to infrastructure on the islands. At a later date, it was decided to use selected islands for 'marooning' species threatened with extinction by exotic predators (particularly the feral cat) on the mainland.

Montebello Renewal is a *Western Shield* project that aims to rid the Montebello Islands Conservation Park of exotic mammals and reintroduce and introduce native mammal species. *Montebello Renewal* has been a joint project between the Department of Conservation and Land Management's (CALM) Threatened Species and Communities Unit and Pilbara Region.

Prior to 1992, knowledge of the islands' fauna had revealed that two mammal species (spectacled hare-wallaby *Lagorchestes conspicillatus* and golden bandicoot *Isodon auratus*) and two bird species (black-and-white fairy-wren *Malurus leucopterus edouardi* and spinifexbird *Eremiornis carteri*) were locally extinct and that black rats *Rattus rattus* and feral cats *Felis catus* were established (Burbidge 1971).

Current human usage of the islands is restricted to short visits by tourists. Several charter boats bring visitors to the islands, mainly for fishing. Montebello Islands Safaris maintains a houseboat in a bay at the southern end of Hermite Island. Morgan and Co own pearling leases covering many bays, the venture being known as Faraday Pearls, named after the channel in which their houseboats and main facilities are moored. This company continues to maintain equipment dumps on the conservation park, eg, on Hermite and Alpha Islands.

1995 WESTERN SHIELD PROPOSAL

The eradication of black rats and feral cats was an aim of the 1995 *Western Shield* proposal. The proposal stated that feral cats would be eradicated by 1996, a date that proved too ambitious. It seemed prudent to eradicate black rats first, as they probably provided a major food source for the cats, making bait uptake less likely.

WESTERN SHIELD STRATEGIC PLAN JULY 1999 TO JUNE 2004

Montebello Renewal is not mentioned in this Plan.

DESCRIPTION OF MONTEBELLO RENEWAL

The project can be best described under six headings:

1. Biogeographic survey of the islands' vertebrate fauna.
2. Rat eradication using rodenticide laid by hand in bait stations.
3. Rat eradication using aerial spreading of rodenticide.
4. Cat eradication using aerial baiting followed by trapping.
5. Introduction of threatened mammals.
6. Monitoring.

1. Biogeographic survey of the islands' vertebrate fauna

Surveys commenced in May-June 1994, after the construction of a base on Hermite Island (now known as Hurricane Hill Hut). The results have been published (Burbidge *et al.* 2000, Burbidge & Fuller 1999). This work confirmed that black rats were distributed on almost every island in the archipelago and that feral cats were restricted to Hermite Island (they had been recorded on Trimouille and Bluebell Islands in the past). It also revealed an additional mammal extinction, of rakali (or water-rat) *Hydromys chrysogaster*. Planning for the eradication of black rats commenced during the surveys.

2. Rat eradication using rodenticide in bait stations

The Montebello Islands have a tropical, arid climate with unpredictable, highly variable rainfall; most rain coming from summer tropical cyclones and thunderstorms and autumn and early winter middle level disturbances (Burbidge *et al.* 2000).

Knowledge of black rat abundance at different times of the year and their annual breeding cycle would have been helpful in designing the eradication project. There was no survey data from the Montebellos that would enable estimates of rat numbers at different times of the year. Breeding data were also not available, but it was thought that breeding was more likely to be dependent on major rainfall events rather than being seasonal. It was considered more important and more feasible to carry out work during the cooler winter and early spring months, when cyclones were unlikely and temperatures and humidity would allow staff and volunteers to work without major discomfort, than to try to time baiting to population abundance or breeding cycles.

In August 1995 a trial eradication was conducted on Renewal Island (58 ha). The trial used bait stations (1 L plastic bottles with two 43 mm holes cut in the sides) with Talon G pellets as the rodenticide. Talon G is a pelletised, bran-based bait containing brodifacoum at 0.005% (0.05 g/kg), manufactured in and registered for

use in Australia. It includes the taste inhibitor Bitrex, designed to prevent ingestion by humans, especially children. Bait stations were pinned to sandy soils with two hooked wires or glued to rocks using Selleys 'All Clear'. The bait stations were initially filled with approximately 100 g of bait, and were rebaited/replaced as necessary three and six days later. An inspection of the island 12 weeks later revealed no sign of rats.

Bait stations were chosen as the preferred eradication method as there was concern that the rodenticide may affect two granivorous birds occurring in the archipelago – bar-shouldered dove *Geopelia humeralis* and brown quail *Coturnix australis*. Limited data on toxicity of brodifacoum suggests that it is toxic to birds (Eason and Spurr 1995) and could lead to bird deaths either through direct ingestion or through secondary poisoning, particularly in raptors. Limited data suggest that brodifacoum has little effect on reptiles and none on invertebrates.

In 1996, a major project was conducted, lasting from late May to early September, involving over 40 people, of whom at least eight were at the Montebellos at one time. Most personnel were volunteers and most were CALM staff, who gave some of their holiday time to assist with the project. Because of the remote location and size of the project, logistics were a major issue. Because the funds remaining from the grant provided by the Commonwealth Department of Primary Industry and Energy were insufficient to pay for the project, significant sponsorship was required and sought. Support was received from West Australian Petroleum (now incorporated into ChevronTexaco), Apache Energy, ACI Plastics Packaging, and the Selleys Chemical Company. The Australian Customs Service also provided some boat transport.

Some 11,000 bait stations (plastic bottles with holes cut in their sides) were laid on a 50 m grid over all larger islands, with smaller islands, islets and rocks being treated with plastic bags of bait laid from a helicopter and by boat. Over two tonnes of Talon G pellets rodenticide were laid, over all the 180 or so islands, islets and rocks in the archipelago. A helicopter was used during the first three weeks, during which time the more remote and difficult to access islands were baited and equipment dumps were established. After that, CALM's vessel *Pseudorca* provided transport within the archipelago. A more detailed description can be found in Burbidge (1997) and on the Montebello Islands Departmental file.

During 1996, no non-target or secondary poisoning was noted. A pair of white-bellied sea-eagles, (*Hieraaetus leucogaster*) nesting on Brooke Island, was observed to be consuming dying rats; however they ate only flesh, discarding the gut contents. Bungarras (*Varanus gouldii*) were also observed eating dead and dying rats to the extent that some droppings contained the green dye from the bait; however, no dead or moribund *Varanus* were observed.

In March 1997, a visit was made to search for rat sign. This revealed small numbers of rat tracks on two islands – Primrose and Crocus, and these were rebaited. In July

1997, a further visit searched for tracks and trapped on all larger islands. No rat sign was detected. During this visit as many bait stations as possible were examined as empty bait stations might reveal inadequate baiting during 1996; however, no empty bait stations were detected except on Primrose and Crocus, the islands rebaited earlier that year.

In 1997, we saw no evidence that native animals were eating the Talon laid in 1996. Of the two granivorous birds occurring in the Montebellos, bar-shouldered doves appeared to be considerably more common in 1997 than in 1994, 1995 or 1996. Brown quail had never been frequently observed previously, but were noted on several islands during July 1997. Raptors, including white-bellied sea-eagles, ospreys, Brahminy kites and kestrels, appeared to be as common as or more common than in past years. Reptiles were also common in July, noting that this is the coolest time of the year. Bungarra tracks were plentiful on all islands on which they occur.

In June 1998, several islands were searched for rat sign but none was detected. The owner of the Pearl Farm told us that his staff had reported rat droppings on one island. However, a search of this locality revealed nothing.

In May 1999, further searches were conducted. On this occasion we found moderate densities of rat tracks on Delta and Campbell Islands and low densities on Hermite Island. Campbell and Delta were baited immediately; however, Hermite was too large to be baited with the staff and other resources available. Rats were not detected on any other island.

3. Rat eradication using aerial spreading of rodenticide

After consultation with staff of the Department of Conservation in New Zealand, it was decided to bait Hermite Island using a spreader bucket slung beneath a helicopter. This technique had been developed in New Zealand and was by then being widely used (Cromarty *et al.* 2002). Observations on non-target and secondary poisoning since 1996 had convinced me that secondary poisoning was not an issue and bait stations were not necessary.

CALM purchased a second-hand spreader bucket as well as the bait for the bucket from New Zealand, as only one company there produced bait suitable for a spreader bucket. The bait used was Pestoff Rodent 20R (16 mm diameter bait) manufactured by Animal Control Products, Wanganui, New Zealand. It contains brodifacoum at 0.002% (0.02 g/kg). It does not contain Bitrex. The bait is not registered for use in Australia and special registration had to be obtained from the National Registration Authority. NZ DoC provided Simon Mowbray, who is very experienced in running aerial baiting operations, to supervise the spreading. An experienced New Zealand helicopter pilot was provided by the contracting company.

Hermite was aerially baited during October 1999. Bait was also applied to the nearby Renewal, Campbell, Delta, Alpha and Bluebell islands in case rats had swum to these islands.

A visit in August 2000 revealed low level tracks on Hermite Island. No tracks or other sign were located on any other island.

It was believed that logistical problems had prevented a fully comprehensive baiting in 1999 (see below) and it was decided to rebait in 2001. A visit in June 2001 revealed rat racks on Alpha and Bluebell Islands, which had been considered rat free since 1996, showing the ability of rats to readily swim between the islands. Tracks were still present on Hermite.

Aerial baiting was conducted in September 2001. On this occasion, a differential global positioning satellite (DGPS) navigation system was used to help the helicopter pilot fly accurately along planned flight lines. All islands from Ah Chong northward to Primrose were baited. Two baitings were conducted, ten days apart; the first at 8 kg/ha and the second at 4 kg/ha. The DGPS system 'painted' a 100 m wide swathe onto the navigation screen following the helicopter's actual track, enabling review immediately after a flight to check for any gaps in the swathes. Figure 2 shows a printout from the navigation system, without the 'painted' 100 m swathe.

Inspections covering all of the larger and many small islands in September 2002 and May 2003 did not reveal any rat activity on any island.

4. Cat eradication using aerial baiting followed by trapping

In 1997, a trial aerial baiting of cats on Hermite was carried out using kangaroo meat sausages with the toxin 1080 as developed at that time by Dr David Algar. Track counts suggested that bait uptake was low and that further development of the cat bait may be needed.

Feral cat eradication was carried out on Hermite Island in 1999. The techniques used and results are described in Algar, Burbidge and Angus (2002).

Feral cat eradication comprised two stages—aerial baiting and trapping. Briefly, aerial baiting utilised the recently developed kangaroo meat sausage baits with flavour enhancers and the toxin 1080. About 1100 baits were dropped by hand from a helicopter. Hermite Island has two main surface types—sand and skeletal limestone. Aerial baiting primarily targeted sandy soils. Four cats, all females, remained after baiting. These were trapped using innovative techniques involving Victor 'softcatch'® traps set either in association with phonic and odour lures or set in narrow runways. Eradication was achieved over a six-week period. Searches for evidence of cat activity in 2000 indicated that cats had been eradicated. Searches in 2001, 2002 and 2003 have confirmed eradication.

5. Introduction of threatened mammals

(i) Mala (Rufous hare-wallaby central Australian subspecies) *Lagorchestes hirsutus* undescribed subspecies

Thirty mala, a subspecies listed nationally and in Western Australia as 'Extinct in the Wild', were introduced to Trimouille Island in 1998. The animals were sourced from the 'Mala Paddock' in the Tanami Desert, NT. The

techniques used and monitoring up to 2001 have been published (Langford and Burbidge 2001). Monitoring in September 2002 and May 2003 suggested that the mala are continuing to increase in numbers and range on the island.

(ii) Djoongari (Shark Bay mouse) *Pseudomys fieldi*

A total of 59 djoongari, a species listed as Vulnerable nationally and in Western Australia, were introduced to North West Island in 1999 and 2000 (30 in June 1999, 29 in August 2000). The animals were sourced from Bernier Island and bred in captivity at Perth Zoo. By 2001 they were abundant and widespread, tracks being present all over the island. In September 2002 and May 2003 inspections revealed a similar situation.

6. Monitoring

Monitoring for the presence of exotic mammals and monitoring the introduced mammal populations is a key component of *Montebello Renewal*. Monitoring has occurred at least annually since 1996 and needs to be maintained on at least an annual basis.

DISCUSSION

General issues

Working at the Montebellos is logistically difficult. The islands are remote and the CALM did not have a seagoing vessel licensed to travel from Dampier to the Montebellos in the Pilbara until 1999. It still does not have an employee in the Pilbara qualified to take the vessel to the Montebellos (volunteers from the Dampier Port Authority captain the boat during the ocean crossings). Summers are hot and humid and working at the islands can be debilitating. Winter weather is often very windy with strong wind warnings being frequent during June, July and August. CALM has depended on the oil industry in particular to assist with logistics. In 1996, West Australian Petroleum (WAPET, now incorporated into ChevronTexaco) provided barges to mobilise and demobilise the operation. Since then Apache Energy has provided helicopter and barge support. The islands are spread over a large distance and there are numerous reefs and sandbanks, making within-archipelago boat usage tricky. Pilbara Region staff visit the Conservation Park irregularly, perhaps only once per year.

Boat transport within the archipelago has been a major issue. Initially, Pilbara Region had a Zodiac located at the Hermite base; however, this frequently punctured on the often sharp rocky coastline. It was replaced by a 4.5 m aluminium dinghy, which was much more suitable. Use of this was limited to non-strong wind conditions. Now changes to Department of Planning and Infrastructure rules prevent its use at the Montebellos unless registered as a tender to a seagoing vessel. Boat use at the Montebellos is still an issue that CALM Regional staff are trying to sort out.

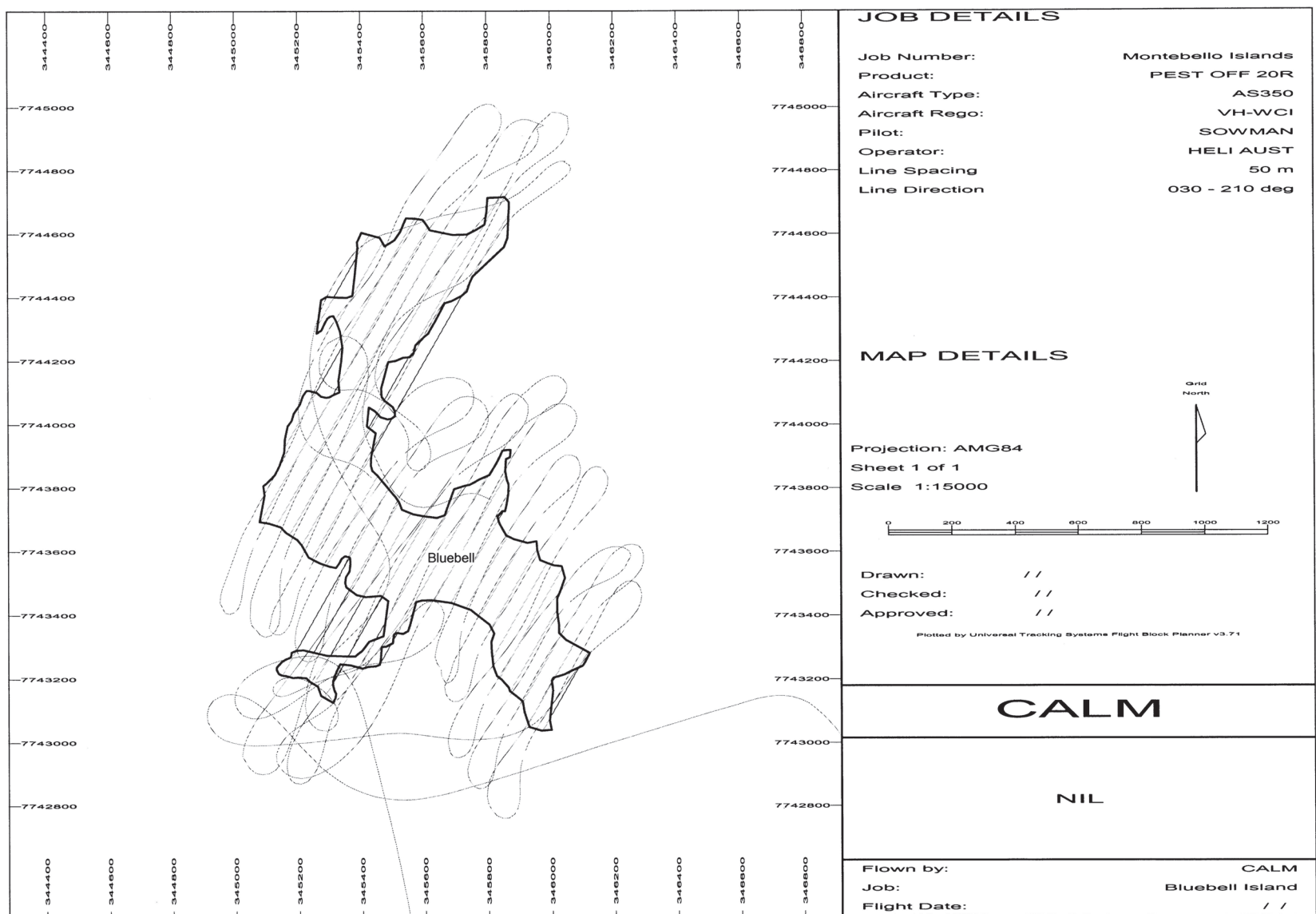


Figure 2. Differential GPS navigation system printout for Bluebell Island.
 Initial baiting at 4 kg/ha at 50 m intervals. Bucket swathe 100 m, providing 8 kg/ha and minimising possibility of gaps.

Fresh water at Hurricane Hill Hut is derived from a single rainwater tank. As rainfall is infrequent, water can be a limiting factor when planning trips. We used a small reverse osmosis plant during 1996 and occasionally since, but the 240 v generator has not always been reliable and the reverse osmosis plant has broken down at critical times. Lack of fresh water almost prevented the last feral cat being killed during the trapping operation, as it would have run out within a few days.

Failure of 1996 bait station rodent baiting

Failure to eradicate exotic rodents on islands is usually due to:

- (i) gaps between the bait stations being too large, or
- (ii) bait not being replaced in bait stations after it has been consumed by dominant rats.

There are two possible reasons for the failure of the 1996 bait station work. The most likely is that the volunteers failed to refill all bait stations during rebaiting operations. This appeared to be the case with Primrose and Crocus Islands, which had to be rebaited in March 1997, and could have been the cause of rats not being eradicated on Hermite, Delta and Campbell Islands (although rats could have swum from Hermite to Delta and Campbell or vice versa as they are separated by only a narrow channel. The second possibility is that rats re-invaded via the pearl farm – the fact that rats were located in 1999 on the three islands closest to the pearl farm supports this hypothesis; however, it is just as likely that some rats remained after the 1996 baiting. Since 1998, CALM has assisted the pearl farm operators to upgrade their quarantine.

There is evidence that Bitrex (denatonium benzoate) reduces consumption of bait by rats (Kaukeinen and Buckle 1992, Veitch 2002) and this may have been a factor in the failure to eradicate black rats in 1996; however, why eradication should have been achieved on most islands and not on a minority of islands is not clear if Bitrex was involved. The Pestoff 20R bait used for helicopter baiting did not contain Bitrex.

The Montebellos is the largest area where rat eradication has been attempted in Australia. The existence of many (very irregularly-shaped) islands close to each other in an archipelago means that eradication has to be achieved on every island within a short time; otherwise any remaining rats will spread rapidly by swimming. In New Zealand, larger areas than the Montebellos have now been successfully rid of rats via aerial baiting; however, these have been single, regular-shaped islands.

Failure of the 1999 aerial baiting

There were significant logistical problems in 1999, largely due to our inexperience in the use of helicopter-borne spreading buckets and associated equipment. The major problems were the frequent failure of the motor that drives the spinner on the bucket while it was being flown under the helicopter (probably due to it being an old engine

that got wet with seawater on the way to the island) and the failure to use a DGPS navigation system to ensure that there were no gaps in the bait laying. These problems were overcome in the 2001 aerial baiting, which proceeded without any major problems.

Introduction of native mammals before eradication had been achieved

Planning for the mala introduction proceeded during a period when it was thought that eradication had been achieved, and the rats were not discovered until after the introduction had taken place. In hindsight, we should have waited for at least three years of non-detection of rats before commencing introductions of native mammals. There was some pressure on CALM to proceed with the mala introduction as this species was extinct in the wild and attempts to reintroduce it to the Tanami Desert had failed due to cat predation. As long as rats have not swum to Trimouille or North West Islands, the introductions will have been justified; there is no evidence that this has happened.

FUTURE PLANS

Monitoring to check that rats have been eradicated at the Montebello Islands should continue. Monitoring on sandy islands can be readily carried out by searching for tracks. Monitoring on rock islands is more difficult. Rats are notoriously difficult to capture in Elliott traps and the use of break-back (kill) traps is contraindicated because it will lead to the death of numerous reptiles. Baited tunnels with ink pads (eg, 'black trakka', manufactured in New Zealand) should be used on rock islands in future.

Quarantine is important to prevent reintroduction of black rats or introduction of other invasive species. Quarantine arrangements have been agreed between CALM and Faraday Pearls and licensed charter boat working in the area. Private boats visiting the area, while having a low risk of transporting invasive animals, are an issue that requires addressing.

If no rat sign is detected, reintroductions of spectacled hare-wallaby, golden bandicoot, rakali and spinifexbirds should be planned for 2004 or 2005. There remains some doubt that black-and-white fairy-wrens ever occurred on the Montebellos (Burbidge *et al.* 2000); however, as this subspecies is restricted to Barrow Island, consideration should be given to translocating it to the Montebellos. Candidates for marooning include the antina (Central Rock-rat, *Zyzomys pedunculatus*) and, possibly, other species restricted to a single island or threatened by cat predation on the mainland.

Should black rats be detected at the Montebellos, an external review of the project should be commissioned before further baiting takes place. The New Zealand Department of Conservation should be asked to provide a reviewer. Action to achieve complete eradication must be carried out quickly after rat detection; otherwise the rats will quickly spread to other islands, including those with threatened mammals.

ACKNOWLEDGMENTS

Funding for *Montebello Renewal* was provided by the Commonwealth Department of Primary Industry and Energy and the Western Australian Department of Conservation and Land Management. Significant support was received from West Australian Petroleum (now incorporated into ChevronTexaco), Apache Energy, ACI Plastics Packaging, Selleys Chemical Company, Australian Customs Service and the Pilbara Regiment, Australian Army. The 1996 rat baiting project and the 2000 feral cat eradication project could not have been carried out without the help of many volunteers, mostly CALM staff who gave up some of their annual leave to help. The 1999 and 2001 aerial baiting work was dependent on help from Simon Mowbray, New Zealand Department of Conservation and Helicopters Australia, particularly pilot Dave Sowman, who came from New Zealand to fly the project.

Many CALM staff, too numerous to list here, helped with the project; however, I would highlight the help of Pilbara staff Fran Stanley and Geoff Kregor, and Jill Pryde from the WA Threatened Species and Communities Unit.

REFERENCES

- Algar D, Burbidge A (2000) Isle of cats. The scourging of Hermite Island. *Landscape* **15**(3), 18-22.
- Algar D, Burbidge AA, Angus GJ (2002) Cat Eradication on Hermite Island, Montebello Islands, Western Australia. In *Turning the tide: the eradication of invasive species* (eds CR Veitch and MN Clout), pp. 14-18. IUCN SSC Invasive Species Specialist Group, Auckland.
- Burbidge AA (1971) The fauna and flora of the Montebello Islands. Department of Fisheries and Fauna Report No. 9. Department of Fisheries and Fauna, Perth.
- Burbidge A (1997) Montebello Renewal. *Landscape* **12**(2), 47-52.
- Burbidge AA, Fuller PJ (1999) Montebello Islands, Pilbara Region, Western Australia. Seabird Islands No. 239. *Corella* **22**(4), 113-115.
- Burbidge A, Langford D, Fuller P (1999) Moving mala. *Landscape* **14**(3), 17-21.
- Burbidge AA, Blyth JD, Fuller PJ, Kendrick PG, Stanley FJ, Smith LE (2000). The terrestrial vertebrate fauna of the Montebello Islands, Western Australia. *CALMScience* **3**(2), 95-107.
- Cromarty PL, Broome KG, Empson RA, Hutchinson WM, McFadden I (2002) Eradication planning for invasive alien animal species on islands – the approach developed by the New Zealand Department of Conservation. In *Turning the tide: the eradication of invasive species* (eds C.R. Veitch and M.N. Clout), pp. 85-91. IUCN SSC Invasive Species Specialist Group, Auckland.
- Eason CT, Spurr EB (1995) Review of the toxicity and impacts of brodifacoum on non-target wildlife in New Zealand. *New Zealand Journal of Zoology* **22**, 371-379.
- Kaukeinen DE, Buckle AP (1992) Evaluations of adverse agents to increase the selectivity of rodenticides, with emphasis on denatonium benzoate (Bitrex) bittering agent. Proceedings of the 15th vertebrate pest conference, pp. 192-198. University of California at Davis, Davis.
- Langford D, Burbidge AA (2001) Translocation of mala from the Tanami Desert, Northern Territory to Trimouille Island, Western Australia. *Australian Mammalogy* **23**, 37-46.
- Veitch CR (2002) Eradication of Pacific rats (*Rattus exulans*) from Fanal Island, New Zealand. In *Turning the tide: the eradication of invasive species* (eds C.R. Veitch and M.N. Clout), pp. 357-359. IUCN SSC Invasive Species Specialist Group, Auckland.

Project Eden – fauna recovery on Peron Peninsula, Shark Bay: *Western Shield* review—February 2003

KEITH MORRIS¹, COLLEEN SIMS², KATHY HIMBECK², PER CHRISTENSEN³, NIGEL SERCOMBE⁴, BRUCE WARD⁵ AND NICOLE NOAKES²

¹ Department of Conservation and Land Management, Science Division, Woodvale Research keithm@calm.wa.gov.au

² Department of Conservation and Land Management, Post Office, Denham WA, 6537.

³ Ellendale Farm, PO Box 134, Balingup, WA, 6253, Centre, PO Box 51 Wanneroo WA, 6946.

⁴ Department of Conservation and Land Management, PO Box 72, Geraldton WA 6531

⁵ Department of Conservation and Land Management, Science Division, Locked Bag 2, Manjimup WA, 6258.

SUMMARY

The Shark Bay area was one of the more mammal rich parts of Western Australia before European settlement. Over the last 200 years, 60% of the native mammals have become locally extinct in this area. *Project Eden* commenced on Peron Peninsula, Shark Bay in 1994. Its objectives were to a) control or eradicate the introduced fauna, b) reconstruct the native fauna of the peninsula, and c) to promote nature – based tourism based on the unique Shark Bay fauna.

Control of sheep, goats and foxes has been successful. Feral cat control has been difficult in the presence of large numbers of rabbits and other prey, however significant advances in the development of an effective feral cat control method have been made. A better understanding of the factors influencing the uptake of baits by feral cats has also been achieved. A captive breeding centre was established to provide animals for translocation. This ensured that wild populations of species restricted to islands or small parts of the mainland were not detrimentally impacted by the removal of large numbers of founders for translocation. Between 1996 and 2002, nearly 70 malleefowl and 150 mammals were bred / reared in captivity and 155 have been released. Malleefowl and bilbies have been successfully reintroduced to Peron Peninsula. Mala and banded hare-wallabies did not persist due primarily to cat predation. Woylies were reintroduced from other wild populations and are persisting in low numbers. Extant small vertebrate population abundances appear to respond more to rainfall events, rather than cat predation, while larger extant vertebrates have increased since sheep, goat, fox and feral cat control has been implemented.

While feral cat control has been demonstrated for short periods, additional work is required to reduce their numbers further, and for longer periods before additional native species can be translocated. In addition to the re-establishment of native fauna and the enhancement of the remnant native fauna, *Project Eden* has provided many benefits relating to the management of pest species and

native fauna in the arid zone. In light of the findings to date, it is proposed that the objectives of this project be revised and that certain actions are necessary to ensure future success. These include a refinement of feral cat control methods, the development and use of models to predict optimum bait uptake times, a review of species suitable for translocation, and the adequacy of existing staff numbers and captive breeding facilities.

INTRODUCTION

Project Eden is an ambitious large-scale conservation project that has as its primary goal the translocation and reconstruction of the pre-European fauna populations of the Peron Peninsula, an area of 1050 square kilometres within the Shark Bay World Heritage Property in Western Australia. The project was an initiative of the Department of Conservation and Land Management (CALM) and was launched by the then Minister for the Environment, Hon Kevin Minson in December 1994. It preceded *Western Shield*, which commenced in September 1996, but it is now regarded as one of the *Western Shield* component programs.

Prior to European settlement, the Shark Bay area of Western Australia had a diverse mammal fauna. Thirty-seven native terrestrial species were known to have occurred on the islands and peninsulas of the area (Baynes 1990). Most of the medium-sized species have disappeared and those that remain now, occur only on Bernier and Dorre Islands. Twenty-five native mammal species once occurred on Peron Peninsula, however, only the large euro *Macropus robustus*, widespread echidna *Tachyglossus aculeatus* and seven smaller species of bats, native rodents and marsupial mice now survive (Table 1). Another rodent, the ash-grey mouse *Pseudomys albocinereus*, has been reported as occurring on Peron Peninsula on the basis of hair samples (Peter Speldewinde, CALM, pers. comm.), but none have been trapped.

Nine species of introduced mammal have been recorded on the Peninsula, of which six still persisted in

the early 1990s (fox, feral cat, rabbit, sheep, goat and house mouse). The presence of these introduced species, particularly the fox and feral cat, is most likely to have precipitated the dramatic decline in native species over the 100 years or so preceding 1994. A clear link has been established between the decline of native mammal species and predation by foxes in the southwest of Western Australia (Christensen 1980, Kinnear *et al.* 1988, 1998, 2002, Morris *et al.* 2003). There are similar concerns about the detrimental impact of feral cats on native mammals, particularly in semi-arid and arid parts of Australia (Gibson *et al.* 1994, Christensen and Burrows 1994, Dickman 1996, Short 1999, Risbey *et al.* 2000).

The Peron Peninsula is the eastern most peninsula of the Shark Bay region of Western Australia, 900 kilometres north of Perth (Figure 1). It lies across the boundary of the Carnarvon Basin and Geraldton Sand plains IBRA (Interim Biogeographical Regionalisation for Australia) regions (Thackway and Cresswell 1995), and has been classified as having a semi-desert Mediterranean type climate (Payne *et al.* 1987). Rainfall averages 220 mm per year, most of it falling between April and September. However, even in the wettest years, rainfall is less than

evaporation (3000 mm per year) and plant growth is confined to periods of available soil moisture following rainfall events. The Bureau of Meteorology regard areas with an annual rainfall of less than 350 mm as arid.

The northern portion of the peninsula comprises extensive red sand plains with tall *Acacia* shrublands, low coastal sand dunes and sea cliffs. The southern portion of Peron Peninsula has undulating plains of calcareous sand supporting low *Acacia* shrublands and *Lamarchea hakefoilia* heaths. Low lying salt pans, or birridas, lie among the sand plains throughout the peninsula. Soils in these are highly saline and gypsiferous with scrubland of saltbush and samphire (Payne *et al.* 1987).

In October 1990, the Peron pastoral lease, which covered most of the peninsula, was purchased by the Western Australian government. In 1993 the Francois Peron National Park (FPNP) was created over the northern half of this area. The southern portion remains Unallocated Crown Land (UCL). The Shark Bay Regional Strategy (Ministry for Planning 1997) proposed that the UCL become timber reserve. Recently, the Western Australian government also purchased the adjacent Nanga pastoral lease.

TABLE 1

Native and introduced terrestrial mammals recorded from the Peron Peninsula, Shark Bay. Derived from Baynes (1990), Baynes (2000) and McKenzie *et al.* (2000a).

