AGSC

Natural Resources Research Workshop

Uluṟu–Kata Tjuṯa National Park

ULURU - KATA TJUTA NATIONAL PARK

RECORD 1997/55

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION
DEPARTMENT OF PRIMARY INDUSTRIES & ENERGY

AGSO Record 1997/55

Proceedings

'Back to the future'

Natural Resources Research Workshop

Uluru–Kata Tjuta National Park

27-29 August 1997

edited by L.G. Woodcock

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Primary Industries and Energy: Hon. J. Anderson, M.P.
Minister for Resources and Energy: Senator the Hon. W.R. Parer
Secretary: Paul Barratt

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

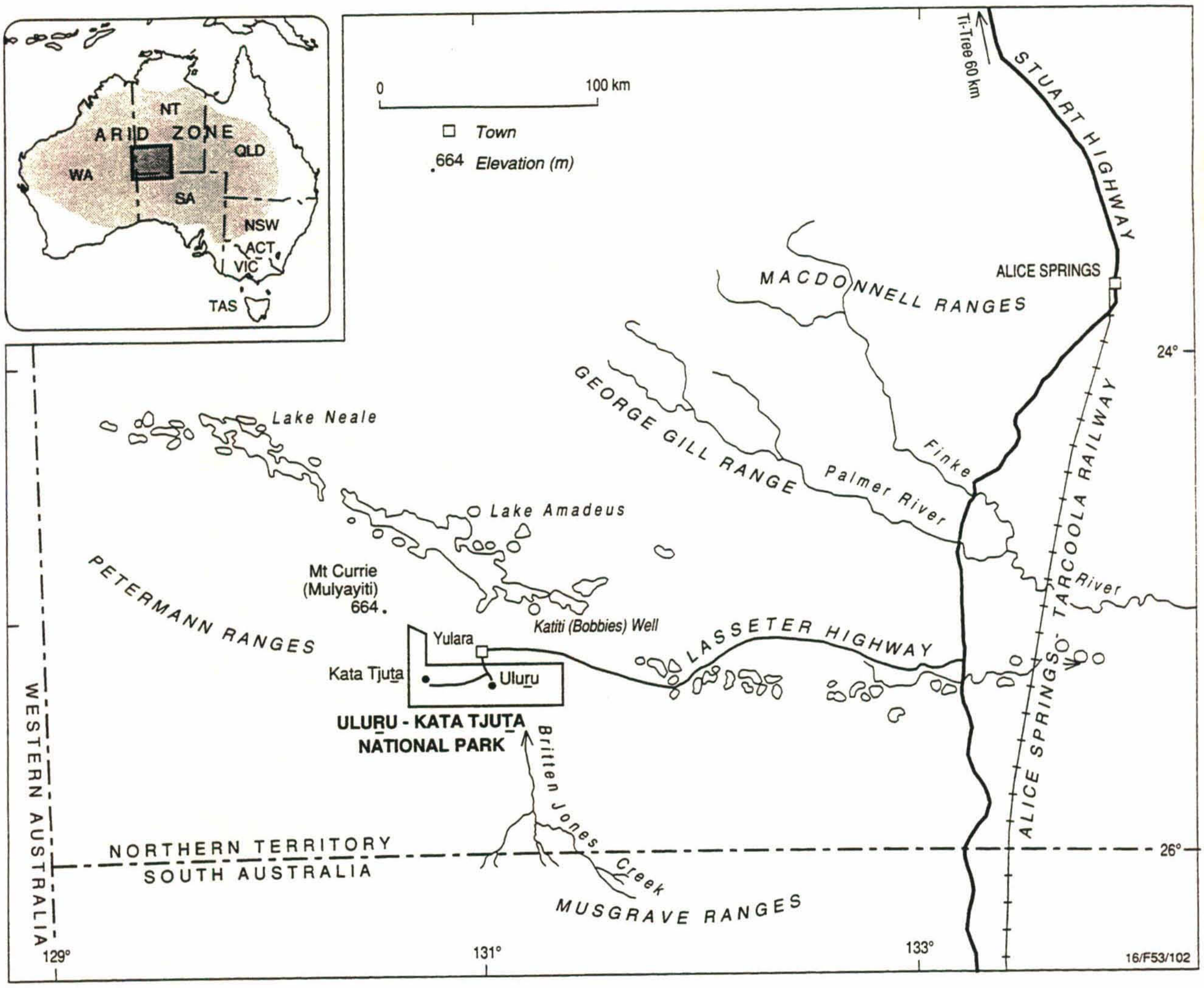
Executive Director: Neil Williams

ISSN: 1039-0073
ISBN: 0 642 27321 9

Contents

Participants at the 'Back to the Future Workshop' Uluru-Kata Tjuta NP, 27-29 August 1997.

BACK ROW (L to R) Bruce Rose, Jeff Foulkes, Bill Low, Graham Griffin
MIDDLE ROW (L to R) Jacquie Shannon, John Harvey, Carol Palmer, Alan Yen, Greg Balding, Jake Gillen, John Higgins, Gerry Jacobson, Grant Allan, Pip Masters, Lynn Baker, Brad Nesbitt, baby Jack in pram
FRONT ROW (L to R) Lynn Pedler, Julian Reid, Pauline English, Steve McAlpin, Jim Noble, Steve Morton
ABSENT Margaret Friedel



Location of Uluru - Kata Tjuta National Park in south-western Northern Territory.

ACKNOWLEDGMENTS

by Jake Gillen
Resources Manager
Uluṟu–Kata Tjuṯa National Park

The internationally recognised cultural and ecological significance of Uluṟu–Kata Tjuṯa National Park is clearly acknowledged by World Heritage status. Much of the status that has been accorded to the Park has been a direct result of the dedicated cooperative contribution made by Aṉangu and Researchers working together within the ethos of joint management. Perhaps the strongest evidence of this cooperative work is reflected in the joint efforts of Aṉangu and a range of scientific researchers in conducting work relevant to appropriate Cultural and Natural Resource Management. The Uluṟu Fauna Survey is undoubtedly the most obvious and significant example of such unique cross cultural collaborative proceedings. It is a mark of the calibre, dedication and commitment of individuals such as Dr Steve Morton, Lynn Baker and Julian Reid all of whom have been involved with this significant survey that they would elect to return to the Park some ten years later to contribute to the development of the next Plan of Management. The contribution made by these and other significant individuals over time has resulted in the accumulation of a considerable body of knowledge that has been vital in furthering the understanding of arid zone ecosystems and their responsible management. In considering and formulating the Natural Resource Management component of the new Plan it is obvious sound common sense to ensure that past achievements are acknowledged and built upon to ensure that the Park is at the cutting edge of World Heritage management into the future.

I must express my sincere appreciation to all those who participated and gave so generously of their time to the Workshop. Given such short notice it was remarkable that, almost without exception, no one hesitated to accept the invitation to participate and provide an individual contribution. A truly dedicated group of individuals whose commitment to the Park and the joint management process has been an inspirational support to Park staff.

In particular due recognition must be accorded to the following for their unique individual contributions;

Gerry Jacobson who played a major role in ensuring that the workshop actually eventuated rather than remaining a vague concept briefly referred to in passing. Gerry was vital in providing moral support during those periods when it appeared that lack of funding would prevent the workshop. I thank him for organising with Lynne Woodcock the collation and dissemination of these papers.

Bruce Rose of the Central Land Council who immediately recognised the significance of the workshop and upon learning of financial constraints offered to assist in covering the catering costs.

Dr Steve Morton who did not hesitate when tentatively approached to facilitate proceedings which he conducted in his usual inimitable fashion.

Dr Bill Low who so ably ensured that the presentation of papers proceeded smoothly and efficiently.

John Higgins from the State of the Environment Unit, Environment Australia, who was instrumental in facilitating the provision of funds to cover the travel costs of a number of the participants.

John Harvey, Senior Resources Ranger, who worked hard logistically to prepare the workshop and ensure smooth proceedings. Greg Balding, Senior Operations Ranger, who so capably video recorded the presentation of papers.

The staff at Maraku Arts and Crafts must be thanked for generously providing space within the warehouse complex for the workshop venue.

KEY WORKSHOP PARTICIPANTS

Dr S. R. Morton	CSIRO, Division of Wildlife and Ecology, Canberra.
Mr J. R. W. Reid	CSIRO, Division of Wildlife and Ecology, Canberra.
Dr J. Noble	CSIRO, Division of Wildlife and Ecology, Canberra.
Dr M. H. Friedel *	CSIRO, Division of Wildlife and Ecology, Canberra.
Mr G. F. Griffin	CSIRO, Division of Wildlife and Ecology, Canberra.
Mr G. E. Allan	NTPWC, Wildlife Research, Alice Springs.
Dr A. Yen	Museum of Victoria, Melbourne.
Mr G. Jacobson	Australian Geological Survey Organisation, Canberra.
Ms Pauline English	Australian Geological Survey Organisation, Canberra.
Dr W. A. Low	W. A. Low Ecological Services, Alice Springs.
Mr S. McAlpin	Consultant Herpetologist, Townsville.
Mr Lynn Pedlar	Consultant Ornithologist, Adelaide.
Mr J. Foulkes	Dept. Environment and Natural Resources, Adelaide
Ms P. Masters	Consultant Ecologist, Alice Springs
Ms L. Baker	Consultant Ethnobiologist, Coffs Harbour.
Mr B. Nesbitt	Consultant Ethnobiologist, Coffs Harbour.

*Dr Friedel was unable to attend the workshop. However, Dr Bill Low made a presentation of her findings on her behalf.

ULURU-KATA TJUTA NATIONAL PARK
NATURAL RESOURCES RESEARCH WORKSHOP

"Back to the Future - Past Research, Future Directions"

27-29 August 1997

WORKSHOP SUMMARY

by

Jacquie Shannon & Jake Gillen

Uluru - Kata Tjuta National Park

This Record presents a range of papers presented at a significant workshop held at Uluru–Kata Tjuta National Park from 27-29 August 1997. The papers were presented by scientists and ecologists with direct research experience in the Park. Prior to the workshop it was requested that the following be considered by individual researchers for their field of interest during the preparation of papers;

- summary of research completed within the Park to date,
- identification of "gaps" in work to date and thus possible future directions for research',
- possible collaborative or cooperative research ventures given current financial constraints',
- identification of environmental indicators for monitoring within the context of State of the Environment reporting, and
- possible environmental implications of tourism.

Rationale

The main impetus driving the workshop was provided by the review in progress of the current Plan of Management for the Park. The new Plan is due to come into effect from early 1998.

Workshop Aims

It was intended that the outcomes of the workshop would provide a major contribution to the development of a Natural Resource Management strategy to be incorporated in the next Plan of Management (1998-2005) for Uluru–Kata Tjuta National Park.

Included in the development of this strategy was the identification of appropriate environmental indicators in order to develop a suitable monitoring framework for a

World Heritage listed Park, as a model of State of the Environment reporting applicable to other World Heritage listed areas in Australia.

Intended Outcomes

- Determination of a strategic work program detailing future research projects and Natural Resource Management issues for inclusion in the forthcoming new Plan of management for the Park.
- Development of environmental indicators for a monitoring program as a National model for State of the Environment reporting program for World Heritage Listed National Parks.
- Identification of collaborative research projects which address future funding needs:
- Identification of processes to identify, assess, monitor and mitigate environmental impacts that relate to tourism activities within the Park for State of the Environment reporting and the next Plan of Management.

Actual Outcomes

The restricted timeframe for proceedings imposed pressure on the above intended outcomes. However given these constraints much was achieved. This collection of papers represents a significant achievement and a very significant contribution to the development of the natural resource management section of the Plan of Management. Outcomes from the workshop have been incorporated in the current draft Plan of Management.

The Workshop Program

August 26-27 - Field orientation.
Participants visited significant research sites in the Park to discuss, in the field, research findings and their implications for management and future research. This set the context for presentations and workshop discussions over the ensuing days.

August 28 - Presentation of Papers
Research findings were presented by participants with ensuing questions and discussions. Facilitated by Dr W.A. Low.

August 29 - Workshop
Facilitated by Dr S. R. Morton, CSIRO, Division of Wildlife and Ecology. Background to the review of the Plan of Management provided by consultant, Ms J Shannon.

The Workshop Process

The development of materials for incorporation into the next Plan of Management 1998–2005 commenced on the evening before a day workshop was facilitated by Dr Steve Morton.

At this introductory briefing, the participants were addressed by the Officer for Joint Management, Mr Paul Josif, and his Aboriginal Community Officer, Tony Tjamiwa regarding their understanding of and aspirations for joint management under the new Plan. The consultant for the development of the Plan, Ms Jacquie Shannon, also addressed the participants describing the processes for the development of the Plan's contents, the differences between the current and the future Plans and her expectations regarding the outcomes of the workshop to be conducted the following day.

The workshop was conducted utilising a participatory planning approach similar to that used by the consultant for the development of the content of the Plan. All work was conducted in small, self–managing groups and at the completion of each task information, ideas and outcomes were exchanged and discussed between the groups through facilitated plenary sessions.

The participants undertook a series of activities to develop their materials as follows:

- Each expert was asked to identify the nature of collaborative work they regarded as being necessary to progress their research for the purpose of Park management during the life of the next Plan;
- The subject matter was subsequently reviewed by the facilitator and the consultant to identify, areas for research ie visitor management, cultural resource management, hydrology and water management, fire management, reintroductions and endangered and threatened species management;
- Groups were then identified according to these areas of research. Each group having scientists with complementary skills;
- The following sessions of small group work were designed to identify outstanding issues and to consider strategic, collaborative actions for their amelioration;
- The associated plenary sessions served to highlight some concerns that were common across all areas, namely the need for regional planning and management; for adaptive management; and the influence of certain natural and social forces on management options ie arid land climatic conditions, soils and geology, water availability and quality, hydrology, fire, cultural practices and the socio–economic system of the region.

Outcomes

The final plenary session saw the development of a comprehensive, strategic approach to the presentation of the actions and prescriptions developed by the participants.

The material was presented hierarchically with the core, common driving forces being identified for inclusion in the introduction. The following level of material presented the areas of management to be addressed, namely, those reflected in the groups which were originally identified. Subsequently, outstanding management issues were described for each of these management areas and, finally actions were ascribed to a majority of the issues. The actions were not prioritised. The only exception to this was an outstanding responsibility identified through the course of discussion, namely the immediate need for NT Power and Water Authority to reassess the hydrology of the Yulara sand plain system. This matter was unanimously referred to the Board of Management for immediate action.

Summary of workshop proceedings

The Context for Natural and Cultural Resource Management

It was reinforced through the course of the workshop that environmental and cultural management for Uluru–Kata Tjuta National Park are inextricably linked. It was unanimously agreed that in order to meet world standard best practice for the management of natural and cultural resources, management within the Park must:

- acknowledge, determine and manage in accordance with the prevailing environmental driving forces, namely Tjukurpa, soils and geology, hydrology, climate, fire and the local and regional socio-economic systems;
- apply adaptive management techniques which incorporate comprehensive consultation, ongoing monitoring and relevant research; and
- undertake Park management within the regional context and aim to encourage and support complementary land and cultural management practices with the land owners of adjoining lands.

Within this context a framework was formulated which identified the key issues for management within the Park and articulated some strategies and actions to address them.

Management Issues

All management issues were regarded as being of equal importance with respect to the future management of the Park and no priority was ascribed to them. They were the:

- maintenance and recovery of biological diversity;
- controlling exotic organisms;
- maintenance of Anangu culture;
- adequate resourcing of cultural activities;
- assessment, management and monitoring of human impacts on the Park's World Heritage values incorporating specific performance indicators;
- evaluation and promotion of relevant initiatives to address socio-economic pressures on Anangu;

- promotion of integrated and cooperative regional management;
- maintenance of an ongoing program of basic, long term research and monitoring including State of the Environment Reporting where appropriate;
- management of hydrology and water resources;
- monitoring of spatial variability in climatic conditions across the Park; and
- fire management.

Proposed Strategies and Actions

Maintenance and recovery of biological diversity

As with all aspects of land management within the Park, the maintenance and recovery of biological diversity requires an integrated approach to land management therefore all strategies and actions that were developed by the workshop apply to this issue.

Special consideration was given by workshop participants to the specific action of a reintroduction program. A summary of the strategy which was proposed for implementation follows. Further detailed information regarding this proposal is available from the Resources Manager, Uluṟu–Kata Tjuṯa National Park:

Phase 1: Planning

A series of three workshops to be conducted including a preliminary community workshop to raise the issue for consideration with Aṉangu, a 5 day workshop for expert scientists and Aṉangu to develop a proposal and a further meeting with the community to discuss the implications of the proposals. Aṉangu to select the preferred proposal and Board to ratify the decision.

Phase 2: Protocol development

The proposal to be expanded to include resourcing needs, timeframes, cultural requirements, site and species identification, training programs, employment opportunities etc.

Phase 3: Implementation

Preditor control program, captive breeding program, release and monitoring program to be undertaken for the first reintroduction with the outcomes of monitoring and reviews being tabled with the Community and the Board. Further reintroduction programs to be considered following the review of the first program. Adaptive management principles to be applied to the management of each reintroduction program.

Controlling Exotic Organisms

The workshop identified the urgent need for a comprehensive assessment of exotic organisms within the Park. This assessment is to be followed by targeted on ground work, the ongoing collection of baseline data and monitoring of the targeted control programs.

Specific actions include the:

- development of an understanding of the regional context of distribution;
- collection of baseline data on species distribution and dynamics;
- documentation and historical review of both introductions and their control;
- monitoring the control of and impacts of exotics on other species;
- integration of traditional considerations; and
- development of an adaptive management program for their control.

Maintaining A̲nangu Culture

The workshop identified the loss of traditional environmental knowledge regarding rare species and fire management by A̲nangu within the Park including the next generation, and elsewhere in the region, as being of utmost importance and requiring urgent attention.

Specific actions to address this matter include the:

- active involvement of A̲nangu living and/or working within the Park in exchanging traditional knowledge and land practices with other Aboriginal communities. This exchange program must include travel between the Park, other Aboriginal communities and onto the associated lands. Issues to be addressed through this work include rare species, locally extinct species, fire management, exotic species control etc;
- development of a proactive program for involving young A̲nangu in the above; and
- supporting and resourcing older A̲nangu to train young in cultural knowledge and practices.

A further critical issue identified by the group was the cultural pressure experienced through the loss of species. Traditional knowledge acknowledges that a diminution in the number of species has direct implications for the condition and health of the country and for those people who have associations with the land in general, and the lost species in particular. To appropriately care for the land species which have been lost need to be reintroduced.

A specific action to address this matter includes the reintroduction of lost species where possible (refer maintenance and recovery of biological diversity above). Cultural benefits of a reintroduction program include the:

- reinstatement of ceremonies;
- increasing A̲nangu involvement and interest in the exotic species control program;
- promotion of the exchange of traditional ecological knowledge; and
- creation of employment opportunities for A̲nangu.

The need for the development and implementation of appropriate safeguards and controls on the collection and utilisation of traditional ecological knowledge was also identified.

Specific actions identified to address this issue include the:

- development of intellectual and cultural property protocols; and
- encouragement and resourcing for Anangu to develop interpretive material including videos and multi media.

The need to further enhance feed back of scientific research to Anangu was also identified as an issue.

Specific actions to address this issue include the routine implementation of workshops and other educational and information exchange fora with Anangu, Mutitjulu Community and school.

Finally, the spiritual appropriation of Anangu knowledge by religious and spiritual bodies other than the Traditional Owners was identified as an ongoing issue.

It was recommended that the practice of any spiritual or religious behaviour within the Park other than that of the Traditional Owners be designated as inappropriate within the Plan.

Adequately Resourcing Cultural Activity

The workshop identified the availability of resources for Anangu in land management as being a significant limiting factor in cultural activities in general, and with respect to land management in particular.

Specific actions to address this matter include the:

- review of vehicle protocols within the Park and other Aboriginal and indigenous communities to ensure Anangu can have effective access to locations for relevant cultural activities;
- recognition and extension of employment opportunities for relevant Anangu traditional knowledge and its practice; and
- investigation into new options for increasing resources for relevant cultural activities.

Assessment, management and monitoring of human impacts on the Park's World Heritage values incorporating specific performance indicators

The workshop identified three sources of human impact on the Park and its values. They were tourists within the Park, Aboriginal and non Aboriginal people visiting, living, working in the Park, and people living and visiting within the region.

These sources of impact affect both the natural and cultural landscape values of the Park acknowledged through its dual World Heritage listing.

With respect to the impact of tourists and visitors to the Park on Anangu culture the following actions were identified:

- definition of the impacts both positive and negative;
- establishment and monitoring of performance indicators;
- empowerment and involvement of Anangu in the definition of tolerable limits of impact and performance indicators;
- development and implementation of a compensation program for Mutitjulu Community associated with visitor and tourist impacts;
- development of a register of incidents of graffiti and/or wilful damage;
- extension of the interpretation program regarding graffiti and wilful damage; and
- enhanced surveillance and control of tourist activities in and around art and cultural sites.

With respect to impacts of residents, workers and visitors to the Park the following actions were identified:

- identification and quantification of the impacts;
- establishment of tolerable limits of impacts and performance indicators for monitoring purposes;
- establishment of mechanisms for feedback to Aboriginal and non Aboriginal residents and workers within the Park; and
- undertake research into whole patterns of land use within the Park.

Both tourists and those living and working within the Park have impacts on soil, vegetation and water. These include trampling, erosion and alterations to surface and ground water regimes. The illegal use of the Park by tourists, roadside camping within the Park and the illegal removal of plants and/or animals from the Park also have significant impact on the values of the Park.

The following actions were identified to address these issues:

- assessment of current visitor behaviour patterns, range and level of activities;
- development of performance indicators specific to activities;
- quantification of the impact of humans on soil, vegetation and water including specific research into the surficial hydrology including local drainage, erosion and infiltration. In all this work the group identified the need to include analysis of Anangu perceptions and values;
- an evaluation of the sustainability of both the quality and quantity of good water supply to the Park;
- modelling of ground water resources and their sustainability for the future;
- improvement in the efficiency of use of both the Dune Plains/Yulara and the Southern/Mutitjulu bore fields;
- the development of a specific management strategy for the transitional sand plains ie Uluru bore field;
- comprehensive implementation of best practice with respect to desalinisation, recycling etc of water resources;

- improved signage regarding access, camping and appropriate behaviour within the Park;
- establishment of routine education programs for Yulara residents and visitors to the Park regarding access, camping and appropriate visitor behaviour within the Park; and
- increased efficiency in the distribution of tickets and permits to the Park.

With respect to the impact of regional visitation and tourism on the Park's values the following actions were identified:
- development and implementation of integrated regional planning involving the Park, Ayers Rock Resort Corporation, Central Land Council and NT Parks and Wildlife;
- assessment of the regional human carrying capacity incorporating a multi-disciplinary systems approach; and
- investigation into the impacts of water extraction on organisms of the bore fields.

Evaluation and promotion of relevant initiatives to address socio-economic pressures on Anangu

The lack of Anangu and Board involvement in the setting and prioritising of budgets was identified as an issue requiring urgent attention.

A specific action to provide for the direct involvement of both these parties in these critical activities was determined as a matter of urgency. With specific training being provided to inform and empower Anangu in these critical decision making processes.

Further, the workshop cited the need to expand the career paths and employment opportunities for Anangu.

Actions to address this issue included the:
- expansion of allocated dedicated staff positions;
- expansion of the adult education program to include English skills, traditional knowledge, working in cross cultural environments; and
- financial reimbursement for traditional land management utilising the CDEP, Green Corp models.

Promotion of integrated and cooperative regional management

The workshop concluded that in some instances the Park is managed in isolation from the surrounding landscape.

In order to address this issue the following actions were identified:
- development and maintenance of efficient and effective information flows with other communities within the region;
- reintroduction of locally extinct species as appropriate (refer Maintenance of Biological Diversity above); and

- support and resourcing for programs operating in the Park to be extended into neighbouring lands in cooperation with the respective land owners.

Maintenance of an ongoing program of basic, long term research and monitoring

The workshop unanimously supported the maintenance of an ongoing program of basic, long term research and monitoring on the grounds that this work often generates unforeseen but valuable outcomes.

Actions to further this issue include the:
- development of a geographical information mapping system for the Park; and
- systematic archiving of data.
- The workshop strongly supported the urgent establishment of a Scientific Advisory Group to contribute to the development of future research needs and strategies for the Park.

Management of Hydrology and Water Resources

The following action was identified as being of high priority for implementation:
- a review of the current existing water resources addressing ecological processes, human use and traditional ecological knowledge (refer also Assessment, Management and Monitoring of Human Impacts).

Monitoring of spatial variability in climatic conditions across the Park

The workshop identified the need to understand spatial and temporal variability on a scale relevant to the processes that affect the Park.

The following action was identified:
- the installation of automatic weather stations at selected permanent faunal monitoring sites.

Fire management

A high priority was given to the urgent review and updating of the current fire management strategy. This review should incorporate the needs of individual species, protection of assets, and should account for traditional management goals and interests. It should also develop mechanisms to incorporate the outcomes of the review into Park management.

Following this review a work program is to be developed incorporating current fire management practices and outcomes from the review. This program will include the following:
- accumulation of data;
- professional development of relevant skills on Park;

- assessment of habitat and species needs;
- ongoing extension of fire management practices from the Park to surrounding lands; and
- monitoring.

Incorporation of Outcomes Into the Plan of Management 1998–2005.

The structure adopted by the workshop participants proved to be very successfully integrated into the draft Plan. The introductory material providing the basis for the drafting of this section of the Plan.

The regional planning and the adaptive planning components of the introduction and subsequent actions are new additions to the Plan. While the Board of Management in providing its direction for the Plan and its contents had initially called for the incorporation of the regional context, the outcomes of the workshop provided a further substantiation of the Board's position. With respect to adaptive planning, the fact that this methodology is at the forefront of management and research in Australia and globally, ensures the Director, Parks Australia, fulfils his legal obligations under the lease to manage the Park according to current global best practice.

Further innovations resulting from the workshop outcomes include:

- The identification of two sections under the Cultural and Natural Resources chapter, one of which relates to the maintenance of the integrity of the cultural resources of the Park, and the other which relates to the maintenance of the integrity of the natural resources of the Park; and
- The incorporation of issues relating specifically to human impacts on both the natural and cultural resources of the Park.

While some of the issues relating to human impact have been implicitly addressed in previous Plans, they will be made explicit in the new Plan. Further, they will have specific actions ascribed to them that relate directly to Park management and the Park's associated responsibilities under its double World Heritage listing as a place with unique natural and cultural landscape values.

The concerted, cooperative and creative efforts of the workshop participants have generated a new era for the Park through this Plan of Management. They are to be thanked and congratulated for their work.

WELCOME TO WORKSHOP PARTICIPANTS

Paul Josif

Co-ordinator, Office for Joint Management, Uluru–Kata Tjuta National Park

- Joint Management is created by virtue of the Uluru–Kata Tjuta National Park lease between the Uluru–Kata Tjuta Land Trust (ie Traditional Owners) and Parks Australia, and the current Plan of Management.
- The Board of Management consists of six Anangu nominees and four other nominees made by the Federal Ministers for Tourism and the Environment. They include a scientist for arid land management and ecology; and the Director Parks Australia.
- The Park is also a biosphere reserve under the UNESCO Man and Biosphere program, a principle of which is to 'conserve for present and future use the diversity and integrity of communities of plants and animals within natural ecosystems and to safeguard the genetic diversity of species on which their continuing evolution depends...'.
- The Park also enjoys World Heritage status for both its cultural and natural landscape values, whose protection is deemed by both the IUCN and implicitly the Australian government to be worthy of protection.

With regard to the specific ecological management, the objectives of the current plan of management are:

- to continue to take into account Anangu ecosystem knowledge and understanding in the planning and implementation of land management within the Park; and
- to continue to investigate and record Anangu ecological system knowledge and understandings and interpret this material for visitors (page 13).

Implementation:

- the Park will continue to employ/contract Anangu to provide ecological advice in the planning and implementation of land management strategies in the Park (page 13).

The Uluru–Kata Tjuta National Park lease says at clause 17(2) that 'the lessee covenants that the flora, fauna, cultural heritage and natural environment of the Park shall be maintained according to best possible management practices established for National Parks anywhere in the world or where no comparable management practices exist, to the highest standards practicable' (page 17, lease).

This is imperative for the strengthening of Resources through up to date knowledge. This is where the State of the Environment research and reporting process provides such a vital function to the Uluru–Kata Tjuta National Park Resources management.

As you all know:

- caring for the land is an essential part of 'keeping the Law (Tjukurpa) straight (page 21, PoM);

- the areas of greatest ecological sensitivity/vulnerability are generally the areas of highest visitation and ecological impact;
- the lessee (Parks Australia) is under considerable pressure to facilitate increased visitation, and therefore to increase gate takings to fill the financial gap created by decreasing Federal funding. The Ayers Rock group thrives on increased visitor numbers. The tourism industry is consistently seeking greater access to Uluru–Kata Tjuta National Park.

There is a perception that tourism is in fact a value of the Park equal to its World Heritage Cultural and Natural Landscape values.

- Financial and other resources are increasingly being channelled into 'visitor management' programs and activities. For example, $200,000 for a Visitor Management Strategy whilst Resources has to beg for money and rely on the good will of people such as yourselves to develop a State of the Environment Strategy.

The cultural and social side of the equation is little better, sure there is a lovely $6m Cultural Centre, but Anangu live in a massively degraded community in terms of both having jobs and infrastructure.

The challenge is for you all to understand the situation in Uluru–Kata Tjuta National Park, as regards Joint Management on the ground, it is not as healthy as it may seem. There are considerable imbalances and conflicting interests. The balancing of resources management and visitor management requirements means daily dilemmas in terms of operational management.

Where should the resources be directed, predominantly towards the visitors and their many needs - as they assume the golden eggs, or more equally balanced and directed to those who nurture the Tjukurpa? I commend you to this workshop and process of developing a State of the Environment report for the Uluru–Kata Tjuta National Park as part of contributing to a process of replacing the rhetoric with well funded and resourced action.

Fire Management at Uluru–Kata Tjuta National Park

Grant Allan[1]

[1] Parks and Wildlife Commission, Northern Territory, PO Box 1046, Alice Springs NT 0871.

Fire management at Uluru National Park has been an important component of land management activities within the Park since the mid 1980s. Active fire management has been recognised as the most effective tool for protection of the Park against events similar to the large wildfire in 1976 which burnt 75% of the Park and was the main impetus for the start of fire research in the region.

This report follows the outline requested by the workshop organisers. The first section provides a brief summary of the work which the author has been involved with since 1982. The main focus has been on fire, but most recently has included GIS analysis of the fire mosaic and habitat modelling for the mulgara.

The second section of this report discusses fire management issues and identifies questions which should be addressed. There is a need for a greater integration of fire management and species management for both flora and fauna. The third section addresses the issue of Anangu involvement in regional fire management and the fourth section discusses State of the Environment reporting. The final section provides a few additional comments on the current Plan of Management, primarily with respect to fire.

1. Summary of Previous Work

The following is a brief summary in point form of Grant Allan's involvement in work conducted within the Park since 1982.

Development of the Uluru NP fire management strategy (1982 - 1984)
* re-mapping land units of Park
* vegetation description and analysis
* experimental fires and initiation of fire management
* development of a fire behaviour model - based on ground sampling
* preparation of a fire management philosophy and strategy (Saxon 1984)

Central Australian Regional Bushfire Research Project (1985 - 1986)
* additional vegetation transects
* airborne radiometer and satellite image data collection
* further experimental fires
* development of a 2nd fire behaviour model - based on airborne radiometer sampling

Review of Uluru Fire Management and the Implementation program (1987)
* updated fire history for Park
* recommended increased spatial extent to burning program
* vegetation assessment and analysis by fire age
* presentation and publication at Ecological Society of Australia Annual Conference 1988 (Allan and Baker 1990)

Habitat Manipulation and Management Burns in Borefields and Yulara Township Areas (1989 - 1992)

* conducted fuel reduction burns within the Yulara Township associated with the CCNT presence at Yulara
* conducted habitat manipulation burns in the Borefields area linked to the mulgara study by Pip Masters

Fire History and Associated GIS Database (1994 - 1997)

* updated fire history for Park from satellite images

Mulgara Habitat Modelling (in association with Pip Masters and Theresa Nano) and Palaeodrainage Study (Jeff Foulkes and Else Foster) (1994 - 1997)

* facilitated update of GIS database for Park
* tested and developed mulgara habitat models

2. Fire Management Issues and Questions to be Addressed

2.1 Review of Fire Management at Uluru NP

2.1.1 Occurrence of Major Wildfires

The patterns of fire on the landscape in the Uluru region have changed dramatically during the the past 50 years. The first records of extensive wildfires were recorded by 1950 air photos. There was evidence of a large fire through the eastern portion of the Park and several smaller ones south of Kata Tjuta. In 1976 a wildfire burnt an area of 20,000 km² south of Lake Amadeus, including 75% of the Park. Smaller wildfires between 1982 and 1990 burnt areas to the north of the Park which had remained unburnt in 1976. Two large fires in 1986 and 1991 burnt areas of the Park which had also been burnt in 1976. On a smaller scale there have been numerous management burns within the Park. With the exception of the 1950 and 1976 fires which were mapped from air photos, satellite images have been used to map the patterns of fire within the Park and the surrounding region. The state of the fire mosaic to 1994 is shown in Figure 1.

2.1.2 1987 Review

A review of the implementation of the fire management strategy was undertaken by Grant Allan and Lynn Baker in 1987 (Allan and Baker, 1990). The primary recommendation was that the scale of the management burns was inadequate to provide protection against a wildfire in the extensive area of the 1976 fire age as the fuel load continued to increase. Although the number and size of management burns has increased during the past 10 years it is recommended that another review of the fire management program should be undertaken.

A second component of the 1987 review was a vegetation sampling program in the range of available fire ages. Malcolm Gill from CSIRO, an eminent Australian fire ecologist, considers that the Allan and Baker (1990) paper was a significant study of vegetation response to fire, but had limitations associated with the restricted number of fire ages available at the time of the study (pers comm). Therefore it is also recommended that the vegetation survey be repeated using the increased range of fire ages currently accessible within the Park.

2.1.3 Fire History Maps and Spatial Analysis

The fire history database for the Uluru region provided the spatial information to review the landscape changes which have been created by fires during the past 20 years. At the simplest level the sequence of 4 maps of the fire mosaic for 1984, 1987, 1991 and 1994 (figure 2 a-d) provides a visual impression of change. The data can be analysed in a variety of ways to provide useful information to guide fire management activities. Several examples are provided and a few important characteristics have been identified.

Figures 3 and 4 show the current distribution of fire ages within the spinifex communities of Uluru NP and those of the surrounding region. A similar pattern exists for the mulga communities shown in figures 5 and 6. The figures indicates a greater fire age diversity outside the Park than within. Both distributions being a consequence of the 1976 wildfire. There is a need for this information to be incorporated into the fire management program because one of the objectives of the program is to create a diversity of fire ages within the Park which is a microcosm of the surrounding region.

Figure 7 is a more detailed breakdown of fire ages using the 11 spinifex communities within Uluru NP. The main highlight is the lack of variety of fire ages within most communities. Only the 5c1 and 5d1 communities have an obvious diversity of ages which are not dominated by the 1976 wildfire and its unburnt remnants.

It is also important to undertake further analysis of the fire mosaic such as an analysis of the fire ages burnt by subsequent fires. This results in the identification of 2 significant points. There has been a relatively small reduction in the areal extent or proportion of the 1976 fire age. In contrast there has been a significant reduction (approximately 50%) of the pre-1976 fire age within the Park since 1977. Such "old growth" areas, which have remained unburnt for periods of 50 to 100 years, can not be readily replaced in an ecosystem and any management plan should aim to carefully manage these areas.

These relatively simple summaries do not adequately address the issue of scale of fires or the pattern of landscape. Therefore further evaluation of the fire mosaic should be undertaken before immediate changes to the burning program within the Park are implemented.

2.1.4 Fire Management in Non-spinifex Communities

Fire management activities and planning must also take into account the fuel loads in the non-spinifex communities of the Park. The patterns of rainfall in recent years have meant that there have been very low fuels in both the mulga and run-on areas of the Park since 1991. Therefore many Park staff have not had any experience with fire management or protection in these areas. It is important that Park staff are reminded that fuel loads can build up quickly in these communities and protection of fire sensitive plants is an important management issue. The preparation of the next fire action plan should consider the question "will the current mosaic of fire ages provide at least some protection for these areas?".

2.2 Change of Fire Management

2.2.1 The Need to Update the Fire Management Strategy

There is a need for an update of the fire management strategy for Uluru NP. The strategy was written in 1984 and has remained a guiding document and the main feature within past Plans of Management for directing fire management activities. There have been significant changes to the management of the Park, the surrounding and internal infrastructures, the responsibilities of Anangu, and our ecological knowledge. All these changes must be addressed and incorporated, where appropriate, into an updated strategy. In general the philosophy of the strategy "based on a patch burning approach" is still sound and has been adopted throughout Australia and the

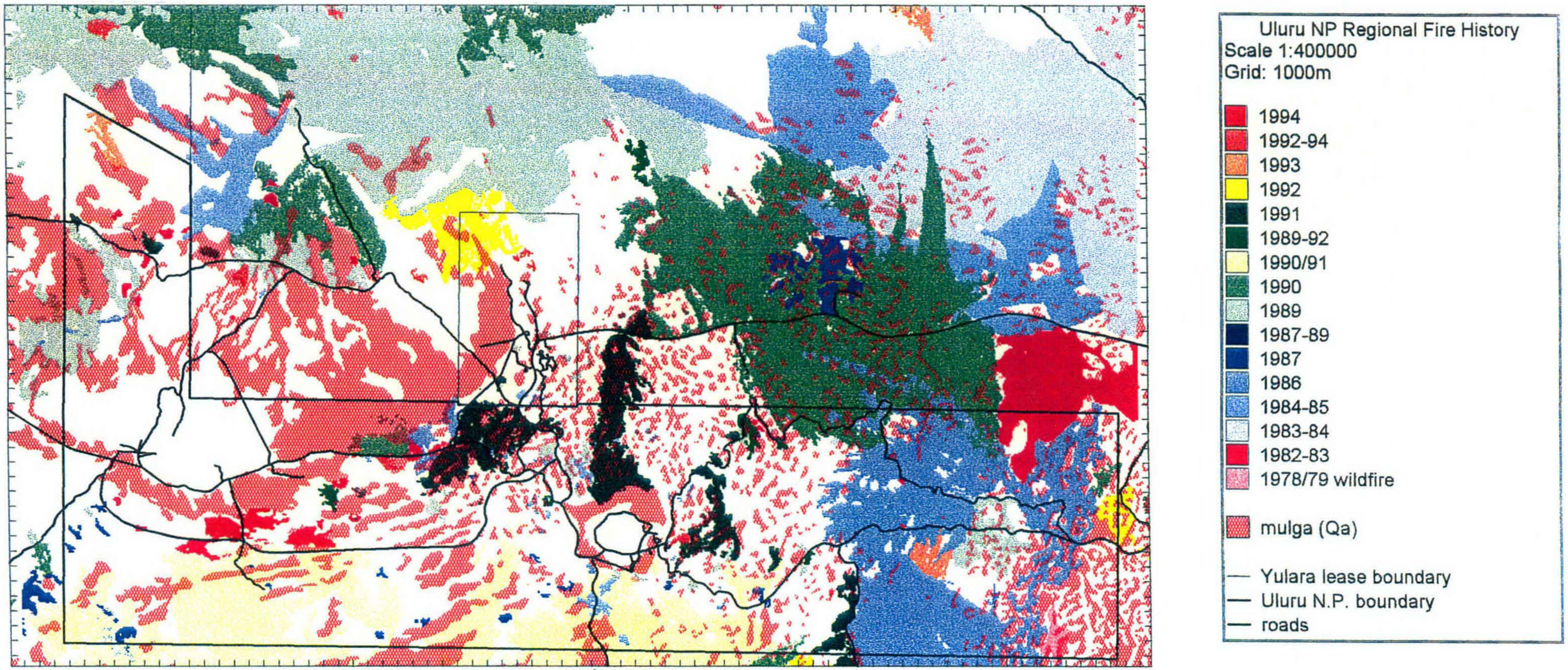


Figure 1. Uluru–Kata Tjuta National Park regional fire history.

world. Nonetheless some of the principles of the strategy which determine the fire management activities require evaluation and review. The result may be a change to the burning program on the Park.

2.2.2 Shift of Fire Management from Protection to Habitat Manipulation

Although the review described above will update the fire management strategy, the update should involve a shift from fire protection to habitat manipulation. The burning program should be based on spatial patterns of fire, vegetation characteristics and the responses of both plants and animals to fire. Fire management must have a broad focus beyond fire protection. Past work has recognised fire as the main tool for habitat and ecosystem management. All fire activities must be considered in terms of their value to the ecosystem and to individual species requirements. Fire protection, for fire exclusion and protection of assets, should be of a very small spatial extent and should be achieved by default.

2.3 Issues of Habitat Manipulation

2.3.1 Recommendations of the Uluru Fauna Survey

It is important that the fire management review also considers and incorporates the recommendations of the Uluru Fauna Survey (UFS). The UFS report (Reid *et al.*, 1993) identifies fauna species that are associated with specific fire ages. To date there has not been an evaluation of the spatial patterns and extent of fire ages within the Park to assess if the fire management program is having a positive, negative or neutral impact on the habitat opportunities for the few specialist species dependent on habitats of a specific fire age.

The UFS states 5 ground rules for incorporation with fire and fauna management. "These are:

1. that the majority of the standing mulga and much of the regenerating 1976 mulga be protected from fire;
2. that the majority of 1976 aged spinifex be protected from fire at least until surveys to search for rare species are concluded;
3. that mallee-spinifex areas are protected from fire until they have been surveyed for rare species;
4. that surveys of these habitats be carried out to assess and map their habitat quality for wildlife, and that recommendations arising from the research be formally written into the fire management strategy, and
5. that, not withstanding the above points, the patch-burn strategy be vigorously pursued to promote landscape and faunal diversity." (Reid *et al.*, 1993, p.139)

The UFS identified habitat preference for vegetation communities by specific animal species. In the spinifex communities, they identified 13 species which are largely confined to the spinifex areas and have preferences for mature spinifex. These are:

3 birds: striated grasswren, rufous-crowned emu-wren, white-winged fairy-wren
9 reptiles: jeweled gecko, short-tailed pygmy monitor, *Ctenotus calurus*, *Ctenotus grandis*, *Ctenotus piankai*, desert skink, nocturnal desert skink, *Notoscincus ornatus*, *Cyclodomorphus melanops*
1 mammal: *Wongai ningaui*

In addition they identified 8 other reptiles which, although found in other places, are dominant species within the spinifex areas and also have a preference for mature spinifex.