SPECIES	STATUS
NATIVE SPECIES	
Echidna <i>Tachyglossus aculeatus</i>	extant
Euro <i>Macropus robustus</i>	extant
Woylie <i>Bettongia penicillata</i>	locally extinct
Boodie <i>Bettongia lesueur</i>	locally extinct
Mala <i>Lagorchestes hirsutus</i>	locally extinct
Banded hare-wallaby <i>Lagostrophus fasciatus</i>	locally extinct
Crescent nailtail wallaby <i>Onychogalea lunata</i>	extinct
Western barred bandicoot <i>Perameles bougainville</i>	locally extinct
Quenda <i>Isodon obesulus</i>	locally extinct
Chuditch <i>Dasyurus geoffroyi</i>	locally extinct
Mulgara <i>Dasyurus cristicauda</i>	locally extinct
Red-tailed phascogale <i>Phascogale calura</i>	locally extinct
Fat-tailed dunnart <i>Sminthopsis crassicaudata</i>	extant
Little long-tailed dunnart <i>Sminthopsis dolichura</i>	extant
Hairy-footed dunnart <i>Sminthopsis hirtipes</i>	extant
Spinifex hopping-mouse <i>Notomys alexis</i>	extant
Shark Bay mouse <i>Pseudomys fieldi</i>	locally extinct
Sandy inland mouse <i>Pseudomys hermannsburgensis</i>	extant
Ash-grey mouse <i>Pseudomys albocinereus</i>	extant ?
Lesser stick-nest rat <i>Leporillus apicalis</i>	extinct
Greater stick-nest rat <i>Leporillus conditor</i>	locally extinct
Pale field-rat <i>Rattus tunneyi</i>	locally extinct
Dingo <i>Canis lupis dingo</i>	locally extinct
Lesser long-eared bat <i>Nyctophilus geoffroyi</i>	extant
White-striped mastiff bat <i>Tadarida australis</i>	extant
INTRODUCED SPECIES	
House mouse <i>Mus domesticus</i>	extant
Feral cat <i>Felis catus</i>	extant
European red fox <i>Vulpes vulpes</i>	extant
Rabbit <i>Oryctolagus cuniculus</i>	extant
Goat <i>Capra hircus</i>	extant
Sheep <i>Ovis aries</i>	locally extinct
Cattle <i>Bos taurus</i>	locally extinct
Horse <i>Equus caballus</i>	locally extinct
Camel <i>Camelus dromedarius</i>	locally extinct

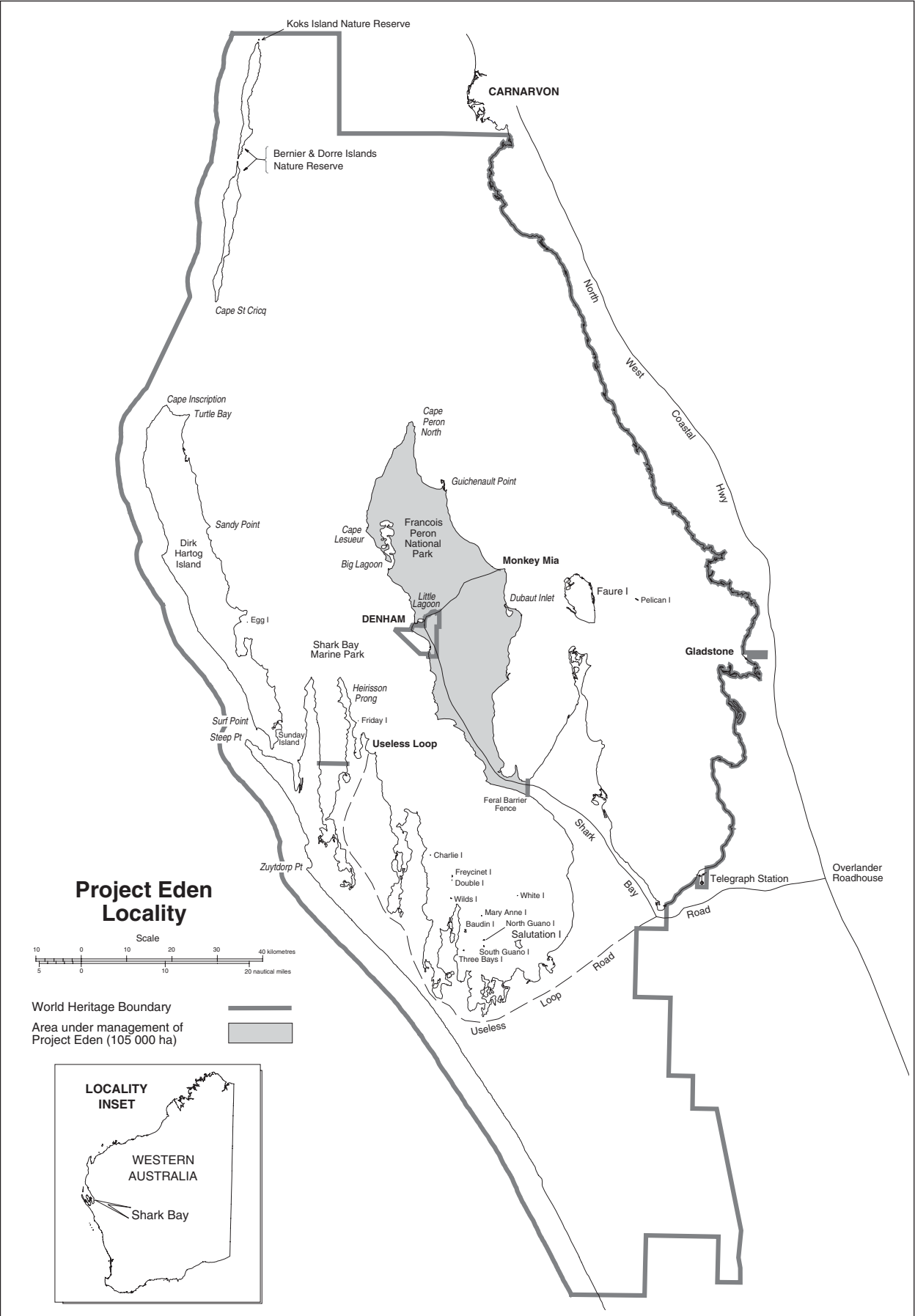


Figure 1. Location of Peron Peninsula, Shark Bay.

Project Eden commenced in December 1994 and the *Project Eden* Management Committee (PEMC), comprising staff from the Department's Midwest Region, Shark Bay District and Science Division was established to oversee the project. This committee was later expanded to include representatives from the Nature Conservation Division and a consultant (a former CALM employee who had been in charge of the project until 1998). A draft strategic plan was prepared in February 1995 (Christensen 1995) with the following objectives:

1. To control introduced predators (foxes and feral cats) and herbivores (goats, sheep and rabbits) on Peron Peninsula.
2. To re-establish a range of threatened animals, particularly mammals.
3. To foster and promote sustainable nature-based tourism to the area.

The project was seen as an 'operational experiment', rather than a research project and was to progress in three phases:

- Phase one – introduced animal control
- Phase two – fauna translocation
- Phase three – nature-based tourism.

Phase two was to be implemented based on the success of phase one, and phase three on the success of phase two.

Initially, one full time project officer was allocated to this project. However, as the work progressed it became clear that several operational staff would be required. *Project Eden* staff now comprise a project officer, a captive breeding manager, an animal husbandry officer, a translocation and fauna monitoring officer, two introduced animal control officers and part of a computer support person. In addition, the CALM Shark Bay District office in Denham provided administrative support. Volunteers have been used to assist with the captive breeding and translocation programs.

Operations Plans for each of the key functional areas - introduced animal control, fauna translocation and monitoring (including captive breeding), communication, and fire protection were also prepared. These operational plans reflected the aims of the initial *Project Eden* Plan and detailed the staff requirements, strategies, methods, budget estimates and timeframes for implementation or achievement of project milestones. The operational plans also provided the basis for meeting the requirements of the *Conservation and Land Management Act 1985* in respect to 'Necessary Operations' approval. A draft recreation and tourism operations plan for nature-based tourism was prepared in 1997, however this plan has not been progressed while the operational focus of the project remains on achieving sustained reductions in introduced predator numbers and fauna translocations.

The aims of each operational plan were as follows:

1. Introduced animal control

To develop and implement operational methodologies for the control of introduced herbivores and predators at sufficiently low levels of abundance so that:

- Existing populations of native fauna can expand to fill all available suitable habitats.
- Habitat conditions are suitable for translocation of locally extinct fauna.
- Introduced animal management is effectively integrated with other management strategies applied to the project area

For foxes and feral cats specifically, to:

- Reduce their density to an average of less than one animal per ten kilometres of transect and to retain it at, or below, this level.
- To eradicate foxes and cats within a five kilometre radius of designated translocation release sites.

2. Fauna translocation and monitoring

- To successfully translocate and reconstruct the mammal fauna of the Peron Peninsula.
- To monitor existing native mammal populations.

3. Communications

- To increase public awareness, understanding and support for *Project Eden*.
- To develop awareness and understanding of CALM as an organisation that cares for and manages the natural environment in an effective and innovative way.
- To convince local residents in Shark Bay as well as the Western Australian public to support the need for control of introduced animals in conservation areas.
- To assist the project in securing funding from the private sector to build a fence at the narrow neck of Peron Peninsula
- To promote the Shark Bay World Heritage Property as a destination for nature-based tourism.

4. Fire management

- To minimise the threat of fire to human life and property
- To minimise the risk of total incineration of the proposed mammal translocation sites at Cape Peron, Peron Road and Herald Bight
- To minimise the impacts of prescribed fire and wildfire on park users, facilities and conservation values.

This report provides a critical review of the aims, strategies, and results of *Project Eden*. It provides an analysis of *Project Eden* in the context of the overall objectives of *Western Shield* and the future of mammal conservation in Western Australia with recommendations for the future. This paper also provides an outline of a number of significant secondary outcomes from the project.

CONTROL OF INTRODUCED SPECIES

Domestic stock

Peron Peninsula has been grazed by domestic stock since 1881, and up to 22 500 sheep at a time have been grazed on the property. Since 1993, all domestic stock (18 861 sheep, 11 cattle and 19 horses) has been removed from the FPNP and south Peron UCL. Feral goat numbers have been reduced from approximately 14 600 to 200–400 animals (Brown 2001). Sheep, cattle and horses were mustered off the lease. Goats were mustered, shot from helicopter and the ground, trapped at water points and shot using the 'Judas' goat method. Ongoing goat shooting and trapping at water points is underway. However the presence of brackish soaks around the coast of Peron Peninsula means that total eradication of goats may not be possible.

Foxes and feral cats

Foxes have been present in the Shark Bay area since the mid 1920s (Jarman 1986). Feral cats probably became established in the area in the 1870s after the European settlement of 'Shark's Bay' (now Denham) in 1850

(Abbott 2002). In September 1994 a preliminary reconnaissance was made of the Peron Peninsula to assess the suitability of the peninsula for the proposed *Project Eden*. During two days of travelling on most of the accessible tracks on the peninsula, very high numbers of rabbit, fox and goat tracks were noted. Because of this it was difficult to determine accurately the extent of cat tracks. There was also an almost total absence of any tracks of small mammals and also the larger reptiles such as Gould's goanna *Varanus gouldii* and the bobtail *Tiliqua rugosa*. Despite this, a monitoring program for foxes and feral cats was commenced from October 1994. Early monitoring methodology consisted of recording the numbers of fox and cat tracks along 20–30 km 'road' transects and converting the results to number of tracks / 100 km following a methodology previously developed and used in the Gibson Desert during project Desert Dreaming (Christensen and Burrows 1995, Algar and Burrows, this publication). At this time numbers of foxes were believed to be approximately 100–120 per 100 km and cats about 6–10 per 100 km (Figure 2). A pre-fox baiting cyanide transect using the methods of Algar and Kinnear (1992) indicated that there were 2.5 foxes per square kilometre on Peron Peninsula (about 2 500 foxes in total). In July 1998 the track transect was modified so that a standard 80 kilometre transect was searched for animal tracks (= Comprehensive Track Count CTC). The CTC was also used to monitor the relative abundance of larger native fauna such as euros, echidnas, emus and goannas. Spotlight surveys were also attempted but soon abandoned because, in spite of the very high numbers of foxes, few were seen due to the density of the vegetation over most of the peninsula. Likewise, feral cats were seldom seen at night.

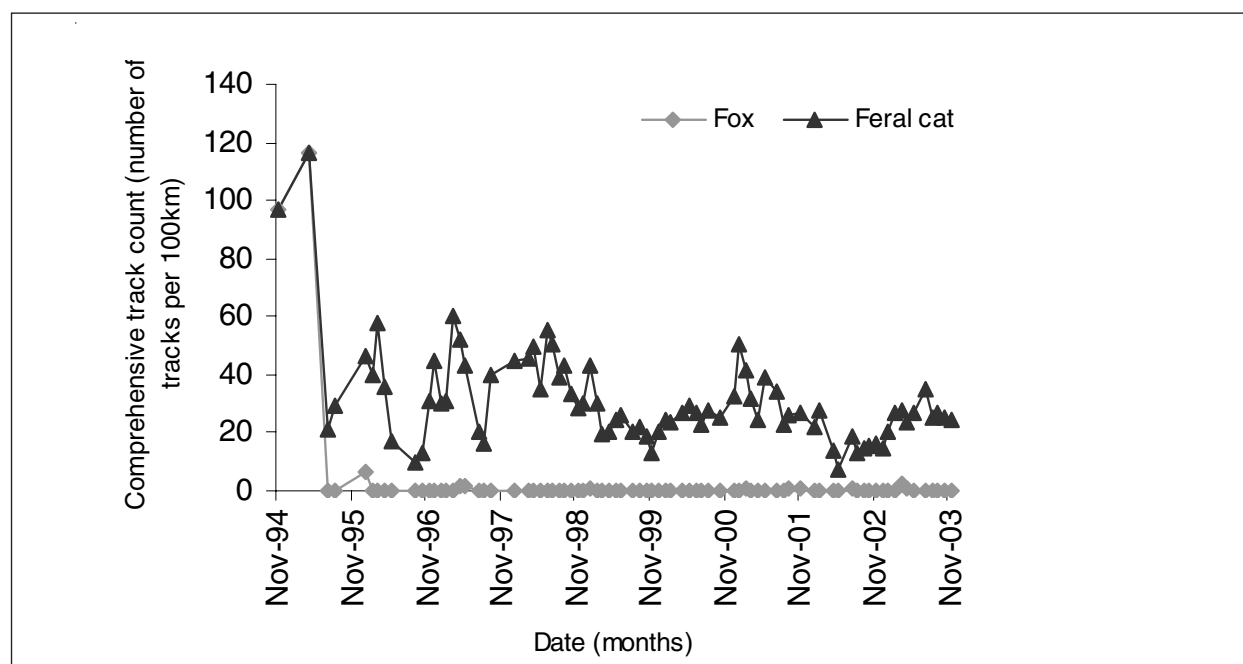


Figure 2. Estimates of relative fox and feral cat abundance on Peron Peninsula in relation to baiting control.

Because of the exceptionally high numbers of foxes present on Peron Peninsula, the initial introduced predator control strategy was to reduce fox numbers through baiting before attempting to control feral cats. The aim was to reduce and maintain fox and cat numbers to less than 10 per 100 km. At this time (April 1995) effective methods for controlling foxes over large areas were known, however techniques for feral cat control were still being developed. *Project Eden* provided an opportunity to test various feral cat control techniques. An aerial fox baiting program in April 1995 using kangaroo meat baits (10 baits per square kilometre) resulted in an estimated 95% reduction in fox abundance. Immediately after, the only signs of foxes were in the Denham town buffer strip where a set of footprints was recorded along the beach, and it is now very unusual to find evidence of foxes north of the barrier fence. The Peron Peninsula is now one of the largest areas (1050 square kilometres) of mainland Australia that is virtually fox free. Following the success of fox baiting, a three kilometre electrified barrier fence was constructed near the narrowest point of the peninsula to prevent / reduce reinvasion from the adjacent Nanga pastoral lease which at that time was not fox baited. Various trials were undertaken with chemicals, such as naphthalene, to stop foxes (and cats) from passing through the gap in the fence where the Denham road passed. These were not successful, and finally a recording of a dog barking and an ultrasonic noise emitter were installed at the gap. These are activated when there is movement across an infrared beam across the road. The success of these deterrents was monitored using sand pads, moistened with kerosene to stop the sand blowing away, to record movement of foxes and cats across the grid. The ultra-sound was not effective in preventing foxes and cats from moving through the gap, however the dog barking did appear to be a deterrent and this has been maintained on the road gap, in addition to a road grid.

Subsequent cat baiting operations (both hand and aerial baiting), and the barrier fence have been effective at maintaining foxes at very low levels on Peron Peninsula. It is now unusual for fox tracks to be detected during the comprehensive track counts (Figure 2). It was predicted that once fox and cat numbers had been reduced to very low levels, control measures other than baiting might be needed to 'mop up' the last few individuals. Two Rhodesian ridgeback dogs were procured for this purpose and in the early months of the project were trained to detect cats and foxes. Following the success with the fox baiting the dog training concentrated on the location of cats. While initial results were promising, the dogs were not able to 'air scent' the cats and this work ceased.

With the success of fox baiting it became possible to more accurately assess relative cat abundance through the use of driven transects covering a standardised 80 km of sandy track. Cat numbers appeared to increase significantly after the foxes had been removed; however at this time, an effective cat bait had not yet been developed. Feral cat control commenced in April 1996 and has involved a number of trapping and baiting regimes

since. Initial cat control focussed on using small, fresh meat 1080 baits coated in 'digest' dropped from an aircraft at 10 baits per square kilometre. This regime was based on the success of previous work undertaken on cat control in the Gibson Desert (Burrows *et al.* 2003). This resulted in an approximately 75% kill of cats. The aerial baiting program was repeated in autumn of 1997, 1998, 1999, however these were less successful with only a 30-50% reduction in feral cat abundance. In addition, in 1996 a trial was undertaken with the effectiveness of secondary poisoning from rabbits killed with 1080 oats. This may have enhanced the effectiveness of the meat baits, however this technique has not been pursued because of the potential impact on non-target native rodents. Development of a cat sausage bait was completed in 1999 (Algar and Angus 2000a) and this was used in monthly ground baitings on Peron in 2000 and 2001. In March 2002, an aerial baiting using 50 sausage baits per square kilometre was undertaken and 13 of 16 radio collared adult female cats (ca 80%) were killed (Maxwell 2002). There was also a consistent decline in the CTC for cats at this time. In March 2003 and October 2003, further aerial baiting programs (50 baits per square kilometre) were undertaken and 35-60% of radio-collared cats were killed (15 and 13 adult cats radio collared in March and October respectively). However, there were not corresponding declines in the CTC at these times and the reasons for this are unclear. The extent to which the CTC is reflecting a decline in the cat population due to baiting, or natural declines due to nutritional stress (Jones and Coman 1982) or reduced breeding has not been determined, and is one of the ongoing difficulties in determining baiting effectiveness.

Aerial and ground baiting from 1996 to 2001 has not been successful in maintaining cats at sufficiently low numbers to allow translocations of most of the targeted native mammals to occur. An analysis of cat stomach contents indicated that rabbits and mice (*Notomys* and *Mus*) form the majority of prey items for feral cats on Peron Peninsula, with larger cats having a greater proportion of rabbits in their diet (Algar and Angus 2000b, Figure 3). The proportion of cats taking baits (= bait uptake) on Peron Peninsula was inversely related, primarily, to rabbit and other prey abundance. Bait effectiveness was therefore greatest in the autumn when rabbit abundance was reduced. In a simultaneous trial using non-toxic rhodamine marked cat baits, bait uptake by cats at Pimbee Station (120 km east-north-east of Peron) with low rabbit densities was significantly greater than at Peron (Algar and Burrows, this publication). Short *et al.* (1997) also predicts that bait uptake by feral cats is likely to be poor when there are high numbers of rabbits present, and Burrows *et al.* (2003) propose that seasonal variation in the abundance of major dietary items of cats in the Gibson Desert (reptiles and small native mammals) affects bait uptake.

However, even in autumn, the effectiveness of baiting on Peron Peninsula was highly variable and between 1997 and 2001 bait uptake was significantly less than in 1996

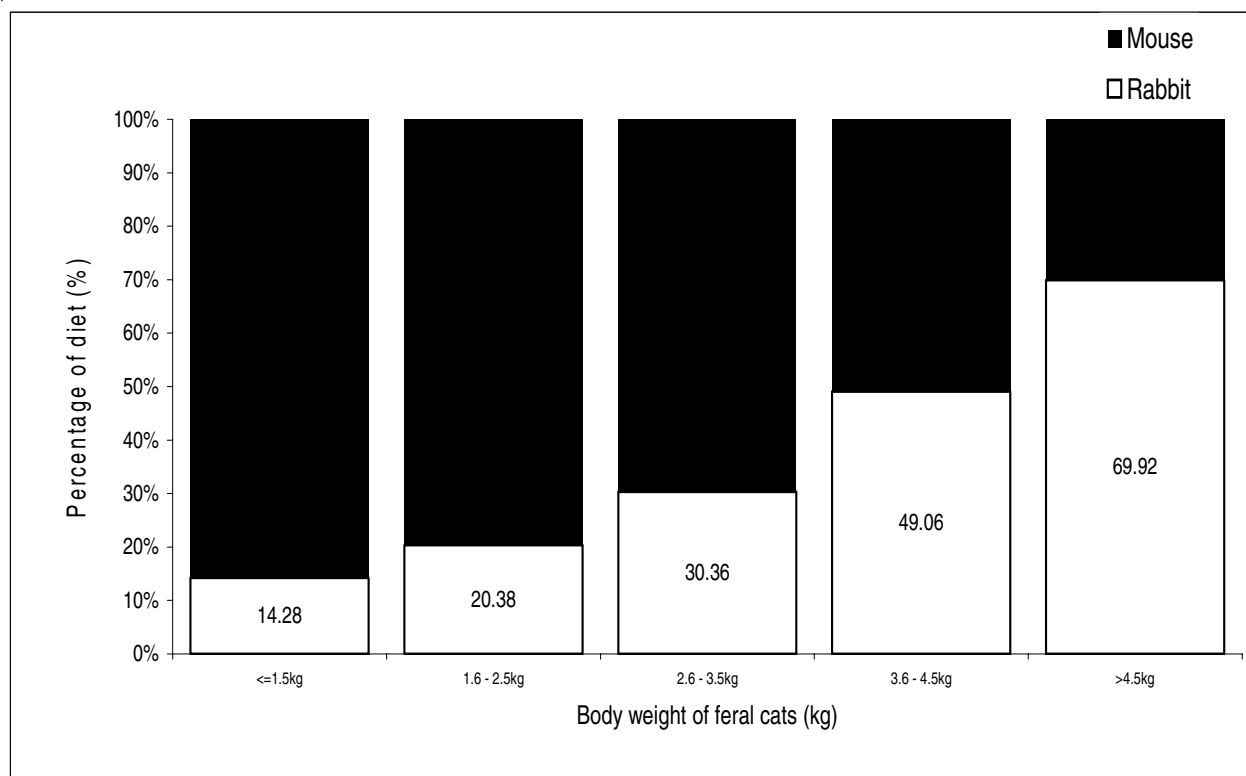


Figure 3. Composition of feral cat diet on Peron Peninsula 1994–2002 ($n = 3400$).

and 2002. Feral cats are able to breed throughout the year on Peron Peninsula, however most cats are either pregnant or lactating between September and November (Figure 4). Consequently the population has a great capacity to increase unless control is ongoing. The baiting in 2002 was shown to be effective in significantly reducing feral cat numbers (> 50% reduction), but that undertaken in March and October 2003, less so. At that time it was difficult to know whether the good bait uptake by cats in 2002 was because of the increased baiting intensity (50 baits per square kilometre versus 10 baits per square kilometre previously), or a particularly low abundance of alternative prey (particularly rabbits) after dry winters in 2001 and 2002 (Figure 5). Rainfall for 2001 and 2002 were 177 mm and 163 mm respectively, well below the average of 220 mm per year, and the reduced number of breeding feral cats at these times was probably as a consequence of this (Figure 4). However, a large amount of information on the abundance of small mammals and seasonal rainfall, together with previous cat baiting effectiveness has now been collected, and a model to predict the percentage of cats likely to be killed based on these variables is now being developed.

Initially, trapping was considered as a mopping up technique to get rid of the 20–30 % of cats that were not baited and there was some success with trapping for cats using cage traps baited with rabbit meat, dead quail and other baits at the start of the project. Subsequently a more effective technique using # 3 Victor ‘soft catch’ traps and olfactory and auditory lures was developed (Meek *et al.* 1995, Algar *et al.* 2002). All of the Peron Peninsula

north of the barrier fence has been systematically trapped on a monthly basis since late 1996. In addition to the CTC referred to above, the cat trappers have also carried out cat track counts as they travel their trap lines each day (= trappers track counts TTC), usually a distance of about 20–30 kilometres.

Since 1996 the various cat control techniques have resulted in CTCs of between 10 and 60% (Figure 2). Following the April 2002 baiting, when 80% of radio-collared cats were killed, the CTC fell from 47% to 11% suggesting that the CTC was providing a reasonably accurate measure of relative cat abundance. However, because of the variability in bait uptake throughout the year, and between years, baiting has only been effective for short periods. Trapping has been the main control method and CTCs have been kept at approximately 20–30%. Despite the lack of pre-control cat track counts, this is considered to be about 30–50% of the cat carrying capacity of the peninsula. However, there is evidence that this level of cat abundance is too high to permit the successful translocation of mala (*Lagorchestes hirsutus*), banded hare-wallaby (*Lagostrophus fasciatus*) and possibly woylie (*Bettongia penicillata*). It is probably also too high for other ‘cat vulnerable’ species such as the greater stick-nest rat (*Leporillus conditor*) and western barred bandicoot (*Perameles bougainville*) to be released. Dickman (1996) regards the impact of feral cats to be greatest on species weighing less than 200 grams. However, in the presence of this level of cat numbers, bilbies (*Macrotis lagotis*) and mallee-fowl (*Leipoa ocellata*) have survived and increased in abundance.

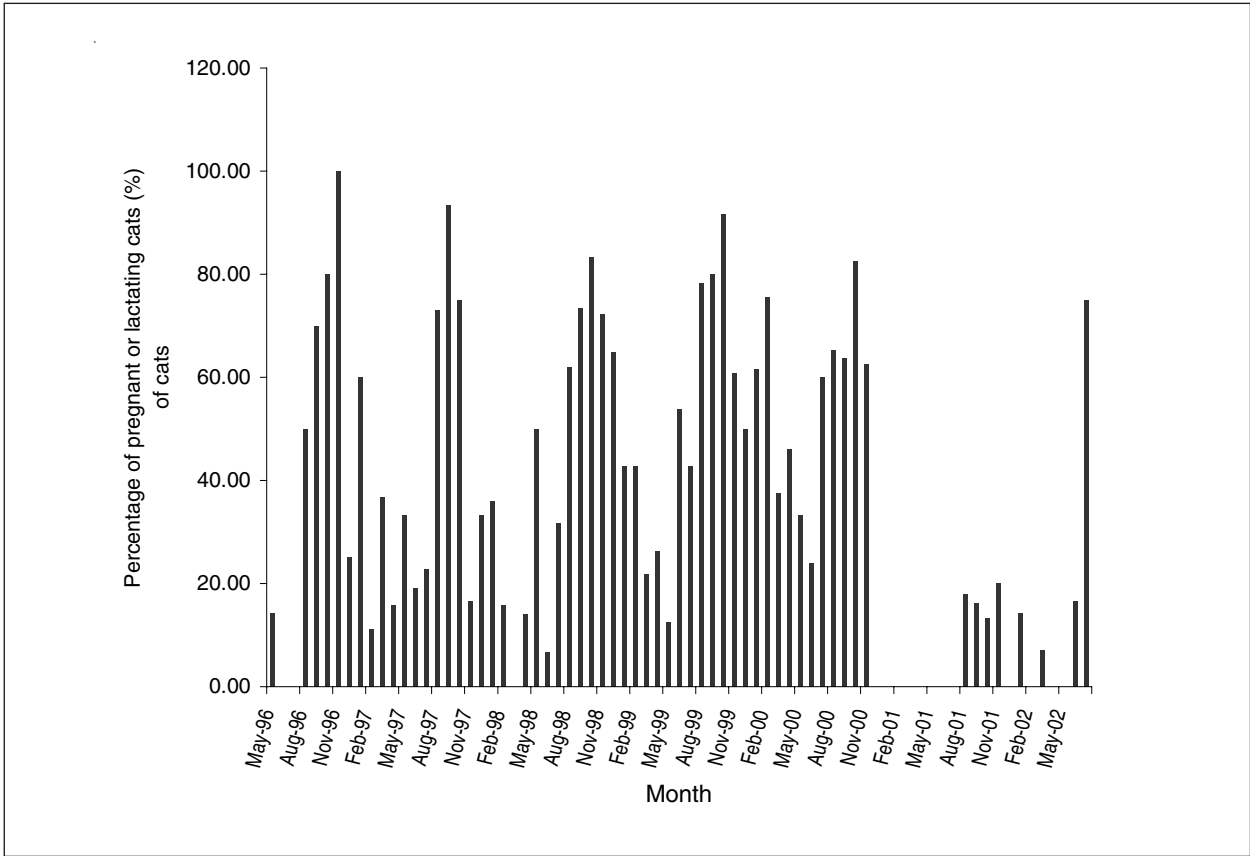


Figure 4. Seasonal percentage of pregnant or lactating feral cats on Peron Peninsula 1996–2002.

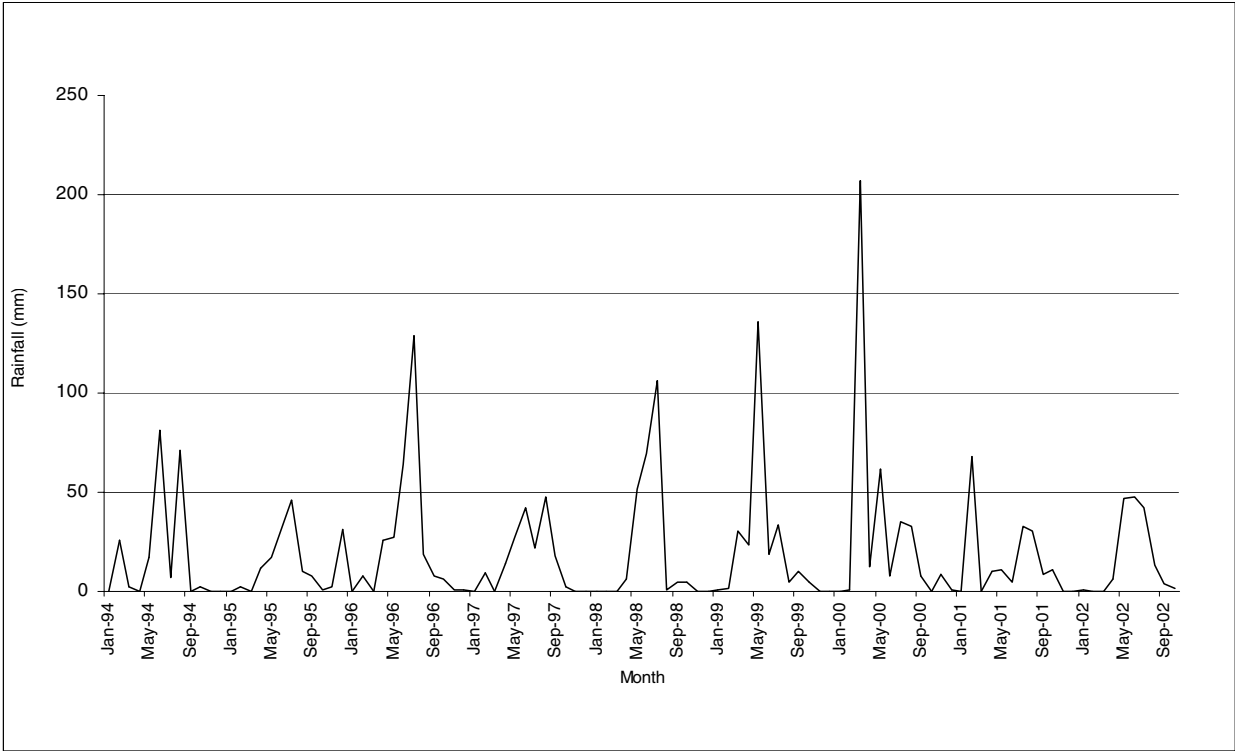


Figure 5. Annual monthly rainfall for Denham 1994–2002.

It is possible that greater control of feral cats will be achieved on Peron Peninsula through broad scale baiting with a highly attractive bait, as has been demonstrated for some islands and parts of the mainland in the arid zone (Algar and Burrows, this publication). However the effectiveness of this may vary depending on environmental conditions and rabbit abundances, and new techniques will need to be developed to target individual problem animals and maintain lower cat densities when baiting is less effective.

Despite the longer than anticipated time for effective feral cat control on Peron Peninsula, this aspect of *Project Eden* has had several benefits. In addition to allowing the establishment of additional malleefowl and bilby (and possibly woylie) populations, and enhancing remnant fauna populations, considerable progress has been made on developing an effective cat control method for Australia. *Project Eden* has provided the opportunity and location to trial various control techniques. In particular research into the variability in bait uptake has been crucial in developing baiting strategies where rabbits are in high abundance. It is the largest area in Australia (and possibly the world) where intensive cat control has been carried out almost on a daily basis for a period of over seven successive years. A significant amount of data (> 3400 cats) have been collected on cat sex, size, weight, colour, breeding condition, stomach contents and capture location. As discussed above, there are also opportunities to develop predictive models to allow managers to better use baiting as an effective cat control method. This project is one of only a few in Australia where it is being attempted to develop integrated cat control techniques at a large scale for conservation purposes in an arid environment. There have also been benefits to the extant native fauna with increases in several of the larger mammal and reptile species. If a regular, effective cat-baiting program can be developed on Peron Peninsula, the area could once again become one of the more diverse fauna regions in Australia.

Rabbits

While there was concern about the impact of high numbers of rabbits on native vegetation on Peron Peninsula, it was realised when *Project Eden* commenced that concerted rabbit control was not achievable. It was also considered that many of the species listed for translocation were capable of at least co-existing with rabbits and that it was more important to control the recognised threats of foxes and feral cats. Robley *et al.* (2002) demonstrated that high rabbit densities had no impact on population characteristics of the boodie (*Bettongia lesueur*) in Shark Bay. On Peron Peninsula, there was concern that rabbit numbers might increase significantly once foxes were removed, however research in NSW had shown that where rabbits occur at high densities (> 15 rabbits / square kilometre), predation was not a limiting factor and population numbers were limited by environmental factors (Pech *et al.* 1992). Very little pre-fox control rabbit monitoring was undertaken and the high numbers of fox tracks confounded that undertaken in 1994. Subsequent monitoring of rabbits through presence/absence at approximately four kilometre intervals along the 80 kilometre CTC transect demonstrates significant seasonal fluctuations in numbers, most likely influenced by winter rainfall patterns (Figure 6).

Unsuccessful attempts at rabbit control have been made through release of myxomatosis and rabbit calici viruses. Myxomatosis was probably always present on Peron Peninsula and in addition two infected rabbits were obtained from Heirisson Prong, and released on the peninsula in September 1994. The disease was noted the following autumn when dying rabbits with symptoms of the disease were observed. To facilitate the spread of the virus, European rabbit fleas were released in 1995 and Spanish rabbit fleas in 1996. Myxomatosis continues to have a sporadic and localised impact on rabbit populations

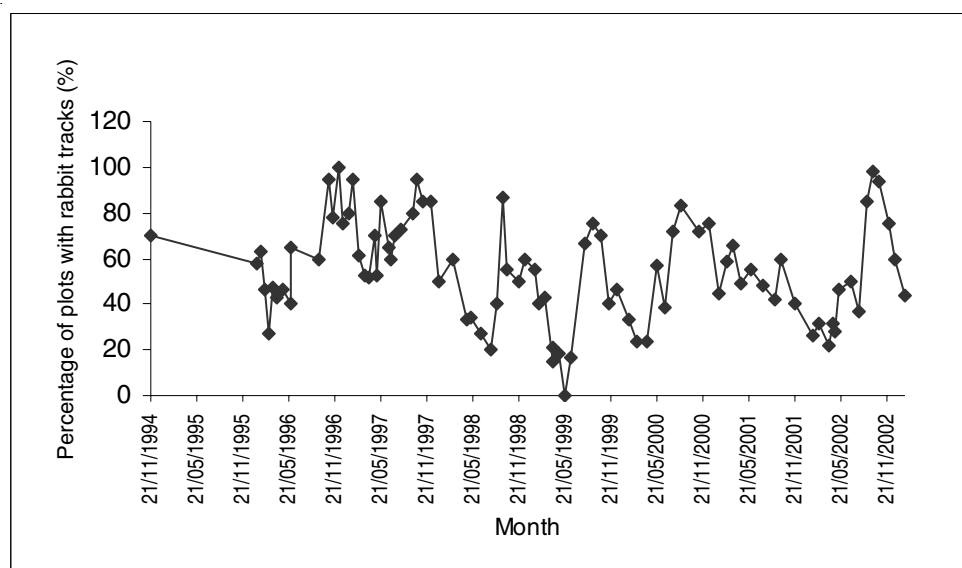


Figure 6. Relative abundance of rabbits on Peron Peninsula estimated by presence/absence at 4 km intervals along the CTC transects on Peron Peninsula.

during periodic epidemics. When rabbit calici-virus became available in 1996, Peron Peninsula was included as an official release site. However there have been no signs of the disease being effective at reducing rabbit numbers. Rabbits were tested positive for antibodies to the disease, however none were found to be dying. A second release of calici virus was undertaken in autumn 1997, but again this does not appear to have become established and was unsuccessful at reducing rabbit numbers. Given that apparent inverse relationship between rabbit abundance and bait uptake by cats, as discussed above, it is important that further work be undertaken on methods for reducing rabbit abundance on Peron Peninsula. Broad scale poison (1080 or sodium fluoroacetate) oat baiting has been considered, however there is potential for non-target species, particularly native rodents to be detrimentally impacted by this.

REMNANT TERRESTRIAL VERTEBRATE FAUNA

Introduction

The introduced animal control carried out by *Project Eden* has been focused at providing habitat that allows successful reintroduction of locally extinct native fauna. Equally important is the recovery of remnant fauna populations that had been struggling to survive competition from introduced herbivores and predation from introduced carnivores. The remnant fauna on Peron Peninsula has been regularly monitored by a series of small vertebrate monitoring grids, as well as through a road-trapping program implemented to also monitor the translocated mammal species. The comprehensive track counts (CTC) have also been used to monitor terrestrial fauna.

Six species of non-volant native mammal are extant on Peron Peninsula (Table 1). Four of these (*Notomys alexis*, *Pseudomys hermannsburgensis*, *Sminthopsis dolichura* and *S. hirtipes*) are monitored by regular trapping in small vertebrate monitoring grids. At least 65 taxa of reptile are known from the Peron Peninsula (Table 2) and up to 27 of these are regularly trapped in either the small vertebrate monitoring grids or road transects. McKenzie *et al.* (2000b) reported that the red sands with hummock grassland habitats on Peron Peninsula supported some of the richest herpetofaunal assemblages in the southern Carnarvon Basin bioregion. No frogs are known from Peron Peninsula, although the western toadlet *Pseudophryne occidentalis* has been recorded at Hamelin Pool at the base of Peron Peninsula (Tyler *et al.* 2000), and there are anecdotal reports of a frog inhabiting dunes near Denham and in the Francois Peron National Park.

Small vertebrate monitoring grids

Since 1995, six monitoring grids, each of 4 x 4 trap sites and comprising sixteen pitfall traps (alternating 15cm

diameter PVC tubing with 20 litre buckets, each with 7m of wire netting) and sixteen Elliott traps have been used to monitor the small vertebrate fauna on Peron Peninsula. A description and location of these is shown in Table 3. These were intended to sample the major vegetation types in the northern part of the Peron Peninsula, however none were set in the extensive *Acacia ramulosa* (wanyu) shrublands. Sampling from 1995 – 2000 was at least once a year (either spring or autumn, or both). Since autumn 2001 the 6 established grids have been run in both spring and autumn. An additional three grids (grids 9, 10 and 11) were installed in spring 2001 as part of fire response research (Hill 2002), to replicate the burnt and unburnt spinifex vegetation.

The results of the small vertebrate monitoring since 1995 are shown in Figure 7. Four native species of small mammal (*Notomys alexis*, *Pseudomys hermannsburgensis*, *Sminthopsis dolichura*, *S. hirtipes*) and the introduced house mouse *Mus domesticus* have been trapped on the grids. *N. alexis* was the most commonly trapped small mammal, accounting for approximately 70% of captures. Twenty seven species of reptile have also been trapped on the grids. The most commonly trapped species include the *Diplodactylus* geckos, the skinks *Ctenotus fallens*, *C. schomburgkii*, *Lerista elegans*, *L. planiventralis* and *Menetia greyii*, and the dragon *Ctenophorus maculatus*. Ten other species of reptile, mainly the larger snakes and skinks have been recorded on the road transects (Table 2). A further 28 species of reptile are known from Peron Peninsula; most of these have been recorded in the southern part of the peninsula.

Mammal trap success rates fluctuated between < 5% to 30%, while reptile trap success rates varied between < 5% and 8%. Mammal trap success rates were highest from August 1996 to August 1999 and this probably reflects the good winter rains received in this period (Figure 5). Lower mammal trap success rates between 2000 and 2002 probably reflect the lower rainfall received at this time.

Hill (2002) showed that the 1997 burns to create a fire buffer across the peninsula did not reduce the richness or abundances of the four native small mammals or the introduced house mouse. Similarly it did not reduce the abundances of agamid (dragons), gekko or varanid lizards, but did reduce the species richness. The dragon *Ctenophorus maculatus* and gekko *Diplodactylus squarrosus* increased in abundance following the fire. However, skinks declined in abundance post fire.

Road transects

Road trapping transects using Sheffield cage traps placed at 200 m intervals along Cape Rose track, Woylie track, Aerial track, and Cyanide track were established in May 1997 to monitor released mammals (woylies). In April 2001 the Fauna Monitoring Trapping Program (FMTP) incorporated the existing road trapping but added more tracks within the release area to form a standardised survey that was run twice a year. From 2001, all species caught,

TABLE 2

List of reptiles recorded from Peron Peninsula (derived from McKenzie *et al.* 2000b, and WA Museum records) and those trapped during monitoring programs.

REPTILE SPECIES	TRAPPED IN MONITORING GRIDS OR ON ROAD TRANSECTS, FPNP.	REPTILE SPECIES	TRAPPED IN MONITORING GRIDS OR ON ROAD TRANSECTS, FPNP.
Gekkonidae (geckos)		Pygopodidae (legless lizards)	
<i>Crenadactylus ocellatus horni</i>		<i>Acyls concinna major</i>	
<i>Diplodactylus alboguttatus</i>	X	<i>Aprasia sp.</i>	
<i>Diplodactylus ornatus</i>	X	<i>Delma australis</i>	
<i>Diplodactylus pulcher</i>	X	<i>Delma butleri</i>	
<i>Diplodactylus squarrosus</i>	X	<i>Delma nasuta</i>	
<i>Diplodactylus stenodactylus</i>	X	<i>Lialis burtonis</i>	
<i>Gehyra variegata</i>	X	<i>Pletholax gracilis edelensis</i>	X
<i>Heteronotia binoei</i>	X	<i>Pygopus lepidopodus lepidopodus</i>	
<i>Nephurus levis occidentalis</i>	X	<i>Pygopus nigriceps</i>	X
<i>Rhynchoedura ornate</i>			
<i>Strophurus michaelsoni</i>	X	Agamidae (dragons)	
<i>Strophurus strophurus</i>	X	<i>Ctenophorus maculatus badius</i>	
		<i>Ctenophorus maculatus maculatus</i>	X
Scincidae (skinks)		<i>Ctenophorus reticulatus</i>	X
<i>Ctenotus australis</i>	X	<i>Ctenophorus scutulatus</i>	X
<i>Ctenotus fallens</i>	X	<i>Lophognathus longirostris</i>	
<i>Ctenotus pantherinus pantherinus</i>		<i>Moloch horridus</i>	X
<i>Ctenotus schomburgkii</i>	X	<i>Pogona minor</i>	X
<i>Cyclodomorphus branchialis</i>			
<i>Cyclodomorphus celatus</i>		Boidae (pythons)	
<i>Egernia kingii</i>	X	<i>Aspites ramsayi</i>	X
<i>Egernia stokesii badia</i>		<i>Morelia stimsoni stimsoni</i>	
<i>Lerista aff. muelleri B</i>			
<i>Lerista connivens</i>		Typhlopidae (blind snakes)	
<i>Lerista elegans</i>	X	<i>Ramphotyphlops grypus</i>	
<i>Lerista kendricki</i>			
<i>Lerista lineopunctulata</i>	X	Elapidae (elapid snakes)	
<i>Lerista macropisthopus fusciceps</i>		<i>Demansia calodera</i>	X
<i>Lerista planiventralis</i>	X	<i>Furina ornata</i>	
<i>Lerista praepedita</i>	X	<i>Pseudechis australis</i>	X
<i>Lerista uniduo</i>		<i>Pseudonaja nuchalis</i>	X
<i>Lerista varia</i>		<i>Rhinoplocephalus monachus</i>	
<i>Menetia amaura</i>		<i>Simoselaps bertholdi</i>	
<i>Menetia greyii</i>	X	<i>Simoselaps littoralis</i>	
<i>Menetia surda</i>	X	<i>Vermicella fasciolata</i>	
<i>Morethia lineoocellata</i>	X	<i>Vermicella littoralis</i>	
<i>Morethia obscura</i>	X	<i>Vermicella multifasciata</i>	
<i>Tiliqua occipitalis</i>	X		
<i>Tiliqua rugosa</i>	X		
Varanidae (monitors)			
<i>Varanus brevicauda</i>			
<i>Varanus eremius</i>	X		
<i>Varanus gouldii</i>	X		

not only the released mammals, were recorded and measured. Elliott traps were added in September 2002 so that extant small native vertebrates could also be sampled over a larger area. The FMTP now covers 38 km of track within the release area and is sampled for four nights in each of autumn and spring each year. Trapping results are shown in Table 4. These indicate that both bilbies and woylies have declined, at least in the survey area. Bilbies may have declined because of movements away from the trapping area, however woylies are more sedentary and the population has probably truly declined. A range of small vertebrates are also trapped along these transects and these trap success rates have generally increased.

Comprehensive track counts

As mentioned above, the Comprehensive Track Count (CTC) commenced in 1995 to assess, monthly, the relative abundance of fauna, primarily the introduced species. This method has also been used to assess the relative abundance of some larger remnant native fauna species – euro, echidna and emu. Recently, other species that have been released onto the peninsula have also been recorded, including malleefowl, woylie, hare-wallaby and bilby.

Results of the native species recorded on the CTC are shown in Figure 8. Increases in the linear average of track counts for the euro, echidna and emu suggest a higher number of these animals in the FPNP since fox/cat control was implemented.

TABLE 3

Location and description of small vertebrate monitoring grids on Peron Peninsula.

GRID #	GPS LOCATION (UTM, NE CORNER OF GRID)	DESCRIPTION	COMMENTS
1	49 754555 E71 44262 N 5.0 km north of Peron Homestead on Cape Peron track	Shrubland of <i>Lamarchea</i> , <i>Hemichroa</i> , <i>Scaevola</i> , <i>Cassytha</i> and <i>Acacia</i> on red/orange sands.	Long unburnt
2	49 754573 E71 44019 N 4.8 km north of Peron Homestead on Cape Peron track	Shrubland of <i>Lamarchea</i> , <i>Hemichroa</i> , <i>Scaevola</i> , <i>Cassytha</i> and <i>Acacia</i> on red/orange sands.	Long unburnt
3	49 753622 E71 47881 N8.9 km north of Peron Homestead on Cape Peron track	<i>Triodia plurinervata</i> with scattered <i>Acacia</i> shrubs on red / orange sands.	Long unburnt
4	49 753780 E71 48985 N 10.1 km north of Peron Homestead on Cape Peron track	Formerly <i>Acacia</i> shrubland and <i>Triodia plurinervata</i> on red/orange sands. After the burn now dominated by <i>Lycium australe</i> .	Burnt March 1997
5	49 754557 E71 63247 N 200 m south of Herald Bight camp area.	Coastal heath on white sand dune grading into <i>Acacia</i> shrubland on red sands.	Long unburnt
6	49 754370 E71 63589 N 150 m north of Herald Bight camp area	Coastal heath on white sand dune grading into <i>Acacia</i> shrubland on red sands.	Long unburnt
9	49 754312 E71 49252 N	Formerly <i>Acacia</i> shrubland and <i>Triodia plurinervata</i> on red/orange sands. After the burn now dominated by <i>Lycium australe</i> .	Burnt March 1997
10	49 754559 E71 49265 N	Formerly <i>Acacia</i> shrubland and <i>Triodia plurinervata</i> on red/orange sands. After the burn now dominated by <i>Lycium australe</i> .	Burnt March 1997
11	49 753912 E71 48627 N	<i>Triodia plurinervata</i> with scattered <i>Acacia</i> shrubs on red / orange sands.	Long unburnt

TABLE 4

Trap success rate (as a percentage) of the main species caught in traps along the road transects during the Fauna Monitoring Trapping Program on Peron Peninsula. (Note: Elliott traps only added to transects in 2002, bilbies and hare-wallabies released in 2000 and 2001 respectively).

SPECIES	SEPT 1998	DEC 1998	NOV 1999	MAR 2001	SEPT 2001	APRIL 2002	SEPT 2002
<i>Bettongia penicillata</i>	0.25	0	0.7	2.2	1.25	0.7	0.3
<i>Macrotis lagotis</i>	-	-	-	1.8	1.1	0.3	0.4
<i>Lagostrophus fasciatus</i>	-	-	-	-	0.7	0.1	0
<i>Notomys alexis</i>	-	-	-	5.2	1.1	6.6	9.2
<i>Pseudomys hermannsburgensis</i>	-	-	-	0	0	0	1.6
<i>Mus domesticus</i>	-	-	-	0	0	0	1.4
<i>Felis catus</i>	-	-	-	0.4	0.2	0	0
<i>Varanus gouldii</i>	-	-	-	1.2	1.4	0.4	2.5
<i>Tiliqua rugosa</i>	-	-	-	0	0.5	0	1.6
<i>T. occipitalis</i>	-	-	-	0	0.1	0	0.3
Thick-billed grasswren	-	-	-	0.3	0.2	1.5	1.5

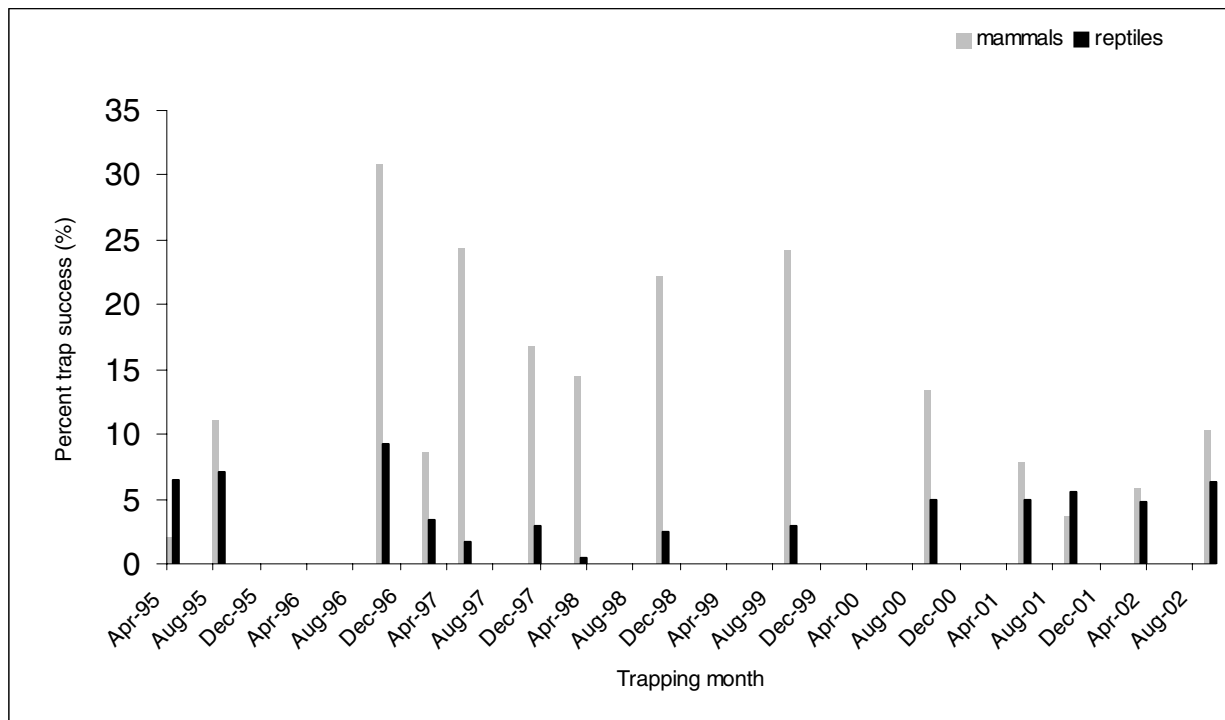


Figure 7. Small vertebrate captures on the trapping grids.

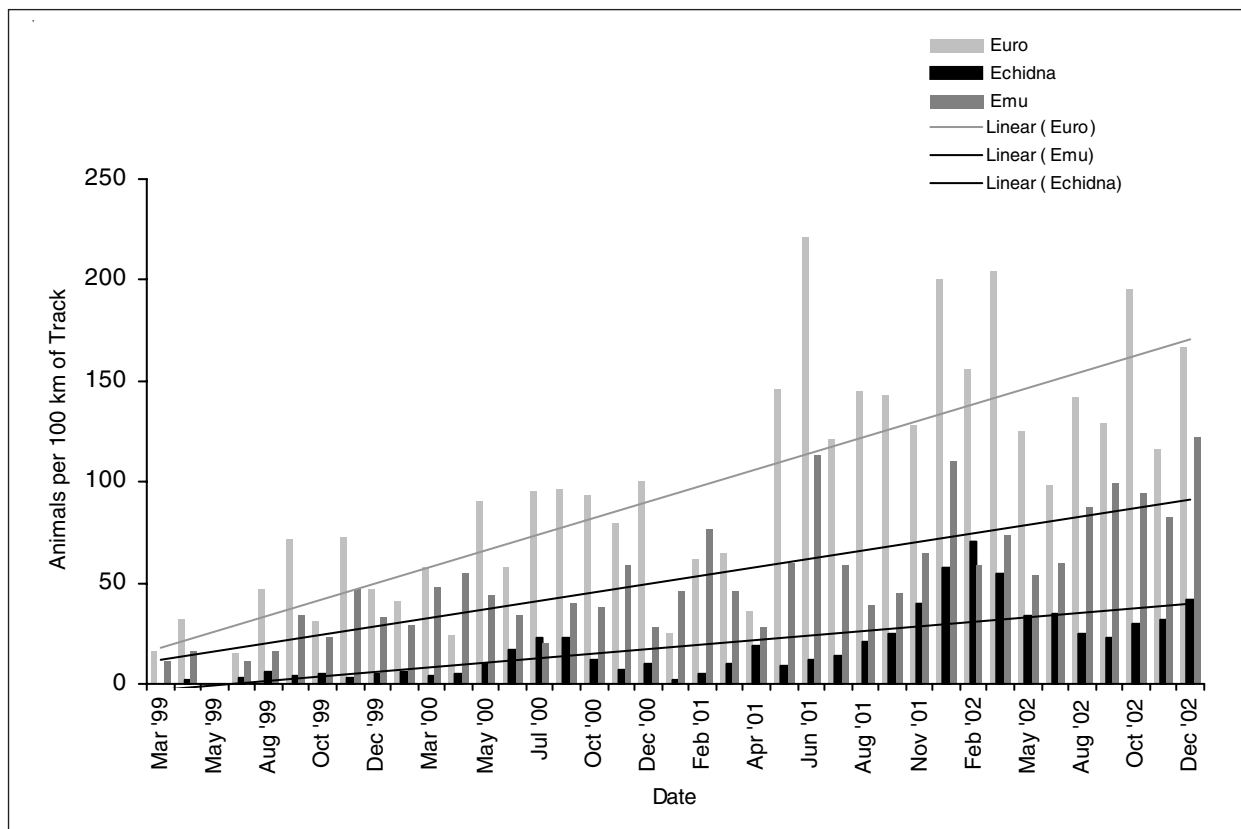


Figure 8. Average and linear trends of track counts of euro, emu and echidna on the CTC transect on Peron Peninsula.

Results and adequacy of monitoring

While there has been some variation in the frequency and timing of fauna monitoring, this aspect of *Project Eden* has been standardised since March 2001 and is now providing valuable information on fauna responses to changes in predation pressure and climatic variation (particularly rainfall) in an arid environment. This is one of the longest running fauna monitoring programs in arid areas of WA.

On the trapping grids, the small mammals and reptiles appear to respond more to rainfall events rather than reductions in fox and feral cat abundance. High trap success rates appear to follow a good rainfall year. However Risbey *et al.* (2000) has demonstrated the detrimental impact of feral cats on small vertebrates at Heirisson Prong and maintaining low numbers of feral cats (as well as foxes) on Peron Peninsula will no doubt benefit this fauna, allowing more rapid recovery after poor rainfall periods. The larger extant fauna appears to have benefited from fox and cat control.

Trapping along road transects has shown an increase in trap success of hopping mouse (*Notomys alexis*), goanna (*Varanus gouldii*), bobtail skink (*Tiliqua rugosa*) and blue tongue skink (*T. occipitalis*). Anecdotal evidence suggest that the larger king brown (mulga) snake (*Pseudechis australis*) and echidna have also increased. Opportunistic sightings of adult and juvenile woma pythons (*Aspidites ramsayii*) have also increased in the last 3–5 years and six adults were radio-tagged in 2003 to investigate habitat requirements and behaviour of this threatened species.

Future

Monitoring of fauna on Peron Peninsula will continue using the small vertebrate monitoring grids, comprehensive track counts and road transects. Two additional trapping grids were established in the dominant *Acacia ramulosa* (wanyu) shrub land in 2003 and an additional trapping session in winter will be added to the existing spring and autumn survey periods.

This comprehensive monitoring program will enable the success of translocations to be assessed as well as

providing long-term information on fluctuations in remnant fauna populations in the arid zone.

CAPTIVE BREEDING

Introduction

Initially, captive breeding on site was not proposed for *Project Eden*. It was intended that animals for translocation would be sourced either directly from the wild, or from other captive breeding facilities, such as Perth Zoo, or Monarto Zoo, South Australia (Morris 1995). However, in 1996 CALM agreed to the establishment of the Peron Captive Breeding Centre (PCBC). This allowed species that were restricted to Bernier and Dorre Islands (such as the banded hare-wallaby and western barred bandicoot), or with limited mainland distributions (such as bilby and malleefowl) to be bred in sufficient numbers for translocation without compromising the viability of the small wild populations. Additional staff were employed to manage this facility and Commonwealth World Heritage Funds obtained in 1996/7 to construct the pens and to collect founder animals from Bernier and Dorre Islands. Ongoing support from the World Heritage fund had been received until 2002/03.

Of the 15 mammal species that are now extinct on Peron Peninsula, up until November 2002 the following species were sourced from elsewhere and bred at the PCBC for translocation:

- bilby (*Macrotis lagotis*)
- western barred bandicoot (*Perameles bougainville*)
- banded hare wallaby (*Lagostrophus fasciatus*)
- mala (*Lagorchestes hirsutus* mainland form)

Other mammal species considered suitable for translocation are listed in Table 7 and would either be captive bred elsewhere, or taken directly from the wild (see Translocation below). In addition, the malleefowl (*Leipoa ocellata*) was selected for artificial hatching and captive rearing to complement the excellent work done by community groups in the WA wheatbelt in conserving this species.

TABLE 5

Numbers of animals involved in the captive breeding program on Peron Peninsula.

SPECIES	SEX	FOUNDER #	TRANSFERRED TO OTHER FACILITIES	RELEASED ON PERON PENINSULA	RESIDENT (AS AT NOV 2002)	TOTAL ANIMALS
Western barred bandicoot	female	18	7	0	16	23
	male	12	4	0	15	19
Banded hare-wallaby	female	13	0	6	17	23
	male	12	0	12	21	33
Bilby	female	10	1	30	20	51
	male	13	5	24	15	44
Mala	female	18	0	7	26	33
	male	11	0	9	21	30
Malleefowl	not sexed	105 eggs collected, 90 hatched	0	67	0	67
TOTAL		197		155	151	323

The numbers of founders for each species are shown in Table 5. The PCBC is a member of the International Species Inventory System (ISIS) and provides updates on the breeding colony for international databases, and the Australian Bilby Studbook.

Reasons for captive breeding at Peron

Captive breeding was undertaken at Peron for several reasons:

- Financial and logistical limitations to source large numbers of animals from wild populations.
- The small size and fragility of remnant island and mainland populations, making it susceptible to decline from removal of large numbers of individuals and disturbance from capture activities necessary in translocations.
- At the time, there was no captive breeding of the required species in WA.
- Acclimation of the animals to the habitat and environmental conditions that they were to be released into.
- Significant financial support from the Shark Bay World Heritage Area and consequent Commonwealth funding.
- Requirement for the Department to maintain control over captive breeding and management of species.

Facilities

The facilities at the PCBC comprise animal breeding and holding pens covering approximately 1.5 ha. and an animal health facility. The first animal pens were those constructed in November 1996 to house malleefowl chicks. These were later used to house surplus bilbies. Thirteen dedicated bilby pens, capable of holding 33 animals, were constructed in 1997 and 1998. Thirty-two dedicated western barred bandicoot pens, capable of holding 64 animals, were built in 1998. Thirty-five pens to hold up to 95 mala and banded hare-wallabies were built in February 1998.

The animal health facility comprises two transportable buildings which house staff facilities, food preparation area,

veterinary treatment room, laboratory and cage room/intensive care, and a storeroom. The facility has its own generator for power supply and battery back-up. Brackish water is provided from an artesian bore at the Peron Homestead and fresh water is carted from Denham.

Results

The total number of animals produced at the PCBC between 1996/97 and November 2002 was 216. This figure is derived from the total animal number (323) minus the number of mammal founders (107) (Table 5). The total cost of producing these animals was approximately \$898 000 (Table 6), or \$4157 per animal. CALM contributed 42% of these costs, or \$1759 per animal. Total maintenance costs per animal, that is without capital expenditure included, was \$3120 per animal.

Malleefowl

Malleefowl eggs were collected from several sites in the northern wheatbelt in December 1996 and again in November 1997, and incubated to hatching in Denham. In 1996, 56 eggs were collected and 50 of these hatched successfully. Eight of these chicks subsequently died for various reasons. In September 1997, another 49 eggs were collected and 40 of these hatched successfully. A total of 67 malleefowl have been released at 6–12 months of age.

The artificial incubation and captive rearing of chicks to 6–12 months of age proved extremely successful at PCBC. Overall success rate from 105 eggs collected to 67 birds released was 64% (86% hatching success and 74% 'fledging success').

Eggs were collected from 18 different mounds (an effective founder population of 36 individuals), providing a good theoretical representation (> 98%) of the heterogeneity of the wild population, and an excellent basis for establishing a new population. This large number of birds released with a high estimated survival of radio-tagged birds, influenced the decision to discontinue further releases unless monitoring of the released population indicated a need to supplement at a future date. Subsequent monitoring has indicated good recruitment and dispersal and there is no need for further captive breeding or translocations at this stage.

TABLE 6

Costs of establishing and maintaining the Peron Captive Breeding Centre. (External funds in 1997/98 were from the Coles Bilby fund and World Heritage funding, other years only from World Heritage).