Figure 2a.   1984 Uluru Regional Fire Mosaic

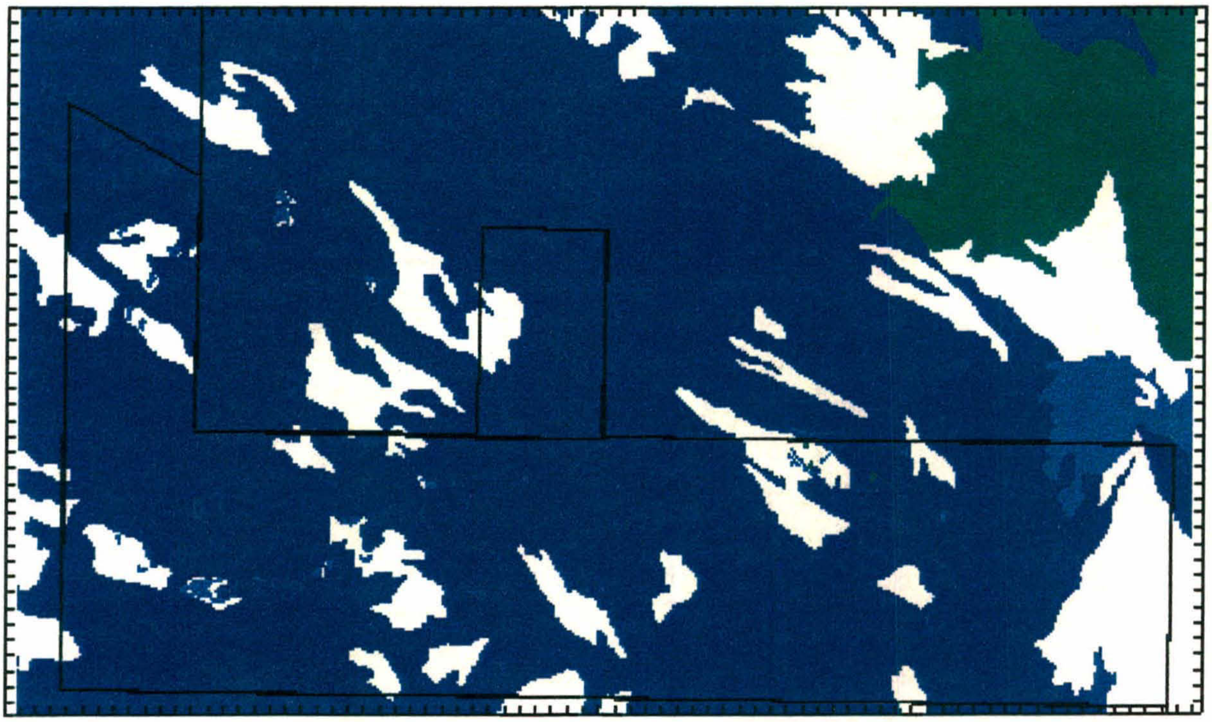


Figure 2b.   1987 Uluru Regional Fire Mosaic

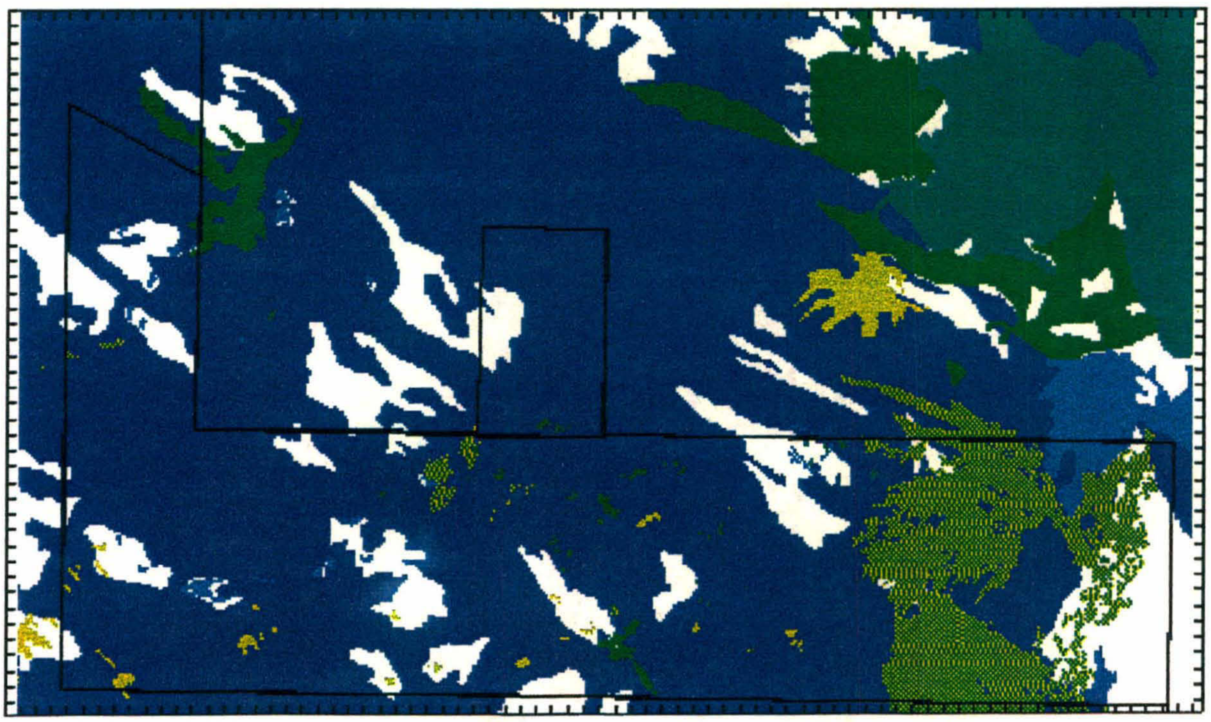


Figure 2c. 1991 Uluru Regional Fire Mosaic

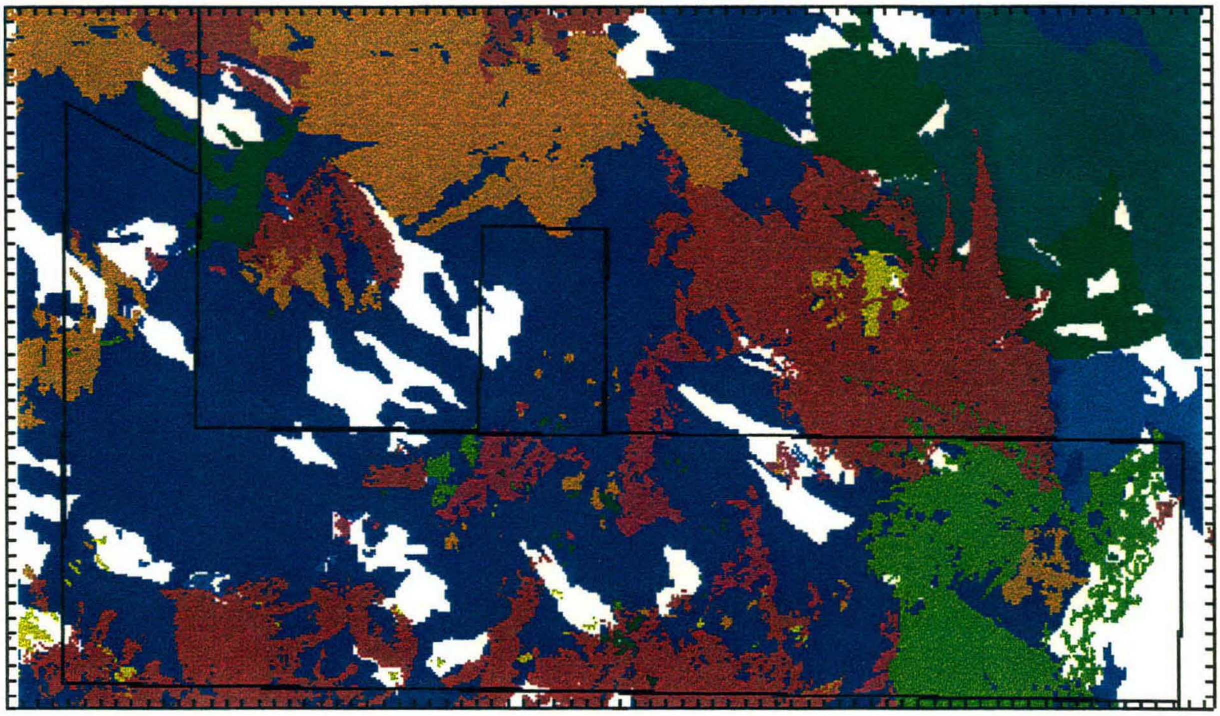


Figure 2d. 1994 Uluru Regional Fire Mosaic

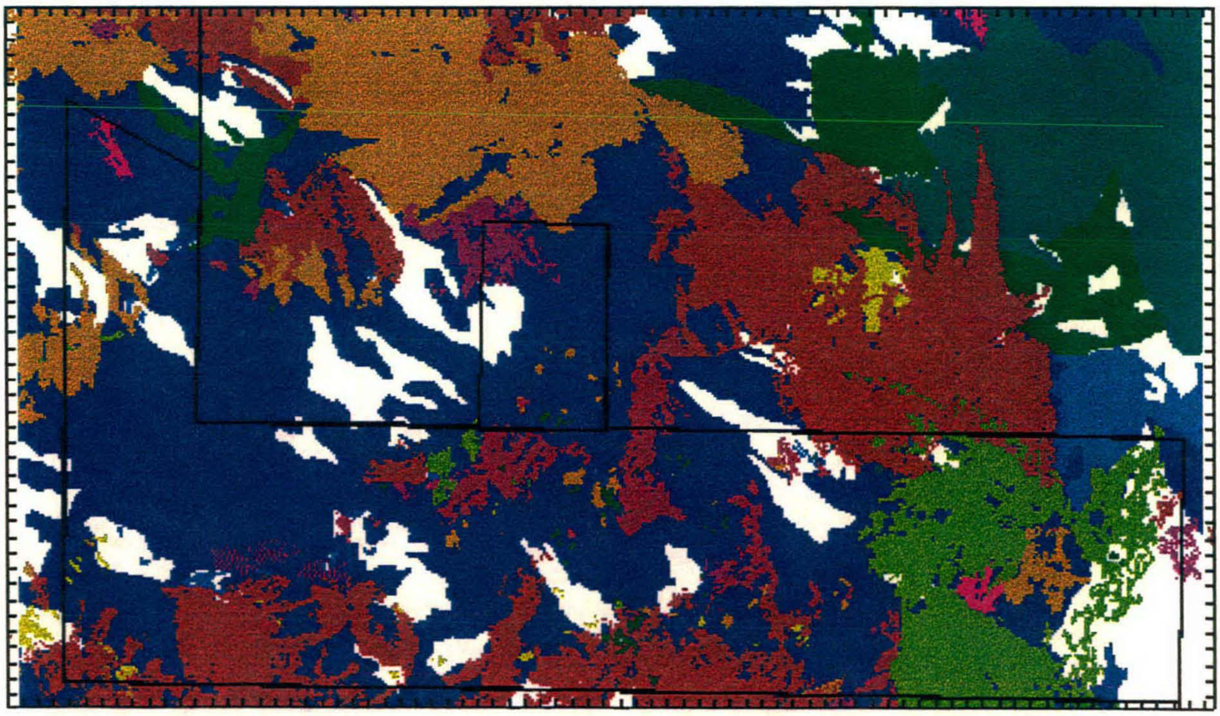


Figure 3. Fire Age Distribution within the Spinifex Communities of Uluru NP

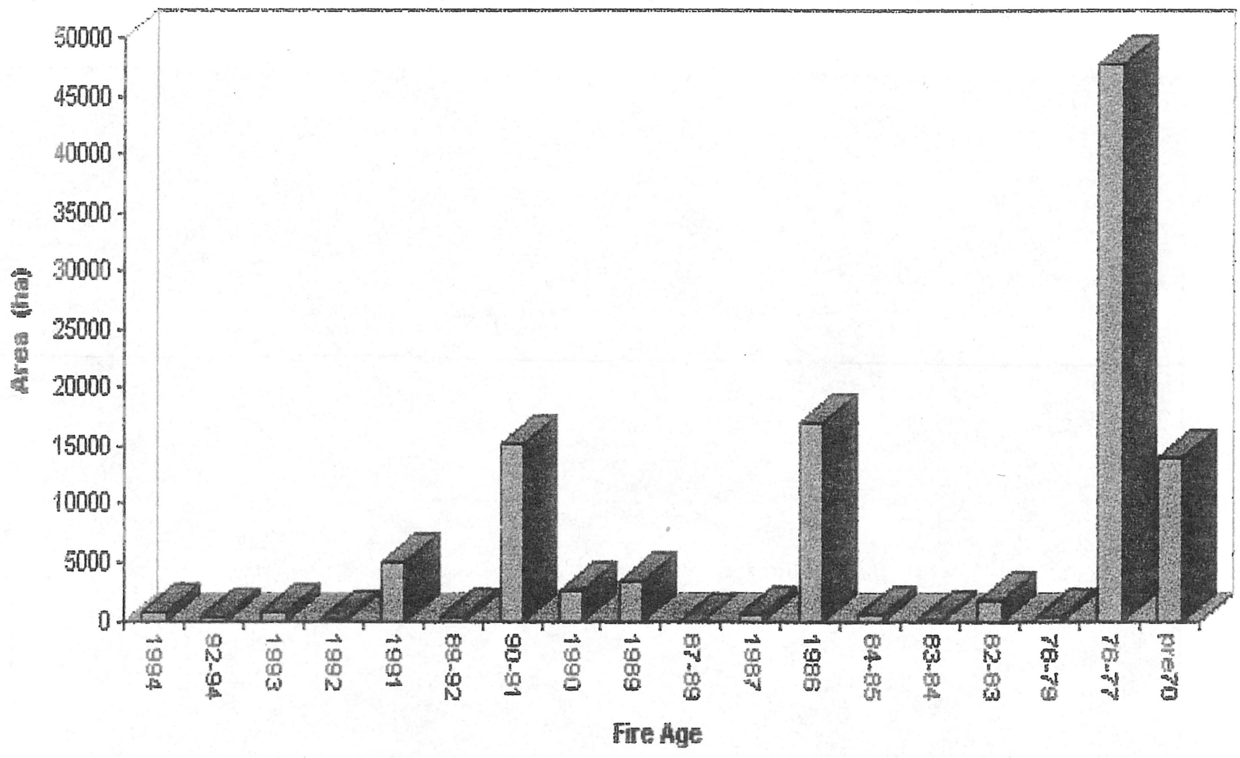


Figure 4. Fire Age Distribution within the Spinifex Communities of the Uluru region

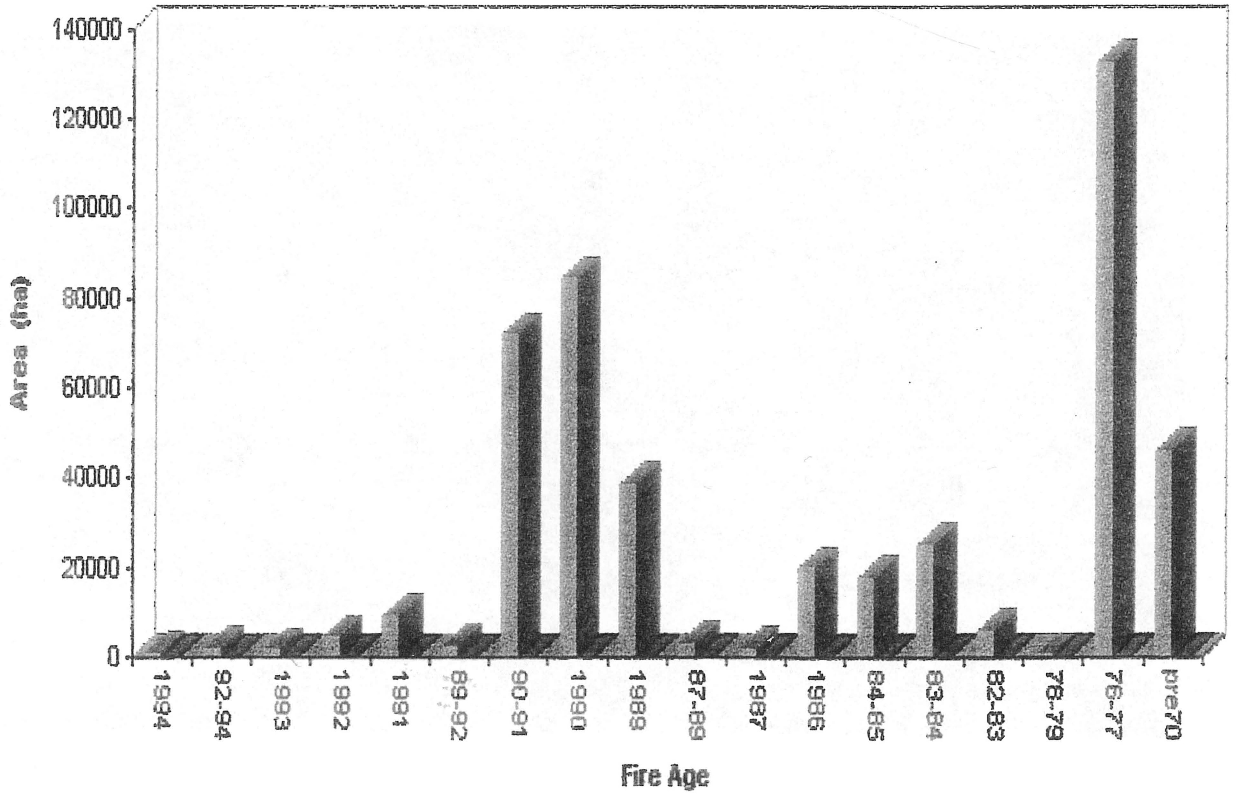


Figure 5. Fire History (to 1994) of Mulga Land Units in Uluru NP

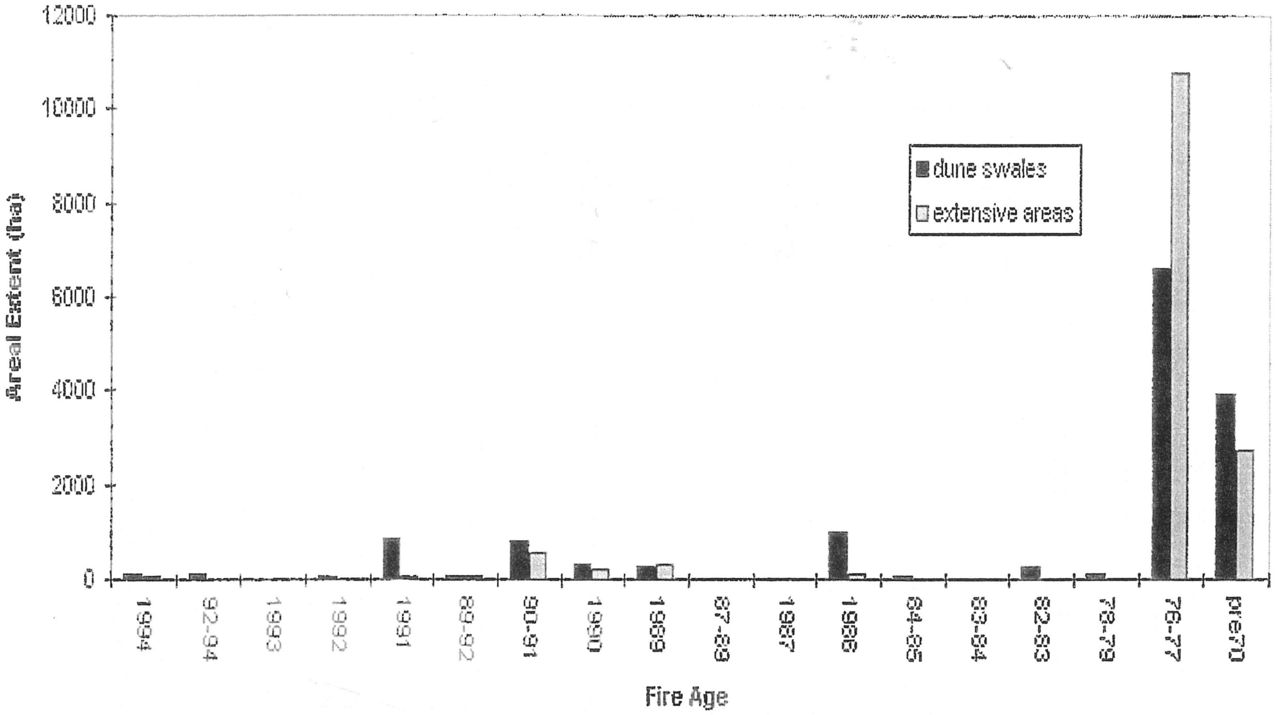


Figure 6. Fire History (to 1994) of Mulga Land Units in Uluru region

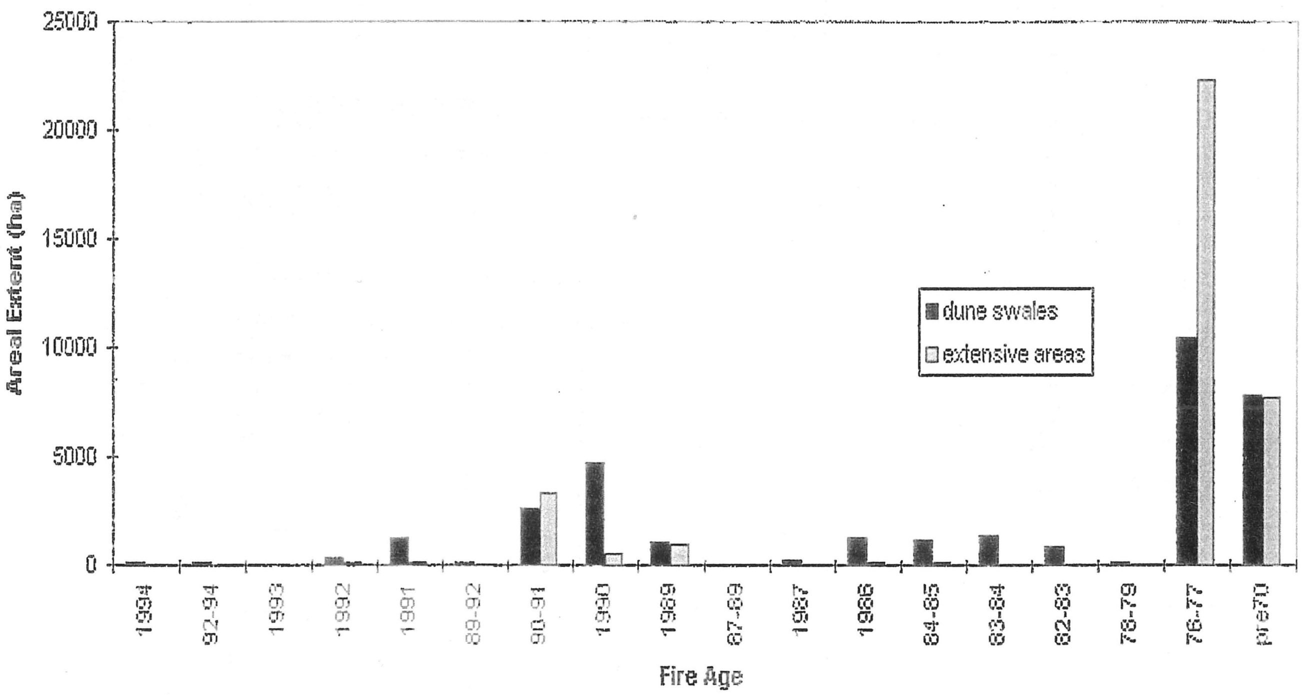


Figure 7. Distribution of Fire Age by Spinifex Community

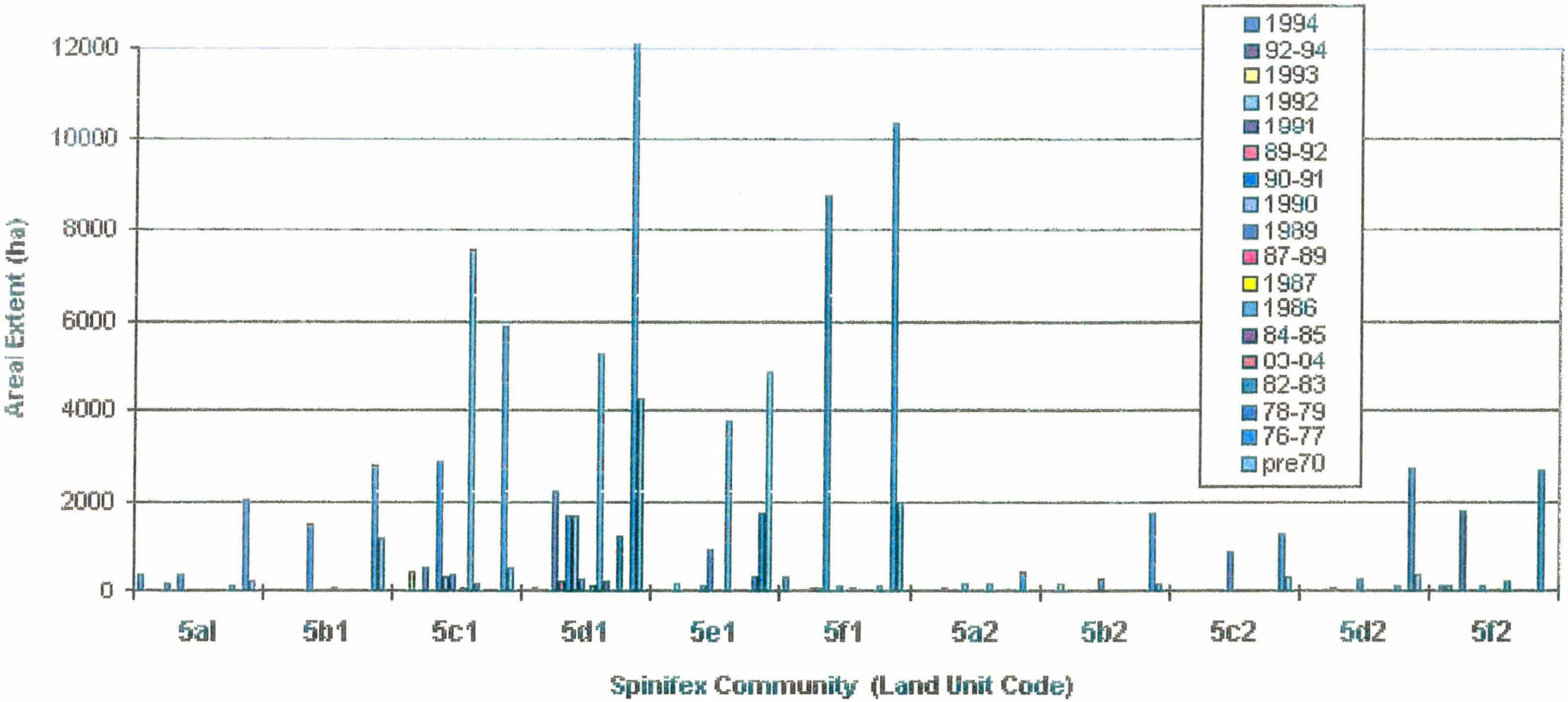
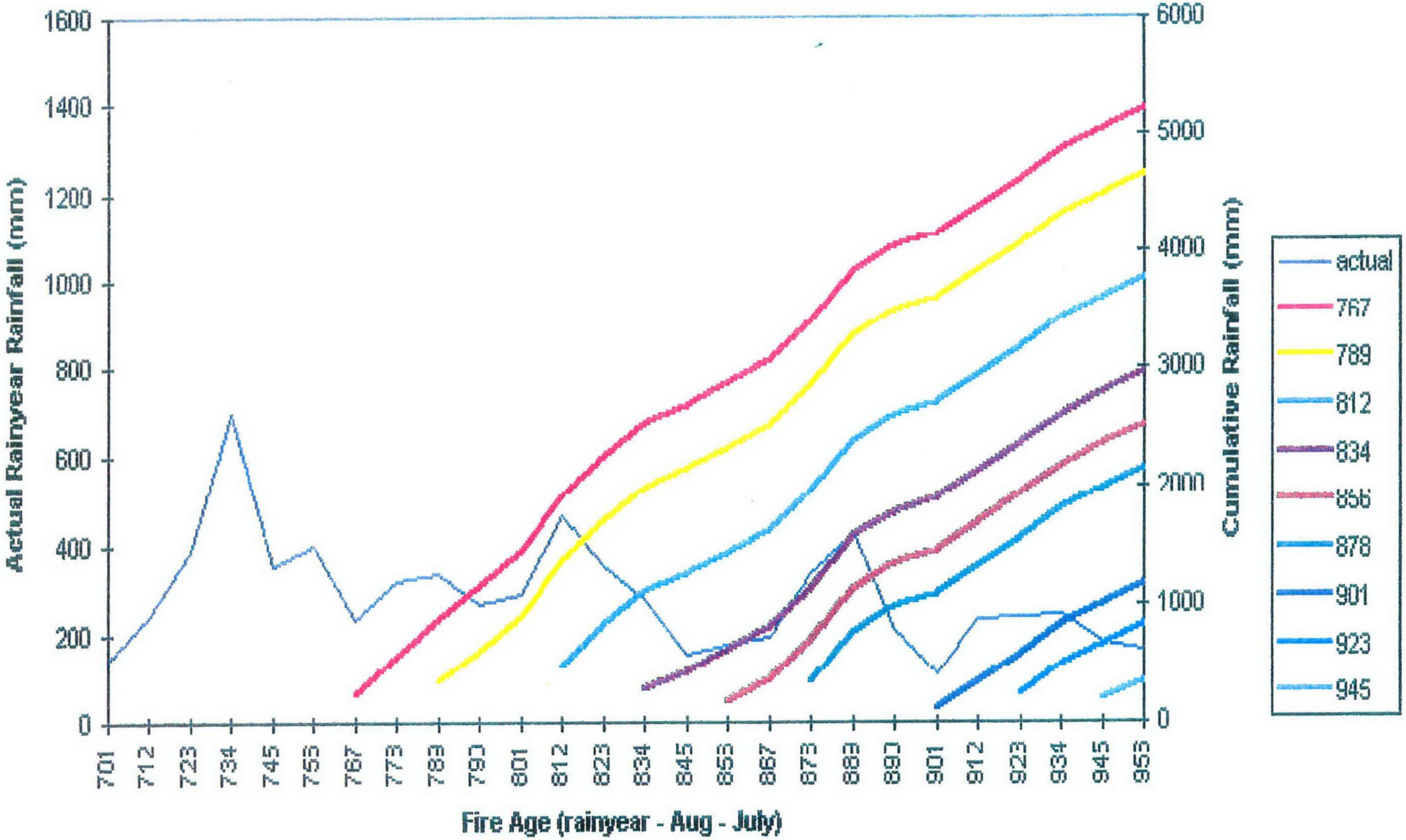


Figure 8. Uluru NP Cumulative Rainfall by Fire Age



2.3.2 Successional State

Consideration of the UFS recommendations and habitat preference must be made in relation to the 'successional state' of the spinifex habitats. It can be difficult to recognise the subtle ongoing change through time of the vegetation cover, fuel loads and species maturity within spinifex communities. It is also important to remember that the rate of change, especially for vegetation cover, is greater for soft spinifex in comparison to hard spinifex. The results from the CSIRO / CCNT Bushfire Research Project found the rate of change related to cumulative rainfall and established a relationship for each spinifex community (Griffin, 1993).

Figure 8 shows the cumulative rainfall for each fire age within Uluru NP and the actual rainfall recorded for a rainyear period of August to July. The next step is to convert the cumulative rainfall to an estimate of spinifex cover (which highlights the merging of the fire ages within the Park) and then spatially extrapolate this information to produce a map of spinifex cover in the Uluru region to assist with fire management planning. Monitoring the temporal changes of this spatial information is equally important. This involves monitoring the state of the vegetation cover in neighbouring patches through the transition from low fuel levels and a natural firebreak to moderate fuel levels sufficient to only carry a wildfire to high fuel which will not longer restrict fire management burns. A potential further extension of this process is to incorporate fire weather conditions to create a bushfire hazard map of the region for selected weather conditions throughout the year.

Consideration of the 'maturity' of the vegetation communities, rather than just the cover of the spinifex (and other vegetation) communities must also be a component of the fire management program in order to maintain an appropriate diversity of fire ages and spatial patterns. The recommendations of the UFS only considered this issue for fauna. At the time of the UFS the 'mature' habitat areas were those areas that had not been burnt during the extensive 1976 fires. It is now necessary to consider the extensive areas which were burnt in 1976. Those spinifex communities are now 21 years old. Key questions which should be considered include:

* In the 6-7 years since the end of the survey has the 1976 fire age progressed toward the 'mature' state?
* How should the 1976 fire age be managed and what criteria can be used to identify areas for continued fire exclusion?

2.3.3 Specific Fire Management Programs for Vegetation Communities

The UFS focused on the identification and management of habitats from a fauna perspective. It is also important to consider the use of fire for habitat management of vegetation. There are several important vegetation communities which should have specific fire management programs. Primarily these are long-lived species which require a level of fire exclusion. A few sample questions for four communities have been posed for consideration.

Acacia ammobia:

- what has been the effect of fires in the community,
  is fire exclusion still a supportable management objective
- what are the fire management needs beyond Uluru NP and can they be met

Thryptomene maisonneuvii:

- what is the size and distribution of long unburnt patches in Uluru NP?
- is fire exclusion a supportable management objective?
- should additional regeneration areas be targeted for fire exclusion?

mulga in swales:

- does the geology map (Qr/Qa) adequately define mulga swale communities?

- should a survey be conducted to assess the status of mulga in relation to Qr/Qa, fire age/fire history, soil characteristics?
- what fire management objectives need to be established?

mallee shrublands:

- what was the effect of the 1991 wildfire on the community?
- what is the spatial mix of fire ages?
- is fire exclusion required?
- what are the fire management needs beyond Uluru NP and can they be met?

2.3.4 General Fire Management Questions

Additional fire management questions also need to be asked during the planning and revision of the fire management strategy. These include:

* can the fire management program cope with the "intensive" management needs of these 4 vegetation communities identified above, and what other communities and / or areas (*Acacia olgana*, buffel grass/*Themeda*, *Eriachne mucronata*) need to be added to the program?

* how can the fire management program be integrated with fauna needs, both species specific and community needs on a spatial scale?

* when are hot burns desirable, if ever and can they be programmed within the spatial patterns of the Park (in consideration of the numerous 'intensive' management needs)?

* how can the fire management program be adequately documented and described to provide continuity through time in response to staff and other changes? This requires a commitment to a functioning GIS and development and maintenance of staff skills.

* what are the long term effects of 'conservation burns' (small low intensity patchy fires), and could they create a desirable or undesirable shrubland?

* how can risk assessment be incorporated into plans for fire exclusion to cope with inevitable wildfires which may affect these areas?

3. Anangu Involvement and Regional Studies

3.1 Two Way Information Exchange

An important aspect of communication between the scientific community and the Anangu which seems to be overlooked by the scientific community is that communication and learning must be a two way exchange. My perception has been that the emphasis has been on collecting traditional ecological knowledge to increase our scientific understanding. There is a need for the experience and knowledge within the scientific community to be understood by the Anangu. This should not be aimed at replacing their traditional ecological knowledge but complementing it with a better understanding of issues such as regional biodiversity and fine scale habitat manipulation for endangered species.

3.2 Regional Perspective and Management

Uluru NP is unique in terms of its freedom to manage the landscape with fire beyond its boundaries. This freedom is linked to the Aboriginal freehold tenure of the surrounding land and the close association of the Anangu people with the Park managers. This opportunity should be promoted and consolidated. Its has significant benefits for the management of individual species such as the mulgara and *Acacia ammobia*, whose populations extend beyond the boundaries, *i.e.* management within the Park only may not be sufficient to ensure their longterm survival.

It is recommended that the Park should coordinate a program of regional fire management with support and funding from organisations such as the Pitjantjatjara Council, ATSIC, CLC, PWCNT, BFC and ARRC.

Regional management is also important. Features such as the mulga communities surrounding Kata Tjuṯa and the Sedimentaries, the rocky ridges northwest of Yulara may require fire management. These areas have been recognised as having significant ecological values. Their significance, associated with their role in the redistribution of water into the Borefields area, has been further elucidated by the results of Pauline English's study. It is important to maintain the integrity of their ecosystem functions and possibly restrict continued development in the area. Coordination of activities and support from regional interests in this area will be more complex than for the fire program but must be undertaken.

4. State of the Environment Reporting

4.1 1996 State of the Environment Report

On the basis of the collective scientific knowledge associated with this workshop, Uluṟu NP is in a strong position to make a significant contribution to State of the Environment reporting for the arid zone of Australia. Although the topic of fire received considerable attention within the 1996 Report, there is a need to develop appropriate indicators. As an illustration, figure 9 taken from the 1996 Report (SOEAC, 1996), is disturbing in its simplicity. It inadequately portrays our understanding of fire and misrepresents the role of active fire management in both central and northern Australia.

4.2 New State of the Environment Indicators

The identification of environmental indicators associated with the complexity of issues associated with fire may need to be the focus of an individual workshop. It will be relatively easy to determine some descriptive indicators based on the patterns of the fire mosaic which was described above. But it will be more difficult to define more quantitative indicators which link spatial patterns to habitat management objectives and also include the concept of performance indicators.

4.3 Collation of Existing Data

There is a need to collate the data which has been collected at Uluṟu NP for its potential contribution to longterm data sets which will be valuable to State of the Environment reporting. There is a significant history of quantitative vegetation sampling which could help evaluate the impact of changes to the fire regime of the Park.

Most fire studies in central Australia have used space for time sampling, for both vegetation and fauna. Despite this approach there have been numerous studies at Uluṟu NP which have included repetitive samples through time. These data sets should be collected and assessed to determine the suitability of the relevant sites for longterm studies, either for vegetation, fauna or both. Other one off studies could provide baseline data for assessing future changes, especially in relation to management program such as the control of rabbits in the Kata Tjuṯa area.

Some of the datasets are:

* Pip Masters' sites in the Borefields area; with vegetation transect data for a 6 year period,

* the UFS sites; with vegetation transect data for 1987-1990, plus 1994/95 and 1997,
* the original fire research program; with vegetation transect data during the period 1982 to 1985.
* the 1989 vegetation survey of the non-spinifex landscapes; with baseline information in the land units surrounding the 2 monoliths.

5. Additional Comments on Current Plan of Management

5.1 Zoning

This section inadequately deals with fire management within the zones, most specifically the minimum management zone. It includes the statement that "Park management is normally restricted to such activities as erosion mitigation, fencing sensitive areas, approved research, control of feral animals and weeds and limited signposting" (p.66). It fails to emphasise that one of the most significant management activities in the Park is fire management. At times it is required within all management zones, but is primarily focused within the minimum management zone.

The next paragraph in the Plan (p.67 para 1) describes examples of minimum management zones. This concept seems to contradict the maps which indicate that the whole Park with the exception of a few small areas of intensive or intermediate management zones is a minimum management zone. The implication of this statement is that the majority of the Park is outside the minimum management zone and therefore not zoned.

The zoning maps do not show several of the intensive management zones listed, specifically the 3 car park areas for Valley of the Winds, Olga Gorge and Mutitjula.

5.2 Flora

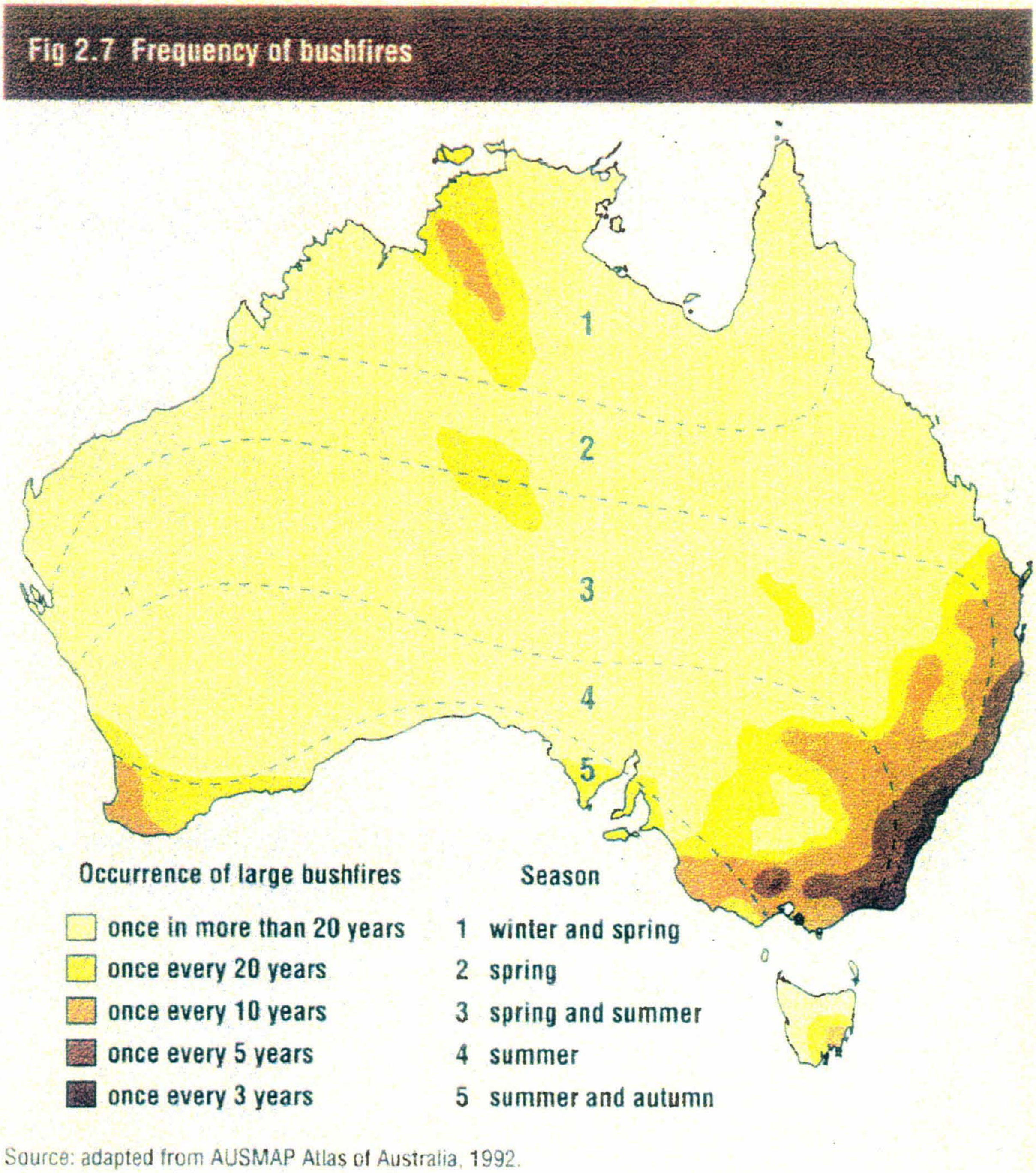
Although the current plan identifies several individual species of rare or uncommon plants, it does not adequately deal with communities and ecosystems. There is not sufficient incorporation of existing ecological knowledge, especially information on the fire sensitivity of many species and communities which could influence management prescriptions for areas. If it is considered that this information is not for public awareness or that it is too detailed for the Plan of Management, then a reference to supporting documents and databases should be provided. The approach could be to have a series of management plans / programs for individual species (similar to species recovery plans) each of which has strong spatial information to ensure Park staff are aware of the locations. Management activities could then take these issues into account.

5.3 Fire

Although the philosophy of *Anticipating the Inevitable* is still valid it has become dated and a new fire management strategy should be prepared. It should have stronger links to many of the changes which have occurred within the Park and the surrounding area, most specifically at Yulara, and the increased understanding of flora and fauna. It could adopt an approach similar to that in NSW, using a series of fire management zones (which could be linked to the Park management zoning scheme). It requires a commitment to spatial recording of data and the use of annual fire action plans.

As recommended in the previous sections there is a need for an evaluation of the fire management program between 1984 and 1996, from both a spatial patterning perspective, and its impact on habitat characteristics. Questions to be asked could include:

Figure 9. Bushfire Map from the 1996 State of the Environemnt Report



* what has been burnt?
* what has been protected?
* can we extend our knowledge of the fire effect on specific species and ecosystems?
* how can the spatial patterning of the fire program be assessed?, and
* is the spatial mix and areal extent of fire ages by vegetation type appropriate.

****

References

Allan, G. & Baker, L., 1990. Uluru (Ayers Rock-Mt Olga) National Park: an assessment of a fire management programme. In: Saunders, D.A., Hopkins, A.J.M. & How, R.A., Australian ecosystems, 200 years of utilisation, degradation and reconstruction. Proceedings of the Ecological Society of Australia, 16: 215-220.

Griffin, G.F., 1993. Changes in vegetation and soil chemistry after fire in three spinifex alliances in central Australia. CSIRO/CCNT Bushfire Research Project, 13, CSIRO /CCNT Technical Report, Alice Springs NT.

Reid, J.R.W., Kerle, J.A. & Morton, S.R., (editors), 1993. Uluru fauna. Kowari, 4, Australian Nature Conservation Agency, Canberra.

Saxon, E.C. & Allan, G.E., 1984. Patch-burn management: site selection. In: Saxon, E.C. (editor) Anticipating the inevitable: a patch-burn strategy for fire management at Uluru (Ayers Rock-Mt Olga) National Park. CSIRO, Melbourne, pp 69-78.

SOEAC (State of the Environment Advisory Council), 1996. State of the environment Australia 1996. CSIRO, Collingwood, Australia.

Palaeodrainage Mapping and Hydrodynamics, Uluru–Kata Tjuta National Park

P. English[1]

[1] c/- Gerry Jacobson, Geohazards, Land & Water Resources Division, Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT, 2601.

Project summary

The aims of the palaeodrainage project were to:
- review and revise current data with respect to palaeodrainage in Uluru–Kata Tjuta National Park;
- overview the hydrodynamics of the Dune Plains aquifer system in the Park; and
- generate coverages for the Park's GIS, to represent subsurface geological layers and hydrodynamic information for the study area.

An underlying aim was to collect and interpret geological and hydrogeological information that could be interfaced with ecological research projects, current and future — including vegetation and faunal distribution surveys, fire-pattern monitoring — and studies of Park management issues. A further underlying aim was to provide information to complement groundwater assessments for the Park to aid future projections and management plans.

The study area is shown in Figure 1. Two main aquifers, the Dune Plains aquifer and the Southern aquifer, supply Yulara village and Mutitjulu community with groundwater resources. The present study concentrated on the Dune Plains area, a sandplain between Kata Tjuta, Uluru, and Yulara. Integrated datasets (airborne magnetic and gamma-ray spectrometric imagery, Landsat Thematic Mapper imagery, a digital elevation model, and water-bore logs) were used to investigate the Cainozoic geology and hydrogeology of the study area. They show that a heterogeneous basement topography of domes and basins with 100 m of vertical relief (a buried 'mini-Kata Tjuta') underlies the Dune Plains.

A significant feature of this buried landscape is a palaeodrainage valley, now the setting for a compound bedrock–Cainozoic-sediment aquifer system which is the major source of water supply for the inhabitants and tourists of the area. The palaeovalley is traversed by major faults in the bedrock, and constricted near Yulara by a local, subsurface elevation of bedrock; both features are important aquifer influences. The palaeovalley was originally a closed valley with discrete depocentres in which lacustrine and alluvial-fan sediments accumulated. Later, a river evolved, and flowed north to Lake Amadeus, not eastward as previously mapped. North of Yulara the palaeoriver spread out in a broad deltaic braid plain to the lake. The braid plain has received recent episodic floodwaters that have disrupted the Quaternary dunefields.

Groundwater calcrete, and a sheetwash landscape unit composed of red earth, are important Quaternary geological units. The sheetwash unit forms broad, gently sloping aprons around outcrops and supports banded mulga shrubland (Fig. 2). During rainfall, surface run-off from this unit constitutes a distinctive 'sheetflow recharge' mechanism that maximises water conservation and infiltration for the adjacent aquifer.

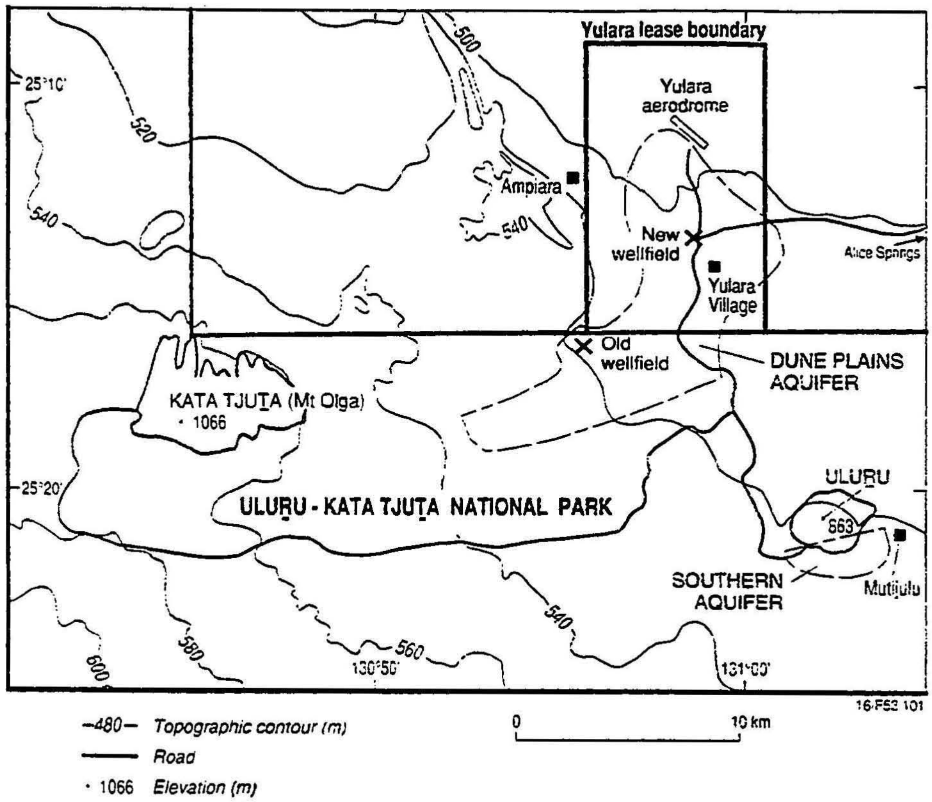


Figure 1. Study area map showing localities of the Dune Plains and Southern aquifers.

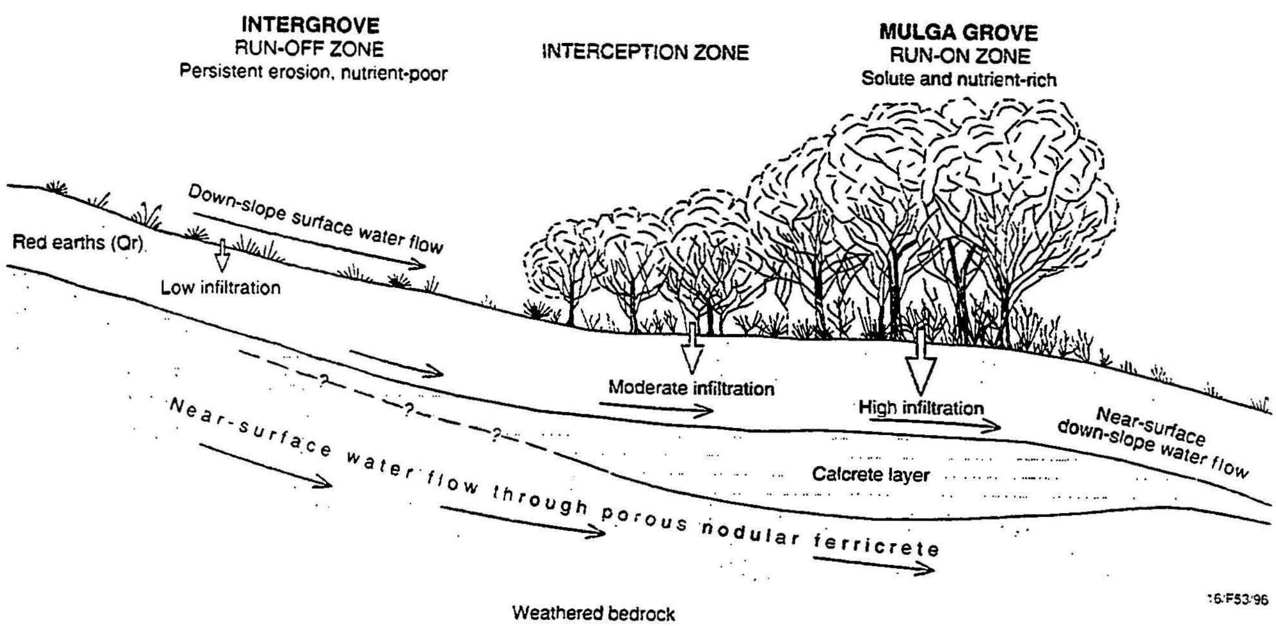


Figure 2. Diagrammatic cross-section of the Qr (Quaternary red earths) sheetwash landscape consisting of intergroves and mulga groves that are alternative run-off and run-on zones. The physical and biological dynamics of the banded mulga shrubland represent a highly ecological response to aridity wherein available water and nutrients are concentrated and accumulated. [Diagram modified after Greene (1997) National Soil Conservation Program report DD042, and Tongway & Ludwig (1997) Landscape Ecology: Function & Management. CSIRO Publishing].

Figure 3. Mulgara (*Dasycerus cristicauda*) marsupial, carnivorous, nocturnal, and classified as vulnerable. A core population of Mulgara inhabits the Dune Plains area. (Photograph by Ken Johnson, Parks & Wildlife Commission of the NT).

The sheetwash landscape unit appears to have an important bearing on the ecosystem of the mulgara (*Dasycercus cristicauda*) (Fig. 3), a vulnerable marsupial that inhabits the Dune Plains. Whereas mulgara populations elsewhere in the Park contract during droughts, the Dune Plains population historically has survived. The transitional zone between the sheetwash red earth–mulga shrubland and the adjacent sandplain–spinifex association coincides with this core mulgara habitat. The hydrodynamic processes of the sheetwash unit carry concentrated nutrients to this zone, at the base of the slope, where infiltration occurs. Enhanced biological activity and possibly also ephemeral near-surface water accumulation in the mulga groves, and the proximity of the mulgara habitat to this landscape unit may be favourable to the survival of mulgara and other vulnerable species in the area.

A report on the palaeodrainage project will be published shortly.

Future directions for research

A review of the Dune Plains and Southern aquifer systems is overdue and is a high priority for the Park and Yulara. A likely Olympics-boosted tourist influx to Yulara/Uluṟu, placing potentially heavier demands than usual on the water supply, accentuates the limited time-frame in which to assess the water resources and remedy any foreseeable problems with respect to long-term water supply and quality by the turn of the century.

Neither the geology nor the hydrogeology of the New Wellfield at the Yulara industrial area is straightforward nor well understood. Ground geophysical traverses may elucidate the basement configuration here, where an interpreted basement high constricts the flow of groundwater. Ground elevations of the production bores in the New Wellfield should be surveyed so that the local potentiometry can be established and the local water-level fluctuations can be monitored.

A program of water sampling for ^{14}C- and ^{36}Cl-dating would aid an assessment of recharge rates and residence times of groundwater in both the Dune Plains and Southern aquifers.

Applied research into the soil, water, and nutrient dynamics of the sheetwash–mulga shrubland unit and its transition into the adjoining sand plains is highly recommended. Research into the proposed 'sheetflow recharge' mechanism, associated with the physical and biological processes of the sheetwash-mulga shrubland unit is warranted, to elucidate the subsurface hydrology and recharge dynamics that may prove to be very important, not only to the Uluṟu area, but also to widespread inland regions elsewhere.

Integration of traditional ecological knowledge

Traditional ecological knowledge of water, Kapi Tjukurpa, within and around the Park should be integrated with hydrogeological research in the region. In particular, the localities of soaks, rockholes and seeps, and Aṉangu knowledge about the flowpaths of surface waters following major rainfall events and floods in recent decades would complement an understanding of the hydrologic patterns and processes of the area.

Implications for tourism

At present, Uluṟu National Park receives 350,000 visitors per year, with the likelihood that this number may increase in the future. Failure to assess and closely monitor the groundwater resources of the two aquifer systems may have deleterious consequences for the inhabitants, visitors, and the tourist industry in terms of diminished water availability and/or degraded water quality, with few alternatives to access viable aquifers elsewhere in the region.

The physical and biological processes of the distinctive landscape units in the Park, and the long-term viability of these highly-evolved and specialised ecosystems are potentially threatened by increased development of the area. The integrated dynamics of the sheetwash-mulga association is particularly vulnerable if subject to the construction of roads/tracks, pollution of recharge or aquifer waters by sewage effluent, and/or the removal of dead wood from the groves.

Collaborative ventures

Collaborative involvement with the Anangu traditional owners of Uluru–Kata Tjuta National Park, and personnel representing Environment Australia, NT Parks & Wildlife Commission, NT Department of Lands, Planning & Environment, and the Australian Geological Survey Organisation is desirable for future research into the near-surface geology, hydrogeology, water resources and ecology of the Park and adjacent areas.

Conjunctive studies of the Cainozoic geology, hydrogeology, and ecology should be integrated with land-unit mapping for other inland national parks, to build an understanding of arid-zone processes and the evolution of broad regions of Australia, and to aid management of and sustainable use of the resources therein.

Acknowledgements

Many organisations and individuals assisted with this project:
AGSO: Gerry Jacobson, Phil Bierwirth, David Champion, Lynne Woodcock and Gail Hill. Uluru–Kata Tjuta National Park (Environment Australia): Jake Gillen, John Harvey, Jacquie Shannon, Felita Mellars-Ramble, Imantura Richards, Daisy Walkabout, Norman Tjakalyiri and Jack Tjiweri. Parks & Wildlife Commission of the NT: Grant Allan. Water Resources Branch of the NT Department of Lands, Planning & Environment: Peter McDonald, George Tongia, Bob Read, Geoff Knott (deceased), Col Garner, David Evans, Allan Russ, and Scotty Balfour. NT Geological Survey: Lex Mulder, Barry Pietsch, Nigel Duncan and Roger Clifton.

****

The ecology of Brushtail Possums *Trichosurus vulpecula* in central Australia and the implications of this on their reintroduction to Uluru–Kata Tjuta National Park

Jeff Foulkes[1]

[1] Dept. of Environment and Natural Resources, GPO Box 1047, Adelaide, SA 5001.

The Brushtail Possum was once common and widespread through arid Australia but their number and distribution has declined considerably since the late 1920's (Kerle *et al.* 1992). They are believed to have disappeared from Uluru National Park in the 1960's. The Brushtail Possum or wayuta is an important totemic animal and formerly a traditional source of meat for Anangu.

The background work began as a study to determine the diet of *T. vulpecula* from scats preserved in caves at Uluru and Kata Tjuta and to compare the plant species composition found in the diet with that around the monoliths. Anangu provided traditional knowledge on the diet of possums and their former distribution.

Dietary analysis revealed that 8 species represented almost 90% and 26 species comprised the remaining 10% of the diet. The composition of the flora around the monoliths appeared to much the same.

The study was extended to examine possum populations outside the park as a feasibility study for their introduction to Uluru National Park. Two main study areas were visited 1) Irving Creek in the Petermann Ranges and 2) Loves Creek in the East MacDonnell Ranges. Other sites in the West MacDonnell Ranges were studied less intensively.

Anangu provided further traditional knowledge on the biology of possums and their tracking skills throughout the study.

Methods

The overall project on included the following aspects:

- impact of predators- diet of dingoes, foxes and cats by scat analysis
- impact of competitors, including the diet of rabbits and possums by scat analysis
- examination of the diet of possums and the nutritional characteristics of dietary and non-dietary items and the comparison of dietary items and their availability in the habitat
- comparison of the floristic, geological, landform, soil nutrient composition of occupied and unoccupied sites throughout their range in the Northern Territory.
- reproduction and habitat use
- examination of within and between population genetic variation to determine if central Australian brushtail possums are genetically distinct and that potential source populations were viable.

Results and Discussion

Predators

Analysis of the diet of predators provided new and disturbing data on predation of brushtail possums, particularly by dingoes. At the beginning of the study, no evidence of predation on brushtail possums was recorded but at Loves Creek, the impact of predators was particularly severe in the second half of the study, with females with pouch young and juveniles being the main victims. Irving Creek was little affected by predators compared with Loves Creek. The experience at Loves Creek demonstrates how quickly shifts can occur in the environment and adversely affect populations. Brushtail possums in central Australia, particularly Irving Creek, are in a predator pit because of the environment being modified by introduced herbivores and to a lesser extent by fire. This results in the habitat being less able to produce enough of the moist, nutritious foods required to achieve significant levels of breeding success in which will allow for brushtail possums to get out of the pit or maintain population size.

Competitors

There is a low level of direct competition between rabbits and possums. Greatest overlap in diet occuring during dry periods. There was a surprisingly high level of dicot material in rabbit scats. More significantly rabbits have severely degraded the habitat of brushtail possums at Irving Creek, and their effects may be responsible for the change in foci of brushtail possum activity there. Irving Creek continues to be the only current site where rabbits occur in any number. The Loves Creek study area has been subjected to the pressures of rabbits and livestock, but destocking and fencing has allowed the vegetation to recover from their impact.

The impact of feral camels was of greater concern, by virtue of their considerable impact on the vegetation at Irving Creek, and in particular their impact on Plumbush *Santalum lanceolatum*, a preferred and essential item in the diet of brushtail possums.

Locations where brushtail possums remain may have been affected by one of the main herbivores, but sites from which they have disappeared have been severely affected by two or more species of herbivores which have access to all habitats at a site. Other sites high up in steep gullies in the MacDonnell Ranges appear to not have been affected at all.

Diet and Plant Nutrients and Moisture

The availability of adequate nutritious and digestible foods is a critical element in describing key habitats and explaining brushtail possum decline. Brushtail possums obtain a balanced diet by consuming a mixture of leaves, flowers, fruits and some supplementary non-plant items. The dietary items that brushtail possums prefer have a significantly higher moisture content, nitrogen, dry matter digestibility and are low in toxins.

If a species has high levels of toxins, but is also rich in nitrogen, it is preferred to species low in toxins but also lower in nitrogen and other nutrients. There are species which are consistently in the diet of brushtail possums whenever they are occur in the habitat. These species include *Santalum lanceolatum, Eucalyptus camaldulensis, Acacia estrophiolata* and mistletoes (*Amyema* and *Lysiana* species). Additionally, flowers and fruits of perennial species are consumed when they are available, particularly those of acacias. Highly nutritious and digestible ephemeral species such as *Erodium* are also consumed during the short periods they are available. Supplementary non-plant foods such as honeycomb and insect larvae are eaten which increased the protein, fat and energy content of the diet. These supplementary foods were consumed by both sexes but a higher proportion of females included them in their diet. The moisture content of foods consistently separated possum sites from non-possum sites, whereas there was no consistent pattern in the concentration of the major nutrients between possum and non-possum sites. This fact notwithstanding, nutrients are important and it is probable that a nutrient threshhold exists, below which brushtail possums cannot persist, but this is yet to be determined. Similarly, a plant moisture content threshold for survival of brushtail possums is likely to exist.

Habitat Preferences

The exclusion of fire appears to be the major reason why brushtail possums occupy some habitats over others. This is indicated by the high mistletoe species diversity. Mistletoes are sensitive to fire and to moisture stress which may result from the removal of cover through fire and drought. The exclusion of fire permits a larger number of plant species, particularly in the shrub layer to reach maturity and be able to produce fruits and seed, and in doing so to provide possums with a greater food source. This also provides a diversity of hosts so that many mistletoe species may occur together as many mistletoe species are host specific.

Secondly, the fact that mistletoes are susceptible to moisture stress and that severe drought increases mistletoe mortality. This indicates that sites with high mistletoe diversity may also occur on sites with reliable ground water access for the host species, enabling their survival during drought.

Soil Nutrients

Major soil nutrients such as nitrogen, phosphorus, calcium, magnesium and potassium were in considerably higher concentrations at possum sites compared with non-possum sites. Available nitrogen and phosphorus levels in particular, were significantly higher at occupied sites compared with unoccupied sites. It appears that these sites have an advantage over nutrient poor sites by having a greater productivity of easily digested ephemeral growth and greater amounts of new growth and regeneration in perennials. Additionally, perennials have a better chance of establishment before the next drought because of nutrients permitting faster growth rates.

This work strongly supports the suggestion that locations where brushtail possums persist have relatively shallow water available for plant growth and /or topographic diversity which concentrates water to particular areas. As described previously, these two factors provide conditions which lead to enhanced moisture availability and longer periods of plant productivity. Extended periods of productivity may result in greater reproductive success and a higher proportion of females breeding successfully. This is also further supported by significant differences in the moisture content of perennial plants between possum and non-possum sites.

Habitat Use and Brushtail Possum Movements

Radio telemetry data revealed that particular habitats and specific parts of habitats, mainly edges, are preferred by brushtail possums. The individual home range size of the two populations studied varied enormously (between 7 and 77 ha), but it appears that home range size reflects habitat quality in terms of food availability and, to a lesser extent, den availability. The home ranges of brushtail possums at Irving Creek compare well with those of other brushtail possum populations, however, home ranges for brushtail possums at Loves Creek were considerably larger than those of other brushtail possums in Australia.

Breeding Biology

Success of breeding and survival of young appears to vary with the availability of suitably nutritious and moist foods for females Despite the small sample size, births appear to occur throughout the year, with the strong seasonal clumping found in southern brushtail possum populations not evident. Further monitoring of populations during dry periods may indicate that breeding and births may decrease in response to lower availability of suitable foods.

Genetics

Examination of microsatelite data revealed a relatively high level of genetic variability within the Irving Creek and Loves Creek populations despite their isolation from other populations and small size.

Mitochondrial DNA analysis showed that central Australian brushtail possums are almost identical to those from around southern South Australia. This indicates that possums from drier parts of South Australia may be a potential source for reintroduction stock.

Conclusions

This work has added a significant amount of information about the ecology of *T. vulpecula* in central Australia, and achieved a greater understanding of the processes involved in the decline of brushtail possums. I believe I have provided a strong understanding of the essential habitat characteristics of extant populations which are required to define the essential elements of habitats suitable for the reintroduction of brushtail possums to parts of their former range.

The evidence gathered in defining the characteristics of habitats strongly indicate that brushtail possums in arid environments require habitats with, mistletoe species diversity (indicative of absence of fire), relatively shallow water tables and/or topographic/geologic diversity, fertile soils and absence or low numbers of competitors and predators.

There is considerable evidence to support the belief that the loss of brushtail possums from Uluru and many other sites is most likely to have been caused by a combination of the impact of feral animals by competition and predation and by increased hunting pressure at the same time an extended drought occurred. It is vitally important that the control of all competitors and predators be implemented and maintained if the proposed reintroduction is to succeed. The events of 1991 involving the increased level of predation at Loves Creek and the impact of camels on the habitat at Irving Creek demonstrates the rapid nature of change in this arid ecosystem and shows that all possible threats to the survival of the population be considered, not only current or perceived threats. This not only includes predators and competitors but also the protection of the site from fire.

In conclusion, the results of this basic research into the ecology of *T. vulpecula* in central Australia and the possible reasons for its decline, indicate that it is feasible to reintroduce this species to parts of its former range. However the demands on time and money to undertake such a programme needs further discussion and in particular the consideration of Anangu expectations.

****

References

Foulkes, J. N. & Kerle, J.A., 1988. Dietary analysis of central Australian Brushtail Possum scats. Report to Australian National Parks and Wildlife Service (unpublished).

Foulkes, J. N. & Kerle, J.A., 1991. Feasibility study for the reintroduction of the Brushtail Possum to Uluru National Park, phase III. Report to Australian National Parks and Wildlife Service (unpublished).

Kerle, J. A. & Foulkes, J.N., 1992. The decline of the brushtail possum *Trichosurus vulpecula* (Kerr 1792), in arid Australia. Rangelands Journal, 14: 107-27.

Impact of tourism at Uluru

Margaret Friedel[1]

[1] CSIRO Centre for Arid Zone Research, PO Box 2111, Alice Springs, NT 0871.

Uluru-Kata Tjuta National Park was gazetted in 1958. In the following decade tourist numbers increased so dramatically that in 1968 rehabilitation was attempted to reduce the impact of erosion in sensitive areas. Structures to hold back water flow were built and exotic perennials were introduced in the hope of stabilising the soil quickly. Unfortunately, some of these exotics were more successful than anticipated, and a few, particularly buffel grass (*Cenchrus ciliaris*), now dominate the most popular gorges at Uluru as well as the edges of roads and tracks. In addition, patches of trees and shrubs have died in some areas and it has been suggested that tourist activity is responsible.

The Project: Impact of Tourism Infrastructure on Environmental Processes at Uluru

The project was led by Dr Margaret Friedel (CSIRO), in collaboration with Des Nelson (CSIRO consultant), Jake Gillen (ANCA), and traditional owners of Uluru. Funded by the National Ecotourism Program, Department of Industry, Science and Tourism, the project was designed to demonstrate the relationships amongst vegetation (including weeds), landscape and soils, and tourist activity. Recommendations were to be developed for rehabilitation, management and visitor education.

Results and Conclusions

The results of the project and comments by many contributors suggest that soil erosion and the spread of buffel grass is enhanced in heavily visited areas. However, these areas are also naturally unstable, so that tourism impact is only a secondary influence.

Old eroded tracks channelled water away from trees like bloodwood in the past, hastening their death in drought. Current tourist activity has contributed very little to the death of these overstorey species. Much tree death is due to large natural events including drought and fire. Indiscriminate fire by tourists probably contributes more significantly to the present loss of trees and shrubs, than disruption caused by old tracks and roads. A great deal of damage was caused through uncontrolled access during the 1950s and 1960s. However, current park management has limited further disruptions and has led to the recovery of many areas. Considering that about 300,000 people visit the park annually in comparison to 4500 in 1960, success of present management is notable. A monitoring program has been recommended which will provide information on outcomes of management and, at the same time, enhance knowledge of the influence of natural events. Such a program will give good insights into what drives environmental change, and will also involve Park staff in the hands-on learning they need to be effective resource managers.

Monitoring for Management

Graham Griffin[1]

[1] Division of Wildlife and Ecology, Centre for Arid Zone Research, CSIRO, PO Box 2111, Alice Springs.

The procedure of **inventory** (resource and process) and **assessment** (level and trend) within a framework of **response** (policy).

- pressure-state-response model
- adaptive process: "learning by doing"
- **Inventory** is a single measurement of state
- **Assessment** is repeat inventory for detecting change (time) or difference (space)
- **Response** is decision to affect management

Monitoring is undertaken for management. I describe here a basic monitoring structure, applicable to any resource and management context. It is based on the pressure-state-response notion suggesting that monitoring is reactive rather then pro-active. If monitoring is conducted at the right level with the right degree of precision then early trends can be detected or predicted and monitoring can become a pro-active tool.

Establishing viable monitoring systems is however often a learning process, in terms of identifying the resource exactly, the indicator, and the accuracy, precision and frequency of inventories.

Resource and Indicator

In defining the resource and process affecting the resource recognise that this is done within a context of resource use. Our concepts and use define the resource!

The indicator reflects the state of the resource and responds to changes in its state at the required level of accuracy.

Assessment

Measuring the state of the resource may require a trade off between precision and accuracy. Measures must be able to be compared in space or time and in relation to process.

Response

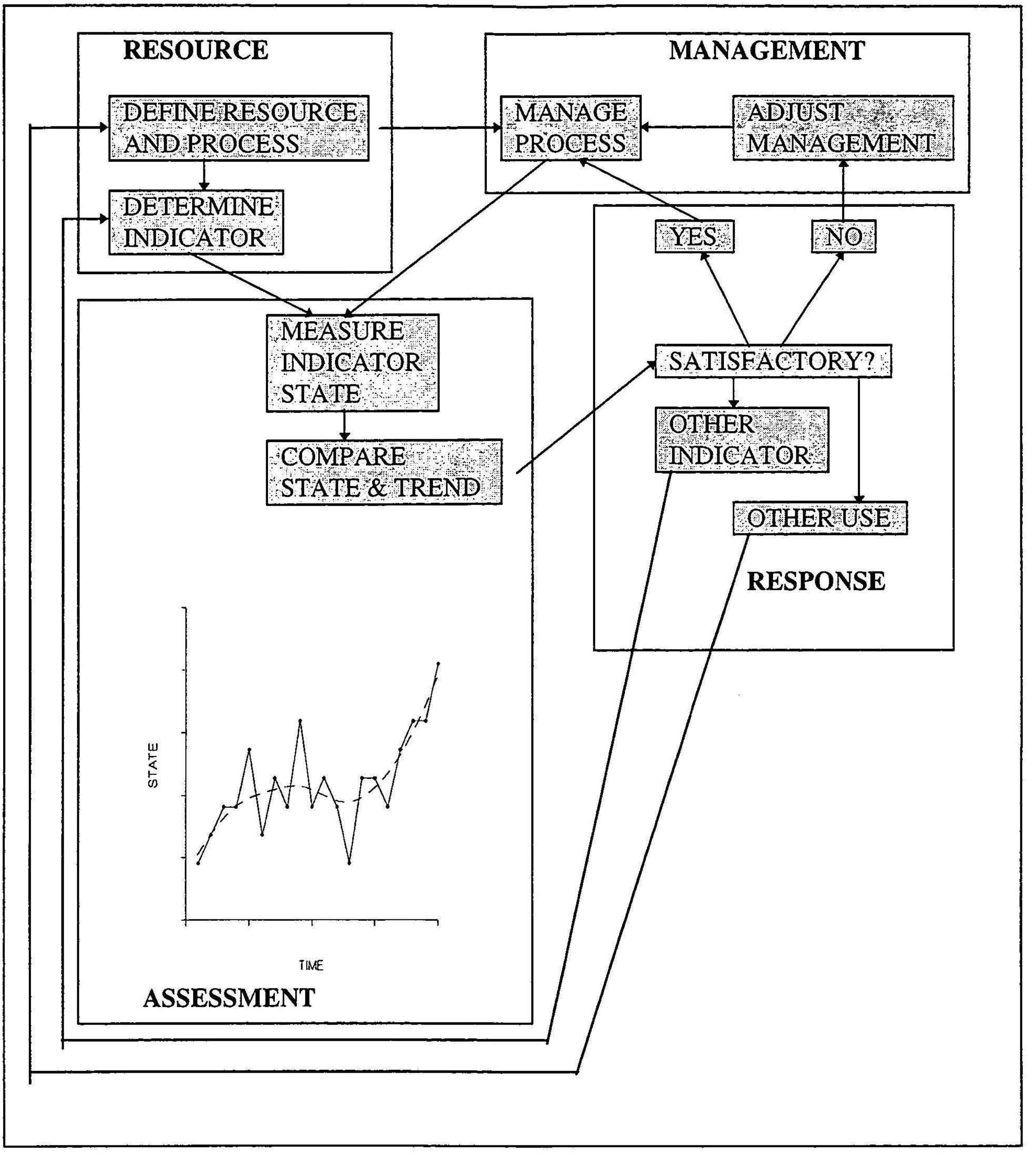
At the outset it must be determined who decides on an action as an outcome in change in state of the resource and what process will be used in deciding that action. In some cases it may be as simple as comparing measures against performance indicators, a standard, or relatively.

Management

Whatever the outcome of the response is it is the process that is managed, not the resource. The decision to manage the resource must be stated in terms of manipulating the process, unless it is to replace or modify the resource.

Meta Indices

The model above describes a single resource, single process and single index. It may be desirable to monitor several resources and processes and derive a meta-index by combining



several indices. Examples are the Consumer Price Index and the various stock exchange indices.

Need to know:

- What is the resource?
- What process(es) currently affect the resource?
- What other process(es) might affect the resource in the future?
- What management is in place to maintain the resource?
- What attribute(s) of the resource and process(es) can be measured to indicate their state?

- What other attributes might also indicate the state of the resource?
- How will they be measured?
- When will they be measured?
- How will they be compared with a standard or previous measures?
- How will they be reported?
- How will the state and trend of the resource be judged?

What management actions are there to correct for undesirable changes in the state of the resource?

The above set of questions attempt to check every step in the diagram presented earlier. Being able to answer each question should be sufficient to establish a monitoring process for a resource. I suggest a pro-forma be established to address these questions.

State of the Environment reporting in Australia

John Higgins[1]

[1] Environment Australia, SoE Reporting, GPO Bx 787, ACT 2601.

State of the Environment reporting in Australia offers a range of models for the proposed state of the environment reporting system for Uluru–Kata Tjuta National Park. This paper will describe the various approaches to SoE reporting in Australia, and note issues relevant to the Park.

Approaches to SoE reporting in Australia

All States and Territories except Victoria and the Northern Territory have formal state of the environment reporting systems, as does the Commonwealth. The Northern Territory has signalled its intention to explore state of the environment reporting, while Victoria has alternative mechanisms for reporting on the state of the environment.

Reporting models

All jurisdictions in Australia use the "pressure-state-response" model (also referred to as the "condition-pressure-response" model and the "driving force-state-response" model) as a reporting framework.

Pressures are human activities that affect the environment. The effects may be beneficial, detrimental, or neutral, although perceived detrimental effects are most often considered significant for reporting purposes.

States (or conditions) are the quality and quantity of "environmental resources" (soil, biota, atmospheric gases, fresh water etc), and environmental processes (nutrient, carbon and water cycling, population dynamics etc).

Responses are human attempts to address perceived environmental problems or potential problems.

As originally conceived, the PSR model was based on the concept of causality. Pressures on the environment affect its condition, and responses address consequent problems. In this form, the model is a powerful tool for addressing a number of environmental issues. For example, the release of ozone depleting substances is a pressure causing the depletion of the stratospheric ozone layer, and eliminating the use of such substances is an effective response.

For a wide range of ecological phenomena, the PSR model cannot be interpreted in the simple, "fundamentalist" fashion. Causal links between human activities and ecosystem processes are seldom as simple as the model implies; multiple causation, ecosystem responses, and lack of scientific certainty all come into play. Accordingly, the PSR model is used mainly as a method for organizing information, with recognition that the implied causal links are "soft" and/or uncertain.

Despite the shortcomings of the PSR model, it is widely used and has the advantage of focussing attention on human activities - these being the element that management is most able to influence.

Variations

The main variations between jurisdictions are in the timing of reporting cycles, the authority responsible for preparing reports, the mandate for reporting, and the inclusion of recommendations. The variations are summarized below.

	Frequency	Responsible authority	Mandate	Recommendations
Commonwealth	4-5 years	Independent Advisory Council drawn mainly from outside government, with administrative and financial support from Environment Australia.	Government policy	No
NSW	3 years	EPA	Legislation	No
Queensland	4 years	Department of Environment	Legislation	No
SA	5 years	EPA	Legislation	No
Tasmania	5 years	Sustainable Development Advisory Council	Legislation	No
WA	3-5 years	Report released by Cabinet	Government policy	Yes
ACT	3 years	Independent Commissioner for the Environment	Legislation	Yes

Table 1. Summary of the variations between jurisdictions.

Environmental indicators

Environmental indicators have three main functions in state of the environment reporting:

1 They reduce the number of measures that would normally be required to give an 'exact' representation of the state of the environment.
2 They simplify the communication process by which information is provided to the user.
3 They facilitate monitoring of trends in the environment by providing quantitative measures of changes in well defined characteristics over time.

Much effort, in Australia and overseas, has been directed to their development. Environmental indicators are simple physical, chemical, biological or socio-economic measures that best represent key elements of a complex environmental system or issue. Indicators are embedded in a system of theory and practice that guides their interpretation and imbues them with meaning.

A particular challenge in developing environmental indicators is that we lack adequate understanding of many important natural systems. Selecting the most appropriate indicators and knowing how to interpret them is thus difficult. As our knowledge develops, it is likely that many of the environmental indicators we select today will be discarded or significantly revised.

The Commonwealth is developing environmental indicators for the seven main themes used for reporting in *Australia: State of the Environment 1996*. These are: inland waters, estuaries and the sea, land, human settlements, the atmosphere, biological diversity, and natural and cultural heritage. A set of recommended indicators will shortly be available for each of land, inland waters, estuaries and the sea, and biological diversity, and recommended indicators for the remaining themes should be available early in 1998.

Implications for SoE Reporting in Uluṟu–Kata Tjuṯa National Park

If a state of the environment reporting system is to be set up for the Park, a number of issues must be addressed. These include:
- who will be responsible for preparing reports?
- how frequently will reports be prepared?
- should reports include recommendations?
- what purpose will the reports serve?
- what will the scope of the reports be?
- what indicators will be used?

These are ultimately questions for the Park management to resolve. I would, however, like to make a few observations and point to a few opportunities.

Given that the plan of management for the Park is reviewed every five to seven years, it may be beneficial to prepare state of the environment reports, say twelve months before the review. State of the environment reports could thus be taken into account when reviewing the plan of management.

Whether or not reports should include recommendations will depend on the purpose of the reporting process, its context, and the mechanisms established to support it. One view is that reports should concentrate on presenting an objective assessment of environmental trends and problems, leaving decisions about how to address the issues identified to processes better placed to evaluate options. Another is that recommendations sharpen the reporting process and make decision-makers more accountable.

In selecting environmental indicators for reporting, the Park has the opportunity to draw on the work that has been done at the national scale. The most relevant national themes are land resources, inland waters (for work on ground waters), biological diversity, and the atmosphere (for work on climate variability and change). Certainly, the spatial scale involved in reporting on the environment in the park is different to reporting on the national environment. Despite this, many of the indicators are still relevant. Some examples are:

- area underlain by rising or falling watertables
- trends in groundwater salinity
- groundwater abstraction versus recharge
- demographics of target taxa
- distribution and abundance of feral pests and weeds
- areas where exotics are rapidly displacing natives
- distribution of human population

tourist visits

Work in the Park could also contribute to the development of environmental indicators for use at the national, and State/Territory scales. For example, one of the most difficult issues for national indicator development is how to report on changes to fire regimes. While fire regimes are recognised as a critical factor affecting biological diversity, there is uncertainty about which parameters are critical to measure and how to analyse trends. The Park has detailed fire history records extending over many years, and could make a significant contribution to understanding how to report on fire regimes.

The environment has cultural, social, spiritual and aesthetic as well as ecological values. These values are powerfully evident in and around the Park. There is thus an ideal opportunity to carry out research that will draw out these links and show how to report on them as part of a state of the environment reporting system.

Uluru–Kata Tjuta National Park

Rabbit control project: Warren monitoring and fumigation

Review of the program 1989 to May, 1997

Conducted for
Australian Nature Conservation Agency, Uluru–Kata Tjuta National Park

Low, W.A.[1]; Baker, Lynn[2,3]; Dobbie, W.[1,4]; Ryan, W.[2]; Grattidge, A.[1,5] and J. Gillen[2]

[1] W.A. Low Ecological Services, P.O. Box 3130, Alice Springs, NT, 0871.
[2] Australian Nature Conservation Agency, Uluru–Kata Tjuta Nat. Park, P.O. Box 119, Yulara, N.T. 0872.
[3] "Wallambia" Consultants, Lot 13, South Arm Road, Urunga, NSW 2455.
[4] Centralian Land Management Association, P.O.Box 2534, Alice Springs, N.T. 0871.
[5] Dept. of Lands, Planning and Environment, Alice Springs, Nt.0870.