YEAR	CAPITAL EXPENDITURE \$		MAINTENANCE EXPENDITURE \$		TOTAL \$
	CALM	EXTERNAL	CALM	EXTERNAL	
1996/97	14 000		30 000		44 000
1997/98		140 000	62 000	30 000	232 000
1998/99		50 000	62 000	31 500	143 500
1999/00			62 000	53 500	115 500
2000/01	6 000	14 000	64 000	76 000	160 000
2001/02			64 000	99 000	163 000
2002/03			16 000	24 000	40 000
TOTAL	20 000	204 000	360 000	314 000	898 000

Bilby

The bilby captive breeding program commenced in August 1997 with 10 wild caught animals from the Pilbara and Kimberley regions of WA. Additions to the breeding stock have been made from other captive colonies (Kanyana, Alice Springs Desert Park, and Monarto), as well as additional wild caught animals. All have come from either WA or the Northern Territory, none from western Queensland, as these are considered to be a different stock. Up until October 2002, 72 bilbies have been raised to adult at Peron and 55 of these have been released into Francois Peron National Park. In addition, seven animals have been traded with either Kanyana or Monarto. Over the five years of this program, 32 of the total of 140 bilbies born have died, however the colony has still increased by a factor of three in this time.

The strategic plan recommended topping up the bilby population in FPNP for up to five years. Captive breeding needs to continue to allow this to occur and additional wild caught animals would benefit the colony and the Australia-wide captive animal gene pool. Captive bred bilbies from Peron could also be used for translocations to other parts of mainland WA as part of the broader *Western Shield* program.

Western barred bandicoot

Thirty western barred bandicoots (18 female, 12 male) were captured by hand on Bernier Island (Red Cliff and Hospital Landing) in April 1998 and transported to the PCBC by helicopter. Initially the rate of breeding success for the bandicoots was high, reaching sufficient numbers for translocation by early 2000 (~80 animals in the first 2 years despite the population remaining un-supplemented). However, feral cat control had not been as successful as hoped and release plans were suspended. Breeding had to cease to stop overcrowding in the pens, as there were no alternative release sites available. Efforts to re-engage the breeding program in early 2001 were unsuccessful and the captive population had declined to 42 animals by September 2002. In addition *Chlamydia* infections and a wart like disease became prevalent at the PCBC and other captive colonies (Bodetti *et al.* 2003) and an intensive research program was commenced with Murdoch University to try to determine the cause of this, and any treatment. This is an unresolved issue with this species in captivity, but a nationwide interagency working group was established for its investigation. Nearly half (41/83) of the colony has died over five years, an annual mortality rate of 11%, and the colony has only increased marginally in this time (from 30 to 42 animals). Until the issue with disease can be resolved, it is considered that this colony is currently unviable and it is being wound down, whilst still contributing to investigation of disease entities discovered in many captive and some wild populations. Faure Island has been identified as a suitable reintroduction site for western barred bandicoots, however founder stock would need to be sourced from disease free locations (possibly Heirisson Prong or Dorre Island).

Banded hare-wallaby

Twenty-five banded hare-wallabies (13 females, 12 males) were collected by hand on Bernier Island (Red Cliff Bay and Hospital Landing) in April 1998. A total of 31 have been raised successfully at Peron and 18 of these were released into FPNP in July 2001. This colony has had an annual mortality rate of 5.4% (18/74 have died over 4.5 years), however the population has still increased two fold in this time. Because of the seasonality of breeding and long pouch life in this species, rate of population increase is not as rapid as initially expected.

The banded hare-wallabies released in July 2001 did not persist because of excessive feral cat predation (Hardman 2003) and no further releases of this species will be made until feral cat abundance has been reduced significantly. Captive breeding will continue so that sufficient numbers (*ca.* 40 animals) are available for release. Captive bred banded hare-wallabies from PCBC could also be used for translocations to other parts of mainland WA. Faure Island has been identified as a suitable site for reintroduction of this species.

Mala

Twenty-nine mala (18 female, 11 male) were taken from the 'Mala Paddock' in the Tanami Desert by Parks and Wildlife Commission of the Northern Territory staff and Aboriginal custodians in July 1999. Mainland mala were selected over the Bernier / Dorre Island animals for *Project Eden* because genetic variation is greatest in the mainland form and an abundant and easily accessed population existed in the Northern Territory. It was also believed that these animals would be better arid and predator adapted than the island animals.

This species has bred well in captivity and sufficient numbers were obtained for a release in July 2001 (1.6 years). There has been an annual mortality rate of 6.3% over three years (14 / 74 have died), however breeding has continued at a high rate. The mala colony is currently beyond capacity and additional holding pens are required. Breeding is currently being restricted until suitable release options, either at FPNP or elsewhere, are found.

Future

The captive breeding program at PCBC has been successful in meeting the objectives set for it in 1997 and the animals that are produced are healthy and adapt well when released.

PCBC is able to continue its production of bilbies, banded hare-wallabies and mala under its current operations. Bilbies have been shown to be able to survive the current levels of cat abundance and ongoing restocking is required for at least the next three years. Bilbies could also be provided from the PCBC for other arid zone releases in WA. If feral cat abundances cannot be reduced below current levels, further releases of banded hare-wallabies and mala at Peron will probably not proceed. If cat control at other mainland sites is shown to be more

effective, the PCBC could provide these species for translocation. Further captive breeding of western barred bandicoots will not occur at the PCBC unless the disease issue can be managed.

The PCBC is well placed to be able to provide animals for arid zone releases. There is already substantial infrastructure and expertise in place and the animals would be acclimatised to an arid environment. It has also demonstrated that it can produce the animals when required. The PCBC has the capacity to produce large numbers of bilbies, banded hare-wallabies and mala for both ongoing *Project Eden* translocations, or translocations to other sites. However, some issues need addressing for this to proceed effectively:

- Program for release of captive bred animals at PCBC – no further release of ‘cat sensitive species’ such as mala and banded hare-wallabies will be made at FPNP until feral cat numbers are significantly reduced. If this cannot be achieved in the next 12–24 months alternative release sites will need to be found for these species. It is likely, however, that other potential mainland release sites will also need to be able to effectively control feral cats before any further releases are undertaken. Other options for release sites of PCBC animals include Faure Island and Dirk Hartog Island.
- The disease issue with the western barred bandicoots needs to be resolved before any further captive breeding occurs at PCBC (or elsewhere). This obviously impacts on planned translocations of this species on the WA mainland.
- The staff workload involved in managing the husbandry (especially maintaining the hygiene of enclosures) was significantly under-rated, so staffing requirements were under-estimated at 2 full-time staff. There are currently 2.5 full time staff dedicated to the PCBC and this is 0.5 to 1.0 staff short of what is required to manage 120–170 animals in captivity. This gap has been partially filled with the use of volunteers, however their availability is limited and sporadic.
- The original design of enclosures was based on the production of smaller numbers of progeny (15–20) that would be released more frequently in a flow-through type situation. Hence there is not sufficient accommodation to hold animals until the required 40–50 animals are available for a single release (while maintaining a core ongoing breeding group). This situation, along with the delayed release date for several species, has created significant overcrowding issues that aggravate the inadequate staffing situation and affect health, stress levels, and reproductive rate within the colony. An additional, large (100 ha.) pen is required to hold large numbers of animals (up to 100), an estimated cost of approximately \$120 000.
- Commitment by CALM to fund the complete running costs of PCBC as continued World Heritage Funding is insecure and would be inappropriate if the PCBC was producing significant numbers of animals for

release outside of Shark Bay World Heritage Area. This amounts to approximately \$100 000 annually.

TRANSLOCATIONS

Introduction

The original draft Operations Plan for reintroductions (Morris, 1995) planned the translocation of seven mammal species. These species were determined on their previous presence on Peron Peninsula (Baynes 1990, Table 1) and on the availability of founder animals for either direct release or captive breeding. The draft strategic plan for captive breeding and translocations (Morris and Sims 1997) proposed 11 species of mammal and the malleefowl be translocated to Peron Peninsula (Table 7). Most of the species identified for translocation are listed as threatened under the WA *Wildlife Conservation Act* 1950 and the Commonwealth’s *Environment Protection and Biodiversity Conservation Act* 1999. Since 1997, four mammal species (woylie *Bettongia penicillata*, bilby *Macrotis lagotis*, banded hare-wallaby *Lagostrophus fasciatus*, and mala *Lagorchestes hirsutus*) and the malleefowl *Leipoa ocellata* have been translocated to FPNP.

All species selected for translocation, except the bilby, were species that had been previously recorded on Peron Peninsula, either as historical or sub-fossil specimens, but were no longer present in 1995 (Baynes 1990, Blakers *et al.* 1984). Another sub-fossil deposit survey was undertaken in 2000 (Baynes 2000) to further search for evidence that bilbies may have existed in Peron Peninsula. None was found, however additional sub-fossil evidence of several additional species were found and included on the list for potential translocations. There had been an unconfirmed report of a bilby at Hamelin Station in 1980 (Peter Mawson, pers. comm.) and the habitat on Peron Peninsula was considered suitable for this species. The bilby was also continuing to decline in WA and translocation to a more secure site was considered to be beneficial to the overall conservation of this species. The translocation of this species (as a reintroduction) was approved in August 2000.

Given that the malleefowl, woylie and bilby had persisted on the mainland in the presence of introduced predators, albeit at reduced distribution and abundance, these species were selected for initial releases at FPNP. Following good early signs of persistence of these species, trial releases of the more vulnerable banded hare-wallabies and mala were undertaken in July 2001. Translocation Proposals were approved for all translocations.

Malleefowl

Release and monitoring

The malleefowl was the first species to be hand raised and released into FPNP. In 1996 and 1997, 105 eggs were collected from 18 active malleefowl mounds within the Wheatbelt, Kalbarri National Park and Nanga Station, and

TABLE 7

Speices identified as potentially suitably for translocation to Peron Peninsula.

	MORRIS 1995	MORRIS 1997	FOLLOWING 2000	TRANSLOCATED 1996–2002	PERSISTING 2002–?
Woylie <i>Bettongia penicillata</i>	x	x	x	x	yes
Western barred bandicoot <i>Perameles bougainville</i>	x	x	x		
Rufous hare-wallaby <i>Lagorchestes hirsutus</i>	x	x	x	x	no
Banded hare-wallaby <i>Lagostrophus fasciatus</i>	x	x	x	x	no
Shark Bay mouse <i>Pseudomys fieldii</i>	x	x	x		
Greater stick-nest rat <i>Leporillus conditor</i>	x	x	x		
Tunney's rat <i>Rattus tunneyi</i>		x	x		
Chuditch <i>Dasyurus geoffroii</i>	x	x	x		
Red-tailed phascogale <i>Phascogale calura</i>	?	x	x		
Golden bandicoot <i>Isoodon auratus</i> / Quenda <i>Isoodon obesulus</i>	?		x		
Brushtail possum <i>Trichosurus vulpecula</i>			?		
Mulgara <i>Dasycercus cristicauda</i>		x	x		
Bilby <i>Macrotis lagotis</i>		x		x	yes
Malleefowl <i>Leipoa ocellata</i>		x	x	x	yes
Dibbler <i>Parantechinus apicalis</i>			x		

artificially incubated at the PCBC. Between 1997 and 1998, a total of 67 individuals between 6–12 months of age, were released onto FPNP, in groups of 3–5 birds, at 14 separate release sites. All were fitted with a permanent metal leg band and 24 (36%) were fitted with a radio transmitter in the form of a perishable necklace. Bird mortality and location was monitored for up to 6 months.

Adequacy of monitoring

Radio tagged birds were tracked daily, initially, and at least weekly after this, until the collar failed. Information obtained, included mortality, general location and dispersal movement. A small number of birds were tracked more intensively to provide more accurate locational data (bi and tri-angulation) and a rough indication of home range. These data are insufficiently detailed to provide statistically significant conclusions on home range sizes, but was sufficient to provide the important information (survival, activity and dispersal) to assess early success of the translocation.

Monitoring since the end of radio-tag life, has primarily involved incidental records of malleefowl tracks and bird sightings, along with the monthly CTC, and these are the current methods for monitoring the population. The search for new malleefowl mounds is on going and *ad hoc*, based primarily around other species monitoring activities and some targeted ground searches where high track activity has been observed. All of the known mounds are regularly monitored three or four times a year for nesting activity.

The CTC provides a standard 'transect' for monitoring dispersal and relative abundance, and along with incidental bird sightings, has been sufficient to assess population health over the long term. More regular monitoring of standard off track transects/grids would have been preferred, but shortage of skilled personnel and difficulty of terrain has prevented this. Reporting of bird sightings by staff and the public has been inconsistent and probably actually declined as the species has become more commonly seen.

Summary of results

During the initial monitoring there were no records of cat predation on any of the radio tagged animals, and the survival rate of released animals in the first six months was estimated at 90%. The sighting and track reports (Figure 9) suggest that the birds have dispersed throughout FPNP and into the southern part of Peron Peninsula. The sighting of a number of sub-adult birds plus animals without leg bands suggest that this species has established well and several new chicks have been observed since the 2002/03 nesting season. The first active malleefowl mound was discovered in 2000, with a total of six active mounds recorded to date. Malleefowl may commence mound building at one year old, but generally successful breeding does not occur until animals are greater than two years old. It is considered that this reintroduction has been successful and no further captive breeding or translocations are necessary. Monitoring of malleefowl abundance from CTC track counts, bird observations and nesting mound activity will continue.

Woylie

Release and monitoring

One hundred and forty seven woylies sourced from Dryandra Woodland and Batalling State Forest have been translocated to nine release sites in FPNP under different seasonal conditions, between 1997 and 2000 (Table 8). The Batalling population had been founded on animals

translocated from Perup in 1983. Thirty-four woylies were fitted with mortality sensing radio-collars. The first release of 12 radio-collared *Dryandra woylies*, involved releasing animals from a fenced enclosure at the release site after 1–2 weeks orientation and acclimation. After the initial trial release all subsequent animals were released directly into the wild ('hard' released), except for the group released into an opened, soft release pen in September 1999. There is no evidence that survivorship was dependent on release methodology (Table 8).

The second and third releases of 49 Batalling animals (8 radio tagged) occurred 4–5 weeks after the first (in late spring 1997). Early monitoring involved trapping along road transects near release sites and known locations of animals. The Fauna Monitoring Trapping Program (FMTP) was implemented in autumn 2001, as a biannual trapping session on a standard 'transect', run along the road network within the release area (encompassing all release sites).

Adequacy of monitoring

Animals were collared and radio tracked between 1997 and 2000. All first release animals were radio tagged and survival monitored over 2–3 wks before further releases were approved. First release animals were trapped and condition assessed prior to subsequent release. This monitoring intensity, however, failed to adequately predict the apparent poor survival of second/third release animals. Individuals from the first 2 release groups were monitored for mortality almost daily up to 9 months post release.

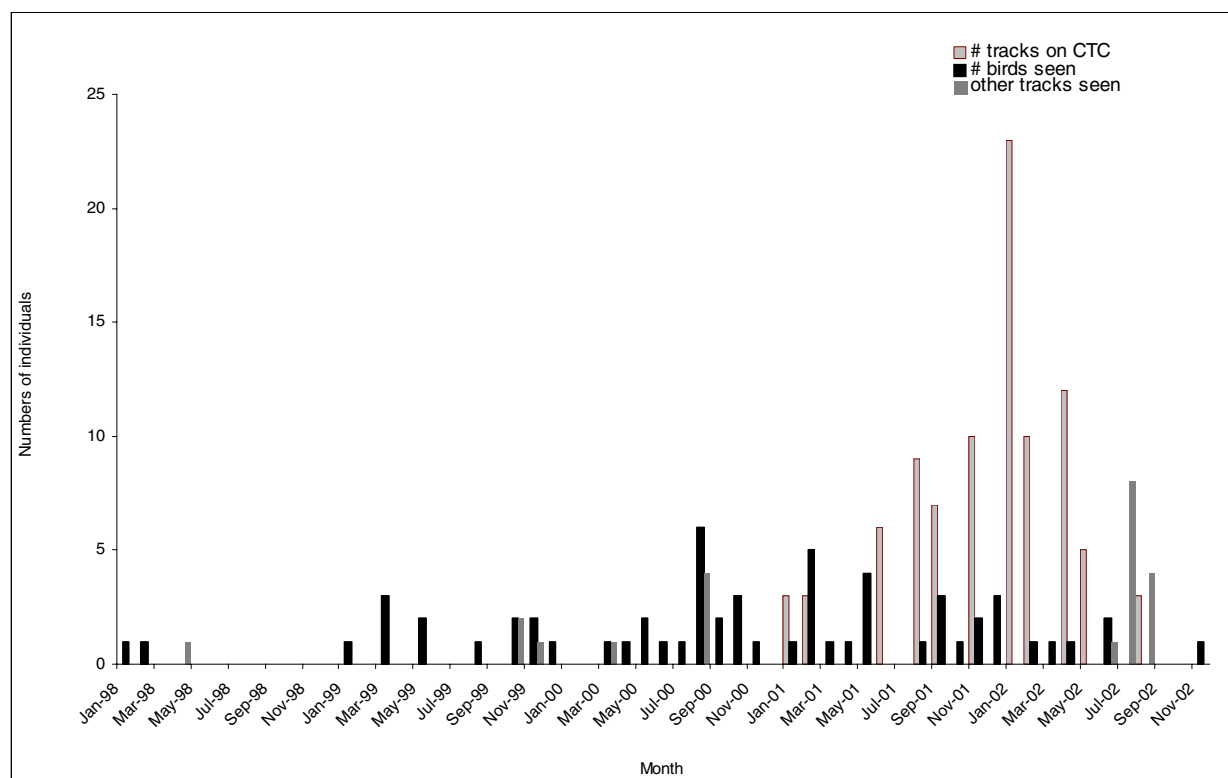


Figure 9. Number of malleefowl observations on Peron Peninsula.

TABLE 8
Details of woylies released into Francois Peron National Park.

DATE	RELEASE SITE	RELEASE TYPE	MALE	FEMALE	TOTAL	# RADIO COLLARED	SOURCE	# DEAD	KTBA AFTER 12 MONTHS
23/9/97	Woylie track	soft	8	4	12	12	Dryandra	4	5
29/10/97	Woylie track	hard	13	10	23	8	Batalling	6	1
4/11/97	Cyanide track	hard	13	13	26	0	Batalling	0	0
15/7/98	10 mile	hard	10	6	16	4	Dryandra	0	2
24/9/99	Woylie track	soft	5	8	13	4	Dryandra	1	4
24/9/99	Woylie track	hard	4	3	7	2	Dryandra	1	2
24/9/99	Aerial track	hard	4	10	14	4	Dryandra	0	1
13/9/00	Warren	hard	5	7	12	0	Dryandra	0	0
13/9/00	Cape Rose track	hard	5	7	12	0	Dryandra	0	1
13/9/00	Graveyard track	hard	5	7	12	0	Dryandra	0	1
TOTALS			82	75	157	34			

The intensity dropped off there after, to every couple of months dependent on available personnel, resulting in inconclusive identification of cause of mortality in several cases (although none were attributed to cat predation as the carcasses were intact). The releases in 1998 and 1999 only had follow up intensive radio tracking periods for the first 2–3 months, with intermittent tracking of animals every couple of months there after. Only five animals were tracked to their nests, with only 15 nests discovered.

From July 1998 to March 2000, more effort was put into trying to find the released animals through targeted trapping every 3–4 months in areas where woylies were known to be. This monitoring was insufficient to provide information on population dispersal and growth. In an effort to develop a non-biased method of monitoring the released population, the Fauna Monitoring Trapping Program (FMTP) was implemented in 2001, when a full time reintroduction officer was employed. In 2002, woylies were again fitted with mortality-sensing radio-collars and targeted trapping was employed (in addition to the FMTP) to determine the possible cause of the population decline that had occurred over the previous 18 months.

Results

The translocation of woylies to FPNP was the first time this species had been reintroduced to an arid environment within its former range. In 1999, a review of progress of woylie translocations 1997–8 to FPNP was prepared (Speldewinde and Morris 1999). Of the first 20 collared

animals released, seven died within three weeks (8% of first Dryandra, and 26% of Batalling radio tagged animals), possibly due to environmental / heat stress. Of the October 1997 release only one animal out of 23 individuals was known to be alive after 12 months, compared to five out of 12 for a release that occurred one month earlier, in September 1997. Similarly, none of the 26 woylies that were released in November 1997 was known to be alive after 12 months. Woylies shelter in above ground nests during the day and by October / November daytime temperatures in Shark Bay can reach > 35°C, which could be lethal to woylies without an adequate thermal refuge. Subsequent releases were made earlier in the year, in July 1998 and September 1999 and 2000. In addition, subsequently all animals were sourced from Dryandra as these were believed to be more arid adapted than the Batalling forest stock. However of the 70 woylies released in 1999 and 2000, only 9 were still known to be alive after 12 months. Twelve woylies were found dead, but mortality was not attributed to either fox or feral cat.

Targeted trapping at release sites resulted in a maximum of 32% of the released animals being caught as well as several new recruits. Most animals were in good body condition and most females showed evidence of breeding. Table 9 shows the number of recruits caught each year, from both target trapping and the FMTP. A total of 22 recruits have been recorded since October 1998, with evidence of breeding by second-generation animals. Table 10 shows the numbers of adults trapped during the FMTP.

TABLE 9
Number of woylie recruits trapped and radio-collared on Peron Peninsula.

YEAR	NUMBER OF WOYLIE RECRUITS TRAPPED	NUMBER OF MALES	NUMBER OF FEMALES	NUMBER OF WOYLIES RADIO-COLLARED
1998	1	0	1	1
1999	7	6	1	0
2000	3	2	1	1
2001	9	3	6	2
2002	2	1	1	2
TOTAL	22	12	10	6

TABLE 10
Number of woylies trapped during the Fauna Monitoring Trapping Program.

TRAPPING SESSION	TOTAL NUMBER OF WOYLIES TRAPPED	NUMBER OF MALES	NUMBER OF FEMALES	NUMBER OF NEW ANIMALS	NUMBER OF RECAPTURES
Autumn 2001	11	7	4	2	9
Spring 2001	9	3	6	4	5
Autumn 2002	5	3	2	1	4
Spring 2002	3	2	1	1	2

A recent drop in numbers of individuals caught in both targeted trapping and the FMTP (Tables 4, 9 and 10), suggest that the population may have declined over the last 18 months. As a consequence, radio-collars were fitted to all animals (9 in total – 3 founders and 6 recruits) caught in 2002, followed by intensive monitoring. From this, the first records of cat predation (33% of collared animals in 2002) on woylies on Peron Peninsula were obtained.

The woylie is still persisting on Peron Peninsula despite several factors (recent drought, poor initial selection of release season and/or source population, fluctuating cat numbers and predation pressure), which have probably contributed to its poor recruitment and precarious long-term population status over the last five years. The current population size may not be viable, but much has been learnt from the previous translocations. However, restocking with a large number (>100) of animals at a time when seasonal conditions are favourable and predation pressure at its lowest (winter), would determine if establishment of a long term, viable population is possible under the present predator levels. Use of mixed source animals and intensive monitoring of comparative survival and condition (genetic assessment of both source populations and recruited animals) would also resolve the question of potential unsuitability of Batalling woylies for all future arid land reintroductions.

Bilby

Release and monitoring

A total of 55 (25 male and 30 female) bilbies were released into five separate release sites in FPNP (most bred at the PCBC) between 2000 and 2002 (Table 11). Tail radio-transmitters were fitted to a proportion of all release groups. Two release techniques were compared to determine the most suitable strategy for future releases. The 'soft release' option involved holding a group of animals in a 3ha enclosure for 2–3 weeks before openings were made in the fence and they are able to leave of their own volition. The 'hard release' technique simply involved releasing a similar size group directly into the wild at the same time. In both soft and hard releases, bilbies were released at dusk into artificial burrows constructed from PVC pipe.

Adequacy of monitoring

A high proportion (53%) of bilbies released were fitted with mortality sensing, tail mounted, radio transmitters, with the tag replaced when the 2–3 month battery life expired. Animals were monitored 2–3 times weekly with regular visits and recordings of the burrows used.

TABLE 11
Numbers of bilbies released into Francois Peron National Park.

DATE	RELEASE SITE	RELEASE TYPE	# MALES	# FEMALES	TOTAL	# RADIO-COLLARED	# DEAD	KTBA AFTER 6 MONTHS
12/10/00	Woylie track	soft	2	3	5	5	2	4
24/11/00	Woylie track	soft	2	2	4	1	0	1
12/10/00	Cape Rose track A	hard	2	1	3	3	0	2
16/11/00	Cape Rose track A	hard	2	3	5	4	1	4
23/5/01	Woylie track	hard	5	3	8	3	1	3
23/5/01	Cape Rose track B	hard	4	4	8	3	1	3
22/5/02	Cape Rose track A	hard	4	7	11	5	0	1
1/8/02	Cyanide track	hard	4	7	11	5	1	

Information obtained, included the type and number of burrows used, surrounding vegetation, general movement and mortality. Aerial searches were carried out when animals were unable to be found on the ground, however these are generally unsuccessful due to the limited range of the transmitters. Known burrows were trapped when emerging young were expected, and all release areas were trapped every two months.

The captures recorded in the FMTP provided a good unbiased comparison between trapping sessions to help determine the initial dispersal and survival of released Bilbies in the FPNP. However the FMTP is unlikely to be able to accurately estimate general population and recruitment levels, as it is generally recognised that 'wild' animals are extremely trap shy and captive-bred animals are generally more trappable. The recording of all tracks found through the monthly CTC and general observations by foot and vehicle throughout the FPNP is another technique used to show the distribution of dispersing animals.

The long term survival and dispersal of released bilbies was difficult to determine due to the short life and limited range of radio-tags that can be used on this species. Animals that were been tracked for up to 12 months suddenly disappeared and it was not clear if they have died or moved away. Some individuals were recaptured some distance from initial release areas suggesting that bilbies are quite nomadic and will move quite suddenly to a new area. More information on the dispersal patterns of this apparently mobile species is required, particularly if this species is to be translocated to other mainland sites. Of particular interest is the relationship between movement patterns and climatic events, such as rainfall and the impact these may have on food and refuge resources. This can only be resolved by tagging individuals with longer life (>12mths) and greater range (3–5 km) transmitters. This may require reconsidering the possibility of using an appropriate neck mounted collar transmitter, rather than the tail mounted transmitters currently in use.

Similarly, the reluctance of wild individuals (hence recruits) to go into traps made monitoring of recruitment and population dispersal difficult. The long term monitoring of burrowing/foraging activity and tracks is the most likely method that will give an indirect measure of population abundance. Continuing CTCs and a planned program of standard track surveys after rain will be employed to provide this information.

Because of the unknown movement patterns of bilbies, and their difficulty to trap, the actual location and survivorship of a high proportion of the released animals was unknown. While 81% of the released animals were known to be alive after six months, only 7% were known to be alive after 12 months. To date no radio tagged bilby has been predated by foxes or feral cats. Four bilbies have been trapped in leg hold traps set to trap feral cats, and have had to be euthanased. Another two were found dead in their burrows. Regular target trapping in the release areas has shown that the animals are in good condition and that a high proportion of the females, are carrying

pouch young. There have been five known recruits to the population since 2001, with evidence of breeding by second-generation animals.

It is too early to determine the long-term success of the bilby translocation. However, there have been no mortalities attributed to foxes and feral cats. Trapped animals are generally in good condition and breeding (including second generation) and recruitment is occurring. These factors suggest that bilbies may be able to persist with the current level of feral cat abundance and successfully establish on Peron Peninsula.

Banded Hare Wallaby and Mala

Both hare-wallaby species were released almost simultaneously and monitored in a similar fashion, so are treated together here.

Release and monitoring

Eighteen captive bred banded hare-wallabies (12 males and 6 females), bred at the PCBC, were released in two groups in July 2001 into FPNP. The 'soft' and 'hard' release strategies were trialled and every individual was fitted with a mortality sensing radio-collar. In August 2001 a group of 16 mala (9 males and 7 females), bred at the PCBC, were released at one 'soft' and two 'hard' release sites. All animals were fitted with a mortality sensing radio-collar.

All animals of both species were monitored on a daily basis for the first couple of months, easing off to every second day until no animals remained. Animals missing on ground searches for more than one week were searched for by aircraft. Mortality, daytime refuge sites, night time home ranges (triangulation) and habitat preferences were obtained for all animals. Faecal pellet collection for parasites and possible diet analysis also occurred. Intensive monitoring was facilitated by this work being undertaken as a Master of Science project by a student from Edith Cowan University (Hardman 2003)

Trapping of the animals in the soft release pen occurred before they were released as well as follow up trapping in the release areas 2-3 months after all animals had been released. Target trapping continued to occur every 3-4 months there after to check on body condition and reproductive status.

Adequacy of monitoring

These two species have been monitored the most intensively of all species released on FPNP to date, and reflects the additional assistance provided by the Masters student. He was able to collect valuable information on home range, mortality and the response of the species' to reintroduction in this environment. The intensity of the radio tracking enabled early detection of mortalities and thus relatively fresh carcasses. This enabled a more conclusive assessment (than in the case of woylies) of the cause of mortality plus the opportunity, in some cases, to act on the finding.

The use of aerial searches enabled most of the dispersing animals to be found, yet four animals (three banded hare-wallabies and one mala) remained unaccounted for. The availability of a student to spend many hours searching for missing animals and gathering refugia details and home range information was extremely beneficial.

The banded hare-wallaby was relatively easy to trap and this assisted in the relative high frequency at which they were captured. The difficulty of capturing the mala, and the stress involved in handling, limited the frequency that this species was trapped. The individuals of this species that dispersed should have been captured and checked more frequently for collar refits as this may have prevented some mortalities attributed to collar complications.

Results

The banded hare-wallaby population survived for 10 months in the presence of feral cats. Most of the animals exhibited an initial drop in weight 1–2 months after release, but most of this was the excess weight the animals were carrying as a result of being captive bred. Regular trapping there after showed that all animals were in good condition and their weight stabilised. As this species is a seasonal breeder there were no signs of breeding until autumn of 2002. While all females handled showed signs of breeding, no individuals were recruited to the population.

All banded hare-wallaby mortalities were attributed to cats, but most of these only occurred towards the end of a very dry year (2001) when other prey (particularly mice) was possibly less abundant. Cat predation tended to occur in clusters, with short periods of high mortality, followed by several months of no incidents. The six banded hare-wallabies that remained, by choice, at the hard release site, survived in the presence of cats for nine months, before all were killed in a 3–4 week period.

The mala persisted for nine months in the presence of cats in the immediate release area. All recaptured females were carrying pouch young and two animals were recruited to the population. Unfortunately the numbers gradually declined due to a combination of factors including cat and wedge-tail eagle predation, stress and collar related mortalities. This species also suffered an initial loss in weight before stabilising and this loosened the fitted radio-collars to the extent that front feet became caught and animals became hung up on vegetation. When only four animals remained alive they were held in the soft release pen for two months whilst an effort was made to reduce the number of cats in the immediate area. Two cats were caught in leg hold traps and when there was no further evidence of cats in the area, the mala were once again released. The remaining four animals were dead within one month of re-release. These results mirror those found by Gibson *et al.* (1994) and confirm the high vulnerability of mala to feral cat predation.

The Average Monthly Rainfall (AMR) figure for the year 2001 was 14 mm. During the 10 months that the

animals were alive the AMR was 9 mm, and the preceding 12 months was 14 mm. This dry period might have had an influence on the abundance of prey that the cat would usually prefer, thus forcing the predator to look elsewhere. This dry weather might also have affected the behaviour of the two species, making them more prone to predators.

The translocations of the banded hare-wallaby and mala were unsuccessful. All animals either died or are unaccounted for. Unfortunately the release of both hare-wallaby species coincided with a low rainfall year and small vertebrate fauna abundances were low. This may have increased the predatory pressure from feral cats on alternative prey species such as the hare-wallabies. The majority of both species did not disperse far from the release sites and their weights and body condition were good, suggesting that the release habitats were suitable. The mala were able to recruit to the population in the nine months of their survival, while three banded hare-wallaby females were close to weaning their young when they were killed 10 months after release. A successful translocation may be achieved by using a larger release group (> 40 animals at a time) in a more favourable year, which may be able to produce more recruits to offset any mortality. This may be particularly so for the mala where predation was a lesser cause of mortality.