Abstract

This abstract is from a project review which is nearing completion (Sept. 1997) and will be presented to the Park as a contract report.

Extinction rate of the diverse range of medium size mammals that once inhabited Uluru–Kata Tjuta National Park (Ayers Rock National Park) was extreme in the last 50 to 75 years and still continues with Possum and Black Footed Rock Wallaby disappearing in the last 10 to 15 years from the Park. Only a single species in the critical weight range, the echidna, is still extant on the Park (Reid, 1991). Much of the blame for this sudden extinction lays with invasion of introduced herbivores, particularly the rabbit, and predators, particularly the fox, in the last 100 years in central Australia (Morton, 1990). Rabbits invaded the Park area shortly after the turn of the century and occupied warrens established by the native Burrowing Bettong (Rat-kangaroo), *Bettongia lesueur*.

The rabbit control program at the Park began in 1988, with long term aims to minimise impact on the landscape and remaining native species and to provide a suitable environment for the re-introduction of locally extinct fauna. Following hand-back in 1985 of the Park to the local Aboriginal (Anangu) peoples, rabbit control had first to be approved by the Park Board of Management and Anangu. Anangu agreed as part of their joint management responsibility for the Park that it was advantageous for the rabbit control program to go ahead.

Mapping of the distribution of rabbit warrens from air photographs was completed in 1988. Within the Park rabbit distribution is concentrated at Kata Tjuta where calcareous alluvial habitat is more suitable and complex. Ripping of warrens in the vicinity of Uluru and Kata Tjuta was completed between February and June, 1989 during the wettest year on record.

Five hundred and thirty warrens were identified from air photographs around Kata Tjuta and 40 warrens were identified around Uluru. Rabbit control was initially done by one-way ripping with a rubber tyred tractor with single 1m tyne between March and June, 1987. All warrens were examined from the ground during the ripping operation and 337 active warrens were ripped at Kata Tjuta and 14 at Uluru. Follow up fumigation of opened holes of all ripped warrens was carried out 2 to 4 weeks after ripping.

Each year following ripping, active warrens have been continually searched for and fumigated. A consultancy (W.A. Low Ecological Services) ensures the whole "control area" is re-treated in early summer each year. Opportunistic monitoring carried out by Rangers throughout each year makes the control program more effective. Rangers spend a variable amount of time fumigating warrens, whenever their schedule allows, particularly during the Kata Tjuta patrol. Periodic turnover of Park staff and frequent unavoidable demands on ranger time have shown the benefits of use of a consultancy which ensures the whole "controlled area" is monitored and fumigated at least once every year on a continuing basis.

Rabbit numbers were high and approaching plague levels in 1987, 1988 and 1989 preceding the control program, however, no counts of rabbits were done to estimate numbers. Active warrens ranged in size from one to over 100 holes per warren and had an average of about 10 active holes per warren providing an alternative index of rabbit population size. The number of active holes was conservatively estimated at over 3300 holes in the two core areas. Counts of active holes and warrens have been used as an index to monitor the fluctuation in rabbit numbers and success of the Control Program.

Reduction in active holes and warrens was greatest immediately following ripping and has shown an exponential decline. Over the nine years in which fumigation of active warrens has been conducted the number of active warrens and active holes around Kata Tjuta has declined by 92% and 99%, respectively, with a short lived 100% decrease in warren activity recorded for Uluru in 1996. The number of active holes at Uluru reduced from about 140 prior to the 1989 ripping to zero in the summer of 1996. At Kata Tjuta the number of active holes has reduced steadily from an estimated 3230 prior to ripping to the lowest number yet achieved, 66 active holes in 36 active warrens in the summer of 1996. Following the wet winter of 1994 and wet autumn of 1997, the number of holes that were active increased. In 1994, there were 481 active holes in 130 active warrens at Kata Tjuta and 6 active holes in 2 active warren at Uluru. In 1997, there were 95 active holes in 51 active warrens at Kata Tjuta and 3 active holes in 1 active warren at Uluru.

The areas occupied by rabbits has been greatly reduced during the control program with some of the less hospitable, and presumably marginal, areas being devoid of rabbits since the initial fumigation.. Areas remaining active are scattered and showed a very much reduced level of activity compared to the start of the project.

Rabbit control began in an exceptionally wet year in which nearly twice the average rainfall was recorded. The following years were mostly exceptionally dry with the recorded rainfall being less than half the yearly average. A small increase in rabbit numbers occurred during the favourable rains in 1994 but this was controlled by fumigation and continued dry conditions in 1995. Likewise in 1997.

The Rabbit Control Program has benefited from the effects of predators as well as climate. Predator sign is more abundant around areas where rabbits still exist and evidence of them digging out warrens and of rabbit hair in the scats is relatively common. Predators include dingoes, foxes, cats and perenties.

The initial reduction in rabbit numbers was accomplished within the Park at least three years ahead of rabbit population crashes which took place in adjacent drought affected pastoral lands in 1992 and 1993. An indication of the continuing effectiveness of the control program in the Park in shown by warren activity assessed in adjacent areas outside the Park in 1996. North of the Park and on Curtine Springs there was an average of about 3 active holes per warren. In the controlled areas of the park the activity in comparable warrens was about 0.6 active holes per warren.

The benefits in vegetation growth on the Park were apparent for a four year period following the control of rabbit numbers in 1989 although kangaroo and camel numbers increased in the rabbit controlled areas. Drought conditions subsequently reduced the ground vegetation cover at all locations to very low levels with fluctuations in the amount resulting from short wet periods (Low *et al.*, unpubl. data).

Several areas contain warrens which tend to reopen regularly. These are probably refuge warren areas or areas prone to reinvasion from adjacent rabbit populations. The areas include:

- Uluru Sunrise Car Park and Old Airstrip Area where rabbits appear to be re-invading from dunes to the east
- Rangers Residence Sand Dune
- portions of the region on the north and south side of Kata Tjuta, particularly the southeast corner of Kata Tjuta

The direct cost of the program has been less than $60,000 with initial mapping and ripping costs of about $10,000 and contract monitoring and control about $45,000 for nine monitoring occasions. Other costs borne by the Park include the cost of the operation of the tractor initially was about 450 hrs of tractor time which at say $30/hr is $13,500, Ranger time and vehicle use, which is difficult to calculate and may average about $1500 per year or an additional $13,500 total. Thus total costs could be about $87,000 over the nine years of the control program.

Results from the nine year Control Program indicate that persistent control is required for rabbit numbers within the Park to be maintained at a reduced level or potentially eradicated.

Calici virus may spread from its present known locations east and south of the Park to Uluru–Kata Tjuta National Park. Ideally, detection of the virus at Uluru should trigger an increased effort to eradicate any survivors of the disease. Rangers should be alert to signs of the virus presence and send any rabbits found dead with no apparent cause of death to the Department of Primary Industries and Fisheries, Alice Springs.

Static fumigation still appears to be the most convenient tool available for control of the few scattered holes which open up. The current practice of using two phosphene pills, wrapped in tissue paper and moistened, for each active hole is recommended in these porous soils. However, pressure fumigation is more thorough in treatment of warrens which reopen frequently. Additional Ranger staff should receive training and licensing in the use of the pressure fumigator.

Although Ranger effort is limited due to other demands on Ranger time, their work extends the control effort throughout the year and permits focusing on particular regions of activity. Ranger effort should continue or increase and be coordinated by one Ranger who is responsible for maintaining day to day records. Ranger effort would be most effective if discrete areas could be allocated to particular rangers for treatment throughout the year.

Concern that reduction in the rabbit population by *Calici* virus will increase predator pressure on native species has little validity at Uluru–Kata Tjuta National Park. Rabbit numbers have already been reduced to less than 2% of the high population by the control program and the virus will not exaggerate the problem for the Park as predator populations have also declined. Monitoring of abundance of predator species should be made a part of the Park's long term Rabbit Control Program to assess continuing changes in predator numbers in rabbit areas as well as non-rabbit areas. Active reduction of introduced predator species such as feral cats and foxes should also be a high priority but it should be undertaken as part of the controlled monitoring program and controlled experiment.

A strategic timing of control and monitoring is recommended. During continuing drought conditions numbers decline due to predation and other environmental stresses and limited breeding occurs in the rabbit population. However, during drought times, rabbits are not as dependant on warrens for shelter and fumigation of warrens for control becomes less effective. Conversely, during good seasons, populations increase as breeding is more extensive and rabbits are more dependant on warrens. Timing of the annual monitoring and control should take place within three months after significant rainfall each year so that breeding does and kittens can be fumigated in active holes in warrens. If significant rains do not occur before the onset of summer, monitoring and control should be conducted in November or December when warrens are likely to be used as shelter from high temperatures and high evaporation rates.

The purpose of the control campaign is to allow Tjukurpa animals, such as Possums, Bilby, Mala, Rock Wallabies, Bettong and Mallee Fowl, to be returned to the Park. This purpose needs to be frequently stated to Anangu and park staff in this long term project in order to maintain interest and effort in the campaign. The support and involvement of the Anangu people needs to be strengthened through reiterating the goals and involving them in the project.

Distribution of Buffel Grass within Uluru–Kata Tjuta National Park 1990

W.A. Low and E.Foster[1]

[1] W.A. Low Ecological Services, PO Box 3130, Alice Springs, NT 0871. December 1990.

Introduction

Buffel Grass *(Cenchrus ciliaris)* was initially introduced into Uluru National Park in 1969 as part of the erosion control and revegetation programmes undertaken at that time. Ponding banks were built and Buffel Grass (cultivar "Gayndah") was planted in all bare areas out from Mutitjula (Maggie Springs). Coopers Clover and Annual Verbine were planted in moist areas. In 1970 the sown areas were resown with Buffel Grass, Kapock Bush, Mitchell Grass and Bluebush. Gulley erosion control traps were built near the Kangaroo Tail about 1972 but no seeding was done as concerns were being expressed about using introduced species.

The main purpose of this study is to outline the current extent of Buffel Grass around Uluru and Kata Tjuta from its initial introduction point at Mutitjula. Comment on future possible distributions and recommendations for control are included.

Methods

Aerial photographs at 1:4000 from August 1989 were examined with a stereoscope and ground-truthing was carried out to show the known distribution of Buffel Grass at Uluru. Air photographs at Kata Tjuta were four years old and at too a small scale to be useful, consequently distribution of Buffel Grass there was determined by ground survey along the roads and in remote areas examined during the warren fumigation programme.

Results

Three maps have been produced indicating the extent of Buffel Grass on Uluru National Park. A large-scale map of Uluru, (as Figure 1), was derived from aerial photo mosaics at 1:4000 and shows locations where Buffel Grass is either scattered or dense. Figure 1 is a large scale map of Uluru drawn on drafting film and separate from this report. The working copy is held by W.A. Low and the final copy is held at Uluru National Park. A more general view of distribution at Uluru is shown at a smaller scale (approximately 1:40000) in Figure 2 where presence or absence only is indicated. The distribution in the Mutitjula Community is not accurately mapped since the 1:4000 air photograph coverage did not extend over the community. It is known to occur there so its limit of distribution is shown as a dotted line. Figure 3 shows the distribution of Buffel Grass at Kata Tjuta. Distribution of Buffel Grass is much more limited at Kata Tjuta. A vehicle log of distribution was taken and is kept on file. The old Uluru–Kata Tjuta road and the borefield road were also surveyed from the road but no Buffel Grass was noted. Buffel Grass tends to be distributed in narrow strips along the disturbed soils at the edge of roads and tracks hence to show its presence in Figure 2 and Figure 3 the width of linear distributions is disproportionately large so it is visible on the map.

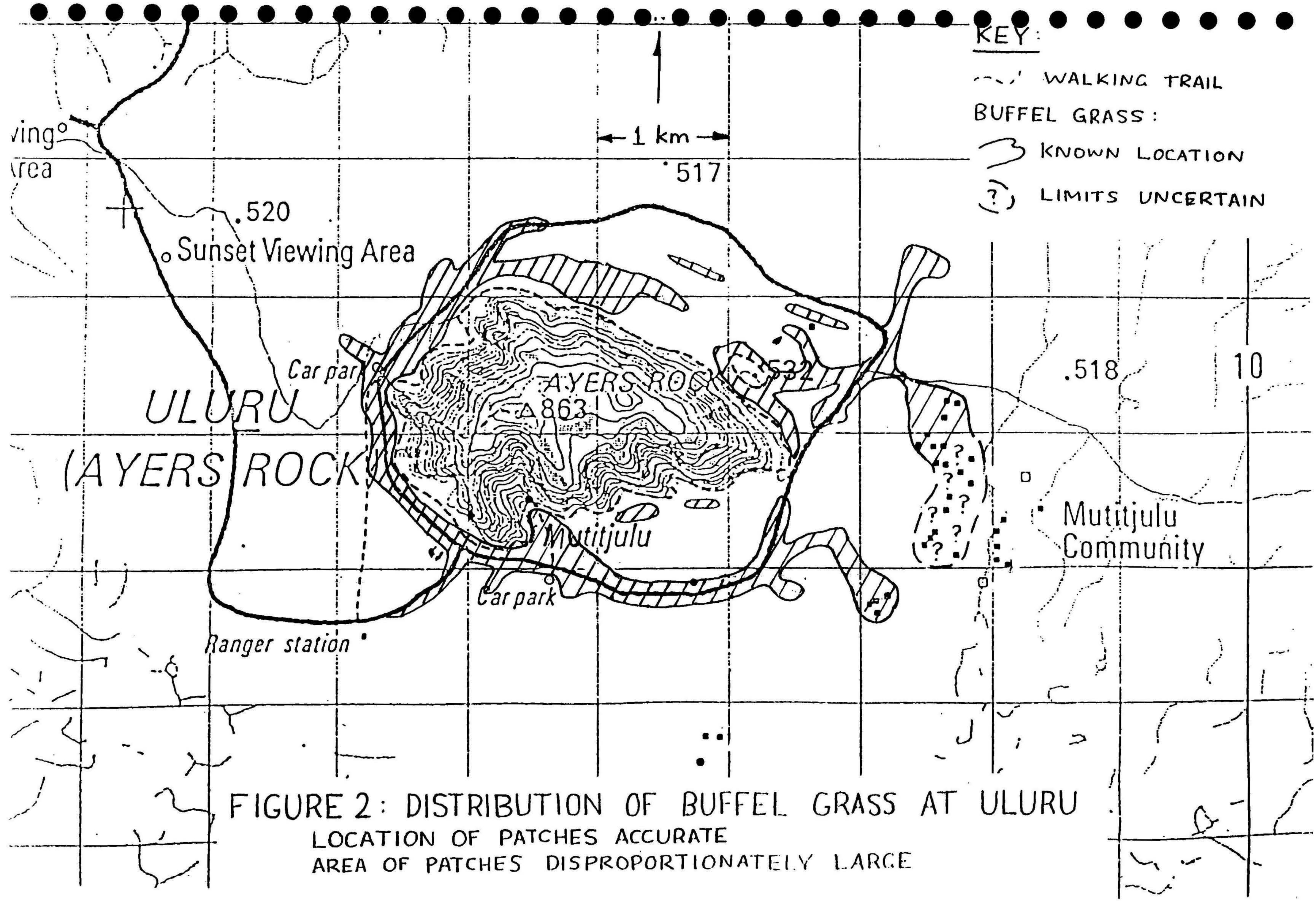


FIGURE 2: DISTRIBUTION OF BUFFEL GRASS AT ULURU
LOCATION OF PATCHES ACCURATE
AREA OF PATCHES DISPROPORTIONATELY LARGE

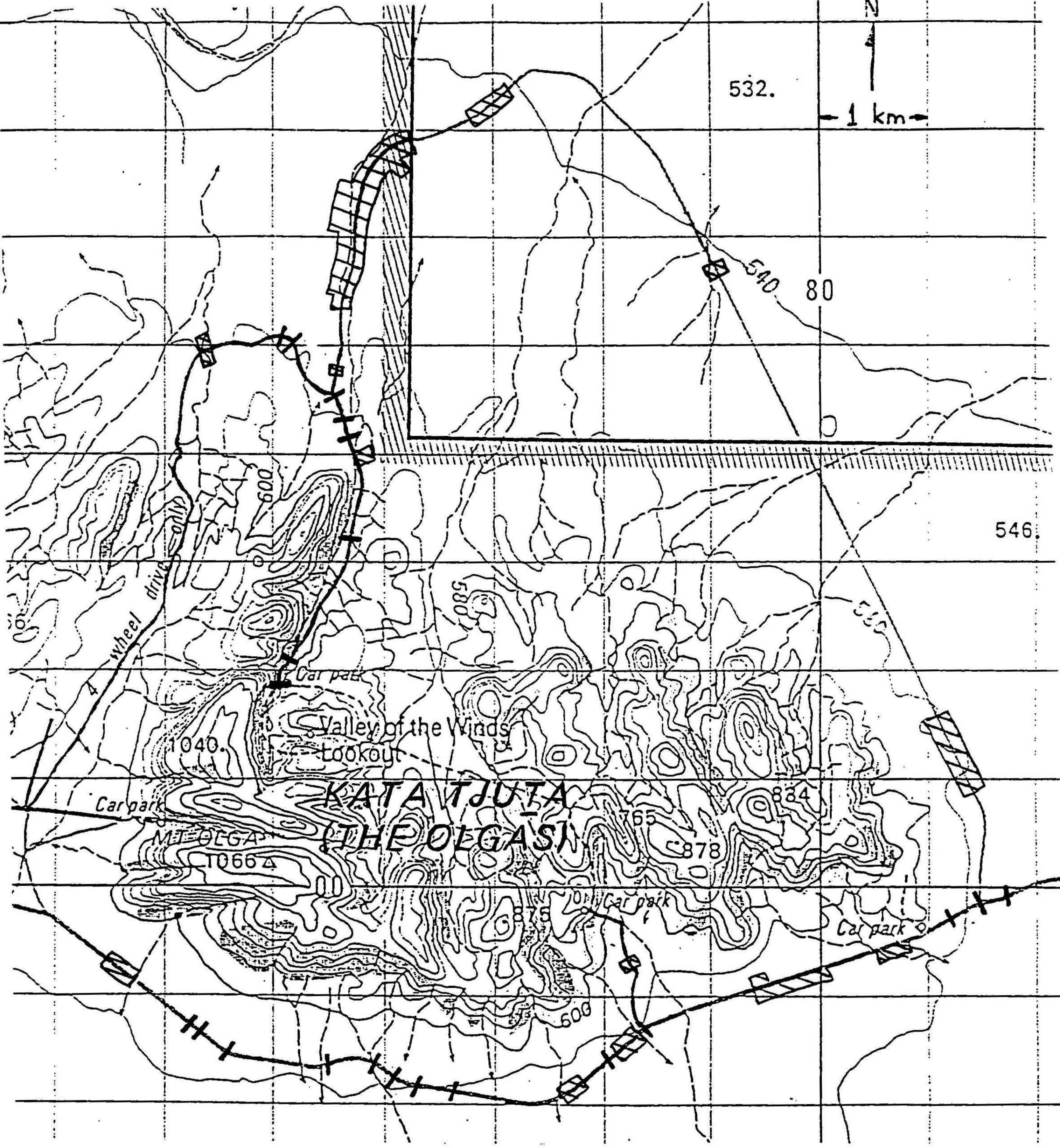


FIGURE 3 : DISTRIBUTION OF BUFFEL GRASS AT KATA TJUTA
LOCATION OF PATCHES ACCURATE
AREA OF PATCHES DISPROPORTIONATELY LARGE

KEY:

BUFFEL GRASS:

PATCH

POINT LOCATION

Discussion

Buffel Grass at Uluru National Park is mainly restricted to and particularly vigorous in better watered disturbed or degraded sites such as eroded walkways, roadsides or old, ripped access roads. This is evident around Uluru where the densest cover was observed at Mutitjula, the area at the base of "the climb", the ripped old entry road, the demolished motel sites and the old ring road route. Deep rooted Buffel Grass requires light textured loam to clay loam soils where water supply is of long duration. For this reason it is unlikely to to be found in well-drained sand areas.

The spread of Buffel Grass from its original location at Mutitjula has been by unplanned seed dispersal. Dispersal of seed is via wind, water or mechanical means by way of human activity. Road maintenance and vehicle traffic are a major component of this mechanical transportation into uninfested areas. This explains the probable introduction of the species into Kata Tjuta. Buffel Grass was not noted along the old Uluru–Kata Tjuta route probably as soils are too sandy. Water transportation of seed is evident at the base of Uluru where Buffel Grass follows drainage lines and can be expected to spread further along these lines. This suggests that Buffel Grass may eventually extend into the whole of the drainage depression areas of scattered Bloodwood on light textured alluvial soils around Uluru. It is unlikely to extend into the red earth soils of the Mulga depression community south of Mutitjula or into the slightly higher ground north of Uluru due to run-off drainage. In addition, established stable plant communities are not readily susceptible to infestation by Buffel Grass.

Three species of *Cenchrus* are present at both Uluru and Kata Tjuta, namely *C. ciliaris* (Buffer Grass), *C. setigerus* (Birdwood Grass) and *C. echinatus* (Mossman River Grass) but *Cenchrus ciliaris* dominates. Mossman River Grass is a registered weed (Class B) and has been collected from Mutitjula Community and at Kata Tjuta. This species is restricted to more continuously watered situations.

Prospects for Control

Any attempt to suppress the current distribution of Buffel Grass and control its further spread would require coordinated efforts and long term commitment. The latter needs to be strongly stressed due to the long survival of the seed store. Buffel Grass seed germinates best in its second year of storage and is known to be viable after 4 to 5 years. Total eradication of this introduced species may not be possible but limiting the extent of future encroachment and a reduction in density may be achievable.

Further consideration of and a more detailed investigation of the options and their economics needs to be undertaken before any course of action is taken. The question of the undesir ability or otherwise of the presence of Buffel Grass needs to be addressed. Buffel Grass was planted to control erosion. Even though its presence in a National Park is not desirable it does fulfil a useful role. Before Buffel Grass is removed a replacement native species or set of species will need to be found.

If it is determined that a course of action is required methods of control would include mechanical or chemical means, species replacement or a combination of all. Possible options include:

1) replacement with competitive native species. This would require trials to determine the most likely species and what inhibition–enhancement treatments would be useful. Inhibition of Buffel Grass by physical removal may enhance establishment of native species. Spraying individual plants or areas with a suitable weedicide such as "Zero" or "Roundup" to inhibit growth at appropriate times of the year may allow native plants to gain a competitive advantage. The effect of any weedicide upon desirable native species would be integral to deciding upon this option. The primary consideration must be that Buffel Grass is replaced by native species and not just removed leaving a void.

2) control of seeding by slashing and mowing accessible areas **before** seed set to prevent seed dispersal. Our experience suggests that burning would not be useful as Buffel Grass tends to survive fire better than native species. In addition, it would burn best only after it has seeded and dried off.

3) altering road maintenance practices so that any roadside grading would be towards the main area of Buffel Grass rather than spreading seed away from the centre of distribution.

4) restricting the use or removal of top-soil from Buffel Grass areas.

Assessment of the availability of biological controls and the time and costs needed to implement them are major factors mitigating against their consideration. There would also be considerable opposition from the pastoral community to the biological control of Buffel Grass.

The scattered natured of Buffel Grass at Kata Tjuta suggests it would be easier to control there and perhaps should be before it becomes well and widely established.

Conclusions

The distribution of Buffel Grass at Uluru National Park at December 1990 has been mapped as accurately as available air photos and rapid ground survey will permit. Air photos at 1:4000 enable this to be accurate for Uluru but the mapped distribution at Kata Tjuta should be viewed as indicative only. A cursory discussion of control possibilities is presented.

Monitoring revegetation of the Old Olgas Road in Uluru–KataTjuta National Park

1992 to 1995

Uluru–Kata Tjuta National Park

W.A. Low, E.C. Foster, W.R. Dobbie, N. de Preu, R. Dunlop, S.R. Eldridge, V. Moss and J. Cook of (or formerly of)[1]

[1] W. A. Low Ecological Services, P. O. Box 3130, Alice Springs, NT 0871. August, 1997.

Introduction

The following report is a summary extract from reports in 1992, 1994a, 1994b, 1995a and 1995b on the rehabilitation of the Old Olga Road.

Rehabilitation of the old Olgas road was completed at the end of 1991.

The old dirt road from Uluru to Kata Tjuta (the Olgas) was in use from the early 1960's. High traffic use, particularly from the late 1970's created a notoriously corrugated road surface. Frequent grading was the only form of road maintenance used and this led to a deepening of the road below the surrounding natural surface level. The road incised a variety of land systems including plains with dense mulga over perennial grasses, calcareous and alluvial soils with acacia shrublands, and spinifex sandplains and dunefields. It intersected and diverted several creek lines around the south side of Kata Tjuta and disrupted surface sheet flow drainage on red earth plains.

A new, sealed road was constructed in more resilient sand dune country to the south and the old road closed to the public in 1991. Rehabilitation works began soon after and were to follow guidelines of Griffin and Nelson (1989). The usually sunken road was deep ripped and filled with sand and windrow soil to approximate natural surface contours. The work was completed near the end of 1991.

Monitoring

An integral component of the rehabilitation process was the monitoring of plant succession and erosion state of the road to ensure success. The sequence of plant succession was monitored at fifteen paired sites within 4 major and 2 minor land units and nine additional unpaired sites in 2 additional minor land units at eight creek crossings. In addition a revegetation trial on the Old Olga Gorge Road was selected to monitor the benefits of brush covering of the road. Long term monitoring sites were established and measured in 1992, rephotographed in 1993, remeasured in 1994 and rephotographed in 1995. Photographic records of monitored sites are in a photo album, one copy held at the Park and one copy held by the consultant. The data are collected using a dry-weight rank method for ground cover, 2m transect for juvenile counts and Bitterlicht gauge for mature trees and shrubs. Reports and data are on data sheets and computer discs in Word and Excel formats.

Methods

Rehabilitation methods used

In some areas the old road was deep ripped with 1 m tines with a bulldozer or in some areas with a grader, to break up the severely compacted surface before fill was added. Some areas were also deep ripped after the fill was added. Ripping helped to partially mix soil from the old road surface with the imported fill material.

In most areas windrow soil from the edge of the road was graded into the ripped road surface, then imported sand placed on top to fill any remaining deficit where needed. The windrows contained a bank of seeds and adventitious root material which have aided rapid regeneration of the former road. It was a mistake to not grade the windrow soil over the fill rather than burying it under the fill.

Bringing sand fill in from another area of the Park also meant the introduction of some plant seeds and roots atypical of some of the plant communities in which they were deposited. The sand fill was collected near the western boundary of the Park, about 3.6km west of the Docker River road junction on the south side of the road. The lateritic sand was from a soft spinifex sand dune/plain community.

Following filling and ripping, the rehabilitated surface was generally levelled to approximate the natural surrounds, and left sufficiently rough to capture wind-blown seed and small pockets of water. Dead brush was laid on a few localised sections of the track to retard wind erosion and help trap seeds.

The rehabilitated road surface was not artificially seeded. It was considered that wind-blown seed from adjacent areas would supply the narrow disturbed zone with sufficient seed for colonisation. In addition, heavy rains should promote suckering of many species into the rehabilitated area. Seed was imported with the fill brought in from the sand quarry.

Selected large trees and shrubs established in the windrows were marked and not disturbed by machinery during the rehabilitation process.

Vegetation Analysis

Total biomass and the proportional composition of the herbage was assessed using Dry Weight Rank and Comparative Yield Score methods. The density of juvenile woody plants was measured by walking 2000 m long 2m wide belt transects within each site. The percent cover of mature trees and shrubs was measured using the Bitterlich gauge. A thorough plant species list was obtained at all sites.

Erosion was visually assessed and documented.

Results

Mechanically, the rehabilitation was a very good job with some minor exceptions. Much of the 32 km road should return to a quality similar to the adjacent communities. Vegetation has establishing along most of the rehabilitated road surface, although there are particular areas, usually where subsoil lateritic sands or clay rich soils provides the surface cover, where the rate of revegetation has been poor.

One exception in some parts of the road are where the top soil from the road verge was graded into the road hollow before the lateritic sand was placed to top up the road hollows. This has been partly overcome by subsequent deep ripping.

Monitoring was intended to direct further management of the reclaimed road to prevent erosion and weed takeover and assist a return to an acceptable state. On the basis of 4 years observations minor additional management work has been recommended to ensure continued successful rehabilitation of the old Olgas road.

Erosion is evident in a few locations associated with former creek crossings and sheetflow runoff on the south and southeast side of Kata Tjuṯa. Appropriate measures to repair and prevent further erosion are required to disperse the water rather than concentrate it in gullies in the road. Most erosion associated with the rehabilitated road is of minor severity.

Some of the existing pond banks need to be lengthened so they effectively direct water off the old road. Additional pond banks are required to inhibit water channelling and gullying on both the old Olgas and the Valley of the Winds roads.

Sticks and brush laid on the rehabilitated surface helped to promote vegetation recovery in several areas, prompting recommendations to lay more ground litter on areas slow to revegetate and on newly constructed pond banks. Initial differences in shrub vs no shrub treatment was used were striking, but after four years the differences are not so apparent.

Some colonising plant species have displayed a weedy habit by proliferating in certain places, but generally weed invasion has not been the problem expected. Ruby Dock, *Rumex vesicarius*, has only been a minor component of some areas around Kata Tjuṯa. Changes in plant succession should be revealed by continuing quantitative monitoring.

Discussion and conclusions

Griffin and Nelson (1989) could find no studies of rehabilitation of old roads to base their recommendations for rehabilitation on. Consequently it was useful to monitor colonisation and the sequence of plant succession in the rehabilitated road and relate it to the techniques used for rehabilitation.

Philosophically and ecologically, additional thought should have been put into source of fill material. Lateritic sand was brought in from the west edge of the park to fill road hollows and has resulted in sand being placed where the adjacent parent soils are different. Plants such as *Triodia pungens, Rulingia loxophylla, Alyogyne pinoniana* and *Thryptomene* have established amidst land types where they don't naturally occur. This is particularly evident where parts of the road along the south side of Kata Tjuṯa pass through calcareous alluvial surroundings. The discordance of the vegetation in road and adjacent areas will likely remain as a distinguishable band for a very long time.

The rehabilitation work was generally well done. However, bringing in red lateritic sand from a Soft Spinifex sand duneplain community has resulted in plants such as *Thryptomene maisonneuvii, Alyogyne pinoniana, Plectrachne schinzii* and *Triodia pungens* establishing where they wouldn't normally occur. This is particularly noticeable amongst the broad expanse of the limestone soils along the south of Kata Tjuṯa and in some mulga/red earth soil areas. Other plants transplanted in this manner include *Calandrinia spp.* and *Codonocarpus cotinifolius*.

The dark red clayey sand which was imported from near the parks western boundary is slightly less acidic than the dark red clayey sand beside the old road, pH 6.0 compared with pH 5.5. Plant regrowth was poor where deep quarried sand (up to 3 m below ground level) was used to fill the road bed. This was initially thought to be a problem, but the results of the growth in 1993, 1994 and 1995 suggest it is not a serious problem as many of the areas which were bare in '92 had become vegetated.

Vegetation is establishing along most of the length of the reclaimed road surface, although some areas are responding better than others. Pioneering regrowth was impressive where erosion control banks had ponded water. Such areas will provide valuable seed sources for their surrounds. Griffin and Nelson (1989) warn against such concentrations of water and the likely dense patches of shrubs which will establish. We do not see that as a problem as it occurs in natural areas as well.

Regrowth was initially poor near the former junction to Olga Gorge, particularly along the centre of the rehabilitated road. There was also an early difference along the old Olga Gorge road which had better vegetation growth where shrub litter was laid on the surface. However, there was less noticeable difference in vegetation establishment by 1993 and 1995.

Salsola kali and *Rumex vesicarius* have both displayed a weedy habit and were commonly the only colonisers in the first year in areas where recovery is slow. *R. vesicarius* was prominent in the vicinity of Kata Tjuṯa but not along the remainder of the old road. Revegetation on restored areas and recently burnt areas was very similar, the only notable difference being the presence of *Dicrastylis sp.* on the rehabilitated road surface and its absence on burnt country. *Dicrastylis sp.* was uncommon in undisturbed areas. In '93 the presence of *Rumex* was not as prominent, perhaps due to the winter rains being a bit late for it. These species are pioneering plants and as the road gets established and is not disturbed, they will be mostly replaced.

Erosion is evident in only a few locations where water channels along the road. Minor erosion gullies are present, chiefly south of Kata Tjuṯa where pondbanking is the recommended form of erosion control. Minor gullying is developing along the old road at some locations. Further pond banks are needed (eg. at the junction of the old Valley of the Winds road) and several existing banks should be extended northwards to disperse run-off into adjacent communities. Some cross road erosion is evident at creek crossings or below pond banks.

Several earth banks would have been more effective if they were made at right angles to the direction of drainage flow instead of at right angles to the road. Several pond banks should be extended to exit on a level contour.

A sign stating that the road is only to be used for essential purposes should be installed back from the Highway to advise Rangers, Aṉangu and unauthorised travellers that the road is not for regular use. Signs would be useful at other access points to the road as well.

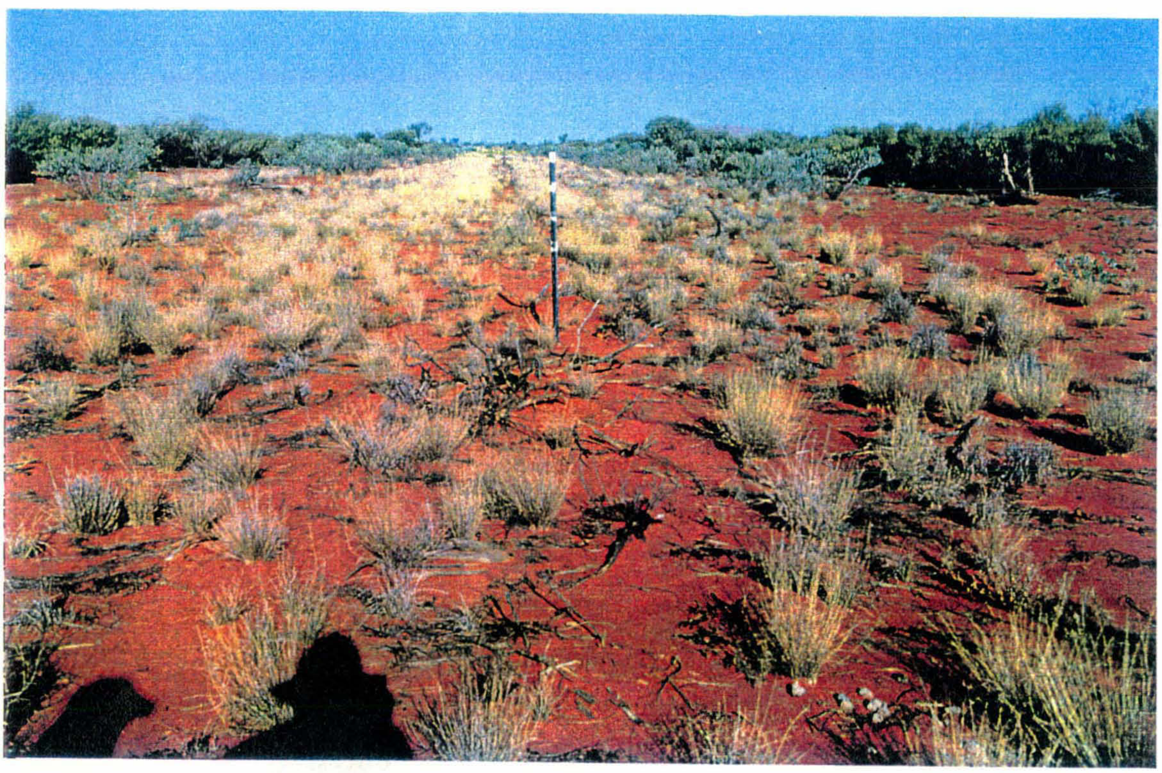
The old road from the old car park adjacent to where the old and the new roads juxtapose at 2.3 km along the Kata Tjuṯa road back to the departure from the Uluṟu Road near the Entry Station could be made into a nature walk with plants labelled along the way. The strip includes an interesting variety of *Acacia* species, several different forms of Mulga and a good array of sand dune and sand plain plant species. The story of the old Olgas road rehabilitation could be an interesting part of the nature trail.

The Valley of the Winds road around Kata Tjuṯa was given a token rehabilitation by grading the mounds along the verge of the road back in to the road gully. This has not stopped water from channelling along the road, particularly in the north-east quadrant and the north western part of the northern quadrant. One purpose of road rehabilitation was to re-establish surface water sheet flow runoff. It is recommended that road rehabilitation of the Kata Tjuṯa Road be carried out using a series of pond banks along the road at intervals as close as economics or fill availability dictate, but frequently enough to assist in re-establishing sheet flooding across the road. Upslope sheet erosion will eventually provide sufficient silt to fill in the intervening gaps.

Plates

Plate 1. Old Olga Road before rehabilitation. Windrows on the road verge were over a metre higher than the road in places. The old road was initially deep ripped before building up the level with lateritic earthy sands and grading the seed rich windrows along the verge back over the surface of the road.

Plate 2. The road in a similar area nearly 4 years after rehabilitation shows the perennial grass Woollybutt, *Eragrostis eriopoda*, well established. In this Mulga swale, *Acacia aneura*, is slow to reestablish but Colony Wattle, *Acacia murrayana*, which grows well in disturbed areas is moving in quickly.



References

Griffin, G. F. & Nelson, D. J., 1989. Environmental guidelines for the rehabilitation of the existing Kata Tjuta Road, CSIRO, Division of Wildlife and Ecology, Alice Springs. Report to Australian National Parks and Wildlife Service.

Foster, E. & Low, W.A., 1992. Monitoring revegetation of the old Olgas Road in Uluru National Park; Introduction and site establishment. Report to Uluru National Park, Australian Nature Conservation Agency, Yulara, Northern Territory.

Low, W.A., Dobbie, W.R., Foster, E. C., dePreu, N. & Dunlop, R., 1994a. Monitoring revegetation of the old Olgas Road in Uluru National Park; 1992 and 1993. Report to Uluru National Park, Australian Nature Conservation Agency, Yulara, Northern Territory.

Low, W.A. & Eldridge, S.R., 1994b. Monitoring revegetation of the old Olgas Road in Uluru National Park; 1994 annual survey; Preliminary findings, observations and recommendations. Report to Uluru National Park, Australian Nature Conservation Agency, Yulara, Northern Territory.

Low, W.A., Eldridge, S.R. & Moss, V.M., 1995a. Monitoring revegetation of the old Olgas Road in Uluru National Park. Report to Uluru National Park, Australian Nature Conservation Agency, Yulara, Northern Territory.

Low, W.A. & Cook, J., 1995b. Monitoring revegetation of the old Olgas Road in Uluru National Park; 1995 annual survey. Report to Uluru National Park, Australian Nature Conservation Agency, Yulara, Northern Territory.

Saxon, E. C., (editor), 1984. Anticipating the inevitable: a patch burn strategy for fire management at Uluru (Ayers Rock-Mt Olga) National Park CSIRO, Melbourne.

Uluṟu–Kata Tjuṯa National Park Rabbit Control Project

A summary of the vegetation monitoring of rabbit warrens at Uluṟu–Kata Tjuṯa National Park, 1989-1995.

W.A. Low, E.C. Foster, W. R. Dobbie, N. de Preu, A. Grattidge, S.R. Eldridge, J. Cook and C. Miller of (or formerly of)[1]

[1] W.A. Low Ecological Services, P.O. Box 3130, Alice Springs, N.T. 0871. August 1997.

Introduction

Since its release in Australia, the European rabbit (*Oryctolagus cuniculus*) has caused profound changes to the flora and fauna (Foran, 1986). The presence of rabbits has contributed to the disappearance of many native mammals from central Australia through direct competition (Low, 1983 and Morton, 1990). It has also been found that although rabbits do not necessarily degrade the herbage layer they restrict its development response to improving seasonal conditions and limits regeneration of trees and shrubs by removal of seedlings (Foran, 1986).

The control of rabbits at Uluṟu–Kata Tjuṯa National Park began in 1989 with the ripping of 344 warrens and has continued with annual monitoring and fumigation. The majority of warrens are located at Kata Tjuṯa (Low and Dobbie, 1989). Since ripping in 1989 herbage and shrub and tree species have been monitored annually for nine ripped warrens (2 at Uluṟu and 7 at Kata Tjuṯa) to assess vegetation response to localised rabbit removal.

Study of vegetation recovery response to removal of rabbit in arid rangelands has established that season and amount of rainfall is the most dominant influence on vegetation response followed by several soil factors and rabbit density (Foran, 1986). The aim of this project is to determine how long the vegetation affected by rabbit grazing will take to return to a similar state to that of the immediate surrounds. This project also provides an extensive vegetation data base for the Park. Because rainfall has such a dominating influence it is necessary to monitor vegetation change over a number of years and through a variety of rainfall events.

Vegetative data, including biomass, species composition and relative abundance was collected in all years except 1993, 1995 and 1996, where photographic records only were collected. Detailed vegetation monitoring was not carried out in 1995 or 1996 as insufficient rain fell to stimulate a significant vegetation response. Monitoring was not carried out in 1993 due to a lack of funds. Photographic records for 1996 are not complete.

The percent composition and frequency of herbaceous species from the first three years of monitoring (1989-1991) were examined using a pattern analysis program, PATN, to hypothesise relationships between sites and subsites and a series of environmental parameters (Low and Foster, 1992).

Methods

Herbage:

'Pasture Species Composition' and 'Frequency' were determined using the Dry Weight Rank/Comparative Yield Score method. Techniques are detailed in the 'Centralian Range Assessment Program' by Bastin (1989), NT Department of Primary Industries and Fisheries.

Assessment sites are centred on a ripped warren and consist of 4 subsites which radiate from the centre to the site edge. Subsite A is at 0m, Subsite B is at 20m, Subsite C is at 50m and Subsite D is at 100m. The outer subsites serve as a control or baseline to monitor patterns of vegetation change on the ripped warrens. 25 quadrats are measured per subsite (100 quadrats per site).

Attempts were made to select all subsites within matched vegetation type, soil type and position in the landscape in an effort to reduce differences in vegetation recovery attributable to locality differences. Each warren centre is marked with a steel dropper from which compass bearings and distances out from the warren are taken.