Conclusions and future translocation plans

The original timeframe identified that translocations were to commence in 1997 and be completed by 2002, with ongoing monitoring after this date (Morris 1995). The woylie and the Shark Bay mouse (*Pseudomys fieldi*) were to be the first species released in 1997, followed by the greater stick-nest rat in 1998 and western barred bandicoot, mala and banded hare-wallaby in 1999. The chuditch (*Dasyurus geoffroii*), a native predator, was to be released after these other species had become established. All translocations would be dependent on 'satisfactory feral animal control' (Morris, 1995). The malleefowl and bilby were added to the species to be translocated in 1997.

Of the five species translocated to the FPNP, the malleefowl and bilby (and perhaps the woylie) are showing signs that they might be able to persist in the presence of the current level of feral cats. Even at lower levels of feral cat abundance the two hare-wallaby species failed to persist. Consequently it is unlikely that several of the other 'feral cat vulnerable' species identified for translocation to the FPNP, such as western barred bandicoot, greater stick-nest rat, and Shark Bay mouse, will be released unless feral cats can be controlled at significantly lower levels, or suitable refuge sites are identified. The chuditch and red-tailed phascogale have coexisted with feral cats at other mainland sites and may be suitable for reintroduction to FPNP. Clearly the list of mammal species suitable for translocation to Peron Peninsula needs to be reviewed.

Another strategy for ongoing translocations of 'cat sensitive species', for example, woylies and hare-wallabies in the presence of feral cats is to only release large numbers

of founders at times of abundant food supply, alternative prey for feral cats (rabbits and small native vertebrates) and thick refugia cover. Sinclair *et al.* (1998) recommend releases of the largest number of animals to increase the likelihood of successful establishment of prey species in the presence of introduced predators. They also proposed that releases into large areas of good habitat enhance survival as predators are less efficient in large patches. However, these measures do not replace the need to reduce the numbers of introduced predators, and should not be viewed as an alternative strategy, rather a complementary one.

Consideration also needs to be given to prevailing El Nino/La Nina drought cycles when planning translocations. Perhaps the best opportunity for establishing populations of small macropods and bandicoots on Peron Peninsula would be to construct a large (> 50 ha) cat proof enclosure which could function not only as a holding pen for larger numbers of captive bred animals, but also a protected refuge for self-sustaining populations. Alternatively the neck of the 'peninsula' to the west of Big Lagoon could be fenced, cats eradicated in this smaller area, and native mammals released.

CALM Policy # 29 (CALM 1995) requires that a translocation proposal be prepared for the translocation of any threatened taxa in Western Australia. While details of post-release monitoring must be provided in this document, criteria for success or failure are not explicitly required. No criteria for success or failure were established for the *Project Eden* translocations. Obviously, total or near total loss of translocated individuals would indicate a failure (as happened with mala and banded hare-wallabies), however where a population may persist at low numbers for some time (for example, the woylie), the outcome of the translocation is less clear. Morris (2000) attempted to address this by suggesting that a series of sequential criteria might be appropriate. This is an issue for other *Western Shield* translocations as well and needs to be addressed across the program.

FIRE MANAGEMENT

Early aerial photographs of Peron Peninsula indicate that there has been a long interval since fire and probably only small patches of vegetation were burnt. However, anecdotal accounts from long time residents suggested that large fires are possible and that a large portion of the peninsula was burnt in the 1950s. A fire management plan was considered necessary once *Project Eden* commenced to protect translocated fauna and facilities. Two fire buffers, each 100 m wide were established as part of that strategy and have been utilised for gathering fire succession data on plants. In addition, a cleared 20 m firebreak was installed around the captive breeding facilities.

The fire buffers traverse the peninsula in an approximate east-west direction and roughly divide FPNP into three similarly sized areas. The buffers were installed

in March 1997 using a combination of vegetation rolling and burning. Attempts at burning the *Acacia ramulosa* (wanyu) scrublands using standard aerial burning techniques used in forest areas, failed to get fire to spread, possibly because of the high salt content of the leaves. High salt content retards burning of plants even when the foliage is dry (for example see: http://www.rfs.nsw.gov.au/index.cfm?cid=87&the_start=7, and <http://www.risklogic.com/Dec2003.html>). At the time, tests of the *Acacia* shrubs showed salt loads for these shrubs to be in the order of 40 times that of shrubs for the forested areas in the South West (Ward 1997). Fire did burn well in the *Triodia* grassland dominated areas. Recovery of this habitat type has been slow in the six years post-fire, with new *Triodia* hummocks taking three years to become visible, and average hummock size in late 2002 only 10–20 cm in diameter.

In addition to providing protection from fire, these buffers provided an opportunity to examine the response of the native vegetation and fauna to burning. Regular monitoring of plant species composition and abundance has shown a shift in species composition between burnt and unburnt areas. More than one third of the species identified in the burnt areas do not appear in the long unburnt vegetation. However, by 2001, both burnt and unburnt plots had a significant increase in species composition. This was probably due to high rainfall events which favoured plant growth. It is also likely that these good conditions are promoting the recovery of vegetation from 100 years of sheep grazing. Fifty-one percent of the new species in the unburnt plots are different to those in the burnt plots and the burnt plots have about 58% of species uniquely different from unburnt plots. The majority of these species are shrubs suggesting a general recovery of vegetation. The small difference between burnt and unburnt plots may be the result of fire-induced species.

Vegetation transects to measure cover and structure in the undisturbed wanyu shrubland indicated that a third of the plants were dead and in a senescent state, which has most likely caused a reduction in productivity. This declining health and vigour of the vegetation requires that some habitat maintenance be done to restore vitality and provide optimum conditions for developing colonies of reintroduced animals. Many mammal and bird species depend on vegetation to provide food and shelter and once habitat suitability drops off they need new more suitable areas to move into. With the long interval since fire on the peninsula vast areas of the vegetation are in a similar state of decline.

Grazing pressure was also measured on the burn buffers by measuring species diversity of plants outside of the fenced plots and comparing with results from plot data. This showed that there was a dramatic reduction (70%) in species diversity and abundance for the grazed areas. Most of the grazing was from goats and rabbits and observations showed that rabbits were digging down beside the newly sprouting plants and eating the fleshy parts below ground. This has had a serious impact on

vegetation recovery for the burnt ground and for future burning operations rabbit and goat control should be factored in as part of the operation.

It is recommended that patch burning be used in FPNP to promote plant growth and diversity, and hence provide suitable habitat for translocated fauna species. Rabbits and goats should be controlled in recently burnt areas to allow plant regeneration. Additional vegetation monitoring plots should also be installed so that all major soil associations are included. Relatively large areas of *Triodia* grassland previously burnt on south Peron in the 1990s have been invaded by buffel grass (*Cenchrus ciliaris*), with little evidence of *Triodia* re-establishing itself in these areas. Future fire management needs to include weed control strategies to prevent invasion of burnt areas by this aggressive species.

BUDGET

Introduction

The original operations plans prepared for *Project Eden* estimated some costs to run the different aspects of the project for the first few years, and a total of \$500 000 over the first two years was initially allocated by the then Executive Director. A large proportion of this (\$186 000) was spent on the construction of the 3.4 kilometre barrier fence at Shell Beach. However, the project commenced as an operational trial in broad-scale introduced animal management and fauna recovery, with an expectation that it would continue to evolve over time, depending on subsequent findings. Consequently there was no provision to make accurate estimates of potential costs early in its life.

The original annual budget estimates for translocations ranged between \$7000 and \$20 000 for four species (Table 12). However, these failed to take into account the salary and transport costs required to operate in a remote and large reserve area, particularly to provide satisfactory monitoring of released and remnant fauna populations, necessary to adequately evaluate the success of the project. The strategic plan also changed considerably as the approaches and strategies changed, and the costs associated with these increased (Morris and Sims 1997).

More realistic estimates of ongoing costs were devised in 1999 (Table 13), and these indicated that up to \$250 000 per year was required for translocations. At this time, total annual costs were estimated to be \$600 000 to \$700 000. The annual budget allocations (CALM and external) and expenditure for *Project Eden* are shown in Table 14. Clearly, the location of *Project Eden* within the Shark Bay World Heritage Area, has allowed access to significant external funding opportunities. However this source of funding has diminished and further CALM funding support was required from 2003/04 on. Funding for the PCBC has been discussed above (Table 6), but it is worth emphasising that CALM has contributed less than half of the overall costs to date of this aspect of *Project Eden*.

An example of actual budget breakdown for the 2001/02 financial year (including external fund sources) is provided in Table 15. In this year, total expenditure was \$583 088, similar to the costs estimated in 1999 (Table 13). Funding for some areas such as translocations / fauna monitoring will need to be increased if larger numbers of animals are to be released and monitored.

TABLE 12

Estimated annual translocation costs for four mammal species at Peron Peninsula (from Morris, 1995).

SPECIES	1996–97 \$	1997–98 \$	1998–99 \$	1999–00 \$	2000–01 \$	2001–02 \$	TOTAL \$
Woylie	13 000	4150	4000	4000	4000	4000	33 150
SBM	4000	5250	1000	1000	1000	1000	13 250
GSRN	3000	4500	1000	1000	1000	1000	11 500
Chuditch	nil	nil	5000	5000	1000	1000	12 000
TOTAL	20 000	13 900	11 000	11 000	7000	7000	69 900

TABLE 13

Revised estimates of *Project Eden* costs.

ACTIVITY	1999–2000	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
Introduced animal control	200 000	200 000	175 000	150 000	125 000	100 000	100 000
Administration	110 000	110 000	110 000	110 000	110 000	110 000	110 000
Captive breeding	175 000	175 000	175 000	175 000	175 000	175 000	175 000
Reintroduction	50 000	150 000	250 000	250 000	250 000	250 000	250 000
TOTALS	535 000	635 000	710 000	685 000	660 000	635 000	635 000

TABLE 14

Annual budget allocations and expenditure for *Project Eden* from 1994/95 to 2002/03.

	1994-5	1995-6	1996-7	1997-8	1998-9	1999-00	2000-01	2001-0	2002-03
	\$	\$	\$	\$	\$	\$	\$	\$	\$
Administration	46243	20000	40000	* ¹	101306	*	141988	141897	128165
Fox/cat baiting	41217	43450	51200	*	157500	*	125512	130810	158249
Rabbit baiting	37100	4300	10200	*	12930	*	1000	1500	1000
Fencing	77000	100450	0	*	5000	*	5000	5000	4000
Public Relations	30000	10000	6000	*	15000	*	5000	1000	*
FireControl	21440	12500	7000	*	*	*	*	*	*
Science Division Operations	0	0	96750	*	47441	*	49000	72449	68774
District Operations	107000	88300	99953	*	81350	*	92500	67344	129907
Total CALM)	360000	279000	311103	310000	470000	470000	420000	420000	490095
External funds	0	0	5000	*	81500	67500	102000	126000	50000
TOTAL	360000	279000	316103	310000	551500	537500	522000	546000	540095
% Expended	55	110	73	157	91	92	100	103	
Budget									
Expend									
\$									
Total (CALM funds only)				3 040 103	2 742 848				
94/95 to 2001/02									
Total (CALM + external funds)				3 962 198	3 302 348				
1994/95 to 2001/02									

¹ Budget figures are either (a) unavailable (mostly because they don't fit the category format currently used and listed here) or (b) incorporated into management activities that would occur irrespective of *Project Eden* and thus not identifiable in the *Project Eden* budget as finite line items.

TABLE 15
Details of *Project Eden* budget allocation and expenditure for 2001/02.

ACTIVITY	BUDGET 2001–2002 \$	EXPENDED JUNE 2002 \$	% EXPENDED
1. ADMINISTRATION			
Project Officer salary and overheads	59 790	60 303	101
Data Management Officer (0.5FTE)	26 815	27 225	102
Consultant	13 500	12 629	94
Travel	4 000	1 580	40
Vehicle	7 500	2 967	40
Office / shed	13 900	17 548	126
Uniforms and training	7 392	3 695	50
Staff allowances	5 000	1 803	36
Radio Hire	4 000	5 077	127
TOTAL ADMINISTRATION	141 897	132 832	94
2. INTRODUCED ANIMAL CONTROL			
Fox/cat control and monitoring	129 810	158 935	160
World Heritage Funding	27 000	27 000	100
Other control – rabbits, goats, fence	7 500	3 922	52
TOTAL INTRODUCED ANIMAL CONTROL	164 310	189 857	116
3. CAPTIVE BREEDING			
PCBC Salary	51 149	48 092	97
PCBC Vehicle	15 000	13 769	92
PCBC Travel	1 300	0	0
PCBC Pen Maintenance	5 000	2 313	46
Total CALM Captive Breeding	72 449	64 175	89
World Heritage Funds	99 000	95 000	96
TOTAL CAPTIVE BREEDING	171 449	159 175	93
4. REINTRODUCTIONS			
Reintroduction officer Salary	45 444	49 104.73	108
Reintroduction Travel	1 300	1 680	129
Reintroduction Materials	9 600	7 759	81
Reintroduction Vehicles	11 000	15 454	140
TOTAL REINTRODUCTIONS	67 344	73 999.40	110
5. PUBLIC RELATIONS	1 000	223	22
TOTAL CALM BUDGET	447 000	461 088	103
TOTAL EXTERNAL FUNDS	126 000	122 000	
TOTAL 2001/02 BUDGET	573 000	583 088	102

COMMUNITY INVOLVEMENT AND COMMUNICATIONS

Project Eden has received considerable interest and attention from state, national and international scientists, volunteers and the media. It has involved many local school groups, and volunteer and work groups. Response has been positive and most visitors regard it as a unique and exciting conservation program. The project has also enjoyed the interest and support of all the respective State Environment Ministers and several Ministerial visits have been arranged to coincide with important activities such as cat baiting, and the first releases of bilbies. A website for *Project Eden* was established in 1999 and in 2001 it was linked to the Shark Bay World Heritage site at http://sharkbay.org/terrestrial_environment/page_06.htm. In 2002, the website was linked to the CALM Naturebase website (<http://www.calm.wa.gov.au/>).

Initially a staff member from the CALM Corporate Affairs Division was dedicated to *Project Eden*, however most community involvement and external communications have been integrated into all the research

and operational aspects of the project, rather than a stand alone activity. While the project has maintained a solid level of community interest there is the potential to be more pro-active in this area and increase the 'flag ship' profile for conservation issues (especially arid land) in Australia. The location, world heritage status and other attractions of Shark Bay, ensure a high number of domestic and international visitors are accessible to any messages imparted by *Project Eden*. It is regarded locally as a very positive activity of the Department.

Progress updates on *Project Eden* has been provided in the Landscape magazine and regular reports to the PEMC, the World Heritage Unit, IUCN Reintroduction Specialist Group Newsletters, Arid Zone Recovery Team meetings and updates, submission of Animal Ethics applications and Translocation Proposals. There are also additional internal reports prepared on specialist activities such as animal collection expeditions to Bernier and Dorre Islands, and disease screening trips to Bernier and Dorre Islands and Useless Loop. However, few articles have been published in refereed journals.

Some of the many community involvement activities, media attention and scientific collaboration the project has engendered in its life include:

Schools and educational activities

Staff have endeavoured to accommodate and interact with school and other educational institutions wherever possible. This is often difficult with no staff dedicated to or trained in educational methodology, but many opportunities to convey a conservation message and develop an appreciation of the unique Shark Bay environment have been taken advantage of.

These include:

- University of Notre Dame Field trip.
- Michigan State University Conservation Biology student excursion.
- Biosphere Week displays and talks to the Useless Loop and Shark Bay Primary School students.
- Talks to Curtin University environmental students, Geraldton TAFE students and students at Perenjori, Eneabba and Chidlow Primary Schools.
- CALM Bushrangers – Manjimup Senior High School.
- Gumula Mirnawarni Education Project talk.
- Involvement of the Yadgalah Aboriginal Corporation in the first bilby release.
- Use of the bilby release by Shark Bay Primary school students as a topic for display at the Geraldton Museum (the students were the winners of the Clem Burns Heritage award for this work).

Volunteers and work experience

Interest from both international and state university students in Biology or Environmental Science has increased significantly as the project has become known. There are now formal links with the Murdoch University Environmental Science Association, placing students for work experience, and similar arrangements are planned with Murdoch University's School of Veterinary and Biomedical Science students, who need to complete formal vacation work experience in different aspects of animal husbandry and medicine. Students from the Frankfurt University, Germany, have undertaken research on the physiology and behaviour of the captive and free-ranging native mammals on the peninsula. CALM Landscape Expeditions have been undertaken to assist in the fauna monitoring on Peron Peninsula annually since 1996, with up to 14 volunteers participating in each trip (Morris *et al.* 2000, 2002). In addition over 60 volunteers with Greencorp and Conservation Volunteers Australia have assisted in construction of *Project Eden* facilities.

Project Eden Community Advisory Committee

The *Project Eden* Community Advisory Committee was established in 1995 to facilitate community support for

the project and to ensure the community were kept informed about progress. Regular meetings were held in the first three years but have diminished since then. Maintaining community support for *Project Eden* is vital and it is proposed that the World Heritage Area focus community group take on this role. The World Heritage Community Consultative and Scientific Advisory Committees have shown considerable interest in, and support for *Project Eden*, and are regularly updated on progress at their meetings.

Media exposure

Numerous media releases have appeared in the local, State and national newspapers. Initially these focussed on the CALM proposal, the construction of the exclusion fence at Shell Beach, the release of RCD for rabbit control, and fox and feral cat control work. Later media articles focussed on the woylie, bilby and malleefowl releases. In 1997 and 2000, the Weekend Australian newspaper ran articles on Landscape Expeditions to Peron Peninsula. In 1998 the PCBC was a focus for media articles on the 'Chocolate Easter Bilby' program, which at that time was sponsored by Coles.

Project Eden has featured on several radio and television programs, including ABC Regional Radio (Karratha), ABC Radio National, the 'Postcards', 'Our WA' and 'Witness' TV programs, Swiss National TV and German ARD TV current affairs.

Popular articles

Visitor information brochures were prepared and made available to the local community and tourists. Annual *Project Eden* newsletters were produced from 1994-1997, but discontinued after this time. There have also been articles on *Project Eden* in popular magazines including Landscape, Australian Geographic, Asian Geographic, Wildlife Australia, Wildlife Magazine and Highway Magazine.

In 1994/95, several information board displays and signs were developed and placed in prominent visitor locations around Shark Bay (Overlander Roadhouse, Shell Beach, Peron Visitors Centre). The *Project Eden* Documentary 'Return to Eden' is screened regularly and is for sale at the Monkey Mia Visitors Centre, and information brochures on the Project are available both here and the CALM Denham Office.

Documentary films

Project Eden has featured in several national and international documentary films since 1999. These include 'Burning Heart' filmed for the National Geographic Society, 'Tales from a Timeless Land – Australia's great national parks' filmed for Nature WA, a Swedish Broadcasting Nature Department documentary, part of the BBC's 'Life of Mammals' documentary series, and the '10 Million Wild Cats' documentary filmed by German ARD TV.

Conference and workshop attendance, presentations and posters

Presentations on *Project Eden* have been made at several State and national forums. These include:

- the Arid Zone Recovery Team meetings in Broome 1997.
- the Australian Veterinary Association Conference, Brisbane 1997.
- the Australian Mammal Society Conference, Perth 1998.
- the Dampier 300 Conference, Fremantle 1999.
- the Australian Veterinary Association Conference, Perth 1999.
- Participation in interagency workshop on Faure Island with Australian Wildlife Conservancy, 2001.
- Participation at Arid Zone Recovery Team meetings, Warburton 2001.
- Presentation to CALM Corporate Executive 2002.
- CALM seminar 2002.
- Participation in interagency Western Barred Bandicoot disease workshop March 2002.
- Poster presentation at the Australian Mammal Society Conference, Warrnambool, Victoria July 2002.

Contributions to research, scientific papers and student projects

Several student projects, unpublished reports and popular articles have resulted from *Project Eden* activities and these are included in the References for this review. These include six Honours or post graduate studies (Adams 2000, Chavand 2003, Cheng 2002, Gleeson 1999, Hardman 2003 and Hill 2002), eight unpublished reports on various aspects of *Project Eden* (Algar and Angus 2000a, b; Baynes 2000, Brown 2001, Maxwell 2002, Speldewinde and Morris 1999, Ward 1997, and Morris and Sims 1997), and popular articles (Liddelow *et al.* 1997, Morris *et al.* 2000, 2002, Smith *et al.* 1996, Algar and Smith 1998, and Thomson and Shepherd 1995). Unfortunately there are few published refereed papers resulting from *Project Eden* activities and this aspect need to be addressed.

Interagency visitors

The project has also received visits by many other interagency staff and representatives, including:

- Don Langford (Parks and Wildlife Commission NT) & elders from Tanami Desert Warlpiri people.
- Bruce Leaver (Head of World Heritage unit, Environment Australia).
- Richard Wrangham (Head of Biology) Harvard University, Boston, USA.
- Dr Larry Dill (Head of ecology unit), Simon Fraser University, Vancouver, Canada.
- Dr Janet Mann, (Psychology and Animal Behaviour Professor), Georgetown University, Washington, USA

- Professor Elke Schleucher, University of Frankfurt, Germany
- Members of the Australian Mammal Society conference, 1998.
- Dr Vincent Serventy (retired).

OUTCOMES AND BENEFITS

Project Eden has provided an important site to assess factors affecting successful fauna translocations in the arid zone. In particular, significant advances have been made in our knowledge and understanding of the levels of fox and feral cat control required, and the relative vulnerability of native mammals to predation. Factors affecting the abundances of extant small vertebrate populations have also been assessed.

Significant progress has been made against the three primary objectives of *Project Eden*:

1. Introduced animal control – sheep have been removed and goats reduced significantly. Foxes have been virtually eradicated and feral cat control had been maintained at between 20 and 30 cats per 100 km of transect for most of the last four years. Baiting has been able to reduce cat abundance below this temporarily, and we now have some knowledge of which biotic and environmental factors influence effective uptake of baits by feral cats. It has also been demonstrated that cats can also be eradicated, in the short term, from specific smaller areas using hand baiting and trapping. If the total predation pressure from foxes and feral cats prior to any control is taken as 100%, and taking into account near eradication of foxes, the predation pressure now is probably about 25% of what it was in 1994. This has benefited the remnant native fauna as well. Information obtained from feral cat control trials at Peron has assisted in the development of an effective cat control technique on large offshore islands (eg Faure Island) and has complemented other large-scale introduced predator control work in arid parts of Western Australia (Algar and Burrows, this publication).
2. Translocation of native fauna – an excellent knowledge of the original mammal fauna of Peron Peninsula has been gained and from this has developed a strategy to reconstruct the fauna of the area. Five species have been reintroduced, three of these have persisted. Monitoring has provided information on mortality, habitat use, home range movements and behaviour of little known threatened species. Valuable information has also been obtained on successful captive breeding and animal husbandry techniques for some of these species. The successful captive breeding program has also allowed for stock to be provided for translocations to other areas (e.g. Faure Island) and will provide CALM with options for translocations to the arid zone when *Western Shield* expands.

3. Education and nature-based tourism development – a large amount of information about wildlife management in the arid zone has been generated from *Project Eden* and this has been disseminated to a wide range of people. The project has a local, national and international profile and support for the work has increased as the project developed. The work has also enhanced the World Heritage qualities of the Shark Bay area. The Department's profile as an organization that cares for and manages the natural environment in an effective and innovative way has been enhanced.

Further work is required to fully achieve the objectives set, however it is important that the investments and gains that have been made, are protected.

As *Project Eden* has developed and progressed, there have been many direct and indirect benefits generated, and these will continue.

1. Many years of continuous monitoring of an arid ecosystem has provided a large amount of information on:
 - Changes in feral cat, fox, goat, and rabbit numbers.
 - Remnant fauna populations.
 - Detailed cat population demographics and diet.
 - Weather and climate history.
 - Establishment of reintroduced species and habitat use.
 - Plant succession following fire.

Integration of these data has produced a detailed knowledge of arid ecosystem changes over time, responses to variables such as rainfall, and various management activities. Continued monitoring will provide insights into longer-term interactions between introduced fauna, native fauna and climate change in an arid environment.

2. A unique location to promote a greater understanding of arid ecosystems:
 - It is readily accessible and sufficiently large to support large fauna populations.
 - It is located in a World Heritage Area and will ultimately enhance these values.
 - The opportunity to involve a wide audience including local and indigenous people, students, researchers and the general public (national and international).
 - Increased education of the general public through websites, interpretation, talks and media.
 - The provision of information and assistance to other researchers involved in arid zone reconstruction programs, e.g. Heirisson Prong biosphere reserve.
3. The development of the Peron Captive Breeding Centre (PCBC) has provided many benefits to both *Project Eden* and other *Western Shield* activities. Captive breeding, veterinary and animal husbandry skills have

been brought into the Department and these have been used not only for *Project Eden* but also elsewhere in *Western Shield* and in collaborative projects with other agencies. It has also provided CALM with the ability to set its own priorities for captive breeding and translocation programs.

Specific benefits of the PCBC include:

- Staff have been assigned specifically to manage the PCBC.
- Simultaneous collection of banded hare-wallabies, boodies and western barred bandicoots from Bernier and Dorre Islands for the Dryandra captive breeding centre.
- Potential to provide captive bred animals for other release sites, e.g. Faure Island.
- Veterinary input to other District operations, e.g. post mortem examinations of marine fauna, treatment of injured wildlife.
- Ability to investigate disease issues and to provide advice on the management protocols, e.g. western barred bandicoot warts and *Chlamydia*.
- Ability to collect samples for genetic analysis, e.g. stick-nest rat, malleefowl.
- Direct links and exchanges of animals with other captive breeding facilities.

FUTURE DIRECTIONS

This review provides an opportunity to recognise the important advances made by *Project Eden* as well as the realistic limitations on future achievements, and to redefine the project's objectives to allow strategic and focused progress for *Project Eden* into the future.

The redefined objectives of the project should be:

1. To achieve and maintain a level of introduced predators that allow recovery of remnant fauna populations and reintroduction of a range of native species.
 - Achieve and maintain at least a 95% reduction of fox presence
 - Achieve and maintain a level of feral cat control that allows the successful reintroduction and persistence of a range of native fauna, including 'cat sensitive' species.
 - Retain a long-term goal of aiming for eventual eradication of feral cats on Peron Peninsula, if technology and conditions should present the possibility.
2. To reintroduce the array of native species that have the potential to survive and persist in the predator and environmental conditions achieved and maintained over time.
3. To enhance and protect the values of the Shark Bay World Heritage Area.

4. To recognize and maintain the values of the Peron Peninsula achieved so far, as a well monitored, documented and managed arid/coastal ecosystem that can be a valuable resource for understanding and testing ecosystem relationships and introduced animal control techniques.

Specifically there are a range of actions that are required to ensure progress with these objectives.

- The goat eradication program needs to be completed through intensive aerial and ground shooting activities.
- The development of an effective broad scale rabbit control program.
- The refinement and use of predictive models for feral cat control, in particular the dependence of good bait uptake on the previous years rainfall, and prey species availability.
- A review undertaken of the list of potential mammal species for translocation.
- The development of translocation programs that examine options for releases under a) current feral cat abundances, b) under significantly reduced feral cat numbers.
- Determining other *Western Shield* translocation requirements for animals bred at the PCBC, particularly to Dirk Hartog Island and mainland arid zone sites.
- Assessing the adequacy of existing staff and holding pens at the PCBC.
- Identifying sources of additional funding, particularly to cover the shortfall generated by loss of World Heritage funding.

Acknowledgments

Project Eden has involved many CALM staff, contractors and volunteers. Without their contribution the results described above would not have been achieved, and the authors would like to thank them for this. Ray Smith was the first project officer and contributed to many of *Project Eden's* early successes. CALM staff Brett Fitzgerald and Brad Barton were closely involved with project management from 1996–8. Terry Cowell provides excellent computing and database support. The feral cat and fox control program has been very labour intensive and we would thank the following: Ross Mack, Christopher Trethowan, Terry Cowell, Marika Maxwell, Gary Desmond, Mark Britza, Mark Charles, Steve Triton, Dave Algar, Joanne Sinagra, John Angus, Rob Brazell, and Bruce Withnell. The fauna monitoring and translocation programs were initiated by Peter Speldewinde, often with volunteers. There has been assistance with the captive breeding facility from Carolyn Garavanta, Natalie Dul, Karen Miller and Kim Pearce. Science Division staff have been involved in the project

since its inception, in particular Neil Burrows, Bruce Ward, Colin Ward, Alex Robinson (deceased) and Graeme Liddelow. The authors also thank Dr Ken Johnson and an anonymous reviewer for their constructive comments on the manuscript.

REFERENCES

- Abbott I (2002) Origin and spread of the cat *Felis catus* on mainland Australia with a discussion of the magnitude of its early impact on native fauna. *Wildlife Research* **29**, 51 – 74.
- Adams P (2003) 'Exchange of parasites and diseases between native mammals and feral cats.' Ph.D. thesis, Murdoch University, WA.
- Algar D, Kinnear JE (1992) Cyanide baiting to sample fox populations and measure changes in relative abundance. In *Wildlife Rabies: contingency planning in Australia* (eds. P O'Brien and G Berry), pp. 135–138. Bureau of Rural Research, Proceedings No. 11. Australian Government Publishing Service, Canberra.
- Algar D, Smith R (1998) Approaching Eden. *Landscape* **13** (3), 28–34. Department of Conservation and Land Management, Western Australia.
- Algar D, Angus GJ (2000a) 'Recommendations on a control strategy for feral cats at Peron Peninsula, Western Australia.' Unpublished Report to the *Project Eden* Management Committee. Department of Conservation and Land Management, Western Australia, September 2000.
- Algar D, Angus GJ (2000b) 'An investigation of bait uptake by feral cats on Peron Peninsula, Western Australia.' Unpublished report, Department of Conservation and Land Management, Western Australia.
- Algar DA, Burbidge AA, Angus GJ (2002) Cat eradication on Hermite Island, Montebello Islands, Western Australia. In *Turning the tide: the eradication of invasive species* (eds CR Veitch and MN Clout), pp 14–18. IUCN SSC Invasive Species Specialist Group, IUCN, Gland, Switzerland and Cambridge, UK.
- Baynes A (1990) The mammals of Shark Bay, Western Australia. In *Research in Shark Bay: Report of the France-Australe Bicentenary Expedition Committee* (ed. PF Berry, SD Bradshaw, BR Wilson), Western Australian Museum.
- Baynes A (2000) 'Report on a contract to search for Bilby remains on Peron Peninsula, Shark Bay, Western Australia.' Unpublished report, Department of Conservation and Land Management, Western Australia.
- Blakers M, Davies SJFF, Reilly PN (1984) *The atlas of Australian birds*. Royal Australasian Ornithologists Union. Melbourne University Press.

- Bodetti TJ, Viggers K, Warren K, Sims C, Timms P (2003) Wide range of *Chlamydia* types detected in native Australian mammals. *Systematic and Applied Microbiology* (in press).
- Brown PH (2001) 'Eradication of domestic stock and feral goats on Peron Peninsula, Shark Bay.' Unpublished Report, Department of Conservation and Land Management, Western Australia.
- Burrows ND, Algar D, Robinson AD, Sinagra J, Ward B, Liddelow G (2003) Controlling introduced predators in the Gibson Desert of Western Australia. *Journal of Arid Environments* **55**, 691 – 713.
- CALM see Department of Conservation and Land Management
- Chavand O (2003) 'The origin and phylogeographic structure of the feral cat population in Western Australia.' Ph.D. thesis, Murdoch University, WA.
- Cheng J (2002) 'Feral cat population modelling on Peron Peninsula, Shark Bay.' Master of Science thesis, Edith Cowan University, WA.
- Christensen PES (1980) A sad day for native fauna. *Forest Focus* **23**
- Christensen P (1995) 'A strategic Plan for *Project Eden*.' Unpublished Report, Department of Conservation and Land Management, Western Australia.
- Christensen P, Burrows ND (1994) Project Desert Dreaming – the reintroduction of mammals to the Gibson Desert. In *Reintroduction Biology of Australian and New Zealand Fauna* (ed M Serena), pp 199 – 208. Surrey Beatty and Sons, Chipping Norton, NSW.
- Department of Conservation and Land Management (1995) Translocation of threatened flora and fauna. Policy Statement No. 29. Department of Conservation and Land Management, Western Australia.
- Dickman CR (1996) Overview of the impacts of feral cats on Australian native fauna. Invasive species program. Australian Nature Conservation Agency, Canberra.
- Gibson DF, Lundie-Jenkins G, Langford DG, Cole JR, Clarke DE, Johnson KA (1994) Predation by feral cats, *Felis catus*, on the rufous hare-wallaby, *Lagorchestes hirsutus*, in the Tanami desert. *Australian Mammalogy* **17**, 103-107
- Gleeson L (1999) 'Diet of the Banded Hare-wallaby.' Master of Science thesis, Cambridge University, UK.
- Hardman B (2003) 'Responses of banded hare-wallabies and mala to reintroduction at Peron Peninsula, Shark Bay.' Master of Science thesis, Edith Cowan University.
- Hill SJE (2002) 'The short-term impacts of fire on small terrestrial vertebrates of Francois Peron National Park, Shark Bay, Western Australia.' Honours thesis, Murdoch University, WA.
- Jarman P (1986) The red fox – an exotic large predator. In *The ecology of exotic animals and plants. Some Australian case histories* (ed. RL Kitching) John Wiley and Sons, Milton, Queensland.
- Jones E, Coman BJ (1982) Ecology of the feral cat, *Felis catus* (L.) in south-eastern Australia. 111 Home range and population ecology in semiarid north-west Victoria. *Australian Wildlife Research* **9**, 409-420.
- Kinnear JE, Onus ML, Bromilow RN (1988) Fox control and rock-wallaby population dynamics. *Australian Wildlife Research* **15**, 435 – 450.
- Kinnear JE, Onus ML, Sumner NR (1998) Fox control and rock-wallaby population dynamics – an update. *Wildlife Research* **25**, 81-88
- Kinnear JE, Sumner NR, Onus ML (2002) The red fox in Australia – an exotic predator turned biocontrol agent. *Biological Conservation* **108**, 335-359.
- Liddelow G, Christensen P, Morris K, Speldewinde P, Smith, Triton S (1997) 'Beyond the Dreaming – *Project Eden* 1997.' *Landscape Expeditions Report* No. 20. Department of Conservation and Land Management, Western Australia.
- Maxwell M (2002) 'Ecology of feral cats *Felis catus* on Peron Peninsula, Shark Bay.' Unpublished report to *Project Eden* Management Committee, Department of Conservation and Land Management WA.
- McKenzie NL, Hall N, Muir WP (2000a) Non-volant mammals of the southern Carnarvon Basin, Western Australia. In *Biodiversity of the southern Carnarvon Basin*. (eds AH Burbidge, MS Harvey, NL McKenzie), pp 479 – 510. Records of the Western Australian Museum Supplement No. 61.
- McKenzie NL, Rolfe JK, Aplin KP, Cowan MA, Smith LA (2000b) Herpetofauna of the southern Carnarvon Basin, Western Australia. In *Biodiversity of the southern Carnarvon Basin*. (eds AH Burbidge, MS Harvey, NL McKenzie), pp 335-360. Records of the Western Australian Museum Supplement No. 61.
- Meek PD, Jenkins DJ, Morris B, Ardler AJ, Hawksby RJ (1995) Use of two humane leg-hold traps for catching pest species. *Wildlife Research* **22**, 733-739.
- Ministry for Planning (1997) *Shark Bay Regional Strategy*. Western Australian Planning Commission.
- Morris K (1995) 'Reintroduction Operations Plan – *Project Eden*' (draft), unpublished, Department of Conservation and Land Management, Western Australia.
- Morris K (2000) Fauna translocations in Western Australia 1971 – 1999: an overview. In *Biodiversity and the re-introduction of native fauna at Uluru – Kata Tjuta National Park* (eds. JS Gillen, R Hamilton, WA Low, C Creagh), pp 64 – 74. Proceedings of a cross – cultural workshop on fauna reintroductions, Yulara, NT. Bureau of Rural Sciences, Kingston ACT.

- Morris K, Sims C (1997) 'Project Eden – Strategic Plan for the Captive Breeding and Translocation of Fauna at Peron Peninsula, Shark Bay.' (draft), unpublished, Department of Conservation and Land Management, Western Australia.
- Morris K, Varley J, Liddelow G, Ward B (2000) 'Beyond the Dreaming – Project Eden 2000.' *Landscape Expeditions Report No. 39*. Department of Conservation and Land Management, Western Australia.
- Morris K, Pearson D, Liddelow G, Ward B, Himbeck K, Smith J (2002) 'Beyond the Dreaming – Project Eden 2001.' *Landscape Expeditions Report No. 45*, Department of Conservation and Land Management, Western Australia.
- Morris K, Johnson B, Orell P, Gaikhorst G, Wayne A, Moro D (2003) Recovery of the threatened Chuditch (*Dasyurus geoffroii* Gould 1841): A case study In *Predators with Pouches* (eds. M Jones, C Dickman, M Archer), pp 345-451 CSIRO publications, Collingwood, Victoria.
- Payne AL, Curry PJ, Spencer GF (1987) An inventory and condition survey of rangelands in the Carnarvon Basin, Western Australia. Technical Bulletin No 73. Department of Agriculture, Perth, Western Australia.
- Pech RP, Sinclair ARE, Newsome AE, Catling PC (1992) Limits to predator regulation of rabbits in Australia: evidence from predator-removal experiments. *Oecologia* **89**, 102-112.
- Risbey DA, Calver MC, Short J, Bradley JS, Wright IW (2000) The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. II. A field experiment. *Wildlife Research* **27**, 135 – 145.
- Robley AJ, Short J, Bradley S (2002) Do European rabbits (*Oryctolagus cuniculus*) influence the population ecology of the burrowing bettong (*Bettongia lesueur*)? *Wildlife Research* **29**, 423-429
- Sinclair ARE, Pech RP, Dickman CR, Hik D, Mahon P, Newsome AE (1998) Predicting effects of predation on conservation of endangered prey. *Conservation Biology* **12**, 564-575.
- Short J, Turner B, Risbey DA, Camamah R (1997) Control of feral cats for nature conservation II. Population reduction by poisoning. *Wildlife Research* **24**, 703-714.
- Short J (1999) 'Decline and recovery of Australian mammals, with particular emphasis on the burrowing bettong, *Bettongia lesueur*.' Ph.D. Thesis, Murdoch University, Perth.
- Sims C (2000) Malleefowl reintroductions at Peron Peninsula, Shark Bay. *Reintroduction News – Bird special edition*. IUCN Reintroduction Specialist Group.
- Smith R, Ward B, Christensen P, Wheeler I, Morris K, Speldewinde P (1996) Beyond the Dreaming – Project Eden 1996.' *Landscape Expeditions Report*. Department of Conservation and Land Management, Western Australia.
- Speldewinde PC, Morris KD (1999) Reintroduction of woylies *Bettongia penicillata* to Peron Peninsula, Shark Bay, as part of Project Eden. A review of progress from September 1997 to December 1998. Unpublished report, Department of Conservation and Land Management, Western Australia.
- Thackway R, Cresswell ID (1995) An interim biogeographical regionalisation for Australia. Australian Nature Conservation Agency, Canberra.
- Thompson C, Shepherd R (1995) Return to Eden. *Landscape* **10** (3), 21-25. Department of Conservation and Land Management, Western Australia.
- Tyler MJ, Smith LA, Johnstone RE (2000) Frogs of Western Australia (Third edition). Western Australian Museum, Francis Street, Perth, WA.
- Risbey DA, Calver MC, Short J, Bradley JS, Wright, I.W. (2000) The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. II. A field experiment. *Wildlife Research* **27**, 135 – 145.
- Ward B (1997) Review of fire protection for the Peron Peninsula. Department of Conservation and Land Management, Western Australia. pp1-4.

The western ringtail possum, *Pseudocheirus occidentalis*, and the quokka, *Setonix brachyurus*, case studies: *Western Shield* review—February 2003

PAUL J. DE TORES^{1,2}, MATTHEW W. HAYWARD^{3,4,5} AND SUZANNE M. ROSIER¹

¹Department of Conservation and Land Management, Wildlife Research Centre, PO Box 51 Wanneroo, Western Australia, 6946.

²To whom correspondence should be addressed. pauld@calm.wa.gov.au

³ Department of Conservation and Land Management, Dwellingup Research Centre, Dwellingup, Western Australia, 6946.

⁴ School of Biological, Earth and Environmental Science, University of New South Wales, Sydney, New South Wales, 2052

⁵ Current address: Addo Predator Re-introduction Project, Terrestrial Ecology Research Unit, Department of Zoology, University of Port Elizabeth, PO Box 1600, Port Elizabeth 6013, South Africa.

ABSTRACT

Case studies are presented for the western ringtail possum, *Pseudocheirus occidentalis*, and the quokka, *Setonix brachyurus*. The ringtail case study summarises information from a recent review of the species' distribution and conservation status, collates information on ringtail populations within the areas covered by the Department of Conservation and Land Management's (CALM) fauna recovery program, *Western Shield*, and draws extensively on the recent findings from translocation programs. Critical to the case study is the finding that (i) monitoring of the response to fox control programs is poor, or non-existent, at all known sites, with the exception of research specific translocation sites. This may reflect the difficulty in censusing and monitoring this species; and (ii) translocation success has not been demonstrated at any translocation release site and the primary translocation site, Leschenault Peninsula Conservation Park, has suffered a significant population decline. Hypotheses are proposed to explain this decline and, in the absence of demonstrated translocation success, critical components for monitoring western ringtail possum translocations are recommended. Monitoring protocols are also recommended for other extant populations within the species' geographic range.

The quokka case study also summarises information from a recent review of the species' distribution and conservation status and collates information on quokka populations within the areas covered by *Western Shield*. The case study also draws extensively on the findings from recent research from the northern jarrah forest. As for the ringtail case study, the quokka case study found monitoring is non-existent or poor, or *ad hoc* at best, at all known sites, with the exception of research specific sites within the northern jarrah forest. Consistent with recently published research findings, intervention management is recommended at these northern jarrah forest sites. An active adaptive management framework,

using fire as a tool to create the preferred structural habitat mosaic, is recommended.

Both case studies highlight the need to review data collection, collation, analyses and reporting processes to ensure data are collected in a manner to allow objective analyses and scrutiny. Under this proposed scenario, any conservation gains can be quantified and documented. Conversely, in circumstances where desired outcomes have not been met, the failure to meet set goals can be identified and mechanisms can be implemented to improve conservation management.

INTRODUCTION

Background and overview

The western ringtail possum, *Pseudocheirus occidentalis*, and the quokka, *Setonix brachyurus*, are within the suite of mammal species considered at risk of predation by the introduced red fox, *Vulpes vulpes*. Both species have shown a contraction in geographic range and abundance since the arrival of the fox in south-west Western Australia and the fox has been implicated as a contributing factor to their decline (de Tores *et al.* 1998; de Tores *et al.* in review; de Tores, unpublished; Hayward *et al.* 2003).

The original *Western Shield* proposal (Burbidge *et al.* 1995) identified the western ringtail possum as a species likely to benefit from broad scale fox control and further implied the quokka, and a suite of other small to medium sized mammals, would also benefit from fox control. With the commencement of *Western Shield*, many operational baiting programs have been implemented and the native fauna response to fox control has been monitored. However, with the exception of site specific research programs, there has been no monitoring of western ringtail possum or quokka population response to fox control.

Fox baiting has been in place at Leschenault Peninsula Conservation Park as part of a translocation release program for the western ringtail possum since the early 1990s and predates *Western Shield*. Similarly, other fox baiting programs have been in place at sites where the western ringtail possum and the quokka are known to occur, although these programs were not specifically designed or implemented to conserve either species.

The western ringtail possum site specific research has been associated with translocation release programs of rehabilitated orphaned and/or injured possums and possums displaced as a result of vegetation clearing and habitat modification or habitat loss at development sites. Monitoring of these populations has recently raised several issues of concern (de Tores and Rosier, unpublished-a; de Tores *et al.* unpublished-a; de Tores *et al.* unpublished-b). Similarly, site specific research investigating the ecology of the quokka in the northern jarrah forest has identified issues of concern for conservation management of the quokka (see Hayward, 2002; Hayward *et al.* 2003; Hayward *et al.* 2004).

The case studies below summarise much of the recent published and unpublished findings and propose specific recommendations relevant to *Western Shield* and conservation management of both species.

Terms of reference for the case studies

Specific terms of reference for the case studies were to:

- i) outline the distribution, changes in status over time and probable causes of change for each species
- ii) identify the components of *Western Shield* being used in the management of each species (e.g. predator control, translocation) and the populations being managed
- iii) identify all the people (and their roles) involved in the management of each species
- iv) describe or tabulate the implementation of *Western Shield* actions with respect to each managed population and the process for modifying prescriptions
- v) in consultation with key people from each involved Region, assess the efficacy of the implementation of *Western Shield* actions and decision making procedures.

The components of *Western Shield*, the people involved, populations monitored and actions implemented in relation to the western ringtail possum and the quokka

Table 1 identifies the components of *Western Shield* relevant to the western ringtail possum and the quokka. Information was provided by CALM regional, district and Science Division staff.

The lack of information on population size and population response to fox control at the locations listed in Table 1 reflects the difficulty of undertaking population studies on both species. The western ringtail possum is not amenable to conventional trapping techniques and

capture-mark-release-recapture (termed 'mark-recapture') methods for estimating population size are not appropriate. Alternative techniques are labour intensive, costly and require training of survey personnel to ensure data collection techniques are consistent and comparable between locations.

The quokka occurs in densely vegetated creeklines over much of its range (Christensen *et al.* 1985; de Tores *et al.* in review; Hayward, 2002; Hayward *et al.* 2004). Conventional trapping in this habitat is physically difficult, labour intensive and has the potential to 'open up' the vegetation and expose resident quokka populations to increased risk from fox predation (de Tores *et al.* in review). Conventional trapping techniques can, and have been used to, estimate quokka population abundance (see for example Hayward *et al.* 2003). However, with the exception of the study by Hayward *et al.* (2003), quokka trapping has usually been undertaken in an *ad hoc* manner and the data has provided information on presence only, or at best has provided indices to abundance. These indices are not necessarily comparable across sites. Alternative techniques are currently being investigated, see for example Alacs *et al.* (2003), where extraction of DNA from epithelial tissue sloughed with faecal pellets was used to confirm species presence. Similarly, Hayward *et al.* (unpublished-b) used faecal pellet counts to derive estimates of quokka abundance. Importantly, this technique was validated by comparison with densities derived from mark-recapture techniques.

The sites listed in Table 1 indicate there is only one *Western Shield* monitoring site (quokkas at D'Entrecasteaux, Nuyts Wilderness) where there has been a response to fox control, albeit only inferred. This response has been inferred by detection of faecal pellets at baited sites of unburnt vegetation immediately outside the boundary of a recent wildfire. Population size has not been quantified and there are no pre fire data on abundance. There are no other *Western Shield* monitoring sites where the western ringtail possum or the quokka has been shown to respond to fox control. Anecdotal accounts (often reported in the media) of increases in abundance of the western ringtail possum and quokka as a result of *Western Shield* baiting are not supported by quantified data. Similarly, records of occurrence have not been shown to equate with persistence of populations.

The lack of a detectable response to fox control should be interpreted cautiously. It should not be seen as indicating an absence of response, but a reflection of the difficulty of deriving reliable estimates of abundance for the western ringtail possum and the quokka.

However, the findings from monitoring the quokka and the western ringtail possum at other sites, i.e. sites monitored intensively as part of specific programs, concluded the quokka has shown no response to baiting in the northern jarrah forest (Hayward, 2002; Hayward *et al.* 2003) and translocation of the western ringtail possum at four sites could not be considered successful, despite the presence of baiting for fox control (de Tores, unpublished; de Tores and Rosier, unpublished-a; de Tores

Table 1

Western Shield monitoring sites where the western ringtail possum and the quokka are known or are thought to be present. Additional sites listed are those where information on density/abundance/presence is known or inferred from monitoring and where fox baiting is carried out.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT REGION	SITES CURRENTLY BAITED AND KNOWN TO SUPPORT POPULATIONS OF THE WESTERN RINGTAIL POSSUM OR QUOKKA	SPECIES PRESENT	BAITING REGIME	TYPE OF MONITORING IN PLACE AND RESULTS FROM MONITORING	SOURCE OF INFORMATION
Swan	Lane Poole Reserve and Keats Forest Block (within the northern Jarrah forest)	western ringtail possum A translocation site. Released animals were rehabilitated possums sourced primarily from wildlife carers in Busseton/Bunbury and surrounding area.	Within the 6 baitings per year treatment of Operation Foxglove	Radio telemetry monitoring was undertaken as part of a student project (Curtin University, Honours project). Indicators of success of the translocation included confirmation of breeding. However, there were no data to indicate young survived to independence and no evidence to suggest released possums survived beyond the first few months post release. Results from Millen (1997) and follow up monitoring indicated a high level of mortality, attributed to predation by the chuditch, <i>Dasyurus geoffroii</i> . Translocation cannot yet be deemed successful. Monitoring commenced in July 1996 and ceased in April 2000 with the absence of funds and the death of the last remaining radio collared possum.	Millen (1997); de Tores and Rostler (unpublished data)
	Northern Jarrah Forest	quokka Seven sites monitored over a 2-year period 2000-2001	Within the 2 and 4 baitings per year treatment of Operation Foxglove with additional monthly baiting in the immediate vicinity of each 'quokka swamp'.	Trapping and radio-telemetry to estimate abundance and survivorship, respectively. Additional details provide in the quokka case study, this paper.	Hayward <i>et al.</i> (2003)
	Northern Jarrah Forest	quokka Scattered populations, known from incidental sightings, road kills and non-target captures when trapping for feral pig control	Within the 2 and 4 baitings per year treatment of Operation Foxglove.	No formal monitoring carried out by <i>Western Shield</i> . Quokka populations are thought to be extinct at two of these sites.	de Tores <i>et al.</i> (in review)
	Karakamia Sanctuary (privately owned wildlife sanctuary)	western ringtail possum A translocation site, possums sourced primarily from wildlife carers and more recently from development sites in Busseton / Bunbury.	Permanent barrier baiting along a predator proof fence line	Radio-telemetry and spotlight monitoring. Translocation success is yet to be confirmed. Data to indicate success include: • survivorship for over 4 years post release; and • confirmed recruitment. However, there is no evidence to show recruits have survived to independence or sexual maturity and dispersal patterns are unknown.	Smitz (2001)
	Karakamia Sanctuary	quokka A translocation release site. Three quokkas released in 1996 ex Big Swamp Wildlife Park, Bunbury and originally sourced from mainland sites. An additional orphaned young from the northern jarrah forest was subsequently released as a juvenile/sub-adult in 1998.	as above	Monitored by opportunistic observations. Chance sightings have indicated recruitment of at least one individual.	Smitz (2001)

Table 1 (continued)

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT REGION	SITES CURRENTLY BAITED AND KNOWN TO SUPPORT POPULATIONS OF THE WESTERN RINGTAIL POSSUM OR QUOKKA	SPECIES PRESENT	BAITING REGIME	TYPE OF MONITORING IN PLACE AND RESULTS FROM MONITORING	SOURCE OF INFORMATION
Swan (cont.)	Yalgorup National Park	western ringtail possum A translocation site. Released animals were sourced from development sites where habitat had been destroyed	Monthly	Radio-telemetry and spotlighting to assess survivorship and density estimates, respectively. Results and additional details are provided in the western ringtail possum case study, this paper.	de Torres and Rosier (unpublished-a)
	Leschenault Peninsula Conservation Park	western ringtail possum A translocation site. Released animals sourced from wildlife carers in Busselton/Bunbury	Monthly, see western ringtail possum case study and appendix 1 this paper for details	Radio-telemetry and spotlighting to assess survivorship and density estimates, respectively. Results and additional details are provided in the western ringtail possum case study, this paper.	de Torres <i>et al.</i> (unpublished-b)
	Harvey River, Water Corporation Managed estate	western ringtail possum	Unclear, baiting appears to have occurred between 1999 and December 2002. Intensity and frequency is also unclear	Presence confirmed in 1997 and estimated to be at very low density. Consultant (B. Jones) commissioned to monitor for the Water Corporation. Unpublished reports indicate the western ringtail possum population in the Harvey River Valley is in 'terminal decline' with one breeding pair thought to be present. Consultant has been retained to monitor this population and three unspecified forest populations and habitat until 2010-2011, fund management by the Dept of CALM. This work was implemented outside the recovery team endorsement process.	de Torres and Rosier (1997) Jones and Northover (2001)
Warren	Ludlow Tuart Forest and other sites in the south west region	western ringtail possum	?	The western ringtail possum is known to occur within the Ludlow and Abba River areas, north of Busselton. Sites known to have been previously baited, no additional information provided by regional staff.	
	Manjimup, Perup Forest	western ringtail possum	4 baitings per year, commenced in 1992 for protection of six species of rare fauna	High density populations detected from <i>ad hoc</i> spotlighting. The declines observed in the nearby Kingston Block have not been observed at Perup.	Ian Wilson (pers. comm.) ⁽ⁱ⁾ Adrian Wayne and John Rooney (pers. comm.) ⁽ⁱ⁾
	Manjimup, Kingston Block	western ringtail possum	4 baitings per year, commenced in 1992 for protection of six species of rare fauna	Annual spotlighting carried out as part of a research program 1997-2002 has detected a decline in the number of sightings per transect. Decline interpreted to be in response to timber harvesting. <i>Ad hoc</i> spotlighting by District staff has provided results consistent with research findings.	Adrian Wayne and John Rooney (pers. comm.) ⁽ⁱ⁾ Wayne <i>et al.</i> (2001a) Ian Wilson (pers. comm.) ⁽ⁱ⁾
	Donnelly, Netic Block	quokka	4 baitings per year, commenced 1992	<i>Ad hoc</i> trapping with low capture success. No response detected.	Ian Wilson (pers. comm.) ⁽ⁱ⁾
	Donnelly, Gibley/Court Block	quokka	4 baitings per year, commenced 2000	Baiting commenced to ameliorate effect of disturbance from roading. No monitoring of response.	Ian Wilson (pers. comm.) ⁽ⁱ⁾

Table 1 (continued)

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT REGION	SITES CURRENTLY BAITED AND KNOWN TO SUPPORT POPULATIONS OF THE WESTERN RINGTAIL POSSUM OR QUOKKA	SPECIES PRESENT	BAITING REGIME	TYPE OF MONITORING IN PLACE AND RESULTS FROM MONITORING	SOURCE OF INFORMATION
Warren (cont.)	Shannon, Crowea Block	quokka	4 baitings per year, commenced 1999	Baiting commenced to ameliorate effect of disturbance from roading. <i>Ad hoc</i> trapping with low capture success. No response detected.	Ian Wilson (pers. comm.) ^(b)
	Shannon, Kinkin/Dordagup area	quokka	4 baitings per year, commenced 1998	Baiting commenced to ameliorate effect of disturbance from roading and fire. No response detected.	Ian Wilson (pers. comm.) ^(b)
	D'Entrecasteaux, Dombakup Block	quokka	4 baitings per year, commenced 1999	Baiting commenced to ameliorate effect of disturbance from roading. <i>Ad hoc</i> trapping with low capture success. No response detected.	Ian Wilson (pers. comm.) ^(b)
	D'Entrecasteaux - Nuyts Wilderness	quokka	Monthly baiting	A large number of quokka deaths recorded as a result of an intense wildfire in the Nuyts Wilderness area in 2001. Quokka presence has subsequently been detected in unburnt patches within the boundary of the Nuyts fire - presence inferred by detection of scats within typical quokka runways at three locations immediately outside the burn boundary. A program (detection of scats) has been implemented to monitor recovery/response post fire.	Greg Freebury (pers comm.) ^(b) Middleton (2001)
South Coast	D'Entrecasteaux - 'Woolbaes Block'	?	6 baitings per year	Annual trapping carried out since March 1997 for the suite of small to medium size mammals. No formal monitoring program in place for the quokka.	Greg Freebury (pers comm.) ^(b)
	Walpole Nornalup National Park - 'Hilltop Area'	quokka	6 baitings per year	Annual trapping carried out since May 1997 for the suite of small to medium size mammals as part of <i>Western Shield</i> . No formal monitoring program in place for the quokka, however quokka presence inferred at sites supporting suitable habitat of spreading sword-sedge, <i>Lepidosperma effusum</i> , and <i>Anarthria scabra</i> .	Greg Freebury (pers comm.) ^(b)
	Walpole Nornalup National Park - Giants Block	quokka	6 baitings per year	Bi-annual trapping carried out since November 1996 for the suite of small to medium size mammals as part of <i>Western Shield</i> . No formal monitoring program in place for the quokka, however quokka presence inferred at sites supporting suitable habitat of spreading sword-sedge, <i>Lepidosperma effusum</i> , and <i>Anarthria scabra</i> .	Greg Freebury (pers comm.) ^(b)
	Walpole Nornalup National Park - Mt Clare area	quokka	6 baitings per year	Annual trapping carried out since 1997 for the suite of small to medium size mammals as part of <i>Western Shield</i> . No formal monitoring program in place for the quokka, however quokka presence inferred at sites supporting suitable habitat of spreading sword-sedge, <i>Lepidosperma effusum</i> , and <i>Anarthria scabra</i> .	Greg Freebury (pers comm.) ^(b)
	Mehniup Hill Nature Reserve	?	6 baitings per year		Greg Freebury (pers comm.) ^(b)
	William Bay National Park	western ringtail possum	6 baitings per year	No formal monitoring program in place for the western ringtail possum.	Greg Freebury (pers comm.) ^(b)

Table 1 (continued)

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT REGION	SITES CURRENTLY BAIED AND KNOWN TO SUPPORT POPULATIONS OF THE WESTERN RINGTAIL POSSUM OR QUOKKA	SPECIES PRESENT	BAITING REGIME	TYPE OF MONITORING IN PLACE AND RESULTS FROM MONITORING	SOURCE OF INFORMATION
	West Cape Howe National Park, 25km West of Albany	western ringtail possum	4 baitings per year	Western ringtail possum known to be present, no <i>Western Shield</i> monitoring or western ringtail possum specific monitoring in place.	Peter Collins (pers. comm.) [®]
South Coast (cont.)	Gull Rock National Park, 14km East of Albany	western ringtail possum	4 baitings per year	Western ringtail possum known to be present, no <i>Western Shield</i> monitoring or western ringtail possum specific monitoring in place.	Peter Collins (pers. comm.) [®]
	Porongurups National Park, 30km North of Albany	western ringtail possum	4 baitings per year	Standard <i>Western Shield</i> monitoring - 5km transects with 50 wire cage and 50 Elliott traps monitored in Spring and Autumn. No specific western ringtail possum monitoring and presence of western ringtail possum is known from one (possibly more) opportunistic sighting only.	Peter Collins (pers. comm.) [®] Jim Shugg (pers. comm.) [®]
	Waychinicup - Mt Manypeaks-Normans inlet, 35-50km East North-East of Albany	western ringtail possum	4 baitings per year	Standard <i>Western Shield</i> monitoring - 5km transects with 50 wire cage and 50 Elliott traps monitored in Spring and Autumn. No specific western ringtail possum monitoring however the western ringtail possum is regularly sighted by field staff.	Peter Collins (pers. comm.) [®]
	Angove Water Reserve, 26km North-East of Albany	western ringtail possum	4 baitings per year	This site is monitored for noisy scrub-bird and western bristle-bird, no specific monitoring for the western ringtail possum, however the western ringtail possum is regularly sighted by field staff. There is recent evidence of recolonisation (fresh scats and animals sighted) of area burnt in 2000.	Peter Collins (pers. comm.) [®]
	Two Peoples Bay Nature Reserve, 28 km East North-East of Albany	western ringtail possum	4 baitings per year	This site is monitored for Gilberts potoroo, noisy scrub-bird and western bristle-bird, no specific monitoring for the western ringtail possum.	Peter Collins (pers. comm.) [®]
	Two Peoples Bay Nature Reserve, 28 km East North-East of Albany	quokka	4 baitings per year	This site is monitored for Gilberts potoroo, noisy scrub-bird and western bristle-bird, no specific monitoring for the quokka, however, quokkas are regularly caught as non target species in trapping programs for Gilbert's potoroo. The quokka is considered to be in relatively high density and may be responding to fox control.	J. A. (Tony) Friend (pers. comm.) [®]

(i) List of people referred to in Table 1 through a personal communication (pers. comm.) with the first author. Listed in citation order from Table 1.

Ian Wilson: Western Australian Department of Conservation and Land Management, District Nature Conservation Co-ordinator, Manjimup.
 Adrian Wayne: Western Australian Department of Conservation and Land Management, Forest Ecologist, Science Division, Manjimup
 John Rooney: Western Australian Department of Conservation and Land Management, Technical Officer, Science Division, Manjimup
 Greg Freebury: Western Australian Department of Conservation and Land Management, South Coast Region, Albany
 Peter Collins: Western Australian Department of Conservation and Land Management, Fauna Conservation Officer, Albany
 Jim Shugg: Former employee of Western Australian Department of Conservation and Land Management, Pemberton
 J.A. (Tony) Friend: Western Australian Department of Conservation and Land Management, Principal Research Scientist, Science Division, Albany

et al. unpublished-b; Millen, 1997; Smitz, 2000; Smitz, 2001).

These issues are discussed in the following case studies.

Case Study 1: The western ringtail possum, *Pseudocheirus occidentalis*

Distribution

The distribution and conservation status of the western ringtail possum was recently reviewed and is detailed in de Tores (unpublished). In summary, the review concluded the western ringtail possum continues to meet the World Conservation Union (IUCN) criteria for a Threatened species in the category Vulnerable. The known extant geographic range of the western ringtail possum was shown to be larger (in terms of extent of occurrence) than inferred by Jones *et al.* (1994). However, this extension of geographic range was attributed to a greater awareness of the western ringtail possum and an increase in the number of known records of occurrence. It was not seen as an indication of recovery or partial recovery of the species. The known extant geographic range was extended by confirmation of records of occurrence in jarrah, *Eucalyptus marginata*, and jarrah/marri, *Corymbia calophylla*, forest near Collie and riverine stands of peppermint, *Agonis flexuosa*, near the Harvey River, east of Harvey.

The review emphasised confirmation of presence should not be equated with long term persistence of populations/subpopulations. The Collie and Harvey River populations were identified as at risk. Threats to these populations include fox predation and habitat modification.

Additional populations considered at risk were at the northern extent of the species range (exclusive of translocated populations) near Bunbury, populations within the greater Busselton area and populations within jarrah/marri forest near Manjimup. Threats to the Bunbury and Busselton populations were identified as habitat fragmentation and population fragmentation associated with urban development. Threats to the Manjimup populations were identified as timber harvesting and burning operations, see also Wayne *et al.* (2000) and Wayne *et al.* (2001b). However, many of the known western ringtail possum populations in the Manjimup area are outside areas available for logging and are within the extensive reserve system (Neil Burrows, CALM, pers. comm.). The forest populations near Manjimup are currently the subject of a research program investigating the ecology of, and quantifying the threats to, the western ringtail possum (Adrian Wayne, CALM, pers. comm.).

The ongoing requirement to clear land for housing and for industry in the greater Busselton area will continue to result in habitat loss and displacement of resident populations of the western ringtail possum. There will be

a continued need for land use planners and wildlife managers to address this issue (de Tores, unpublished). Proponents of development projects have traditionally adopted a strategy whereby the issue of western ringtail possum conservation is addressed through translocation. This issue is relevant to, and discussed in, the case study.

Background

The western ringtail possum case study is based on, and extracts information from, previous reports, publications and a suite of publications in preparation. The response of the western ringtail possum and the response of *in situ* resident populations of the common brushtail possum, *Trichosurus vulpecula*, at western ringtail possum translocation release sites are specifically addressed in the case study. Details on survivorship, habitat use by individual radio-collared animals, breeding success, dispersal, home range, capture and handling/sedation are given in the background summary only and detailed in a series of manuscript currently in preparation [de Tores (unpublished), de Tores *et al.* (unpublished-b), de Tores and Rosier (unpublished-a), de Tores and Rosier (unpublished-b), de Tores *et al.* (unpublished-c) and de Tores and Rosier (unpublished-c).]