<u>Woodies (trees/shrubs):</u>
a) A 'Juvenile Stick' is used to measure the density of juvenile shrubs and trees by walking a 10 x 2m wide belt transect across the site area. All sites are 200m x 200m (0.4 ha.). Transects sample 10% of the overall site area.
b) The Bitterlich gauge is used to measure aerial cover of mature trees and shrubs.

<u>Photopoints:</u>
All sites are photographed using a 50mm lens setting for the subsites and either a 35mm or 50mm lens setting for the overview shots from photopoints.

Results

Results after the first three years of monitoring were superb on nearly all sites and subsites, especially the warren subsite, subsite A. Most of this regrowth can be attributed to the heavy rainfalls in 1989 and the timing of rainfall in the following two years. However, the below average rainfall and the prolonged dry winters in 1994 and 1995 have seen a general decrease in herbage biomass. In 1994 the rabbit warren subsites at all 9 sites had mostly reverted to bare ground with considerable use by kangaroos and camels. It has been a general trend that the subsites located at distances 20m, 50m and 100m from the warren show progressive differences in species composition, diversity and biomass with increasing distance from the warren but the warrens themselves remain distinct from the overall vegetation pattern of the particular site.

Canopy cover of mature trees and shrubs has generally remained relatively constant over the six years of detailed monitoring, with some sites recording an increase or decrease at various times. The density of juvenile trees and shrubs has also remained relatively constant with only 2 sites increasing in 1992 and only one site increasing in 1994.

The reinvasion of rabbits at several sites has been a consistent problem and this certainly has an impact on the vegetation. However, the level of rabbit activity has continued to decline each year since ripping in 1989 due to fumigation efforts and dry conditions.

The PATN analysis done on the data from 1989-1991 was not able to conclusively determine any patterns in vegetation recovery due to the small amount of data used. However, it was able to provide an indication of the direction of vegetation change. The analysis did confirm for the majority of sites the original assumption that the ripped warren site is environmentally and compositionally dissimilar to the remainder of the study site. Ordination showed that the warren sites, subsite A, are dissimilar in all sites except 5 and 7. It is recommended that several more years of data collection is required before analysis is performed again.

Discussion

There are many difficulties in accurately sampling arid land vegetation which is spatially and temporally patchy. Inherent in the data for each year of monitoring are sampling errors and inconsistencies due to differences between observers between years. Thus any trends in vegetation change indicated in the reports produced are at a broad scale.

Grazing Pressure on Herbaceous Vegetation:
Although it is difficult to quantify the grazing pressure that exists on the warren study sites it is possible to comment on the change in level of rabbit grazing.

An evaluation of the Rabbit Control project for the Park indicated that since ripping in 1989 the program has achieved a considerable reduction in rabbit numbers and hence rabbit grazing pressure at both monoliths but particularly Uluru (Low, *et al.*, 1995). At the time of vegetation monitoring in 1994 very few sites had been recolonised and Site 6 warren was entirely inactive for the first time since 1989. Plates 1 and 2 show the impact reinvasion of rabbits has had on the warren subsites. A number of sites are continually heavily grazed by kangaroos and in some cases camels. It seems that kangaroo use is replacing rabbit grazing impact on herbaceous vegetation.

Herbaceous Vegetation:
Results of the vegetation monitoring at Uluru–Kata Tjuta National Park reinforce the dominating influence of rainfall on changes in plant composition. Rainfall since the start of the project six years ago, with the exception of 1989 and 1993, has been below average. Early results were superb due to the high level of rainfall in 1989, the good summer rains in 1990 and some winter rain in 1991. However, due to the uncommonly dry winters and dry years preceding 1994 and 1995, results for these years have been extremely poor with few species growing well on any sites. The distribution of rains during 1993 and 1994 caused a change in species composition at most sites. The concentration of rainfalls in the early part of the year for 1994 and 1995 led to a marked reduction in winter germinating forbs and any summer perennials that may have germinated were dead by the time of monitoring.

Generally the outer subsites show a progressive increase in species diversity and biomass with increasing distance from the ripped warren. The disturbance such as soil turnover, due to warren construction and the impact of ripping, has altered the soil qualities of the warren site from that of the surrounding area. The ripped warren is likely to remain distinct from the surrounds for up to 50 years, as many relict mallee fowl "warrens" in the area are at least this age and are still discrete from the surrounds.

Shrubs and Trees:
Juvenile shrub and tree density has remained relatively constant over the 6 years of monitoring with various fluctuations at several sites at different times. Site 7 in 1994 showed a marked increase in the number of juvenile shrubs and trees.

Canopy cover of mature trees and shrubs has also remained relatively constant since monitoring began in 1989, however, 1994 saw a general increase for all sites. In interpreting the results it was applied that there must be a difference of 10% between years for a change to be acknowledged. This is to account for sampling errors and variation between different observers (Friedel, 1987). Variation in canopy cover between years may also be explained by slight changes in sampling sites, growth stage of the plant and browsing by camels.

Conclusions

Reports written for each year of the vegetation monitoring do not attempt to extract any conclusive patterns in vegetation change but simply describe the state of vegetation and draw some obvious comparisons between years. Patterns of vegetation change involved in the revegetation process will only be detected by continuing the program of detailed pattern analysis. After the initial PATN analysis it was concluded that a larger data base was required to determine if patterns of change are forming. It is hoped that six years of data will be adequate to determine more definite patterns in revegetation of ripped warrens and their immediate surrounds and allow assessment of the usefulness of the project.

This study examines the beginning of a long term process of rehabilitation and revegetation but also has the added service of measuring fluctuations occurring in the vegetation for the Park over time and examines associations with dominating influences. This information is useful for general Park management.

Recommendations

1. Monitoring of vegetation for ripped warrens should continue so as to build a data set sufficiently large for analysis of herbaceous, shrub and tree data in relation to rainfall, soil type and grazing impact.

2. Monitoring and control of rabbits is a continuing requirement for Uluṟu–Kata Tjuṯa National Park.

****

Plate 1: An overview of Site 6 in 1990 showing the bare ground in the centre of the site where the warren exists. Although most warren sites revegetated well after ripping, this site was the exception as rabbits continued to reinvade until 1993 preventing any substantial regrowth of vegetation (L90/9/2-8A).

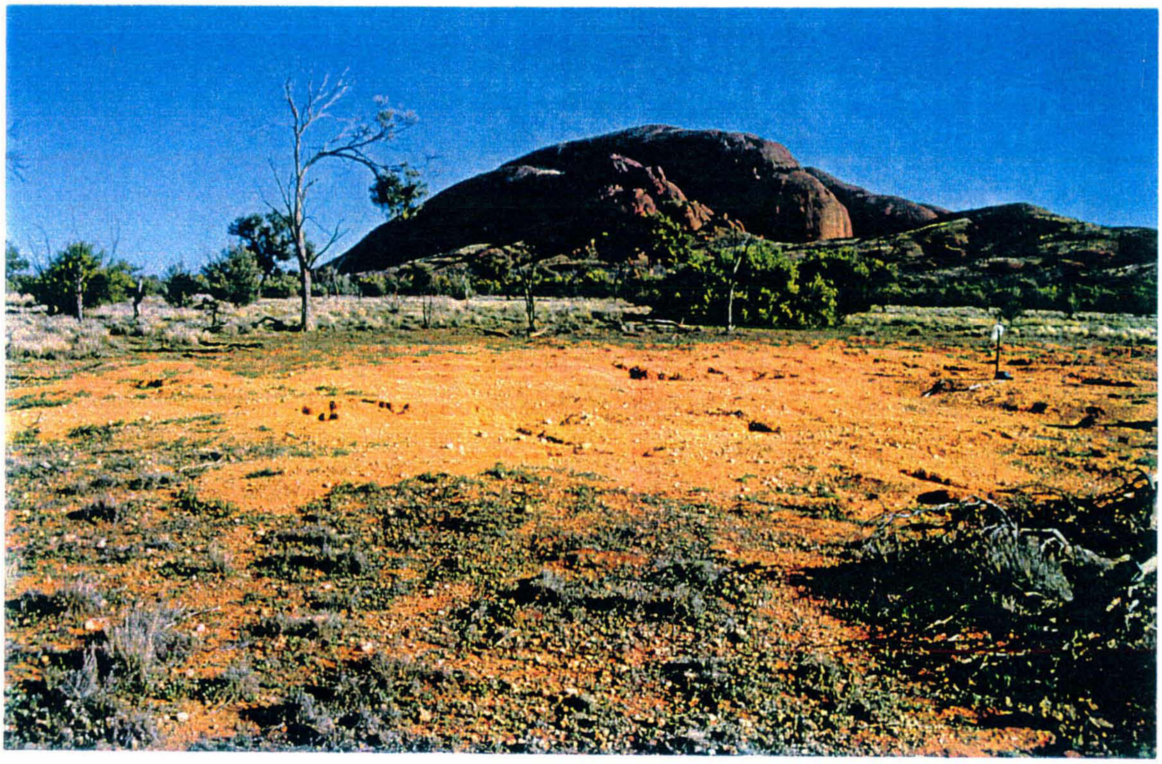
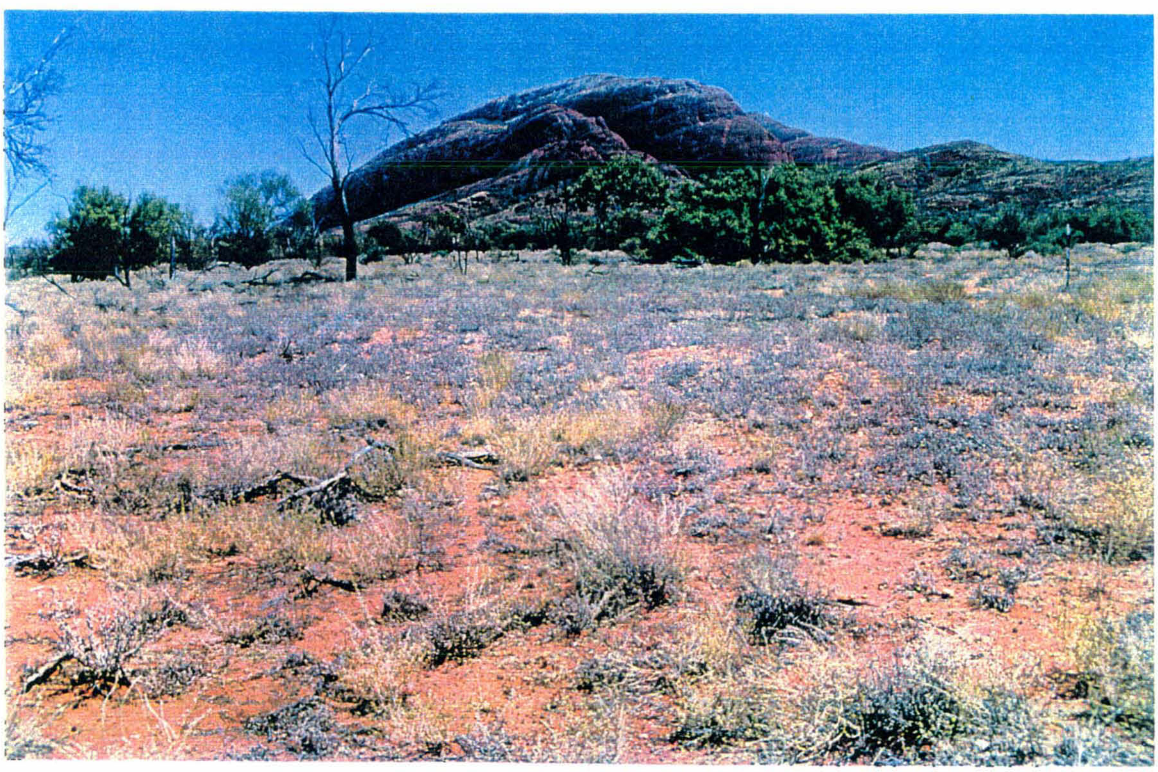


Plate 2: An overview of Site 6 in 1994 the first time since 1989 that the warren was entirely inactive. The relatively constant rains of 1993 and the early rains in 1994 would have stimulated this revegetation, however, the local eradication of rabbits from this sight has enabled the vegetation to persist (L94/10/7-19).



References

Bastin, G., 1989. Centralian Range Assessment Program. Technical Bulletin No. 151, Department of Primary Industries and Fisheries, Alice Springs.

Foran, B.D. 1986. The impact of rabbits and cattle on arid calcareous shrubby grassland in central Australia. *Vegetatio*. 66: 49-59.

Friedel, M.H. 1987. Evaluation of Methods for Monitoring Sparse Patterned Vegetation in Arid Rangelands. II. Trees and Shrubs. *Journal of Environ. Manag*. 25: 309-318.

Low, W.A. 1983. *Rabbit Biology and Control in Arid and Semi Arid Lands.* Proc. of a Review, Nov 1982. Conservation Commission of the Northern Territory, Alice Springs.

Low, W.A. and Dobbie, W. 1989. *Rabbit Warren Ripping Program at Uluru-Kata Tjuta National Park*: Various reports from March to May for ANCA, Uluru- Kata Tjuta National Park.

Low, W.A. and Foster, E. 1992. Uluru National Park Rabbit Control Project: *Initial analysis of herbage recovery on selected rabbit warrens 1989-1991 data.* Unpublished report to ANCA.

Low, W. A., Grattidge, A. and Eldridge, S.R. 1995. Uluru-Kata Tjuta National Park Rabbit Control Project: *Vegetation Monitoring of Ripped Warrens: Year 6, November 1994.* Unpublished report for ANCA.

Morton, S.R. 1990. The Impact of European Settlement on the Vertebrate Animals of Arid Australia: a Conceptual Model. *Proc. Ecol. Soc. of Aust.* 16: 201-213.

TJAKURA *Egernia kintorei* The Desert Skink

Steve McAlpin[1]

[1] 75 Albert Street, Cranbrook, Queensland 4814.

Introduction

Egernia kintorei is a large, robust skink that constructs complex multi-entranced burrow systems on desert sandplains and dunefield swales. These burrow systems are characterised by the presence of one or more large, external latrines adjacent to a burrow entrance. *E. kintorei* has been recorded from numerous widely scattered localities over a vast area of inland Western Australia, western Northern Territory and north-western South Australia. No museum specimens have been collected from South Australia since 1934 or from Western Australia since 1964. *Egernia kintorei* was listed as vulnerable in the Action Plan for Reptiles (Cogger et al 1993). It was included in the list of highest priority species at Uluṟu (Reid et al 1993, Reid and Hobbs 1996). Uluṟu–Kata Tjuṯa National Park is the only National Park in Australia known to contain *E. kintorei.* A twelve month study has so far been undertaken of *Egernia kintorei* at Uluṟu. During this study I documented the distribution, abundance, habitat requirements, status and basic biology and ecology of *E. kintorei,* determined existing and potential threats and advised on appropriate conservation strategies (McAlpin 1997). In association with A<u>n</u>angu and Park staff I also documented traditional ecological knowledge associated with Tjakura.

Traditional significance

Tjakura is an important lizard to A<u>n</u>angu in the Western Deserts region. It is a significant Tjukurpa animal and is also a highly esteemed food item. It is very well known to older people throughout the region. Most A<u>n</u>angu informants consider Tjakura to be less common and widespread than in former times. It is said to commonly share its burrow system with other significant sandplain animals: murtja - the mulgara; and kuniya - the woma python, though neither of these are said to prey upon tjakura. A<u>n</u>angu report tjakura historically to have been found around the Mutitjulu community and also from the now well known localities of the borefield and the sunset viewing areas of the Park.

Surveys

Two methods were initially used to determine the distribution, abundance status and habitat requirements of *E. kintorei* across the Park. On A<u>n</u>angu advice only sandplain, dunefield swales and the margins where sandplain meets mulga-grove were analysed. Much of the direction of the initial field survey work was based upon information provided by A<u>n</u>angu informants.

1) Long transect walks were undertaken through areas of potential habitat and any *E. kintorei* burrows were mapped with the aid of a GPS.

2) Relevant habitat in the Park was stratified into 20 categories using two landform

types - i) sandplain and ii) dunefield; two vegetation types - i) soft spinifex, *Triodia pungens* and ii) hard spinifex, *Triodia basedowi*; and five fire ages i) pre 1976, ii) 1976-79, iii)1982-85, iv)1986-89 and v) 1990-94.

A further category of 1976 sandplain-mulga grove ecotone was included in the survey. A map stratifying the Park to these categories was produced for me by the Parks and Wildlife Commission. Two stratifications were not represented in the Park and could not be surveyed. Ten 1 hectare plots from each of the remaining 19 stratifications were randomly selected across the Park, plotted onto the map and then intensively surveyed for the presence of *E. kintorei*. Vegetation for each site was also mapped and categorised and the percentages of tree cover, shrub cover, grass cover and bare ground was estimated and recorded for each plot.

Following the broad scale survey an area on the borefield that was relatively densely populated was established for an intensive survey on aspects of biology and ecology. Forty five burrows in an area of about 20ha were marked, mapped and monitored. These burrow systems contained a total of about 90 lizards. Using a combination of Elliot and pit traps 37 lizards were captured and PIT tagged.

Habitat and status

E. kintorei were found in both sandplain and dunefield swale habitats and in areas of both soft and hard spinifex. The sandplain of the borefield is vegetated by hard spinifex with a very sparse shrub layer. The sunset viewing area, vegetated by soft spinifex, is mapped as sandplain although the ground is sloping and is topped by dunes. The area has a well developed shrub layer and in this respect closely resembles dunefield swales. Sixteen of the 190 sites contained one or more burrow systems. Of the 100 dunefield sites surveyed, four contained burrow systems. Of 90 sandplain sites surveyed, 11 contained burrow systems. Eighty of the 190 sites were burnt within the past 10 years and 12 of these 80 sites contained burrows. Four of the remaining 110 sites burnt before 1986 contained burrows. Sites burnt within the past 10 years are characterised by extensive bare ground, averaging 65%, with small to medium sized vigorous spinifex clumps constituting about 25% and a shrub layer varying from absent to well developed and up to 20%.

The distribution of *E. kintorei* across the Park is far from predictable. Very extensive areas of the Park that appear to offer ideal habitat are either unoccupied or are extremely sparsely occupied. Relatively large populations occur on the borefield and at sunset viewing area with much smaller, scattered populations found between these two concentrations. Small numbers were found on the sandplain that runs out from the borefield to the south of Kata Tjuṯa and in the area of sandplain that encircles Uluṟu. None were found east of the sandplain that encircles Uluṟu although very extensive dune corridors that appear to offer excellent habitat are located along the Tuart track and adjacent to the Amata road in the eastern third of the Park. Both of the major population concentrations are in areas that were burnt in 1976 and subsequently had patchy fires in the mid to late 1980's. The total population in the Park may be fewer than 1000.

Biology and ecology

The borefield study site proved to be extremely dynamic during the six months period of fieldwork during September 1996 to February 1997. The lizards are inactive during the coldest three to four months of the year, emerging from hiberation in September. *E. kintorei* display a strongly bimodal activity pattern above ground during hot weather with emergence from the burrow for a few hours in early morning and then again from late afternoon until late evening. Several old burrows that had been abandoned in the past were opened up and came into use. Two completely new burrows were being constructed. Two abandoned mulgara burrows were converted for use, as was one *Egernia striata* burrow. Several burrow systems showed signs of simultaneous use by mulgara and *E. kintorei* and three mulgara were captured while trapping for lizards. A few individuals of both adult and juvenile *E. kintorei* moved between existing burrows. An adult pair moved into a disused burrow just prior to parturition and five neonates were subsequently captured in that burrow system. Females give birth during January and possibly into February. It appears that from one to six young are produced in a litter. Very little interaction was observed between lizards, including lizards living in the same burrow system. At one large system two adults, one yearling and two neonates were observed basking at the one time. All were sitting at different burrow entrances. Similarly five yearlings were observed at another burrow system all sitting at separate burrow entrances and occassionally rushing out up to 1m from the entrance to eat swarming termites.

Wherever *E. kintorei* were found in the Park their burrow systems were always adjacent to numerous large, flat, bare pavements of *Drepanotermes sp.* termites nests. These termites constituted the bulk of the diet of *E. kintorei* during the study period. Uluru has a marked summer rainfall bias and the swarming of termites following summer storms provides vast quantities of food. For weeks following these storms termites are active harvesting spinifex and lizards are also able to consume large quantities of workers.

In the summer of 1996/97 storms and termite swarming and harvesting coincided with the period of *E. kintorei* reproduction. *E. kintorei* has previously been considered an omnivore (Pianka 1986, Horner 1992, Ehmann 1993). 1996 was the second driest year on record at Uluru and very little plant material was available, however petals of the daisy *Leuchochrysum stipitatum* were found in several scats. Other recorded food items included beetles, cockroaches, grasshoppers, ants, spiders and a blindsnake.

Threats

Threats to the population in the Park include tourism, predation, competition and wildfire. The population at the sunset viewing area is divided by the main visitor access road. Other smaller populations occur adjacent to the main roads in the vicinity of the entrance station and the Kata Tjuta road junction. There have been numerous reports by Park staff of *E. kintorei* roadkills and one such specimen was available for analysis during the study. Peak daily *E. kintorei* activity coincides with a period of intense roaduse following sunset. It could be expected that lizards will continue to be killed by vehicles although the level will be difficult to quantify. At the sunset carpark use of the adjacent bush as a toilet has resulted in the trampling of burrows.

Numerous burrow systems were located that had been dug into by dingos. They are unable to dig out the whole burrow and would need to take a lizard by surprise in order to catch it. An adult male *E. kintorei* was killed at the borefield study site by a dingo during December 1996. Similarly cats and foxes would need to ambush a lizard or catch it in the open away from a burrow. I was shown tracks where a cat had sat in wait adjacent to a burrow entrance and then pounced on a tjakura. I was told that the lizard struggled free and escaped. Cat and fox tracks can be frequently found in the areas of *E. kintorei* burrows.

One *E. kintorei* burrow was located that had been appropriated by rabbits. Old scats at the latrine and the continued absence of fresh scats over several months of monitoring indicated that the lizards had abandoned their burrow.

A presumed threat but one that has in no way been quantified is that of wildfire. The great fires of 1976 burnt over three quarters of the area of the Park. Fires of this kind have large amounts of fuel that carry them through extensive areas leaving very little on the ground surface. How *E. kintorei* responded to the events of 1976 will never be known but perhaps the current patchy distribution of the species in the Park is attributable to this event. The current management practise of creating a mosaic of different fire ages may have largely negated the threat of an extensive wildfire. Nevertheless the quite substantial areas that hold the major populations could be at risk to fire in the future. Much of the area of borefield within the Yulara lease was last burnt in 1976 and a wildfire through the lease could be extensive and extremely damaging to wildlife populations.

Recommendations

Recommendations in the final report of the *E. kintorei* study included undertaking a cooperative management approach of the borefield between the Park Board and the Yulara Corporation, long term monitoring of core *E. kintorei* population areas by Park staff, and production of an integrated patch burning plan. A number of other recommendations are included among the future research directions listed below.

Directions for possible future research

- Production of a predictive model for *E. kintorei* distribution in the Park.
- Search of unsurveyed potential habitat.*
- More detailed mapping of burrow localities.
- Monitor *E. kintorei* response to a fire. *
- Monitor general movement of PIT tagged subadults.
- Monitor expansion or contraction of the main populations and of minor populations. *
- Investigate interaction with murtja and kuniya. *
- Investigate level of reliance on *Drepanotermes* as food supply.
- Attempt experimental relocation of a population into the east of the Park. *
- Maintain control area of burrow systems that remains unburnt. *

Investigate level and impact of cat, fox and dingo predation.*

Integration of traditional ecological knowledge

Much information was provided to me by members of the Mutijulu community during the course of this study. This included extensive comment on lizard habits and life history and interpretation of tracks and signs while in the field. There are many areas of potential future research where Anangu participation would be invaluable (see 'Directions for possible future research'). Numerous taped interviews were recorded during the study, documenting the traditional knowledge held by senior members of the Mutijulu community. This very extensive body of material has been transcribed and is held at the Park headquarters. Collection and compilation of this knowledge should be continued.

Possible future collaborative ventures

- Formulation of an integrated control burning plan that considers the impact on all important species. Workers on all the main species to be involved.
- Study of the termites at Uluru and their role in the life history of *E. kintorei.*
- Investigate the role of palaeodrainage in influencing the distribution of *E. kintorei.*
- The role of fire history and controlled burning in influencing *E. kintorei* distribution.

Indicators

- Annual monitoring of the two main population areas by counting active burrow systems.
- Monitoring fire age of main population areas.
- Continued rainfall registration.
- Monitoring the state of termite populations in the major *E. kintorei* localities.
- Continued monitoring of water table heights on the borefield.

****

References

Cogger, H.G., Cameron, E.E., Sadlier, R.A. & Eggler, P., 1993. The action plan for Australian reptiles. Australian Nature Conservation Agency, Canberra.

Ehmann, H., 1992. Encyclopedia of Australian animals, Reptiles. Angus and Robertson. Sydney.

Horner, P., 1992. Skinks of the Northern Territory. Northern Territory Museum of Arts and Sciences, Darwin.

McAlpin, S., 1997. Conservation of the Great Desert Skink, *Egernia kintorei,* at Uluru–Kata Tjuta National Park. Northern Territory University, Darwin.

Pianka, E.R., 1986. Ecology and natural history of Desert Lizards. Princeton University Press, Princeton.

Reid, J.R.W. & Hobbs, T.J., 1996. Monitoring the vertebrate fauna of Uluru–Kata Tjuta National Park, phase II. Final Report. CSIRO, Alice Springs.

Reid, J.R.W., Kerle, J.A. & Morton, S.R., 1993. Uluru fauna. Australian National Parks and Wildlife Service, Canberra.

The Mulgara *Dasycercus cristicauda* (Krefft) (Marsupialia: Dasyuridae): ecological characteristics, implications for management and future research

Pip Masters[1]

[1] 18 Burke St, Alice Springs, 0870.

Introduction

Since the turn of the century, a third of the mammal species of arid Australia have suffered a drastic decline in distribution and abundance (Morton and Baynes 1985, Burbidge and McKenzie 1989). Uluru National Park has not escaped the massive loss of mammals, with 16 species being lost from the Park during this period and only four medium-sized mammal species remaining. Some, including the brush-tailed possum, *Trichosurus vulpecula*, have become locally extinct in the last twenty years which indicates that the extinction process is still underway (Baynes and Baird 1992, Reid *et al.*1993).

The mulgara is one of the few medium-sized mammals that still exists at Uluru National Park. Nationally, the mulgara is classified as vulnerable to extinction (Baker 1996; IUCN 1996, Maxwell *et al.* 1996) and until recently very little was known about its distribution, habitat or field ecology. Mulgaras are known to be patchily distributed occurring in pockets of habitat dominated by spinifex grasslands. The population at Uluru National Park is restricted to the northern boundary of the Park with the majority of the population residing outside the Park in the area occupied by the Yulara Leasehold (Baker 1996). The security of this population is uncertain, and to date targeted management has been minimal.

Information on the distribution and habitat requirements of a species at a landscape level, combined with the targeted collection of ecological data is critical for identification of the threatening processes operating on species, for prediction of the security of species and for the identification of research and management directions. This paper collates the information collected during recent studies of mulgara ecology and distribution.

Distribution and Ecological Characteristics

The detailed ecological characteristics of the mulgara are described by Masters (1997a). This study compares and contrasts two populations, one on the southern edge of the present range on the boundary of Uluru National Park (25^{0}17'S, 130^{0}55'E), and the other on the northern edge of the present range in the Tanami Desert, at Sangsters Bore (20^{0}50'S, 130^{0}20'E).

The two study areas differed in a number of ways. The Uluru population was located in an area dominated by *T. basedowii*. The average rainfall for the region over the last forty years (until 1995) was 279 mm and the spinifex grasslands within the region are thought to burn once every 25 years. The Sangsters Bore population was located in an area dominated by *T. pungens*. Rainfall in the region is much higher averaging 443 mm, therefore the growth of the spinifex grasslands is faster and fires are more frequent. This region burns on average every eight years. The ecological characteristics of the two populations are compared and contrasted below.

Population biology and movement patterns

Mulgaras breed annually in the field, producing a litter once a year despite having a polyoestrous reproductive cycle. Females have a maximum litter size of six with a sex ratio of 1:1. Individuals can survive for more than one breeding season, but only a very small proportion of individuals survive to the third year despite captive animals living for up to six years (Woolley 1971, Masters 1997a). At Uluru 33 % of females survived to breed in their second year.

There was a decline in the number and body condition of mulgaras over winter, with males fluctuating more than females. On occasion males were completely absent by September, the time when pouch young were present. The high success of juveniles was reflected by the increase in the population which occurred in late spring and summer. The population remained high until the following winter.

Mulgaras appear to be highly sedentary; males and females maintain home ranges of 1.5-14 ha which, on average, overlap by less than 20 %. By September home ranges were established and no transients were evident. The high site-fidelity of mulgaras suggests that adults have a low tendency to disperse. However, the dispersal rate of sub-adults may be greater, particularly for males which move away from their natal area. This study did not clarify the dispersal rate of mulgaras hence this still needs to be identified considering the patchy nature of the mulgaras distribution.

Other studies have found that populations in high quality habitats usually have higher densities and survival rates, are occupied for longer periods, and have lower rates of immigration than those in low quality habitats (Cockburn and Lidicker 1983; Adler and Wilson 1987; Dickman and Doncaster 1989). Overall the population in the Tanami Desert appeared to be less secure than that at Uluru, as indicated by a lower density and lower survival rate, despite greater body weight per individual. Hence, the Uluru population appears to be more secure with a higher rate of increase, density, and a longer life span of individuals.

Diet and food availability

As previous work has shown, the diet of the mulgara consists of a broad range of terrestrial invertebrates, reptiles and small mammals (Fleay 1961; Masters 1997b). This study found no difference in diet between the sexes, but a difference between the Tanami and Uluru study areas, with more scats containing reptiles at Uluru and more containing scorpions in the Tanami Desert. There was no significant seasonal variation in the diet for animals in the Tanami Desert, but at Uluru the diet in summer (January to March) differed from that in other seasons due to an increase in consumption of grasshoppers and centipedes and a decrease in beetles.

Food resource availability varied both spatially and temporally. There were seasonal fluctuations in invertebrate numbers; however, there were also huge differences in invertebrate biomass between years, possibly due to the overriding effects of fire history and rainfall.

There were substantial differences in invertebrate biomass between study areas, with the Tanami grids yielding a higher biomass than that collected from Uluru. Despite the high biomass of food resources, the population density of mulgaras in the Tanami was lower, although the average weight of individuals was greater. Consequently, the biomass of food resources explained only a small amount of the variation in the size and condition of the population which led to the hypothesis that habitat characteristics were the major limiting factor of mulgara distribution.

Habitat

Baker (1996) characterised mulgara habitat following the collection of habitat data from a number of locations distributed across Australia. She found mulgaras were located in areas dominated by either *Triodia pungens* or *T. basedowii* with clayey and sandy loam soils and a shrub or tree layer. Areas of medium-aged spinifex were most frequently occupied. The successional stage following fire also has been found to influence the distribution of mulgaras (Masters 1993; Baker 1996). In addition Baker (1996) identified the influence of a drainage system as being important to mulgara distribution.

Masters *et al.* (1997) characterised the habitat of the mulgara and other species, in an area of 210,000 km^2 in the Tanami Desert using a stratified sampling design. The study area was divided up according to landscape type (areas of drainage, sandhills, sandplains, or laterite) and fire history (old, intermediate and recently burnt areas) and, where possible, ten survey sites were randomly placed in each classification. Using this survey technique Masters *et al.* (1997) found that mulgaras were not distributed evenly across the landscape, however, the species of spinifex rather than drainage lines *per se,* was found to be the strongest correlate with mulgara distribution.

Where *Triodia basedowii* was the dominant spinifex species, these was a 40% chance of encountering the presence of mulgara tracks. In areas dominated by *Triodia pungens*, there was a 10% chance of encountering mulgara tracks. However, when this species of spinifex was associated with *Melaleuca* spp., which indicates the presence of a drainage system, or in areas which were within 500 m of a rocky outcrop, the chance was much greater. As found by Baker (1996), areas dominated by *Plectrachne schinzii* were never occupied by mulgaras despite the landscape type. This suggests that habitat variables, relating to the distribution of spinifex species rather than the presence of a drainage system, are the dominant factor influencing the distribution of mulgaras.

As found previously (Baker 1996, Masters 1997a), spinifex shape also correlated with mulgara distribution. Spinifex shape is related to spinifex species. *Triodia basedowii* always grows into a hummock formation, *T. pungens* can grow in a variety of forms but tends to be in a hummock formation when growing on sand sheets over drainage systems, and *Plectrachne schinzii* grows predominantly in a stoloniferous formation. It is difficult to identify why the shape of the spinifex may be important to mulgara distribution, however, the open spaces between hummocked shaped spinifex may increase hunting success, and therefore survival.

The frequency of encountering mulgaras also decreased from south to north. Mulgaras were widely distributed and frequently encountered in the southern part of the study area where *Triodia basedowii* dominated the landscape. Further to the north *T. basedowii* became less prevalent, limited to the laterite rises, and *T. pungens* and *P. schinzii* become dominant. In the southern two thirds of the study area drainage systems, which were generally dominated by *T. pungen*, were found to support mulgaras, however, further north drainage systems became unsuitable. The soils increased in clay content and Mitchell grass, or Coolibahs over *Plectrachne* sp. Dominated. In this region mulgaras were limited to laterite rises which were generally dominated by *Triodia basedowii.* The results from this study have clarified a number of points:

1. The mulgara was found to be broadly distributed over vast areas of *T. basedowii* and not limited to drainage systems as previously thought (Gibson and Cole 1992, Baker 1996);

2. Drainage systems are only important in areas dominated by *T. pungens*;

3. Mulgaras are not limited to areas of greater nutrient and water availability, i.e. drainage systems as previously suggested (see Morton 1990);

Future Research and Management Recommendations

The above findings highlight a number of areas where information is inadequate. If we are to manage the Uluru population effectively we need to:

1. Identify the distribution of the mulgara in relation to spatial and temporal availability of suitable habitat within the broader region surrounding Uluru National Park. The survey undertaken by Baker (1996) was hindered by recent wild fires to the north that reduced habitat suitability and, although populations were found west of the Park, the extent of these populations was not spatially clarified. The distribution of mulgara populations needs to be identified on a regional scale to the north and west so we can identify the interconnections between populations and therefore the likelihood of genetic exchange. This could be undertaken using the same technique used by Baker (1996).

2. Dispersal ability needs to be more accurately described. This information is also necessary for the identification of the extent of genetic exchange between populations. This maybe possible using both radio-transmitters and traditional tracking techniques. The importance of this step will be determined by the outcome of the above research. In the event that the populations are linked over a large area this may not be necessary.

3. Preliminary population viability assessment of mulgaras could be undertaken when information on dispersal and the extent of nearby populations has been obtained. The models can be used to estimate the security of the species under different scenarios incorporating the effects of habitat destruction (e.g. development by Yulara township) and fire management. Once again, the importance of this step will be determined by step 1.

4. Although the mulgara population appears to be secure at this stage, baseline information needs to be collected on fluctuations in the population and environmental variables which may influence the population in the future. The following programs should be implemented:

a) Monitor the population dynamics of the mulgara so that population declines can be detected early and management adjusted accordingly.

b) Apply fire management. Fire management in one of the most obvious tools which can be used for management of mulgara populations in spinifex grasslands. The mulgara is more abundant and has a higher breeding success in mature spinifex (Baker 1996, Masters 1993, 1997a). By maintaining a variety of fire ages within a region, suitable habitat is more likely to be consistently present. Within these patches a policy of burning during the cool part of the year might be most appropriate for the mulgara. Cool burns will provide patchy areas of vegetation and hence cover and run ways within a localised area. Fire management can improve habitat quality and maintain links to other areas of suitable habitat, hence increasing densities, and increasing genetic exchange.

c) Develop a strategy to manage and minimise habitat damage in core mulgara habitats. This is particularly important in the area of the borefields and within the area of the Yulara Leasehold. Ideally the Park and the Resort should manage the area jointly. Without this it is likely that the population will be threatened in the future because the majority of the population occurs in the Resort. To date, no environmental management or planning is evident within the Yulara Leasehold and future expansion of developed areas, and therefore habitat destruction, is likely.

d) Identify predator loads. Although predation does not appear to be a problem to the population at the moment, we need to identify the composition and level of predators that are associated with the mulgara population. It is possible that future changes in management or environmental conditions could alter the balance between predators and the mulgara populations. Activities which may effect the security of the mulgara population include the control of dingoes. This could be detrimental to the existence of the mulgara population in the event that the high dingo population influences the abundance of other predators such as foxes and cats. Predator loads will also need to be determined before any re-introductions of other rare species takes place.

e) During the meeting G. Griffin suggested that the distribution of the spinifex species had also changed. With this information in mind the monitoring of changes in spinifex species would also be prudent. Within the region of the Park the mulgara is limited to *Triodia basedowii*. In the event that there is a shift away from this species, the mulgara population will also decline.

f) An adaptive management strategy needs to be put in place which aims to determine and influence the population changes which occur following different management strategies.

****

References

Adler, G.H. & Wilson, M.L., 1987. Demography of a habitat generalist, the white-footed mouse, in a heterogeneous environment. Ecology, 68, 1785-1796.

Baker L., 1996. The distribution, habitat requirements and status of the Mulgara (*Dasycercus cristicauda*, Krefft). Master of Science thesis, University of New England, Armidale.

Baynes, A. & Baird, R.F., 1992. The original mammal fauna and some information on the original bird fauna of Uluru National Park, Northern Territory. Rangeland Journal, 14, 92-106.

Burbidge, A.A. & McKenzie, N.L., 1989. Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. Biological Conservation, 50, 143-198.

Cockburn, A. & W.Z. Lidicker, W.Z., 1983. Microhabitat heterogeneity and population ecology of an herbivorous rodent, *Microtus californicus*. Oecologia, 59, 167-177.

Dickman, C.R. & Doncaster, C.P., 1989. The ecology of small mammals in urban habitats II. Demography and dispersal. Journal of Animal Ecology, 58, 119-127.

Fleay, D., 1961. Breeding the Mulgara. Victorian Naturalist, 78, 160-167.

Gibson, D.F. & Cole, J.R., 1992. Aspects of the ecology of the Mulgara, *Dasycercus cristicauda* (Marsupialia: Dasyuridae) in the Northern Territory. Australian Mammalogy, 15, 105-112.

IUCN., 1996. IUCN red list of threatened animals. IUCN, Gland, Switzerland.

Masters, P., 1993. The effects of fire-driven succession and rainfall on small mammals in spinifex grasslands at Uluru National Park, Northern Territory. Wildlife Research, 20, 803-813.

Masters, P., 1997a. The Mulgara *Dasycercus cristicauda* (Krefft) (Marsupialia: Dasyuridae) at Uluru National Park, Northern Territory. Australian Mammalogy.

Masters, P., 1997b. An ecological study of the Mulgara *Dasycercus cristicauda* (Krefft) (Marsupialia: Dasyuridae) in central Australia, Northern Territory. Ph.D thesis, University of Sydney, NSW.

Masters, P., Nano, T., Southgate, R., Allan, G., & Reid, J., 1997. The Mulgara: its distribution in relation to landscape type, fire age, predators and geology in the Tanami Desert. Internal report to the Australian Nature Conservation Agency.

Maxwell, S., Burbidge, A.A. & Morris. K., 1996. The 1996 action plan for Australian marsupials and monotremes. Wildlife Australia, Project Number 500.

Morton, S.R. 1990. The impact of European settlement on the vertebrate animals of arid Australia: a conceptual model. Proceedings from the Ecological Society of Australia, 16, 201-213.

Morton, S.R. & Baynes, A., 1985. Small mammal assemblages in arid Australia: a reappraisal. Australian Mammalogy, 8, 159-169.

Reid, J.R.W., Kerle, J.A. & Baker, L., 1993. Uluru fauna: mammals. In: Reid J.R.W., J.A. Kerle & Morton, S.R., (editors), Kowari, 4, Australian Nature Conservation Agency, Canberra, 69-78.

Woolley, P.A., 1971. Maintenance and breeding of laboratory colonies of *Dasyuroides byrnei* and *Dasycercus cristicauda*. International Zoo Yearbook, 11, 351-354.

Patterns and processes in arid zone ecology and management

S.R. Morton[1]

[1] CSIRO, Division of Wildlife and Ecology, PO Box 84, Lyneham ACT 2602.

Introduction

In order to provide some setting for discussions about the ecosystems of Uluru National Park, let us begin by considering some basic principles of arid zone ecology. In my rapid perspective I will rely largely on overview rather than proffering factual backup, because the broad principles given here can be tested against the pictures springing from each of the subsequent presentations. Nevertheless, it is worth noting at the beginning that the small number of principles I'll go on to mention have to a large extent emerged from studies conducted at Uluru. The research effort in the Park has not only provided substantial value in terms of advice to management, but also to fundamental understanding of the processes at work in the arid Australian landscape, as we see them at the present level of understanding. After we have looked at these issues, I wish to go on to consider some other factors that I believe are important when considering the relationship between research and management, and which might help stimulate some discussion during the coming couple of days.

Some fundamental principles of pattern and process

All of you know about the things I am about to say. They have been commonly debated and argued over in this particular scientific community many times during the past 10 to 15 years, and Mark Stafford Smith and I attempted to summarise them in 1990.

Rainfall: Its unpredictability through time is the major driving force in arid Australia. This is the principal environmental feature demanding adaptation on the part of virtually every organism, and influencing the distribution and abundance of each. The key feature is globally unusual variability driven, we now realise, by the El Nino - Southern Oscillation effect. The outcome is annual rainfalls skewed towards lower totals, indicating that the normal situation is drier years that occasionally are interrupted by much wetter years. The impacts of these unusually wet years on important parts of the physical and biological systems, such as in replenishment of groundwaters and establishment of perennial plants, are almost impossible to exaggerate. I would hazard a guess that several speakers to follow will mention the effects of this variation on particular components of the environment!