The translocation release sites referred to in the case study are within Leschenault Peninsula Conservation Park and Yalgorup National Park. Both reserves are currently baited for fox control and fall within the *Western Shield* fauna recovery program.

Western ringtail possum translocations to Leschenault Peninsula Conservation Park

Background and objectives

Leschenault Peninsula Conservation Park is located immediately north of Bunbury and approximately 160 km south of Perth.

Prior to the first release at Leschenault in 1991, injured and/or orphaned possums passed on to wildlife carers for rehabilitation and possums displaced by habitat destruction from the Busselton area, were released in an *ad hoc* manner at the discretion of wildlife carers. Translocation release site selection was determined by wildlife carers and there was no assessment of the fate of released animals.

A pilot study by Jones (1991) followed the progress of rehabilitated western ringtail possums released at Locke Nature Reserve, Busselton. Five western ringtail possums were fitted with radio-collars and released. Within six weeks, four were dead and the condition of the retrieved carcasses indicated the cause of death was fox predation. In August-September 1991, Leschenault Peninsula Conservation Park was identified as a more appropriate release site. Site selection was on the basis of presence of extensive stands of suitable habitat, i.e. presence of peppermint, *Agonis flexuosa*, the preferred diet of the western ringtail possum, and tuart, *Eucalyptus*

gomphecephala, known to provide suitable tree hollows. Tuart and peppermint woodland and forest are known to support high density western ringtail possum populations in the greater Busselton area.

Leschenault Peninsula Conservation Park is within secure conservation estate. It is an 11km long, narrow peninsula highly suitable to baiting. It is bounded by the Indian Ocean and Leschenault estuary, with a narrow, 600m wide, isthmus providing the only opportunity for re-invasion by foxes.

Leschenault is north of the northern most known coastal occurrence of the western ringtail possum, but within the species' former geographic range. If successful, the release program would result in an extension of the species current range and establish a new population within secure conservation estate. It would also provide wildlife carers with the opportunity to contribute to a program with positive conservation outcomes.

1080 baiting commenced in September 1991 and a 4-weekly baiting regime (13 baiting sessions per year) was implemented, using the existing roading network for vehicle delivery of baits. The standard 4.5mg 1080 dried meat baits were used and approximately 100–115 baits were distributed at each baiting event.

The first release of eight rehabilitated possums was in September 1991. All released possums were sourced from wildlife carers. Subsequent release dates were largely determined by wildlife carers, with a total of 106 rehabilitated western ringtail possums released over the period 1991 to 1997.

Monitoring protocols for released animals, criteria used to determine success and results from monitoring are detailed in de Tores *et al.* (unpublished-b). In summary, released possums establish regular use of dreys and tree hollows. Home range estimates were comparable to reports in the literature and unpublished information on home range for the western ringtail possum and the common ringtail possum, *Pseudocheirus peregrinus*. Females were shown to produce young, the sex ratio of young was not significantly different from parity and dispersal patterns of young were consistent with that expected from the literature, i.e. female young stayed within the natal range and male young dispersed. Recruits to the population were also shown to breed successfully.

Spotlight transects were conducted in 1996, 1997 and 1998 and results (summarised below) confirmed the western ringtail possum population progressively increased.

The translocation was deemed to be successful, subject to follow-up spotlight monitoring confirming the population level had been sustained or increased and subject to the outcome of proposed genetic analyses. Specific issues proposed for the genetic analyses include assessment of the effective population size and examining whether breeding is restricted to a limited number of individuals (de Tores *et al.* unpublished-b).

Follow up spotlighting was carried out in 2002 and identified a decline in density of the western ringtail

possum (density estimates are detailed below). The number of sightings fell from 77 in 1996, 75 in 1997 and 100 in 1998, to 2 in 2002. The corresponding number of common brushtail possum sightings was 89 in 1996, 119 in 1997, 102 in 1998 and 114 in 2002.

The cause of the decline in western ringtail possum density is unclear. Possible explanations include competition with the common brushtail possum, increased predation by cats, foxes or pythons, prey switching (rabbit numbers have been significantly reduced and may no longer be as prevalent in the diet of introduced and native predators), effects from drought, presence of disease (toxoplasmosis has been confirmed in the ringtail population at Yalgorup), unsuitable habitat or a combination of these possible causes.

However, the most parsimonious explanation for the decline is an increase in the level of fox predation as a result of changes to the 1080 baiting regime. Appendix 1 details the history of 1080 baiting, post 1997 at Leschenault. The baiting history shows there was a 3 month period (31/12/1998 to 24/3/1999 - corresponding with a known peak period in fox dispersal) where 2 consecutive monthly baitings were missed and an additional 2 months in the period 26/5/99 to 18/12/99 where monthly baiting was not carried out (5 baitings only carried out in this 7 month period).

Monthly baiting also appears to have been missed in June 1998, April 2000, August 2000, February 2001, August 2001, November and December 2001 and March 2002. All of the missed baitings are between the 1998 and 2002 spotlight surveys. The multiple months when baiting was not carried out may have been sufficient to result in temporary increases in fox numbers and cause the decline in the western ringtail possum population.

Other changes to the baiting regime at Leschenault have also been implemented. Specifically, fewer baits are now delivered at each baiting session and baits are now buried. These changes further confound interpretation of the cause of the decline in western ringtail possum density. These changes in protocol alone may account for an increase in fox numbers, as bait uptake by foxes is reduced when baits are buried (Thomson and Kok, 2002). A switch to buried baits at rock wallaby sites was also shown to result in an increase in predation (Kinnear, CALM, pers. comm.).

The hypothesis that the missed baiting events and changes to the baiting regime were responsible for an increase level of predation and subsequent decline in density of the western ringtail possum is not mutually exclusive of any other factor, or combination of factors, contributing to the decline.

The sections below address the methodology used to derive the estimates of density for the western ringtail possum and the common brushtail possum. The alternative hypothesis that competition with the common brushtail possum was responsible for the decline in western ringtail possum density is discussed.

Methodology

Release dates, radio-telemetry monitoring and home range estimates

All released animals were fitted with a reflective ear tag and implanted with a Trovan® passive transponder to provide a unique identifier. Breeding status/condition was assessed and standard morphometrics were recorded and are detailed in de Tores *et al.* (unpublished-b).

A subset of all released animals was radio-collared and monitored to determine survivorship, home range and habitat use. Initially, conventional single stage radio transmitters with loop aerials (Biotel, South Australia) were used. These were subsequently replaced with two stage transmitters with movement sensitive (mortality) circuitry (AVM, USA; and Biotrack UK) with a 2-hour period of inactivity required to trigger mortality mode. Further details of radio-collars used, history of use and development of a breakaway collar for use on subadult and juvenile western ringtail possums is given in de Tores *et al.* (unpublished-b) and de Tores and Rosier (unpublished-b).

Home range data collected included nocturnal and diurnal location records to determine core range (diurnal locations only) and home range inclusive of nocturnal foraging area (diurnal and nocturnal locations combined). All estimates were derived using the Harmonic Mean Analysis option (Dixon and Chapman, 1980) of RangesV/6 software (Kenward *et al.* 2003; Kenward and Hodder, undated). Home range results are reported for 95% isopleths in de Tores *et al.* (unpublished-b), as is the rationale for use of Harmonic Mean Analysis.

Distance sampling model selection and density estimates for the western ringtail possum and the common brushtail possum

Density estimates were derived annually from spotlighting data for 1996, 1997, 1998 for the western ringtail possum and 1996, 1997, 1998 and 2002 for resident populations of the common brushtail possum.

Two vehicle driven spotlighting transects were established and each was spotlighted for six to nine consecutive nights from mid March to early June each year. Two operators (one driver and one spotter) were required on each occasion. Spotlighting personnel varied minimally, with the same person (PdeT) present at each spotlighting event. Full details of equipment and description and justification of methodology are provided in de Tores *et al.* (unpublished-b).

Density estimates were derived using DISTANCE Sampling protocols (Buckland *et al.* 2001) and the Line Transect option of the software DISTANCE 4.0 (Thomas *et al.* 2002).

Model selection in DISTANCE is based on the Information-Theoretic approach and Akaike Information Criteria (AIC). A series of *a priori* candidate models was compared and the preferred model determined on the basis of AIC values and differences in AIC values (delta (Δ)AIC) (Buckland *et al.* 2001). Models with a ΔAIC of

less than 2 are considered to be equally well supported by the data (Buckland *et al.* 2001; Burnham and Anderson, 2002).

Distance sampling to determine habitat use of the common brushtail possum

Habitat categories were delineated on the basis of the floristic and structural vegetation units identified by Trudgen (1984). Trudgen's (1984) mapped vegetation units were provided digitally by CALM's Information Management Branch and modified, post ground-truthing, to reflect structural and successional changes post 1984. Habitat units were then mapped in the Geographic Information System (GIS), Arcview. A GPS location record (post processed differential GPS) was recorded for each sighting record in 2002. The ArcView GIS extension XTools was used to identify the habitat unit in which each spotlighting sighting record occurred.

Results

Model selection and density estimates for the western ringtail possum

Estimates of density (from 252 sighting records) from the preferred model are shown in Table 2 and show increasing western ringtail possum density from 1996-1998. Two sightings only were recorded for the same annual sampling effort in 2002 and therefore no density estimates were derived for 2002.

Model selection and density estimates for the common brushtail possum

Estimates of density (from 424 sighting records) from the preferred model are shown in Table 3 and show increasing common brushtail possum density from 1996-1998 and 2002.

Model selection and habitat use of the common brushtail possum

Density estimates per stratum are shown in Table 4. Table 5 lists the habitat units derived from Trudgen (1984), modified to reflect structural changes post 1984 and used as strata in the preferred model. Common brushtail possum density estimates varied by an order of magnitude between the two highest density strata (stratum 3, 92 records; stratum 2, 19 records).

Western ringtail possum translocations to Yalgorup National Park

Background and objectives

Releases commenced in July 1995 in response to the management requirement to relocate possums displaced as a result of habitat modification/removal at development sites in the greater Busselton and Bunbury area. Yalgorup National Park was identified as an appropriate release location as it supported suitable habitat and, if successful, the translocations would result in a further extension of

TABLE 2

Output from the preferred model from DISTANCE, stratified by year, to estimate western ringtail possum density at Leschenault Peninsula Conservation Park 1996–1998.

STRATUM (YEAR)	DENSITY ESTIMATE (NO/HA)	%CV	DF	95% CONFIDENCE INTERVAL
Stratum: 1996	0.28390	19.67	25.78	0.19018 - 0.42379
Stratum: 1997	0.30220	16.01	29.67	0.21834 - 0.41825
Stratum: 1998	0.45915	13.46	30.08	0.34927 - 0.60359

TABLE 3

Output from the preferred model from DISTANCE, stratified by year, to estimate common brushtail possum density at Leschenault Peninsula Conservation Park 1996 – 1998 and 2002.

STRATUM (YEAR)	DENSITY ESTIMATE (NO/HA)	%CV	DF	95% CONFIDENCE INTERVAL
Stratum: 1996	0.24317	18.14	31.16	0.16850 - 0.35094
Stratum: 1997	0.36774	15.02	37.45	0.27176 - 0.49761
Stratum: 1998	0.36461	13.71	45.06	0.27699 - 0.47993
Stratum: 2002	0.38963	13.56	47.07	0.29695 - 0.51123

Table 4

Output from the preferred model from DISTANCE, stratified by habitat category, to estimate common brushtail possum density at Leschenault Peninsula Conservation Park, 2002. Descriptions of habitat categories are given in Table 5.

STRATUM (YEAR)	DENSITY ESTIMATE (NO/HA)	%CV	DF	95% CONFIDENCE INTERVAL
Stratum 1:	0.0009	101.26	12.00	0.0001 - 0.0056
Stratum 2:	0.0616	31.41	21.91	0.0326 - 0.11632
Stratum 3:	0.17545	14.03	27.59	0.1318 - 0.23359
Stratum 4:	0.0089	86.55	5.48	0.0014 - 0.0577

TABLE 5

Habitat categories in which common brushtail possum sightings were recorded during the 2002 spotlight transects at Leschenault Peninsula Conservation Park.

DESCRIPTION OF HABITAT UNIT	HABITAT STRATUM
Low shrubland, low open shrubland, high open shrubland to high shrubland, closed heath	1
<i>Agonis flexuosa</i> (peppermint) woodland of low open forest to low closed forest, inclusive of areas with <i>Eucalyptus gomphocephala</i> (tuart) overstorey and/or tuart emergents.	2
<i>Eucalyptus gomphocephala</i> woodland with relatively sparse <i>Agonis flexuosa</i> understorey	3
Beach, mobile dunes, poorly stabilised areas disturbed by waste disposal	4

the geographic range of the western ringtail possum and establish populations in secure conservation estate. The translocations were also carried out under the belief the Leschenault translocations had been successful.

A total of 142 western ringtail possums was caught and relocated from six development sites in period July 1995 to September 2001. Releases were at two sites within Yalgorup National Park, White Hill and Preston Beach. Fox baiting was initiated at both sites prior to the first release and a monthly baiting regime has been maintained. All released possums were sourced directly from development sites, prior to or during site clearing. In each case, a contribution to funding for capture, relocation and monitoring was provided by the development proponent.

Methodology

Release dates, radio-telemetry monitoring and home range estimates

The timing of release of western ringtail possums was largely determined by the site clearing requirements of the development proponents responsible for funding the relocation and monitoring of the displaced possums. Protocols for recording standard morphometrics, assessing breeding condition, radio-collaring and release were similar to the protocols adopted for the Leschenault releases and are detailed in de Tores and Rosier (unpublished-a).

Monitoring of survivorship, home range and habitat use is similar to that described for Leschenault. However, use of differential GPS enabled sub-metre accuracy of

diurnal and nocturnal location records and detailed analysis of habitat use. Additional data were also collected on den tree, tree hollow and diurnal rest site use and are described in de Tores and Rosier (unpublished-a).

DISTANCE sampling model selection and density estimates

One walked spotlight transect of approximately 1.4 km was established at each release site. Spotlighting was carried out over 14 consecutive nights in March/April 2002 and density estimates for the western ringtail possum and resident populations of the common brushtail possum were derived using the DISTANCE sampling protocols (Buckland *et al.* 2001) as described for Leschenault. Post processed differential GPS locations were recorded for each sighting.

DISTANCE sampling to determine habitat use of the western ringtail possum and the common brushtail possum

Aerial Photograph Interpretation (API), using 1 : 20 000 stereo paired aerial photographs and a stereoscopic viewer, was used to identify and delineate vegetation units. Vegetation units were ground-truthed and unit boundaries digitised on geo-referenced aerial photographs using the GIS software ArcView (ESRI, 1992-2000). Vegetation units were subsequently grouped into habitat units. The ArcView GIS extension XTools was used to identify the habitat unit in which each spotlighting sighting record occurred.

Results

Criteria for success

As for the Leschenault translocations, the following criteria for success have been met:

- Released possums established regular use of dreys and tree hollows
- Home range estimates were comparable to reports in the literature and unpublished information on home range for the western ringtail possum and are comparable to home range estimates from Leschenault
- Females have been shown to produce young and the sex ratio of young was not significantly different from parity
- Dispersal patterns of young were consistent with that expected from the literature, i.e. female young stayed within the natal range and male young dispersed
- Recruits to the population were also shown to breed successfully.

Success criteria yet to be established are:

- Confirmation the population has increased and can be sustained
- Maintenance of genetic diversity and confirmation that breeding is not restricted to a limited number of individuals.

Model selection and density estimates for the western ringtail possum and the common brushtail possum

The density estimates for the western ringtail possum and common brushtail possum at each site are given in Table 6 and Table 7, respectively.

Habitat use of the western ringtail possum and the common brushtail possum

Density estimates per stratum (habitat category) for the western ringtail possum and common brushtail possum are shown in Table 8 and 9 respectively and were derived from the preferred models, stratified by habitat category. Table 10 lists the habitat categories derived from grouping the API defined vegetation units. Western ringtail possum density estimates were higher in stratum 5 and common brushtail possum estimates were higher in stratum 6.

Discussion

Density estimates, habitat use and distance sampling

The output from the preferred model to estimate western ringtail possum density at Leschenault (Table 2) showed a pattern of progressively increasing density for 1996-1998. Similarly, the common brushtail possum showed a pattern of increasing density from 1996-2002 (Table 3). However, the net increase in density of the common brushtail possum in the period 1998-2002 (the period when the western ringtail possum density declined) was 0.025 individuals/ha. The implication is that this very small increase in common brushtail possum density is unlikely to result in an increase in the level of interspecies competition and is unlikely to have resulted in the decline in western ringtail possum density.

The output from the preferred models to estimate western ringtail possum and common brushtail possum densities, stratified by habitat stratum, at Leschenault and Yalgorup (Tables 4, 8 & 9) show a clear pattern of habitat partitioning at Yalgorup. The western ringtail possum showed a preference for habitat stratum 5 (dense *Agonis* understorey) and the common brushtail possum showed a preference for habitat stratum 6 (sparse *Agonis* understorey). Data were insufficient to enable the same analysis for Leschenault (i.e. only two western ringtail possum sightings from 2002), however, the common brushtail possum showed a preference for habitat stratum 3 (*Eucalyptus gomphocephala* woodland with sparse *Agonis* understorey). This habitat unit is analogous with the habitat unit preferred by the common brushtail possum at Yalgorup and suggests habitat partitioning may also have occurred at Leschenault. Under this scenario, i.e. habitat partitioning and a very small net increase in common brushtail possum density, it would seem unlikely competition between the two species was responsible for the decline of the western ringtail possum at Leschenault. In a study examining habitat use of the two sympatric possum species, Jones and Hillcox (1995) also found the relative abundance of the two species was largely

TABLE 6

Output from the preferred model from DISTANCE, stratified by site, to estimate density of the western ringtail possum at each translocation release site within Yalgorup National Park. Estimates from 2002 spotlighting data.

STRATUM (YEAR)	DENSITY ESTIMATE (NO/HA)	%CV	DF	95% CONFIDENCE INTERVAL
Stratum: Preston Beach	1.0378	34.52	20.89	0.51637 - 2.0857
Stratum: White Hill	0.69214	24.41	34.17	0.42455 - 1.1284

TABLE 7

Output from the preferred model from DISTANCE, stratified by site to estimate density of the common brushtail possum at each site within Yalgorup National Park. Estimates from 2002 spotlighting data.

STRATUM (YEAR)	DENSITY ESTIMATE (NO/HA)	%CV	DF	95% CONFIDENCE INTERVAL
Stratum: Preston Beach	0.53213	39.70	40.41	0.24566 - 1.1527
Stratum: White Hill	0.62306	46.78	46.30	0.25453 - 1.5252

TABLE 8

Output from the preferred model, stratified by habitat category, to estimate density of the western ringtail possum at Yalgorup National Park. Descriptions of habitat strata are given in Table 10.

STRATUM (YEAR)	DENSITY ESTIMATE (NO/HA)	%CV	DF	95% CONFIDENCE INTERVAL
Stratum: 5	0.60605	37.08	72.89	0.2964 - 1.2394
Stratum: 6	0.17677	39.14	30.47	0.0818 - 0.38200

Table 9

Output from the preferred model, stratified by habitat category, to estimate density of the common brushtail possum at Yalgorup National Park. Descriptions of habitat strata are given in Table 10.

STRATUM (YEAR)	DENSITY ESTIMATE (NO/HA)	%CV	DF	95% CONFIDENCE INTERVAL
Stratum: 5	0.0809	24.45	35.78	0.0496 - 0.13190
Stratum: 6	0.1772	17.03	17.03	0.1262 - 0.24887
Stratum: 7	0.0231	64.95	28.11	0.0069 - 0.0779

TABLE 10

Habitat units within which western ringtail possum and common brushtail possum sightings were recorded during the 2002 spotlight transects at Yalgorup National Park, see text. See also de Tores and Rosier (unpublished-a) for details of the vegetation categories.

DESCRIPTION OF HABITAT UNIT	HABITAT STRATUM
<i>Eucalyptus gomphocephala</i> woodland/open woodland to 25m with dense <i>Agonis flexuosa</i> understorey.	5
<i>Eucalyptus gomphocephala</i> woodland/open woodland to 25m with sparse <i>Agonis flexuosa</i> understorey.	6
<i>Eucalyptus gomphocephala</i> woodland/open woodland to 25m with absence of <i>Agonis flexuosa</i> in the understorey.	7

determined by floristics. The western ringtail possum was more abundant in areas with more peppermint and the common brushtail possum was more abundant in areas with more tuart.

This further suggests factors other than competition with the common brushtail possum may have been responsible for the decline in western ringtail possum density.

Changes to the baiting regime and the statutory responsibilities for recording locations where 1080 baits are laid

It is unclear if changes to the baiting regime were responsible for the decline in western ringtail possum density at Leschenault. However, it remains the most parsimonious explanation. In the absence of experimental controls, the cause of the decline is unlikely to be unequivocally explained. Re-instating the 4-weekly baiting regime is recommended if further western ringtail possum releases are proposed at the Leschenault release site. This will require resolution of the conflict between management for conservation and management for visitor use (see below).

Similarly, the variation in detail of the record keeping for 1080 bait delivery made it difficult to interpret exactly how many baits were distributed at Leschenault at each baiting event. This further confounds identification of a cause and effect relationship between the number of baits delivered monthly and the decline of the western ringtail possum population.

Conflict between conservation management and management for visitor use

The decision to amend the baiting regime at Leschenault was primarily in response to the findings from a risk assessment which identified a potential risk to park users and domestic pets brought into the Park (R. Armstrong, CALM, pers. comm.). The operational application of several other 1080 baiting programs using conventional dried meat baits has also recently been amended as a result of similar risk analyses. As was the case at Leschenault, risk assessment at other sites has resulted in reductions to the frequency and intensity of baiting programs and the method of laying baits has changed to a buried bait delivery system. The latter imposes additional costs to baiting programs and has been shown to result in a reduced uptake of dried meat baits (Thomson and Kok, 2002).

When preparing, implementing and reviewing existing and proposed 1080 baiting programs, managers of conservation estate are expected to address the conflict between management for conservation purposes through the use of 1080 and management for visitor use. This is often done in the absence of information on community values and community expectations.

It is recommended that CALM implements a program to assess community attitudes to, and expectations from, its use of 1080 baiting for fox control. This will allow assessment of public expectation of a state government

agency with the primary objective of nature conservation and the potentially conflicting, secondary objective of fulfilling the demand for public use, notwithstanding the latter's requirement to be consistent with the primary objective. Assessment of community attitudes and expectations will ultimately assist the Department with refining philosophies and improving strategies for baiting conservation estate and thereby reduce conflict between management objectives.

Translocation as a management tool and the importance of monitoring

Translocation is now widely accepted as a management tool for re-establishing species throughout their former range and in habitats from which they have become extinct. However, it should not be seen as a panacea for resolving all issues associated with fauna range contractions and regional extinctions (de Tores *et al.* unpublished-b). In the case of the western ringtail possum, translocation is yet to be shown to be an effective management tool. The potential for the translocations at Leschenault to succeed appears to have been compromised by changes to the baiting regime. Re-instating the former baiting regime and initiating further releases should be supported by research to assess the interaction between the suite of resident and introduced predators, the long term interaction between the western ringtail possum and the common brushtail possum and the importance of site specific habitat factors (de Tores *et al.* unpublished-b). The fate of the Yalgorup translocations is also yet to be determined (de Tores and Rosier, unpublished-a). Further translocation of the western ringtail possum (i.e. translocation to additional sites) is not recommended until the outcome of translocations to Leschenault and Yalgorup is known and there is a clear understanding of the factors influencing translocation success/failure.

To achieve this, monitoring needs to be focussed to ensure translocation outcomes can be assessed against specific criteria for success. Equally important is the need to specify the criteria for failure. Planning for translocation programs must also ensure resources are sufficient to enable monitoring to be effective. This may necessitate reducing the number of sites monitored or increasing the resources committed to monitoring.

If translocation can be established as a viable management strategy for the western ringtail possum, monitoring effort and intensity may be able to be relaxed. However, in the absence of demonstrated success, critical components of monitoring western ringtail possum translocation outcomes include:

- determining the fate of released possums—we recommend radio telemetry, ideally incorporating mortality circuitry and new advances, such as contact telemetry, as they become applicable for small to medium size arboreal marsupials. Analytical techniques focussing on survivorship are recommended, such as the known fate model from Program MARK (White, 2001)

- determining the fate of recruits to the population—we recommend use of breakaway collars for this purpose (de Tores and Rosier, unpublished-b) to ensure this age class is monitored and the survivorship and dispersal patterns determined
- estimating population changes through quantifiable measures – we recommend changes to population size should be assessed through the use of techniques which quantify these changes and don't simply report spotlight count data. Recommended techniques include DISTANCE Sampling (Thomas *et al.* 2002)
- assessing the effectiveness of predator control – this involves monitoring fox, cat and other predators to determine the effectiveness of introduced predator control and ideally should incorporate an assessment of the extent of interactions between predators. Monitoring should address the issues of mesopredator release and intraguild predation (Polis *et al.* 1989).

The *Western Shield* program in general appears to have little focus on monitoring fox populations. Monitoring of fox (and where appropriate, cat) populations is strongly recommended. This monitoring should assess fox and cat presence at treatment (baited) sites and control (unbaited) sites with the objectives of assessing whether the baiting program has achieved set targets of predator density reduction, and if met, determining if this has resulted in biodiversity conservation gains, as measured against the criteria for translocation success or by increases in native fauna abundance and survivorship.

Monitoring western ringtail possum response to fox control at locations other than specific translocation and other research sites has been poorly addressed by the *Western Shield* program. We recommend implementing a program to identify the sites of high conservation value to the western ringtail possum. We further recommend initiating a structured monitoring program at selected sites representative of the range of habitats occupied by the western ringtail possum. This monitoring program should assess western ringtail possum population changes and responses to fox control and the impact of other management practices and disturbance regimes. We advocate use of monitoring and analytical techniques with strong mathematical foundations (e.g. DISTANCE Sampling and the Information-Theoretic approach) and caution against use of simple spotlight count techniques and scat count techniques without appropriate validation of these techniques. We particularly caution against use of either of the latter two techniques where justification for the use of one is based on correlation with the other unvalidated method.

CASE STUDY 2: THE QUOKKA, *SETONIX BRACHYURUS*

Distribution

The distribution and conservation status of the quokka was recently reviewed by de Tores *et al.* (in review). The

quokka was shown to have suffered a decline in geographic range in the 1930s, coinciding with the arrival of the fox in south-west Western Australia. A further decline appears to have occurred in the period 1980 to 1992, however, the latter may be an artefact of the IUCN methodology for assessing range contraction. Predation by the introduced red fox was implicated as a major cause of the initial decline, while ongoing predation, habitat destruction and modification through altered fire regimes appear to have contributed to the continued decline.

An increased awareness of the presence of the quokka on the mainland has resulted in numerous records of occurrence since 1992, has confirmed the existence of several populations at the northern extent of the quokka's known geographic range and indicated the current extent of occurrence to be similar to that in 1992. However, censuses at six locations in the northern jarrah forest (Hayward *et al.* 2003) indicated low abundance and only one population has persisted on the Swan Coastal Plain. Persistence of this population needs to be verified.

The review (de Tores *et al.* in review) emphasised the need for urgent management attention at sites in the northern jarrah forest, where Hayward *et al.* (2003) concluded the few remaining small populations constitute the terminal remnants of a collapsing metapopulation. The review further recommended:

‘...management of the quokka should adopt an adaptive management approach, under which research and monitoring is focused on examining the response of the quokka to a variety of management practices including habitat manipulation through the use of fire, fox baiting and pig control.’

Further, the review identified emphasis should initially be placed on the most vulnerable populations – those in the northern jarrah forest and the Stirling Range.

The Stirling Range population(s) are geographically isolated from other south coast populations and may have been traditionally isolated, or may represent a remnant of a once contiguous population. In either case, the status and security of these isolated populations was recognised as warranting further investigation.

The review also identified the lack of quantitative data on quokka populations from southern forest and south coast regions. Recommendations for southern forest and south coast areas included the requirement for:

‘...surveying to assess quokka population size, the extent of immigration and emigration and assessment of the range of habitat types used by quokkas’. The review further recommended ‘this be combined with spatial analyses of known extant populations and suitable and potentially suitable habitat. The role of fire in establishing and maintaining preferred habitat should be determined and a program to assess the potential effects from management operations should be implemented.’

The review concluded the quokka continues to meet the IUCN criteria for listing as a Threatened species in the category Vulnerable.

Background

The quokka case study is based on recent publications and a suite of publications in review and in preparation. The case study has extracted information from these manuscripts, and has placed emphasis on the quantitative analyses from the northern jarrah forest carried out by Hayward (2002) and reported in Hayward *et al.* (2003), Hayward *et al.* (2004), Hayward *et al.* (unpublished-a), Hayward *et al.* (in review-b) and Hayward *et al.* (in review-a).

Quokka population structure in the northern jarrah forest

Results from mark-recapture studies at northern jarrah forest sites previously known to support populations of the quokka confirmed low density at six sites. Density and abundance estimates were derived by Hayward *et al.* (2003) for four of the seven sites trapped and at an additional site (Gervasse, near Collie) by de Tores *et al.* (in review). Where appropriate, the Jolly-Seber model of 'death but no immigration' was used. Abundance estimates for these five sites are shown in Table 11. A sixth site, Rosella Road, is also listed, however, only one individual was trapped and data were therefore insufficient to derive abundance estimates. No captures were recorded at an additional two sites where the quokka is now thought to be locally extinct (Hayward *et al.* 2003).

With the exception of Victor Road, all sites are baited as part of *Western Shield* or Operation Foxglove (a broadscale 1080 baiting program in the northern jarrah forest of south-west Western Australia – the predecessor to *Western Shield*). Victor Road had the highest proportion of juveniles and pouch young and therefore has the greatest propensity to increase. Hayward *et al.* (2003) believed the low population density at the unbaited Victor Road site reflected a low level of recruitment following weaning. The Hadfield Site, which ranked second in its propensity to increase (i.e. showed a high proportion of juveniles and pouch young), showed a relatively high density and abundance. This may reflect the quokkas ability to increase in abundance in the presence of fox control. However, despite the six year baiting program, quokka populations in the northern jarrah forest have not shown a pattern of increase in response to fox control (Hayward *et al.* 2003).

Hayward *et al.* (2003) concluded the absence of a detectable response to fox control may reflect on-going predation, despite the presence of baiting programs, and may also reflect the absence of the quokka's specific habitat requirement for a mosaic of seral stages within the *Agonis linearifolia* swamps.

Habitat requirements

Habitat use by the quokka was investigated in a study of 58 radio collared quokkas at the northern jarrah forest sites (Hayward *et al.* in review-a). Quokkas were found to be largely restricted to *Agonis* swamps. Quokkas were shown to prefer early seral stage *Agonis* swamp habitat, burnt within the previous ten years, where this seral stage was part of a mosaic including older age classes (Hayward *et al.* in review-a).

The presence or absence of quokka populations at 66 sites in the northern jarrah forest was further investigated. General Linear Modeling (GLM) with stepwise removal of variables identified a preferred model to describe the quokkas' preferred mosaic.

The explanatory variables of the preferred model were:

- the number of 1080 meat baits delivered per hectare
- the average age of the swamp (calculated as the area of each swamp habitat unit at a site multiplied by the average number of years post fire of that unit and then divided by the total area of swamp to obtain an average number of years post fire)
- a habitat factor score (NJF4, characterised by possessing large areas of *Agonis* swamp burnt five to nine years previously).

The preferred model (Model 11, Table 12) therefore indicated that, in addition to the requirement for fox control, quokkas are more likely to be present at swamps which support young (five to nine year) post-fire successional stages and long average ages since fire. Further use of model selection (the Information-Theoretic approach, and specifically Akaike Information Criteria, or AIC) (Burnham and Anderson, 2002) identified two other models which were equally well supported by the data. All models examined are shown in Table 12. The variables used in the modeling process are described in Table 13.

TABLE 11

Estimates of quokka abundance at sites from the northern jarrah forest. Estimates derived from the Jolly-Seber model of death but no immigration, with the exception of Rosella Road, where only 1 individual was trapped.