Patterning of soils and moisture: The geological stability of the continent over countless ages has resulted in lack of rejuvenation of soils. Many landforms have been exposed to surface conditions for tens of millions of years, often more than a hundred million years. Under such conditions there has been long-standing leaching of nutrients, and in such a flat landscape the spatially complex runoff/runon patterns exaggerate the importance of differentiation of soil fertility by enhancing differentiation of moisture status. The result is strong and profoundly influential patterning in plant production and species composition.

Plant life-histories: Heightened variability of rainfall, high degrees of soil differentiation, and subtle spatial variation in moisture supply all conspire to produce a wonderful array of life-histories in plants. The caricature of "drought-evaders" and "drought-endurers" is quite simply inadequate to describe the spectrum of life-histories made possible by the variation in soil moisture and nutrients. Nevertheless, the occasional heavy rainfalls, and the groundwater storage thereby produced, seem particularly to have allowed the development of a diverse and abundant perennial flora.

Fire: Occasional heavy rains produce a flush of plant material; in addition, buildup of perennial plants produces substantial biomass. This material often burns. Fire is a key feature in much of arid Australia to an extent not often seen in other arid systems.

Animals: The conjugation of variable rainfall patterns, striking soil differentiation, vegetation patterning, widely varying life-history strategies in plants, and fire has produced through evolutionary time an awesome array of radiations in animals and in their life-history strategies. As an animal ecologist, I still find it the most interesting environment by far among all those I've worked in.

Having quickly covered these notions, I would like to turn to some broader issues swirling around in ecological research and its connections to management. I want to spend a little time exploring the ways in which ecological insight finds its way into management, and at least to touch on some lessons that ecologists might learn from managers, and vice versa. I will begin with a quick consideration of some of the changes taking place in ecology at present.

A quiet revolution in ecology

Ecology has undergone something of a quiet revolution during the past 20 years (Pickett *et al.* 1992; Pickett and Ostfield 1995). Concepts that were considered firmly established in previous decades have undergone considerable revision, even reversal. Consider the following developments, which are summarised from a manuscript by Richard Hobbs and myself.

The flux of nature: Previous generations of ecologists operated within the equilibrium paradigm, the assumption that the natural world was fundamentally a stable collection of communities in which each species had its ordered position and in which any disturbance would result in an ordered successional progression leading through subclimax phases back to the original climax (Christensen 1988). Ecological communities were considered to be organised, patterned collections of co-evolved species, into which incompatible species could not penetrate (Simberloff 1982). In recent years we have seen this notion of organisation and stability give way to a vision of flux. Most ecologists have come to the view that the natural world is characterised more by instability than permanence, by frequent disturbance that continually pushes ecosystems in alternative directions instead of causing them to return inevitably and regularly to their original condition; more by unique specific responses than coordinated, predictable, tightly constrained combinations of species, as individualistic responses outweigh tendencies towards regularly occurring communities, i.e. the *nonequilibrium paradigm* (Pickett *et al.* 1992; Fiedler *et al.* 1997). This paradigm does not hold that ecological equilibria are non-existent, but rather that they are scale-dependent and embedded in nonequilibrial conditions. However, the nonequilibrium paradigm does imply that predictable end-points to the successional process following disturbance are rare and that multiple stable states may exist.

Multiple stable states: Disturbance inevitably sets in train some form of succession. It is apparent now that the course of the succession is difficult to predict, because the direction which the ecosystem or assemblage takes is contingent upon the particular circumstances of the disturbance and the nature of the biophysical conditions that follow it. The notion of contingency brings history to the fore: history very much matters in patterns and processes of community change. As a consequence, the end-point of many successional processes is not a predictably uniform outcome; instead, several states are possible, depending on the contingent circumstances (Noble and Slatyer 1980; Hobbs 1994). Depending on the frequency of the disturbances, these multiple states may be stable for long periods of time. The differences in outcomes of successional events in seemingly similar assemblages or ecosystems may well follow meaningful patterns, but the itineraries are not easily predictable at the outset of the journey.

Patchiness and landscape ecology: The re-emergence of landscape ecology springs from realisation that understanding and management of the natural world depends as much on the analysis of flows of resources across ecosystems as it does on the study of quadrats. But perhaps the principal issue underpinning landscape ecology is recognition of the vital importance of patchiness (Turner and Gardner 1991). Patchiness focusses on the spatial matrix of ecological processes, and emphasises the fluxes of materials and organisms within and between parts of the landscape. It is a form of spatial heterogeneity in which boundaries are discernible, and in which units appear as contrasting, discrete states of physical or ecological phenomena (Ostfeld *et al.* 1997). An array of patches constitutes a mosaic at whatever scale is appropriate for investigation. The study of patch dynamics promises to provide a valuable framework in which to understand and to manage the landscape mosaic.

Prediction: The nonequilibrium paradigm sees ecosystems as probabilistic rather than deterministic; inherently, therefore, most ecologists believe that ecosystems are characterised by uncertainty rather than by predictability. We cannot avoid the lack of predictability; consequently, there is a need to identify the bounds or conditions under which decisions can be made in the face of uncertainty. Risk analysis, and adaptive management through more detailed involvement of managers in research and development, are the principal routes by which ecologists are struggling to work with unpredictability.

Ecology and land management

What might the issues stirred up in the previous section mean for the relationship between ecological researchers and land managers? Pahl-Wostl (1995) has recently summarised the significant shifts in attitudes and expectations of what ecology can deliver, and how environmental risks should be assessed; some of these items are shown in Table 1. Of particular note is her suggestion that risks should be measured in terms of the reduction of degrees of freedom for future action; in other words, the extent to which future options are foreclosed.

	Current attitude	**Required attitude**
Research	-reduces uncertainties	-uncovers uncertainties
	-makes quantitative predictions	-generates innovative, qualitative knowledge
	-focuses on mechanism, process	-focuses on organisation, pattern
	-provides expert knowledge	-engages as partner in a social dialogue
Management	-views nature as a machine	-views nature as partner

	-is rigid, controlling	-is flexible, adaptive
	-aims at change towards preconceived goals	-fosters evolution, innovative action
Risk assessment		
-source	=phenomenon or process	=system structure, organisation
-risk	= undesirable events	=restriction of evolutionary potential
-measure	=probability of damage	=decrease in degrees of freedom

Table 1. Contribution of ecological research to environmental management (modified from Pahl-Wostl, 1995).

Conclusion

Ecology is a science in transition, moving from one set of paradigms to another and grappling with new sets of questions. It is clear that the principles outlined at the beginning of the paper have little predictive power, and this situation is unlikely to change - ecology has no simple formulae or models available to predict the outcomes of management actions. Nevertheless, through the sorts of changes in approach outlined in Table 1 we can still provide guidance which will focus efforts and maximise their likely benefits through facilitation of a diversity of responses to today's problems.

****

References

Christensen, N.L., 1988. Succession and natural disturbance: paradigms, problems, and preservation of natural ecosystems. In: Agee, J.K. & Johnson, D.R., (editors) Ecosystem management for parks and wilderness. University of Washington Press, Seattle, 62-86.

Fiedler, P.L., White, P.S. & Leidy, R.A., 1997. The paradigm shift in ecology and its implications for conservation, In: Pickett, S.T.A., Ostfeld, R.S., Shachak, M. & Likens, G.E., (editors) The ecological basis of conservation: heterogeneity, ecosystems and biodiversity. Chapman and Hall, New York, 83-92.

Hobbs, R.J. (1994). Dynamics of vegetation mosaics: can we predict responses to global change? Écoscience, 1, 346-356.

Noble, I.R. & Slatyer, R.O., 1980. The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. Vegetatio, 43, 5-21.

Ostfeld, R.S., Pickett, S.T.A., Shachak, M. & Likens, G.E., 1997. Defining the scientific issues. In: Pickett, S.T.A., Ostfeld, R.S., Shachak, M. & Likens, G.E., (editors) The ecological basis of conservation: heterogeneity, ecosystems and biodiversity. Chapman and Hall, New York, 3-10.

Pahl-Wostl, C., 1995. The dynamic nature of ecosystems. Chaos and order entwined. Wiley and Sons, Chichester.

Pickett, S.T.A. & Ostfeld, R.S., 1995. The shifting paradigm in ecology. In: Knight, R.L. & Bates, S.F., (editors) A new century for natural resources management. Island Press, Washington D.C., 261-278.

Pickett, S.T.A., Parker, V.T. & Fielder, P., 1992. The new paradigm in ecology: implications for conservation biology above the species level. In: Fielder, P. & Jain, S., (editors) Conservation biology: the theory and practice of nature conservation. Chapman and Hall, New York, 65-88.

Simberloff, D. 1982. A succession of paradigms in ecology: essentialism to materialism and probabilism. In: Saarinen, E. (editor) Conceptual issues in ecology. Reidel, Boston, 63-99.

Stafford Smith, D.M. & Morton, S.R., 1990. A framework for the ecology of arid Australia. Journal of Arid Environments, 18, 255-278.

Turner, M.G. & Gardner, R.H., (editors), 1991. Quantitative methods in landscape ecology. The analysis and interpretation of landscape heterogeneity. Springer-Verlag, New York.

Setting the scene: ethnobiology

Brad Nesbitt[1] and Lynn Baker[1]

[1] Wallambia Consultants, 1070 South Arm Rd, Urunga NSW 2455.

The following observations and suggestions are based on our association with Anangu at Mutitjulu and AP lands over the period from 1986 to 1997. We have been directly involved in management at UNP up until 1990 and since that time indirectly through specific programs or employment arrangements. We are therefore not familiar with the details of all projects or the degree of Anangu involvement in projects in recent years. As a result proposals or suggestions made by us here may already be implemented at UNP. Also much of what we discuss is probably more in the way of reinforcing UNP managers experience with our own more recent experiences on the AP lands.

1. Summary of research and survey work conducted with Anangu in the park or surrounding lands.

1997	A.P. Land Management Workshop Stage 1.
1997	Roxby Downs / DENR / A<u>n</u>angu Co-operative re-introduction proposal
1991 - 1997	Co-operative Biological Survey program with A<u>n</u>angu Pitjantjatjara Council and S.A. Department Environment Natural Resources within the AP Lands. • Mallee fowl survey and research • Black footed rock wallaby survey and research • Black footed rock wallaby protection program: 1080 predator bait program • Marsupial mole survey and research • Education programs with schools • Teacher training ANTEP • Feral animal control • Fire management • A<u>n</u>angu ranger / community ranger training • Rockhole maintenance
1995	A.P. Fire Management workshops
1994	A.P. Waru (Black-footed Rock Wallaby) surveys
1986 - 1990	Ulu<u>r</u>u National Park • Ulu<u>r</u>u Fauna Survey • Brushtail possum reintroduction survey • Owl pellet survey for historical mammal species list • Black-footed rock wallaby survey UNP and surrounding rocky outcrops • Mulgara research • *Egernia kintori* survey • Marsupial mole survey • Striated Grasswren survey • Fire management • Eco-tourism (liru walk)

2. Identified gaps in research to date, possible future directions for research and proposed collaborative programs.

Rare Species Management / Reintroduction

Reintroduction of species is very high on the Anangu agenda of caring for country. Some Anangu from the AP lands have visited reintroduction projects and captive breeding programs in South Australia and are very keen to have similar projects implemented on their lands.

Some Anangu at UNP and AP have also taken a strong interest in the protection of rare species such as Mulgara, mallee fowl, black-footed rock wallabies, marsupial moles, brushtail possums and woma pythons. There has also been some conflict between Anangu over protection versus traditional use of some of these species eg. mallee fowl eggs.

Brushtail Possum

Brushtail possums are still very high on the Anangu agenda for reintroduction, particularly on the AP lands. The reintroduction of Brushtail possums was identified by Anangu in the 1990 AP Land Management workshop as a priority for reintroduction. Anangu from throughout the AP Lands have expressed this viewpoint whilst working on the AP biological surveys. A feasibility study for the reintroduction of this species to UNP was commenced in 1988 by Jeff Foulkes and Ann Kerle. This project was strongly supported by Peter Kanari, Kata Kura and Mutitjulu Community. It is tragic that the reintroduction project did not occur in Kanari's lifetime; and now Kata Kura is no longer capable of active involvement at the level initially proposed.

Black-footed Rock Wallaby

The black-footed rock wallaby disappeared from UNP in the 1980's. Work elsewhere in WA and AP Lands has begun to identify the threatening processes involved in this species' decline and programs have been implemented in both areas to address the issue. These programs are both co-operative programs between the relevant government land management agency and Aboriginal communities and rely heavily on Anangu support for on the ground management. There is a real opportunity at this time for UNP to become involved in this work and look at reintroduction of rock wallaby to the Kata Tjuta area.

A black-footed rock wallaby program at Kata Tjuta could be combined with a Brushtail possum reintroduction program in the same area. Suppression of predators and herbivorous competitors (currently underway with rabbit control works) in the area would have benefits for both species' reintroduction. The programs at AP and Warburton are being conducted using the same protocols. If UNP initiated a similar project then the program combined with the other two projects would have regional significance and could be utilised as a State of the Environment (SoE) indicator.

It would be ideal if there was UNP involvement in collaborative projects with AP to address rare species management on a broader scale, in particular with species such as black-footed rock wallabies, mulgaras, mallee fowl, *Egernia kintori* and striated grass wren.

An opportunity potentially exists for UNP to also work in a collaborative way on the proposed Roxby Downs/ S.A. DENR/ Anangu reintroduction project in the Roxby Downs area. Should this project proceed it would provide training and educational opportunities for UNP Anangu.

Education / Training

There is a need for an education link for Anangu between UNP and AP. Many Anangu on the AP lands are becoming confused about the recognition of certain rare species as these species are either no longer located on the AP lands or are very rare. For example, Anangu on the AP lands are confused about mulgara (Murtja)and *Egernia kintori* (Tjakura) and are using the names Murtja and Tjakura to identify other animals tracks and burrows. Also few Anangu on the AP lands are confident to undertake traditional burning practices and are therefore not burning their country.

In the past UNP Anangu have contributed to training AP Anangu on burning through workshops conducted on the AP lands and AP Anangu have visited UNP previously on a fire management information tour. Anangu at UNP have expertise in the identification of rare species such as mulgaras and *Egernia kintori*. This knowledge would be extremely valuable to transfer to Anangu on the AP lands. This could be accomplished by having Anangu from AP visit UNP where they could work with Anangu experts from UNP to clarify their recognition of these animals, their tracks, burrows etc. This would need to include some animals being trapped or dug out to be viewed. As is probably the case at Mutitjulu, many younger people on the AP lands also have reduced expertise in recognising the more common tracks etc and confuse names due to their lack of experience and critical training by elders. A program which encourages transfer of knowledge and information between UNP and AP could assist in slowing this decline.

The above program would benefit from the development of an adult education program at Mutijulu which focuses upon the teaching/refreshing peoples traditional ecological knowledge (TEK). A training program could be developed which combines TEK with modern science practices to provide courses in: fire management, feral animal control, rare species management, flora and fauna identification and behavioural characteristics. Development of skills in interpretation and recording TEK on ecological surveys would also benefit the Parks' programs.

There is a need for Anangu interpreters trained specifically for work in the environmental science field. This training could cover a number of facets important to interpreting in this field. In particular it could address the need for the interpreters to question and reply in full detail, not in abstract or to simplify information. Information can easily be lost, the smallest detail can be important in understanding which particular species is being discussed, or details pertaining to a species habitat requirements or breeding behaviour. This could be addressed through a specific training course.

Research projects should where possible be targeted to Aboriginal researchers to encourage people to enter into research and management disciplines. An Aboriginal post-graduate student is undertaking research on the 1080 baiting program set up to protect a black-footed rock wallaby colony in AP. Anangu trainees, rangers and others working in science related fields may well benefit from small workshops with Aboriginal people working at this level. This can provide important role models and the potential to create mentors for Anangu at UNP.

Education and training of Anangu in conservation management will help Anangu better participate in Park management and help them meet the objectives of the lease agreement which require the maximum participation of Aboriginal people and their knowledge in the management of the Park.

Faunal Studies

There is need for a project to further the documentation of Anangu knowledge regarding birds (assuming this has not already been addressed at UNP). This project would require an expert ornithologist working with an Anangu specialist to survey birds in the UNP area.

Intellectual and cultural property rights

Intellectual and cultural property rights are even more of an issue today than before. Aboriginal people are becoming more and more involved in research programs which collect TEK and there is more and more an issue of loss of control of this knowledge. We are unsure of UNP's current policy with regard to ensuring control remains with Anangu particularly with contract research projects. UNP are in a unique position to research this issue and further develop protocols and legal frameworks which protect these rights. Such research would have benefits at a regional level. The number and extent of implementation of protocols which address and protect intellectual and cultural property rights could form the basis of a SoE indicator of the State of Aboriginal cultural heritage.

Anangu project co-ordination

Using an Anangu co-ordinator (Ginger Wikilyiri) on the AP surveys has proven highly successful in ensuring the survey runs smoothly. The co-ordinator ensures that the appropriate traditional owners are involved in the project and that Anangu workers are adequately consulted and incorporated into the entire survey. He also has helped gain access to a number of desirable locations for the survey that otherwise might not have been accessible. Having a co-ordinator with whom 'wish lists' for rare species have been discussed has been highly fruitful as he has consulted widely with other Anangu between surveys and then has been able to direct the survey team to locations where these rare species are located. The pivotal point of the success of this set up has been 'ownership' of the program by the Anangu co-ordinator. He has a vested interest in ensuring that other Anangu support the program so that he remains employed and he also gains substantial status from being 'in charge' of the project. He also uses this status to engage other Anangu in discussions about species conservation. For example when a woma python was recently captured on the AP lands, Ginger took it to schools and on Ernabella television to explain the importance of the find and to explain why it was important to protect woma pythons. He then ensured that the animal was released back to its original location.

Such successes can help individuals to take a high profile on conservation and management issues and help promote Anangu support for programs.

Resourcing

Projects involving Anangu will not succeed unless adequate financial and human resources are allocated to the project. Projects involving Anangu tend to need strong and continuous supervision. In some instances this supervision can be successfully undertaken by Anangu, but unfortunately at this time, often Piranpa supervision or co-ordination is required to ensure that the project remains ongoing. This is particularly important where control programs need intermittent but ongoing maintenance to keep up routine program work eg. 1080 baiting.

Incorporating cultural aspects

There have been numerous discussions during surveys with Anangu about the importance of incorporating the spiritual side of caring for species and landscapes with the physical programs. For example, some Anangu men on the AP lands have been talking about the importance of resurrecting rock wallaby ceremonies as part of the rock wallaby protection program (apparently this ceremony has not been conducted for a long time).

Incorporating such aspects into a program can strengthen peoples commitment to the program and is a way of involving the broader Anangu community in support of the program.

Working with Anangu on a regional basis

We believe it is important for UNP to work on a regional basis with Anangu from AP and the Land Council regions to the west and east of the Park. This can assist in 'selling' projects to funding bodies on a regional basis as for State of the Environment reporting, and also access Anangu expertise from other areas. It also means that management programs such as fire management or rare species management have a broader regional base.

Discrete versus large projects

Anangu seem to get more involved when working on small discrete projects rather than larger ones. Projects which are linked to homelands or individual areas or species seem to get more ongoing enthusiasm and initiative than larger scale broad projects.

3. Implications of Tourism

There is a lot of potential for ethno-ecological tourism, where Anangu can use their TEK to inform and educate visitors about the fauna, flora and habitats of the Park. This could potentially be linked with research and/or management projects to help fund projects.

4. Summary of Proposed Collaborative Ventures

Brushtail possum reintroduction program at Kata Tjuta in collaboration with UNP/Mutitjulu, CCNT, AP, CALM, DENR.

Black-footed rock wallaby reintroduction program at Kata Tjuta in collaboration with UNP/Mutitjulu, CALM, DENR, AP, CLC, CCNT.

Traditional ecological knowledge exchange project in collaboration with AP and UNP/Mutitjulu.

Education, rare species reintroduction training in conjunction with the Roxby Downs (Western Mining) reintroduction project. Collaborators are Roxby Downs (Western Mining), DENR, Anangu and UNP/Mutitjulu.

5. State of the Environment Indicators for Monitoring

Density and distribution of rare species within UNP - utilise Anangu tracking skills to monitor rare species and pest species such as introduced herbivores and predators.

Density of vertebrate within UNP - utilise Anangu tracking skills to monitor pest species such as introduced herbivores and predators.

Density and distribution of Brushtail possums and black-footed rock wallabies - monitoring as part of reintroduction program at UNP.

Assessment of the number and extent of implementation of protocols which address and protect Aboriginal intellectual and cultural property rights.

Mitika mounds at Uluru-Kata Tjuta: Mesoscale patterns and processes

Jim Noble[1], Bill Low[2], Gerry Jacobson[3], Jake Gillen[4] and the Mutitjulu Community[5]

[1] CSIRO, Division of Wildlife and Ecology, Lyneham, ACT 2602.
[2] W.A. Low Ecological Services, Alice Springs, NT 0871.
[3] Australian Geological Survey Organisation, Canberra, ACT 2601.
[4] Environment Australia, Biodiversity Group, Yulara, NT 0872.
[5] CMA Ininti Store, Ayers Rock, NT 0872.

Introduction

In terms of biological diversity, Australia is classed as one of the 'megadiverse' countries, much of this unique character resulting from the wide-ranging diversity of its marsupial fauna. Unfortunately the conservation record of this biodiversity is not good with 18 of these endemic species now extinct and representing 30% of global mammalian extinctions over the last century (World Conservation Monitoring Centre 1992). Much of this attrition has occurred within a specific group, the medium-sized marsupials or mesomarsupials (Noble 1996) ranging in bodyweight from *c.* 2-7 kg. Some of these are now totally extinct, some extinct on the mainland, while others became restricted to small isolated populations having disappeared from much of their original distribution (Morton and Baynes 1985, Low 1986, Burbidge and McKenzie 1989, Johnson *et al.* 1989, Baynes and Baird 1992).

Of particular note in this regard was the **mitika** or burrowing bettong (*Bettongia lesueur*) which originally had one of the widest mainland distributions of any of the native mammals prior to European settlement (Finlayson 1958, Burbidge 1988, Short and Turner 1993). Until recently however, this species had disappeared entirely from mainland Australia, surviving only as island populations off the Indian Ocean coastline of Western Australia. A powerful burrower, it was able to construct subterranean nest systems in rocky terrain inhospitable to smaller fossorial animals. On the mainland, these were usually characterised by a horseshoe-shaped perimeter mound up to 30 m in diameter surrounding a calcrete lens partially exposed in the central depression. Beneath the calcrete layer, often around 30 cm thick, were several entrances which had been constructed wherever the calcrete was soft enough to excavate (Noble 1993). Morton (1990) proposed that the restriction of mesomarsupials like the **mitika** to such refugia during droughts may well have exposed them to greater risk of local extinction through increased predation pressures.

There is considerable effort now being directed towards conserving these rare and endangered populations, including reintroducing species back into areas where they were once believed to have been present (Beckmann 1990, Christensen and Burrows 1994, Nelson *et al.* 1992, Short and Smith 1994, Short *et al.* 1989, 1992). In order to do this successfully however, not only must exotic predators and competitors be effectively controlled, but such reintroductions must also be made, where such information is available, into preferred habitats. Fortunately in the case of **mitika**, its previous existence has been clearly imprinted in landscapes exhibiting high taphonomy such as the 'hard red' sites commonly found in mulga country. Here relict warrens still clearly exhibit the unmistakable morphological traits described elsewhere (Noble 1993).

There is a strong association between the rabbit (*Oryctolagus cuniculus*) and the **mitika**. The legacy of ready-made, pre-fabricated warrens conferred considerable advantages on invading rabbits, particularly in those landscapes where the massive red earths and rocky substrate would otherwise have deterred them from constructing warrens. Not only did **mitika** warrens facilitate their rapid invasion of the arid zone last century, but they also provided refuge warrens enabling rabbits to survive extended droughts (Myers and Parker 1965). In 'soft red' landscapes such as sandplain where the taphonomy is not as strong, old **mitika** sites may only exhibit subdued morphologies following burial by more mobile soils. In such country however, rabbits may have behaved as surrogate burrowing bettongs by continuing to utilise these sites over the past century following the demise of the original inhabitants. Even though the warrens have often been heavily reworked by rabbits, it is often possible to still recognise vestiges of the **mitika** perimeter mound.

Studies into the size, distribution and abundance of **mitika** mounds in different landscapes of the West Darling region of New South Wales have led to preliminary estimates of potential population sizes, as well as certain geo-ecological hypotheses, being generated. Particular attention has been focussed on the possible role of past mesomarsupials in mediating several mesoscale landscape processes (*sensu* Holling 1992) including nutrient cycling, dispersal of seeds and spores of mycorrhizal fungi, regulation of shrub populations and patch dynamics (Noble 1993, 1995, 1996). Population estimates of **mitika** must necessarily be conservative given that Finlayson (1958, p. 242) found that numbers ".... fluctuate greatly and its occurrence is local and discontinuous and not uniform. Warrens housing a big population during one season may be found quite deserted the next."

This paper describes results obtained from additional field studies undertaken in Uluru–Kata Tjuta National Park in 1995 and 1996 to validate assumptions relating to the habitat geology and landscape ecology of **mitika** mounds in arid regions other than the West Darling. Additional observations on **mitika** sites were also undertaken at widely separated locations including the adjoining property of "Curtin Springs", Finke Gorge National Park further north as well as "Atartinga" and "Mt Skinner" Stations northeast of Alice Springs, to broaden the range of landscapes examined.

ULURU–KATA TJUTA AND REGIONAL STUDIES

Geology and Palaeodrainage

Uluru–Kata Tjuta National Park is underlain by sedimentary rocks of the Amadeus Basin with prominent formations including the Mount Currie Conglomerate which may form both Uluru and Kata Tjuta while the Carmichael Sandstone crops out north of "Curtin Springs" (Wells *et al.* 1970). Elsewhere the Hermannsburg Sandstone is prominent in the Finke Gorge National Park while the "Atartinga" and "Mt Skinner" sites are both underlain by the Waite Formation and chalcedonic limestone (Shaw *et al.* 1975).

Quaternary calcrete of late Pleistocene origin (22-75,000 years) crops out near "Curtin Springs" and in the Yulara Creek-Bobby's Well area northeast of Uluru where it forms a carapace (up to 12 m thick) between the sand dunes. Because of its groundwater origin, the surface is mounded due to continual crystallisation at the base. The terms vadose and phreatic are commonly used in the calcrete and karst literature (e.g. Jacobson and Arakel 1987) with vadose seepage referring to rainwater or soil water percolating downwards through fissures and pores. As the soil profile becomes progressively drier, the carbonate is eventually precipitated out of the soil solution to form vadose calcrete. Phreatic calcrete in contrast is formed in the phreatic zone below the groundwater table where all substrate cavities remain permanently saturated.

Jacobson *et al* (1989) identified a palaeodrainage system located between Uluru and Kata Tjuta dating back to the Upper Cretaceous when it was connected to the major palaeodrainage system underlying Lake Amadeus. The ancient valley is now filled with about 100 m of Tertiary and Quaternary sediments, the latter characterised by the present dune systems. The main trunk of the palaeodrainage system now features a chain of groundwater-discharge playas including Lake Amadeus. The playas have a characteristic association of playa-bed gypsum, bordering gypsum dunes and thin gypcrete crusts. The gypsite and gypcrete playa deposits are believed to be mainly of Holocene age (8-16,000 years).

Rabbit Control Program

A major rabbit control program has been underway in the Park for several years now and maps prepared from 1:25,000 air photographs illustrate clear patterning of warrens relative to local relief (Low 1989), the highest warren densities being generally located midslope within calcareous interfluves of the **puti** - a Pitjantjatjara term for fans and alluvium (Baker and Mutitjulu Community 1992). The frequent presence of pedogenic calcrete, either within these warrens or in close proximity, suggested the strong possibility that most of the warrens had originally been constructed by **mitika**. In view of the success of the rabbit control program (Low *et al.* 1995, Grattidge *et al.* 1996), and given that the 1991 Plan of Management for the National Park had also cited the long-term goal of re-establishing extinct fauna of cultural significance (**Tjukurpa**), it was deemed appropriate to undertake preliminary field studies in September 1995 and June 1996 with this goal in mind.

These studies had the following objectives:

(1) to gather more detailed information about the landscape ecology of **mitika** at Uluru–Kata Tjuta and other sites with a view to the eventual reintroduction of the species into preferred habitats by undertaking detailed landscape analyses in selected **mitika** habitats;
(2) to demonstrate to the Anangu that the next stage in the rabbit control program in the National Park, that is, the reintroduction of **mitika** and other Tjukurpa species such as **nganamara** (mallee fowl) and **waru** (possum), was being given serious consideration;
(3) to encourage the active collaboration of the local Aboriginal community at Mutitjulu so that their corporate knowledge could be accessed, recorded and incorporated into reintroduction plans; and
(4) to ultimately develop appropriate decision-support systems based on robust models of the region's landscape ecology and hydrogeology.

Landscape Analyses in Mitika Habitats

Detailed landscape analysis (Tongway 1991) was undertaken at several representative **mitika** sites near Uluru and Kata Tjuta where warrens were selected on the basis of morphological integrity (see Fig. 1) and after classifying according to classes described elsewhere (Noble 1993), their positions were recorded using GPS and relevant features of their habitat geology noted. Topographic profiles of transects running through the middle of warrens, as well as parallel control transects adjacent to individual warrens, were constructed from data collected using a dumpy level (± 1cm) (Figs 2 and 3). At some sites, herbage density and compositon, together with the precise disposition of surface obstruction elements using a point-centred quarter technique, were also measured above and below the warren. Soil samples were also

Figure 1(a). **Mitika** class I warren near Kata Tjuṯa (UTM 678 113, 7208 226) showing exposed calcrete and characteristic perimeter mound.

Figure 1(b). **Mitika** class II warren (UTM 678 814, 7208 659) with more subdued surface morphology at Kata Tjuṯa.

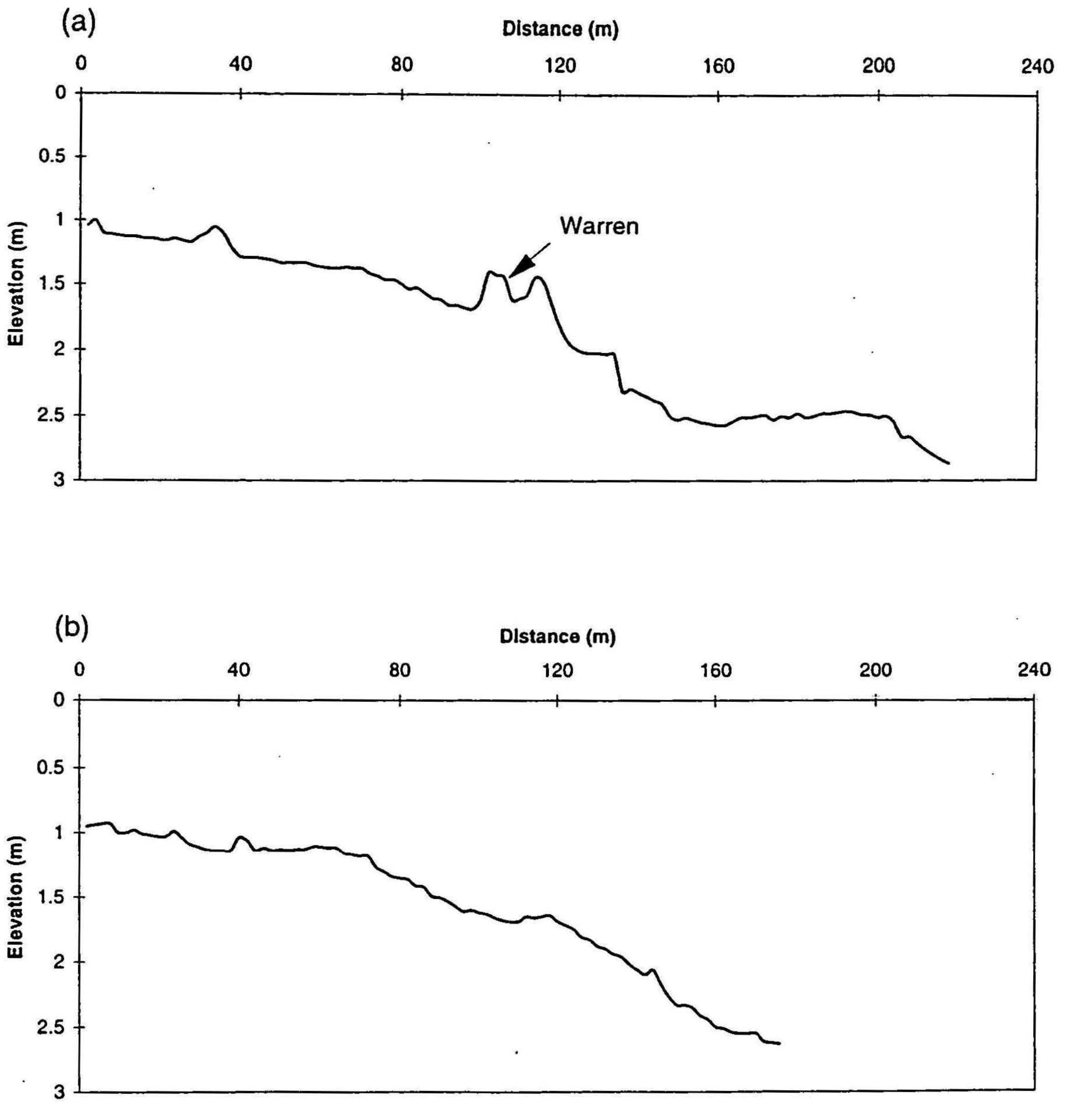


Figure 2. Topographic profiles for (a) the warren and (b) adjacent control transects recorded at the **mitika** site shown in Figure 1(b).

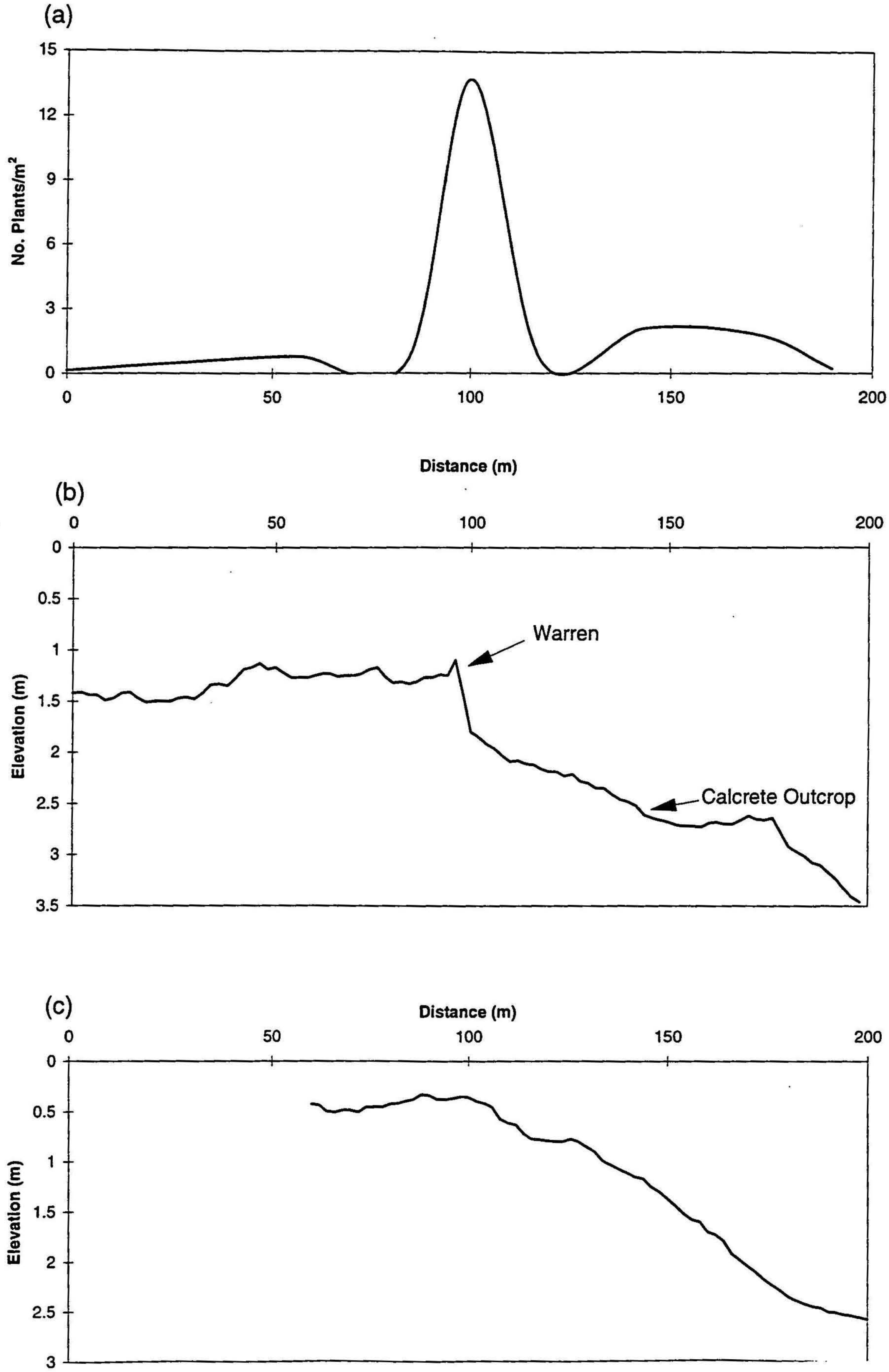


Figure 3(a). Variations in herbage density along the transect passing through the centre of a ripped warren at Kata Tjuṯa near Vegetation Site 8 indicating high plant density in the original warren site; (b) topographic profile of the same transect; and (c) profile of control transect parallel to that shown in (b).

taken at two depths (0-2 and 2-4 cm) at various points along the transect running through the **mitika** warren to characterise changes in nutritional status by subsequent chemical analysis of pH, electrical conductivity, organic carbon and available nitrogen. In addition, calcrete samples were also taken for subsequent radiocarbon dating. Where appropriate, Anangu elders (especially Norman Tjakaljiri, Billy Wara, Johnny Tjango and Edith Richards) were also interviewed at key sites and their views recorded on tape for later transcription by Greg Snowdon of Uncharted Journeys.

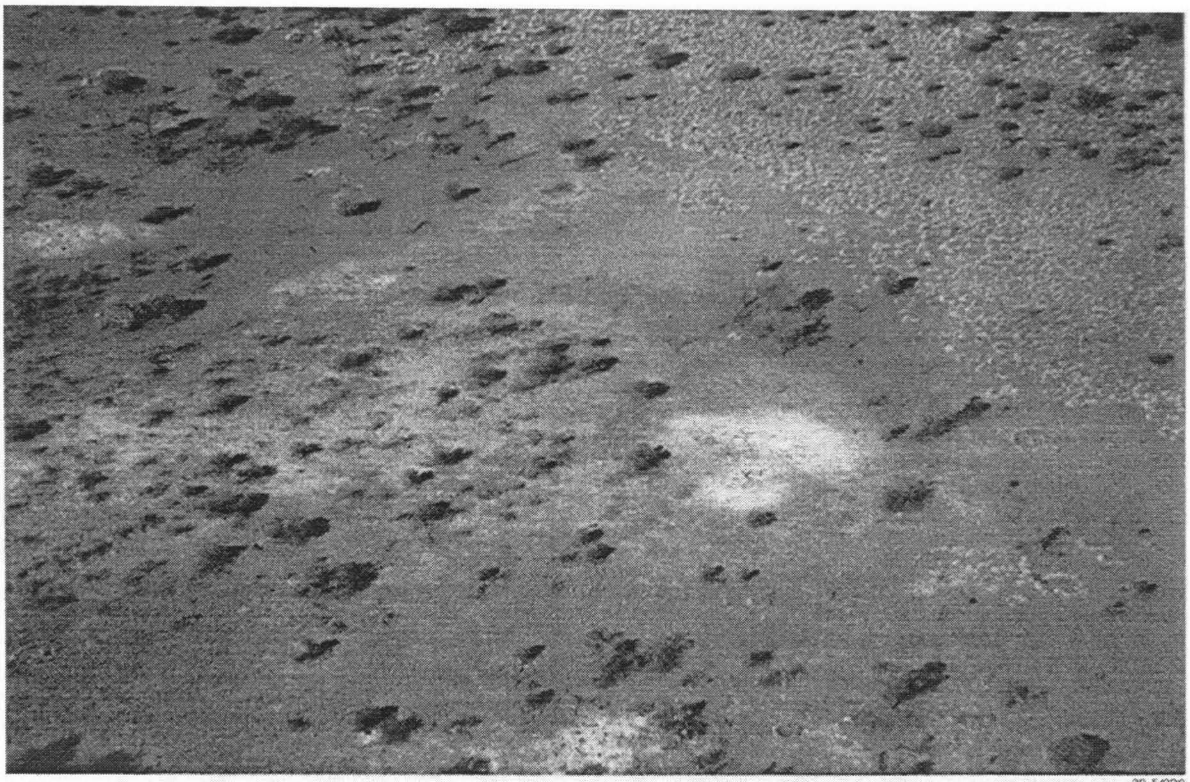
Two elders (NT & JD) accompanied the scientific party on a second field sampling exercise along a transect between Lake Amadeus and Uluru aligned approximately north-south in proximity to a palaeodrainage system. This transect was chosen primarily because it covered several geological habitats along a vadose-phreatic calcrete sequence thereby enabling validation of the hypothesis that well-preserved mitika warrens are closely associated with calcrete-rich landscapes. The transect approximated the route followed by the Horn expedition in 1894 during its journey south to inspect Uluru when they kept mounting ".... one sandhill after another, all covered with tussocks of Porcupine grass, amongst which the kangaroo-rats, *Bettongia lesueur*, kept dodging in and out with remarkable agility" (Spencer 1896, p. 84). Following aerial reconnaissance, further detailed landscape analyses were undertaken at two sites, one at a warren located in gypcrete in a dune adjacent to the southern arm of Lake Amadeus joining Yulara Creek and the other a class I **mitika** warren (UTM 723 158, 7230 872) situated in a depositional calcrete-dominant landscape (evaporational calcrete overlying depositional calcrete) near Bobby's Well (Fig. 4).

RESULTS AND DISCUSSION

These preliminary studies provided further empirical support for the hypothesis that many, if not most, of the rabbit warrens ripped as part of the rabbit control program initiated in 1989 (Low 1989, Low *et al.* 1990), were originally constructed by **mitika**. Detailed landscape analyses based primarily on small-scale topographic surveys, indicated a strong relationship between warren location and a disjunction in the catenary gradient. This nick-point or break in slope was also evident in the parallel control surveys (Figs 2b and 3b) suggesting geologically-mediated control of erosional processes resulting from the precipitation of pedogenic calcrete. Radiocarbon dating of samples collected by one of us (GJ) at the Sedimentaries indicated precipitation of calcrete had occurred on the pediment over a considerable time period ranging from 6-12,000 years BP.

Overall, data including GPS position, class, diameters, total and active rabbit entrances, habitat geology and local vegetation were collected for a total of 38 putative **mitika** sites at Uluru–Kata Tjuta and regional sites and these are tabulated elsewhere (Noble *et al.* 1996). Details of traditional ecological knowledge in relation to **mitika** have also been summarised in that report and a transcript of field discussions has also since been completed.

Mitika warrens, especially unoccupied ones, have also behaved as major obstruction elements in the landscape resulting in the formation of fertile patches immediately upslope of the perimeter mound as well as inside the central depression as demonstrated by the significantly higher levels of soil nutrients in these zones (Noble *et al.* 1996). This increased fertility has, in turn, led to higher plant densities, usually herbaceous plants in the upslope sites (Figs. 3a and 5a) and woody plants inside the central depression site. The results of detailed obstruction analysis at selected sites (undertaken to characterise the local landscape's ability to 'capture' runoff and nutrients) indicated that the density of minor obstruction elements, e.g. wood residues and grass hummocks, was generally higher above the warren



30-5/229

Figure 4(a). Aerial views of the class I **mitika** warren site analysed near Bobby's Well.

30-5/230

Figure 4(b). Ground views of the class I **mitika** warren site analysed near Bobby's Well.

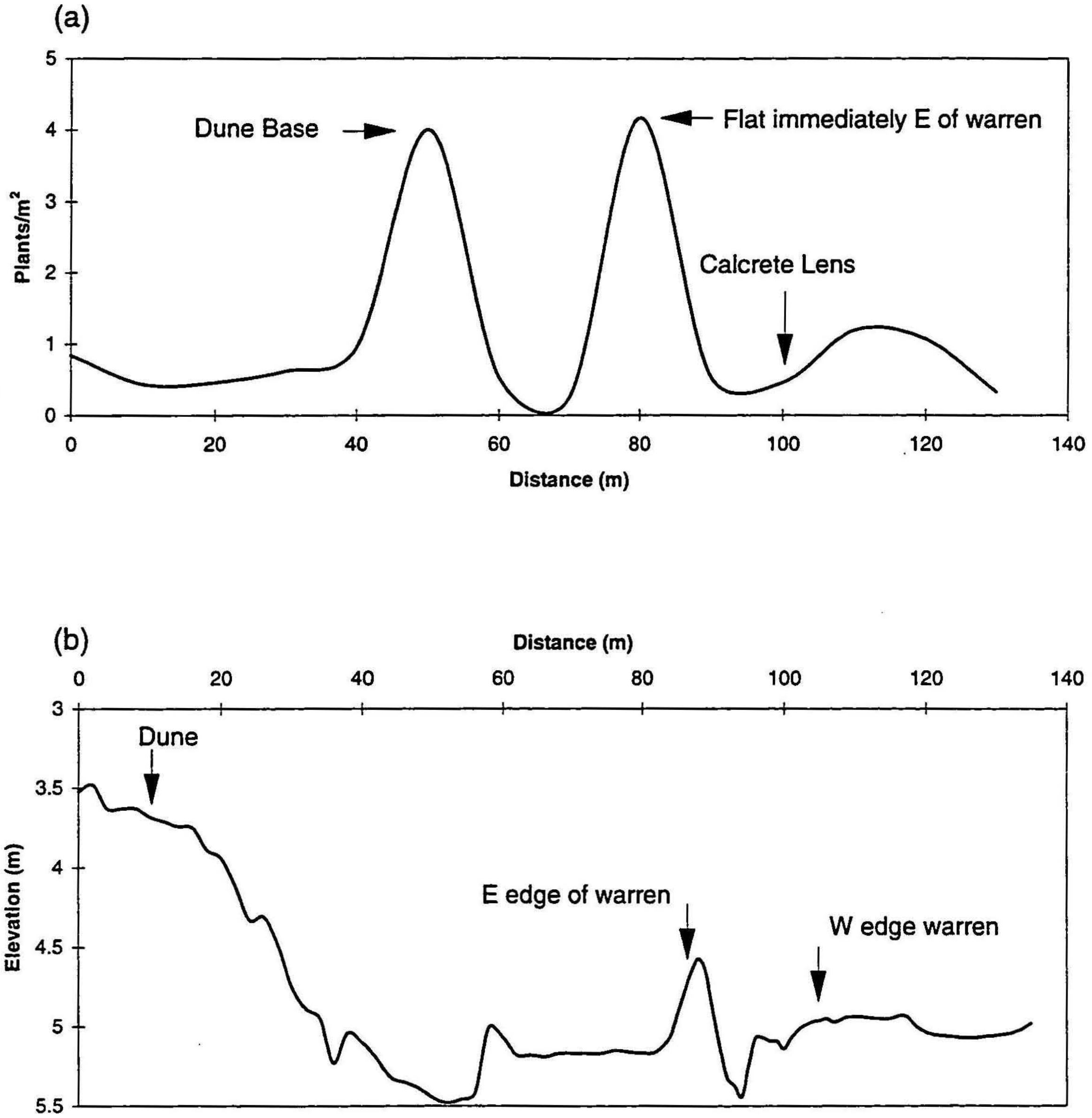


Figure 5(a). Variations in herbage density along the **mitika** transect near Bobby's Well illustrating high density zones at the dune base and immediately adjacent to the warren perimeter mound; (b) topographic profile of the same transect.

although obstruction density overall was site-specific and strongly related to steepness of the gradient.

Given the importance attached by the Anangu to the reintroduction of **Tjukurpa** fauna into Uluru–Kata Tjuta, it seems only a matter of time before such activities are given the necessary scientific and funding support. Although the studies outlined in this paper are by no means definitive, there is now a basic understanding emerging in regard to **mitika** habitat ecology. Such information, when applied with the experience gained from current reintroduction projects underway elsewhere (Short and Smith 1994), together with the emergence and application of appropriate predator-prey models (Sinclair *et al.* in press), suggest such initiatives should ultimately have a reasonable probability of success. Subsequent exploitation for either commercial (e.g. ecotourism) or cultural (e.g. **Tjukurpa**, traditional food etc.) purposes, is a fundamental issue to be resolved in dialogue with the Anangu before self-sustaining **mitika** populations have been re-established.

ACKNOWLEDGMENTS

We wish to acknowledge the support and encouragement provided by the following people: Bob and Pat Barber, "Mt Skinner" Station; Dennis Matthews, Finke Gorge National Park; Bob and Marie Purvis, "Atartinga" Station; and Peter Severin and staff, "Curtin Springs" Station, for allowing access and assisting in the location of **mitika** sites; Graham Griffin and Craig James, CSIRO Alice Springs for helpful discussions and logistical support; and finally Norman Hindley (chemical analysis of soils), Gil Pfitzner (preparation of figures), and Liz Poon (photographs), all with CSIRO Wildlife and Ecology at Canberra.

****

References

Baker, L.M. & Mutitjulu Community, 1992. Comparing two views of the landscape: aboriginal traditional ecological knowledge and modern scientific knowledge. Rangeland Journal, 14, 174-89.

Baynes, A. & Baird, R.F., 1992. The original mammal fauna and some information on the original bird fauna of Uluru National Park, Northern Territory. Rangeland Journal, 14, 65-91.

Beckmann, R., 1990. Bringing back the bettongs. Ecos, 65, p32.

Burbidge, A.A., 1988. Burrowing bettong *Bettongia lesueur*. In: Strahan, R., (editor) The Australian Museum complete book of Australian mammals. Angus and Robertson, Sydney, 187-9.

Burbidge, A.A. & McKenzie, N.L., 1989. Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. Biological Conservation, 50, 143-98.

Christensen, P. & Burrows, N., 1994. Project desert dreaming: experimental reintroduction of mammals to the Gibson Desert, Western Australia.In: Serena, M., (editor) Reintroduction Biology of Australian and New Zealand Fauna. Surrey Beatty & Sons, Chipping Norton, 199-207.

Finlayson, H.H., 1958. On central Australian mammals (with notice of related species from adjacent tracts). Part III - the Potoroinae. Records of the South Australian Museum, 13, 235-302.
Grattidge, A., Low, W.A., Smith, C.E. & Cook, J., 1996. Uluru–Kata Tjuta National Park rabbit control project: warren monitoring and fumigation. Results for year seven November 1995, and a brief evaluation of the program. Report to the Australian Nature Conservation Agency (unpublished).
Holling, C.S., 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. Ecological Monographs, 62, 447-502.
Jacobson, G. & Arakel, A.V., 1987. Calcrete aquifers in the Australian arid zone. Proceedings of International Conference on Groundwater Systems Under Stress, Brisbane, 1986, Australian Government Publishing Service, Canberra.
Jacobson, G., Lau, G.C., McDonald, P.M. & Janowski, J., 1989. Hydrogeology of the Lake Amadeus–Ayers Rock Region, Northern Territory. Bureau of Mineral Resources, Australia, 230.
Johnson, K.A., Burbidge, A.A. & McKenzie, N.L., 1989. Australian macropods: status, causes of decline, and future research and management. In: Hulme, I., Grigg, G. & Jarman, P., (editors) Kangaroos, Wallabies and Rat-Kangaroos. Surrey Beatty & Sons, Chipping Norton, 641-57.
Low, W.A., 1986. The disappearance of mammal species from pastoral areas of central Australia: a land management problem? In: Joss, P.J., Lynch, P.W. & Williams, O.B., (editors) Rangelands: a resource under siege. Australian Academy of Science, Canberra/Cambridge University Press, Sydney, 551-2.
Low, W.A., 1989. Uluru National Park rabbit control project, vegetation monitoring. Report to Australian National Parks and Wildlife Service (unpublished).
Low, W.A., Smith, C.E., Latz, S. & May, O., 1990. Uluru National Park rabbit control project - warren fumigation. Year two, December 1990. Report to the Australian National Parks and Wildlife Service (unpublished).
Low, A.W., Grattidge, A., Smith, C.E., Eldridge, S.R., Ryan, W. & Gillen, J., 1995. Uluru–Kata Tjuta National Park rabbit control project: warren monitoring and fumigation. Report to Australian Nature Conservation Agency (unpublished).
Morton, S.R., 1990. The impact of European settlement on the vertebrate animals of arid Australia: a conceptual model. Proceedings of the Ecological Society of Australia, 16, 201-13.
Morton, S.R. & Baynes, A., 1985. Small mammal assemblages in arid Australia: a reappraisal. Australian Mammalogy, 8, 159-69.
Myers, K. & Parker, B.S., 1965. A study of the biology of the wild rabbit in climatically different regions in eastern Australia. CSIRO Wildlife Research, 10, 1-32.
Nelson, L.S., Storr, R.F. & Robinson, A.C., 1992. Plan of management for the Brush-Tailed Bettong, *Bettongia penicillata* (Gray 1837) (Marsupialia, Potoroidae) in South Australia. National Parks and Wildlife Service, Department of Environment and Planning, South Australia.
Noble, J.C., 1993. Relict surface-soil features in semi-arid mulga *Acacia aneura* woodlands. Rangeland Journal 15, 48-70.
Noble, J.C., 1995. Bettong (*Bettongia* spp.) biocontrol of shrubs in semi-arid mulga *Acacia aneura* rangelands: an hypothesis. In: Page, M.J. & Beutel, T.S., (editors) Ecological Research and Management in the Mulgalands. University of Queensland Gatton College, Australia, 139-46.

Noble, J.C., 1996. Mesomarsupial ecology in Australian rangelands: burrows, bettongs (*Bettongia* spp.) and biocontrol of shrubs.In: West, N.E. (editor) Rangelands in a Sustainable Biosphere. Proceedings of the 5th International Rangeland Congress, Salt Lake City, Utah. Society for Range Management, Denver, 395-6.

Noble, J., Low, W., Jacobson, G. & Gillen, J., 1996. Distribution and abundance of relict warrens constructed by the burrowing bettong (*Bettongia lesueur*) at Uluru–Kata Tjuta National Park. Report to the Australian Nature Conservation Agency, Project DN70 (unpublished).

Shaw, R.D., Warren, R.G., Kopras, J. & Green, D.E., 1975. Alcoota 1:250,000 Geological Map. Bureau of Mineral Resources, Canberra.

Short, J. & Turner, B., 1993. The distribution and abundance of the burrowing bettong (Marsupialia: Macropodoidea). Wildlife Research, 20, 525-34.

Short, J. & Smith, A., 1994 Mammal decline and recovery in Australia. Journal of Mammalogy, 75, 288-97.

Short, J., Turner, B. & Majors, C., 1989. The distribution, relative abundance, and habitat preferences of rare macropods and bandicoots on Barrow, Boodie, Bernier and Dorre Islands. Final Report to the National Kangaroo Monitoring Unit, Australian National Parks and Wildlife Service. CSIRO, Midland.

Short, J., Bradshaw, S.D., Giles, J., Prince, R.I.T. & Wilson, G.R., 1992. Reintroduction of macropods (Marsupialia: Macropodoidea) in Australia - a review. Biological Conservation, 62, 189-204.

Sinclair, A.R.E., Pech, R.P., Hickman, D., Mahon, P. & Newsome, A.E., in press. Predicting effects of predation on conservation of endangered prey. Conservation Biology.

Spencer, B., (editor), 1896. Report on the work of the Horn scientific expedition to central Australia, Parts 1-4. Melville, Mullen and Slade, Melbourne.

Tongway, D.J., 1991. Functional analysis of degraded rangelands as a means of defining appropriate restoration techniques. In: Gaston, A., Kernick, M. & Le Hou②rou, H., (editors) Proceedings of the 4th International Rangeland Congress, 22-26 April 1991, Montpellier, France. Service Central d'Information Scientifique et Technique, Montpellier, 1, 166-8.

Wells, A.T., Forman, D.J., Ranford, L.C. & Cook, P.J., 1970. Geology of the Amadeus Basin, central Australia. Bureau of Mineral Resources, Australia, Bulletin 100.

World Conservation Monitoring Centre, 1992. Global Biodiversity: Status of Earth's Living Resources. Chapman and Hall, London.

Fire and Striated Grasswrens in Uluṟu–Kata Tjuṯa National Park

Lynn Pedler[1]

[1] PO Box 41, Parndana SA 5220.

Knowledge of Striated Grasswrens *Amytornis striatas* is at an early stage, both in understanding many aspects of their ecology in central Australia and elsewhere, and in central Australia, assessing their use as environmental indicators, in particular for monitoring the benefits/impacts of traditional burning practices on biodiversity.

Striated Grass areas are cryptic, sedentary, ground dwelling birds occupying *Triodia* habitats. The species has a wide but patchy range in sandplain from the Murray Mallee and northern Eyre Peninsula, through north-western South Australia, parts of the Northern Territory and far western Queensland and west to the Pilbara region. In the Flinders Ranges and Pilbara region distinctive forms occur in rocky habitats. The nominate sandplain form varies in dorsal colour, matching the substrate - brownish in the Murray Mallee to rich rufous in central Australia. The substrate is also harder in southern areas so it is advantageous to study central Australian populations of this grasswren where long series of tracks produced can be used to locate the birds. In other areas it is usually necessary to rely on hearing calls or playing tape recorded song to elicit a response. Use of tracks makes it possible also to identify areas which are not occupied as well as being helpful in determining preferred habitats and home ranges.

In at least some regions the species is considered rare. It has declined through habitat clearance and fragmentation and possibly habitat senescence in agricultural areas. The few records from central Australia certainly give the impression of rarity and in many areas of apparently suitable habitat (such as in Uluṟu–Kata Tjuṯa N.P.) they do indeed have a sparse patchy distribution. There are probably many localities where their presence is overlooked because of both, cryptic behaviour and general lack of ornithological survey in suitable habitat by workers familiar with the species. Notable are several reports in recent years in north-western South Australia, confirming that scattered populations (at least) still exist in a region where there have been very few historical reports.

The primary purpose for investigating *Amytornis striatus* in Uluṟu–Kata Tjuṯa N.P. was to ensure that populations were not inadvertently eliminated during managed burning of *Triodia* habitats, following traditional A̲nangu practices. Only one localised population was found during the 1988 biological survey, so locating other populations was a priority. Habitat and fire age classes used were determined to assist longer term management.

The author spent 19 days in August 1991 searching *Triodia*/sandplain in Uluṟu–Kata Tjuṯa N.P. covering approximately 300km on foot in that period. The range of fire age classes for each vegetation type was dominated by mature 1976 burnt (15 year old) areas with relatively small areas of more recently burnt country available (notably 6-14 y.o. habitats) and large gaps in representation of older habitat.

Grasswrens were seen or heard at 9 locations including the 1988 biological survey site. At a further 10 sites tracks were most likely to have been made by additional grasswren groups. Apart from one area of tracks south-east of Kata Tjuṯa, sites were scattered in the eastern portion of the park. Soft spinifex *Triodia pungens* areas with *Grevillea* and *Acacia* shrub thickets were used except at the westernmost confirmed location near the borefields where grasswrens used hard spinifex *T.basedowi* and mixed hard and soft spinifex with shrub thickets.

Many areas in a range of habitat types including mallee areas appeared structurally suitable for grasswrens but had no grasswren like tracks. Very little evidence of use of long unburnt (>40 years post fire) country was found and that was in areas patchily burnt 5 and 15 years previously.

Most observations and tracks were in 15 year old habitat and the three nests found were built into the tops of 15 year old *Triodia pungens* clumps. Notable however was that one of those nests was in a tiny unburnt remnant within habitat burnt 5 years previously. At another site, grasswrens remained in shrub thickets in 5 y.o. habitat, though older unburnt remnants were available nearby. Most of the 15 y.o. habitat used by grasswrens adjoined or included patches burnt 1-5 years previously and shrub thickets or dense mature *Triodia* provided cover, with tracks showing foraging up to 50m into patches burnt less than a year previously.

It is clear, even from the limited sites known, that grasswrens will occupy habitat as young as 5 years post-fire and use even younger areas where these adjoin mature habitat. Clearly the species is able to use patchily burnt country as well as extensive uniform aged mature habitat, however in 1991 it was difficult to find large areas of uniform aged habitat, so it is unclear whether use of edges and patchily burnt country is in artefact of what was available or a preference for patchiness. A major factor influencing whether grasswrens use younger habitats appears to be availability of cover into which to retreat when alarmed This may be either regenerating shrub thickets as in 5 y.o. habitat observed, or unburnt remnants of mature vegetation. In older open habitats, dense areas of low shrubs such as *Thryptomene* provide cover.

Recommendations for habitat management, following the brief 1991 survey still apply, until more information is available. Patch burning areas adjacent to known grasswren populations will provide some protection from extensive wildfire in the short term while providing regenerating habitat which can be occupied within several years. Patchy, intricate burn patterns will allow earlier use of such areas (i.e. even within one year) and are more likely to ensure survival of existing fauna including grasswrens in unburnt remnants.

A managed burn observed in 1991 continued overnight and resulted in a relatively clean burn over a larger area than planned, including a site containing grasswrens, and none were found in small remnants or adjacent country next day. While it may be argued a "firebreak" rather than "managed habitat" was achieved in this case grasswrens were again found adjacent to this site in early 1997 (J.Gates *pers. comm.*) perhaps having originated from other known populations nearby.

Further Work

Clearly further monitoring is needed to determine whether the patch burning program, continues to remove grasswren populations or to maintain or enhance their habitat. Now that a greater age range of habitats is available this monitoring will more accurately define the species habitat preferences. Searching at and near sites found in 1991 will determine the species persistence in the presence or absence of fire.

Simply defining presence/absence of grasswrens using tracks, calls and sightings may be a useful indicator of the effectiveness of managed burning for maintaining diversity of *Triodia* habitats. However more detailed population study will enable much better understanding of the species response to fire and habitat age. Little is known of population density, home ranges, site fidelity, dispersal of young, fate of birds in fire events and size of remnants needed to support populations.

Because of difficulty observing grasswrens, radiotelemetry is likely to be useful in conjunction with colour banding individuals and monitoring tracks. Periodic monitoring of populations in a range of habitat classes and investigating fate of birds in areas burnt with varying intensity are useful areas for further work and could be integrated with monitoring other species occupying those habitats. Integrated monitoring may reveal whether grasswrens have similar cycles of abundance to other species in response to seasonal and fire events or a unique pattern which may need specialised management.

Traditional Knowledge

Anangu know grasswrens as "miriliriyirilyi", apparently including both sandplain inhabiting *A.striatus* and rock inhabiting *A.purnelli* as well as the three *Malurus* species found in the region within this name which is onomatapaeic for the calls for the White winged FairyWren *M.leucopterus*. However during 1991 an Anangu ranger showed her direct knowledge of *A.striatus* habits by using concentrations of tracks to locate an active nest. *A.striatus* is more terrestrial than other sandplain malurids and lends itself to tracking in this region. Apart from knowledge of their habits and stating that they (wrens and grasswrens?) were "all over" (i.e. widespread) there appears to be no cultural significance attached to these small birds.

Tourism

Potential for adverse human impact on grasswrens appears limited through relatively minor use of sandplain areas by tourists. Grasswrens appear well adapted to patchy habitat so structures such as roads are unlikely to be significant problems. Few visitors are likely to seek out the species, however public use of taped calls should not be encouraged as repeated or prolonged use may have adverse impact on local populations.

Other Birds

Several sedentary bird species have not recently been recorded or are uncommon in Uluru–Kata Tjuta N.P. and knowledge of the location and habitat needs would be useful for land managers. Species such as Rufous crowned Emuwren recorded prior to 1976, but not found since, can be searched for while monitoring grasswrens. Others such as Chestnut breasted Quailthrush or Whitebrowed Treecreeper occupy different habitats and would need to be specifically sought.

Uluru–Kata Tjuta surveys: baseline, monitoring, long-term research, new lines of inquiry and management implications

Julian Reid[1]

[1] CSIRO Wildlife & Ecology, PO Box 84 Lyneham 2602.

Introduction

A brief history of vertebrate survey research conducted on Uluru–Kata Tjuta National Park (UNP) over the past 10 years is presented. The major results of the research along with their management implications are summarised. While always having been applied to the needs of wildlife management, the research has progressed from inventory survey to monitoring. Largely with the benefit of hindsight and the literature, a planning, research, monitoring and management framework tailored to natural-resource research for management in sizeable arid Australian conservation parks is proposed. Finally, two serious wildlife conservation issues are highlighted, both associated with mass tourism and its potential impacts. The role that future research might play in the resolution of associated conflicts between tourism and wildlife conservation interests is evaluated. Comments from Jim Noble and Irene Guijt have improved the manuscript, but the idisosyncratic structure and content remain my own, tailored as they are to the workshop rather than a general audience.

In 1987 the Australian National Parks and Wildlife Service (now Parks Australia, PA) and CSIRO Wildlife and Ecology commenced a three year survey of the vertebrate fauna of UNP. In consultation with traditional owners eight survey sites were selected for repeat sampling (Fig. 1). Seven samples from each site were obtained using standard trapping and censusing procedures for birds, reptiles and terrestrial small mammals. The sites represented the range of major habitats on the park and incorporated considerable within-site variation with respect to fine-scale topography, fire history and vegetation. Twice yearly consultancy reports were compiled for PA including detailed final reports: Kerle & Morton (1988); Reid & Morton (1989); Reid *et al.* (1991); Reid *et al.* (1993). The integration of traditional ecological knowledge (TEK) with western scientific approaches was a feature of the survey's design and implementation, and Anangu were involved strategically and operationally at all stages (Baker & Mutitjulu Community 1992; Baker *et al.* 1992, 1993; Reid *et al.* 1992). Wide ranging recommendations on wildlife and landscape management were presented as were directions for future research. Some of the survey's (western) ecological findings with implications for management are summarised in this report.

Reid *et al.* (1993) endorsed the directions of wildlife management taken by UNP's Board of Management and staff, particularly with respect to visitor management, vigorous pursuit of the patch burning strategy, rehabilitation of disturbed sites and targeted research. In recognition of the World Heritage stature of the park and of potential impacts of mass tourism, Reid *et al.* (1993) recommended that monitoring of the park's vertebrates would be advisable and that the established sites could be used for repeat surveys at three-year intervals. Accordingly CSIRO was engaged to resurvey the vertebrate fauna in early and late summer 1994/95 (Reid & Hobbs 1996). Six of the eight original sites were resurveyed and two new sites were established to sample distinctive environments not included in the original survey (Fig. 1, Table 1).

The resurvey was conducted towards the end of a prolonged dry spell, but despite the adverse conditions virtually the entire sweep of resident vertebrate fauna was detected including all the species of mammal and reptile identified by Reid *et al.* (1993) as having high priority for monitoring and conservation. An initiative taken in the 1995 survey was to survey terrestrial invertebrates caught in the pitfall traps used for vertebrates (Yen *et al.* 1996). A rich invertebrate fauna was revealed of mostly undescribed species. Just how rich the invertebrate fauna of the park may be, can only be guessed at without at least a second comparable survey. Partly for this reason it was recommended that a second combined invertebrate and vertebrate survey be conducted after the dry seasons broke. Such a survey commenced shortly after this workshop was held. Some spatial complexities and contrasts in the manner in which plant, different invertebrate and vertebrate assemblages are distributed across Uluru are briefly presented.

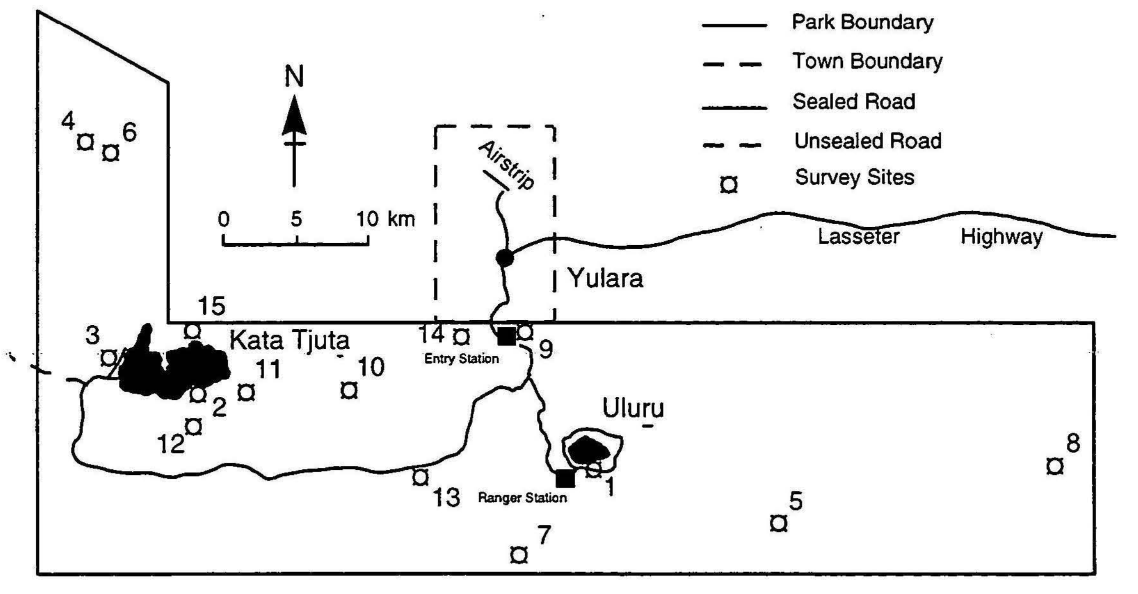


Figure 1. Map of Uluru–Kata Tjuta National Park showing location of fauna survey sites

Table 1. Brief habitat descriptions of survey sites. Sites 14 and 15 were established in 1994/95 in the monitoring phase of research. Sites 1-8 were sampled seven times, 1987 - 1990. * Sites used for monitoring in 1994/95 and 1997.

Site #	Substrate	Landform	Dominant Vegetation
1*	Hard	Monolith & Fan	Bloodwood, perennial tussock grasses
2	Hard	Monolith & Fan	Varied
3	Hard	Foothills & Fan	Bunch grass, *Ptilotus*, some mulga
4*	Hard	Gently sloping plain	Mulga
5*	Soft	Dunefield	Soft spinifex, desert oak
6*	Soft	Dunefield	Hard spinifex
7*	Soft	Dunefield	Mallee, mulga, soft spinifex
8*	Soft	Dunefield	Sandhill mulga, mulga, soft spinifex
9	Soft	Dunefield	*Plectrachne*

Table 1 (Continued). Brief habitat descriptions of survey sites. Sites 14 and 15 were established in 1994/95 in the monitoring phase of research. Sites 1-8 were sampled seven times, 1987 - 1990. * Sites used for monitoring in 1994/95 and 1997.

Site #	Substrate	Landform	Dominant Vegetation
10	Soft	Sandplain	Mixed spinifex, desert oak
11	Soft/Hard	Dune & Fan	Soft spinifex, bunch grass, mulga
12	Soft	Sandplain	Soft spinifex, desert oak
13	Soft	Dunefield	Mallee, mulga, soft spinifex
14*	Soft	Sandplain	Hard spinifex
15*	Hard	Watercourse & Fan	Red gum, titree, mulga

Fauna Survey's Major Findings with Implications for Management 1.

Spatial Distribution Patterns - Assemblage Composition

Small mammals and reptiles observe a major distinction between habitats with 'hard' substrates and sandy or 'soft' soils. Given knowledge of soil type, and successional state in the case of spinifex dominated landscapes, assemblage composition can be reliably predicted. This is a general rule, there are important variations and it does not apply as well to birds, but the distinction is major: the ground-dwelling faunas of these two contrasting environments are quite different and consistently so. Furthermore, sandy spinifex environments are consistently more species rich, particularly in lizards, than hard sites for these two vertebrate groups. This knowledge is important to managers as it allows for simple yet valid habitat models and maps to be constructed and communicated; they apply to a large section of the park's vertebrate fauna. The ground fauna of alluvial fans adjacent to the monoliths is similar to that in the distant mulga plains, while 'spinifex is spinifex' in one respect- it is immaterial whether the species is *Triodia pungens, T. basedowii* or *Plectrachne*, the faunal assemblage will be much the same. If the spinifex cover is razed by fire the composition changes dramatically but again reasonably predictably (Masters 1993, 1996; Reid *et al.* 1993).

Due to topographical constraints and to protect important cultural sites, the actual monolithic landforms could not be surveyed independently of surrounding fans; yet there are distinctive reptile, mammal and bird species tied to these landforms, particularly in the larger heterogeneous Kata Tjuta complex. In reality, therefore, there may be three distinctive faunal habitats that correspond broadly with Allan's (1984) recognition of three land systems: Gillen (monoliths, screes and adjacent fans), Karee (mulga plains) and Simpson (sandplain and dunefield). The matching is only partial, however, as lizards and small mammals of the fans (Gillen) are basically those of the mulga plains and lower fans (Karee) once the saxicoline (rock-dwelling) species drop out.

The distribution of birds is controlled largely by the dominant taller perennial vegetation, and spinifex does not play a direct role except for a few species. It is the tight relationship between most bush birds and the taller shrub and tree component of their habitat that causes the breakdown of the simple dichotomy - hard vs soft substrates - described above. At two of the soft sites mulga *Acacia aneura* is prominent and, despite spinifex cover being greater, this is sufficient for the bird assemblages there to resemble a typical mulga bird community (e.g. Cody 1994) more so than the impoverished bird community typically associated with sandy spinifex landscapes with few emergent taller shrubs and that occurs at Sites 5 and 14. At Site 6, another soft site, though mulga is not prominent within its confines, there are adjacent stands of mulga. The spillover of birds from the mulga tall shrublands onto the site is sufficient to 'pull' this avian assemblage towards a mulga bird community, as evidenced in ordination analyses (Fig. 2). Again in contrast to reptiles, the bird assemblages at the four sites around the monoliths (Sites 1, 2, 3, 15) are different to both mulga and spinifex environments. This appears to reflect the enhanced productivity of the run-on vegetation adjacent to the monoliths as much as particular avian preferences for rocky environments though there are a few species that fall into the latter category.

Not all spinifex is spinifex however! The distinctive fauna of the tract of transitional sandplain around the Yulara Bores (YBTSP) along the northern boundary of the park is well documented (Masters 1993, 1996, 1997; Reid *et al.* 1993; Foulkes *et al.* 1995; Reid & Hobbs 1996; McAlpin 1997). A great deal of research effort has now probed the underlying biophysical causes of this area's distinctiveness, and is the focus of several other presentations in the forum. Suffice to mention here that two additional fauna sites were deliberately located in other areas of sandplain and, though only surveyed once, were found to support small mammal and reptile asemblages more akin to the park's widespread dunefield landcsapes than this particular location. Because the Yulara Bores habitat lacks substantial shrubs and has scant emergent trees, birdlife there is distinctive only in its dullness and poverty.

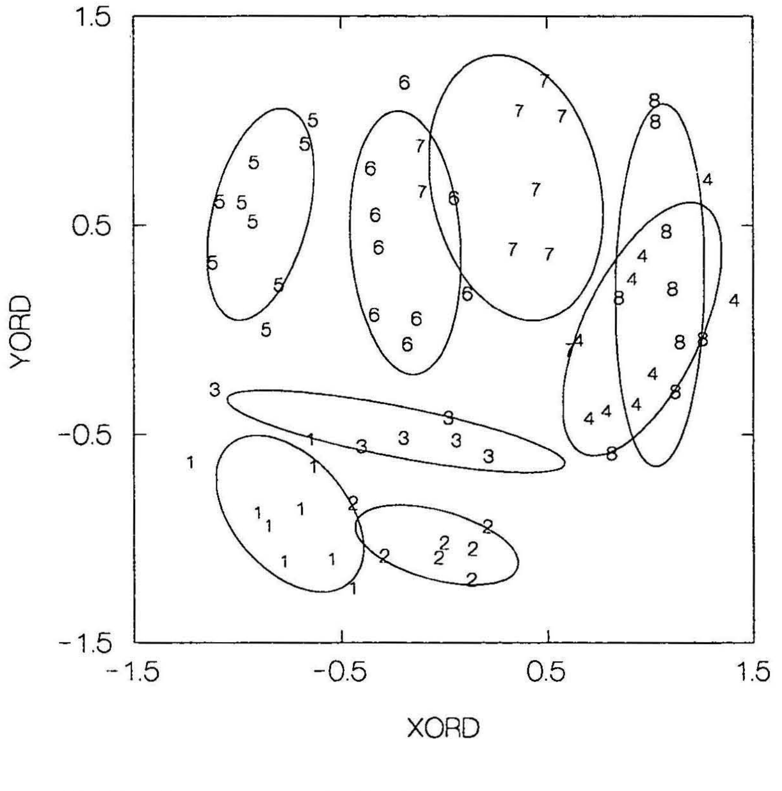


Figure 2. Ordination of multiple bird community samples at Sites 1-8.
Note the pull of Site 6 samples towards the mulga-dominated samples of Sites 4, 7 and 8.

Fauna Survey Major Findings with Implications for Management 2.

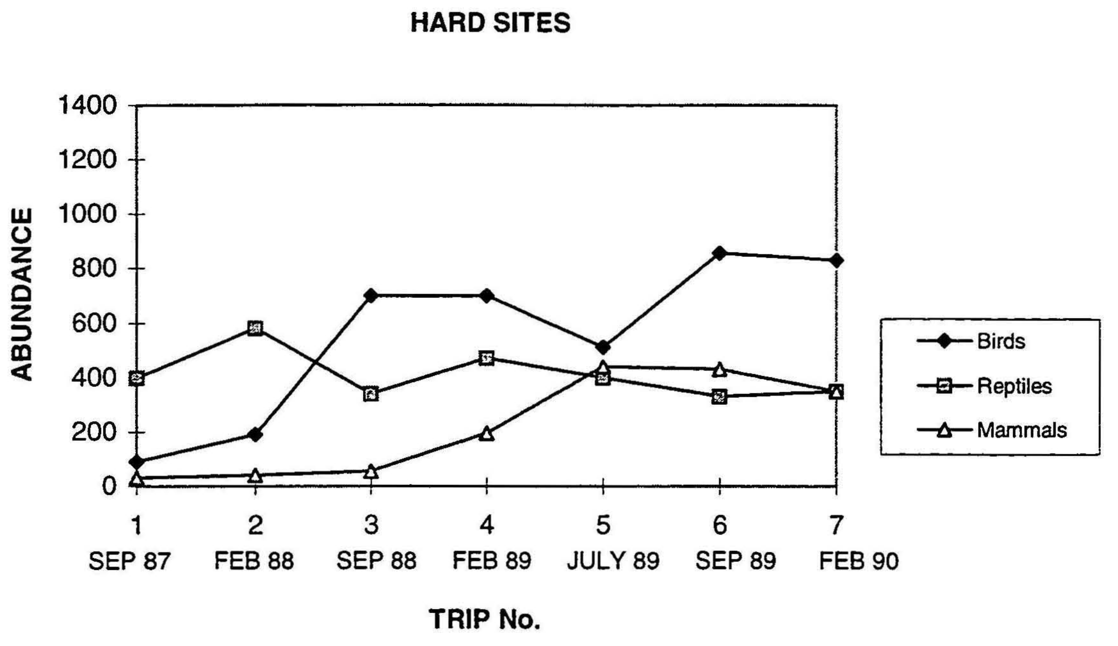
Temporal Patterns - Community Dynamics

Under the model conceptualised by Morton (1990) and Stafford Smith & Morton (1990) for the ecological functioning of arid Australia, the redistribution of water and nutrients is a critical process in determining characteristic patterns of wildlife distribution and dynamics. This redistribution occurs through above and below ground drainage systems and operates over a range of spatial scales. In particular, the concentration of water and nutrients in certain parts of the landscape, the run-on areas, and their storage in soils (and plant organs) for subsequent biological uptake and activity are considered important but variably so depending on the type of organism. The extremes of boom and bust dynamics can be attenuated by these storage lags and extended periods of production. Biological refugium theory derives from similar reasoning (Morton *et al.* 1995).

Repeated sampling, followed in the original fauna survey, allowed variation through time to be assessed. Empirical support for the conceptual model described above was gained by comparing the dynamics of the bird communities, particularly, at the spinifex sites (largely devoid of the effects of rainfall redistribution) and the run-on sites adjacent to the monoliths. Bird abundance peaked on the spinifex sites in spring 1988 soon after the major drought-breaking rains in Easter 1988, before rapidly declining despite further substantial rains. By contrast bird abundance did not peak at the hard sites until the end of the survey in the summer of 1989/90 (Fig. 3). The avian response at the hard sites was extended and there was a smaller difference between minimum and maximum abundance than at the soft sites. These contrasting patterns were interpreted in the following manner. Avian food resources literally exploded on the soft sites after the torrential Easter rains and a massive immigration of nomadic birds filling diverse trophic niches caused an immediate hike in total abundance. The interesting corollary is that these sites' capacity to respond to further rains, at least in the production of avian resources, appeared spent - much of the previously bare ground was now vegetated and perhaps a period of nutrient limitation was entered, with too many of the local system's nutrients locked up in the abundant plant (and avian) biomass.

The responses by reptile and small mammal assemblages lend only qualified support to the above interpretation. Peak abundances in both groups at the soft sites were higher than at hard sites, and so accordingly temporal variability was greater given the similar minimum abundances (across all three vertebrate groups). Reptile activity/abundance increased markedly in spring 1988 at and consistently across the four soft sites, and was still moderately high in that same 'summer' period in early 1989. Activity on the hard soils varied among sites, but overall when averaged showed little variation in capture rates across the survey's duration. There was not the gradual increase in reptile activity on hard sites shown by birds. While small mammals did exhibit a gradual increase, this pattern was virtually identical at the soft sites (Fig. 3) - only the amplitude was greater on soft sites. Because the rodent population boom continued to the final survey, we could not test the proposition that rodent abundance remained higher on the hard sites for longer. Finally, although reptile species richness was generally almost twice as high on soft sites, the number of reptiles captured averaged slightly higher at the three monolith sites. Provided trapping rates index activity and abundance uniformly among habitats, reptile biomass is probably much higher in these environments, because species found on the hard sites are typically larger than their close relatives in spinifex habitats.

A longer period of research than the three years allotted to the original survey would have provided additional insights such as the timing of the decline of the rodent boom in



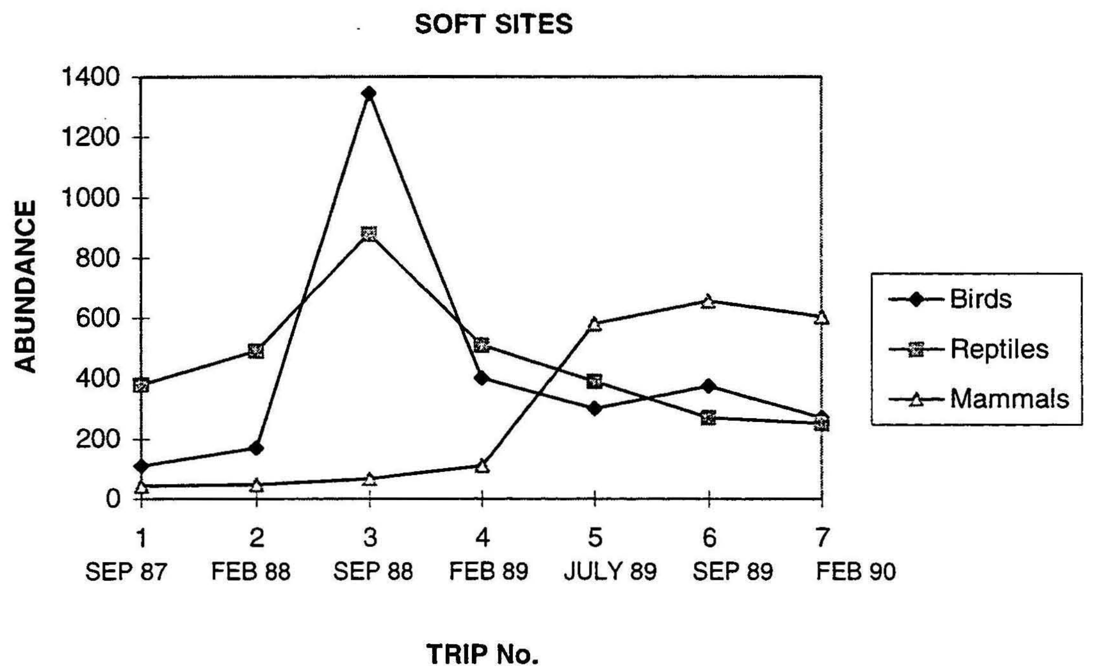


Figure 3. Comparison of relative abundances of three vertebrate groups at Hard and Soft Sites over the three year survey period.
Abundances refers to, averaged per site: total number of all birds counted; number of reptiles pit-trapped (X 10); number of small mammals captured per 1000 Elliott-trap nights.

different environments. While the value of long-term research in highly unpredictable arid Australian environments is again emphasised, sufficient evidence in support of the 'landscape functioning model' was obtained to direct management attention to the following:

1. run-on areas are ecologically distinctive and probably critical habitat for the persistence of certain species and functional groups;
2. accurate mapping should be undertaken to identify areas of greatest water and nutrient accumulation;
3. these areas, in turn, should be the focus of integrated pest plant and animal control, tourism management (with possible exclusion zones), rehabilitation works and reintroduction programs.