SITE	ESTIMATE OF ABUNDANCE	SOURCE
Chandler Road	10 ± 0	Hayward <i>et al.</i> 2003
Hadfield	29 ± 5	Hayward <i>et al.</i> 2003
Kesners	36 ± 6	Hayward <i>et al.</i> 2003
Rosella Road	no estimate	Hayward <i>et al.</i> 2003
Victor Road	9 ± 1	Hayward <i>et al.</i> 2003
Gervasse	49 ± 4	de Tores <i>et al.</i> in review

TABLE 12

Model selection statistics for the presence/absence of quokka populations at 66 sites from the northern jarrah forest of south-west Western Australia. The models are numbered sequentially from the null model. The statistic for the Akaike Information Criterion (AIC), the difference in AIC values (delta (Δ) AIC) and the Akaike weights are also shown. Models with a lower AIC are deemed to best fit the data (Burnham and Anderson, 2002). Models with a Δ AIC of less than two have substantial support while those with a Δ AIC greater than seven have no support (Burnham and Anderson, 2002). Akaike weights provide a weight of evidence in favour of each model and reflect the probability that the model is the Kullback-Leibler best model for the data (Burnham and Anderson, 2001). The model variables are described in Table 13. See also the text comments noting this process is a hybrid between conventional GLM and the Information-Theoretic approach.

MODEL	AIC	DAIC	AKAIKE WEIGHTS
1. Null model Pres/Abs ~ Slope + Distance to forest edge + Length of Swamp + Baits + Age + Mosaic + Distance to disturbance + Rainfall + NJF1 + NJF2 + NJF3 + NJF4 + NJF5	72.6195	12.8377	0.0001
2. Null model with NJF1 deleted	70.9039	11.1221	0.0009
3. Model 2 with Mosaic deleted	69.4129	9.6311	0.0022
4. Model 3 with Slope deleted	67.9952	8.2134	0.0047
5. Model 4 with Rainfall deleted	66.7131	6.9313	0.0095
6. Model 5 with Distance to forest edge deleted	65.3131	5.5313	0.0181
7. Model 6 with NJF3 deleted	63.9917	4.2099	0.0364
8. Model 7 with Swamp length deleted	62.0052	2.2234	0.0705
9. Model 8 with NJF5 deleted	61.5839	1.8021	0.1903
10. Model 9 with Distance to disturbance deleted	60.3629	0.5811	0.2349
11. Model 10 with NJF2 deleted	59.7818	0	0.4325

Models 9 and 10 equally well describe the data (Δ AIC < 2.0 in both cases). Given habitat Factor NJF2 (a high proportion of jarrah-marri open forest and 15–19 year post-fire *Agonis* swamp) was negatively correlated with quokka abundance (Hayward *et al.* in review-b), the additional explanatory variables determining quokka abundance are:

- absence/reduction of NJF2 (Model 10) (i.e. absence of a high proportion of jarrah - marri open forest and 15–19 year post-fire *Agonis* swamp)
- increasing distance to disturbance (Model 9).

Note: the model selection process presented is a hybrid between conventional GLM and the Information-Theoretic approach as described by Burnham and Anderson (2002). A more rigorous application of the Information-Theoretic approach, reviewing a more comprehensive set of a priori candidate models is given in Hayward et al. (in review-b)

Habitat features have previously been associated with the persistence of quokka populations. Quokkas were thought to exhibit a preference for a mosaic of freshly burnt (< 10 years) and long unburnt areas (Christensen and Kimber, 1975; Hayward *et al.* 2003). The NJF4 variable relates to the presence of large areas of *Agonis* swamp shrubland burnt between five and nine years previously. When this variable is viewed with the other explanatory variable of the preferred model, i.e. the average age of the swamp, further weight is added to Christensen and Kimber's (1975) earlier hypothesis.

These features, combined with the additional explanatory variable from Model 10, highlight the importance of a mosaic of age classes within the swamp with early (< 10 years post-fire) and late (large values for average age of the swamp) seral stages as important for

quokka presence. The intermediate seral stage is avoided. This is a mosaic of specific age classes (young and old) rather than simply a mosaic of mixed age classes.

GENERAL DISCUSSION AND RECOMMENDATIONS IN RELATION TO THE FURTHER IMPLEMENTATION OF WESTERN SHIELD

The importance of habitat and habitat management

Fox predation has contributed to the decline of a suite of species, including the western ringtail possum and the quokka. However, fauna declines are unlikely to be the result of a single dimensional causal factor, such as predation (de Tores *et al.* unpublished-b). In the case of the quokka in particular, fox control alone will be insufficient to ensure its effective long term conservation. There is a clear requirement for habitat management.

Specific recommendations are detailed in Hayward *et al.* (2003), (Hayward, 2002), de Tores *et al.* (in review), Hayward *et al.* (in review-a) and Hayward *et al.* (unpublished-c) for management of quokka populations in the northern jarrah forest and include:

- the use of fire to create and maintain a mosaic of specific age classes;
- the use of fire to ensure suitable habitat is available for dispersing quokkas; and
- adoption of a landscape approach to habitat management for the quokka to ensure interpatch distances are short and patches of suitable habitat are within dispersal range.

TABLE13

Variables used in modeling the occurrence (presence/absence) of the quokka at 66 locations within the northern jarrah forest of south-west Western Australia. Correlated variables excluded from analyses are marked with an asterisk. Table modified from Hayward *et al.* (in review-b)

VARIABLE NAME	DESCRIPTION	VARIABLE NAME	DESCRIPTION
Aspect *	A categorical variable determined by the map bearing in degrees along the down slope direction of the watercourse. This variable was included due to the potential for south-facing sites to have different ecological attributes from north-facing ones.		truthed during the quokka surveys. Habitat units were described according to floristic, structural and other biological features (Hayward, 2002; Hayward <i>et al.</i> in review-a). The percentage which each habitat unit made up of the entire study site was subsequently combined using principal components factor analysis. Habitat factors were denoted as NJFF1-5. This variable was used following previous findings that quokkas prefer a mosaic of freshly burnt and long unburnt areas of swamp (Christensen and Kimber, 1975; Hayward <i>et al.</i> in review-a).
Baiting	The total number of poisoned fox baits laid per hectare around the swamp since feral animal control began in 1994. Higher levels of baiting in the northern jarrah forest have been shown to result in significant increases in the density of predation-sensitive native fauna and to have reduced densities of foxes (de Tores, 1999). The range of baiting levels arose due to variations in the annual frequency of bait delivery within the <i>Western Shield</i> and Operation Foxglove programmes which range from an unbaited control region through biannual, quarterly and two monthly baiting regimes and more frequent and intense baiting at specific sites (e.g. around quokka populations) where monthly baiting was implemented (de Tores, 1999; Hayward <i>et al.</i> 2003; Thomson and Algar, 2000).	Rainfall	Mean annual rainfall was derived from distances from rainfall isohyet maps provided by CALM Information Management Branch. Rainfall was thought to be an important descriptive variable after it was found that all extant quokka populations are found in areas receiving more than 1,000 mm of precipitation per year (de Tores <i>et al.</i> in review; Hayward, 2002; Hayward <i>et al.</i> 2003).
Distance from forest edge	The distance from the interface between the state forest and cleared, residential or agricultural lands and the centre of each particular swamp. This variable was used following the finding that foxes reinvaded areas near the forest boundary rapidly after poison baits were laid (de Tores, 1999).	Slope	The angle from horizontal to the ground that the one km length of swamp fell by, calculated using topographical maps. Although all <i>Agonis</i> swamps exist in the relatively flat, broad upper reaches of creek systems along the eastern edge of the northern jarrah forest (Hayward <i>et al.</i> in review-a), they appear to change into different habitat types where the terrain becomes too steep or too flat (Hayward, 2002). Consequently, the slope of each site was used as a descriptive variable.
Distance to nearest disturbance	The distance from the centre of the swamp to the nearest source of anthropogenic disturbance (mining, agriculture, urban areas). This variable was used to investigate the effect of disturbance on quokkas.	Swamp age (in years since last fire)	The average number of years since fire burnt the swamp (Hayward <i>et al.</i> in review-a) calculated as the area of each swamp habitat unit at a site multiplied by the average number of years post fire of that unit and then divided by the total area of swamp to obtain an average number of years post fire. This meant sites with a mosaic of burn ages could be compared with sites with one age class. With age since fire previously identified as a factor affecting quokka presence (Christensen and Kimber, 1975; Hayward <i>et al.</i> in review-a), the average swamp age was used to determine whether there was a preference for any particular age class (Hayward <i>et al.</i> in review-a).
Disturbed habitats *	The number of habitat types at each site which were classified as disturbed (cleared or revegetation) by Hayward <i>et al.</i> (in review-a). This variable was also intended to investigate the effect of disturbance on quokkas.		
Ecotone *	The percentage of the site made up of ecotonal habitat types surrounding the <i>Agonis</i> swamp shrubland (bullich swamp forest, bullich-blackbutt open forest, blackbutt open forest) Hayward (2002). This variable was included to test whether the species was an ecotonal specialist.		
Habitat number *	The number of different habitat types found at a site. This variable was intended to investigate the mosaic preference of quokkas (Christensen and Kimber, 1975).	Swamp mosaic value	The number of swamp habitat units found at each site was considered as a variable in conjunction with swamp age following the habitat preferences of quokkas.
Habitat type	The percentage of each habitat type (according to the methods in Hayward (2002) and Hayward <i>et al.</i> (in review-a)) which made up the one km section of swamp and an area 100 metres wide either side of the swamp. Visual examination of digital images was used to delineate habitat unit boundaries which were subsequently ground-	Swamp length	The number of kilometres that the creek line retained the characteristic <i>Agonis</i> vegetation. This was determined from raster images of aerial photographs that were imported into a GIS and geo-referenced. Tributaries were added to the total swamp length with the expectation that larger swamps would possess larger populations.

In the absence of this management intervention, regional extinction of the northern jarrah forest quokka populations is highly likely (Hayward *et al.* 2003).

Western Shield: management for critically endangered, endangered or vulnerable species?

Priority for allocation of *Western Shield* resources is largely directed to 'threatened' species (CALM, undated). Within the category 'threatened', there also appears to be a philosophy of prioritising allocation of *Western Shield* resources to species at higher levels of threat (PdeT, personal observations). We recommend adoption of the alternative, environmental triage approach (see Possingham, 2001).

Although the environmental triage process is fraught with the danger from inappropriate and/or veiled political agendas, it provides a strategy for allocating resources to those species which can respond/recover as a result of early management intervention. Adopting this approach may provide a more strategic use of *Western Shield* resources.

The importance of quantitative analysis and accurate information dissemination

Compiling lists of species presence and occurrence is a useful component of fauna conservation and fauna management – it provides managers with base line information on the resources to be managed. However, compiling lists of occurrence should not be seen as an end in itself. Generating lists does not equate with long term persistence of species and does not infer effective conservation management has, or will be implemented. Similarly, we caution against providing lists of the number of species translocated and lists of species within areas where fox control has been implemented. We recommend these lists be supported by quantified analyses. In the case of translocation programs, we recommend data be collected and reported on translocation success and progress towards success or recognition of shortcomings. In the case of areas managed for fox control, we recommend data be collected and reported on the effectiveness of the fox control effort (i.e. by monitoring and reporting on fox populations at baited and unbaited sites) and the response of the fauna at baited and unbaited sites.

Two recent publications promoting the success of *Western Shield* have referred to the western ringtail possum translocations to Lane Poole Reserve and Yalgorup National Park. Curry and Kierath (1999) claimed:

'... there have been numerous successful species reintroductions. These include ... the western ring-tail possum (*Pseudocheirus* [sic] *occidentalis*) to Lane Poole Conservation Park, Yalgorup National Park'

The eight page, March 2000 supplement 'WA forests today' inserted in all local Perth metropolitan newspapers claimed:

... Other endangered native animals such as the ... ring-tailed possum are also beginning to thrive after being reintroduced into forest inside and outside reserves.

In neither case did the authors check the validity of the claims with the researchers concerned. Neither the Lane Poole nor the Yalgorup National Park translocations can yet be considered successful. The Lane Poole translocation may have failed (see Table 1).

Similarly, claims have been made of increases in the abundance of the quokka in southern forest areas. Although these claims may be true, there are no quantifiable data to support them. Unsubstantiated claims of translocation success and fauna recovery can only serve to undermine the validity of genuine successful translocations and quantifiable achievements of *Western Shield*.

The success of *Western Shield* will ultimately be judged by the long term effectiveness of the conservation management actions implemented. Claims of effectiveness can best be demonstrated by quantified data analysis, not by anecdotal accounts and unsubstantiated claims of success. The *Western Shield* program has the potential to deliver significant conservation gains. To unequivocally demonstrate these gains, we recommend the data collection, collation, analyses and reporting processes be reviewed to ensure data are collected in a manner to allow objective analyses and scrutiny. Under this proposed scenario, any conservation gains can be quantified and documented. Conversely, in circumstances where desired outcomes have not been met, the failure to meet set goals can be identified and mechanisms can be implemented to improve conservation management.

ACKNOWLEDGMENTS

The authors wish to thank all CALM staff who contributed valuable information used in this manuscript. We also thank Dr Per Christensen and an anonymous referee for comments on, and constructive criticism of, the original manuscript.

REFERENCES

- Alacs E, Aplers D, de Tores PJ, Dillon MJ, Spencer PBS (2003) Identifying the presence of quokkas (*Setonix brachyurus*) and other macropods using cytochrome *b* analyses from faeces. *Wildlife Research* **30**, 41-47.
- Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L (2001) *Introduction to Distance Sampling. Estimating abundance of biological populations*. Oxford University Press. Oxford.
- Burbidge AA, Start AN, Morris KD, Armstrong R (1995) 'Western Shield – Bringing back our wildlife.' Department of Conservation and Land Management, Western Australia.

- Burnham KP, Anderson DR (2001) Kullback-Leibler information as a basis for strong inference in ecological studies. *Wildlife Research* **28**, 111-120.
- Burnham KP, Anderson DR (2002) *Model Selection and Multimodel Inference. A Practical Information-Theoretic Approach*. Second Edition. Springer-Verlag. New York.
- CALM see Department of Conservation and Land Management
- Christensen P, Annels A, Liddelow G, Skinner P (1985) Vertebrate fauna in the southern forests of Western Australia: a survey. Bulletin 94. Forests Department of Western Australia. Perth.
- Christensen PE, Kimber PC (1975) Effects of prescribed burning on the flora and fauna of south-west Australian forests. In *Managing Terrestrial Ecosystems*. Brisbane. (eds. J Kikkawa and HA Nix). Ecological Society of Australia. Proceedings of the Ecological Society of Australia **9**, 85-106.
- Curry S, Kierath M (1999) Take Your Partners. *Landscape* **14**, 47-53.
- Department of Conservation and Land Management (1999) 'Western Shield Fauna Recovery Program. Strategic Plan. July 1999 to June 2004.' prepared by the Western Shield Strategic Group for the Western Australian Department of Conservation and Land Management. Perth, Western Australia.
- de Tores, P (1999) 1997-1998 Report to Environment Australia National Feral Animal Control Program ISF06638. Control and Ecology of the Red Fox in Western Australia - Prey Response to 1080 Baiting Over Large Areas. Unpublished report prepared for Environment Australia, National Feral Animal Control Program. ISF06638. Department of Conservation and Land Management, Western Australia.
- de Tores PJ, Rosier SM (1997) 'Harvey Basin allocation plan: western ringtail possum survey.' Unpublished report prepared for the Waters and Rivers Commission. Perth, Western Australia.
- de Tores PJ, Rosier SM, Paine G (1998) Conserving the western ringtail possum. *Landscape*, **13**, 28-35.
- de Tores PJ, Hayward MW, Dillon MJ, Brazell R (in review) Review of the distribution, causes for the decline and recommendations for management of the quokka, *Setonix brachyurus* (Macropodidae: Marsupialia), an endemic macropod marsupial from south-west Western Australia. *manuscript submitted to Records of the Western Australian Museum*.
- de Tores PJ (unpublished) Review of the distribution and conservation status of the western ringtail possum, *Pseudocheirus occidentalis* (Pseudocheiridae: Marsupialia), and implications for conservation management. *manuscript in preparation*.
- de Tores PJ, Rosier SM (unpublished-a) Conservation management of the western ringtail possum, *Pseudocheirus occidentalis*: (ii) Translocation of possums displaced as a result of habitat destruction. *manuscript in preparation*.
- de Tores PJ, Rosier SM (unpublished-b) An expandable, breakaway radio-collar for use on sub-adult and juvenile western ringtail possums, *Pseudocheirus occidentalis* (Marsupialia: Pseudocheiridae). *manuscript in preparation*.
- de Tores PJ, Rosier SM (unpublished-c) Use of Ketamine and Xylazine for immobilisation of the western ringtail possum, *Pseudocheirus occidentalis*, and the brush-tailed bettong, *Bettongia penicillata*. *manuscript in preparation*.
- de Tores PJ, Rosier SM, Millen N (unpublished-a) Translocation of the western ringtail possum, *Pseudocheirus occidentalis*, to the northern jarrah forest of south-west Western Australia. *manuscript in preparation*.
- de Tores PJ, Rosier SM, Paine G (unpublished-b) Conservation management of the western ringtail possum, *Pseudocheirus occidentalis*: (i) Translocation of rehabilitated possums. *manuscript in preparation*.
- de Tores PJ, Terrell B, Rosier SM (unpublished-c) A new immobilising tranquiliser dart gun for capture of the western ringtail possum, *Pseudocheirus occidentalis*, and other small marsupials. *manuscript in preparation*.
- Dixon CR, Chapman JA (1980) Harmonic Mean Measure of Animal Activity Areas. *Ecology* **61**, 1040-1044.
- ESRI (1992-2000) *ArcView GIS Version 3.2a*. Environmental Systems Research Institute, Inc.
- Hayward MW (2002) 'The ecology of the quokka (*Setonix brachyurus*) (Macropodidae: Marsupialia) in the northern jarrah forest of Australia.' PhD thesis. School of Biological, Earth and Environmental Science. University of New South Wales. Sydney.
- Hayward MW, de Tores PJ, Dillon MJ, Fox BJ (2003) Local population structure of a naturally occurring metapopulation of the quokka (*Setonix brachyurus* Macropodidae: Marsupialia). *Biological Conservation* **110**, 343-355.
- Hayward MW, de Tores PJ, Auger ML, Fox BJ, Banks PB (2004) Home range and movements of the quokka *Setonix brachyurus* (Macropodidae: Marsupialia), and its impact on the viability of the metapopulation on the Australian mainland. *Journal of Zoology* **263**, 219-228.
- Hayward MW, de Tores PJ, Banks PB (in review-a) Habitat use and preferences of the quokka *Setonix brachyurus* (Macropodidae: Marsupialia) in the northern jarrah forest of Australia. *manuscript submitted to Journal of Mammalogy*.
- Hayward MW, de Tores PJ, Dillon MJ, Banks PB (in review-b). Modeling the occurrence of the quokka (*Setonix brachyurus*: Quoy & Gaimard 1830) (Macropodidae: Marsupialia) in Australia's northern jarrah forest. *Manuscript submitted to Biological Conservation*.

- Hayward MW, de Tores PJ, Augée ML, Banks PB (unpublished-a) Mortality and survivorship of the quokka *Setonix brachyurus* (Macropodidae: Marsupialia) in the northern jarrah forest of south-west Western Australia. *manuscript to be submitted*.
- Hayward MW, de Tores PJ, Dillon MJ, Fox BJ, Banks PB (unpublished-b) Use of faecal pellet counts to estimate population density of the quokka, *Setonix brachyurus* (Macropodidae: Marsupialia). *manuscript submitted to Wildlife Research*.
- Hayward MW, de Tores PJ, Fox BJ (unpublished-c) Post fire succession in *Agonis linearifolia* swamps in the northern jarrah forest of south-west Western Australia. *manuscript to be submitted*.
- Jones B (1991) 'Western ringtail possum.' Unpublished file record of the Western Australian Department of Conservation and Land Management.
- Jones B, Hillcox S (1995) A survey of the possums *Trichosurus vulpecula* and *Pseudocheirus occidentalis* and their habitats in forest at Ludlow, Western Australia. *The Western Australian Naturalist* **20**, 139-150.
- Jones B, Northover M (2001) 'The Harvey ringtail possums after the SHRS.' Unpublished report prepared for the Water Corporation. Water Corporation. Perth, Western Australia.
- Jones BA, How RA, Kitchener DJ (1994) A field study of *Pseudocheirus occidentalis* (Marsupialia: Petauridae). I. Distribution and habitat. *Wildlife Research* **21**, 175-188.
- Kenward RE, South AB, Walls SS (2003) Ranges6: For the analysis of tracking and location data. Online manual. v1.2. Wareham, UK. ISBN 0-9546327-0-2. Anatrack Ltd.
- Kenward RE, Hodder KH (undated) RangesV. An analysis system for biological location data. Institute of Terrestrial Ecology. Furzebrook Research Station, Wareham, Dorset, United Kingdom.
- Middleton E (2001) 'Nuyts Wilderness Wildfire Impact Report. 7-11 March 2001, Walpole, Western Australia.' Unpublished report prepared for the Department of Conservation and Land Management, Western Australia.
- Millen N (1997) 'Translocation of the Western Ringtail Possum, *Pseudocheirus occidentalis*, to the Northern Jarrah Forest of South West Western Australia: analysis of habitat use, home range and survivorship.' Honours Thesis. Curtin University of Technology, Perth.
- Polis G, Myers C, Holt R (1989) The ecology and evolution of intraguild predation: potential competitors that eat each other. *Annual Review of Ecology and Systematics* **20**, 297-330.
- Possingham HP (2001) The business of biodiversity: applying decision theory principles to nature conservation. Issue 9. The Australian Conservation Foundation and Earthwatch Institute. Melbourne.
- Smitz A (2000) 'Karakamia Sanctuary. Western Ringtail Possums. July 2000 Progress Report.' Unpublished report prepared for the Department of Conservation and Land Management, Western Australia.
- Smitz A (2001) 'Karakamia Sanctuary. Western Ringtail Possums. December 2001 Progress Report.' Unpublished report prepared for the Department of Conservation and Land Management, Western Australia.
- Thomas L, Laake JL, Strindberg S, Marques FFC, Buckland, ST, Borchers DL, Anderson DR, Burnham KP, Hedley SL, Pollard JH (2002) Distance 4.0. Release 1. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. Available: <http://www.ruwpa.st-and.ac.uk/distance/>.
- Thomson PC, Algar D (2000) The uptake of dried meat baits by foxes and investigations of baiting rates in Western Australia. *Wildlife Research* **27**, 451-456.
- Thomson PC, Kok NE (2002) The fate of dried meat baits laid for fox control: the effects of bait presentation on take by foxes and non-target species, and on caching by foxes. *Wildlife Research* **29**, 371-377.
- Trudgen ME (1984) The Leschenault Peninsula - A Flora and Vegetation Survey with an Analysis of its Conservation Value and Appropriate Uses. Bulletin 157. Report prepared for the Department of Conservation and Environment. Perth, Western Australia.
- Wayne A, Ward C, Rooney J, Wheeler I (2000) 'The immediate impacts of timber harvesting and associated activities on the Ngwayir (*Pseudocheirus occidentalis*) in the Jarrah forest of Kingston State Forest Block. Progress Report December 2000.' Unpublished report prepared for the Western Australian Department of Conservation and Land Management.
- Wayne A, Rooney J, Ward C, Wheeler I, Mellican, A (2001a) 'Spotlight surveys to investigate the impacts of timber harvesting and associated activities within the jarrah forest of Kingston State Forest, with particular reference to the koomal (*Trichosurus vulpecula*) and ngwayir (*Pseudocheirus occidentalis*). Progress Report April 2001.' Unpublished report prepared for the Western Australian Department of Conservation and Land Management.
- Wayne A, Wheeler I, Ward C, Rooney J, Mellican A (2001b) 'The impacts of timber harvesting and associated activities on the small terrestrial vertebrates of the Jarrah forest. Kingston Project Progress Report. May 2001.' Unpublished report prepared for the Western Australian Department of Conservation and Land Management.
- White GC (2001) Program MARK. Mark and Recapture Survival Rate Estimation. Version 2.1. Department of Fishery and Wildlife. Colorado State University. Fort Collins. <http://www.cnr.colostate.edu/~gwhite/mark/mark.htm>.

APPENDIX 1

Record of 1080 baiting at Leschenault Peninsula Conservation Park, September 1997–April 2002

DATE	ENTRY IN 'DISTRICT 1080 REGISTER' ⁽¹⁾	NUMBER OF BAITES USED	COMMENT	IRV NO.
19/09/1997	Lesch. Pen. Hadfield	319	Can't determine how many baits laid at Leschenault and how many at Hadfield	676
15/10/1997	No record in 'District 1080 Baiting Register' of baits removed. Source of baits is therefore not clear	100	CALM 'Property Baiting Report' and informal baiting return show 100 baits laid at Leschenault ⁽³⁾	
12/11/1997	No record in 'District 1080 Baiting Register' of baits removed. Source of baits is therefore not clear	100	CALM 'Property Baiting Report' and informal baiting return show 100 baits laid at Leschenault ⁽³⁾	
10/12/1997	No record in 'District 1080 Baiting Register' of baits removed. Source of baits is therefore not clear	100	CALM 'Property Baiting Report' and informal baiting return show 100 baits laid at Leschenault ⁽³⁾	
5/01/1998	Ground baiting	228	Additional informal baiting return and CALM 'Property Baiting Report' show 100 baits laid at Leschenault. Nothing to indicate where the remaining 128 baits were laid ^{(2) (3)}	687
4/02/1998	GB monthly ?....	200	Additional informal baiting return and CALM 'Property Baiting Report' show 100 baits laid at Leschenault. No indication where remaining 100 baits were laid ^{(2) (3)}	695
6/03/1998	Hadfield. L. Peninsula	356 (375 less 19 returned same day)	Can't determine how many baits laid at Leschenault and how many at Hadfield ⁽²⁾	3401 (?)
30/03/1998	Penn	156 (200 less 44 returned same day)	Additional informal baiting return shows 100 baits laid at Leschenault. Can't determine where remaining 56 were laid ^{(2) (3)}	3408
5/05/1998	L/Penn. Gervasse	226	Can't determine how many baits laid at Leschenault and how many at Gervasse	illegible
2/07/1998	Monthly ground baiting	214 (328 less 114 returned same day)	Additional informal baiting return shows 100 baits laid at Leschenault. No indication of where remaining 114 baits were laid ^{(2) (3)}	3430 (?)
30/07/1998	Lesch Pen. Hadfield, Gervasse	200	Can't determine how many baits laid at Leschenault, Hadfield or Gervasse	3434
26/08/1998	L/Penn Had/Gervasse	200	Can't determine how many baits laid at Leschenault, Hadfield or Gervasse	3435

APPENDIX 1 (continued)

DATE	ENTRY IN 'DISTRICT 1080 REGISTER' ⁽¹⁾	NUMBER OF BAITES USED	COMMENT	IRV NO.
24/09/1998	Hadfield	400	Additional informal baiting return shows 176 baits laid at Leschenault, 76 more than historically required ⁽²⁾ . Presumably the remaining 224 baits were laid at Hadfield	3443
30/10/1998	No record in 'District 1080 Baiting Register' of baits removed. Source of baits is therefore not clear	100	Additional informal baiting return shows 100 baits laid at Leschenault ⁽³⁾	Louisa
4/12/1998	Hadfield	146	Additional informal baiting return shows 111 baits laid at Leschenault ⁽²⁾ . Unlikely the remaining 35 only were laid at Hadfield	3456
31/12/1998	Ground Bait	175 (200 less 25 returned same day)	Additional informal baiting return shows 100 baits laid at Leschenault. No indication of where remaining 75 baits were laid ⁽³⁾	3459
24/03/1999	Lesch	141	Additional informal baiting return shows 101 baits laid at Leschenault. No indication of where remaining 40 baits were laid ⁽²⁾	3473
23/04/1999	Lesch Hadf	248	Can't determine how many baits laid at Leschenault and how many at Hadfield	3475
26/05/1999	Lesch	130	Unlikely all 130 laid at Leschenault ⁽²⁾	3476
6/07/1999	L/Penn	200	Unlikely all 200 laid at Leschenault ⁽²⁾	3486 (?)
11/08/1999	Leschenault/Hadfield	200	Can't determine how many baits laid at Leschenault and how many at Hadfield	3488
23/09/1999	Lesch	313	Unlikely all 313 baits laid at Leschenault ⁽²⁾	348? (?)
18/10/1999	Lesch Pen	299	Unlikely all 299 baits laid at Leschenault ⁽²⁾	3496
18/12/1999	Leschenault Hadfield Gervasse	440	Can't determine how many baits laid at Leschenault, Hadfield or Gervasse	3498
?/1/2000	Gervasse Lesch Hadfield	200 (381 less 181 returned presumably on the same day)	Can't determine how many baits laid at Leschenault, Hadfield or Gervasse	5805
?/2/2000	Hadfield Gervasse Lesch	315 (651 less 336 returned presumably on the same day)	Can't determine how many baits laid at Leschenault, Hadfield or Gervasse	5807
?/3/2000	Leschenault Peninsula	98 (200 less 102 returned presumably on the same day)		5813
17/05/2000	Ground baiting Gervasse Lesche Had	321	Can't determine how many baits laid at Leschenault, Hadfield or Gervasse	5825
29/06/2000	Ground bait Batalling Leschenault Hadfield	527 (629 less 102 returned same day)	Can't determine how many baits laid at Batalling, Leschenault or Hadfield	5837
19/07/2000	Ground bait Gervasse Hadfield Leschenault	354 (502 less 148 returned following day)	Can't determine how many baits laid at Gervasse Hadfield or Leschenault	5839

APPENDIX 1 (continued)

DATE	ENTRY IN 'DISTRICT 1080 REGISTER' ⁽¹⁾	NUMBER OF BAITS USED	COMMENT	IRV NO.
13/09/2000	Leschenault Hadfield	200	Can't determine how many baits laid at Leschenault or Hadfield	5851
17/10/2000	Lesch Hadfield Gervasse	360	Can't determine how many baits laid at Leschenault, Hadfield or Gervasse	5854
23/11/2000	Leschenault Peninsula	200	Unlikely all 200 baits laid at Leschenault ⁽²⁾	5857
20/12/2000	Lesch Gervasse Hadfield Well	574	Can't determine how many baits laid at each location	5864
23/1/2000 (presumably 2001)	Leschenault Peninsula	340 (400 less 60 returned following day)	Unlikely all 340 baits laid at Leschenault, no other location listed ⁽²⁾	5866
7/03/2001	Leschen Welly NP Hadfield	400	Can't determine how many baits laid at each location	5904
9/04/2001	Leschenault Hadfield	245	Can't determine how many baits laid at each location	5867
16/05/2001	Batalling Block / Lesch	400	Can't determine how many baits laid at each location	5869
20/06/2001	Ground bait Leschenault WR	266 (318 less 52 returned same day)	Unlikely all 266 baits laid at Leschenault, no other location listed ⁽²⁾	5870
23/07/2001	Leschenault / Gervasse	105	100 baits required for Leschenault alone, so presumably either one or both sites baiting was not completed	5883
7/09/2001	Ground bait Leschenault WR	66 (256 less 190 returned same day)	100 baits required for Leschenault, unclear why only 66 laid	5886
23/10/2001	Leschenault	87 (200 less 113 returned same day)		5921
4/01/2002	Leschenault / WDC (not highlighted by Frank, but presumably went to Leschenault as indicated)	117 (301 less 184 returned same day)	Can't determine if all 117 went to Leschenault or WDC (?)	5941
31/01/2002	Ground baiting Leschen / Hadfield	200	Can't determine how many baits laid at each location	5946
11/04/2002	Ground baiting Wellington Lesch Pen	170 (539 less 369 returned same day)	Leschenault added as a location post photocopying of original. Can't determine how many baits laid at each location.	5960

- (1) Identified (highlighted on a copy of 'District 1080 Register') as baiting at Leschenault, unless otherwise specified.
- (2) Historic/traditional required number of baits for Leschenault is 100. Therefore, it seems unlikely the number of baits indicated in the District 1080 Register were all laid at Leschenault.
- (3) Without the informal baiting return there would be no record of where baits were laid.

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