Tests of Spatial Structures Across Taxonomic Assemblages

It is logistically infeasible and we hope unnecessary to manage a park the size of UNP on an individual patch by patch basis. Therefore, park managers need landscapes classified into habitats or other environmental strata, so that they can develop more generic but still habitat-specific management strategies. A major challenge for ecologists and park managers then is to disentangle their perceptions of a landscape and component habitat types from other valid, alternative, and perhaps more useful landscape classifications. Different types of organisms will be distributed across a single landscape in different ways. Human size and eyesight characteristics may lead to semi-intuitive land classifications that are constrained towards a particular range of scales: hundreds of metres to tens of kilometres most likely. The actual scale will vary from one situation to the next for a wide range of reasons, but including:

- the extent of surveyed area;
- the vantage point, e.g. ground, light aircraft or map;
- the management objectives;
- budgetary and knowledge limitations;
- the particular taxon being studied.

Taking the last point, an insect ecologist will tend to operate at smaller scales, big game researchers at larger scales and so on. Therefore, while certain scale distinctions can be appreciated, there could still be a tendency for an erected landscape classification to be treated as the sole spatial reality rather than as a hypothesis or as just one of several valid models of distribution. There is a need for objective methods of landscape and habitat classification, and for tests of various landscape and other spatial effects on the distribution of different biotic groups. The results summarised in the previous two sections illustrated that bird assemblages are distributed differently to other terrestrial vertebrate groups across UNP.

The layout of pitfall trap sites at Uluṟu allowed investigation of two such effects, habitat classification and spatial auto-correlation. Spatial auto-correlation is the increasing likelihood that measurements of biophysical parameters will be similar the closer in space the measurements are taken - self-evident, perhaps, but rarely do ecologists use the information content of the spatial auto-correlation signal (Legendre & Fortin1989; Borcard *et al.* 1992; Burgman & Williams 1995).

Multivariate analysis of reptile data at the 14 individual pitfall sites located in UNP's spinifex dominated landscapes across four survey sites, revealed there were three distinctive reptile assemblages tied to specific habitats, namely dunes irrespective of fire history, early successional flats prior to spinifex becoming prominent, and mature spinifex flats (Reid *et al.* 1993). It is noted that this three-way habitat classification of the regional dunefields accorded well with both western and A<u>n</u>angu researchers' perceptions of these landscapes. Also Master's (1996) study of a lizard community in transitional sandplain supported the division between early successional and mature flats (no dunes in her study area). A randomisation test using the Bray-Curtis community index of dissimilarity was performed to gauge the strength of the habitat structuring influence on the composition of reptile assemblages. The test is based on 'analysis of similarity' (ANOSIM) routines that are non-parametric, multivariate analogues of ANOVA (Clarke 1993; Clarke & Warwick 1994). The result confirmed the robustness of the reptile habitat classification ($P < 0.001$), though it is pointed out that ideally the test needs to be performed on an independent data set. Because of the hierarchical, pitfall site-within-survey site layout of trap sites, a basic test for spatial auto-correlation could be performed using ANOSIM. The results showed that, with habitat and some other complexities accounted for, a spatial auto-correlation effect was not evident. The composition of pitfall-trapped reptile assemblages within 500 m of each other (i.e. on the same survey site) were no more similar to each other than to those 15+ km apart, at least no more similar than would be expected by chance alone with certain potentially confounding factors accounted for. This result was surprising, but the conclusions are tentative because we were restricted to comparisons of faunas across different habitats and because of the complex null models that had to be formulated (with, therefore, inherently low statistical power).

I have examined the floristic and invertebrate data gathered at these same pitfall sites over the summer 1994/95 in a similar manner to investigate the proposition that 'as a first pass' this same three-way classification of the region's dunefields effectively models the habitat for these organisms. Note that terrestrial invertebrates are treated as both a single taxon ('all invertebrates') and subsetted as all ants, all spiders and 'the rest' (all invertebrates minus ants and spiders; Table 2). The surprising result obtained was that neither the ant nor spider assemblages were distributed along the lines of the habitat classification, whereas habitat structuring of all invertebrates (including ants and spiders) was significant, driven obviously by the 100 non-ant, non-spider species. Evidence for auto-correlative structure at the 500 m scale in these two invertebrate groups was lacking, existed for plants and almost certainly would have been detected for birds had census data been collected in a similar manner.

Table 2. Comparisons by ANOSIM of spatial structures in assemblages of various organisms

	All Invertebrates	*Ants*	*Spiders*	*The Rest*
# spp.	186	39	47	100
Habitat	P=0.001	P=0.421	P=0.108	P=0.001
Autocorr.	P=0.077	P=0.188	P=0.146	P=0.191

	Vegetation (69 spp.)
Habitat	P=0.013
Autocorr.	P=0.001

Note that potential effects of acontemporaneous sampling can be ignored - the strong effect is a spatial auto-correlation phenomenon alone. However, non-random site selection may have influenced the strength of the signal.

	Reptiles		
Summer 1 (1987/88)		*Summer 4 (1994/95)*	
Habitat	P=0.001	*Habitat*	P=0.047
Autocorr.	P=0.203	*Autocorr.*	P=0.221

It is evident that these very different groups of organisms respond spatially in different ways to environmental variation across the one landscape. Even different types of invertebrate are distributed quite distinctly from one another. These observations are consistent with recent theoretical developments (e.g. Holling 1992; Wiens 1995) but this kind of complexity will make land management for diverse objectives, including biodiversity conservation, an exacting task. There will be no single habitat classification, at least at these fine spatial scales, that acts as a good template for all organisms. With their important management implications, these provisional results are sufficiently interesting to warrant a better stratified, more intensive multi-taxon survey. Spatial scaling relationships, including but not limited to auto-correlation, should be investigated through the incorporation of a more rigorous hierarchical sampling design as advocated by Milne (1992).

Ecological Monitoring, Species Persistence, Ecosystem Condition, Monitoring for What?

A major objectives of biodiversity management at Uluru–Kata Tjuta National Park is to conserve all species naturally occurring in the Park. This was specified as the most important reason for instigating the Uluru fauna survey: 'to provide information that will allow management to maximise the probability of maintaining the full complement of animal species in the park indefinitely' (Reid *et al.* 1993). Assuming this is a worthy and still valid objective, how should the park service go about ensuring its full complement of animals persist and, equally importantly, how much money should be invested in the task and how would that finite sum best be spent? We have argued previously that 'ecological monitoring' is required to fulfil the overriding objective of maintaining all vertebrate species (Reid *et al.* 1993; Reid & Hobbs 1996). The periodic detection of each species at UNP is the only way park managers can faithfully gauge their success in this regard. A well designed and adequately resourced monitoring program can meet this basic requirement, at least for the park's vertebrates, but it should deliver more than this alone.

In fact the process of repeatedly surveying the fauna to ensure that persistence of each species has occurred may be more aptly described as surveillance than monitoring under most definitions of these terms (e.g. Spellerberg 1991; Hellawell 1991; Taplin 1996). Adapted from Taplin (1996) Table 3 presents the differing objectives and activities of Survey, Surveillance and Monitoring, terms he defined as follows (with my comments added in parentheses). Survey is the standardised collection of observations (once only or repeated?) made at a range of sites within a restricted period of time without clear preconceptions of how the results will be structured. Surveillance is an extended program of surveys (usually using established sites but see Skalski 1990) to ascertain the variability and range of states that might be encountered over time. Monitoring is intermittent surveillance (ongoing or finite depending on the aims, at regular intervals or strategically-timed depending on the environment and biology) to ascertain either the extent of compliance with a predetermined standard or the degree of deviation from an expected norm or threshold. Mobbs (1997) made clearer the distinction between the three activities by separating the spatial component (Survey) from the temporal (Surveillance) and by specifying that only Monitoring has predetermined performance targets (after Spellerberg 1991). By implication, Survey and Surveillance are required to build the baseline by which Monitoring targets - the permitted range of states or variation - can be set.

Below I have refined a basic planning-research framework (after Davis 1993) making it more iterative so that it follows more closely the principles of adaptive management (Walters 1986; Ludwig *et al.* 1993) by including the monitoring element within a research, management response and performance evaluation cycle. The practice and communication of

Table 3. Framework for vertebrate monitoring in desert environments (after Taplin 1996)

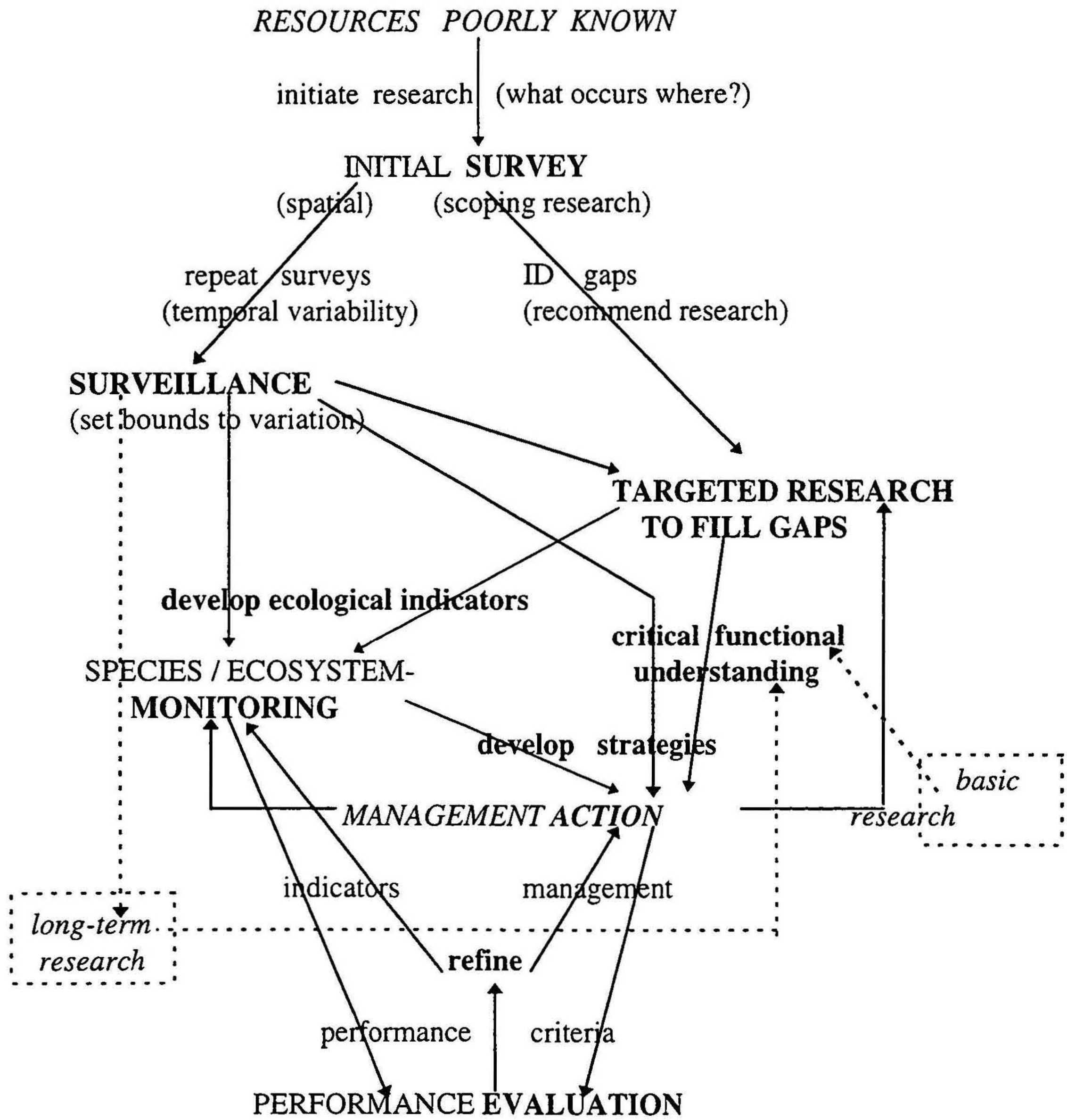
Component	*Time Frame*	*Activity*
Survey (Inventory)	3-5 years	Development of robust survey design and techniques to detect nearly all species and/or estimate population sizes Identification of priority sites/species for monitoring through a conservation evaluation process Development of baseline and habitat models for species, communities
Surveillance	10-15 years	Development of techniques to estimate production and survival Annual estimation of population size for selected species Evaluation of disturbance regimes, assessment of temporal variations Compilation and analysis of environmental data - later stages Development of simple predictive models - later stages
Monitoring	ongoing	Refinement of models Improvement in environmental data bases

monitoring are hampered by the differences in meaning of commonly used terms, despite the attempts of many authors to standardise usage (Eberhardt & Thomas 1991; McKenzie *et al.* 1992; references cited in previous paragraph). Here the distinctions between Survey (spatial), Surveillance (temporal) and Monitoring (prescribed targets) are maintained, but the following additonal confusion-ridden terms, Evaluation and Indicators, are defined. I wish to distinguish between Monitoring the environment (whether using biotic or abiotic Indicators) and Evaluating the success or performance of the monitoring program (or other management activity). Often the latter (vital) appraisal component is referred to as 'monitoring'. While the usage may be correct in common English, in the 'research, monitoring, planning framework' presented here I believe the distinction is useful to avoid ambiguity. Furthermore, the term Indicator could be reserved for the monitoring component, and the term 'performance' or 'compliance' criteria (Criteria) is proposed for Evaluation.

Key Research-Management Issues on the Park 1.

Causes of the Biotic Distinctiveness of the Yulara Bores Transitional Sandplain
Several species including two of national conservation significance - mulgara *Dasycercus* cristicauda, great desert skink *Egernia kintorei* - are largely confined to this restricted area of habitat (Reid *et al.* 1993; Masters 1997; McAlpin 1997). What is the functional (landscape-

driven, ecological) cause of the area's distinctiveness? Do we need to know the cause, could the area not be simply and more cheaply managed by choosing the 'no research' or 'limited research' option? One management strategy might be to maintain overall habitat quality through the use of fire (i.e. continuation of the current burning strategy) and by minimising traffic and new developments. An additional safeguard would be the regular monitoring of the significant species - the limited research option. These cheap options are attractive for obvious reasons, but it could also prove to be cheap in a less positive sense. The limited-action approach to management may be appropriate and justified on financial grounds over



Stylised 'research-monitoring-planning framework' loosely followed at Uluru since inception of vertebrate research in 1987. The dashed lines and boxes represent possible 'intangible benefits' or outcomes that cannot be anticipated necessarily in advance.

---

large areas of the park but, I argue, not in this particular case. The area's conservation significance is too high to manage from a 'blissful state of relative ignorance'. Assume in the future a low-level surveillance of the area reveals negative trends. A functional understanding of how the system works should increase the chances of pinpointing the likely causes of the problem, taking appropriate management action and doing it sufficiently quickly, perhaps in time to avert a local extinction. Doing the research now to achieve the functional understanding may be a vital safeguard for the future. A second reason for continuing to investigate the landscape processes responsible for the area's ecological distinctiveness and significance, relates to its close proximity to Yulara. It could face real if somewhat diffuse threats from operations associated with the tourism industry. Under a cumulative impact scenario, a series of minor developments and land uses that might seem insignificant in isolation could collectively lead to serious habitat degradation or otherwise constitute a serious risk to the ecosystem. A sound functional understanding should assist in the amelioration of impacts associated with threatening developments and allow informed opposition to the more serious of proposed developments in the area. Further research appears vital.

The Key Research-Management Issues on the Park 2.

Mass tourism and carrying capacity

What are the ecological impacts of mass tourism:

- directly, on resources within the Park?
- and indirectly, at and around Yulara through the servicing of tourists, carrying out civil and administrative functions and through various related infrastructure developments?

• This is the outstanding research opportunity and management challenge unique to UNP.

• Can mass tourism on this scale (350 000 visitors a year) be managed to have negligible impact?

• Is the volume limitless, can the growth in tourist numbers continue forever?

• If the answer is no, how to do we go about setting safe but 'industry-friendly' levels?

Carrying capacity will vary with location and type of tourist activity - active vs passive pursuits - and similar considerations will apply to the indirect effects of tourism. Carrying capacity, i.e. ceilings on tourist numbers, may have to be considered on several time scales, e.g. daily, seasonal, annual.

In comparison with the research opportunities posed by tourism, doing basic or strategic research on the following topics for instance:

• impacts of exotics (feral cats, foxes, weeds);

• finding effective eradication and control methods of exotics;

• reintroductions of locally extinct fauna;

• biological survey;

while important, can be and has been performed in many parts of arid Australia. Research associated with these sorts of activities should be applied and tactical and, if pursued, would fit into feasibility, monitoring and evaluation components of the adaptive management cycle.

Research requirements for detecting direct within-Park impacts of tourism

Currently effective ecological indicators sensitive to contemporary tourist impact are not obvious. Although simplistic it seems that most of the on-park direct and overt impacts of tourism are historical legacies that resulted from the unwise siting of the original tourist facilities and associated drainage-control works at Uluru. In the contemporary setting since Yulara has been established, trampling and compaction adjacent to heavily used walking trails, disturbance of wildlife in these same areas, and mortalities along the major roads may be the most serious direct impacts of tourism in the Park. Geographically, Uluru is the most heavily visited area and where impacts are likely to be most severe. Experimental fine-scale approaches may prove useful in assessing the sensitivity of trialled indicators, and to determine if impacts are detectable at different visitation rates. Scaling-up trials would then need to be conducted to ensure that the chosen indicators are robust, sufficiently sensitive and economically feasible when applied at landscape scales appropriate to management.

The Yulara Bores Transitional Sandplain dilemma: much more than a research issue

With respect to tourist activity in the park, research in relative isolation may be able to provide effective monitoring and management protocols that are readily implemented. However, the complexity of management issues involved with Yulara and its potential effects on the natural resources of the Park and adjacent areas is an order of magnitude higher. This complexity arises because the identified area of high conservation significance, the Yulara Bores Transitional Sandplain, spans three jurisdictions - the Park, the Yulara lease and the Katiti Land Trust - and lies mostly outside the Park. The traditional owners of the Sedimentaries and Ayers Rock Resort Corporation have legitimate rights to pursue land use objectives within the areas under their control, but some land uses could be inimical to conservation and sustainable-use goals. Off-park activities and developments in the Sedimentaries and Yulara district are beyond the control of the park's managers, yet have the potential to impair identified significant natural values on the park (Reid *et al.* 1993). For instance, there are three species having national conservation status: the mulgara and great desert skink referred to earlier and striated grasswren *Amytornis striatus*. For the first two the area provides habitat critical for their persistence in the Park region. In cases such as this, landscapes cannot be managed in isolation if conservation goals are to be met. How then might protection of the area's significant values best be approached?

The 'key players' involved are the Park owners and managers, Katiti Land Trust traditional owners, Ayers Rock Resort Corporation and local Northern Territory Government authorities. External researchers, I suggest, do not have a key role to play as such, though the research requirement here is no less demanding than in the previous case. An open and cooperative relationship needs to be forged between all the interest groups and their different outlooks, concerns and 'needs' will need to be aired and resolved. If the lines of communication are opened, and a 'win win' spirit adopted, perhaps it would be possible for a staged planning, development and research process to be adequately resourced and implemented with bipartisan support. Again, the iterative or cyclical adaptive management framework should guide the process of planning, tourism development, research and trans-jurisdictional management response. Research will need to be multidisciplinary, with the natural environmental and socioeconomic components tightly integrated. Under this scenario, research is seen to be just one of the several planks that have to be negotiated, resourced and integrated within an overarching planning and management framework. Effective communication is an all-important ingredient to a successful outcome for the conservation management of the Yulara Bores area, and conservation goals have to be balanced with economic, cultural and other development goals. It has to be admitted that political forces operating at levels higher than the region considered here may make acceptable outcomes difficult to achieve. The balancing of various competing interests' goals could mean that no single participating body should expect to be completely happy with what outsiders might consider a jointly successful outcome.

****

References

Allan, G.E., 1984. Fire history and land units of Uluru. In: Saxon, E., (editor) Anticipating the inevitable, pp. 13-24. CSIRO, Melbourne, 13-24.

Baker, L.M. & the Mutitjulu Community, 1992. Comparing two views of the landscape: Aboriginal traditional ecological knowledge and modern scientific knowledge. Rangeland Journal, 14, 174-89.

Baker, L., Woenne-Green, S. & the Mutitjulu Community, 1992. The role of Aboriginal ecological knowledge in ecosystem management, In: Birckhead, J., de Lacy, T. & Smith, L., (editors) Aboriginal involvement in parks and protected areas. Australian Institute of Aboriginal and Torres Strait Islander Studies, Canberra, 65-73.

Baker, L., Woenne-Green, S. & the Mutitjulu Community, 1993. Anangu knowledge of vertebrates and the environment. In: Reid, J.R.W., Kerle, J.A. & Morton. S.R., (editors). Kowari, 4, 79-132.

Borcard, D., Legendre, P. & Drapeau, P., 1992. Partialling out the spatial component of ecological variation. Ecology, 73, 1045-1055.

Burgman, M.A. & Williams, M.R., 1995. Analysis of the spatial pattern of arthropod fauna of jarrah (*Eucalyptus marginata*) foliage using a Mantel correlogram. Australian Journal of Ecology, 20, 455-457.

Clarke, K.R., 1993. Non-parametric analyses of changes in community structure, Australian Journal of Ecology, 18, 117-43.

Clarke, K.R. & Warwick, R.M., 1994. Change in marine communities. An approach to statistical analysis and interpretation. Plymoth Marine Laboratory and Natural Environmental Resources Council United Kingdom, Plymoth.

Cody, M.L., 1994. Mulga bird communities, I: Species composition and predictability across Australia, Australian Journal of Ecology, 19, 206-19.

Davis, G.E., 1993. Design elements of monitoring programs: the necessary ingredients for success. Environment Monitoring and Assessment, 26, 99-105.

Eberhardt, L.L., & Thomas, J.M., 1991. Designing environmental field studies. Ecological Monograph, 61, 53-73.

Foulkes, J., Foster, E., & de Preu, N., 1995. Palaeodrainage systems and the conservation of Australian deserts. Conservation Commission of the Northern Territory, Alice Springs.

Hellawell, J.M., 1991. Development of a rationale for monitoring. In: F.B. Goldsmith, F.B., (editor) Monitoring for conservation and ecology, Chapman and Hall, London, 1-14.

Holling, C.S., 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. Ecological Monograph, 62, 447-502.

Kerle, J.A., & Morton, S.R., 1988. Distribution and abundance of vertebrate fauna of Uluru (Ayers Rock - Mount Olga) National Park. Final report, phase II. Report to the Australian National Parks and Wildlife Service, CSIRO, Alice Springs (unpublished).

Landres, P.B., Verner, J., & Thomas, J.W., 1988. Ecological uses of vertebrate indicator species: a critique. Conservation Biology, 2, 316-28.

Landres, P.B., 1992. Ecological indicators: panacea or liability? In: McKenzie, D.H., Hyatt, D.E., & McDonald, V.J., (editors) Ecological indicators. Proceedings of the International Symposium, Fort Lauderdale, Florida, 16-19 October 1990, Elsevier, London, 1295-1318.

Legendre, P., & Fortin, M.J.,1989. Spatial pattern and ecological analysis. Vegetatio, 80, 107-138.

Ludwig, D., Hilborn, R., & Walters, C., 1993. Uncertainty, resource exploitation, and conservation: lessons from history. Ecological Applications, 3, 547-9.
McAlpin, S., 1997. Conservation of the Great Desert Skink, *Egernia kintorei*, at Uluru–Kata Tjuta National Park, Northern Territory. Consultancy report to Australian Nature Conservation Agency, Department Biological Sciences, Northern Territory University, Darwin.
McKenzie, D.H., Hyatt, D.E., & McDonald, V.J., (editors), 1992. Ecological indicators. Proceedings of the International Symposium, Fort Lauderdale, Florida, 16-19 October 1990, Elsevier, London.
Masters, P., 1993. The effects of fire-driven succession and rainfall on small mammals in spinifex grassland at Uluru National Park, Northern Territory. Wildlife Research, 20, 803-13.
Masters, P., 1996. The effects of fire-driven succession on lizards in spinifex grassland at Uluru National Park, Northern Territory. Wildlife Research, 23, 39-48.
Masters, P., in press 1997. The mulgara *Dasycercus cristicauda* (Marsupialia: Dasyuridae) at Uluru National Park, Northern Territory. Australian Mammal.
Milne, B.T., 1992. Indicators of landscape condition at many scales. In: McKenzie, D.H., Hyatt, D.E. & McDonald, V.J., (editors) Ecological indicators. Proceedings of the International Symposium, Fort Lauderdale, Florida, 16-19 October 1990, Elsevier, London, 883-895.
Mobbs, C. In: Mahanty, S., Guijt, I., & Carr, A., (editors), 1997. Tracking change: Community monitoring in natural resource management. Workshop Proceedings, 30 June 1997. Department of Forestry, School of Resource and Environmental Management, Centre for Resource and Environment Studies, Australian National University, Canberra and IIED, London.
Morton, S.R., 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.
Morton, S.R., Short, J. & Barker, R.D., 1995. Refugia for biological diversity in arid and semi-arid Australia, Biodiversity Series No. 4, Department of Environment, Sports and Territory, Canberra.
Reid, J.R.W., Baker, L., Morton, S.R. & the Mutitjulu Community, 1992. Traditional knowledge + ecological survey = better land management. Search, 23, 249-51.
Reid, J.R.W. & Hobbs, T.J., (editors), 1996. Monitoring the vertebrate fauna of Uluru–Kata Tjuta National Park, phase II - Final report. CSIRO, Alice Springs.
Reid, J.R.W., Kerle, J.A. & Morton, S.R., (editors), 1991. Uluru fauna survey. The distribution and abundance of vertebrate fauna of Uluru (Ayers Rock-Mount Olga) National Park, Northern Territory. Final report to the Australian National Parks and Wildlife Service. CSIRO, Alice Springs.
Reid, J.R.W., Kerle, J.A. & Morton, S.R. (editors), 1993. Uluru fauna. The distribution and abundance of vertebrate fauna of Uluru (Ayers Rock-Mount Olga) National Park, Northern Territory, Kowari, 4, Australian National Parks and Wildlife Service, Canberra.
Reid, J.R.W. & Morton, S.R., 1989. Distribution and abundance of vertebrate fauna of Uluru (Ayers Rock - Mount Olga) National Park. Final report, phase III. Report to the Australian National Parks and Wildlife Service, CSIRO, Alice Springs (unpublished).
Skalski, J.R., 1990. A design for long-term status and trends monitoring. Journal of Environmental Management, 30, 139-14.

Spellerberg, I.F., 1991. Monitoring ecological change. Cambridge University Press.
Stafford Smith, D.M. & Morton, S.R., 1990. A framework for the ecology of arid Australia. Journal of Arid Environments, 18, 255-278.
Taplin, A., 1996. Monitoring programs for seabirds: a conceptual framework. In: Ross, G.J.B., Weaver, K. & Grieg, J.C., (editors), The status of Australia's seabirds: Proceedings of the National Seabird Workshop, Canberra, 1-2 November 1993. Biodiversity Group, Environment Australia, Canberra, 29-34.
Walters, C.J., 1986. Adaptive management of renewable resources. McGraw-Hill, New York.
Wiens, J.A., 1995. Landscape mosaics and ecological theory. In: Hansson, L., Fahrig, L. & Merriam, G., (editors), Mosaic landscapes and ecological processes. Chapman & Hall, London.
Yen, A.L., Reid, J.R.W. & Wainer, J., 1996. A pitfall trap survey of ground dwelling invertebrates. In: Reid, J.R.W. & Hobbs, T.J., (editors), Monitoring the vertebrate fauna of Uluru-Kata Tjuta National Park. CSIRO, Alice Springs.

Back to the future workshop: the invertebrate fauna

Alan L. Yen[1]

[1] Museum of Victoria, 71 Victoria Crescent, Abbotsford, Victoria 3067.

Summary of the work conducted to date within the Park

The primary requirements for faunal resource inventory are encapsulated by the following questions: What species occur there? Where are they found? What do they do?

Compared to the knowledge available for the flora and the vertebrate fauna, invertebrate knowledge is still a big leap behind. There are three reasons for this:

1. A reluctance to support invertebrate studies adequately even though they are acknowledged as critical elements of the arid zone;

2. the number of invertebrate species makes total inventory an impractical short-term aim, so there is a need to develop short-cut ways to inventory invertebrates; and

3. invertebrate work is different from working with plants and vertebrates because field work generates a lot of laboratory time to sort and identify material.

The Museum's programme at Uluru so far has been very much directed at looking to answer the first two questions (What species occur there and Where are they found?). The work that we have undertaken has been very much a traditional collection and identification approach because of the necessity to reach some threshold of knowledge before we can be confident about any short-cuts that we use. The main aim has been to set up reference collections so that they are available for use of both specialist taxonomists and people undertaking work in this area so that they can add to the knowledge base.

The invertebrate survey has involved five field trips since late 1994. Field work has been conducted over a wider region of central Australia, and Uluru is only one of several study areas. The study sites that we have used are the Fauna Survey sites, and we were involved with the last Fauna Survey in 1995.

We have employed a variety of quantitative and qualitative collecting techniques, but have relied primarily on two techniques: pitfall trapping for ground dwelling invertebrates and Malaise traps for flying insects.

For the last 10 months, John Wainer has been sorting and identifying the material. He has sorted all quantitative samples from central Australia to the ordinal level, and is currently sorting all the ants to morphospecies. Ken Walker has sorted and identified all native bees to the species level. Some of the other orders are being prepared to send out to relevant specialists for identification.

In general terms, the dominant groups of invertebrates, in terms of numbers of individuals, that our quantitative collecting methods have gathered are: ants, spiders, flies, parasitic wasps, bugs, beetles, springtails, with grasshoppers/crickets and moths forming a lesser, but still significant, component.

It is more interesting to look briefly at the data set from the 1995 Fauna Survey which only identified material collected in drift-fence pitfall traps. A total of 344 invertebrate morphospecies was collected. The most speciose groups were: Araneae [spiders] (82 morphospecies), ants (76), Coleoptera [beetles] (57), Hemiptera [bugs] (27), Mutillid wasps (25), Orthoptera [crickets/grasshoppers] (20), and Blattodea [cockroaches] (15) (Yen *et al.* 1996).

The most interesting aspect of these numbers of species of different groups is the high number of species of spiders. The arid zone was considered to have a very high number of ant species, and perhaps the role of spiders as a predatory force has been under-estimated. When the number of ant morphospecies collected from all quantitative techniques at all Uluṟu sites over the three years is considered, a total of 157 morphospecies of ants is found. Similar data for the spider fauna are not available yet.

For the drift-fence pitfall trap Faunal Survey results, the dominance of the major groups expressed as numbers of individuals was different in that the fauna was dominated by ants, with spiders and beetles as secondary groups (Yen *et al.* 1996).

Preliminary analyses have been conducted on the invertebrate data from the drift-fence pitfall trap Faunal Survey. In general, when all invertebrates are taken into consideration, there is a tendency for sites to be grouped on the basis of soil type, the proximity of monoliths (and thus associated runoff), and the presence of vegetation (Yen *et al.* 1996). However, it is likely that invertebrates operate on a much finer environmental scale when compared to plants and vertebrates, and more fine scale information is required to assist interpretation of the invertebrate data.

It is worth noting that few introduced invertebrates have been found so far in central Australia. For example, the introduced honey bee, *Apis mellifera*; is restricted to areas associated with larger settlements and has not been recorded from Uluṟu.

Another factor to be considered is how different the fauna at Uluṟu is from other parts of central Australia. For example, Ken Walker has analysed the native bees and found that the fauna at Uluṟu is most zoogeographically linked to that at Watarrka, but these two areas are very distinct from the fauna to the east and north.

Identified "gaps" in work to date and possible future directions for research

There are numerous gaps in our knowledge of the invertebrate fauna. The following is a list of gaps, not necessarily in order of priority.

1. Methodology

Each sampling technique is biased towards certain groups of invertebrates, and it is preferable to use a range of techniques. However one obvious group absent from the collections made so far is the termites. The techniques employed simply do not collect termites, and some specialist termite collecting techniques need to be tested. The ecological importance of termites, both as the primary feeders of spinifex and as food for many vertebrates (and probably invertebrates), has been proposed, but actual data on termites are lacking.

2. Spatial and temporal variation

There has not been enough consideration of local spatial and temporal variation and their effects on the invertebrates. Most faunal surveys are planned and conducted on the home ranges of vertebrates, which will, in most cases, be at too large a scale for invertebrates. There is a need to look at the distributions of major invertebrate groups at a small spatial scale (for example, the differences between the top of dunes, mid dunes and in swales) and over time (both daily and seasonal).

3. The role of key invertebrate groups

Two invertebrate groups, termites and ants, are thought to be primary agents in the arid zone. Further work is required to inventory these groups as well as conducting research on their ecology. Other groups will play important roles, and the high species richness of spiders found in the Fauna Survey suggests that their importance has been underestimated. In the temporary aquatic habitats, the roles of crustaceans such as shield and fairy shrimps requires further investigation.

4. The effects of sudden weather events (rain) on invertebrate activity

Summer rains seem to trigger activity among many invertebrates. The life cycles of many invertebrates seem to be keyed into these rains, and monitoring of some of these species should be undertaken.

5. Life history information of selected species

The life histories of selected invertebrates should be studied. The selection of species should be based on their ecological and/or cultural importance.

6. Insect/plant interactions

The surveys undertaken by the Museum have neglected the fauna of plants. More work is required to survey the major herbivorous insects as well as the invertebrate pollinators. There could be some intricate interactions (e.g. plant/herbivore/ant) which could be used as indicators.

7. Decomposition

Except for termites feeding on spinifex, the roles of invertebrates in the decomposition of plant material requires further work. The relative roles of mites (Acarina), springtails (Collembola) and moth larvae should be investigated.

8. Aquatic habitats, especially temporary ponds

Temporary ponds are the habitats for many invertebrates. The fauna associated with these ponds and the rapid life cycles of these animals will provide further insight into adaptations of the fauna to an arid environment.

9. Vertebrate-invertebrate interactions

The invertebrate diets of vertebrates could be further investigated. The questions that require answering are whether the diet is selective or random and whether certain items are an essential element of the diet of the vertebrates.

10. Responses to fire

Data on the responses of invertebrates to different fire regimes are lacking. This is an important area for integrated botanical, zoological and cultural research.

Further research in many of these identified gaps would be facilitated if there are persons on-site available to do the work. A rapid response to undertake appropriate sampling or regular sampling over a prolonged period may be required.

Integration of traditional ecological knowledge

The value of traditional ecological knowledge is only beginning to be recognised. Preliminary work has begun on the invertebrates, but this has been based primarily on cataloguing Anangu names for invertebrates (Yen *et al.* 1997). This work has reached the stage where detailed life history and ecological information should be recorded from Anangu. This should involve collaborative work between scientists, linguists and Anangu.

Implications of tourism

The implications of tourism on invertebrates are difficult to discuss with the lack of information regarding invertebrates. Invertebrates are useful in monitoring small scale disturbances, such as trampling and grazing. One area that may warrant examinations is the expansion of bush tucker exploitation for ecotourism. This could have important ecological and cultural implications if too much pressure is put on to these resources in a limited area or at inappropriate times.

Possible collaborative ventures

Selected invertebrate groups can be integrated with the following: flora and fauna surveys, fire studies, disturbance studies, traditional ecological knowledge, and vertebrate diet studies.

Identification of indicators for monitoring

Invertebrates are ideal for monitoring because of their diversity, abundance, and relative ease of sampling (for most). The difficulty is to decide which invertebrates should be used, and this really depends on what we want to monitor: biodiversity, sustainability, disturbance, etc.

The factors that need to be considered when considering invertebrate indicators are:

1. <u>Ecological importance (trophic role)</u>

Although all species can be considered to be ecologically important, some groups may play more obvious significant roles in particular systems. This may involve a particular ecological function (e.g. herbivory, decomposition, pollination, seed harvesting, predation, parasitism, occupying a lower level in the food chain, i.e. lizard food), or a group of invertebrates whose members are involved in one or more functions (e.g. ants, beetles).

2. <u>A large number of species</u>

Groups that have a large number of species that have different ranges of distribution (some narrowly distributed, others widely distributed) and a range of life history strategies would be better indicators.

3. Respond to factors being monitored

This could involve rapid response (short-lived, fast breeders) or a longer term response (long-lived, slow breeders).

4. Practicality for study

This involves ease of sampling, sorting and identification, preferably a group with good taxonomic and biological knowledge as back up.

It is unlikely that any one group of invertebrates can act as an indicator, and it is likely that a suite of invertebrates that reflects a range of ecological roles needs to be found. The obvious candidates for consideration are ants, spiders, beetles, termites, bugs, crickets/grasshoppers, parasitic wasps, flies, moths, and native bees.

One group of animals that visitors to Uluru are certain to come across are invertebrates. In most cases they are considered a nuisance. It is important that the astute powers of observations of these visitors be channelled into taking a more ecologically positive view of invertebrates, and ultimately, to all elements of the arid environment. Hence, while research is important, information transfer of research results is also very important.

Acknowledgements

Dr John Wainer (Invertebrate Survey, Museum of Victoria) and Dr Ken Walker (Entomology, Museum of Victoria) provided important information for this presentation.

****

References

Yen, A.L., Gillen, J., Gillespie, R., Vanderwal, R. and the Mutitjulu Community, 1997. A preliminary assessment of Anangu knowledge of central Australian invertebrates. Memoirs of the Museum of Victoria, 56(2), 631-634.

Yen, A.L., Reid, J.R.W. & Wainer, J., 1996. A pitfall trap survey of ground dwelling invertebrates. In: Reid, J.R.W. & Hobbs, T.J. (editors), Monitoring the vertebrate fauna of Uluru National Park, Phase II - Final Report. Consultancy report to the Australian Nature Conservation Agency. CSIRO, Alice Springs, 139-159.

List of participants

Name	Organisation	Address	Phone / Fax / E-mail
Grant ALLAN	Parks and Wildlife Commission, NT	Box 1046 Alice Springs NT 0871	08 89 518 219 08 89 555 190 gha@nmdl02.ncom.nt.gov.au
Pauline ENGLISH C/- G.Jacobson	Australian Geological Survey Organisation	GPO Box 378 Canberra ACT 2601	02 6249 9758 02 6249 9970 gjacobso@agso.gov.au
Jeff FOULKES	Dept. Environment & Natural Resources	GPO Box 1047 Adelaide SA 5001	08 8204 8896/0? 08 8204 8889 jfoulkes@denr.sa.gov.au
Margaret FRIEDEL	CSIRO Centre for Arid Zone Res.	PO Box 2111 Alice Springs NT 0871	
Jake GILLEN Jacquie SHANNON	Resources Manager Uluru-Kata Tjuta National Park	PO Box 119 Yulara NT 0872	08 89 562 760 08 89 562 064 jgillen@anca.gov.au
Graham GRIFFIN	CSIRO Div.Wildlife & Ecol. Centre for Arid Zone Res.	PO Box 2111 Alice Springs NT 0871	08 89 500 125
John HIGGINS	Environment Australia State of the Environment Reporting	GPO Box 787 ACT 2601	02 6274 1646 02 6274 1336 jhiggins@dest.gov.au
Gerry JACOBSON	Australian Geological Survey Organisation	GPO Box 378 Canberra ACT 2601	02 6249 9758 02 6249 9970 gjacobso@agso.gov.au
Bill LOW	W.A. Low Ecological Services	PO Box 3130 Alice Springs NT 0871	08 89 555 222 (ph/fax) LowEcol@ozemail.com.au
Steve McALPIN		75 Albert Street Cranbrook Queensland 4814	077 793 269
Pip MASTERS		18 Burke Street Alice Springs NT 0870	08 89 527 66
Steve MORTON	CSIRO	POBox 84 Div. Wildlife & Ecol. Lyneham ACT 2602	02 6242 1696 02 6241 3343 steve.morton@dwe.csiro.au
Brad NESBITT Lynn BAKER	Wallambia Consultancies	1070 South Arm RD Urunga NSW 2455	02 6655 0098 walambia@midcoast.com.au
Jim NOBLE	CSIRO	PO Box 84 Div. Wildlife & Ecol. Lyneham ACT 2602	02 6242 1643 02 6241 4020 jim.noble@dwe.csiro.au
Lynn PEDLER		PO Box 41 Parndana SA 5220	08 85 593 247
Julian REID	CSIRO	PO Box 84 Div. Wildlife & Ecol. Lyneham ACT 2602	02 6242 1622 j.reid@dwe.csiro.au
Alan YEN	Museum of Victoria	71 Victoria Crescent, Abbotsford, VIC 3067	